Photographic Moon Book

Alan Chu

Version 3.5

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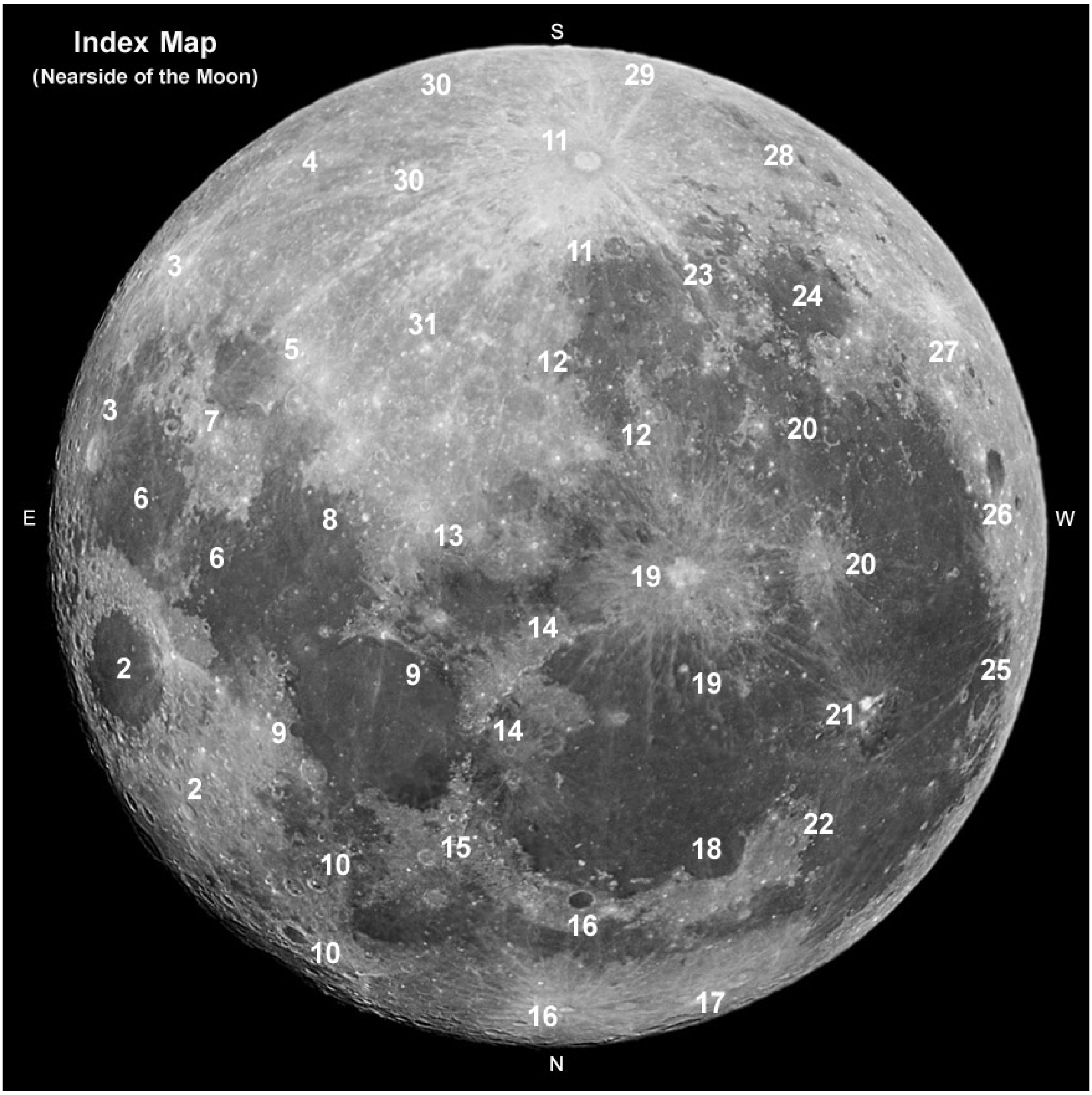

Lunar Features by Map No.

1. The Geologic Moon
2. Mare Crisium, Proclus, Palus Somni, Cleomedes, Messala
3. Langrenus, Vendelinus, Petavius, Furnerius
4. Janssen, Fabricius, Vallis Rheita, Mare Australe
5. Theophilus, Cyrillus, Catharina, Rupes Altai, Fracastorius
6. Mare Fecunditatis, Messier, Censorinus, Taruntius, Cauchy
7. Capella, Isidorus, Torricelli, Bohnenberger, Gutenberg
8. Sabine, Ritter, Hypatia, Delambre, Arago, Lamont
9. Serpentine Ridge, Plinius, Posidonius, Menelaus, Manilius
10. Atlas, Hercules, Bürg, Endymion, Mare Humboldtianum
11. Tycho, Clavius, Maginus, Deslandres, Pitatus, Hesiodus
12. Ptolemaeus, Alphonsus, Rupes Recta, Hipparchus, Fra Mauro
13. Rima Ariadaeus, Rima Hyginus, Rimae Triesnecker, Agrippa
14. Montes Apenninus, Rima Hadley, Archimedes, Aristillus
15. Montes Caucasus, Eudoxus, Aristoteles, Vallis Alpes, Cassini
16. Plato, Mons Pico, W. Bond, Meton, North Pole Region
17. J. Herschel, Anaximander, Philolaus, Pythagoras, Babbage
18. Sinus Iridum, Montes Recti, Bianchini, Sharp, Maupertuis
19. Copernicus, Eratosthenes, Stadius, Euler, Lambert, Hortensius
20. Kepler, Marius, Letronne, Reiner Gamma
21. Aristarchus, Herodotus, Vallis Schröteri, Prinz
22. Gruithuisen, Mons Rümker, Mons Delisle
23. Capuanus, Ramsden, Marth, Bullialdus, Kies
24. Gassendi, Rimae Hippalus, Vitello, Mersenius
25. Eddington, Struve, Russell, Seleucus, Olbers
26. Grimaldi, Hevelius, Cavalerius, Riccioli, Hedin
27. Darwin, Byrgius, Rimae Sirsalis, Crüger, Billy
28. Schiller, Schickard, Phocylides, Wargentin
29. Bailly, Longomontanus, Wilhelm, Mee, Hainzel
30. Maurolycus, Faraday, Stöfler, Boussingault
31. Catena Abulfeda, Catena Davy, Crater Arrays
32. Domes
33. Lunar Rays

Event 1. Libration
Event 2. Terminator
Event 3. Crescent
Event 4. Eclipse

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About This Book

The current version is intended for advanced lunar observations. It is also a complement to the cartographic *Rükl Atlas of the Moon* and the large-plate *Hatfield Photographic Lunar Atlas*.

The book collects about 270 photographs including the mosaics. Most of them were taken in Hong Kong with a 10-inch (254 mm) Newtonian reflector and a 1/4-inch CCD since 2003. It meets the following criteria:

- All lunar images are selenographic south up unless otherwise noted. They resemble the eyepiece views in the author's telescope.
- The date, time, Moon age and equipment used during an exposure are given together with a brief description of the lunar features.
- An Overview to refresh the observational basics, followed by a summary on the Geologic Moon.
- A section on the Methods of Imaging.
- In general, images of the lunar nearside are sequenced in regional MAPs from East to west, e.g. Mare Crisium and Petavius come first, finally Grimaldi and Schickard. Lunar events such as eclipses are described in the EVENT pages. A cross-reference with Rükl's and Hatfield's maps is also indicated in the page corner whenever applicable.
- The English-Chinese index at the back of the book facilitates the search of 1,000 named features. The glossary explains lunar terms in simple language.

The current version is downloadable from https://forum.hkas.org.hk/Web/Moonbook_3v5.pdf or delivered in CD by post. It is best viewed in 19-inch or bigger PC screen.

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1. Overview

Our natural satellite, the Moon, is a fascinating object. It is a little more than a quarter of the Earth diameter, about 1.3 light-seconds away. Virtually it has no atmosphere, no surface water and no active volcanism. Lots of surface features can be observed through telescopes as small as 6-cm (2.4-inch) aperture, and they change in view under different angles of sunlight.

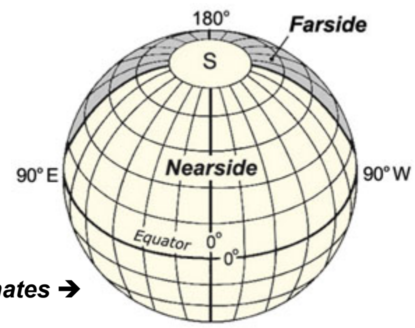
Lunar features are traditionally classified in Latin as

Mare	(sea, plural: *maria*)	海
Oceanus	(ocean)	洋
Sinus	(bay)	灣
Lacus	(lake)	湖
Palus	(marsh)	沼
Mons	(mountain)	山
Montes	(mountain range / group of mountains)	山脈 / 山群
Vallis	(valley)	谷
Promontorium	(promontory / cape)	岬 / 海角
Rima	(rille / cleft / fracture, plural: *rimae*)	溪 / 溝紋 / 裂縫
Rupes	(scarp / cliff / fault)	懸崖 / 峭壁 / 斷層
Dorsum	(wrinkle ridge, plural: *dorsa*)	皺脊
Catena	(crater chain)	環形山串

while craters are named after mythic legends or individuals who contributed in science, technology, philosophy, mathematics or expedition. Crater is a generic term for circular depression, typically a ring mountain or a walled plain which has relatively large and flat floor. There are 33,000 craters greater than one-km diameter visible with an Earth-based telescope, about 870 of them bear names and 5,400 are identified by a letter placed towards the center of an adjacent prominent crater, e.g. *Gassendi A*. The largest crater visible from Earth is *Bailly* on the south limb. It is a walled plain, outer diameter 300 km. Dozens of craters are also centers of bright rays. On the dark maria, wrinkle ridges and small extinct volcanoes called domes are visible under very oblique sunlight.

Lunar features are best seen when they are near the terminator, the border line between light and shadow. Their positions are defined by the selenographic coordinates in which the 0^0 latitude and 0^0 longitude are within a small mare named *Sinus Medii* (Central Bay). This sinus is visible in binoculars, see next page. The lunar hemisphere permanently facing Earth is termed the nearside; it ranges from 90^0 E to 90^0 W through the 0^0 longitude. When the Moon's south pole is positioned at top, the east limb of the nearside is at the left-hand side, the west limb is at the right-hand side.

Surface features of the nearside are depicted under Map 1 to Map 33 with the selenographic south at top and the east at left. Lunar phenomena about libration, terminator, crescent and eclipse are illustrated under Event 1 to Event 4. A map of the Farside that opposes the nearside is also given.

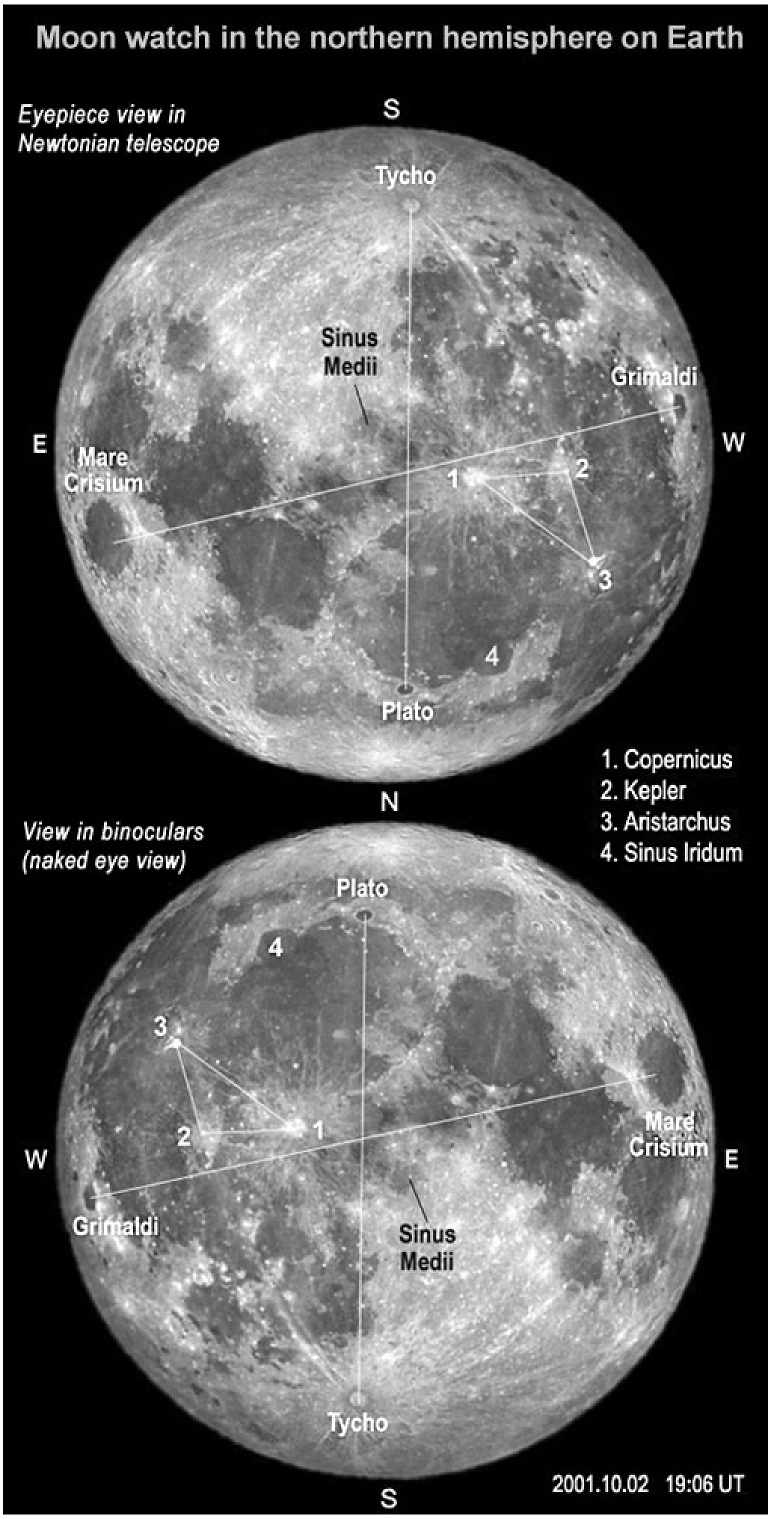


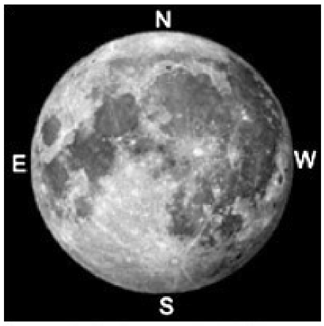
Selenographic Coordinates →

Landmarks on the Moon

Mare Crisium, Grimaldi, Tycho and Plato form a cross; Copernicus, Kepler and Aristarchus form a triangle. Sinus Medii is almost at the center of the disc. The thumbnail is the mirror-reverse image through a star diagonal fitted on refractor or catadioptric telescope. N, S, E and W are selenographic directions as seen by an astronaut on the Moon; they are similar to the geographic directions on Earth.

In telescopes, the eastern half of a Moon disc (S-E-N) looks slightly brighter than the western half (S-W-N).





In refractor or catadioptric telescope with star diagonal

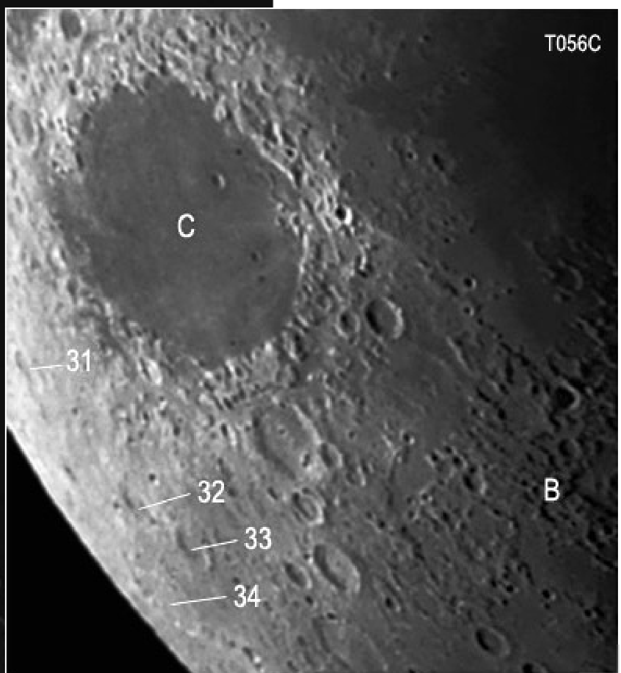
The Moon Lady in Children's books

Turn diagram upside-down for Moon watch in the southern hemisphere.

The Moon in small telescopes

This Moon crescent was photographed with a digital camera one hour after sunset through a 3-inch (8 cm) refractor. South is up. It represents a typical view of the Moon from a small telescope at low magnification. Although the telescope is small, it shows plenty of surface features such as craters, mountains and dark plains of solidified lava (the so-called 'maria'). Small telescopes are less sensitive to air turbulences. Even owners of big instruments enjoy the use of smaller telescopes in field work and poor-seeing nights. The inlets are cropped parts of the original image.

1. Janssen
2. Fabricius
3. Metius
4. Brenner
5. Vallis Rheita
6. Vallis Snellius
7. Snellius
8. Stevinus
9. Wrottesley
10. Furnerius
11. Petavius
12. Vendelinus
13. Langrenus
14. Lamé
15. Santbech
16. Colombo
17. Gutenberg
18. Fracastorius
19. Capella
20. Taruntius
21. Proclus
22. Cleomedes
23. Geminus
24. Messala
25. Macrobius
26. Römer
27. Atlas
28. Hercules

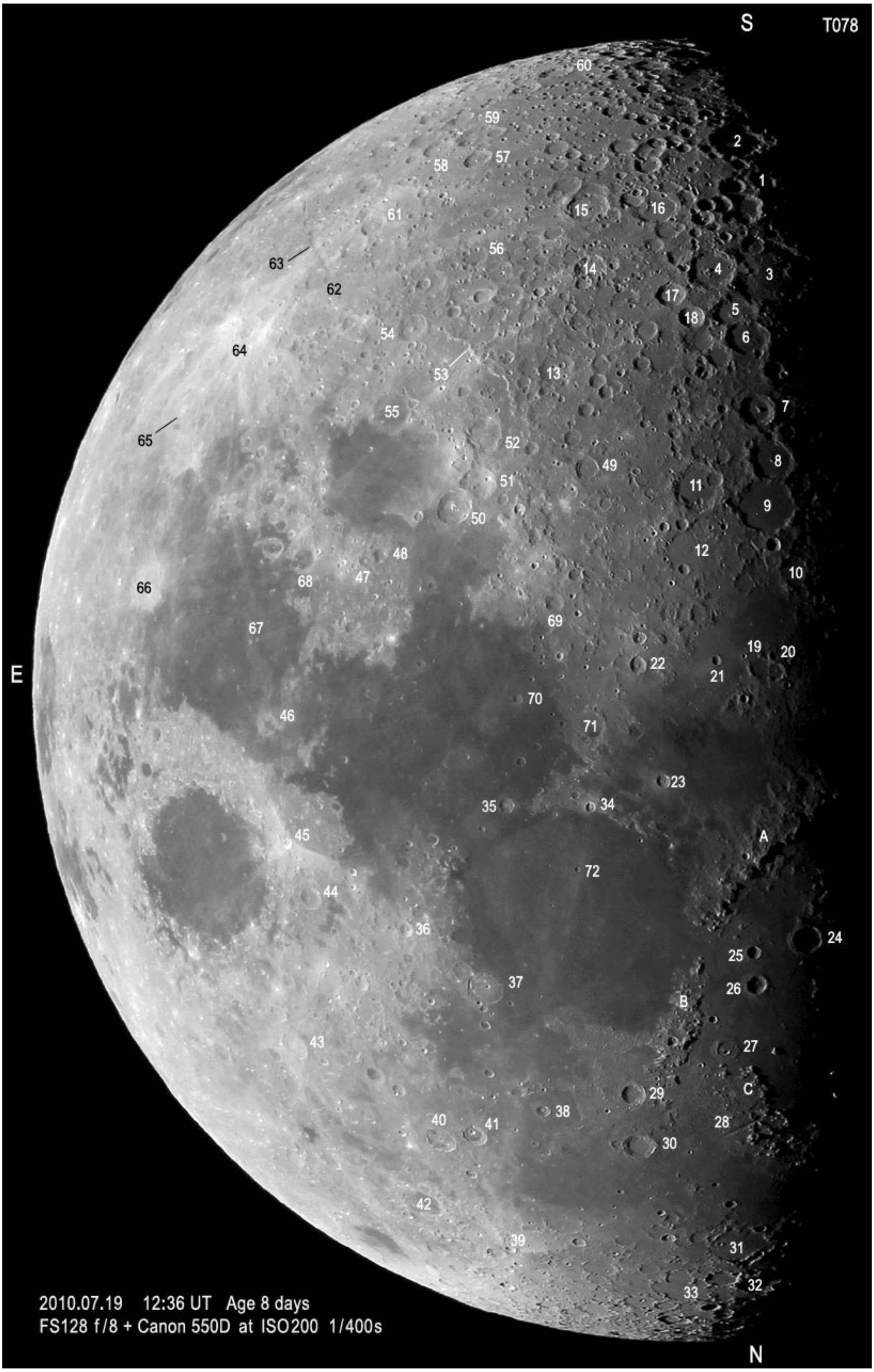


29. Endymion
30. Hubble
31. Plutarch
32. Hahn
33. Berosus
34. Gauss
35. Condorcet
36. Vlacq
37. Boussingault

A. Montes Pyrenaeus
B. Montes Taurus
C. Mare Crisium

The Moon and its terminator

The terminator is the border line between light and shadow. It looks irregular because of different height and albedo (reflectivity) of surface features. Features away from the terminator are often too bright (e.g. No. 66) or hidden in darkness (e.g. No. 24), yet they become distinctive when the bright margin of the terminator passes over them.

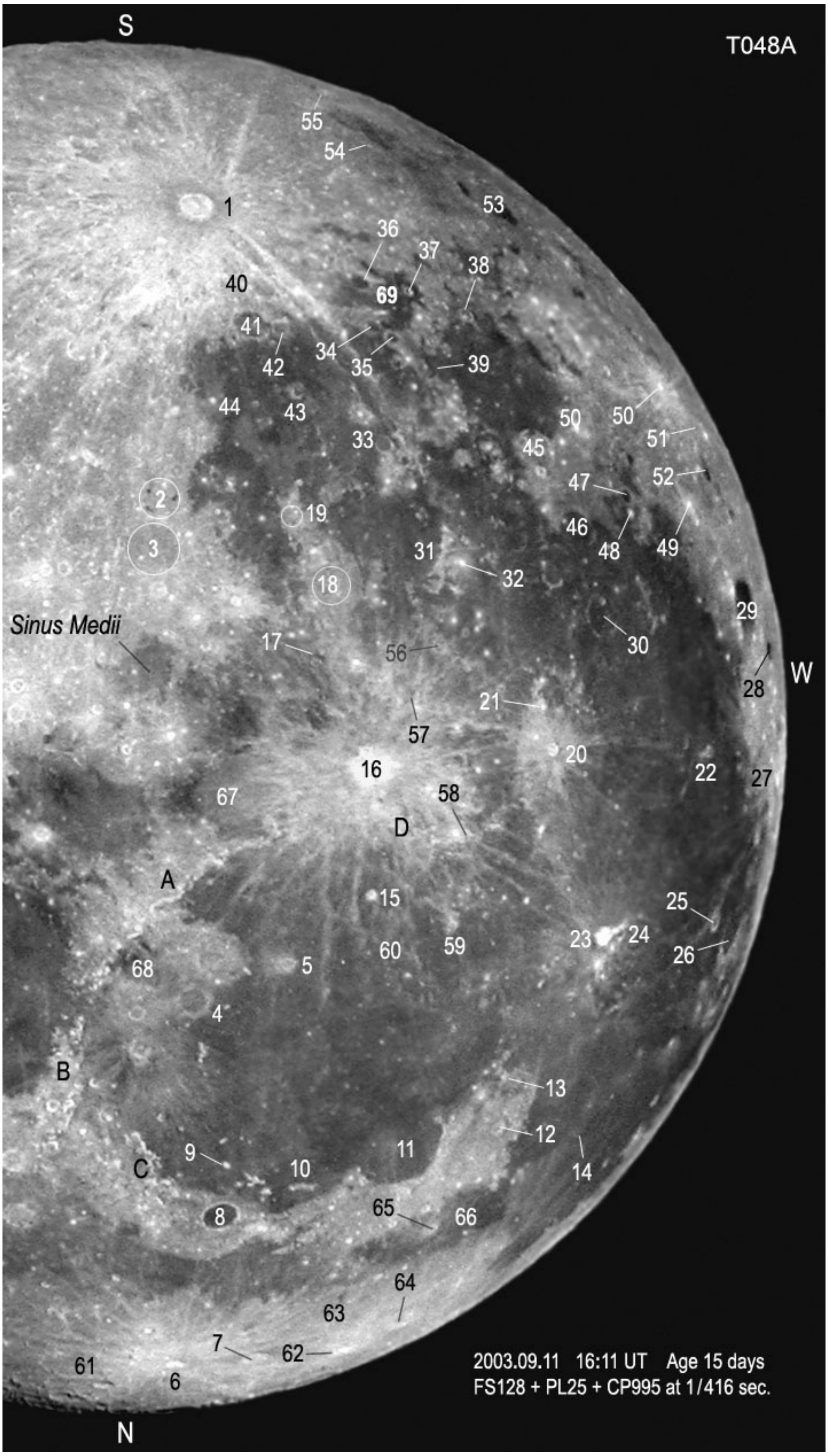


1. Tycho
2. Maginus
3. Deslandres
4. Walther
5. Regiomontanus
6. Purbach
7. Arzachel
8. Alphonsus
9. Ptolemaeus
10. Flammarion
11. Albategnius
12. Hipparchus
13. Sacrobosco
14. Gemma Frisius
15. Maurolycus
16. Stöfler
17. Aliacensis
18. Werner
19. Murchison
20. Pallas
19. Autolycus
21. Triesnecker
22. Agrippa
23. Manilius
24. Archimedes
25. Autolycus
26. Aristillus
27. Cassini
28. Vallis Alpes
29. Eudoxus
30. Aristoteles
31. W. Bond
32. Goldschmidt
33. Meton
34. Menelaus
35. Plinius
36. Römer
37. Posidonius
38. Bürg
39. Thales
40. Atlas
41. Hercules
42. Endymion
43. Geminus
44. Macrobius
45. Proclus
46. Taruntius
47. Capella
48. Isidorus
49. Abulfeda
50. Theophilus
51. Cyrillus
52. Catharina
53. Rupes Altai
54. Piccolomini
55. Fracastorius
56. Riccius
57. Pitiscus
58. Vlacq
59. Hommel
60. Manzinus
61. Janssen
62. Rheita
63. Vallis Rheita
64. Stevinus
65. Petavius
66. Langrenus
67. Messier A
68. Gutenberg
69. Delambre
70. Arago
71. Julius Caesar
72. Bessel

A. Montes Apenninus
B. Montes Caucasus
C. Montes Alpes

The Moon at full brightness

This image shows the western half of a full moon. No terminator is visible. Tycho, Copernicus, Kepler and Aristarchus (No. 1, 16, 20 & 23) radiate extensive bright rays that overwhelm large areas of the surface. Other landscapes lose their contrast too, though recognizable. The full moon is generally not a favorable time to spot lunar details.

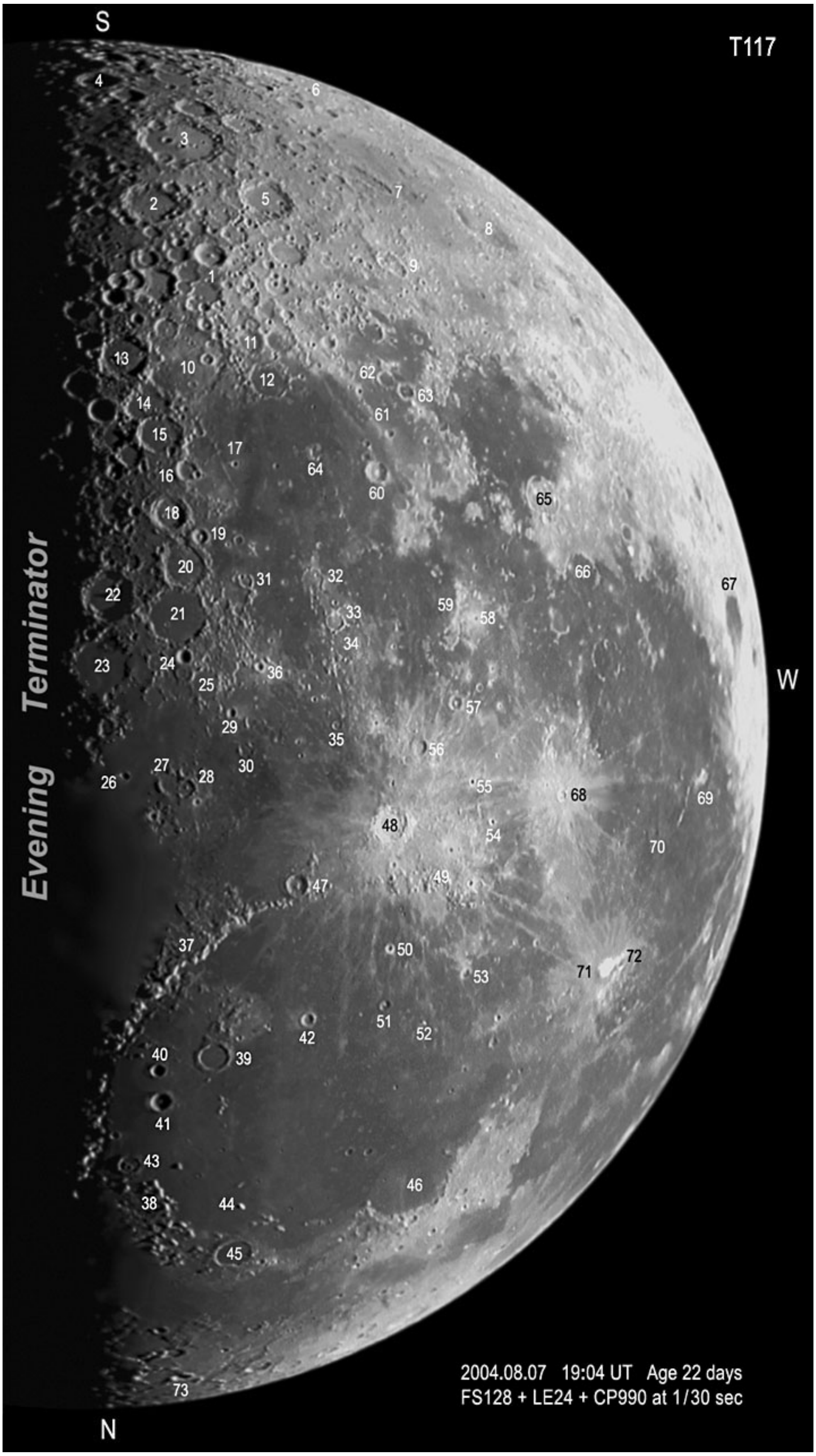


1. Tycho
2. Alphonsus
3. Ptolemaeus
4. Archimedes
5. Timocharis
6. Anaxagoras
7. Philolaus
8. Plato
9. Mons Pico
10. Montes Recti
11. Sinus Iridum
12. Mairan
13. Mons Gruithuisen Gamma
14. Mons Rümker
15. Pytheas
16. Copernicus
17. Gambart
18. Fra Mauro
19. Guericke
20. Kepler
21. Encke
22. Reiner Gamma
23. Aristarchus
24. Herodotus
25. Seleucus
26. Eddington
27. Glushko
28. Riccioli
29. Grimaldi
30. Flamsteed P
31. Montes Riphaeus
32. Euclides
33. Bullialdus
34. Mercator
35. Campanus
36. Capuanus
37. Ramsden
38. Vitello
39. Hippalus
40. Wurzelbauer
41. Pitatus
42. Hesiodus
43. Wolf
44. Birt
45. Gassendi
46. Letronne
47. Billy
48. Mons Hansteen
49. Sirsalis
50. Byrgius A
51. Darwin
52. Crüger
53. Schickard
54. Schiller
55. Zucchius
56. Lansberg
57. Reinhold
58. T. Mayer
59. Euler
60. Lambert
61. Meton
62. Carpenter
63. J. Herschel
64. Pythagoras
65. Harpalus
66. Sinus Roris
67. Sinus Aestuum
68. Palus Putredinis
69. Palus Epidemiarum

A. Montes Apenninus
B. Montes Caucasus
C. Montes Alpes
D. Montes Carpatus

The Moon and its "evening terminator"

The terminator is designated "evening" because the places under it are experiencing sunset. If a moon man stands now on the floor of crater No.23, he will see the setting Sun and anticipate nighttime as the terminator crosses the crater from east to west (from left to right of the frame). Compare this photograph with T078 in previous page which was taken 7 days before the full moon. T078 shows the "morning" terminator implying the Sun is rising over that part of the Moon. In T117, note also the highland region, around 2~3 o'clock position on the west limb. It is even brighter than the full moon because the Sun is illuminating it at high angles (hence appears white and featureless).



1. Tycho
2. Maginus
3. Clavis
4. Moretus
5. Longomontanus
6. Bailly
7. Schiller
8. Schickard
9. Hainzel
10. Deslandres
11. Gauricus
12. Pitatus
13. Walther
14. Regiomontanus
15. Purbach
16. Thebit
17. Rupes Recta, Birt
18. Arzachel
19. Alpetragius
20. Alphonsus
21. Ptolemaeus
22. Albategnius
23. Hipparchus
24. Herschel
25. Flammarion
26. Triesnecker
27. Murchison
28. Pallas
29. Mösting
30. Schröter
31. Davy
32. Guericke
33. Parry
34. Fra Mauro
35. Gambart
36. Lalande
37. Montes Apenninus
38. Montes Alpes
39. Archimedes
40. Autolycus
41. Aristillus
42. Timocharis
43. Cassini
44. Mons Pico
45. Plato
46. Sinus Iridum
47. Eratosthenes
48. Copernicus
49. Montes Carpatus
50. Pytheas
51. Lambert
52. Mons La Hire
53. Euler
54. Milichius
55. Hortensius
56. Reinhold
57. Lansberg
58. Euclides
59. Montes Riphaeus
60. Bullialdus
61. Kies
62. Mercator
63. Campanus
64. Wolf
65. Gassendi
66. Letronne
67. Grimaldi
68. Kepler
69. Reiner Gamma
70. Marius
71. Aristarchus
72. Herodotus
73. Anaxagoras

Impact Craters and Lunar Rays

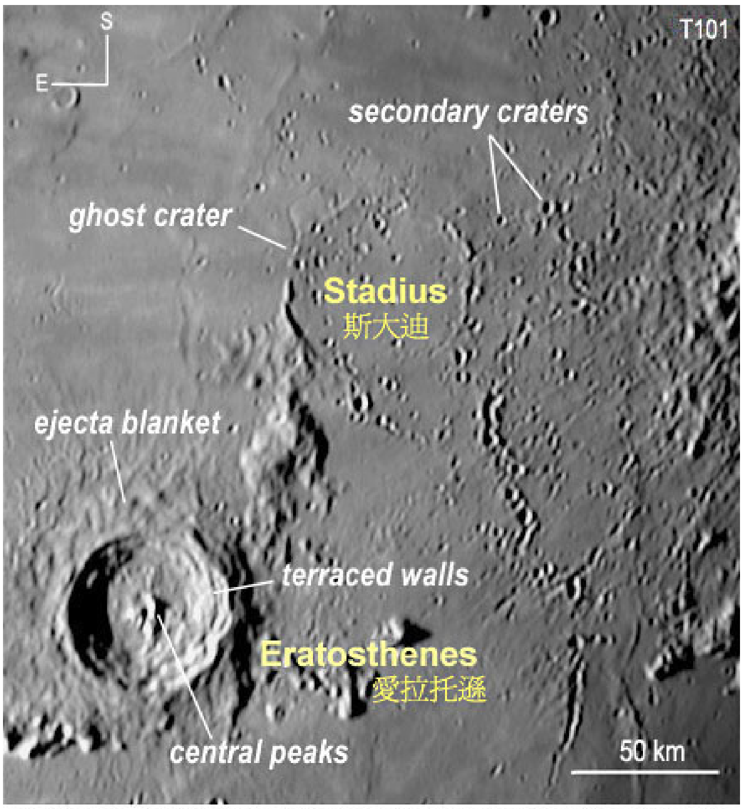
Over 99% of the existing lunar craters are impact originated. Their diameters range from about 300 km to 1 km and below. Diameters larger than 300 km are generally referred to ***impact basins****.*

A typical impact crater, commonly called complex crater, is illustrated by Eratosthenes in Image T101. It is a prominent object in the central region of the Moon disc. The crater is characterized by ***central peaks*** *and circular* ***terraced walls****. The highest peak rises some 1500 m above the crater floor, and the rim of the terraced walls measures 58 km across. Both the peaks and terraced walls are natural formations from a massive impact process, in which the impactor was an asteroid-like body of several kilometers only, hitting the lunar surface at 20 km per second or so. The tremendous impact energy vaporized a large portion of the impactor and melted the rocky materials of the impact site to a much larger circular cavity. The sudden release of impact pressure also induced a concentrated rebound that uplifted subsurface rocks into central peaks. Other impact melt splashed out in all directions as* ***ejecta****. Part of the ejecta deposited around the cavity as* ***ejecta blanket****, the rest might take the advantage of low surface gravity (1/6 that of Earth) to fly far away before striking the surface again to form* ***secondary craters****. The right half of T101 shows a mix of secondary craters from various sources. They are too small to have central peaks, or even irregular in shape due to grazing trajectories of impact at reduced velocities (2 km per second or less).*

The inner terraced walls of Eratosthenes formed marginally few minutes after the impact contact. At later stage when the walls could not sustain their own weights, they collapsed in segments along the steep slopes, making the terrace more profound. Usually, lunar craters with diameters less than about 20 km are lack of terraced walls. Simple craters with diameters less than about 15 km are shaped like a bowl with crested-rim; sometimes they have low rise in the floor. Craters with off-center peaks are probably due to oblique impacts.

Craters can be modified afterwards, such as the lava-flooded Archimedes in next page and Stadius in T101. Stadius is a ***ghost crater*** *almost buried beneath the surface, leaving only a bare hint of recognition.*

In general, craters created by explosion on impact remain circular regardless of the impact direction, except for very oblique impacts (less than about 5^0 *measured from ground level). A crater caused by very oblique impact is Messier as shown below. It appears elongated. The neighboring Messier A is a double crater, the source of ejecta in the pattern of dual* ***rays****. These rays suggest that the impactor, probably broken into two pieces, intruded from east to west at a grazing angle. Lunar rays are elaborated in Map 33.*



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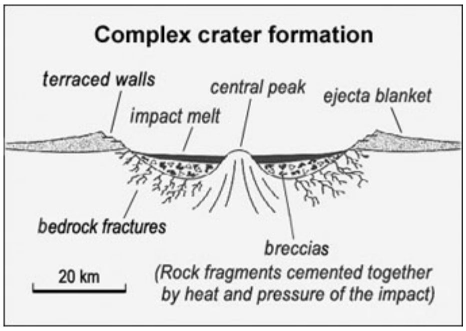
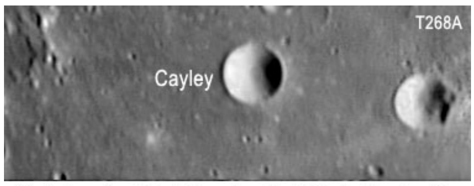
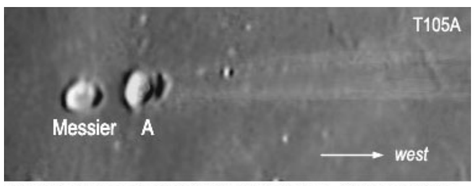




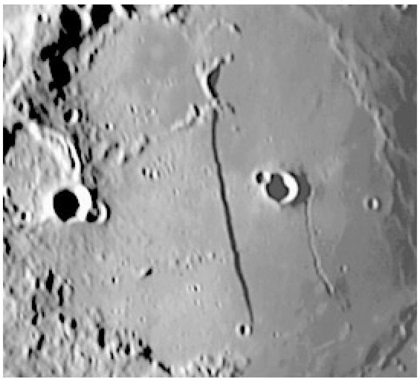
Cayley is a simple bowl-shaped crater, 14 km in diameter. Its depth-diameter ratio is 1 : 5. A larger crater like Eratosthenes, however, has reduced depth-diameter ratio, typically 1 : 16.



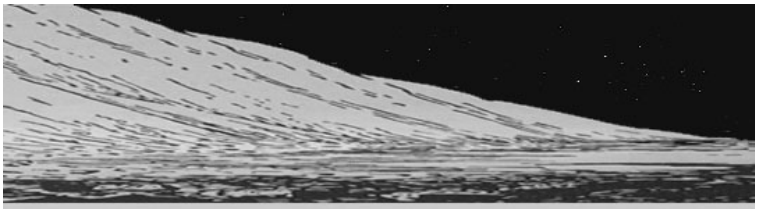
Messier A is a crater with dual ejecta rays, diameter 13 km.

It must be aware that lunar nomenclature is not always exact. For instance, today's selenographic coordinates make Mare Orientale (Eastern Sea, Farside map) confusingly on the western longitude. Vallis Rheita in Map 4 is not a true valley but a chain of overlapping craters. Grimaldi in Map 26 appears like a lava-filled basin more than a crater. The Straight Wall (Rupes Recta) in Map 12 is not a narrow wall but a fault where its western side slopes down by 300 m. Many lunar views in Earth-based telescopes are dramatically different from the scenes on the Moon's surface and from the images taken in space. Below are some comparisons.

The Straight Wall 直壁



View in telescope, Map12

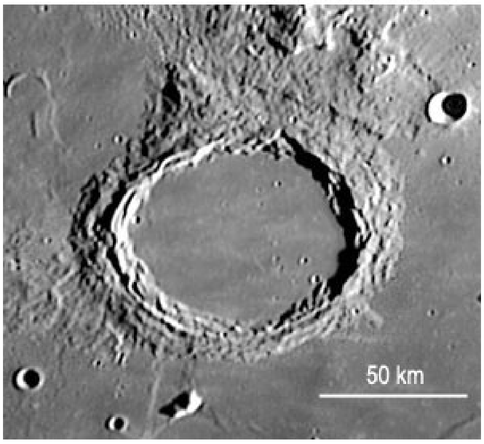


Standing at the foot of the 300-m high Straight Wall.

In telescope, the Straight Wall with shadow appears like a steep cliff. Actually its slope is rather gradual, average gradient under 10°. The steepest slope is roughly 30°.

(Modified from a sketch in Perelman's Astronomy For Entertainment, Moscow, 1958.)

Crater Archimedes 阿基米德環形山

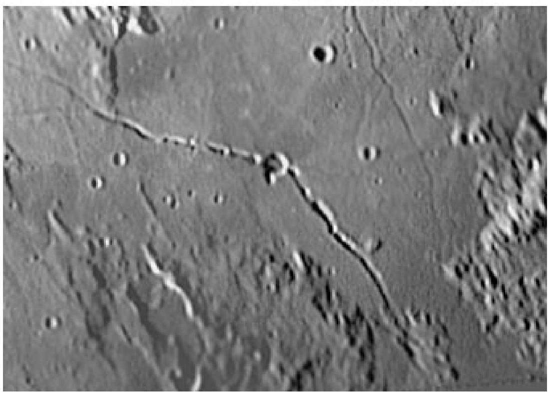


View in telescope, Map14

For an observer at the center of Achimedes, a large lava-flooded crater, his horizon distance is 2.5 km. He can only see the upper part of the distant surrounding walls because the curvature of the lunar surface blocks the bottom slopes of the walls.

(Sketch from Perelman's Astronomy For Entertainment, Moscow, 1958.)

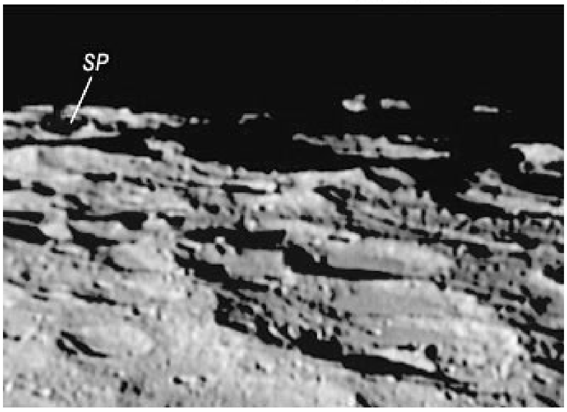
Rima Hyginus 海金努斯月溪



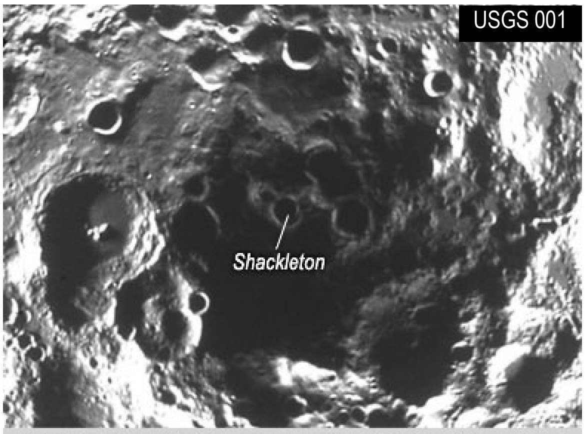
View in telescope, Map 13

Rima Hyginus from Lunar Orbiter 4 probe, 1967. This close-up shows numerous craterlets on the lunar surface not resolvable by any observatory telescopes. The central crater is Hyginus, diameter 9 km. It has flat floor and non-crested rim, hence appears volcanic more than impact-originated.

Lunar South Pole 月球南極

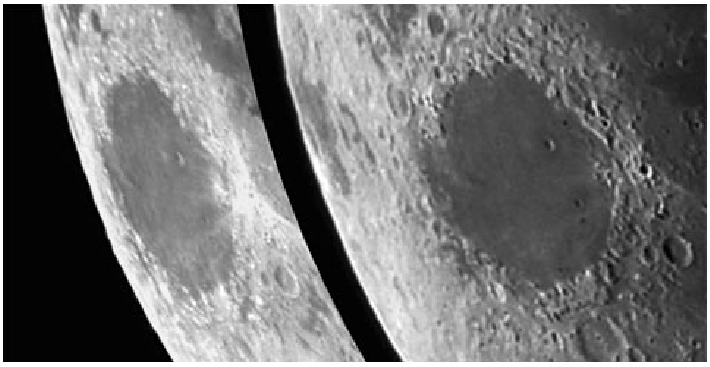


View in telescope, Map 29. The lunar south pole (SP) is hardly observed from the Earth.

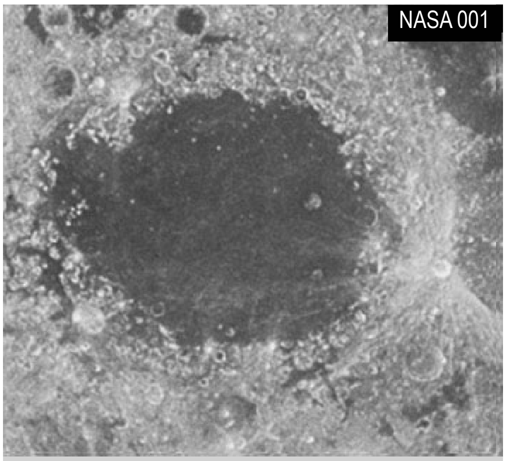


The lunar south pole mapped by Clementine probe in 1994. It lies within Shackleton, a 19-km crater almost permanently in shadow.

Mare Crisium 危海

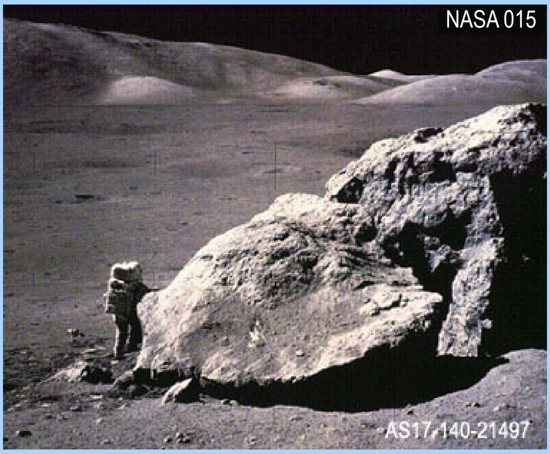


Two views of Mare Crisium in telescope. Their aspect ratio (east-west : north-south diameter) is different due to libration. Libration is the apparent vertical or horizontal rocking motion of the Moon in orbit. It tilts the surface features seen near the Moon's limb, or even makes them temporarily out of sight. Libration is detailed in Event 1 pages.



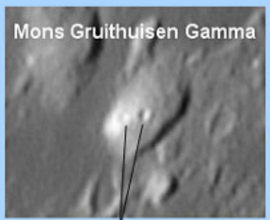
This image from Apollo 11 spaceceaft shows the non-oblique view of Mare Crisium. Its east-west diameter is longer than the north-south by 33 %. (Image cropped from AS11-44-6667)

Resolving Power of Telescopes



Left: *The isolated boulder on the Moon is probably a dropping of ejecta from crater impact. Although it looks big to the Apollo-17 astronaut, it is not detectable by any observatory optics. Even the Hubble Space Telescope, with its 2.4-m mirror, is unable to spot moon rocks smaller than about 80 m. At best night, a 25-cm (10-inch) telescope resolves to 0.45 arcseconds, or lunar craters of about 800 m in diameter.*

Right: *A 25-cm (10-inch) telescope can be tested by resolving the pit-craterlet pair in Mons Gruithuisen Gamma, Map 22.*

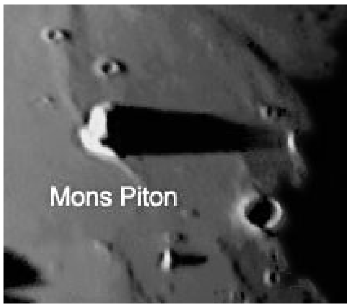


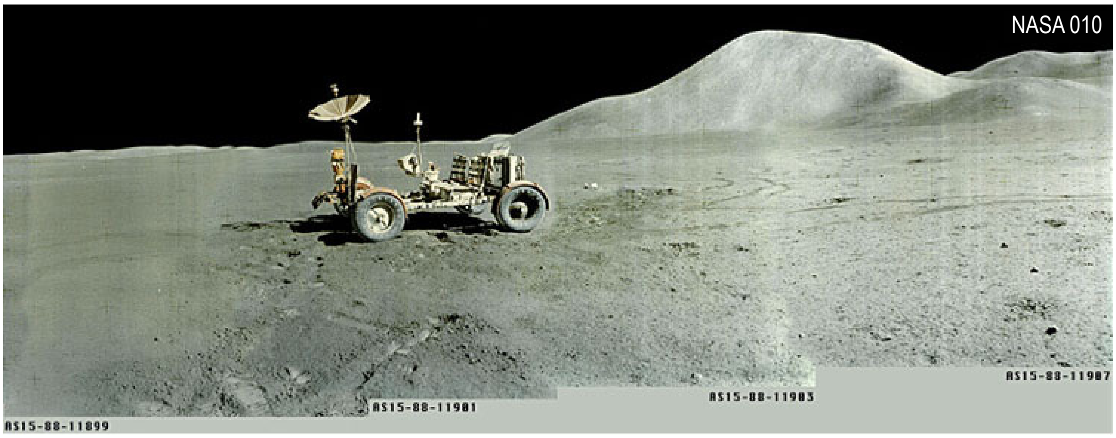
pit-craterlet pair (diameter ~1 km)

In telescopes, a crater close to the lunar terminator looks like deep hollow because the shadow on it exaggerates the impression of depth. Actually the floor of a lunar crater with central peaks is not deep against its diameter. For example, the cavity of Tycho (figure below) is 85 km in diameter, 4.6 km deep. The depth-diameter ratio is 1 : 18, rather shallow by terrestrial norm. During the full moon, the exaggerated depth of Tycho will vanish, and the crater looks almost flat with a dark halo.

3/4 Tycho in shadow   1/2 Tycho in shadow   No shadow (at full moon)

The shadow effect, together with the global curvature of the Moon, also play trick to the appearance of lunar mountains. In the right figure which shows the telescope view of Mons Piton, an isolated mountain in Map 15, it has the appearance of a steep cliff, exaggerated by the long triangular shadow under low illumination. However, an astronaut on the Moon would find its slope quite gradual, roughly 20^0. This is because the global curvature of the Moon is greater than that of the Earth; the short horizon distance of the astronaut (2.5 km) makes him or her to perceive Mons Piton not as steep as the shadowed view in telescopes.



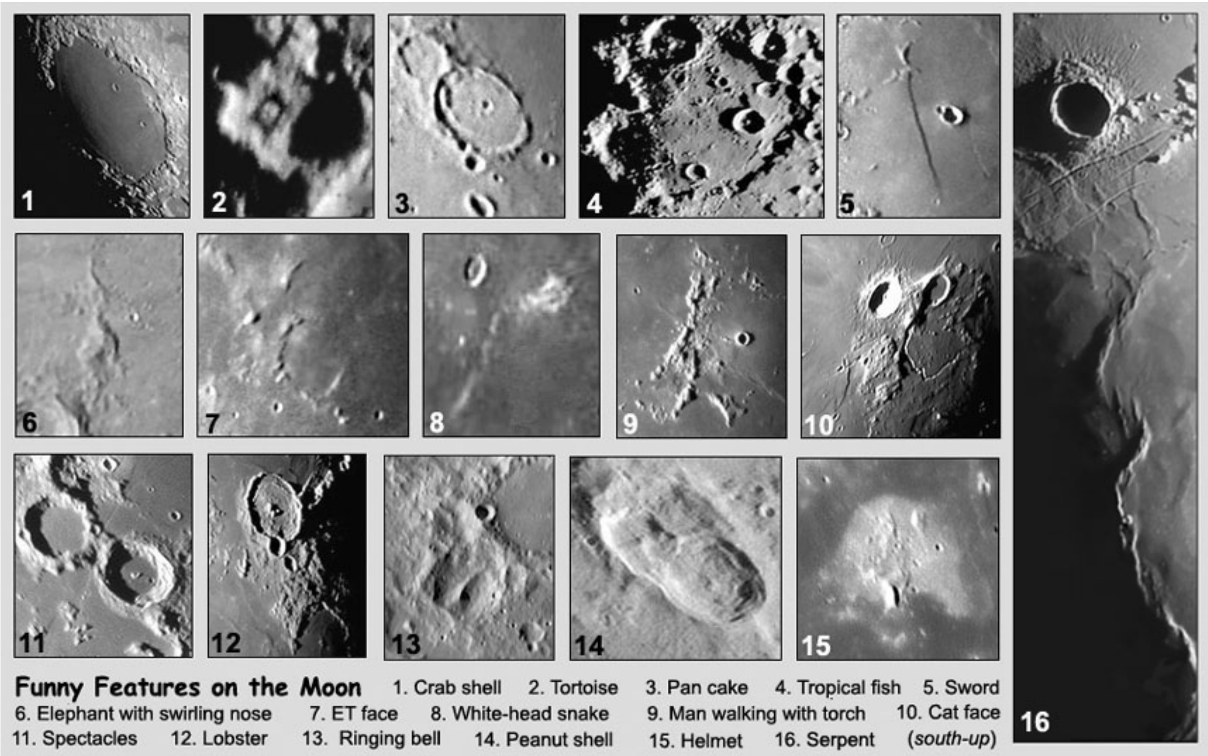


The above mosaic shows the landing site of Apollo 15 (July 1971). The mountain is Hadley Delta at the foothills of Montes Apenninus Map 14. Astronauts called it a "featureless mountain" (quite true in this picture). They found lunar scenery almost white or black. They also reported that distances on the Moon were hard to estimate, partly because the Moon's surface curves more sharply than that of the Earth and hence the horizon is closer, partly because there is no atmosphere and hence no softening of shadows. Note that on the airless Moon, the sky is dark even at daytime. The radio antenna on the rover points to the Earth, which remains almost stationary to the landing astronauts.

Although the Moon is physically a barren world compared to our vivid Earth, yet there are lots of surface features visible in telescopes. See these funny highlights:

Funny features on the Moon

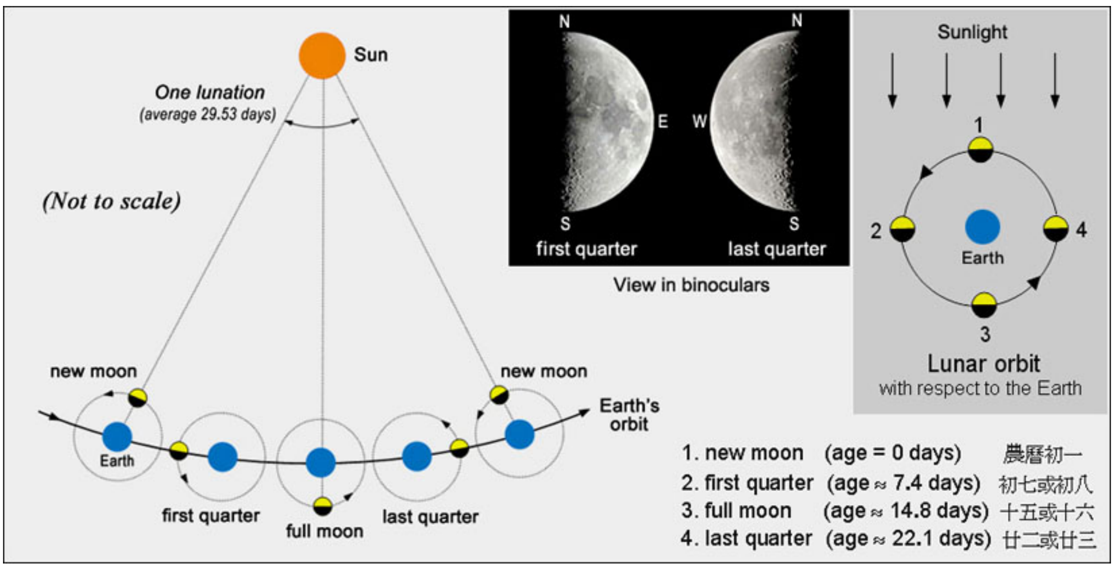
Under certain illuminating conditions, some lunar features may look conspicuous and funny in telescopes. Below are the glimpses of them. Their details are traceable from the **MAP** *pages.*



Age of the Moon

*The age is the number of days that has elapsed since the last new moon. In average, the new moon recurs every 29.53 days; this period is called synodic month or one lunation. Because the Moon's and Earth's orbital speeds are not uniform, the first quarter, the full moon and the last quarter may occur slightly earlier or later than the indicated age. It is also possible to have two full moons in a calendar month, e.g. June 2007 and then March 2010 in Hong Kong (approximately 7 times in a 19-year period). "**Blue Moon**" is a misinterpreted term for the second full moon in the same month. Rarely the Moon is tinted blue unless the atmosphere is filled with dusty particles or water droplets about 1 micron wide. These particles strongly scatter red light while allowing moon light to look blue.*

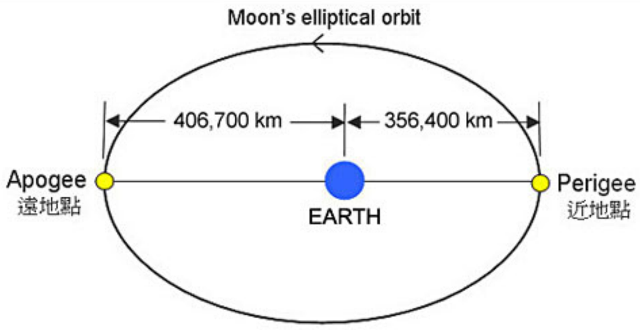
In the drawing below, note also the Moon must orbit about the Earth more than 360^0 from new moon to next new moon. The new moon is not visible except in solar eclipses.



Apogee and Perigee

*The angular diameter of the Moon is about 0.5^0, equivalent to viewing a pencil thickness at an arm's length. It varies according to the instantaneous Moon-observer distance. Thus the Moon appears about 1.5 % bigger at zenith (overhead) than at horizon, though this change is small. To an observer on the Earth's equator, the Moon's angular diameter can vary between 29.8 arcminutes at **apogee** (farthest from Earth) and 34.1 arcminutes at **perigee** (closest to Earth), a cyclic change of almost 14%. When the Sun, Moon and Earth are aligned near perigee, total solar eclipse is possible because the silhouette of the new moon looks big enough to block the entire Sun.*

***Perigean spring tide** refers to the greatest amplitude of water level which 'springs' up and down between high and low tide. It will occur when the Moon is at perigee and when the Sun, Earth and Moon (whether new moon or full moon) are aligned to reinforce gravitational interactions. Such phenomena are not uncommon and are notable at some coastal spots in Hong Kong, e.g. on 2005.01.11~12, the new moon was at perigee; the river in Shatin overflowed the bank during the high tide.*



(The Moon's elliptical orbit is exaggerated to show its apogee and perigee.)

River overflowed a bank during perigean spring tide. This picture was taken shortly after tidewater retreat.

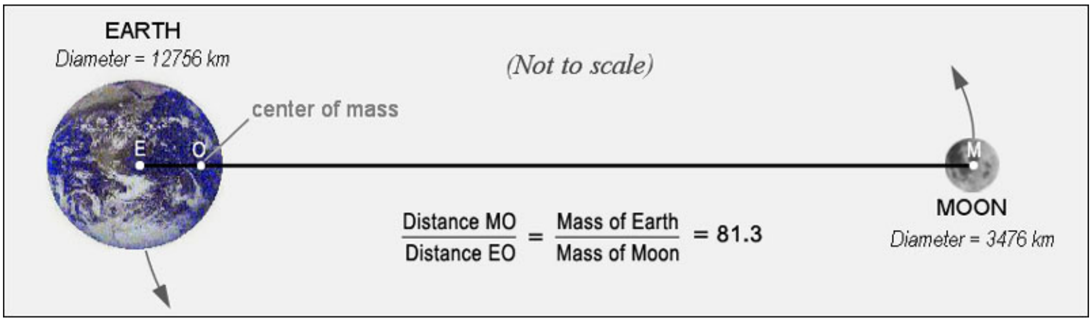
The Earth-Moon System

*Actually the Earth and the Moon move in slightly elliptical orbits about the **center of mass** of the system which acts as if all the mass were concentrated there. The Earth and the Moon are always in opposite sides of the center of mass. They go around this center once every sidereal month (27.3217 days).*

The center of mass is about 1900 km below the Earth's surface when the Moon is at perigee, and 1400 km below the Earth's surface when the Moon is at apogee.

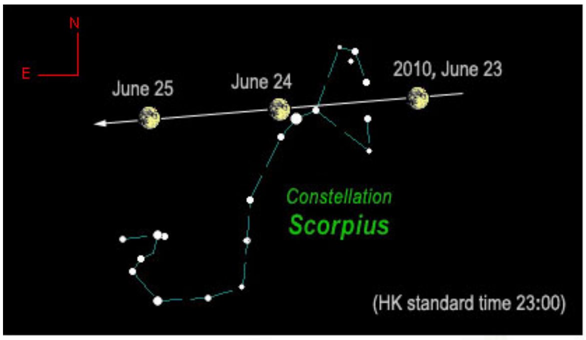
The center of mass is not stationary. It follows the Moon's orbital motion to sweep an elliptical loop inside the Earth globe. It also revolves about the Sun once every sidereal year (365.2564 days).

Over time, the friction of tidewater slows down the Earth's axial spin by 0.0017 second per century. This loss of spin is absorbed in the Moon's orbital motion by the principle of conservation of angular momentum. It causes the Moon to spiral away from the Earth at average of 3.8 cm per year. Total solar eclipses will no longer be possible 600 million years from now. However, the Moon remains with the same face (nearside) locked towards Earth. The Moon's distance shall not increase forever. It would stabilize some billion years later, probably at 560,000 km. By that time, one lunation would be lengthened to 55 days; the Earth's rotation would be dramatically slowed down; or perhaps the Sun might have expanded to a red giant destroying the Earth and the Moon **!**

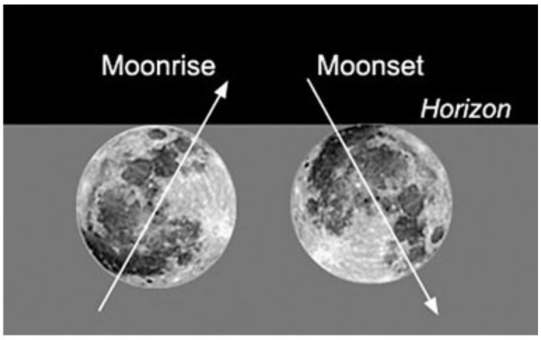


Moonrise and Harvest Moon

Between apogee and perigee, the Moon moves 11.8 ~ 15.4 degrees per day eastward among the star background. As a result, moonrise recurs every 24.3 ~ 25.2 hours, and so it must be delayed in successive days. There is always one day with no moonrise (e.g. 2010.07.05 Hong Kong) and one day with no moonset (2010.07.19) in each month.



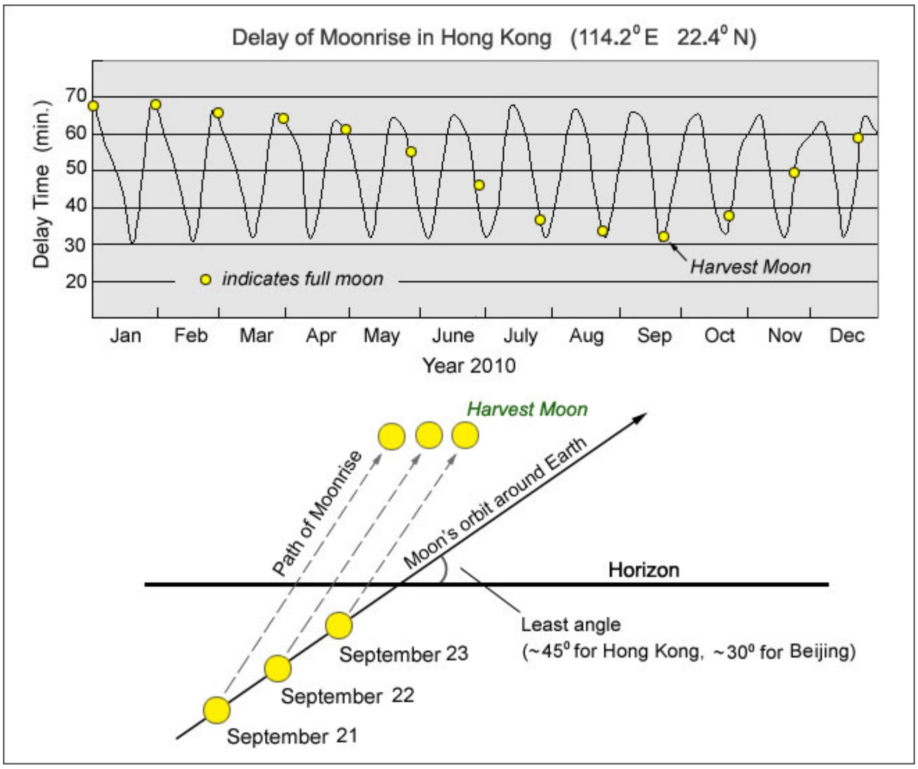
The Moon's motion relative to stars: It takes the Moon two full days to cross Scorpius from west to east.



Exact moonrise or moonset is defined by the time when the upper limb of the Moon is even with the horizon.

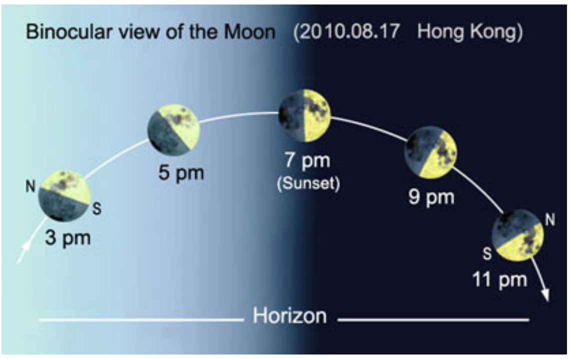
The graph below shows the delay of moonrise *in Hong Kong during 2010, which changes from about 32 to 68 minutes or vice versa in every two weeks. This proves a very large variation of moonrise time in a lunation. The general saying that the Moon rises about 50 minutes later per day is not applicable most of the time.*

Harvest Moon *refers to the full moon that rises at minimum delay time during a year. It happens in few successive nights close to autumnal equinox (September 23) in the northern hemisphere. At these nights, the full moon rises around the time of sunset, and it appears only ~32 minutes later than the Moon did the day before. This is because at days close to autumnal equinox, the ecliptic, and hence the Moon's orbit, is at its least angle to the horizon at the time of moonrise in the northern latitudes. In higher latitudes (e.g. 50^{0} N), the daily delay time of the Harvest Moon is even shortened to 20 minutes or less. Harvest Moon happens in March in the southern hemisphere. It is so named because the moonlight helps farmers to work at harvest time.*



Tilting of the Moon's terminator, as seen from Earth

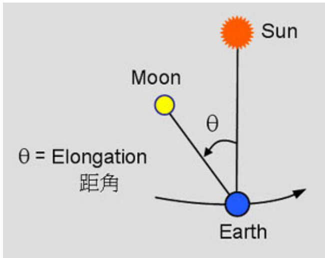
Between moonrise and moonset, the Moon in the sky seems to tilt differently from the vertical. This is because our eyes see the sky as its projection on the celestial sphere, and the Moon appears to move in a curved path above the horizon. Such perception is illustrated by a binocular watch on 2010.08.17 Hong Kong. At 3 pm, the first-quarter Moon was visible in daylight at an altitude of about 20^0. It was rising in south-east with the upper end of the terminator tilting to the observer's left hand side. At transit when the Moon was highest above horizon, the terminator looked almost vertical. Thereafter the Moon sank westward, and the terminator tilted to the right.



Brightness of the Moon

Due to the elongation of the Moon from the Sun, the brightness of the Moon changes against its age in a lunation. Maximum brightness is at the full moon, equivalent to visual magnitude of about –12.7. Minimum brightness is at the crescents, see the following table.

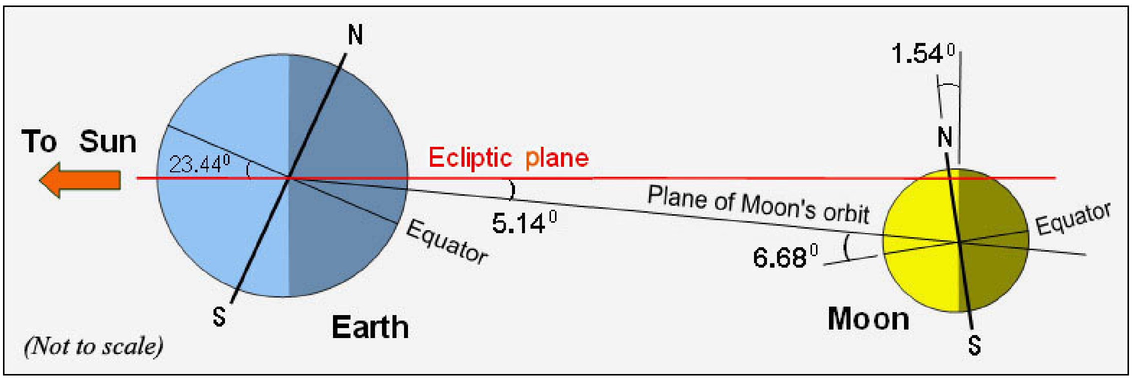
Note that the eastern half of a Moon disc is slightly brighter than the western half, and that at ages approaching full illumination, the Moon rises in the afternoon and is naked-eye visible in daylight.



Moon Age (days)	3	5	7	first qtr.	9	11	13	full moon	17	19	21	last qtr.	24	26	28
Elongation	37^0	61^0	85^0	90^0	110^0	134^0	158^0	180^0	207^0	232^0	256^0	270^0	293^0	317^0	341^0
Relative Brightness	< 1	3	6	8	16	30	58	100 (full illumination)	49	26	13	8	4	1	<1

Searches of water-ice on the Moon

The Moon's rotation axis is almost perpendicular to sunlight. Hence the Sun never rises high above the horizon at the polar regions of the Moon. Some craters at the poles are so deep that sunlight probably never reaches their bottoms where the temperature is extremely cold (perhaps –200^{0}C). These craters have been thought for a long time to trap water-ice shed by comet impacts. In 2009 and 2010, the NASA's LCROSS impact mission and NASA radar on the Indian Chandrayaan-1 probe found evidences of water-ice in craters at the lunar poles. Researchers also reported that the water signatures in the Apollo lunar samples may have originated from comets. (Nature Geoscience Letter doi:10.1038 / ngeo1050)



An experience in lunar observation

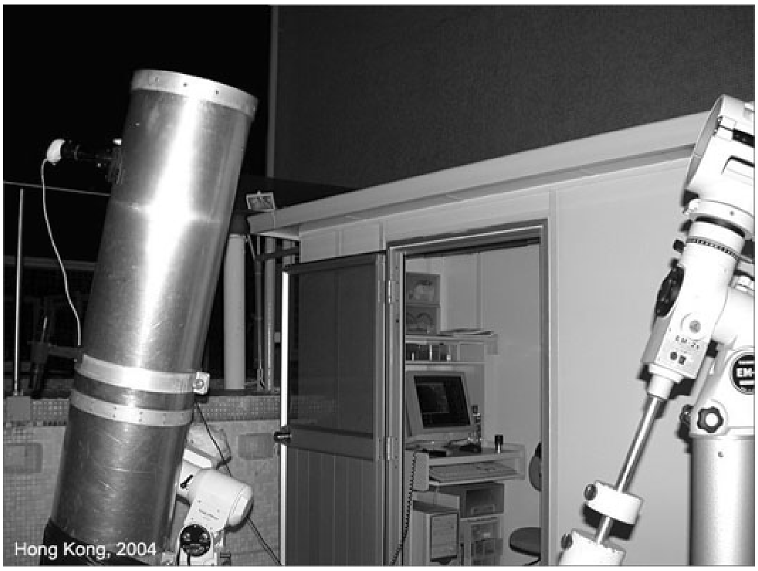
The requirements of a Moon telescope are not critical except personal preference. The author's preference tends to be three:

- A 4-inch (102 mm) f/8 refractor for portability. Its front objective is an apochromatic fluorite which resolves nicely to 1.1 arcseconds or lunar craters of about 2 km in diameter.
- A 5-inch (128 mm) f/8 refractor for imaging at wide field (happened to be fluorite too).
- A 10-inch (254 mm) f/6 Newtonian for imaging lunar details. It resolves to 0.45 arcseconds, hardly dews in nighttime and is most frequently used.

The 5- and 10-inch are not supposed portable. Newtonian bigger or longer than 10-inch f/6 is seldom used because the observer needs to "stand high on stool" by the eyepiece (sounds to cause falling accident), and the seeing is not always supportive. The C9 (Celestron 9.25-inch Schmidt-Cassegrain) is sometimes used when the 10-inch Newtonian is unavailable, e.g. recoating of mirror. In the author's experience, a collimated C9 gives best optics among all Celestron Schmidt-Cassegrain, but it never outperforms a quality, equal-aperture Newtonian. The Celestron kit of vibration suppression pads is highly recommended. It kills vibration residue of the telescope almost instantly, and has been tested equally well for loading as heavy as 68 kg.

Try to observe the Moon even when the seeing is mediocre, because the peculiar view of a landscape lasts for few hours only (e.g. the "golden handle" and wrinkle ridges of Sinus Iridum MAP 18). If this session is missed, the observer must wait at least 4 weeks to meet similar view. Avoid the use of star diagonal because it gives an awkward (mirror reverse) view not compatible with most Moon maps. During image capture, it does not matter to orientate "*south- or north-up*". South-up is more convenient to observers who really look into telescopes, and north-up is more common in topography.

The Moon after last quarter rises late at night or even at dawn. Be relaxed before observation. It is advantageous to plan an observing session in advance, such as the example in next page. Always check the collimation of the optics and allow them to reach thermal equilibrium; these are essential for high magnification works.



The author's current site for lunar (and planetary) observation.

Left is a 10-in (254 mm) f/6 Newtonian; right is a moveable mount for 4- to 5-in refractors. The site is at open top of a 32-storey building in Hong Kong. A high wall behind the site chamber blocks the east to south view. No roof is allowed by building regulations. When the Newtonian is not used, it is simply protected with plastic sheet and solar shield.

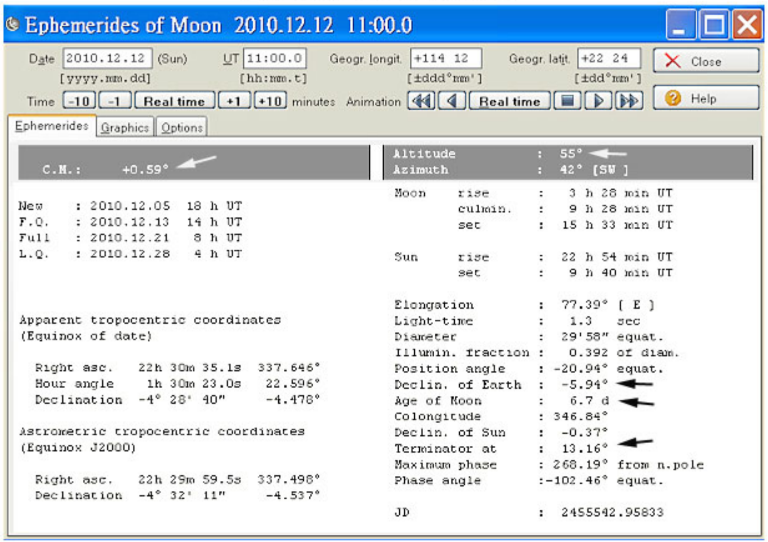
*During the very hot summer (50^0C+ on ground surface in afternoon**!**), it helps to spray the floor by water, and hence to minimize local air turbulences.*

Here is an example to plan observing the features in Map 8 where Apollo 11 landed on their vicinity. They include crater Sabine, Ritter, Lamont, Armstrong, and the nearby domes, rilles and wrinkle ridges.

***** *EXAMPLE* *****

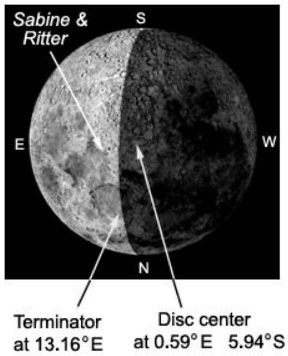
The References page at the end of the book suggests a freeware *WinJupos* for moon ephemerides, a set of tables giving the predicted positions of the Moon (and planets). Download this freeware from Internet. After setup, select the object "Moon" in the dialogue window. Input the date, UT (universal time) and geographic location similar to below.

Ephemerides of the Moon



+ means East or North - means West or South

The Moon on 2010.12.12 11:00 UT



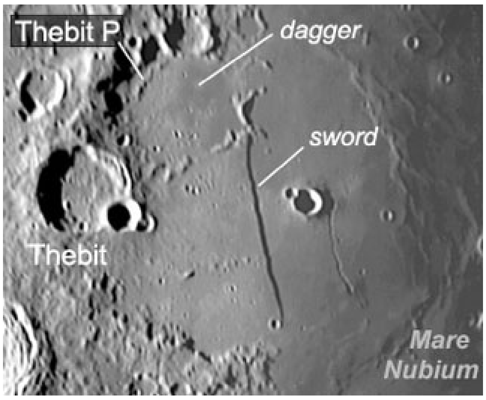
WinJupos then predicts that at the given input, the Moon is 55^0 high in SW direction and is sinking. Its age is 6.7 days. Its C. M. (***Central Meridian***) is $+0.59^0$, meaning the Moon disc is centered at longitude 0.59^0 E and hence an extra 0.59^0 zone of libration** is visible along the east limb. Similarly, ***Declination of Earth*** -5.94^0 implies that the Moon disc is centered at latitude 5.94^0 S, giving an extra 5.94^0 zone of libration near the south pole. ***Terminator at*** 13.16^0 (E) indicates that crater Sabine & Ritter are illuminated at favorable angles similar to T096 of Map 8. The angles are also oblique enough to spot the wrinkle ridges around Lamont. On the other hand, crater Armstrong is known small (about 5 km or 2.5 arcseconds angular). It is easier to spot Armstrong with bigger telescopes, as well as the domes and rilles in the map.

In the above table, *Terminator at* 13.16^0 is just an alternative quote of ***Colongitude*** 346.84^0 **, because they always sum to 360^0, 180^0 or 0^0. The colongitude tells the instantaneous position of the terminator from which one can calculate the sunlight angle, and hence the height of a surface feature from the length of its shadow. A method to determine lunar surface heights is given in the References page.

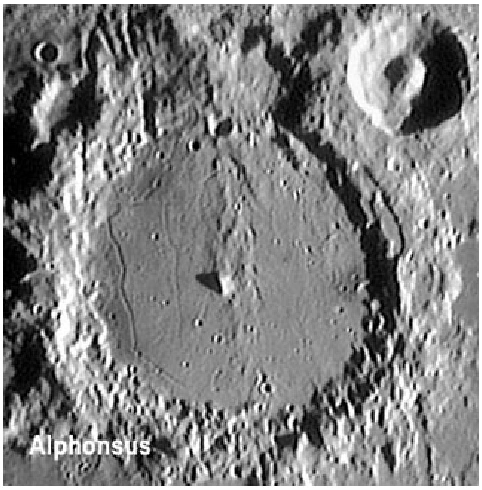
WinJupos also provides a calculator for the distance between two points of selenographic coordinates. However it is not the only program available. There are other Internet sources of moon ephemerides and computing tools.

** *Libration and Colongitude are elaborated in* Event 1 *and* Event 2 *pages respectively.*

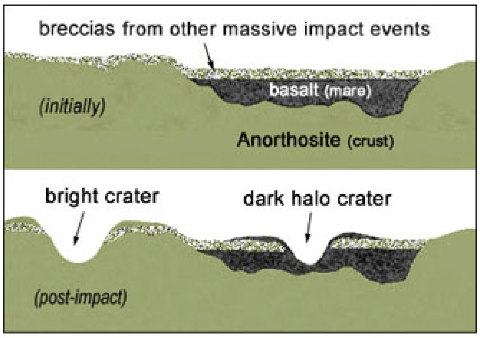
IMAGINATION helps tremendously in lunar observation. Give a name or token to your feature favorite. It will not appear in standard Moon atlas but is a good marker of memory. For instance, the Straight Wall (***Rupes Recta***) can be thought as a sword with a handle at the southern end. This handle is also the wall portion of the "ghost crater" ***Thebit P***, see figure at right or Map 12. The floor of Thebit P is shaded by a pattern of darker lava which resembles a dagger. The combination is then a sword and a dagger side by side on the edge of Mare Nubium.



The imagination may be extended to crater ***Alphonsus,*** see figure at right or Map 12. Its floor shows three small, dark lava patches along the inner rim, and there are clefts and craterlets on the patches. Such appearance suggests that it might be a remnant of local volcanism, probably very young by geologic age. If the Moon's interior is not totally inert, someday volcanic outgases may leak through the craterlets. They would be ionized by sunlight, becoming luminously noticeable as some kind of LTP (lunar transient phenomena). LTP are temporary changes in color, brightness or shape on the lunar surface. They have been reported for decades even during the Apollo missions, although a lot of them remain controversial. The three most likely explanations of LTP are: a flash from meteorite impact, some form of electrostatic discharge and outgoing gases ionized by high-energy particles from space.



In Map 1 which is intended as a geologic briefing, there is a page to introduce Moon rocks. The *basalt* is a dark rock cooled from extruded lava. The light-colored *anorthosite* is the oldest rock from the lunar crust. The *breccia* type is cemented fragments of pre-existing rocks caused by heat and pressure in impact events. This rock scenario may inspire speculation about the peculiarities of some geologic features. Books and web links about lunar geology are highlighted in the References page.



A scenario of Moon rocks. Dark halo craters could hint the possibility of pre-existing basalts hidden under a layer of breccias (the so-called *cryptomare*).

To investigate lunar formations, few principles can be applied for first approximation:

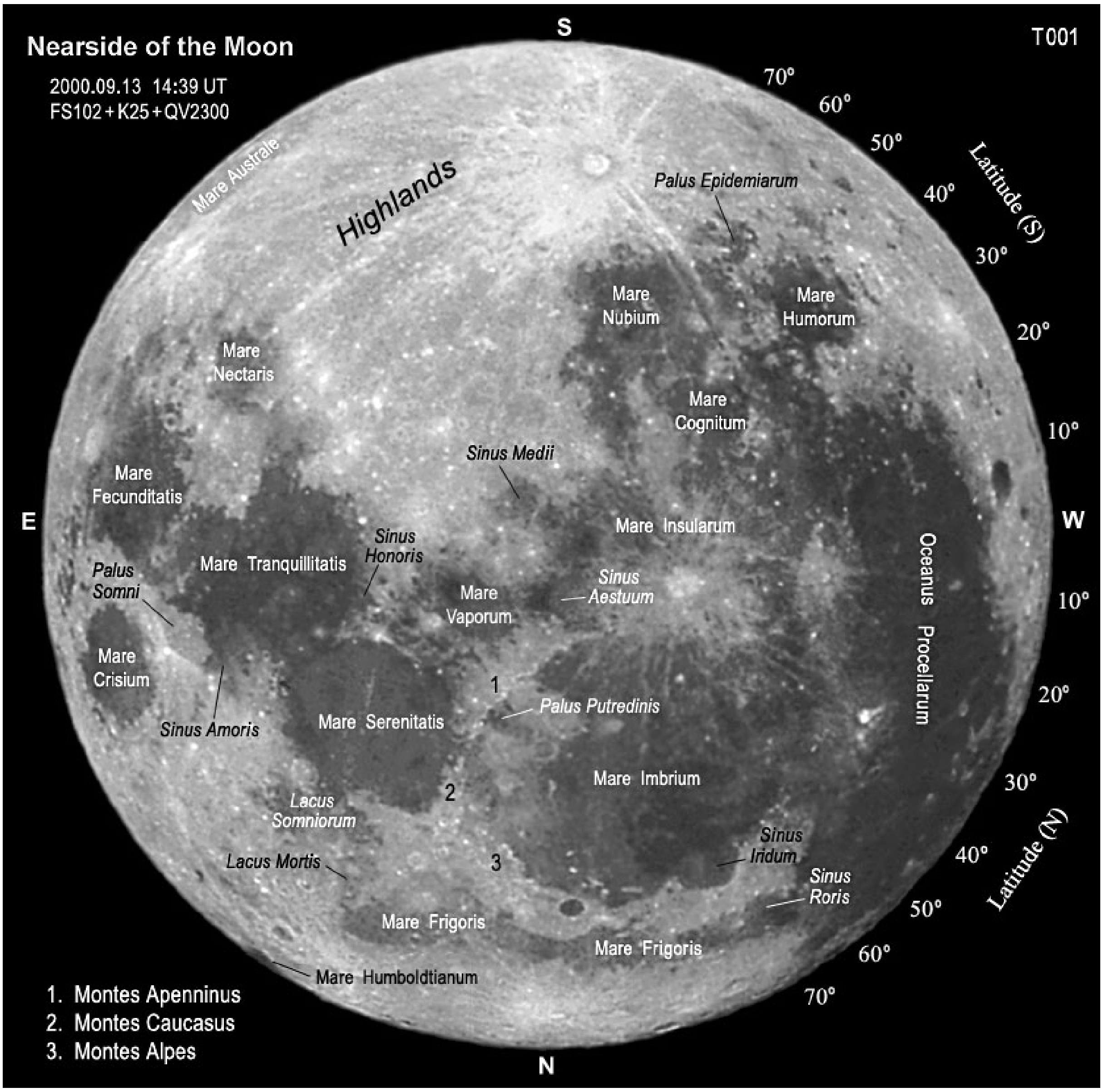
- Small craters are superposed on larger craters.
- Young rocks are superposed on older rocks.
- The rocks on a local surface are not necessarily original; they could come from anywhere else on the Moon.
- Ancient surface is marked by higher density of impact craters.
- Impacts and volcanism may reshape, obliterate or overwhelm pre-existing features.
- Wrinkle ridges often outline the buried ring or rimmed structure in lava-filled basins.

Of course these principles are merely common sense. Occasionally there are odds.

The Geologic Moon

The Moon keeps the same face towards the Earth. One-third of this face (the nearside) is darkened by *maria (*singular: *mare)*, the Latin for “seas”. The term began in the 17th century when the darken areas were thought to be water. In fact maria are smooth lowlands of solidified lava, typically 500~2000 m thick over the lunar crust. They erupted some 3 billion years ago and are younger than the bright surrounding highlands. Maria share 17% of the lunar global surface.

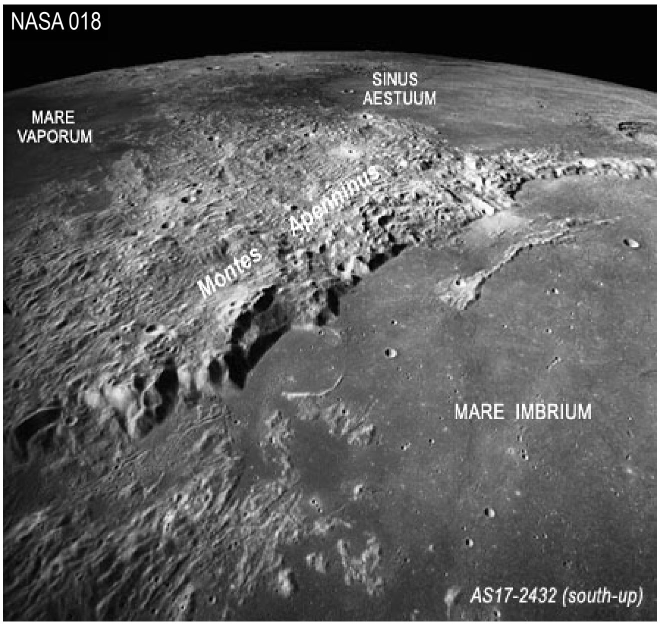
Dark plains of relatively small areas are Latinized as *Sinus* (Bay), *Lacus* (Lake) or *Palus* (Marsh). *Montes* are “mountain ranges”. Three huge montes run along the eastern edge of Mare Imbrium — Montes Apenninus, Montes Caucasus and Montes Alpes as shown in T001. They are part of the rising rim of the impact basin that holds the lava floor of Mare Imbrium.



Mare Australe	Southern Sea 南海	**Mare Nectaris**	Sea of Nectar 酒海	**Palus Putredinis**	Marsh of Decay 凋沼
Mare Cognitum	Known Sea 知海	**Mare Nubium**	Sea of Clouds 雲海	**Palus Somni**	Marsh of Sleep 夢沼
Mare Crisium	Sea of Crisis 危海	**Mare Serenitatis**	Sea of Serenity 澄海	**Sinus Aestuum**	Bay of Billows 暑灣
Mare Fecunditatis	Sea of Fertility 豐富海	**Mare Tranquillitatis**	Sea of Tranquillity 靜海	**Sinus Amoris**	Bay of Love 愛灣
Mare Frigoris	Sea of Cold 冷海	**Mare Vaporum**	Sea of Vapors 汽海	**Sinus Honoris**	Bay of Honor 榮譽灣
Mare Humboldtianum	Humboldt's Sea 洪保德海	**Oceanus Procellarum**	Ocean of Storms 風暴洋	**Sinus Iridum**	Bay of Rainbows 虹灣
Mare Humorum	Sea of Moisture 濕海	**Lacus Mortis**	Lake of Death 死湖	**Sinus Medii**	Central Bay 中央灣
Mare Imbrium	Sea of Rains 雨海	**Lacus Somniorum**	Lake of Dreams 夢湖	**Sinus Roris**	Bay of Dew 露灣
Mare Insularum	Sea of Isles 島海	**Palus Epidemiarum**	Marsh of Epidemics 疫沼	*(Maria on the east limb are given in* Event 1 *pages.)*	

Highlands and Maria *are two major types of terrain on the lunar surface. While highlands are bright, heavily cratered and aged as old as 4.5 billion years, the maria are younger dark plains of lava and hence less cratered. The lunar lavas are enriched in iron and titanium. They also differ from those on Earth in being very fluid, with a viscosity similar to that of motor oil, so that they flow for great distances. The largest lunar mare is Oceanus Procellarum (Ocean of Storms) on the right portion of T0273. It stretches 2500 km north-south but is not contained within a single well-defined impact basin. By contrast, Mare Imbrium on the lower part of the picture sits in an impact basin, diameter 1100 km. The prominent crater with long arms of rays is Tycho. It is 110 million years old, one of the youngest craters ever known.*

(*This image is 1700 x 2200 pixels, and can be zoomed large in its PDF version.*)



Orbital View of Montes Apenninus

A wide-field picture from Apollo 17 in December 1972. South is up. Montes Apenninus, which forms part of the rising rim of the Imbrium basin, is the largest mountain ranges on the nearside of the Moon. The height of some peaks exceeds 5000 m above the mare level. The slopes of Apenninus towards Mare Imbrium are quite steep but the back slopes between Mare Vaporum and Sinus Aestuum are gradual. The back slopes are believed to form from a gigantic hurricane of ejecta at low angle during the Imbrium impact 3.85 billion years ago. (One can imagine the stunning moment of this very massive impact !)

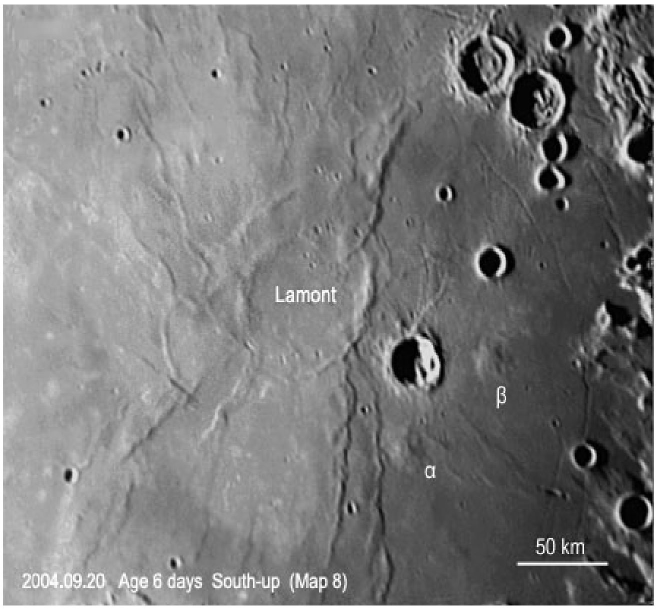
The telescope views of Montes Apenninus are given in Map 14.

Orbital View of Mare Imbrium

This is an oblique view from Apollo 15 in July 1971, when the crew flew over the southwest region of Mare Imbrium. South is up. Lava flow (arrow) towards the center of the mare is traceable. This indicates that lava could erupt again, even after the mare formed. Wrinkle ridges, also known as mare ridges, are prominent in the bottom half of the picture. They are surface folds caused by lateral compression during the subsidence of massive lava in the Imbrium basin. As the lava subsided, its volume was squeezed in the concave-shaped basin. Lateral compression accumulated on the mare surface and created the folds which appeared braided and low, generally under 200 m.

Mons La Hire is a highland remnant partially submerged in lava. It is about 1500 m high, base 11 x 25 km. The spray of small irregular craters around the mountain was formed by low-angled impacts of debris ejected from Copernicus, a large crater 500 km to the south (not shown here).

Many isolated mountains on maria, such as those along the northern edge of Mare Imbrium in Map 16 and Mons Delisle in Map 22, are nonflooded highland remnants.



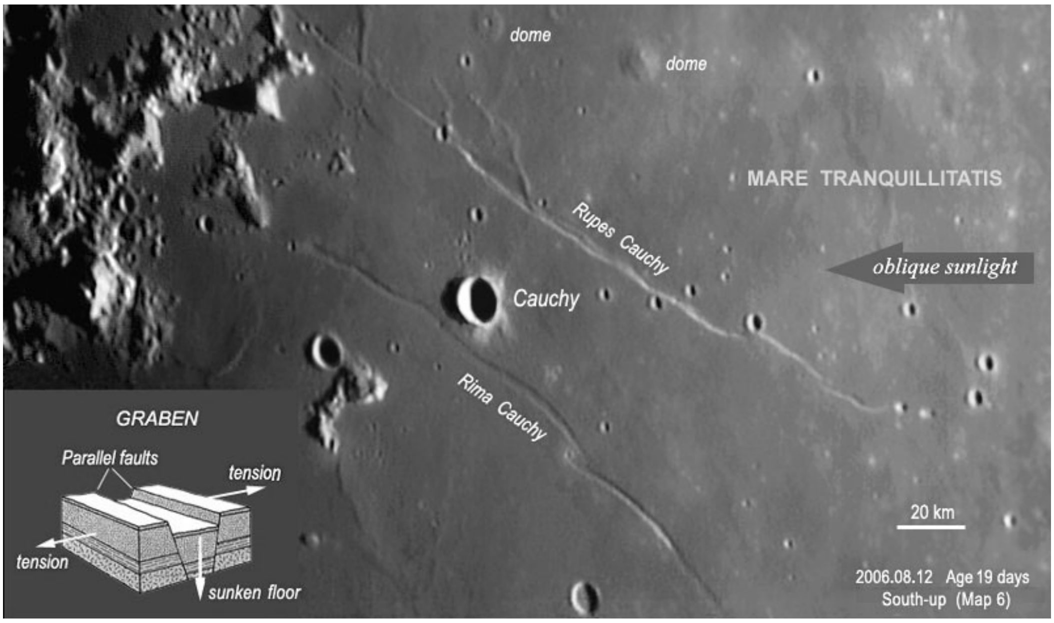
Wrinkle Ridges around Lamont

Wrinkle ridges can form in other ways. Here in the western part of Mare Tranquillitatis, the crater Lamont is outlined by two concentric ridges with radial arms blended in a brighter zone. The predecessor of Lamont is likely a large impact crater or basin buried in the mare. The wrinkle ridges are merely thin shelf of lava dragged over the rims and peaks of the crater/basin. Similar ridges are found in Jansen R (Map 9), Ancient Newton (Map 16), Lambert R (Map 19), Flamsteed & Letronne (Map 20), and Wargentin (Map 28).

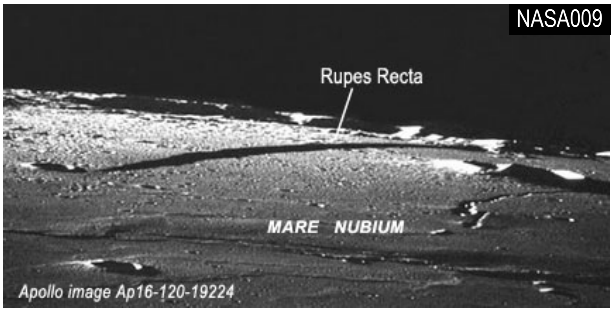
Lamont contains a mascon (mass concentration) as evidenced by increased gravitational pull on orbiting spacecraft. The domes α and β are extinct volcanoes with low incline of slopes, details in Map 32.

Faults and Grabens

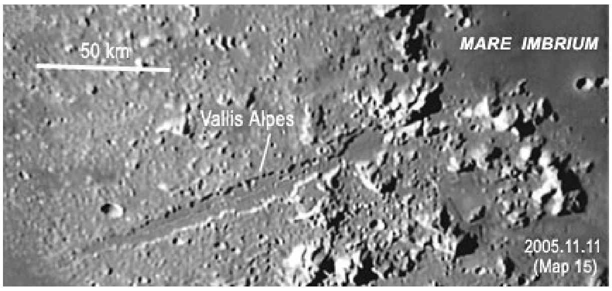
A. *Faults and grabens, represented by Rupes Cauchy and Rima Cauchy in Mare Tranquillitatis, are commonly found at mare-basin borders. In general, they are caused by tensile stress, e.g. when a massive lava sheet deformed the crust under it. Rupes Cauchy is a fault where there has been slippage which is distinguishable as brightened slope under oblique sunlight from the west. Rima Cauchy is a graben formed from two parallel faults with a sunken floor between them. Note that when a mare subsided by its own weight, it is possible to create faults or grabens (by tensile stress) and wrinkle ridges (by lateral compression) on the mare surface. See the illustration on Mare Serenitatis, Map 9.*



B. *Rupes Recta, commonly called the Straight Wall, is a fault possibly triggered by shock waves of the gigantic Imbrium impact (which is over 1000 km away), and later activated by the lava loading of Mare Nubium. Its mare-facing slope is about 10^0. Details in Map 12.*



D. *Vallis Alpes is literally a valley. Structurally it is a wide graben formed in the rim of the Imbrium basin during impact. Its predecessor could be a deep fracture open to stress. Later it was modified to current width (up to 11 km) by the loading of massive lava in the Imbrium basin.*



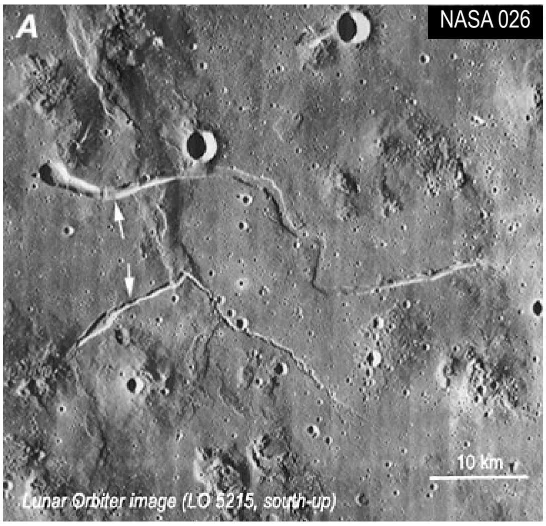
C. *Rupes Altai is a magnificent mountain fault, or more accurately described as a 'scarp' since it has a slope far steeper than Rupes Recta. It is the surviving rim of the impact basin that holds Mare Nectaris. Details in Map 5.*

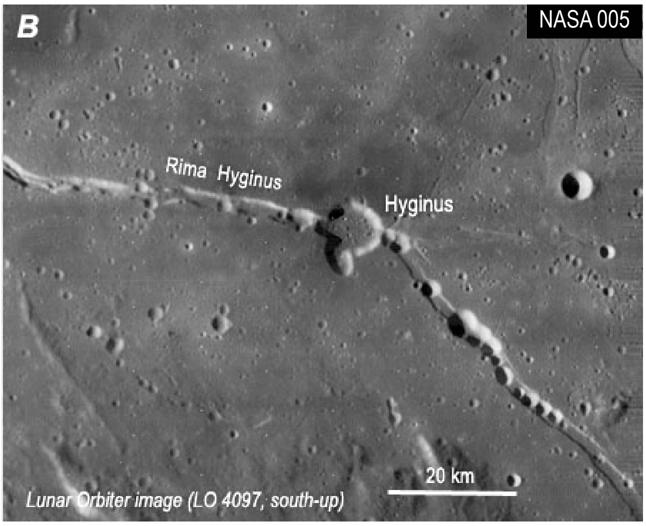
Lava Channels

***A**. This image, taken by Lunar Orbiter 5 at an altitude of 110 km, shows a complex of wrinkles ridges, rilles and dome hills in the northwest of Marius at Oceanus Procellarum. These domes formed from concentrated rise of magma (subsurface molten rock). They lack smooth appearance due to unsteady changes in magmatic characteristics, such as rates of eruption and cooling. The arrows indicate a pair of sinuous rilles located at about 14^0 N 57^0 W. Each rille is a lava channel where the lava outlet is a crater. They are seen cross-cutting a wrinkle ridge.*

Sinuous rilles are distinctly different from rivers on Earth. For example, they usually start in a small crater and become narrower instead of larger as they flow downslope. They may have abrupt breaks and sometimes splits. Sinuous rilles were first seen on the Moon and later on Mars and Venus. Their identity had not been clear until the Apollo 15 astronauts visited Rima Hadley at the foothills of Montes Apenninus (Map 14). Other examples of sinuous lava channels are Rima Marius in Map 20, Vallis Schröteri in Map 21 and Rimae Herigonius in Map 24.

***B.** Lava channels are not necessarily sinuous. Here the 2-section Rima Hyginus is thought to be a lava channel because Hyginus is lack of crested rim that is typical with impact craters. The tiny craters along the rille could be individual events of lava collapse. Compare the lunar lava channels with the terrestrials in C & D.*





Terrestrial Lava Channels and Lava Tubes

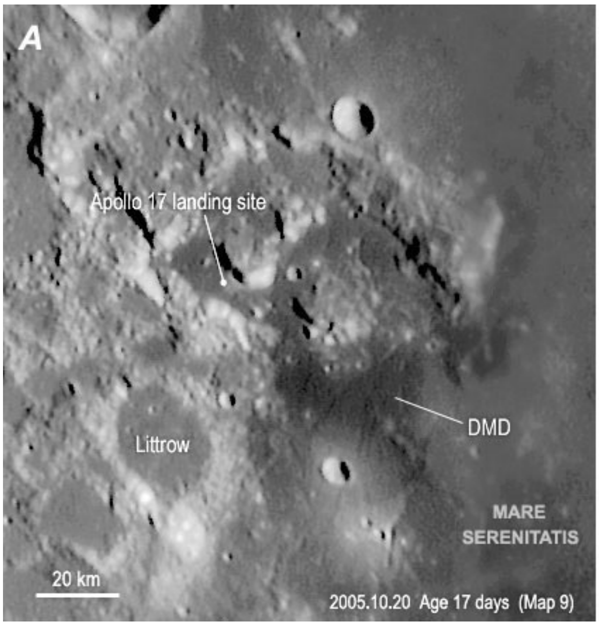
***C.** The cone in the distance is Pu'u O'o volcano, Hawaii. The lava channel is one of the many eruptions of Pu'u O'o. It flows rapidly between the solidified margins (called "levees") of pre-existing channels. Similar channels are also found on the Moon, but they are thought to discharge in enormous rate (more than 10 million kilograms per second). The hot lava channel shown here is approximately 4 meters wide, far smaller than the lunar scale.*

***D.** Lava flow can form tubes which allow lava to flow in relatively long distance without significant cooling. This image is a typical example. Known as Thurston Lava Tube in Hawaii, it is 3 meters in diameter and has two lava benches on the left wall. On the Moon, lava flow could begin in a tube. A rille then formed when the tube collapsed by shocks on its roof or interferences from other impacting events.*

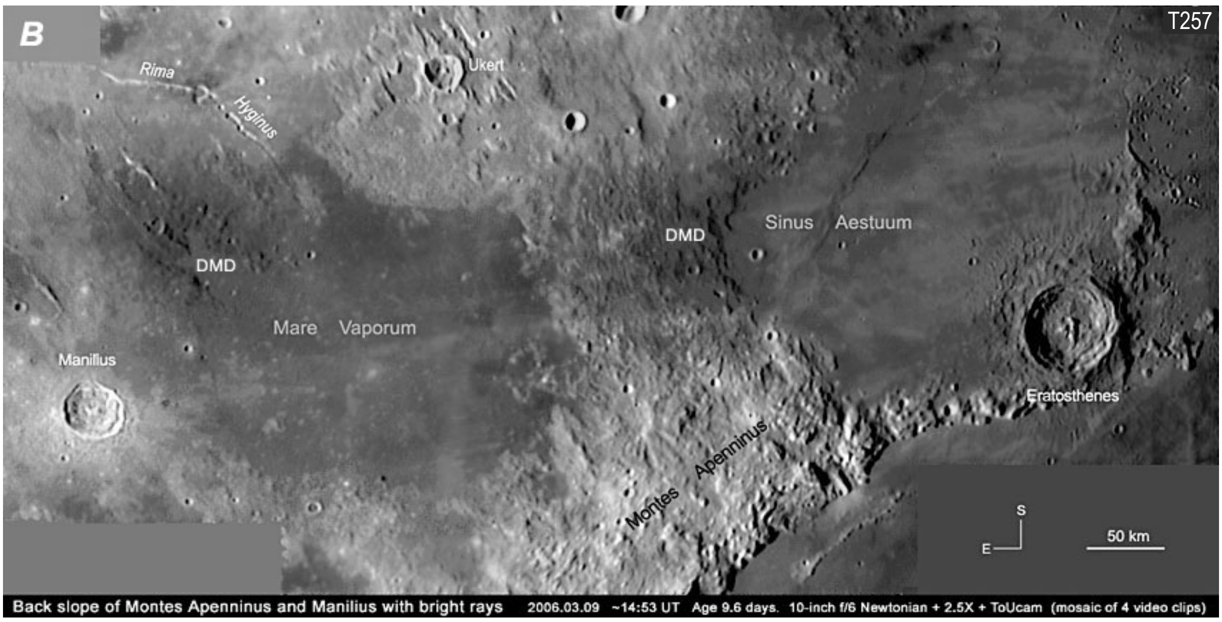
Dark Mantle Deposits and Bright Rays

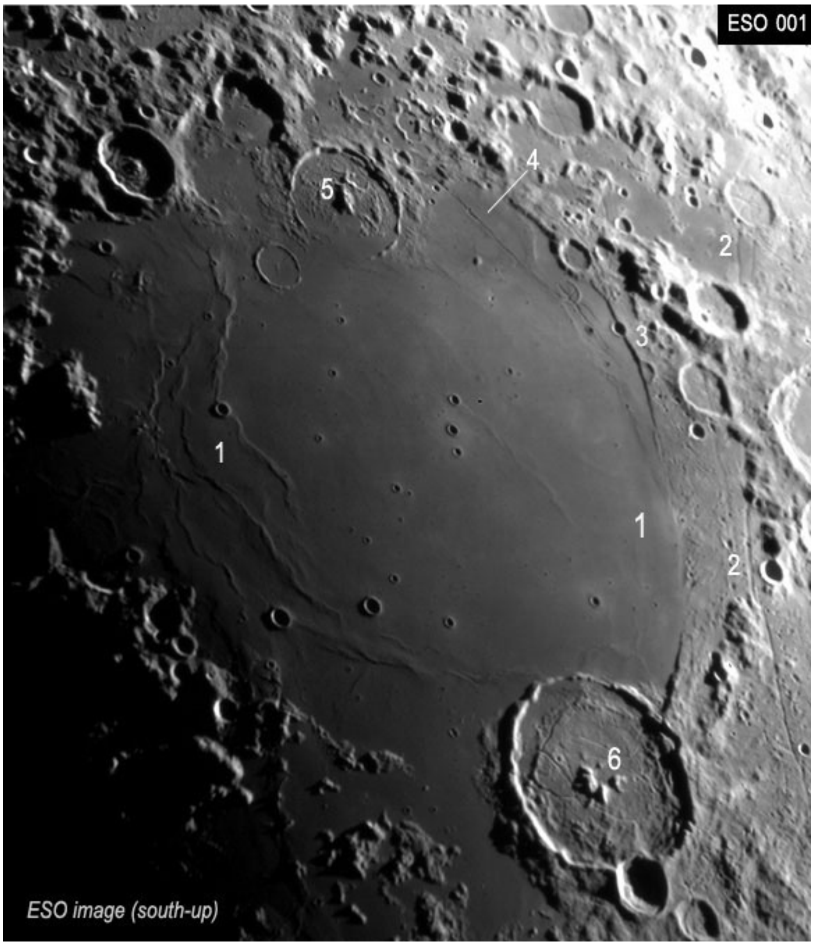
A. *DMDs (Dark Mantle Deposits) refer to remarkably dark areas on the lunar surface. Remote sensing suggests the DMDs are rich in iron and titanium that turn color even darker than the average maria. The only DMD samples are the soils drilled by the Apollo 17 astronauts in the Littrow region. They were volcanic ashes with tiny glassy beads similar to the quickly cooled droplets from the fire-fountains in Hawaii. Unexplored DMDs are presumably formed by fire-fountaining, a process in which pressured magma in the mantle rises to the lunar surface, allowing gases trapped in the lava to escape (called outgassing). These gases --- thought to be carbon monoxide --- act as propellants to shoot the lava hundreds of meters high. En route the lava cools quickly as glassy black beads and rains down to mix with other volcanic ashes on the ground.*

The fragmental rocks and ashes produced from explosive volcanic eruptions (e.g. a fire-fountain) are collectively described as "pyroclastic" meaning "fire-broken".



B. *By contrast, bright rays are more conspicuous in telescopes. An observed example is shown by Manilius, a 38-km impact crater in the bottom image. At this Moon age when the Sun's altitude is about 35^0, Manilius emits long rays extending to Sinus Aestuum, range over 400 km. The rays are the crater's ejecta materials under solar illumination. During impact, they deposited as projectiles in the form of discrete blocks, clusters of disaggregated debris and powders. The brightening is more profound as the rays sweep the dark Mare Vaporum and the DMD at the back slope of Apenninus. Rayed craters are supposed younger than non-rated craters. Details in Map 33.*



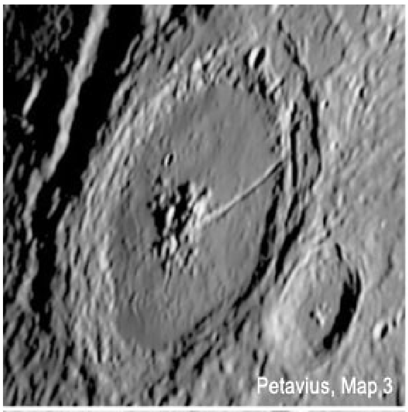


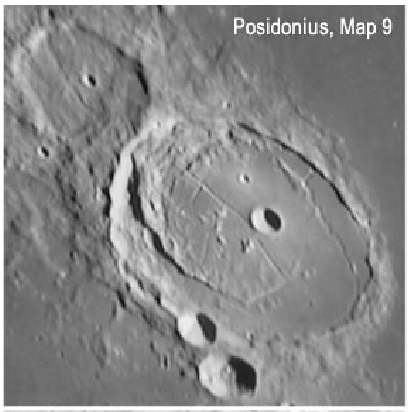
Mare Humorum

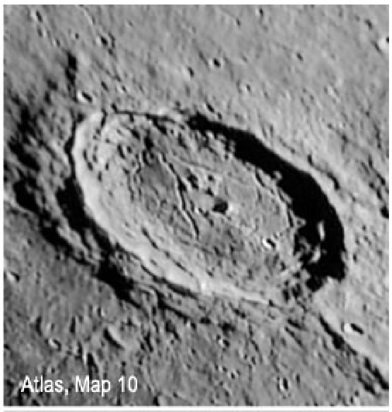
Similar to Mare Imbrium, Mare Humorum (Sea of Moisture) is a lava plain inside an impact basin. It is a spectacular region for lunar photography, diameter 380 km. The depth of lava at the central zone is greater than 3 km. The massive lava subsided and deformed the crust underneath it, creating concentric wrinkle ridges (Label 1), surface fractures (2) and scarp (3) along the edge of the basin. Label 4 is a regional dark mantle deposit through which a linear rille runs. The origin of this rille is unclear. Doppelmayer (5) is an impact crater on the inner slope of the basin's circumference, hence semi-flooded during the eruption of lava in the basin. Gassendi (6) is also an impact crater modified by post-volcanism. It represents a class of feature called FFC (floor-fractured crater). Generally FFCs are big, shallow and lie near the borders of maria where the lava is relatively thin. They formed by magma which rose through basin fractures and ponded under the crater floor. The pressure of the magma lifted the crater floor and produced the fractures. Sometimes, lava leaked onto the floor, creating small ponds of lava, sinuous rilles and dark halo craters.

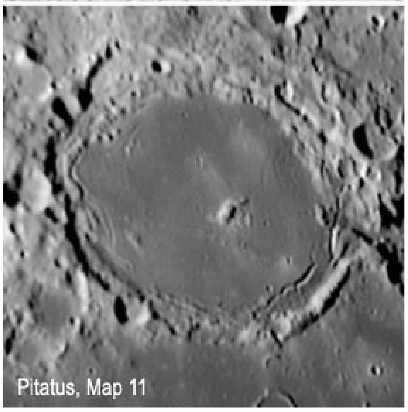
Imaged by European Southern Observatory in Chile with its 2.2-m MPG Telescope on 1999.01.12, when the Moon was 24 days old.

FFC Examples







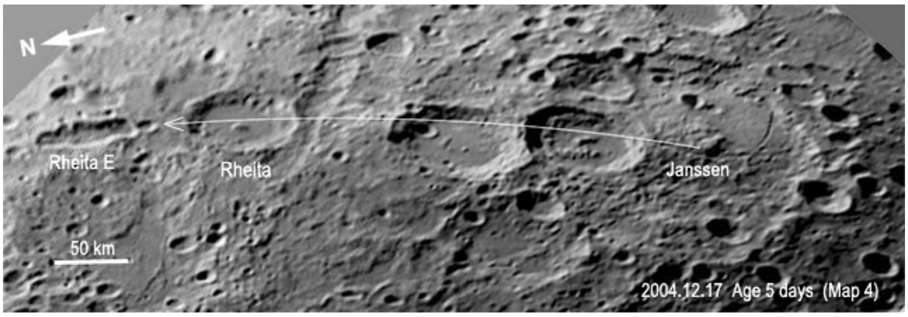


Elongated Craters and Concentric Craters

Elongated craters can be impact in origin or volcanic.

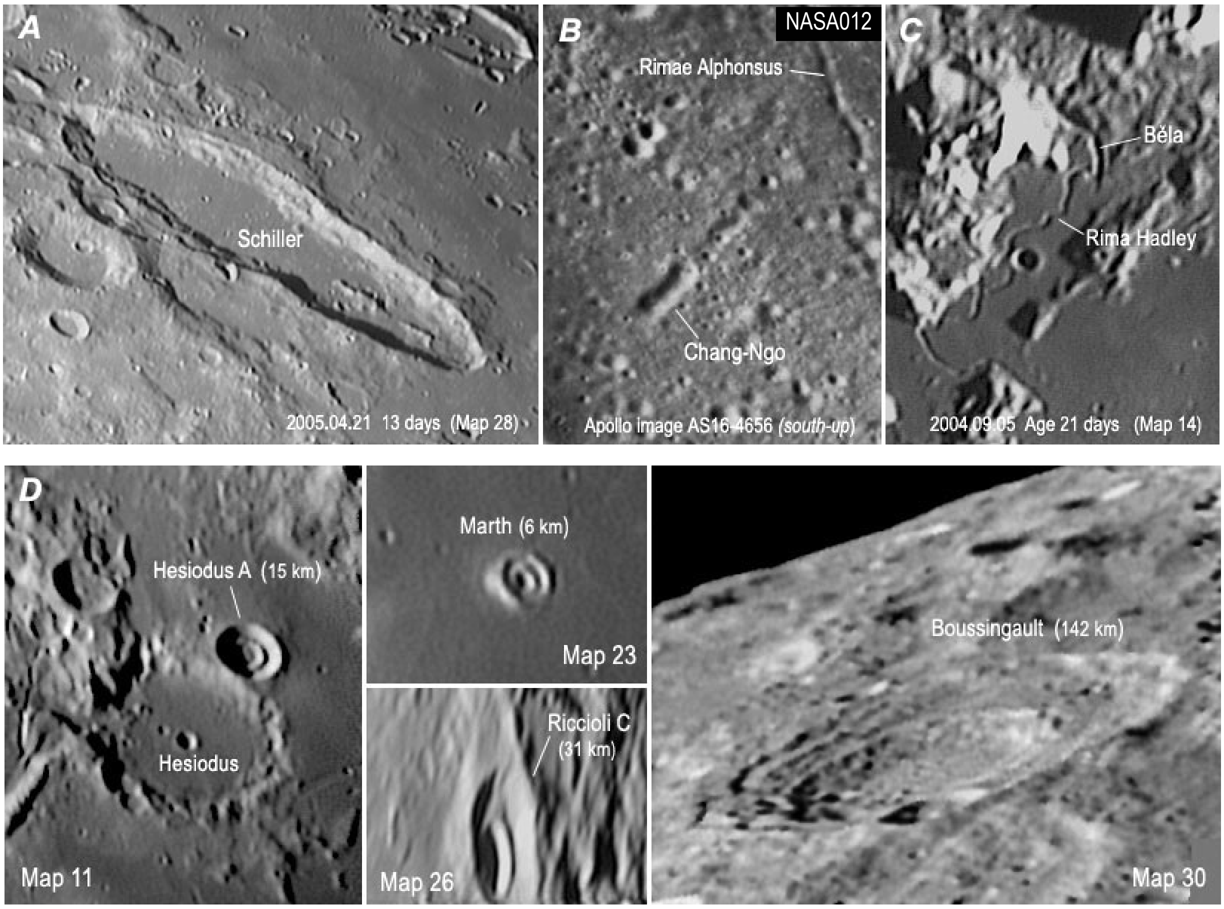
A. Schiller is a truly elongated crater on the Moon's southwest limb, size 70 x 180 km (Map 28). Its predecessor probably consisted of two or more near-sized and overlapped craters. Later they were fused together during a grazing impact event.

B. Chang-Ngo 嫦娥, a small elongated crater inside Alphonsus (Map 12), is most likely caused by secondary impact as suggested by its scalloped floor. An elongated crater sometimes hints the source of the impact. For example, in the map below, Rheita E could be a secondary crater produced by the ejecta of the primary impact at Janssen.



C. Běla is an elongated crater at the foothills of Montes Apenninus, size 2 x 11 km (Map 14). It is believed to be a lava vent where Rima Hadley begins. Rima Hadely is a genuine lava channel visited by the Apollo 15 astronauts in 1971.

D. In telescopes, few concentric craters are observable. Their "double" walls are presumably the results from coincidence of concentric impacts. When the impacts were not concentric, a pear-shaped crater like Torricelli in Map 7 could form.



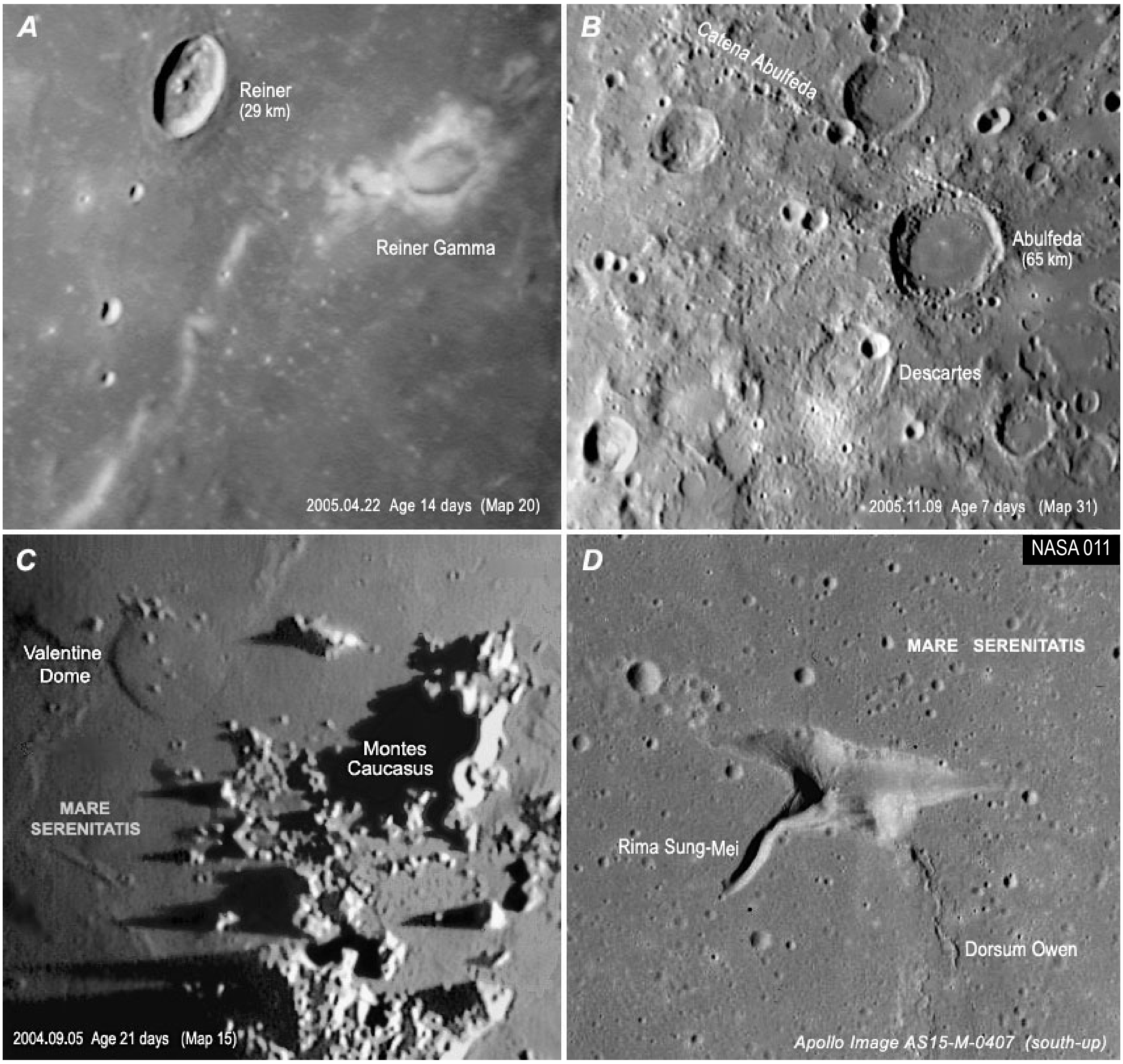
Unusual Features

A. *The Moon is depleted of a global magnetic field. Reiner Gamma, however, is one of the few magnetic anomalies. It appears as a swirling deposit of bright material near Reiner in Oceanus Procellarum (Map 20). Various models were attempted to explain its mystery, including a local impact by a comet and the focusing effect of shock waves from the Moon's farside, but none of them are fully convincing.*

B. *The bright spot at the outer rim of Descartes (Map 31) is another magnetic anomaly. The source of magnetism is thought to be at depth, because the thorium and iron concentrations over the spot are no different from its vicinity. To the south is Catena Abulfeda, a chain of craterlets resulted from secondary impacts or fragmental impacts of a tidally disrupted asteroid.*

C. *Valentine Dome is a 'paper-thin' circular plateau on Mare Serenitatis (Map 15), diameter 30 km, height no more than 100 m. It requires a very low Sun angle to be visible, $2^0 \sim 3^0$ for instance. There are several protrusions and a faint crossing rille on the dome surface. Their origins are enigmatic.*

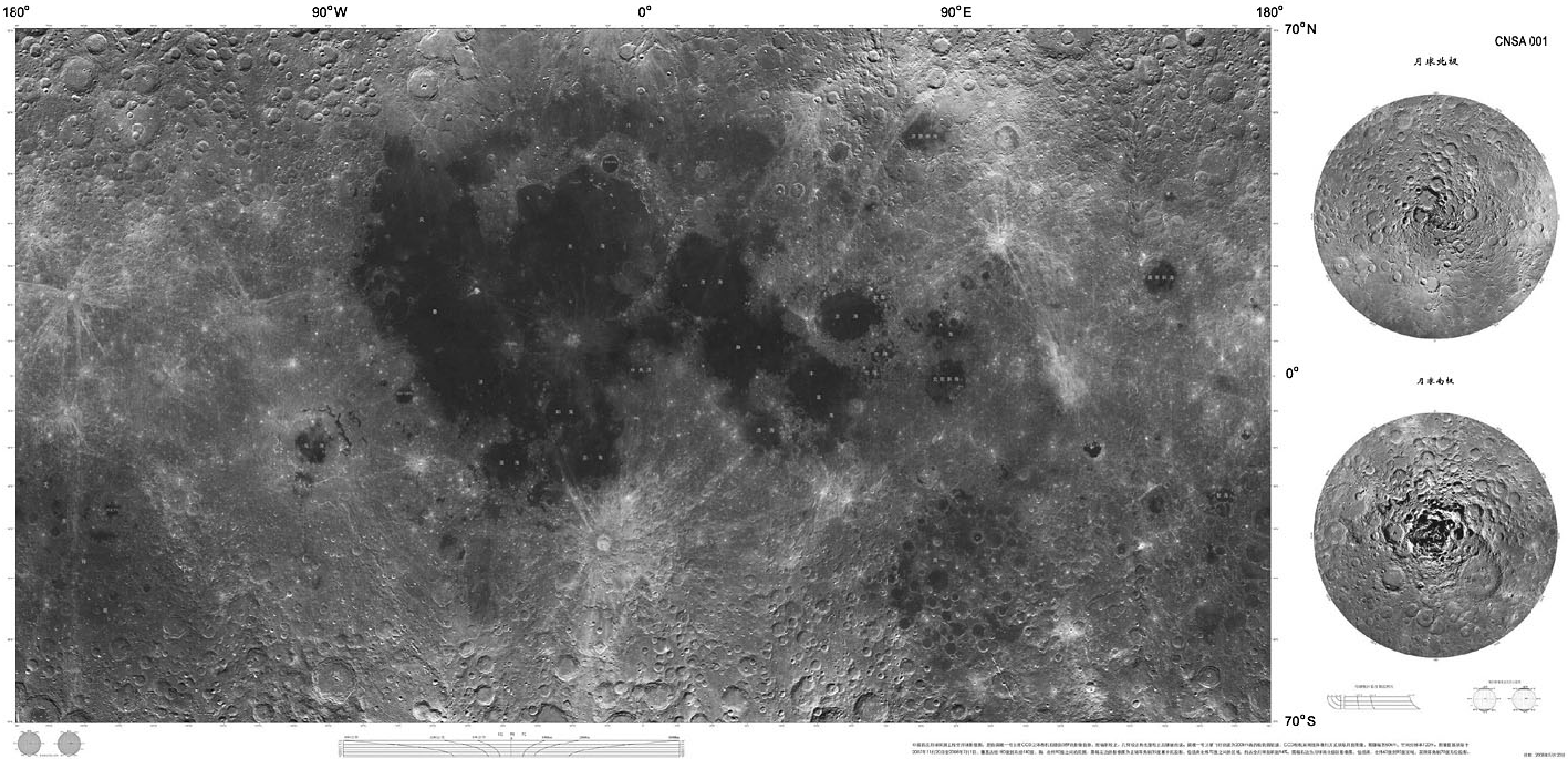
D. *The irregular crater at the tip of Dorsum Owen is elusive to terrestrial observers (Map 9). This Apollo 15 image resolves it to a 3-prong depression. The prongs could have formed from merging three or more volcanic vents on Mare Serenitatis. Rima Sung-Mei is likely a lava channel extending from the vent, length 4 km.*



(Remark: The NASA book "Apollo Over the Moon" contains about 200 annotated images of the lunar nearside and farside. Newer high resolution images are also accessible from the "Apollo Image Archive" project website. See *References page.)*

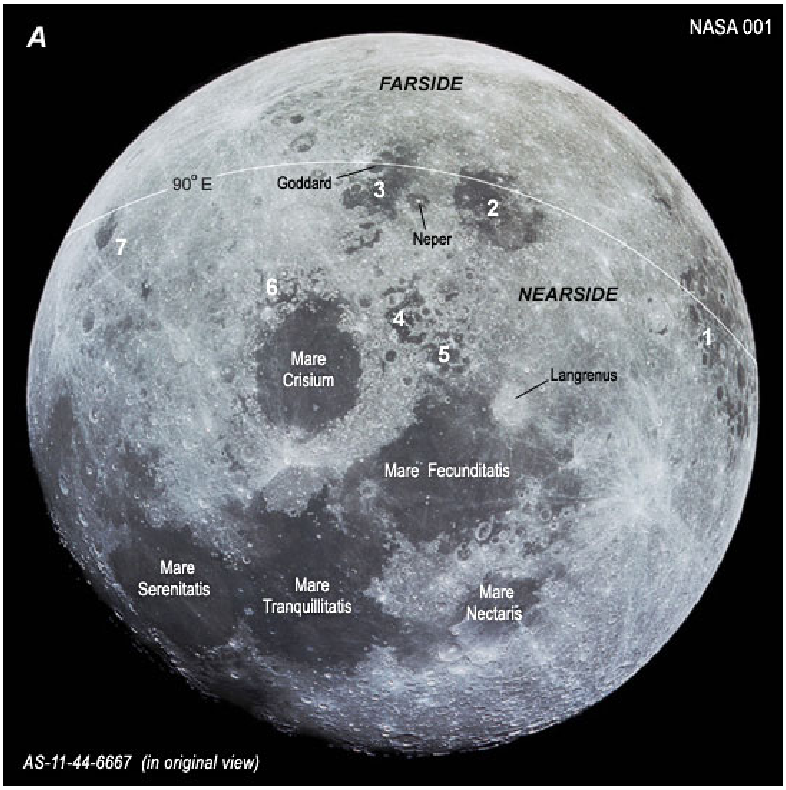
The Global Moon

A global map of the Moon from the Chang'e-1 probe (嫦娥一號) launched in China in 2007. The main map is presented in Mercator projection from 70⁰ N to 70⁰ S (like a regular world map), north-up. It covers a surface similar to the area of Africa. The side maps are the polar regions. Note that nearly all maria are concentrated in the nearside from 90⁰ W to 90⁰ E via 0⁰. They share 1/6 of the Moon's global surface. Tycho, a rayed crater to the south of the nearside maria, remains to be the brightest beacon. Two farside rayed craters are recognizeable: Giordano Bruno at 36⁰ N 103⁰ E and Jackson at 22⁰ N 163 ⁰W. Two circular farside maria are also visible: Mare Orientale 東海 at left (93⁰ W) and Mare Moscovienese 莫斯科海 at right (148⁰ E). The lunar south pole is located at the center of the lower side map; it is inside a permanently cold depression almost without sunlight.



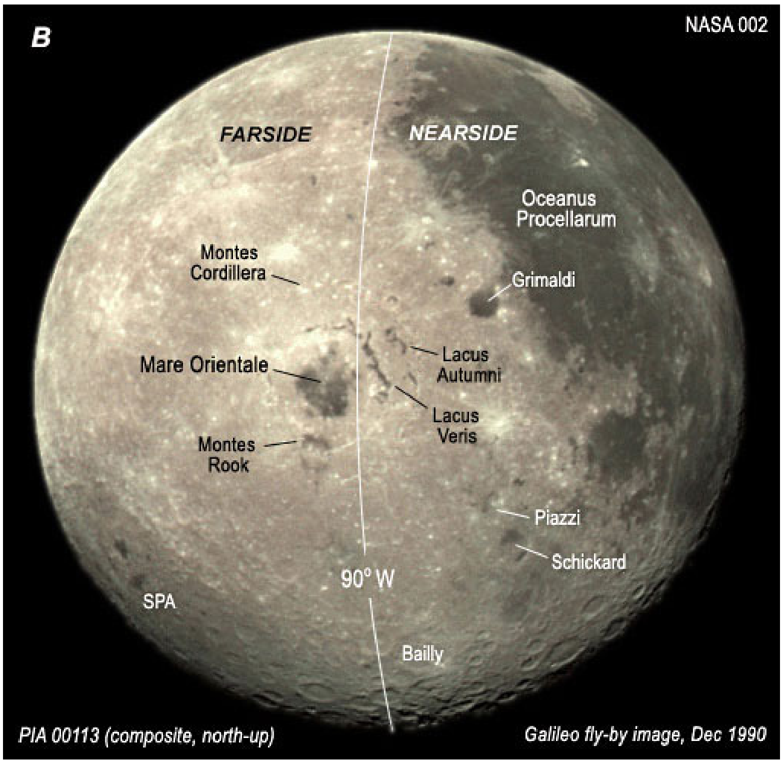
MAP 1

Between the Nearside and Farside



***A.** This view, taken at 18,000 km from the Moon during the return trip of Apollo 11 in July 1969, is quite different from terrestrial impression. The left side is selenographic north. It shows a large circular surface of the Moon but does not represent the full hemisphere. The white line (longitude 90^0 E) through Goddard separates the Moon's nearside from its farside. Maria 1 to 7, whose terrestrial views are always limb-foreshortened, are now displayed in favorable perspective.*

1. Mare Australe (Southern Sea) 南海
2. Mare Smythii (Smith's Sea) 史密斯海
3. Mare Marginis (Border Sea) 界海
4. Mare Undarum (Sea of Waves) 浪海
5. Mare Spumans (Foaming Sea) 泡海
6. Mare Anguis (Serpent Sea) 蛇海
7. Mare Humboldtianum (Humboldt's Sea) 洪保德海



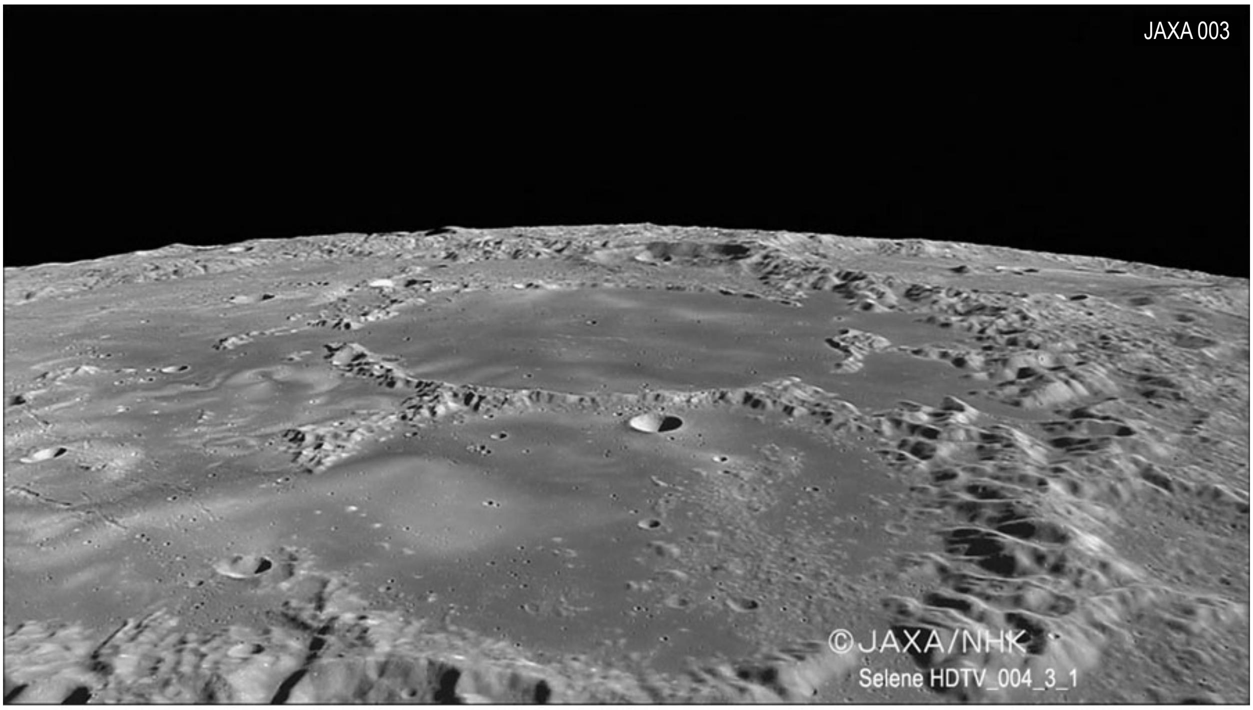
SPA = South Pole - Aitken, *an impact basin, diameter 2300 km.*

***B.** Mare Orientale (Eastern Sea) is almost at the center of the Galileo fly-by image, but on Earth it is hidden behind the west limb of the Moon and is partially visible only at very favorable librations. The mare is centered at 19^{0}S 93^{0}W, about 320 km across. Physically it is the lava-flooded portion of the Orientale impact basin. The shock waves from the impact resulted in concentric multi-rings of mountains, including Montes Rook and Montes Cordillera at diameter of 930 km. In wide-field high-resolution maps, the Orientale ejecta can be traced as distant as the location of Schickard.*

By comparing the Moon's nearside and farside, it can be seen that the dark maria are concentrated in the nearside but the farside is mostly brighter highlands with very few maria. It also shows, in general, maria tend to be circular in shape. This suggests that, like craters, the maria were firstly triggered by huge impactors which struck the Moon some time ago, thus forming basins. The basins subsequently flooded with lava that flowed out through the cracks in the crust, forming the maria that appear in maps. The maria are relatively thin lava sheet on the crust, so their total volume is small, about 0.1% of the bulk Moon.

A question is why maria are concentrated in the nearside. The common belief is that asymmetric development of the Moon made the farside crust generally thicker than the nearside crust, as shown in next page. The farside crust has limited deep cracks to eject magma, hence very few maria. The density of lunar crust (~2.9 g/cc) is also less than that of magma (~3.3 g/cc) in the mantle. These combined effects shift the Moon's center of mass from the center of figure by two kilometers and make the thinner crust side slightly more massive than the opposite hemisphere. Over time, the Earth's gravity must have dragged the Moon until its more massive (thin crustal) side locked towards Earth.

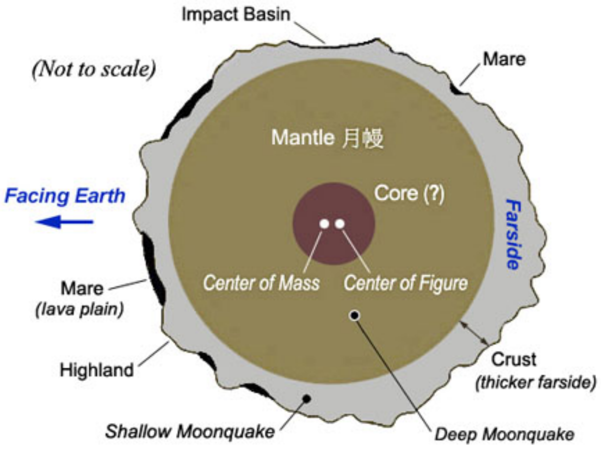
In the image NASA 002, SPA marks the South Pole-Aitken of the lunar farside. It is the largest impact basin in the solar system, diameter 2300 km, depth 12 km and age at least 4.1 billion years. Scientists thought that the shock waves from the SPA impact traversed the Moon's interior to the opposite face, producing part of the cracks in the nearside crust where maria formed. However, the crustal thickness at SPA is inferred 20 ~ 30 km only. There were supposedly ample crustal cracks to eject magma, nevertheless only few spots of lava flow have been found in the basin. The anomalous lack of maria in SPA remains to be a topic of research.



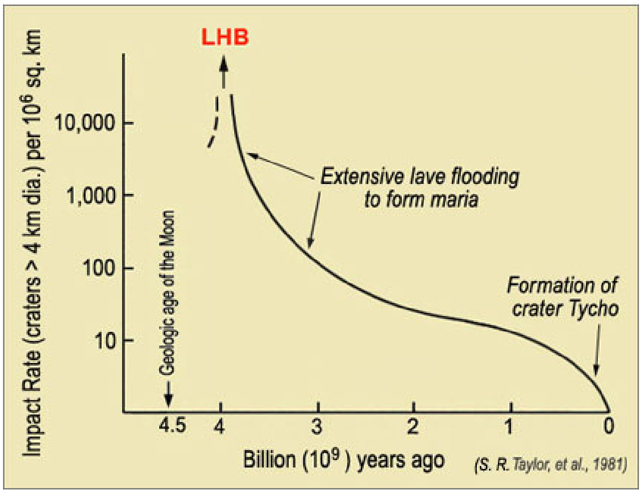
A broad view of Mare Ingenii on the northwest edge of South Pole-Aitken basin. The white swirling streaks are magnetic anomalies. (*Selene image*)

Cross-section of the Moon's Interior

The lunar crust is 50 km thick in average, range 20 to over 100 km. The farside holds the thinnest and thickest parts of the crust. However the thick majority lies on the farside. Overall the nearside crust is thinner. It is easier to eject magma from the upper mantle through the cracks of the nearside crust after colossal impacts, hence creating the maria we see from Earth. The farside has very few maria due to thicker crust. Analyses of the lunar rocks indicated that the early Moon did have a weak magnetic field but it is depleted now. The existence for a metallic core is speculative from the lunar seismic and physical data. If the core exists, its diameter is probably less than 700 km.



Moonquakes: *The Moon is lack of plate tectonics. Therefore it is not surprising that moonquakes are less intensive and less frequent than earthquakes. Most moonquakes are 700 ~ 1000 km deep in the mantle; they are triggered by the Earth's and Sun's tidal forces especially during the perigee, and may have mild magnitude below 2.5 in the Ritcher scale. Shallow moonquakes are rare but stronger with magnitude up to about 5.5; they are caused mainly by meteorite impacts or slumping of crater walls. Fewer than 3000 moonquakes are detected per year, whereas hundred thousands of earthquakes are noted per year with similar equipment on Earth. During moonquakes, the Moon "rings" like a bell for tens of minutes because there is no liquid water on the Moon to damp down vibrations.*



Lunar Impact History

Left: *The impact rate on the Moon can be deduced from crater counts. Generally it is much higher during the first 0.8 billion years of lunar history. The high initial impact rate is probably due to early stages of planetary accretion, or fragmentation of nearby asteroids. The exact cause of early bombardment is uncertain but it is likely that the impact rate increased abruptly at about 3.9 billion years ago, a transient stage known as LHB (Late Heavy Bombardment) or lunar cataclysm.*

Most impact basins formed during the LHB. Following the LHB is a rapid drop of impact rate between 3.8 and 3.2 billion years ago. In this period, many impact basins on the thinner side of the crust were lava flooded. Since then volcanic eruption faded. The maria and mountains we see today remain nearly same status as 3.0 billion years ago.

Lunar Regolith

Although the impact rate to produce craters is slow today, the airless Moon is still under day-night temperature stress and continuous bombardment by countless micrometeoroids, cosmic rays and charged particles of the solar wind. As a result, a layer of loose and broken rock and dust, termed regolith, has accumulated 3 to some tens of meters thick over the lunar crust. The right picture from Apollo 16 shows the astronaut's bootprints on the lunar regolith. He is dragging a rake through the regolith to collect rock fragments. Despite the "light" weight of the astronaut under low surface gravity (1/6 that of the Earth or about 25 kg on the Moon), his bootprints appear quite heavy suggesting that the regolith is loose indeed. It is this loose layer that scatters sunlight making the full moon very bright.

The dusty particles in lunar regolith are known as "moondust". They are abrasive and electrostatically sticky, as noted by the Apollo astronauts. Lunar regolith also contains traces of small black glass beads, size 1 mm in average. These beads were produced by melting due to the heat and pressure of micro bombardment.

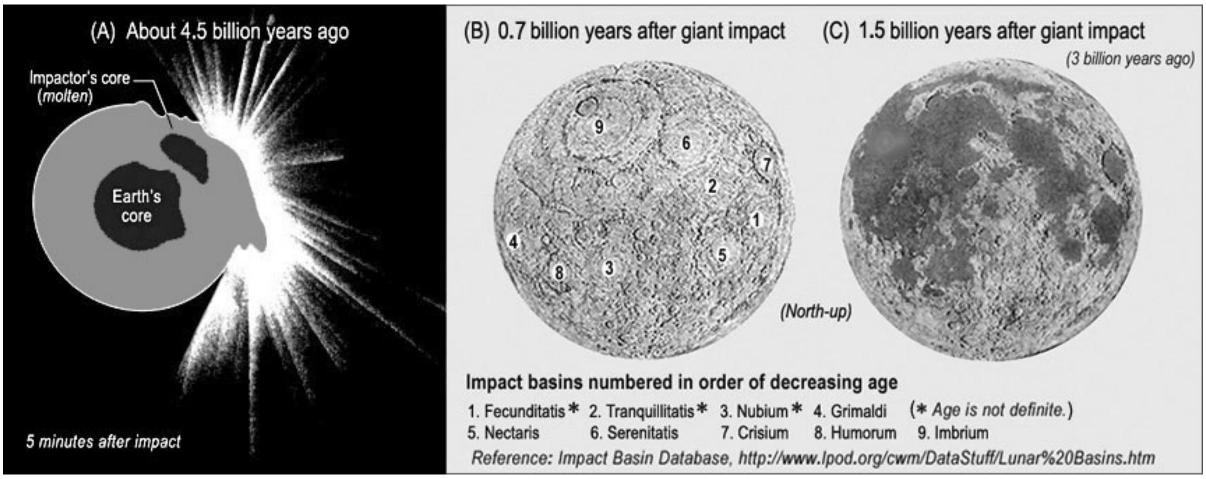
Below the regolith is often "megaregolith", a broad layer of broken-up debris and fractured bedrocks created by larger impacts on the original crust, typically 2 km thick. Megaregolith is very common since the Moon is full of impact events.

The Giant Impact Hypothesis

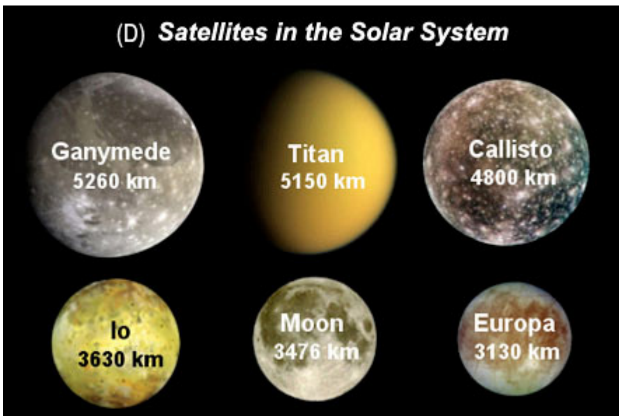
A. *This hypothesis, supported by computer modeling, is generally favored for the origin of the Moon. It states that about 4.5 billion years ago, a proto-planet "Theia" of diameter 6000 km struck the proto-Earth at an oblique angle. The dense heavy core of Theia fell into the surviving Earth while its less dense mantle and part of the Earth exploded as debris into space. Some debris fell back to Earth. Other debris accreted to form the Moon orbiting Earth at less than 1/15 of present distance but beyond the Roche limit. The process of giant impact and accretion finished within 100 years (a rather short duration). It made the initial Moon covered by a global hot* ***magma ocean*** *possibly 200 ~ 800 km thick. The giant impact also caused the early Earth to spin 4 times faster than today.*

B. *About 0.7 billion years after the giant impact, the Moon migrated to 1/3 of present distance. Its surface had solidified with impact basins and craters covering 80 % area of the global crust.*

C. *The time was 3.0 billion years ago. Many impact basins on the thinner part of the crust flooded with lava, forming the dark maria much similar to those seen today. The lava flooding spread broadly because of the low surface gravity and intensive eruption of magma at low-viscosity (like motor-oil). At present the Moon is locked with its thinner crust side towards Earth at mean distance of 384,400 km, and one day is lengthened to 24 hours.*

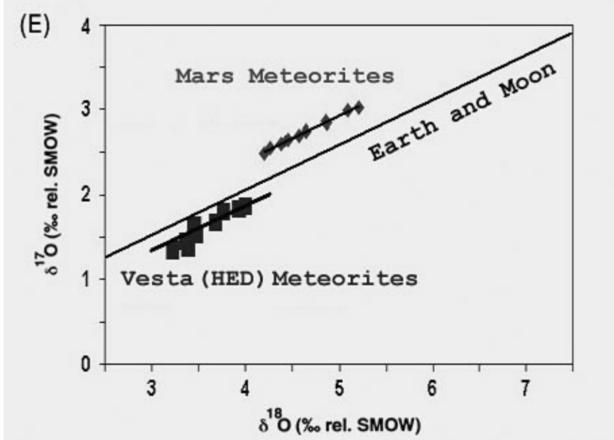


The Giant Impact Hypothesis is favored because it accounts for (1) the lack of water and other volatile elements in the Moon; (2) the fast spin of the ancient Earth; (3) the enormous angular momentum of the Earth-Moon system, see Figure D; (4) the identical abundances of stable oxygen isotopes (^{16}O, ^{17}O, ^{18}O) in terrestrial and lunar rocks, see Figure E. The Earth and Moon, which lie on the same line in the plot of oxygen isotope abundance, hints that both bodies formed at the same time from the same part of the solar nebula.



	Distance from planet (dia. of planet = 1)	Mass (mass of planet = 1)
Ganymede (Jupiter III)	7	1 / 13000
Titan (Saturn VI)	10	1 / 4200
Callisto (Jupiter IV)	13	1 / 18000
Io (Jupiter I)	3	1 / 21000
Moon	30	1 / 81
Europa (Jupiter II)	5	1 / 40000

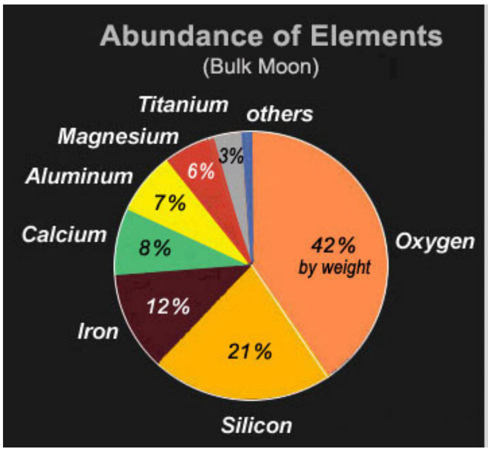
Among all satellites, the Moon has anomalously high value of angular momentum (a property based on the satellite's distance and mass relative to its parent planet).

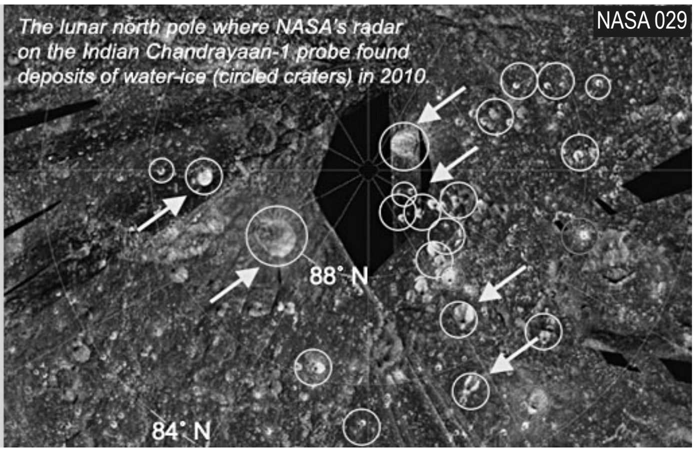


The oxygen isotopic compositions of rocks from Earth, Mars, and the asteroid Vesta, the largest asteroid that melted, define three parallel lines on this plot of ^{17}O / ^{16}O vs. ^{18}O / ^{16}O. The lines are parallel because on each body the oxygen isotopes were separated according to their masses, when the rocks formed. Cosmochemists measure the ^{18}O / ^{16}O and ^{17}O / ^{16}O ratios in terms of deviations in parts per thousand from a standard (delta ^{18}O and delta ^{17}O). The usual standard is mean ocean water, abbreviated SMOW, for Standard Mean Ocean Water. Pure ^{16}O would plot at -1000 parts per thousand on both axes. (Source http://www.psrd.hawaii.edu)

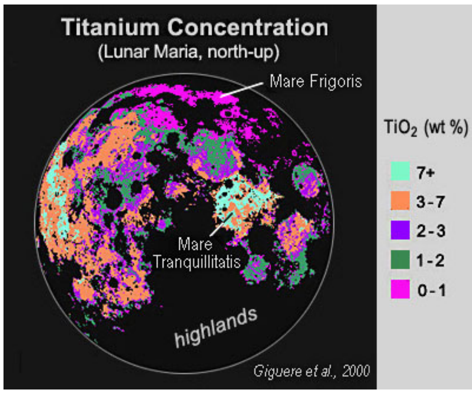
Abundance of Elements

A. *The abundance of elements on the Moon is shown by a statistical pie chart. These elements do not stand alone but are bonded to oxygen as oxides, so iron may exist as FeO and titanium as TiO_2. Hydrogen is enormously depleted, nevertheless the NASA's radar on the Indian Chandrayaan's probe found deposits of water ice on the lunar north pole in 2010. The water-ice may have originated from impacts of comets. An earlier LCROSS impact on the south pole also found signatures of water and hydroxyl (OH). Other surveys showed hints of water molecules at various latitudes. These molecules probably formed from the solar wind which carries hydrogen ions to react with the oxygen compounds in the lunar regolith. They appears less at lower latitudes, where stronger sunlight is likely to break water molecules apart.*

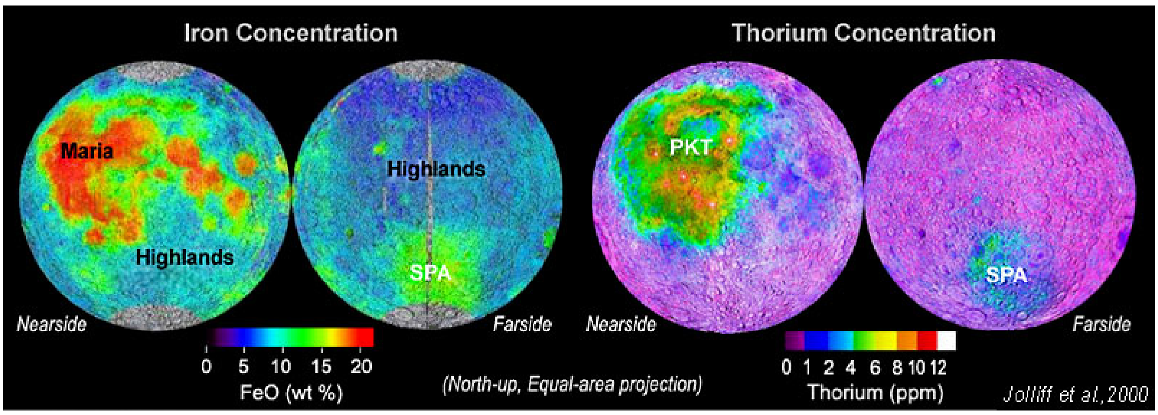




B. *The map at right was derived from filtered images of Galileo probe en route to Jupiter. It shows the titanium/TiO_2 concentration in the Moon's nearside. Highland areas have been masked black. Generally lunar maria contain titanium at different weight percentages. They can be grouped as high-titanium (more than 7 % TiO_2), low-titanium (2-7 % TiO_2) and very-low-titanium (less than about 2 % TiO_2). In spectral measurements, areas of high-titanium tend to be bright in the blue end of the spectrum, e.g. Mare Tranquillitatis. Areas of low-titanium tend to be brighter in the red end, e.g. Mare Frigoris. The variation of titanium levels indicates that lunar magma could erupt from different depths and at different times.*



C. ***Picture Left:*** *The iron/FeO map was derived from Clementine spectral reflectance data in 750 & 950 nm wavelengths. It shows the maria have iron contents somewhat higher than the highlands. The farside green area is SPA (South Pole-Aitken basin) with intermediate iron level.* ***Right:*** *The thorium map was derived from the data of the gamma ray spectrometer in Lunar Prospector probe. It shows thorium, a radioactive element, is concentrated in the zone known as PKT (Procellarum KREEP Terrane) which corresponds to Oceanus Procellarum, Mare Imbrium and its southern region. KREEP is a special radioactive rock containing thorium.*



Moon Rocks

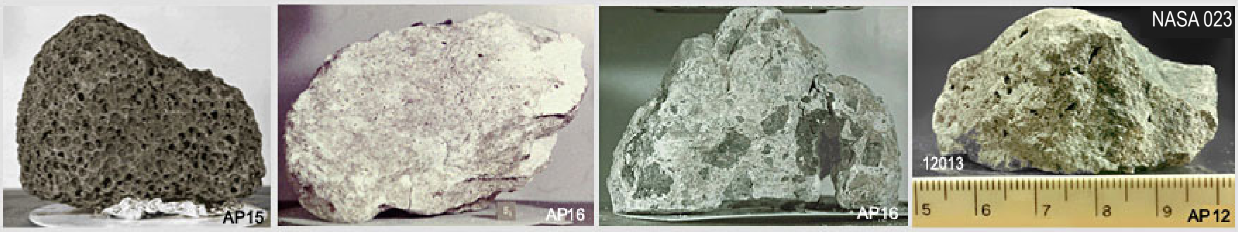
Compared with terrestrial, Moon rocks contain relatively few volatile elements and virtually no intrinsic water. This is a strong support to the giant impact hypothesis that the initial Moon was molten, at least partially.

*Among the 382 kg of rocks collected by the Apollo, there are two distinct groups: **mare basalt** in the lava plains and **anorthosite** in the mountainous highlands. The mare basalt is mostly 3.2 ~ 3.8 billion years old whereas the anorhosite is older, age up to 4.4 billion years. Mare basalt and anorthosite are just broad terms of rocks; they can be named specifically by their mineral abundance* **

Figure (a) shows a sample of mare basalt. It is this type of rock that makes lunar maria look dark in telescopes. The sample is vesicular because of many holes in its body. It indicates that gas must have dissolved under pressure in the lava from which this rock solidified. When the lava reached the airless Moon's surface, bubbles formed as the gas pressure dropped. The rock appears dark because it contains iron-magnesium minerals 'pyroxene' 輝石 *and 'olivine'* 橄欖石 *(in less level), and/or some iron-titanium mineral 'ilmenite'* 鈦鐵*. By contrast, Figure (b) shows the anorthosite found commonly in lunar highlands. It contains almost solely 'plagioclase feldspar'* 斜長石*, a mineral rich in silicon, calcium and aluminum. Hence it is light-colored and less dense than the iron-rich basalts. During the infant period when the Moon's surface was molten, the less dense anorthosite rose to the top, forming the crust with highlands. The anorthosite is believed to be the most ancient type of moon rocks. It is the material of the original lunar crust. On the other hand, the mare basalt formed from lava flooded on the lunar surface; hence it must be a younger and relatively shallow layer over the anorthosite.*

*Figure (c) shows another rock type sorted by appearance — **breccia**. It is composed of angular fragments of other rocks cemented mechanically by the heat and pressure in impact events. The lunar regolith acts as the cementing agent. It is common in impact melt and ejecta terrains. Many Apollo's collections are breccias.*

*Figure (d) shows a unique sample of **KREEP** rock firstly found by the Apollo. It is a breccia enriched by potassium (K), rare-earth elements (REE), phosphorus (P) and radioactive elements (e.g. thorium & uranium) whose decay had supported the heat and viscosity of magma in the early Moon's interior. These elements are incompatible to common rock-forming process because of unsuitable ionic size or charge; hence KREEP rocks are supposed to intrude into the crust in the last chemical phase of the magma ocean. Remote sensing indicates the KREEP concentrated in the PKT zone. The Apollo collection indicates the KREEP generally reside in breccias, especially in the impact-melt breccias. Sometimes they exist as the puzzling form of "KREEP basalt" like Figure (e). The average KREEP is older than the mare basalt but younger than the anorthosite. Its occurrence hints the pre-mare volcanic activity in the lunar crust.*



(a) Mare Basalt 月海玄武岩 (b) Anorthosite 斜長岩 (c) Breccia 角礫岩 (d) KREEP 克里普岩

*Besides the dominating anorthosite, a series of magnesium-rich rocks named **Mg-suite** also make up a minor fraction (perhaps 10%) of the crust. How they began and reached the crust is unclear. The Mg-suite are plutonic rocks (formed at great depth) that dwelled probably deeper than the source region of mare basalts. Heat and convective overturning in the interior of the early Moon brought these rocks within the reach of surface. The Mg-suite rocks have REE patterns parallel to KREEP and hence both are related.*

During massive impact, some ejecta pieces escaped from the Moon's gravity. A rare number reached Earth as lunar meteorites. So far few tens of lunar meteorites have been found, mostly in Antarctica, northern Africa and central Asia. They were identified coming from different parts of the Moon, and are valuable supplement to the limited Apollo samples.

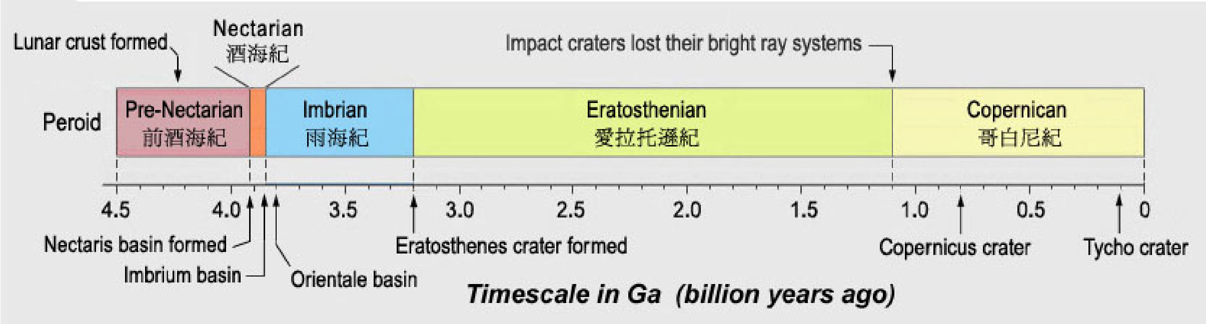
(e) KREEP Basalt *Apollo 15386*
Its origin is puzzling.

** *Rocks are composed of different kinds of aggregates called minerals. Moon observers occasionally read unfamiliar jargons on rocks and minerals. For example, the lunar highland rock "anorthosite" is sometimes described as "plagioclase feldspar" by geologists because the rock is dominated by the mineral named plagioclase feldspar. In this case, anorthosite and plagioclase feldspar refer to the same thing. Basalt intrinsically means any dark rock solidified from lava flow. Here it is emphasized as "mare basalt" to reflect its dominant abundance in the lunar maria. If a basalt-like rock happens to contain the radioactive KREEP elements (explained in other paragraphs), it is called KREEP basalt or simply KREEP in broad sense.*

MAP 1

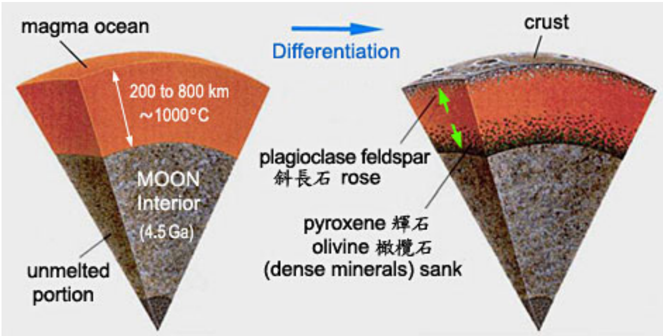
Lunar Geologic Timescale

The lunar geologic (or selenologic) timescale is divided into several unequal periods, beginning as early as 4.55 Ga (one Ga = 1 billion years ago) when the Moon had accreted from impact debris that orbited around the Earth.



● ***4.55 - 4.5 Ga*** *The initial Moon was red hot due to the heat generated by giant impact and accretion. The global surface was covered by a magma ocean possibly 200 ~ 800 km thick. A second model suggests the entire globe was molten due to the heat released by decay of short-life radioactive elements in the deep interior.*

● ***Pre-Nectarian 4.5 - 3.92 Ga*** *The magma ocean was cooling down through differentiation, primarily the crystallization of minerals which are the basic components of rocks. Heavy minerals (e.g. pyroxene and olivine) sank to the magmatic mantle. Less-dense minerals (e.g. plagioclase feldspar) rose to form the most ancient anorthositic crust. The KREEP and other rock minorities were the last to intrude into the crust. Due to asymmetric crystallization, the crust was not uniform in thickness. Some oldest craters and about 30 impact basins including the farside South Pole-Aitken are recognized in this period.*



● ***Nectarian 3.92 - 3.85 Ga*** *This period corresponds to the transient stage of LHB (Late Heavy Bombardment) mentioned earlier. At least 10 impact basins, including the nearside Nectaris, Serenitatis, Crisium and Humorum basins are recognized. Their ejecta formed the upper layer of the rugged and cratered terrains found in the highlands.*

● ***Imbrian 3.85 - 3.2 Ga*** *It began with the formation of the Imbrium basin on the nearside. Other impact basins formed progressively in the next 100 million years, including the youngest Orientale on the farside. Intensive lava-flooding in the basins and large craters (e.g. Archimedes and Plato) followed to produce mare basalts. The flooding might recur at different time sessions within hundreds of million years; hence it reshaped the pre-existing terrains. Localized volcanism was active.*

> **Remark:** Sometimes the Imbrian period is subdivided into the Early Imbrian and Late Imbrian epochs. The Early Imbrian ranges from 3.85 to about 3.75 Ga (formation of relatively young basins). The late Imbrian ranges from about 3.75 to 3.2 Ga (active period of lava flooding). This subdivision, however, is obscure.

● ***Eratosthenian 3.2 - 1.1 Ga*** *Volcanism faded but not totally ceased. Less intensive bombardment continued. Craters, such as Eratosthenes formed in the beginning of the period, lost their ejecta rays gradually through space weathering by cosmic rays, solar winds and micrometeoroids. By the end of this period, pre-existing impact craters were presumably lack of bright rays.*

● ***Copernican 1.1 Ga - Present*** *Additional impact craters such as Copernicus and Tycho formed in this period although the impact rate was slow. They are relatively young and hence able to preserve their visible rays. So far a thin layer of regolith has accumulated over the lunar surface. Its thickness varies from few meters on the maria to some tens of meters on the old-aged highlands. Lunar regolith traps the ancient atoms of the solar winds, mainly hydrogen and helium. It hints the early evolution of the Sun apart from the Moon.*

For comparison: Tycho crater formed 0.1 Ga; creatures on Earth bloomed 0.5 Ga; dinosaurs became extinct 0.065 Ga.

Due to limited samples of Moon rocks and the possibility of land reshaping by impacts and volcanism in the pristine past, there is still much debate to mark certain key events along the geologic timescale. The timescale is therefore a general marker of lunar evolution and does not reflect an exact age.

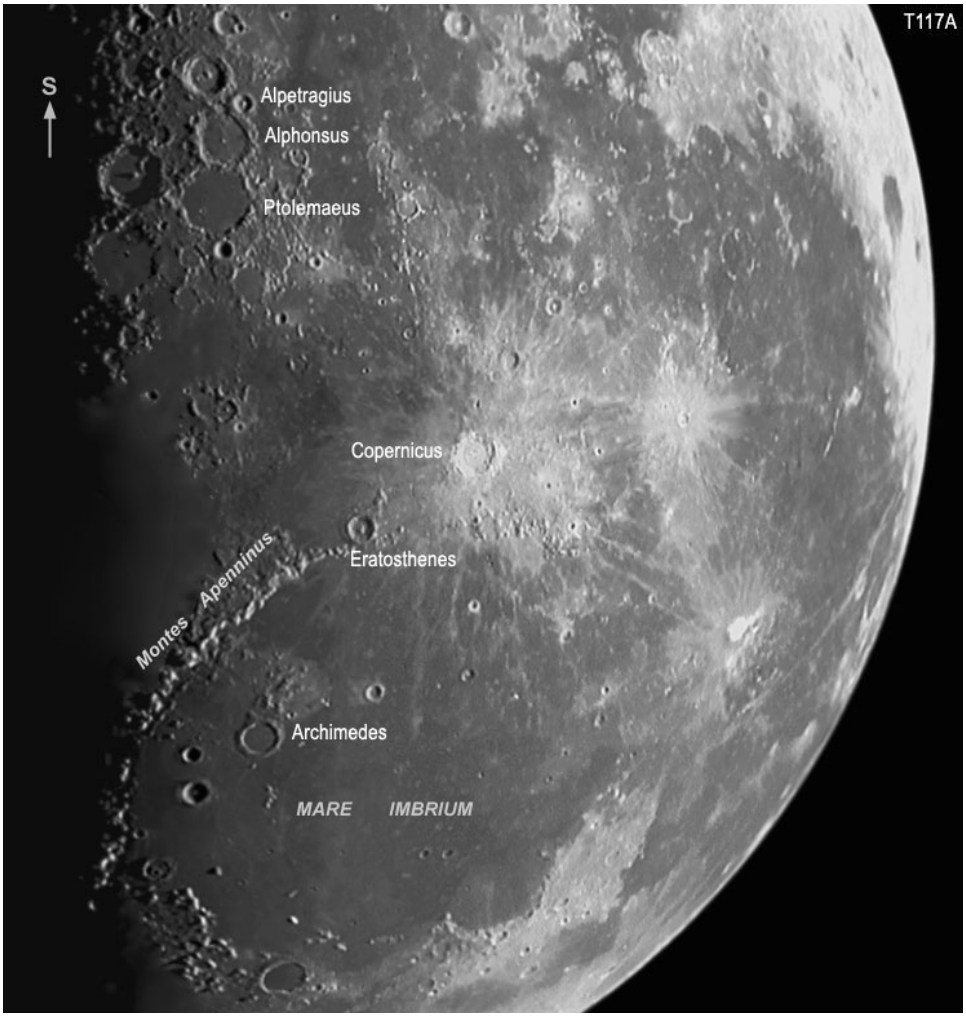
Comparison of Geologic Ages

Without knowing the exact geologic ages, the sequence of landforms in a lunar region can sometimes be realized. The basic methodology includes a checking of crater density, ejecta rays and strata (rocky layers) in the areas of interest, and reasoning them by the "superposition" principle. Superposition is no special. It simply tells that older surface is marked by higher density of craters; small craters are usually superposed on larger ones and the strata on top are usually younger. This methodology, of course, assumes no post-movement or interference to overturn the formation sequence. It has been quite effective to compare geologic ages, as demonstrated by the following image.

1. *The small crater Alpetragius is younger than Alphonsus because it is superposed on the rim of Alphonsus.*
2. *The crater density in the Ptolemaeus region is greater than the crater density in Mare Imbrium. The Ptolemaeus region must be older than the mare, since the impact rate on the Moon decreases with time.*
3. *Montes Apenninus is the partial rim of the Imbrium basin that holds Mare Imbrium. Apenninus must be older than the mare.*
4. *Archimedes is located at the inner circumference of the Imbrium basin and flooded by the lava of Mare Imbrium. Its age must be younger than the Imbrium basin but older than Mare Imbrium.*
5. *Eratosthenes is superposed on mare and remains intact. It must be younger than Mare Imbrium.*
6. *Copernicus preserves a system of bright rays. The crater must be the youngest of all above.*

The formation sequence in the Imbrium-Copernicus region, in order of decreasing age, is therefore

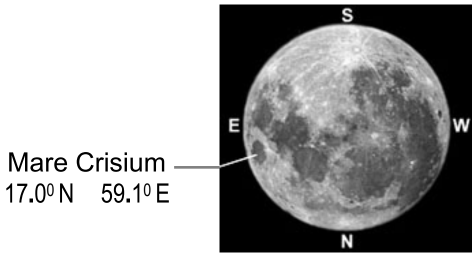
Montes Apenninus (Imbrium basin) → Archimedes → Mare Imbrium → Eratosthenes → Copernicus.

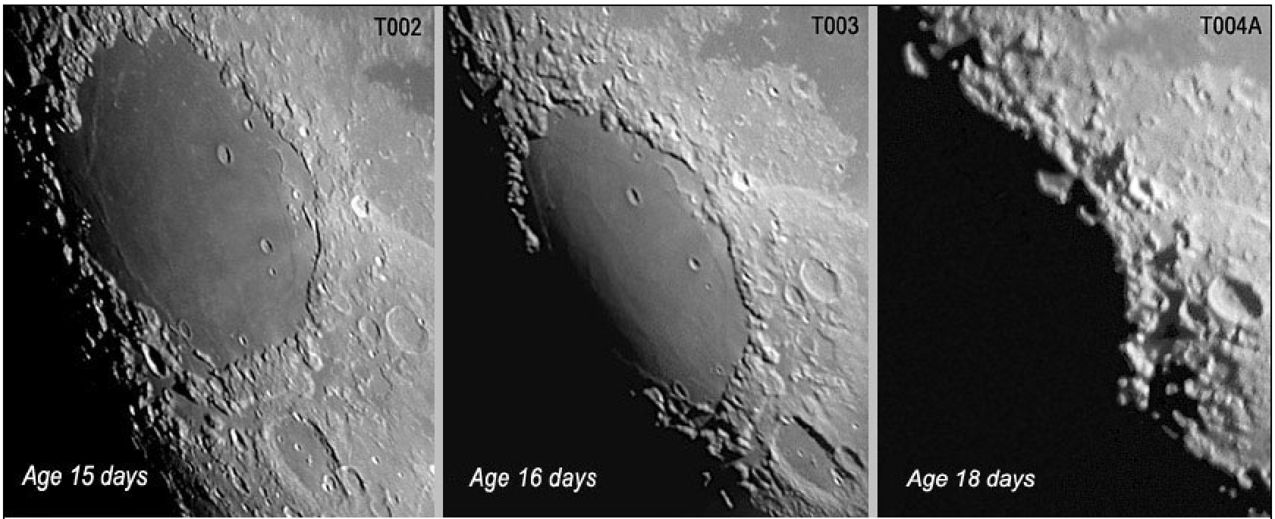


MAP 2

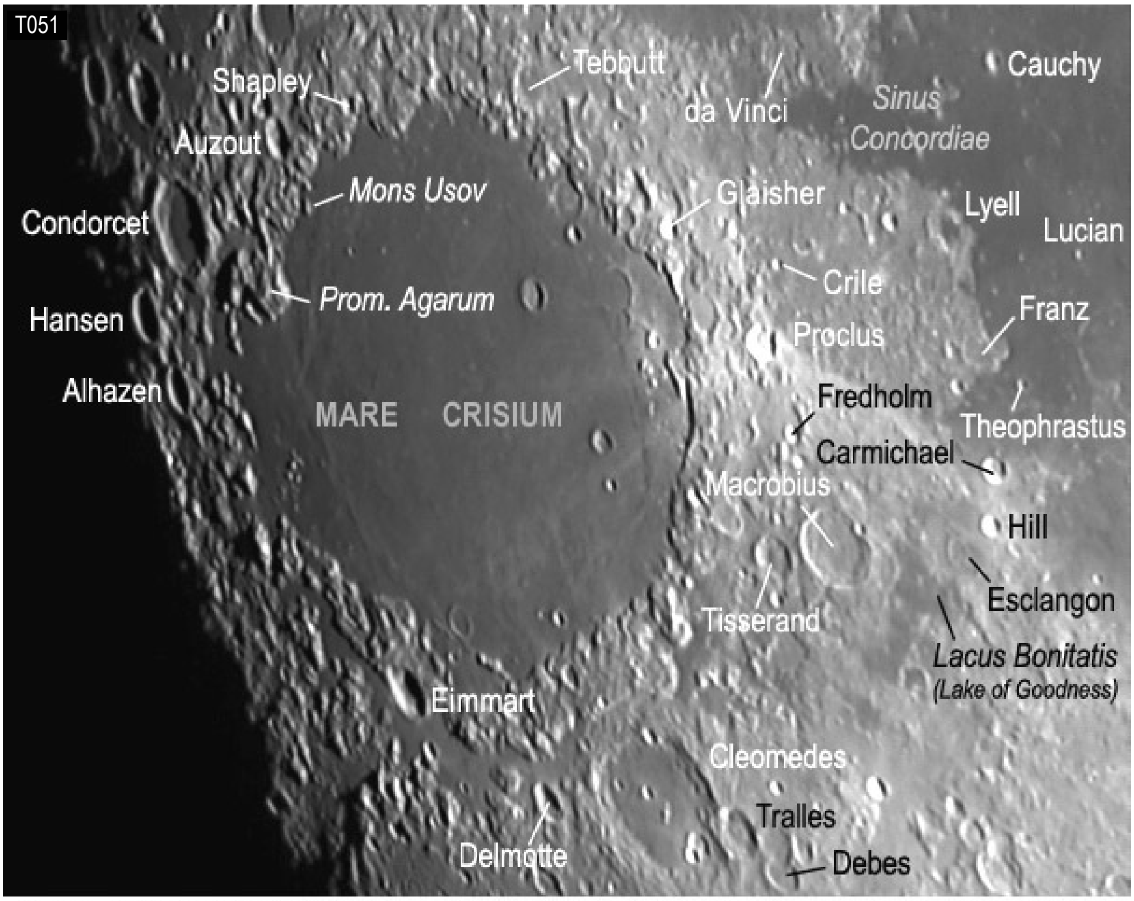
Mare Crisium, Proclus, Palus Somni, Cleomedes, Messala

Hatfield 3, 4
Rükl 26, 27, 37, 38, 16





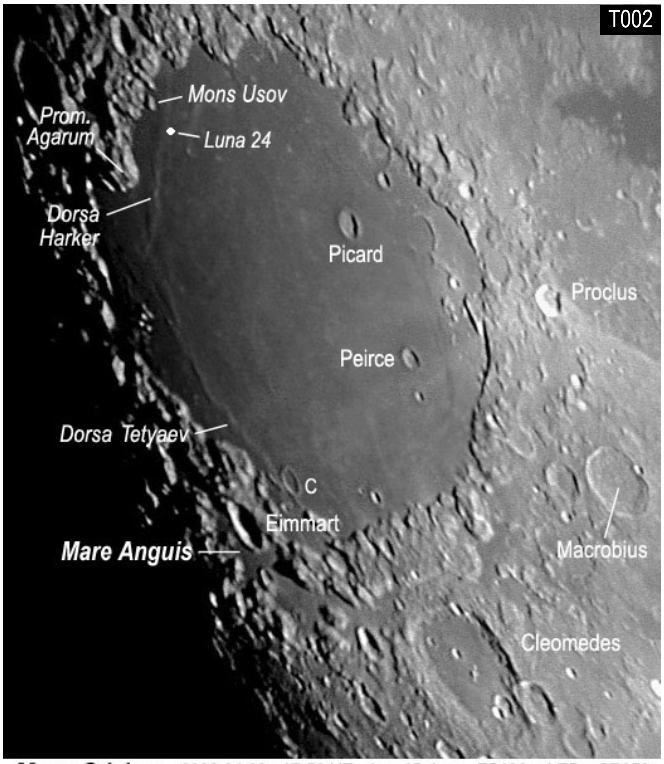
3 views of Mare Crisium *Left:* 2000.04.20 17:52 UT FS102 *Middle:* 2000.09.15 12:25 UT MK67 *Right:* 2006.11.08 20:06 UT ETX90



MARE CRISIUM 2004.08.31 19:07 UT Age 15 days. Longitudinal libration 6°. 10-in f/6 + ToUcam at prime focus

Mare Crisium (Sea of Crises) is a dominating landmark. It is the dark lava-filled portion of an impact basin formed in the Nectarian period. The mountains around the basin average to 3000 m high. The mare measures 560 km east-west and 420 km north-south, but to Earth the north-south diameter always appears longer due to foreshortening. Mare Crisium is estimated to form 3.4 billions years ago. It is the site of a gravity anomaly known as a "mascon", or mass concentration caused chiefly by local uplift of dense mantle material into the lunar crust during the impact. The lava in the basin only partly accounts for the excess gravity. Mascons also exist in other circular maria and large flat-floored craters. Their high-gravity causes lunar satellites orbiting at low altitudes to either impact the Moon or to be flung out into interplanetary space after a few years.

Under oblique illumination, concentric wrinkle ridges are visible along the inner circumference of Mare Crisium. The most apparent wrinkle ridges are ***Dorsa Harker*** and ***Dorsa Tetyaev*** on the eastern edge (Image T002); they measure 180 ~ 200 km in length. Crater ***Eimmart C*** happens to locate on the northern tip of Dorsa Tetyaev, and the combined formation resembles a string looped at one end. The neighbor of ***Eimmart*** is an irregular patch of lava named ***Mare Anguis*** (Serpent Sea); it seems to be a leak piece from Mare Crisium. The cape on the southern edge is ***Promontorium Agarum***; it rises about 5000 m above the mare and looks almost disconnected from the rest of the highlands. In 1976, the Soviet probe Luna 24 returned soil samples from the vicinity of Promontorium Agarum.

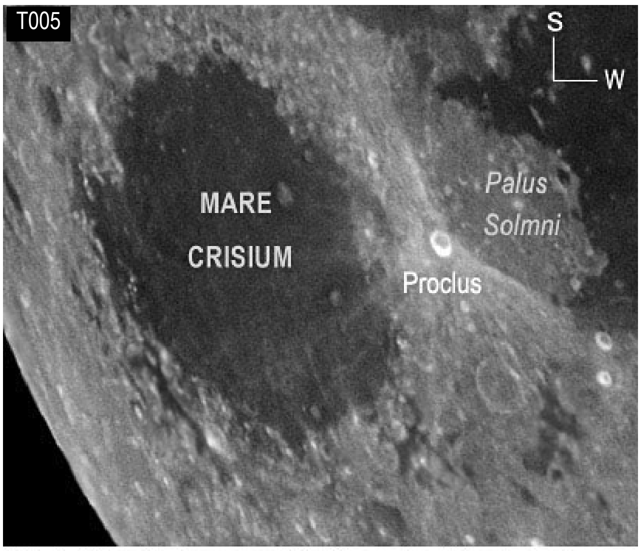


Mare Crisium 2000.04.20 17:52 UT Age 15 days. FS102 + LE5 + CP950

The end pages of this map give a closer view of the Crisium region.

Proclus 16.1^0 N 46.8^0 E
Palus Somni 14.1^0 N 45.0^0 E

Proclus is a prominent impact crater on the western highlands of Mare Crisium. It has sharp rim and rough floor, 28 km in diameter, 2400 m deep. Its ejecta begins to shine as asymmetrical pattern of rays around Moon age of 5 ~ 6 days, gradually glowing up to be one of the brightest features on the entire Moon. The longest ray slides through the dark floor of Mare Crisium, extending for a distance over 600 km. The asymmetrical ray pattern is an evidence of a grazing impact, in which the space impactor intruded from southwest (top right corner of T005) and hit the Moon surface at very low angle, likely a few degrees from ground. A low-angled impact is characterized



The bright reflection around the inner rim of Proclus makes this crater resembling a bull's eye. (2000.06.15 16:28UT Age 13 days) by ejecta in confined directions. The lower the impact angle, the more unidirectional the ejecta is. This explains ***Palus Somni*** (Marsh of Sleep), a diamond-shaped terrain at the immediate west of Proclus, is lack of Proclus' ejecta rays. Palus Somni measures 150 km east-west and looks neither a complete highland nor dark mare. Its northern floor is rough but the southern floor is relatively flat. The peculiar hue of Palus Somni had been a study subject by geologists in the past.

Proclus & Palus Somnii 2004.12.19 ~12:13 UT Moon age 7 days. 10-in f/6+2.5X+ToUcam (*mosaic*)

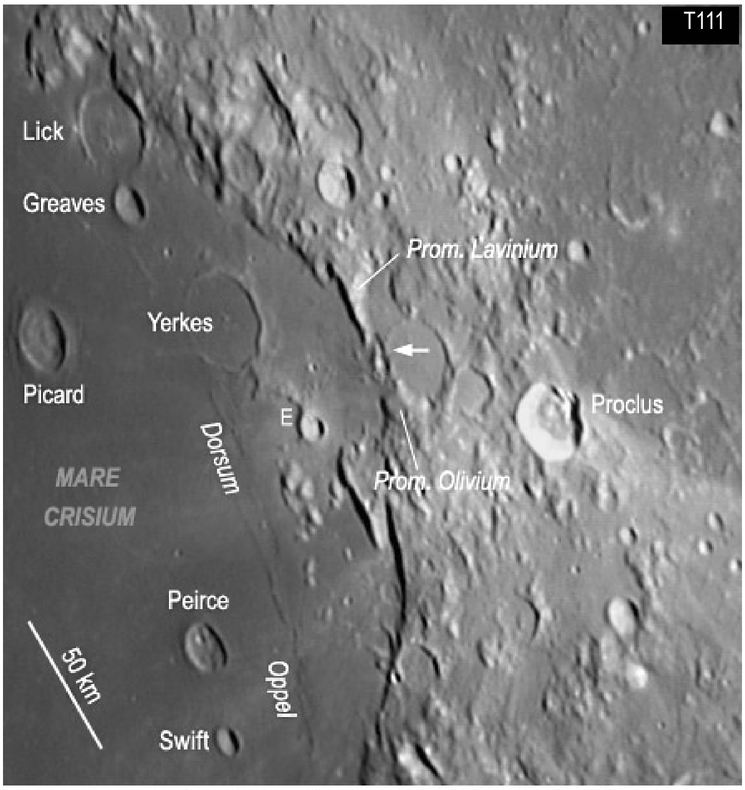
Proclus G 12.7^{0}N 42.7^{0}E
A 33-km crater on the floor of Palus Somni. Its north rim opens to a conspicuous, narrow V-shaped trough. (***Isidorus B*** in Map 7 and ***Vogel*** in Map 31 have similar appearance.)

Macrobius 21.3^{0}N 46.0^{0}E
An impact crater with terraced walls and central peaks, diameter 64 km. Its rim is interrupted by a small crater. The adjacent ***Tisserand*** (36 km) looks like a small version of Macrobius. A small irregular patch of mare named ***Lacus Bonitatis*** (Lake of Goodness) spreads in the vicinity; its full view is given in T051, starting page.

Sinus Concordiae 10.8^{0}N 43.2^{0}E
Bay of Concord, an inconspicuous bay-like mare adjoining the southern edge of Palus Somni, east-west length about 140 km.

(Image T111)

O'Neill's Bridge 15.2^{0} N 49.2^{0} E
This nicknamed feature, firstly noted by amateur John O'Neill in 1953, is elusive. It is noticeable shortly after the full moon when the terminator approaches the west edge of Mare Crisium. During unfavorable seeing, it resembles a bridge connecting two spiky capes: ***Promontorium Lavinium*** and ***Promontorium Olivium*** (both are unofficial names). When seeing is good, it resolves into two adjoined, small eroded craters.



O'Neill's Bridge (arrow) is a nicknamed feature composed of two adjoined, small eroded crater. 2004.08.31 16:53 UT Age 15 days. 10-in f/6 + 2.5X + ToUcam

Picard 14.6^{0} N 54.7^{0} E
Peirce 18.3^{0} N 53.5^{0} E
Picard (diameter 22 km) and Peirce (18 km) are the most noticeable craters on the floor of Mare Crisium.

Lick 12.4^{0} N 52.7^{0} E
Yerkes 4.6^{0} N 51.7^{0} E
This is a pair of similar shaped flooded craters. Lick is 31 km in diameter. Yerkes is 36 km and connects to a satellite crater (***Yerkes E***, 10 km) through a ridge.

Dorsum Oppel 18.7^{0} N 52.6^{0} E
The most noticeable wrinkle ridge on the western edge of Mare Crisium, length 270 km. This dorsum, together with ***Dorsa Harker*** and ***Dorsa Tetyaev*** on the eastern edge (Image T002), form a concentric ring of wrinkle ridges which might hint a buried inmost ring (first ring) of the Crisium basin. The mare lava then filled in the basin's second ring.

(Images in next page)

Cleomedes 27.7^{0} N 56.0^{0} E
Geminus 34.5^{0} N 56.7^{0} E
Messala 39.2^{0} N 60.5^{0} E
Cleomedes is a prominent crater in the north of Mare Crisium. It is 125 km in diameter, with small craters, central peaks and an elusive rille (***Rima Cleomedes***) on the floor. Its northern wall is somewhat eroded and interrupted by the smaller crater ***Tralles*** (43 km). On the contrary, ***Burckhardt*** (56 km) is a bigger crater that overlaps a close pair of small craters (***Burckhardt E*** & ***Burckhardt F***). This does not follow the rule that small craters are superposed on larger ones.

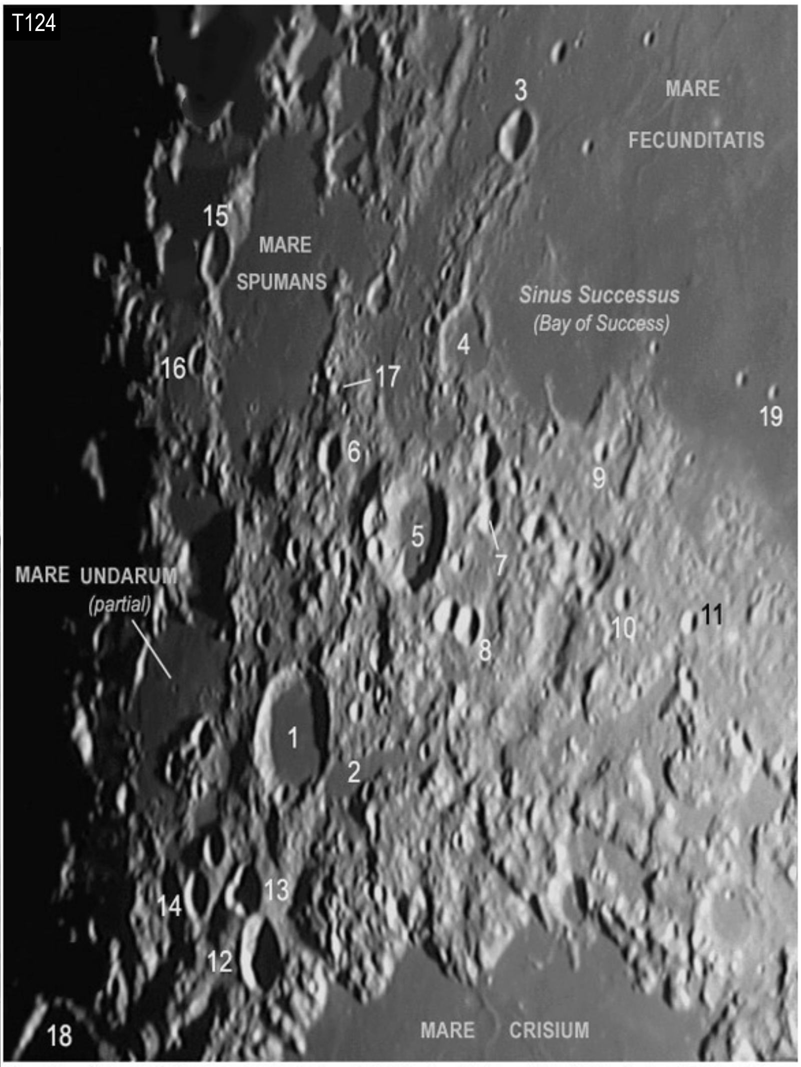
Further north of Cleomedes are ***Geminus*** and ***Messala***. Geminus is 85 km across, with a central peak and a wide cleft cutting on the southern rim. ***Messala*** is a fairly large walled plain with irregularities on the floor, diameter 125 km. ***Germinus C*** and ***Messala B*** are small craters which bear long bright rays during the full moon; but the origins of these rays are uncertain.

Lacus Spie (Lake of Hope) 43.0^{0} N 65.0^{0} E
A small lava plain near Messala, about 80 km across.

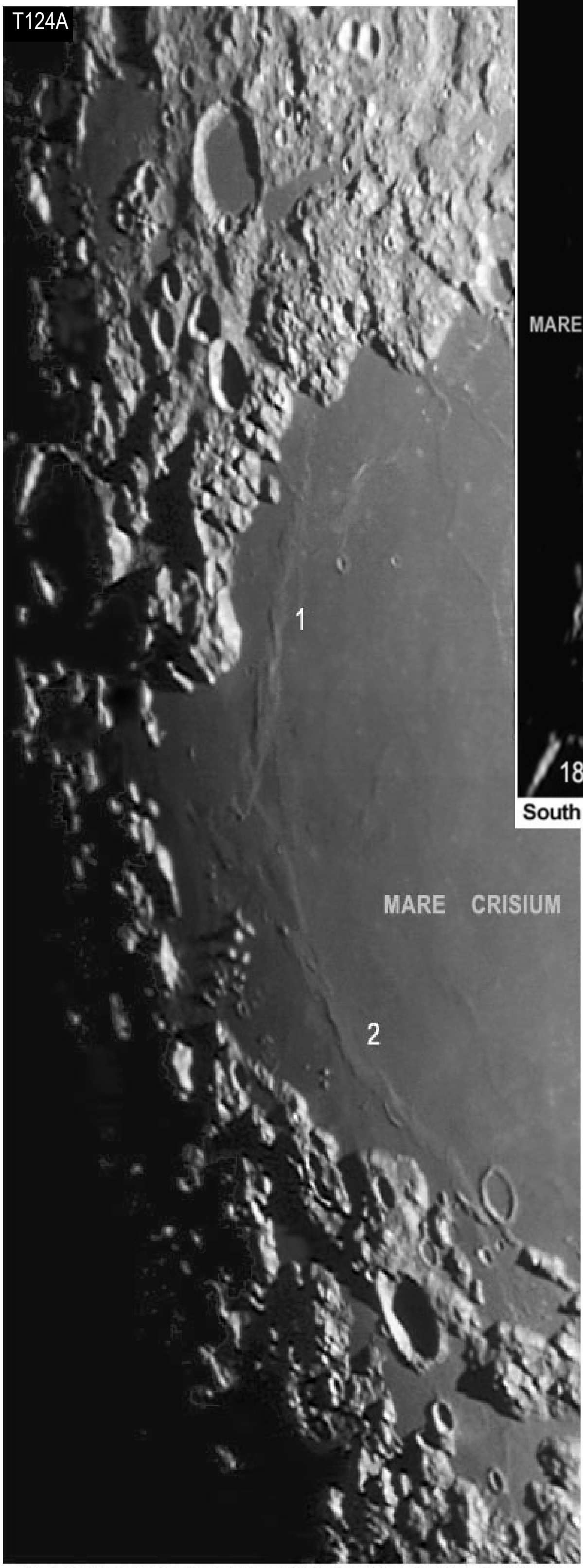
1. Messala 2. Messala B 3. Schumacher 4. Mercurius 5. Zeno 6. Lacus Spei (*Lake of Hope*)
2004.08.31 17:38 UT Moon age 15 days. 10-in f/6 Newtonian + 2.5X + ToUcam at 1/100 sec.

↑ North of Mare Crisium

Remark: *The rings of the Crisium basin are not well preserved but their remnants are still traceable in T002 where ring 1 is marked by the overlying wrinkle ridges on the mare; ring 2 is the mare boundary and ring 3 intersects with Cleomedes. Ring 4, barely recognized in T238, intersects with Geminus and Berosus.*



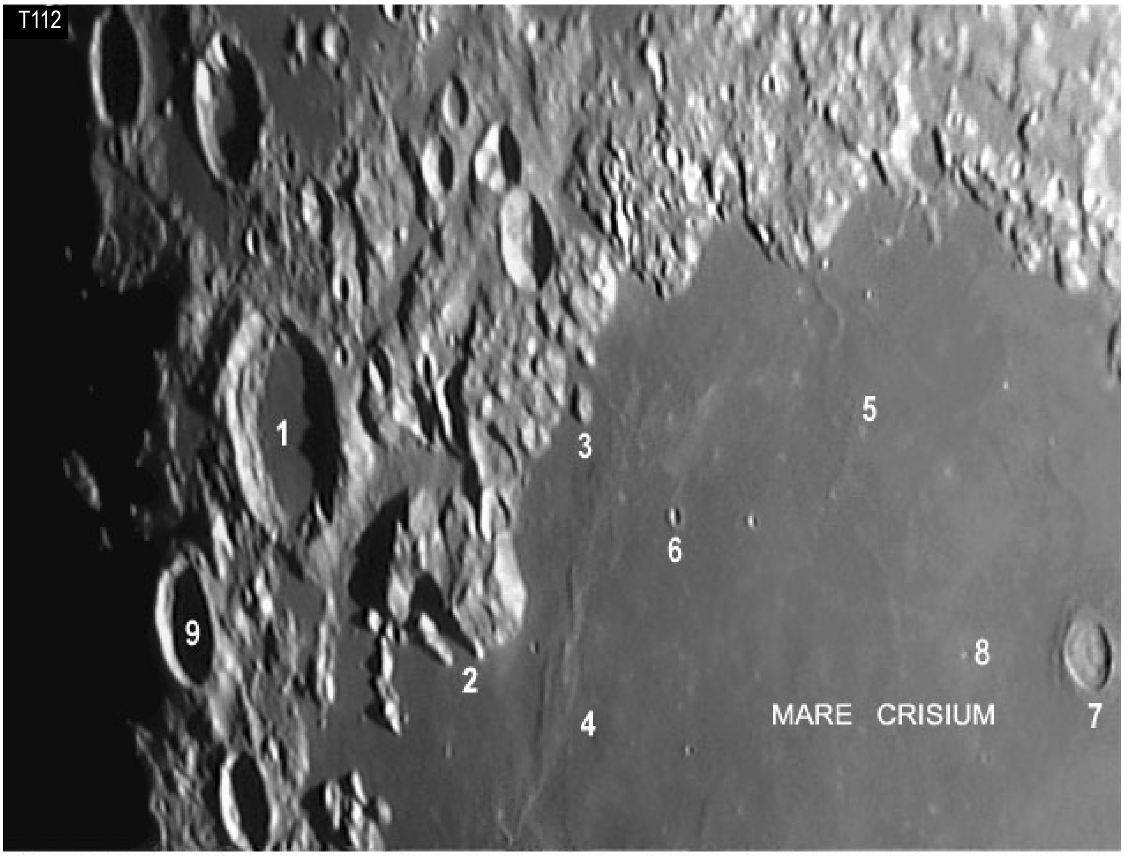
South of Mare Crisium 2004.08.02 ~17:53 UT Age 16 days. 10-in f/6 Newtonian + 2.5X + ToUcam



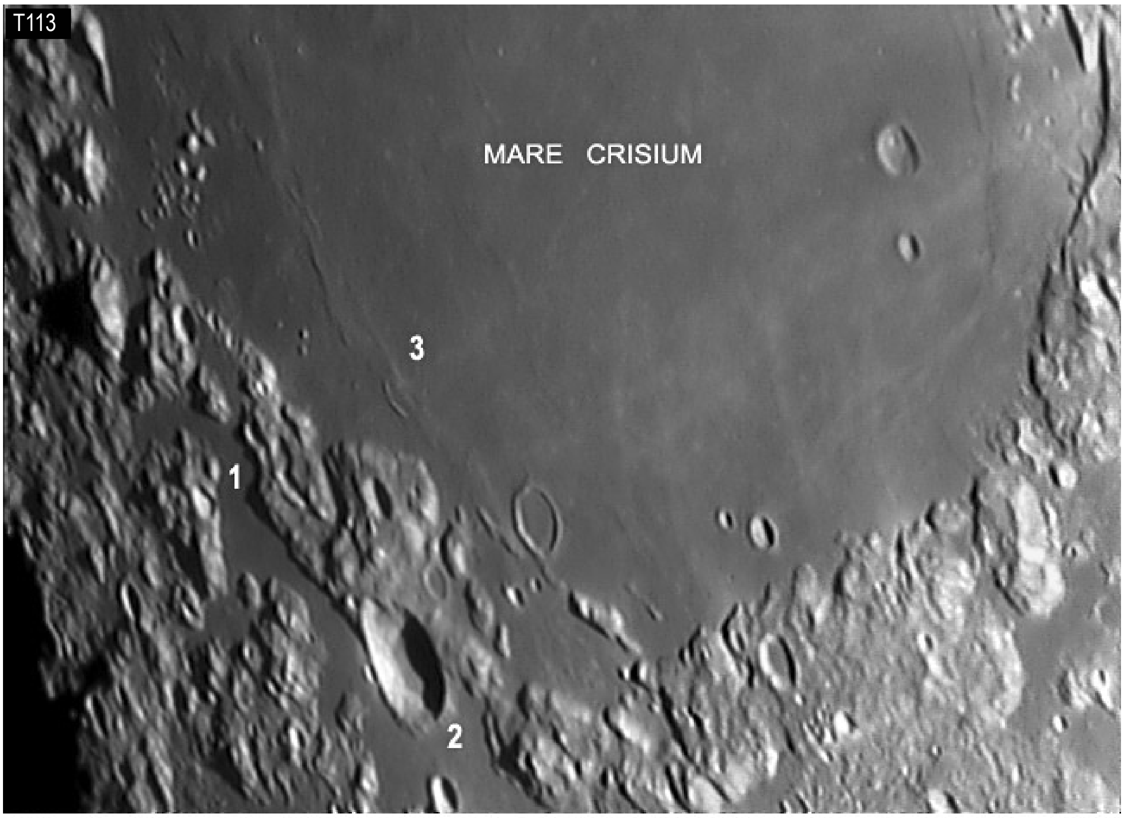
Dorsa Harker (1) & Dorsa Tetyaev (2) at east edge of Mare Crisium
2004.08.02 ~17:40 UT Age 16 days. 10-inch f/6 Newtonian + 2.5X + ToUcam

Above:

1. **Firmicus** *(diameter 56 km)*
2. **Lacus Perseverantiae**
   (Lake of Persistence, a small wedge-shaped lava plain extruded from Firmicus, length 70 km.)
3. **Webb** *(21 km)*
4. **Condon** *(34 km)*
5. **Apollonius** *(53 km)*
6. **Townley** *(18 km)*
7. **Cartan** *(15 km)*
8. **Daly** *(17 km)*
9. **Ameghino** *(9 km)*
10. **Bombelli** *(10 km)*
11. **Abbot** *(10 km)*
12. **Auzout** *(32 km)*
13. **van Albada** *(21 km)*
14. **Krogh** *(19 km)*
15. **Pomortsev** *(23 km)*
16. **Stewart** *(13 km)*
17. **Petit** *(5 km)*
18. **Condorcet** *(74 km)*
19. **Smithson** *(5 km)*



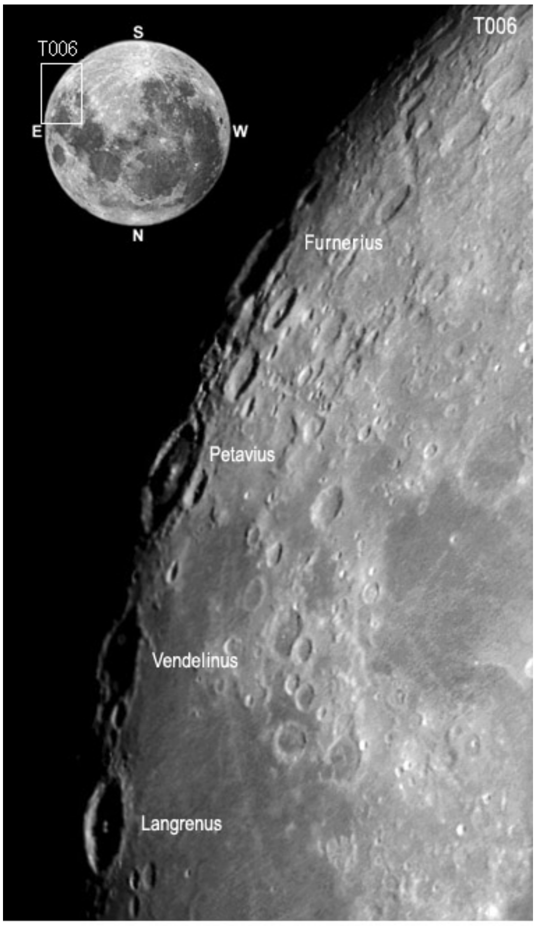
1. Condorcet 2. Prom. Agarum 3. Mons Usov 4. Dorsa Harker 5. Dorsum Termier 6. Fahrenheit 7. Picard 8. Curtis 9. Hansen 2004.08.31 18:38 UT Age 15 days. 10-in f/6 Newtonian + 2.5X + ToUcam



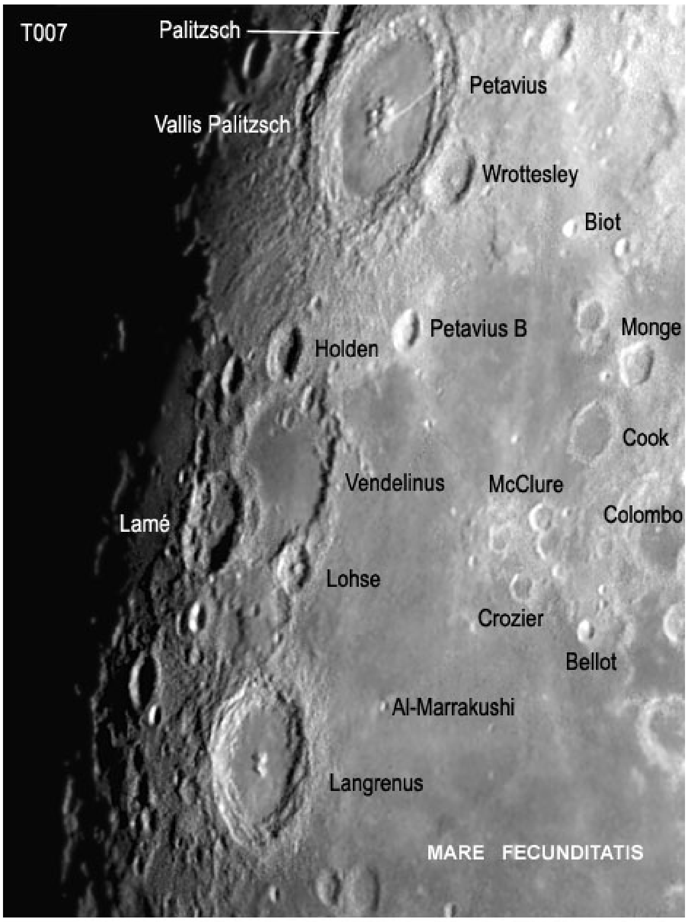
1. Mare Anguis (*Serpent Sea*) 2. Eimmart 3. Dorsa Tetyaev 2004.08.31 18:54UT Age 15 days. 10-in f/6 + 2.5X + ToUcam

Langrenus, Vendelinus, Petavius, Furnerius

Hatfield 15, 16
Rükl 49, 59, 60, 69



Furnerius to Langrenus 2000.09.15 15:52UT Age 17 days. MK67+CP950



Petavius to Langrenus 2000.04.20 17:58 UT Age 15 days. FS102+LE5+CP950, 1/4s

The magnificent chain of craters in Image T006 — The Great Eastern Chain — lines up on the terminator when the Moon age is 15 ~ 17 days.

Langrenus 8.9^0 S 61.1^0 E
A prominent crater with terraced walls, central peaks and hilly floor, diameter 127 km. The walls rise to 2700 m high. At moderate illumination, the floor is tinted yellowish-brown compared to its surroundings. After first quarter, Langrenus appears as a very bright patch. In the past, the crater was reported a site of LTP (lunar transient phenomena).

Vendelinus 16.4^0 S 61.6^0 E
A worn walled plain, diameter 131 km. Its rim is interrupted by ***Lamé*** (84 km) and few smaller craters.

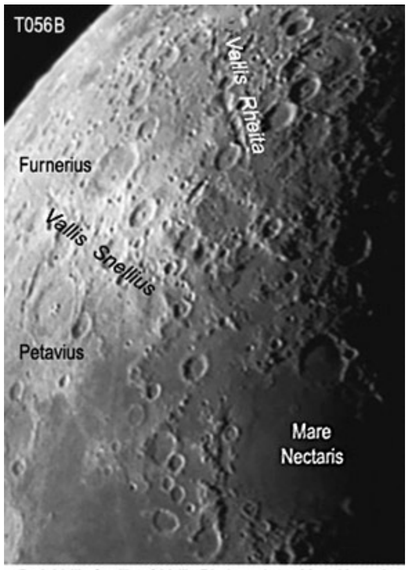
Petavius 25.1^0 S 60.4^0 E
A large ring mountain with terraced walls and central peaks, diameter 188 km, depth 3300 m. It is believed to form in the early Imbrian period, and is an example of the so-called "floor-fractured crater" which is marked by the prominent cleft (main part of ***Rimae Petavius***) along the crater radius. Less prominent clefts run along the inner rim and the north-eastern floor. These clefts, together with the dark patches on the floor, are thought to be manifestations of volcanism after the impact. The western wall of Petavius adjoins ***Wrottesley*** (57 km); the eastern wall is flanked by a crater-valley pair, ***Palitzsch*** (41 km) and ***Vallis Palitzsch*** (130 x 20 km).

Furnerius 36.0^0 S 60.6^0 E

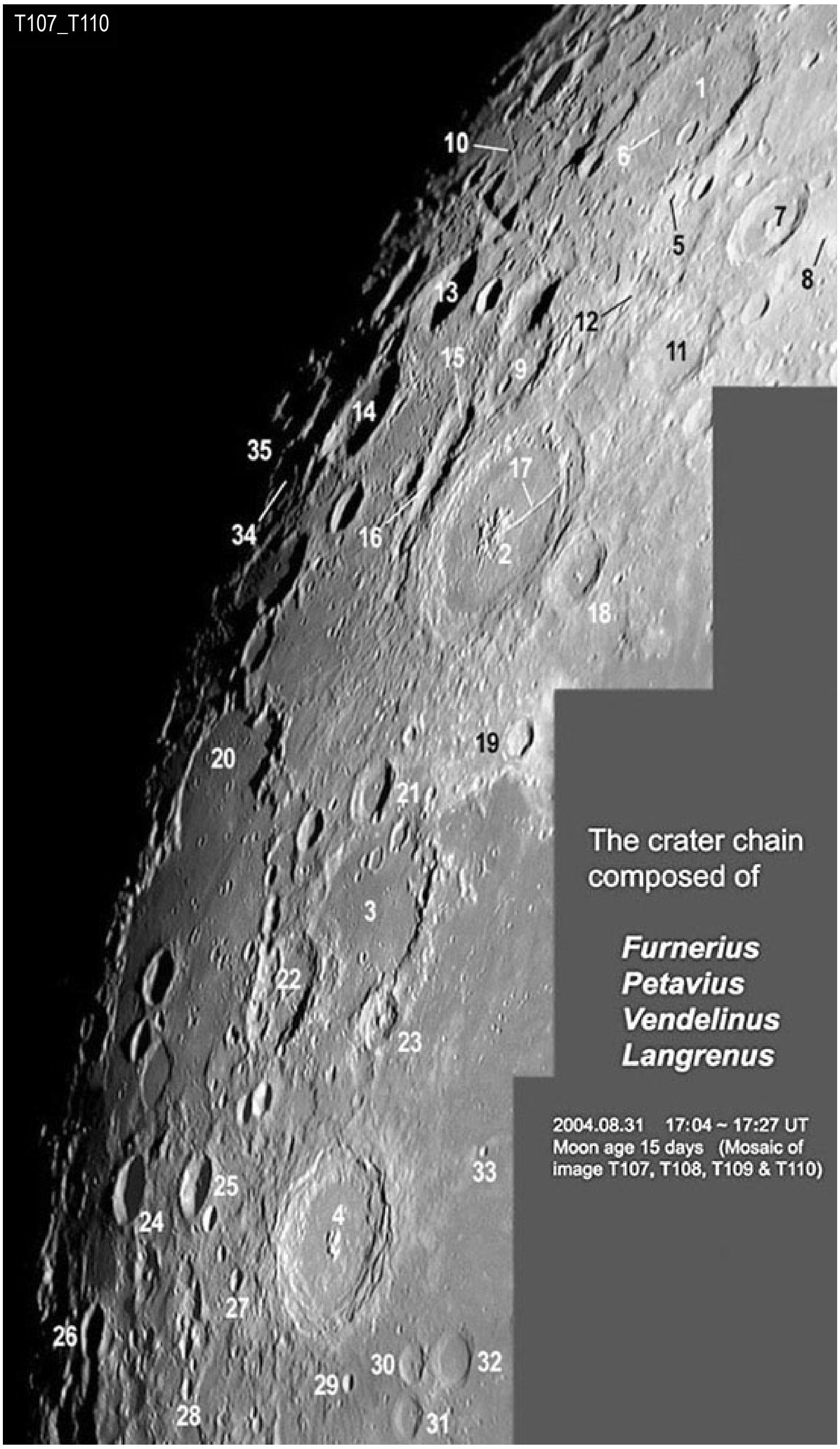
Furnerius is a walled plain, diameter 135 km. Its northern wall is heavily worn. Its floor contains lava patches, an off-center crater and a rille (***Rima Furnerius***, length 50 km). Outside the northern wall is ***Vallis Snellius***, a 590 km-long valley pointing towards the impact basin that holds ***Mare Nectaris***, see Image T056B. The valley floor appears as a chain of many overlapping craters. Similar to ***Vallis Rheita*** in Map 4, Vallis Snellius was created by secondary impacts during the formation of the Nectaris basin.

Snellius, Petavius B, Furnerius A, Stevinus A

These craters are centers of bright rays.



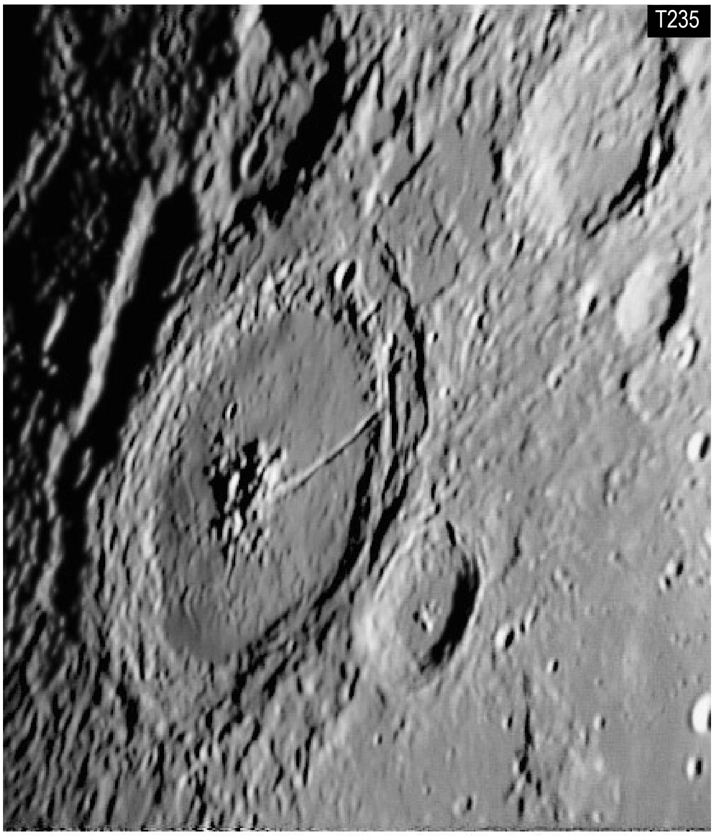
Both Vallis Snellius & Vallis Rheita point to Mare Nectaris.



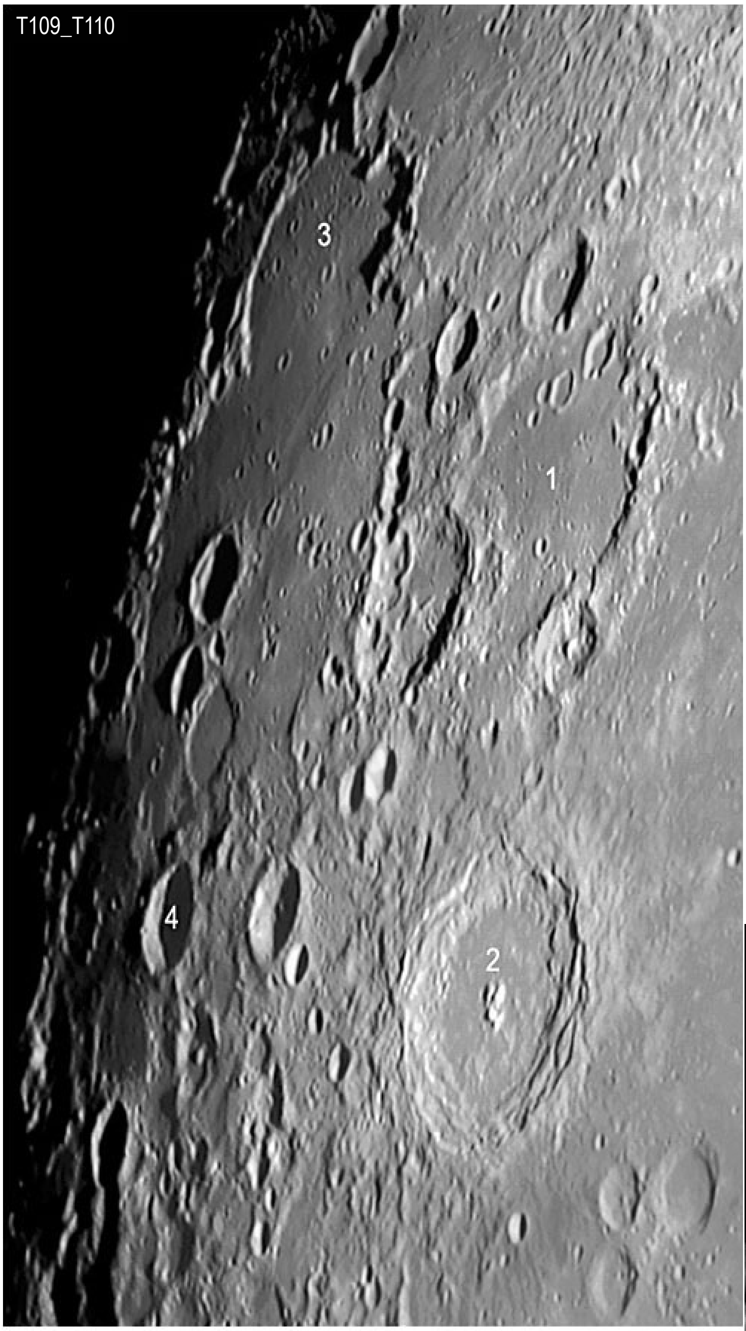
1. Furnerius *(Dia. 135 km)*
2. Petavius *(188 km)*
3. Vendelinus *(131 km)*
4. Langrenus *(127 km)*
5. Furnerius A
6. Rima Furnerius
7. Stevinus *(74 km)*
8. Stevinus A
9. Hase *(83 km)*
10. Rimae Hase (83 km)
11. Snellius *(82 km)*
12. Vallis Snellius
13. Adams *(66 km)*
14. Legendre *(78 km)*
15. Palitzsch *(41 km)*
16. Vallis Palitzsch
17. Rimae Petavius
18. Wrottesley *(57 km)*
19. Petavius B
20. Balmer *(138 km)*
21. Holden *(47 km)*
22. Lamé *(84 km)*
23. Lohse *(41 km)*
24. Kapteyn *(49 km)*
25. Barkla *(42 km)*
26. von Behring *(38 km)*
27. Somerville *(15 km)*
28. Born *(14 km)*
29. Acosta *(13 km)*
30. Atwood *(29 km)*
31. Naonobu *(34 km)*
32. Bilharz *(43 km)*
33. Al-Marrakushi *(8 km)*
34. Phillips *(122 km)*
35. Humboldt *(189 km, hidden)*

1. Furnerius 2. Furnerius A *(bright)* 3. Stevinus 4. Stevinus A *(bright)* 5. Rimae Hase 6. Snellius 7-7. Vallis Snellius *(end to end)* 8. Adams 2004.08.31 17:14UT Age 15 days. 10-in f/6+2.5X+ToUcam

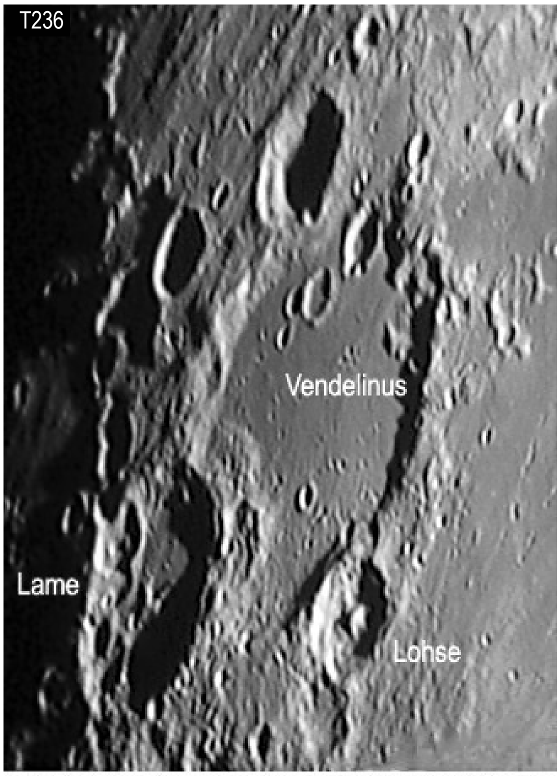
Petavius 2004.08.31 17:04 UT Age 15 days. 10-in f/6 scope



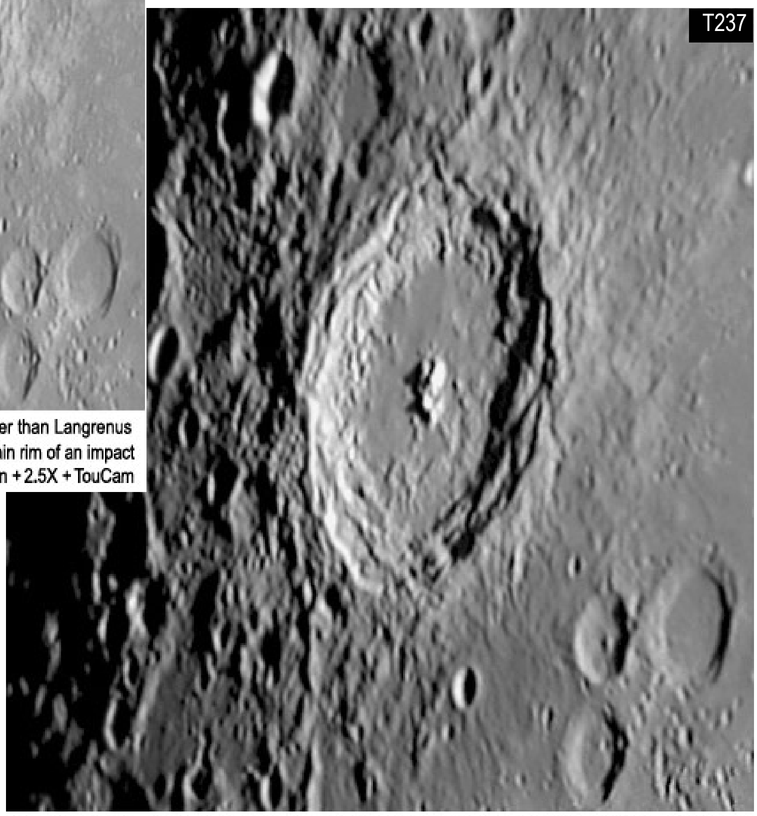
Petavius 2005.10.19 16:08 UT Age 16 days. 10-in f/6 Newtonian + 2.5X + ToUcam



1. Vendelinus 2. Langrenus 3. Balmer 4. Kapteyn Vendelinus is older than Langrenus as suggested by the crater impacts on its rim. Balmer and Kapteyn are on the main rim of an impact basin (in oblique view). 2004.08.31 ~17:20 UT Age 15 days. 10-in f/6 Newtonian + 2.5X + TouCam



2004.08.02 18:15 UT Age16 days. 10-in f/6 + 2.5X + ToUcam

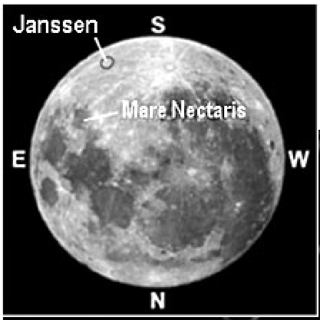


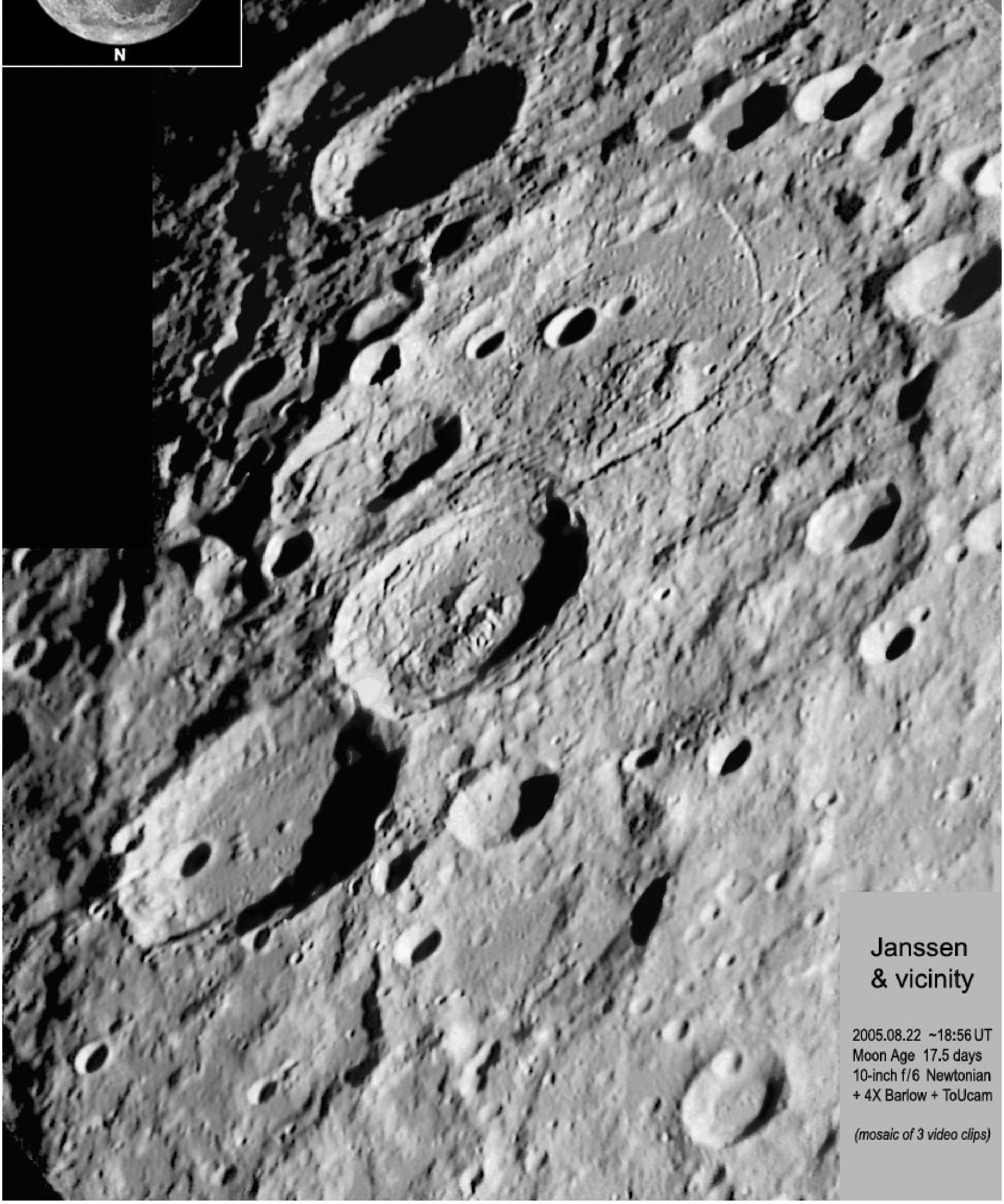
Langrenus 2004.08.02 18:10 UT Age 16 days. 10-in f/6 Newtonian + 2.5X + ToUcam

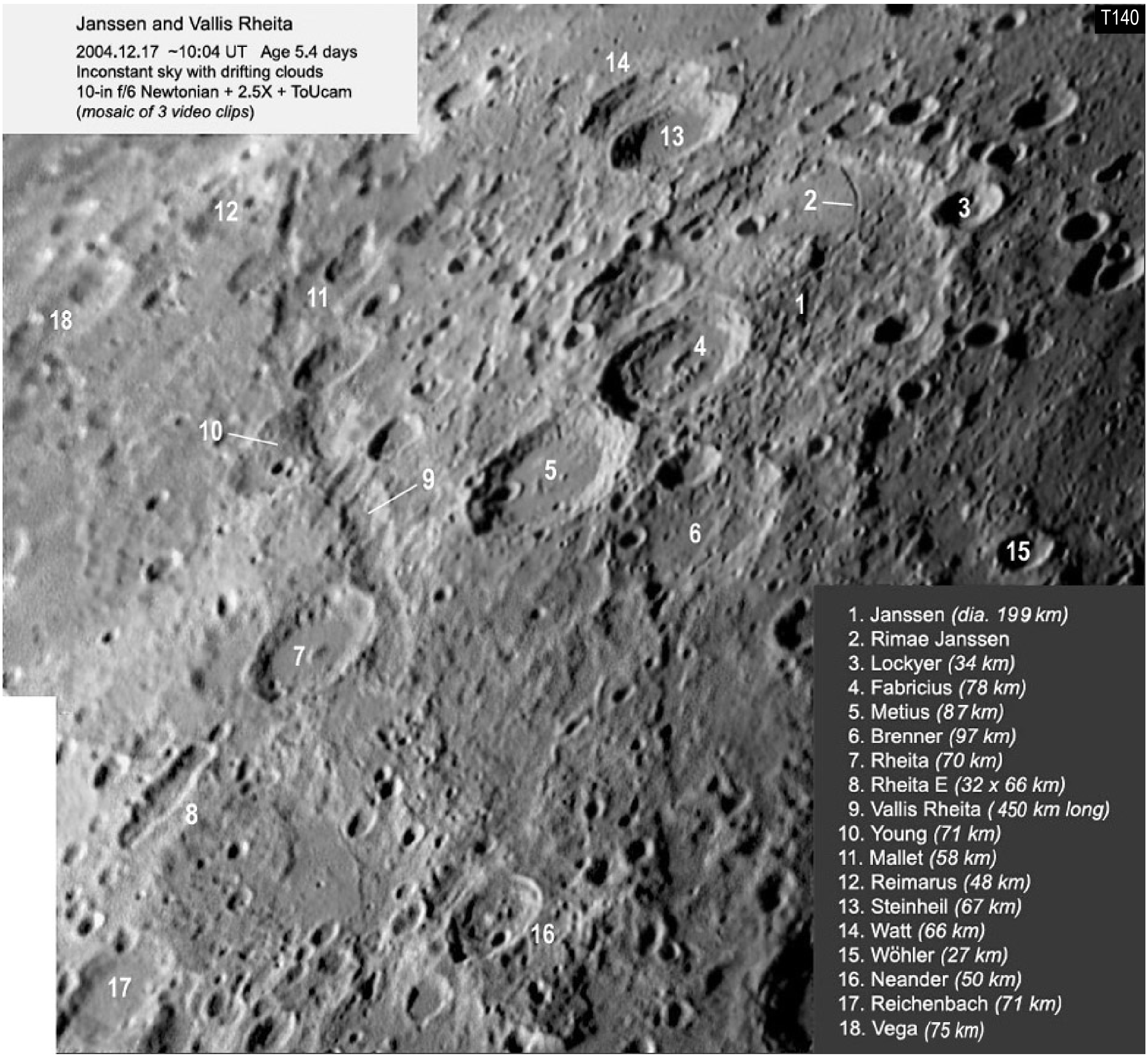
MAP 4

Hatfield 16
Rükl 67, 68, 69, 76

Janssen, Fabricius, Vallis Rheita, Mare Australe







Janssen 45.4^0 S 40.3^0 E
A large walled formation with craters, rilles and mountain massifs on its floor, diameter 199 km. It is highly eroded by impacting debris from the Nectaris basin and hence must be very ancient (formed in Pre-Nectarian period). The system of curved rilles that crosses the southern floor is ***Rimae Janssen***, length about 120 km. It appears like stress fracture but no one knows the exact cause. The northwest wall of Janssen is broken by the fairly large crater ***Brenner*** (97 km).

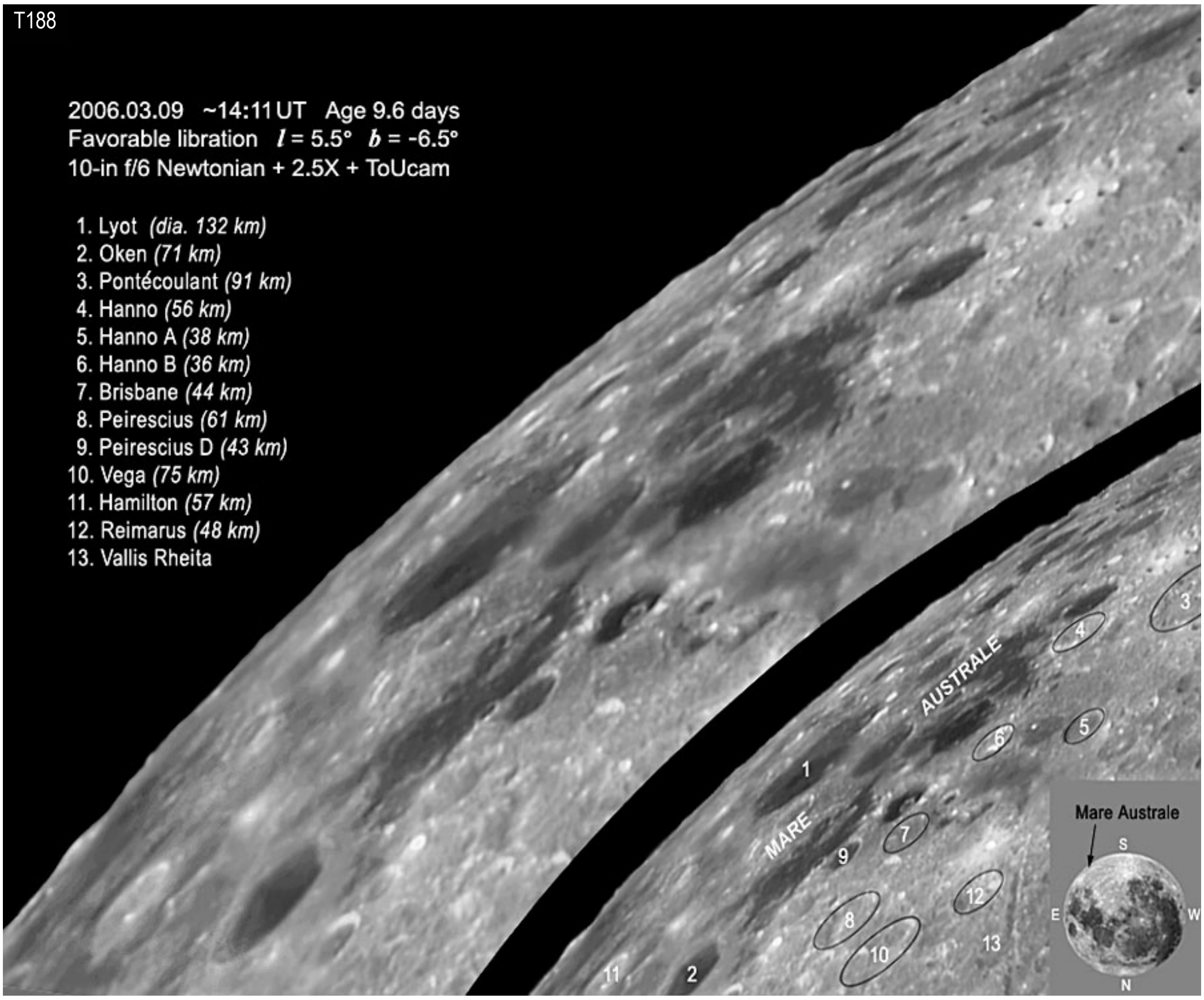
Fabricius 42.9^0 S 42.0^0 E
This crater is located within Janssen. It is 78 km in diameter, with a small central peak. At one observation with small telescope, the wall appeared double, making it look as if one crater is almost perfectly centered in another. However, high-power telescopes confirm this is not a double wall but a lumpy ridge like a horse-shoe.

Metius 40.3^0 S 43.3^0 E
A crater joining the walls of Janssen and Fabricius, diameter 87 km, with a low central peak.

Vallis Rheita 42.5^0 S 51.5^0 E *(Image T140)*
Vallis Rheita is a long linear valley near Janssen, 450 km in length, width up to 30 km. It begins from the outer rim of ***Rheita*** (70 km), passes through ***Young*** (71 km) and ***Mallet*** (58 km), then ends beyond ***Reimarus*** (48 km). The floor of Vallis Rheita appears as a chain of overlapping craters more than a true valley. The chain also points to Mare Nectaris (T056B, Map 3), suggesting it was created by secondary impacts during the formation of the Nectaris basin. ***Rheita E*** is an elongated crater-valley feature, size 32 x 66 km; probably it was created by the fusion of few pre-existing craters or by a grazing secondary impact during the formation of Janssen.

Steinheil 48.6^0 S 46.5^0 E
Watt 49.5^0 S 48.6^0 E
A pair of overlapped craters, each about 67 km in diameter. The east inner wall of Steinheil houses a group of small but noticeable craters (T228).

Mare Australe 38.9^{0}S 93.0^{0}E *(Image T188)*
Mare Australe (Southern Sea) is on the south-east limb, covering the nearside and farside of the Moon with a span of about 600 km. To the terrestrial observers, it is a difficult object due to limb-foreshortening. Mare Australe is thought to occupy a large old impact basin. The crust beneath the basin is somewhat thicker than the nearside, hence less mare filling the basin. In Lunar Orbiter images, nearly 200 craters of different sizes are still exposed from this mare. ***Lyot***, a flooded walled plain (132 km), is the most prominent. More details in Farside map.



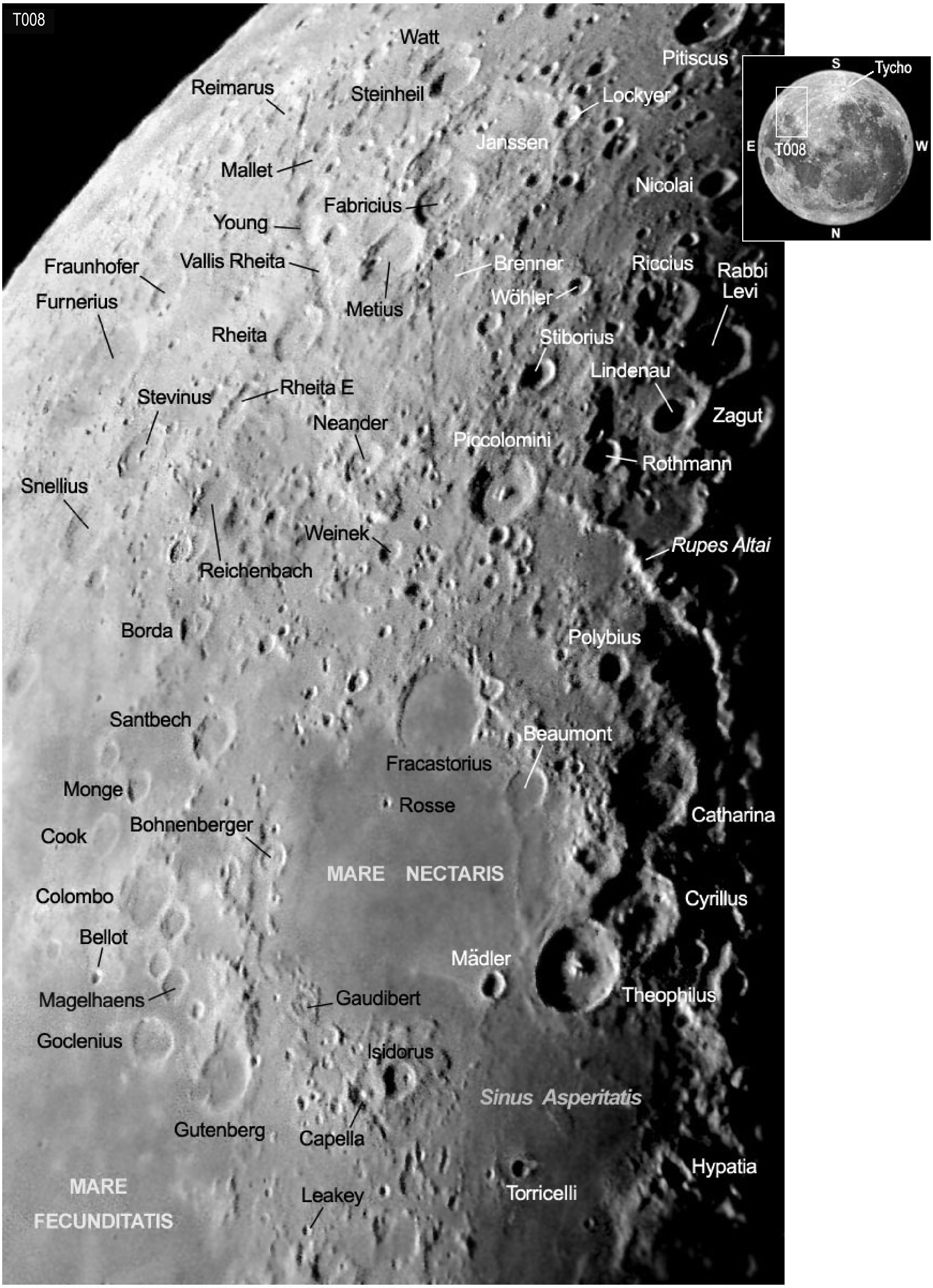
Mare Australe and Janssen during the first quarter 2010.09.15 11:12 UT Age 7.0 days Libration $l = +7.5^{\circ}$ $b = +1.5^{\circ}$ Tak FS128 f/8 + 1.4X + Canon 550D at ISO400 1/200s (cropped)

MAP 4

MAP 5

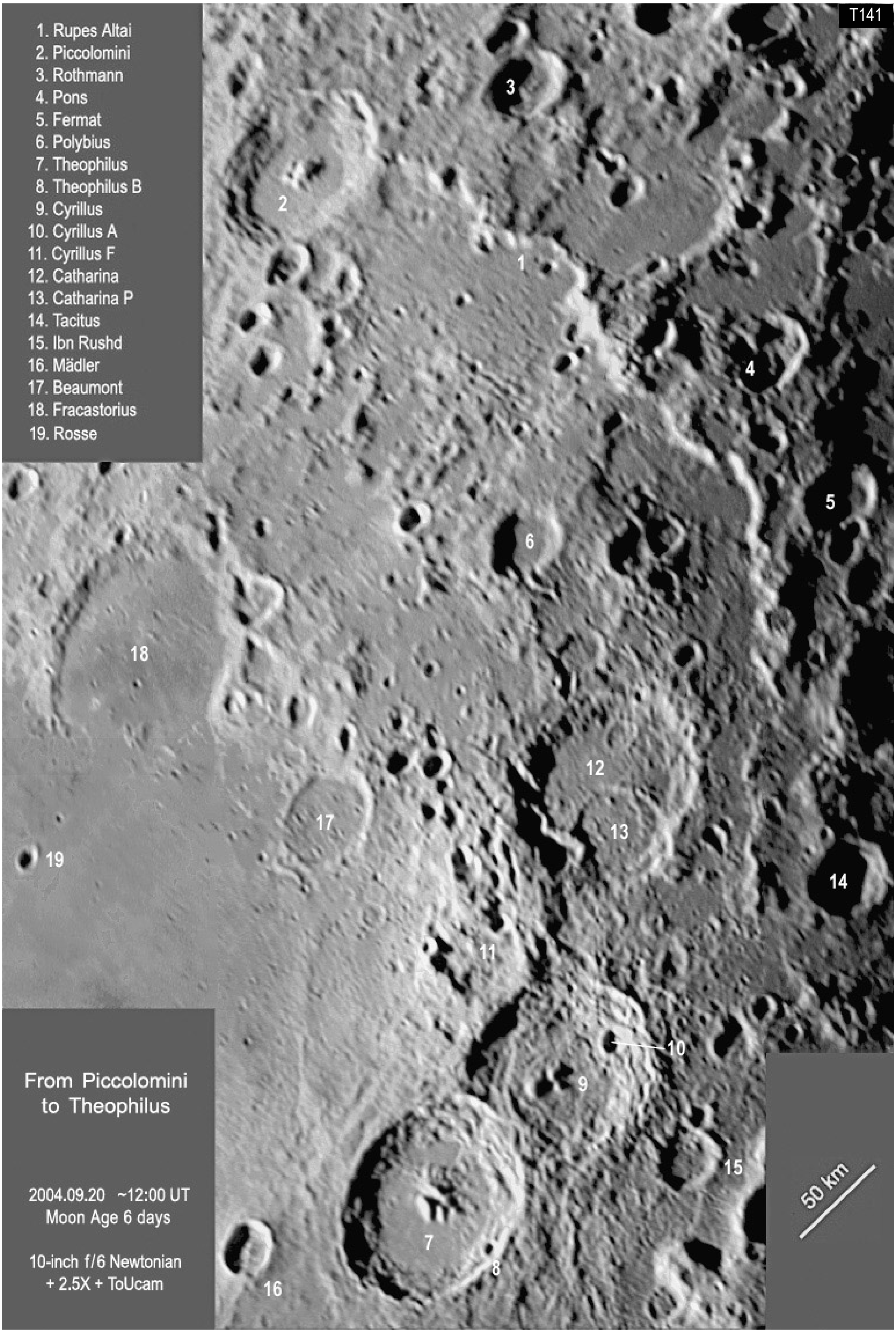
Mare Nectaris, Theophilus, Cyrillus, Catharina, Piccolomini, Rupes Altai, Fracastorius

Hatfield 15, 13
Rükl 46, 57, 58, 67

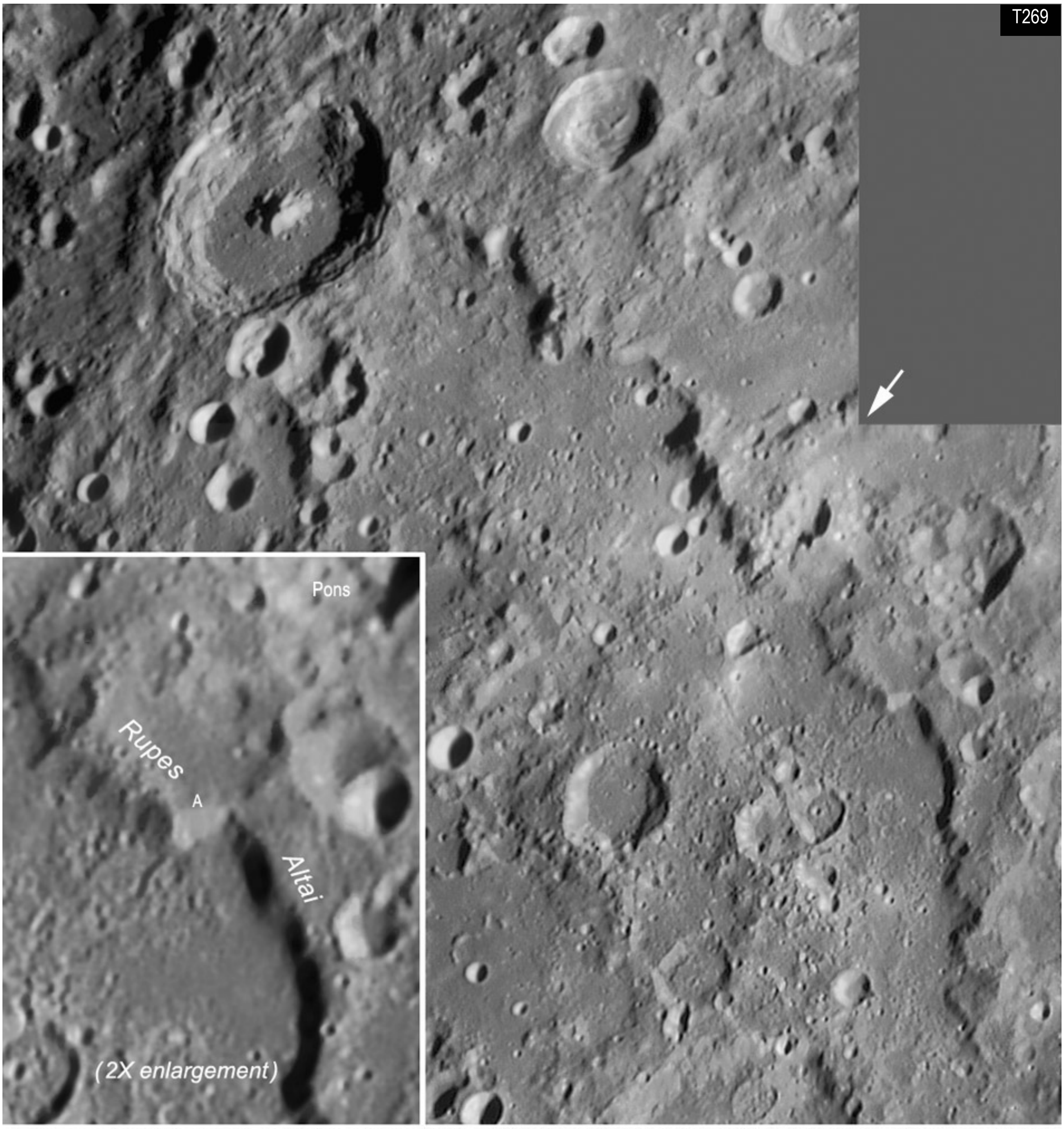


Janssen to Torricelli 2000.11.02 12:14 UT Age 6 days. FS128 + LE12.5 + QV2300 at 1/6 sec.

From Piccolomini to Theophilus



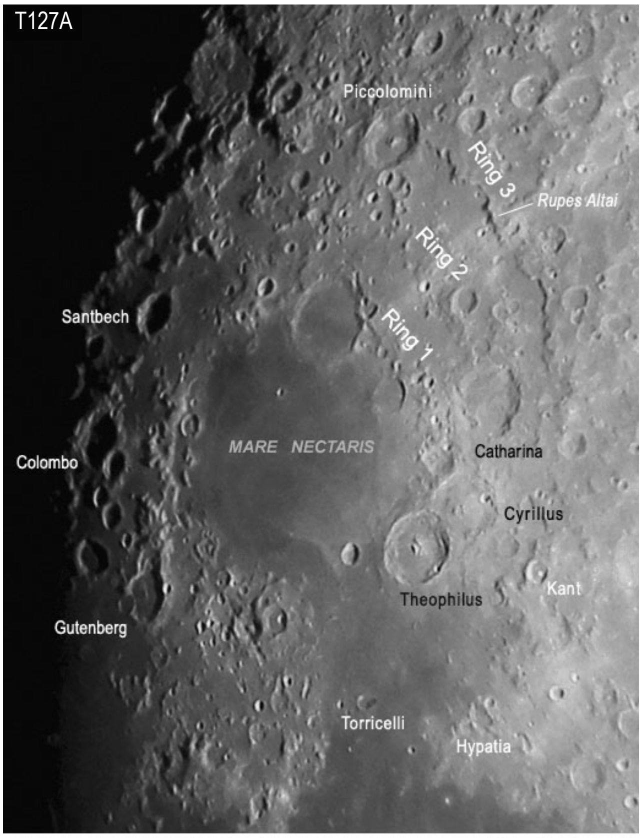
Piccolomini and Rupes Altai at Moon age of 19 days



Piccolomini and Rupes Altai 2006.08.12 21:30 ~ 21:41 UT Age 18.7 days. 10-inch f / 6 Newtonian + 2.5X + 1.6X + ToUcam, 95 % resized. (*mosaic*)
The 2X enlargement shows a section of Rupes Altai with abrupt slope. Position A is roughly 3000 m higher than the foot of the cliff. Due to low surface gravity (1/6 that of Earth), a stone dropping from position A will take a full minute to reach the ground.
The arrow points a patch of bright albedo, probably caused by the ejecta of the Fracastorius or Tycho impact. Tycho is a rayed crater 1000 km to the southwest.

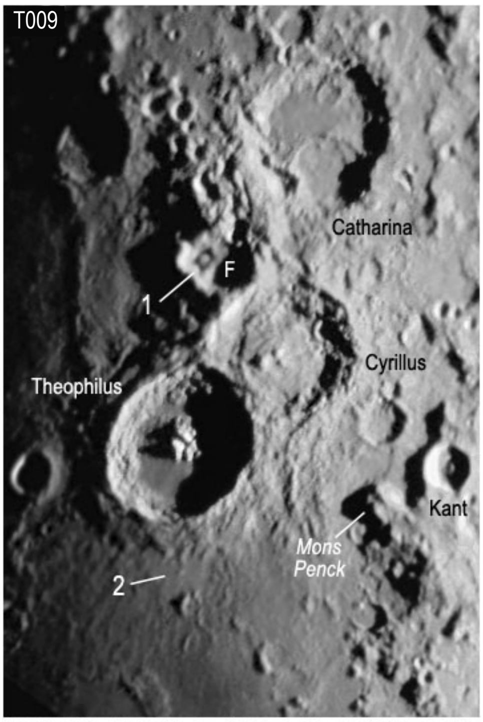
Remark: Distance dropped by a free-falling object on the lunar surface is equal to $1/2 \cdot \boldsymbol{g} \cdot \boldsymbol{t}^2$, where $\boldsymbol{g}$ is the gravitational acceleration (= 1.62 m/s^2) and $\boldsymbol{t}$ is the time of falling.

Mare Nectaris (Sea of Nectar)
15.2^{0} S 35.5^{0} E
This is a small mare inside an impact basin formed in the Nectarian period (3.9 billion years ago), diameter about 330 km. The impact basin is traceable by a pattern of three concentric rings, as suggested in Image T127A. Piccolomini and Rupes Altai lie on Ring 3, the outmost ring of the basin. Theophilus, Cyrillus and Catharina form a prominent crater trio between Ring 1 and Ring 2.

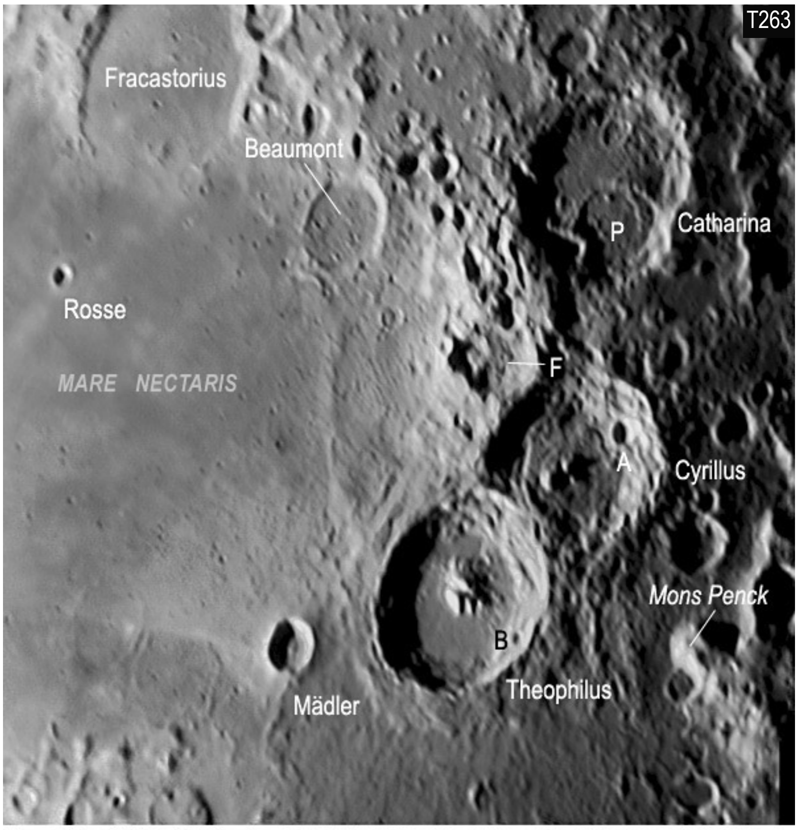


2010.09.26 16:48 UT Age 18.3 days. Tak FS128 f/8 + Canon 550D at ISO200 1/400s (cropped)

Theophilus 11.4^{0} S 26.4^{0} E
A ring mountain from the Eratosthenian period, diameter 110 km. Its massive terraced walls rise some 4000 m above the interior. At high powers, these walls appear as linear segments of landslides. The north-western wall contains a small crater (***Theophilus B***, 8 km). Theophilus also contains magnificent multiple central mountains with one of the peaks rising 1400 m above the floor. The floor looks smooth and flat because it was filled with impact melt. Impact melt is also seen at the outer rim. After first quarter, Theophilus is brightened up with a hint of rays. It becomes very bright in the full moon.

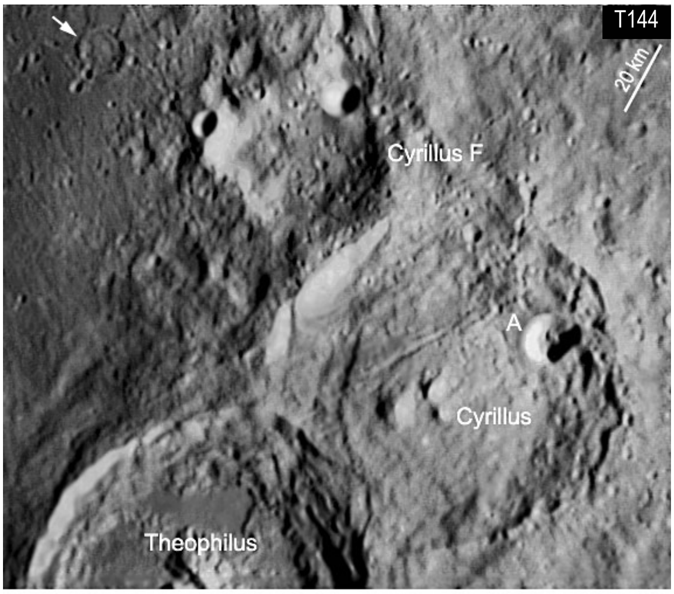


2001.05.12 18:20 UT Age 19 days. C9 + LE12.5 + CP990
1. Tortoise-shaped shadow on Cyrillus F. 2. impact melt



Theophilus, Cyrillus & Catharina 2006.07.31 12:18 UT Age 6.3 days. 10-in f/6 Newtonian + 2.5X + ToUcam
Note: The small crater Rosse lacks a ray system but is crossed by a Tycho's ray. (Tycho not shown here).

Cyrillus 13.2^0 S 24.0^0 E
A ring mountain with disintegrated wall and three central peaks, diameter 98 km. It is obvious that the Theophilus impact destroyed a section of Cyrillus's walls. Cyrillus is therefore older than Theophilus. The southwest wall contains a small crater, ***Cyrillus A***. The floor of Cyrillus does not appear smooth like the floor of Theophilus, but rough with ridges and depressions. The floor of ***Cyrillus F*** (diameter 44 km) also contains a shallow depression with central uplift. It casts a tortoise-shaped dark shadow at Moon age of about 19 days. (Image T009 and T144).



Cyrillus & Cyrillus F 2006.08.12 21:43 UT Age 19 days 10-in f/6 Newtonian + 4X + ToUcam
The arrow points to an interesting crater trio (Beaumont A + 2 craterlets) that resembles a magnifying glass.

Catharina 18.1^0 S 23.4^0 E
A damaged crater, diameter 104 km. Catharina is connected to Cyrillus by a broad valley, and is believed the oldest of the trio. It has been heavily obliterated by several impacts. There are big and small craters on its floor (the most prominent being ***Catharina P***), but no central peaks. The central peaks must have existed years ago but finally overwhelmed by Catharina P.

Beaumont 18.0^0 S 28.8^0 E
A lava-flooded crater on the western edge of Mare Nectaris, diameter 53 km. A low ridge runs northward from the crater rim.

Mädler 11.0^0 S 29.8^0 E
A 27-km crater. Its ejecta blanket is fan-like and relatively whitish. See also Map 7.

Piccolomini 29.7^0 S 32.2^0 E
A 87-km crater from the late Imbrium period, with central peak and terraced walls, 4500 m deep.

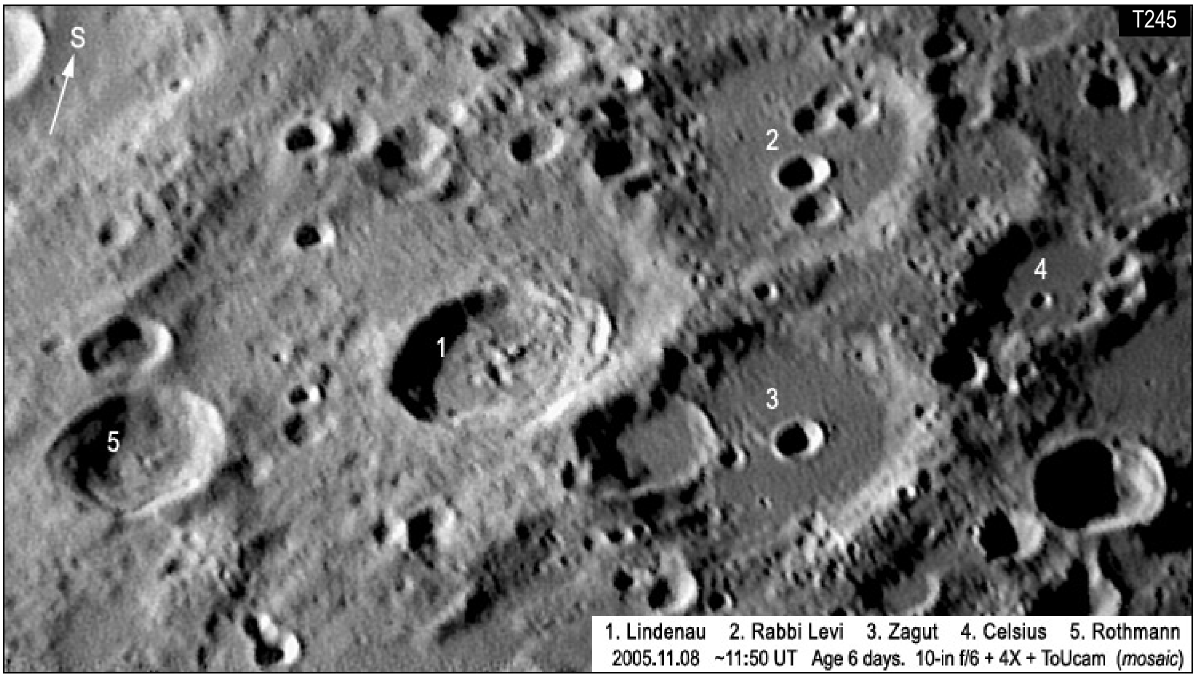
Rupes Altai 24.3^0 S 22.6^0 E
A sinuous mountain scarp running between Piccolomini and Catharina, about 430 km in length. Its altitude varies, roughly 2000 m in average. The scarp is part of the ring system of the Nectaris basin (T127A). The steepest slope lies near ***Pons*** and ***Fermat*** (T141 & T269); it drops by about 3000 m.

(Image T245, next page)

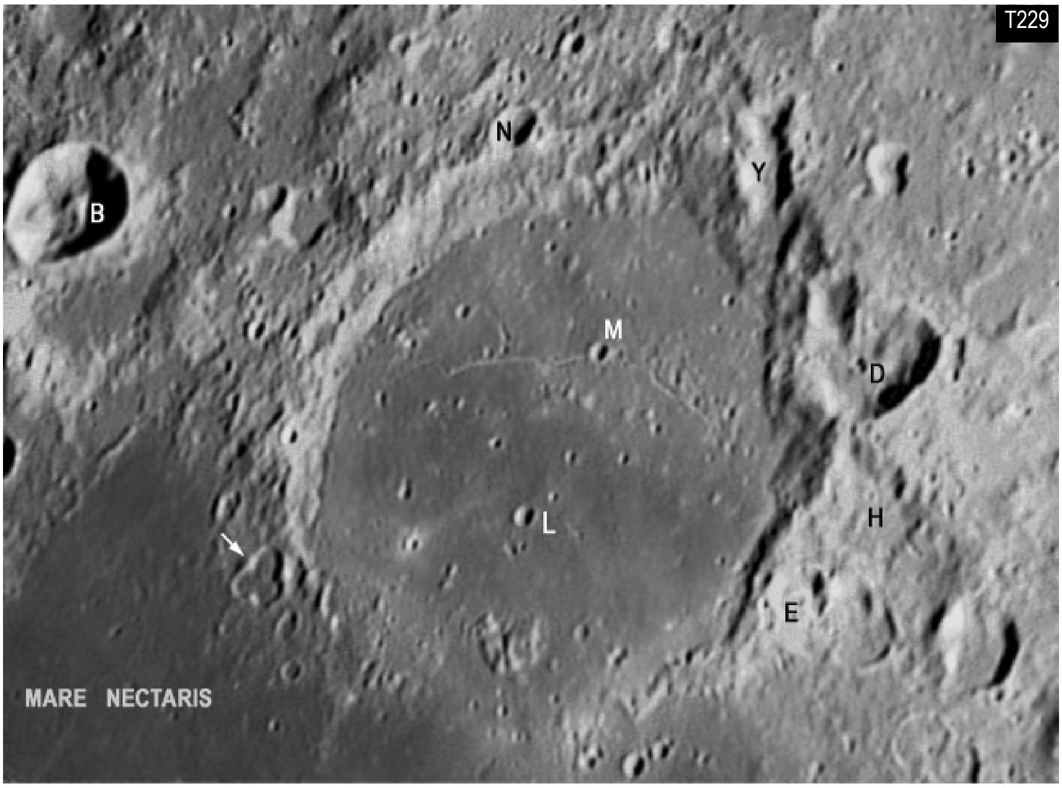
Lindenau 32.3^0 S 24.9^0 E
A terraced crater with multiple central peaks, diameter 53 km, 2900 m in depth.

Rabbi Levi 34.7^0 S 23.6^0 E
An 81-km crater with 5 smaller but prominent ones on the floor. Its eastern wall is heavily ruined by a cluster of impact craters.

Zagut 32.0^0 S 22.1^0 E
A crater adjoining Rabbi Levi, diameter 84 km. Its floor contains a small central crater. Its southeastern wall looks linear and interrupted by a fairly large crater (***Zagut E***, diameter 35 km).



1. Lindenau 2. Rabbi Levi 3. Zagut 4. Celsius 5. Rothmann
2005.11.08 ~11:50 UT Age 6 days. 10-in f/6 + 4X + ToUcam (*mosaic*)



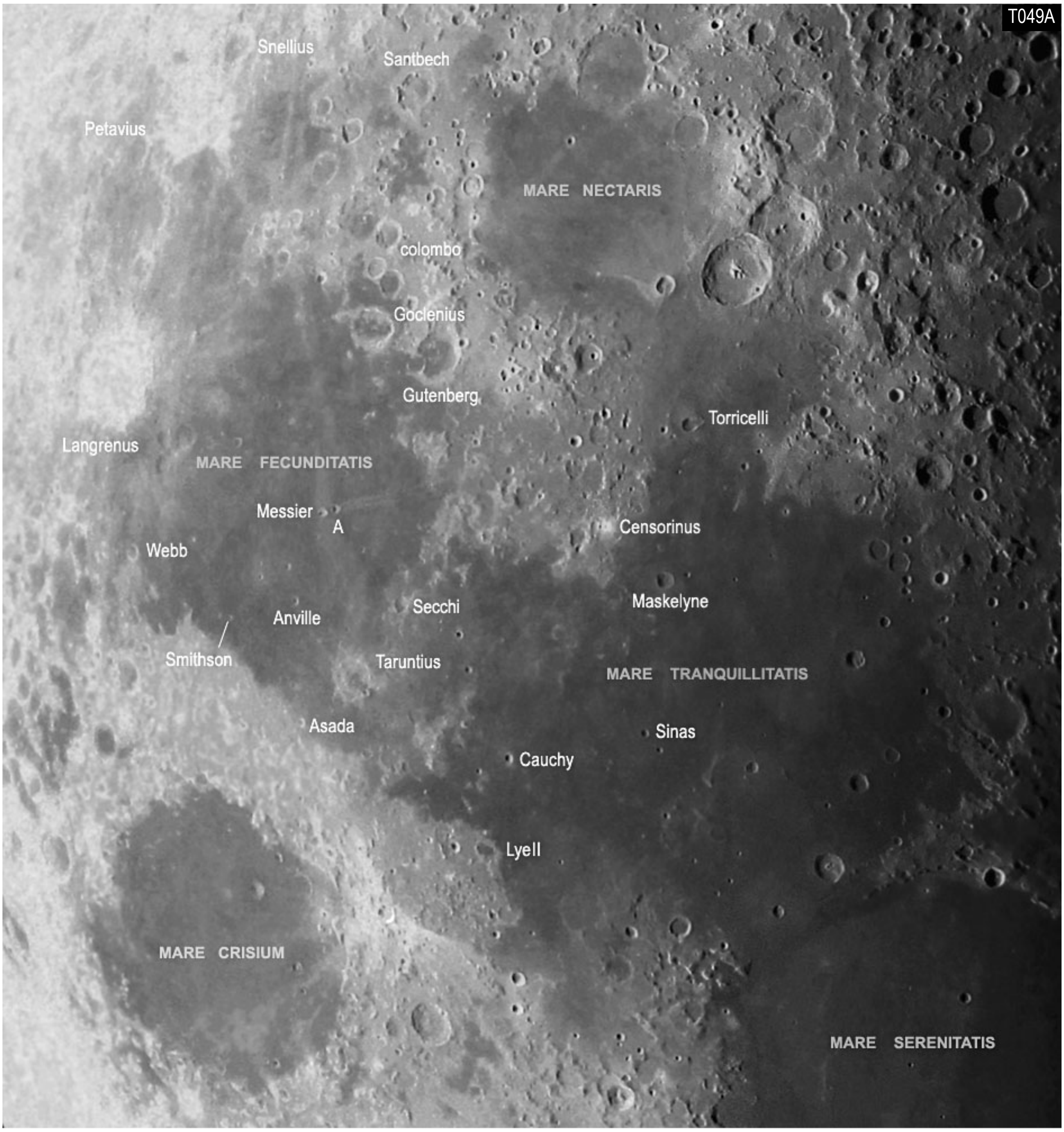
Fracastorius 2005.08.22 19:07 UT Age 17.5 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam, 93 frames stacked.

Fracastorius 21.5^0 S 33.2^0 E *(Image T229)*
An incomplete walled plain, diameter 112 km. Its bay-like floor opens to Mare Nectaris and contains a long faint rille that intersects ***Fracastorius M***. This rille is a fracture caused by surface stress. The floor also contains a tiny rayed crater and dome-like hills. Fracastorius must have formed after the Nectaris impact. Later, the rille and craters formed inside Fracastorius after the lava intruded and solidified. Note also the interesting crater-trio (arrow) in T229.

MAP 6

Mare Fecunditatis, Messier, Censorinus, Taruntius, Cauchy

Hatfield 3
Rükl 36, 37, 47, 48



2010.09.15 11:12 UT Age 7.0 days Libration *l* = +7.5° *b* = +1.5° Tak FS128 f/8 + 1.4X + Canon 550D at ISO400 1/200s. (90% resized, *cropped*)

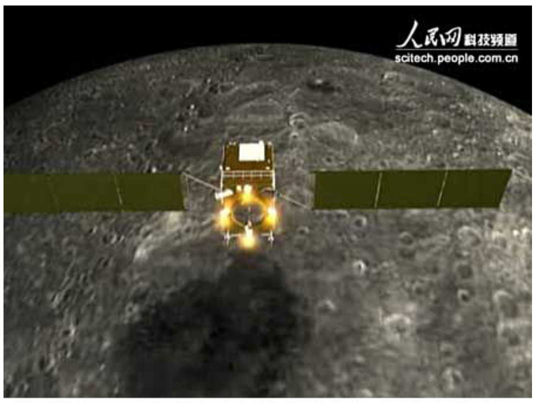
Mare Fecunditatis (the Sea of Fertility) is located in an old impact basin which formed in the Pre-Nectarian period (Hartmann, 1971) and has an estimated diameter of about 900 km. The mare material, however, is relatively young, about 3.4 billion years old based on the tiny sample returned by the Soviet Luna 16 mission. There are no prominent features on the mare except the crater pair Messier and Messier A. On the eastern edge of Fecunditatis is the crater Langrenus, often seen as a bright patch after the first quarter.

1. Messier 2. Messier A 3. Rima Missier 4. Lubbock 5. Rimae Goclenius 6. Amontons 7. Ibn Battuta 8. Lindbergh 9. Dorsa Geikie 10. Dorsa Cato 11. Dorsum Cayeux 12. Dorsum Cushman 13. Rimae Secchi 14. Chang'e-1 impact site. 2004.08.02 17:53 UT Age 16 days. 10-in f/6 + 2.5X +ToUcam, 130% resized.

(Image T105)

Messier 1.9^0 S 47.6^0 E
Messier A 2.0^0 S 47.0^0 E
A pair of small impact craters in Mare Fecunditatis (Sea of Fertility), diameter 11 ~ 13 km. Messier looks oval in shape that is definitely not caused by foreshortening. Messier A is a double crater, the source of two bright rays radiating to the west like cometary tails. The dual rays are in fact ejecta deposits of the impact, each measures over 100 km in length. This double crater probably formed simultaneously by a grazing binary or broken impactor.

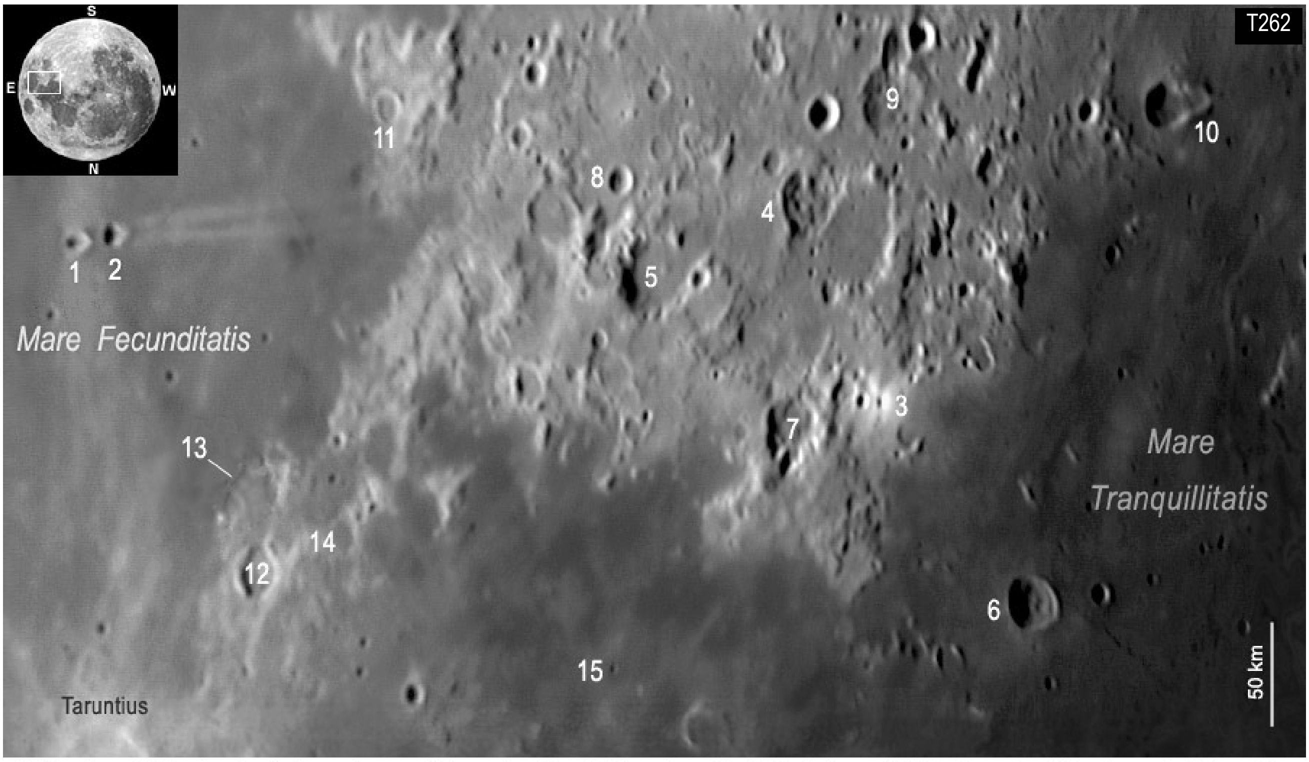
Label 14 is the impact site of the China's lunar orbiter Chang'e-1. It was launched in October 2008 and was deliberately crashed onto Mare Fecunditatis after 16 months of successful service.



An artist image showing Chang'e-I impacted the moon. Credit: people.com.cn

Rima Messier 1.0^0 S 45.0^0 E
An inconspicuous rille, length about 100 km.

Rimae Secchi 1.0^0 N 44.0^0 E
An elusive short rille, length 35 km. It is in the south of ***Secchi*** (Label 13, T262 in next page).

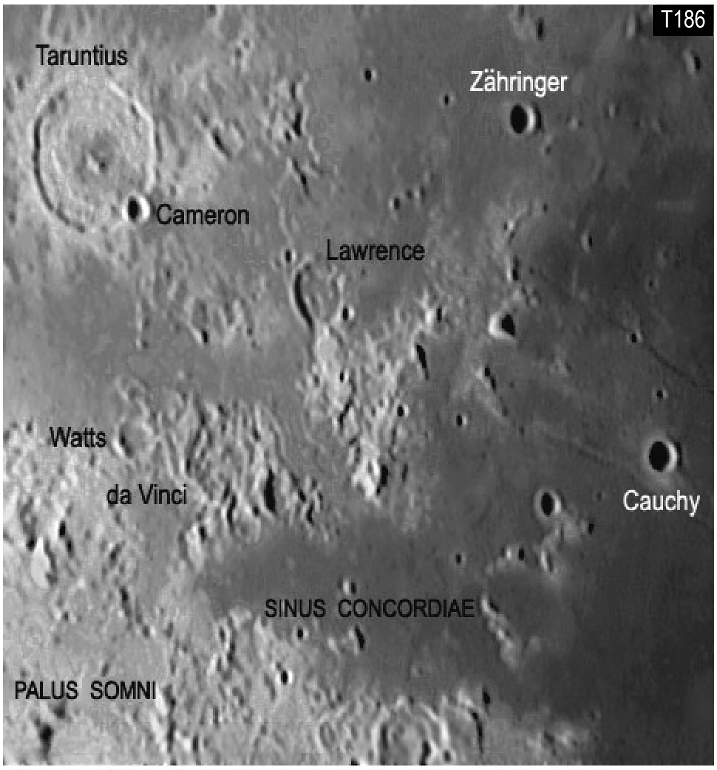


1. Messier 2. Messier A 3. Censorinus 4. Censorinus C 5. Censorinus N 6. Maskelyne 7. Maskelyne A 8. Leakey 9. Isidorus B 10. Torricelli 11. Lubbock 12. Secchi 13. Rimae Secchi 14. Montes Secchi 15. Menzel 2006.07.02 12:40UT Age 7 days. 10-in f/6 Newtonian + 2.5X + ToUcam

(Image 262)

Censorinus 0.4^0 S 32.7^0 E

A crater on the southern edge of Mare Tranquillitatis, diameter 3 km. It is surrounded by a white halo and is exceptionally bright under high illumination.



Taruntius & Cauchy 2004.12.17 10:54 ~ 11:01 UT Age 5.4 days. 10-in f/6 + 2.5X + ToUcam

Maskelyne 2.2^0 N 30.1^0 E

A crater with terraced walls and central peak, diameter 23 km. Its rim is somewhat polygonal.

Secchi 2.4^0 N 43.5^0 E

A crater with broken wall, diameter 22 km. Its western rim adjoins a narrow mountain range (***Montes Secchi***, length about 50 km).

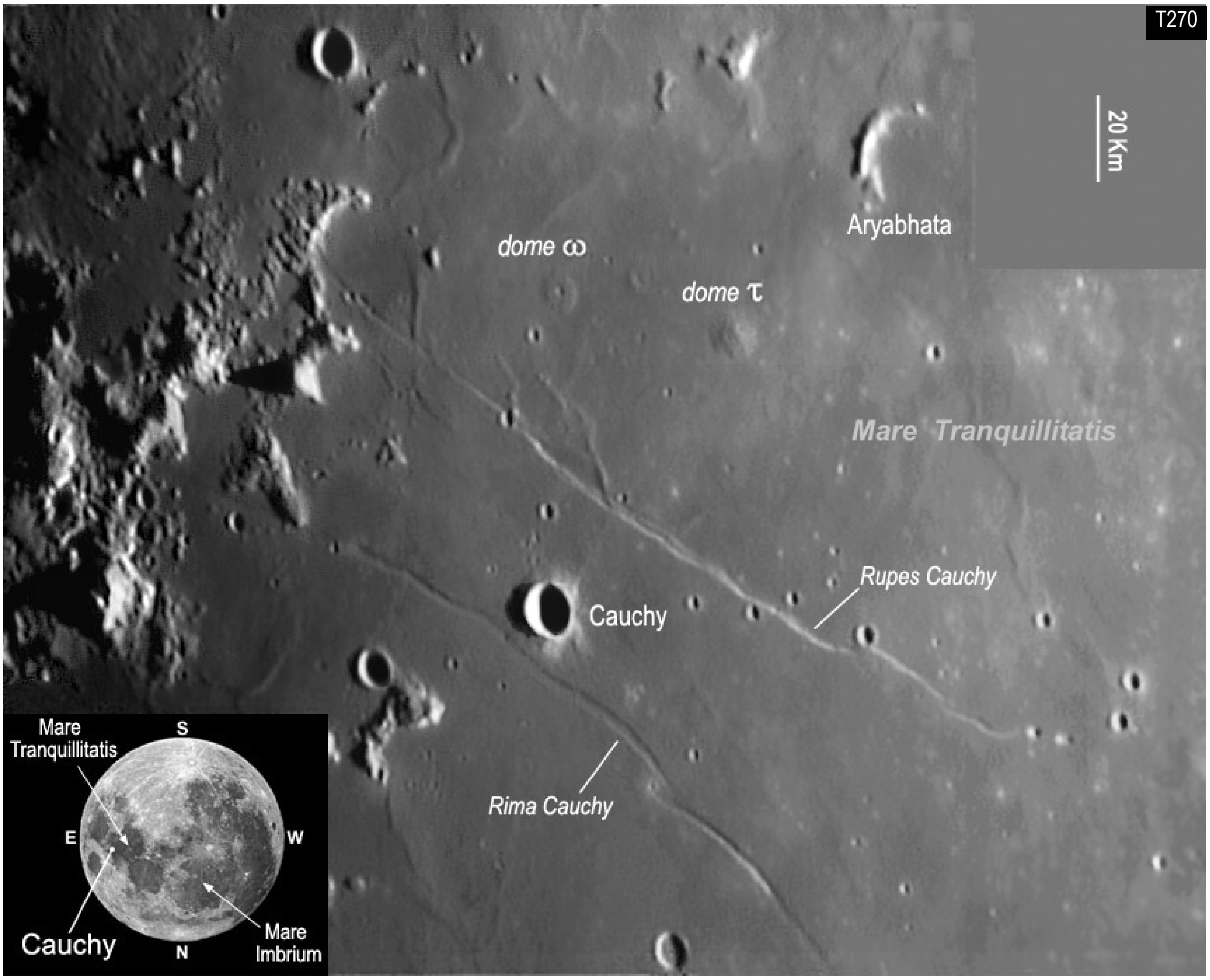
(Image T186)

Taruntius 5.6^0 N 46.5^0 E

A rayed crater at the "neck" between Mare Fecunditatis and Mare Tranquillitatis. It is 56 km in diameter, with concentric walls and a central peak rising from the partially darkened floor.

da Vinci 9.1^0 N 45.0^0 E

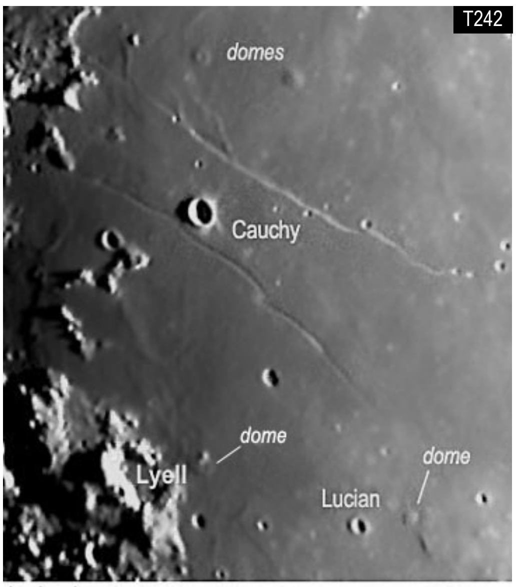
A heavily disintegrated crater, diameter 37 km. Its floor is rough.



Cauchy and its vicinity 2006.08.12 ~21:11 UT Age 18.7 days. 10-inch f/6 Newtonian + 2.5X + 1.6X + ToUcam (mosaic of 2 video clips)

Cauchy 9.6^0 N 38.6^0 E

A 12-km crater with sharp rim, bright in the full moon. It sits between ***Rupes Cauchy*** (a fault, length 120 km) and ***Rima Cauchy*** (a graben, length 140 km). Their parallelism resembles Rupes Recta and Rima Birt in Map 12. Rupes Cauchy looks strange because its ends taper off to thin rille segments. The pair, which run on the inner circumference of Mare Tranquillitatis and radially to Mare Imbrium, were thought to appear initially when the immense lava in Mare Tranquillitatis subsided. The shock waves from the subsequent Imbrium impact triggered them to their final form. To the south are two volcanic domes, ***Cauchy Tau*** (τ) at ~14 km diameter and ***Omega*** (ω) at ~10 km. Their heights are 200 m less, so they are visible only at low illumination. The summit craterlet (caldera) on dome ω is called ***Donna***, diameter 2 km. Dome τ has few elusive pits on its sloping surface.



Lucian dome 2005.10.21 15:37UT Age 18 days. 10-in f/6+2.5X+ToUcam

Aryabhata 6.2^0 N 35.1^0 E

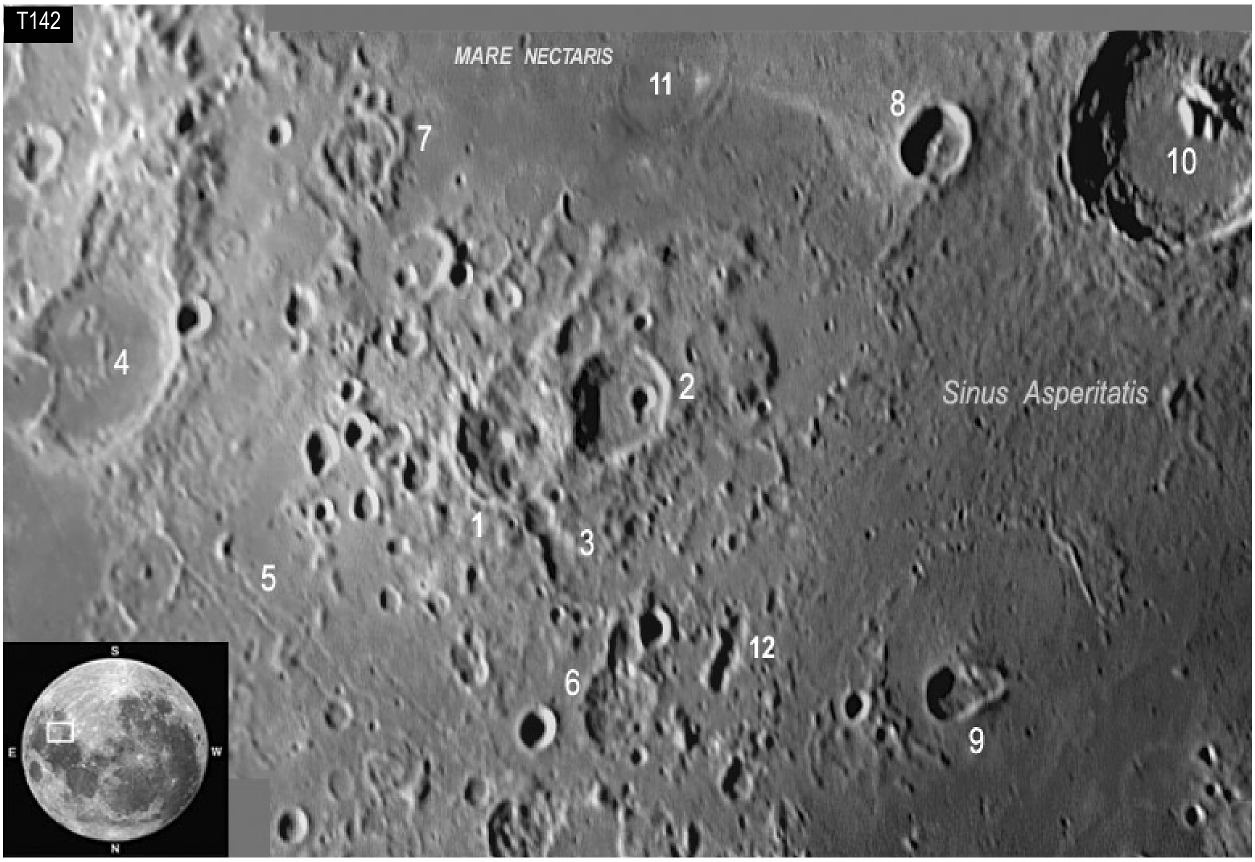
Remnant of a flooded crater, diameter 22 km.

Lyell 13.6^0 N 40.6^0 E **Lucian** 14.3^0 N 36.7^0 E

There are domes near these craters, see T242.

Capella, Isidorus, Torricelli, Bohnenberger, Gutenberg

Hatfield 15
Rükl 47, 48, 58



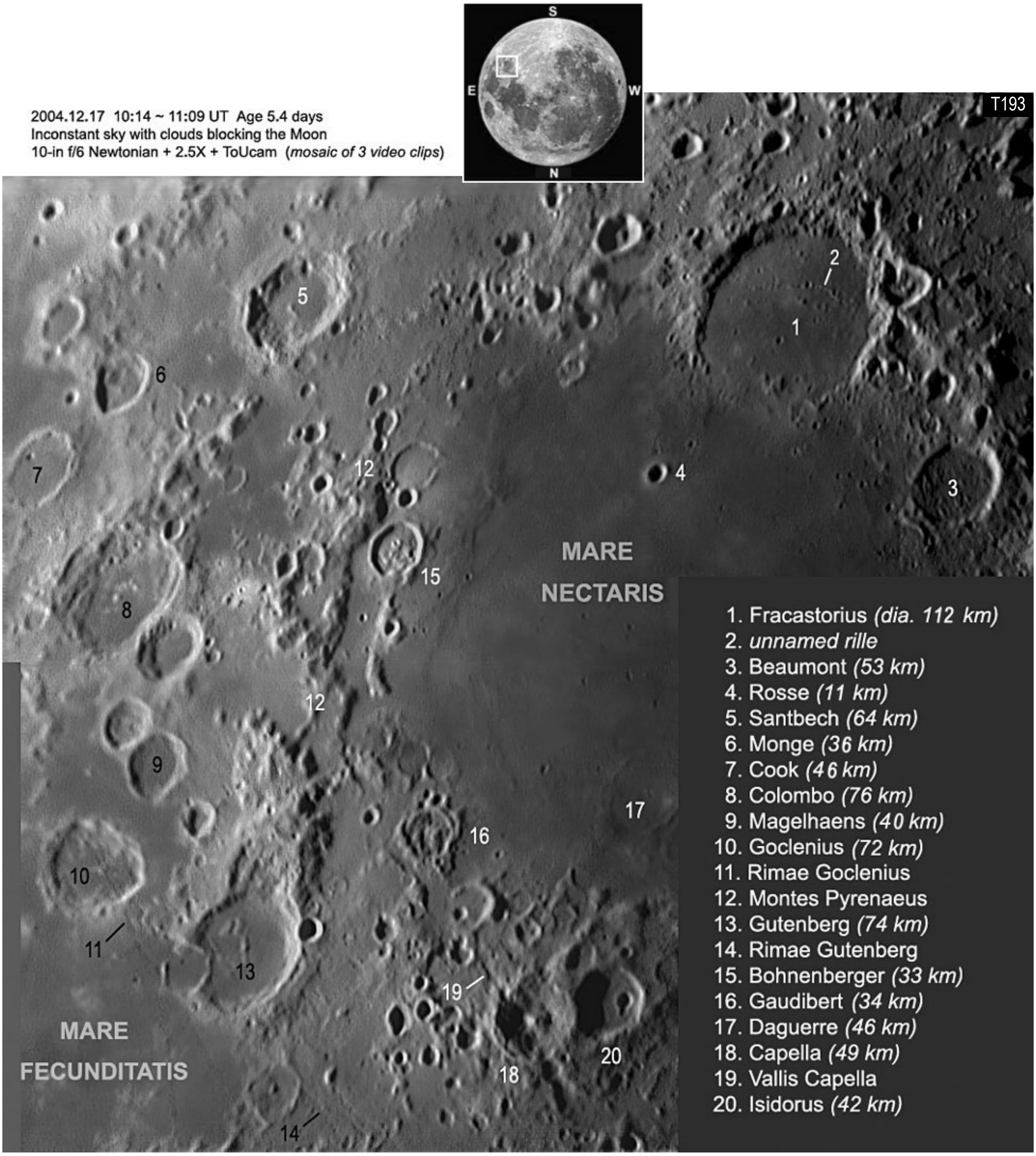
1. Capella 2. Isidorus 3. Vallis Capella 4. Gutenberg 5. Rimae Gutenberg 6. Isidorus B 7. Gaudibert 8. Mädler 9. Torricelli 10. Theophilus 11. Daguerre 12. *a crater-valley* 2004.09.20 ~11:17 UT Age 6 days. 10-in f/6 Newtonian + 2.5X + ToUcam.

Capella 7.5^0 S 35.0^0 E
A crater in the north of Mare Nectaris, diameter 49 km. It has an oversized central peak with a summit pit. ***Vallis Capella*** passes through Capella, overall length about two times the crater diameter. It tapers off southeastward, and is actually an alignment of broken or overlapped craters. If Image T142 is turned clockwise, Capella resembles a monkey face.

Isidorus 8.0^0 S 33.5^0 E
A crater with relatively flat floor, diameter 42 km. Its wall is interrupted by Capella. It has no central peak. A prominent crater (***Isidorus A***, 10 km) is located on the floor near the western rim. A nameless crater-valley feature, formed by overlapping craters, exists near ***Isidorus B*** (30 km).

Mädler 11.0^0 S 29.8^0 E
A 27-km crater with fan-shaped ejecta blanket. See also Map 5.

Torricelli 4.6^0 S 28.5^0 E
Torricelli is an elongated crater probably caused by two simultaneous impacts, span 22 km. It is inside a ghost crater located in ***Sinus Asperitatis*** (Bay of Roughness) where the floor is rough due to the ejecta of the Theophilus impact. The western wall of Torricelli is open and linked with a smaller crater, hence the whole formation appears pear-shaped.



Goclenius 10.0^0 S 45.0^0 E
A crater crossed by ***Rimae Goclenius***, 54x72 km. It glows to a bright ring after the first quarter.

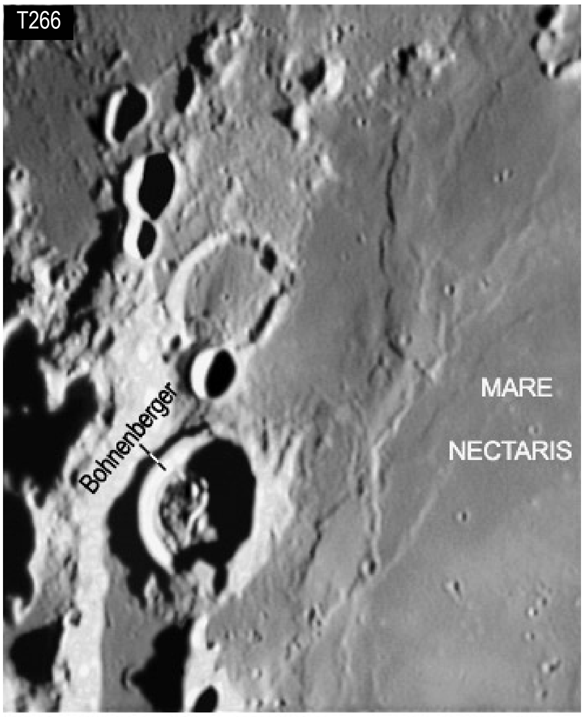
Gaudibert 10.9^0 S 37.8^0 E *(Image T193, Label 16)*
A crater with internal massifs and ridges, diameter 34 km. Its southern wall adjoins a trio of small craters while the rest of the walls are surrounded partially by mountain ranges.

Daguerre 11.9^0 S 33.6^0 E *(T193, Label 17 and T142, Label 11)*
A ghost crater in Mare Nectaris, diameter 46 km. A rayed craterlet is on the inner western floor.

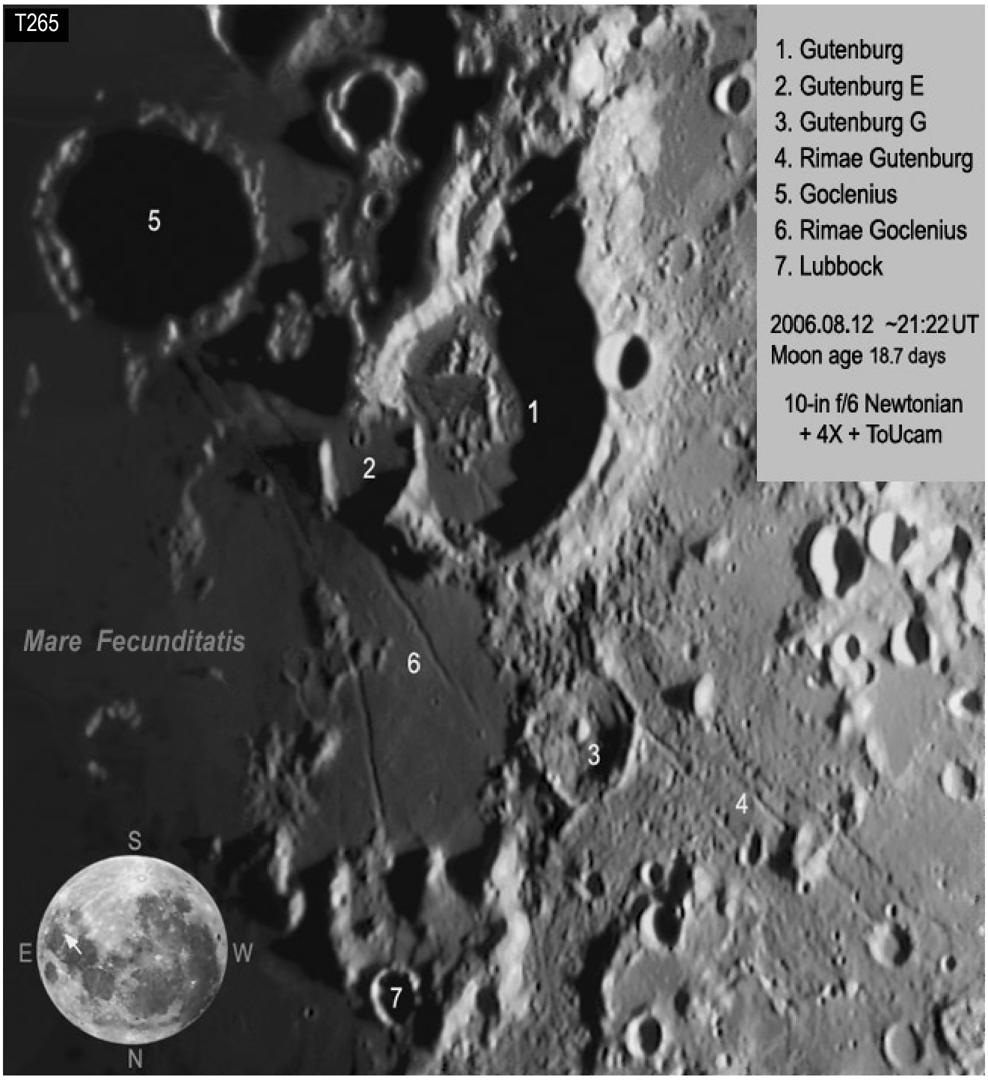
Montes Pyrenaeus 15.6^0 S 41.2^0 E *(Image T193)*
Mountain range from the south of ***Gutenberg*** to ***Bohnenberger*** and beyond, length 164 km. It is part of the inmost ring of the Nectaris impact basin. The mountain range between ***Santbech*** and ***Colombo*** is also remnant of the middle ring. See all rings of the basin in T127A, Map 5.

Bohnenberger 16.2^0 S 40.0^0 E *(Image T266)*
A crater with internal low hills, diameter 33 km. It rests on the eastern edge of Mare Nectaris where wrinkle ridges are prominent at Moon age of 19 days.

Gutenberg 8.6^0 S 41.2^0 E *(Image T265)*
A flooded crater, diameter 74 km. Its eastern wall is broken by a smaller flooded crater. ***Rimae Gutenberg*** (length 330 km) and ***Rimae Goclenius*** (length 240 km), run along the edge of Mare Fecunditatis. They are fractures caused by the subsidence of massive lava in the mare.

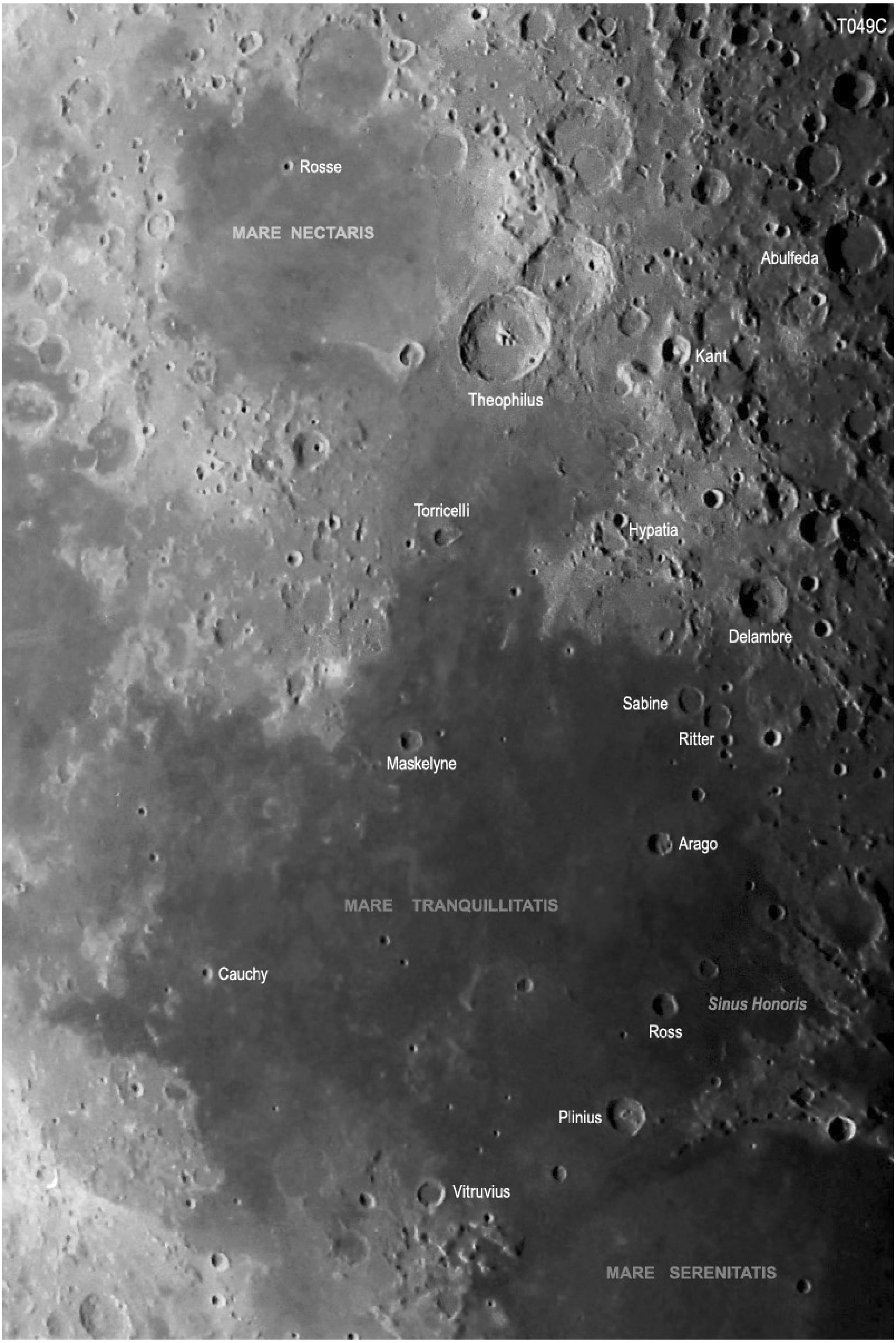


2006.08.12 21:23 UT Age 19 days. 10-in f/6 Newtonian + 4X + ToUcam

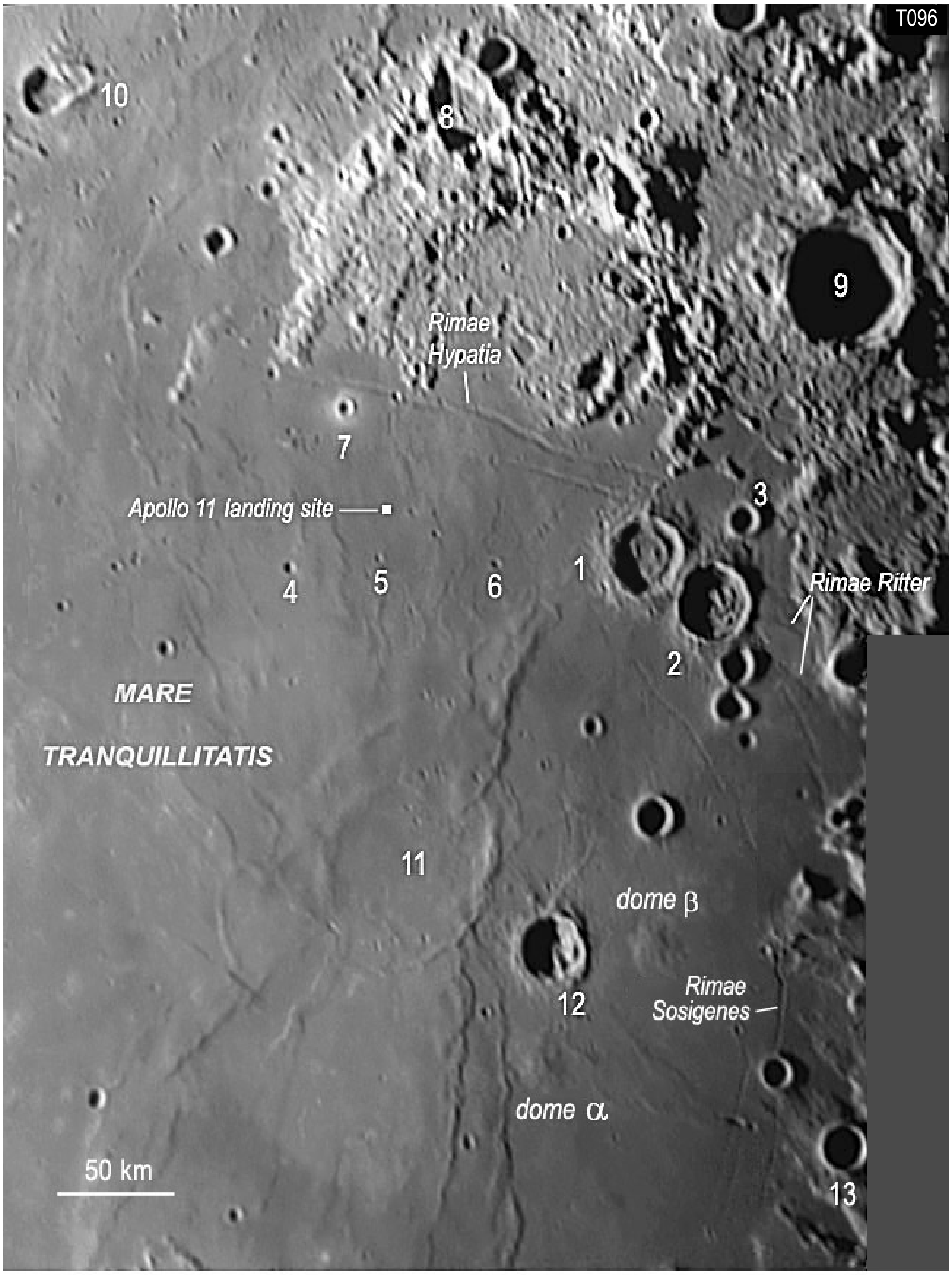


Sabine, Ritter, Hypatia, Delambre, Arago, Lamont

Hatfield 1,13
Rükl 35, 46



Mare Tranquillitatis and Mare Nectaris 2010.09.15 11:12 UT Age 7.0 days. Tak FS128 f/8 + 1.4X + Canon 550D at ISO400 1/200s.



1. Sabine 2. Ritter 3. Schmidt 4. Armstrong 5. Collins 6. Aldrin 7. Moltke 8. Hypatia 9. Delambre
10. Torricelli 11. Lamont 12. Arago 13.Sosigenes 2004.09.20 11:13UT Age 6 days. 10-in f/6+2.5X+ToUcam

Sabine 1.4^0 N 20.1^0 E **Ritter** 2.0^0 N 19.2^0 E

Two adjoining craters near the equator, each about 30 km in diameter and with rough floors. A prominent ridge intersects the southern rim of Sabine. On July 20, 1969 the Apollo 11 Lunar Module landed on the east of Sabine. The landing site is a flat area called ***Statio Tranquillitatis*** (Tranquillity Base). It is truly flat and was chosen by the Apollo mission planners to prevent any obstacle or hazard during final descent. To honor this pioneer expedition, three nearby craters are named after ***Armstrong*** (4.6 km), ***Collins*** (2.4 km) and ***Aldrin*** (3.4 km). Armstrong is the Apollo 11 astronaut who first set his foot on the Moon; Collins and Aldrin are other crew members.

Two linear surface fractures, ***Rimae Hypatia*** (206 km) and ***Rimae Ritter*** (100 km), are located tangential to the edge of Mare Tranquillitatis near Sabine and Ritter.

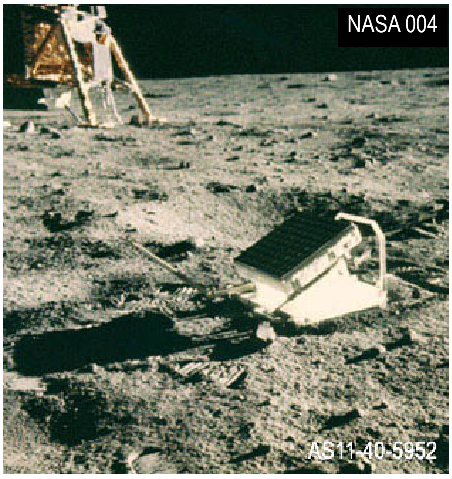
Moltke 0.6^0 S 24.2^0 E
A 6-km crater. Its bright halo makes easier to recognize where Armstrong should be.

Hypatia 4.3^0 S 22.6^0 E
A curiously shaped crater. It measures 28 x 40 km and appears to sit on its own plateau.

Delambre 1.9^0 S 17.5^0 E
A terraced crater, 51 km in diameter, about 3000 m deep.

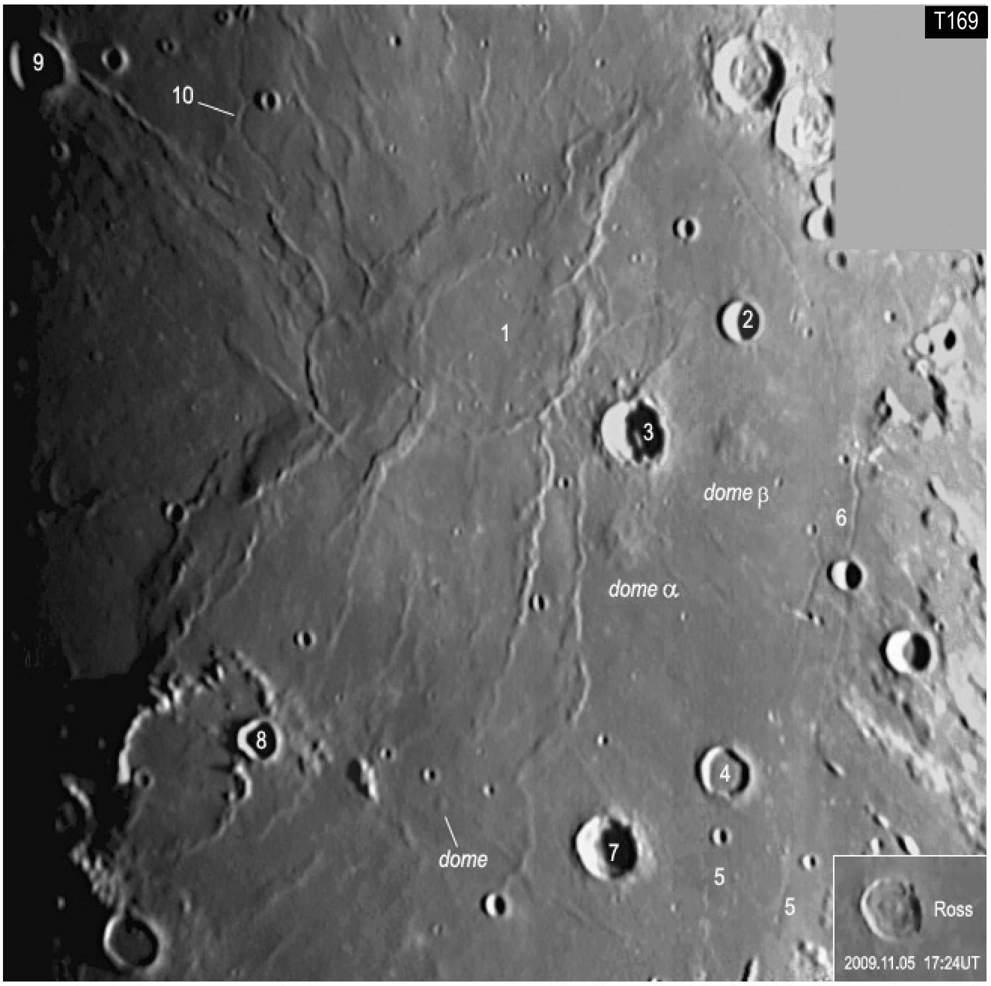
Arago 6.2^0 N 21.4^0 E
A crater with sharp rim and ridged floor, diameter 26 km. Two domes (α, β) and few smaller domes are in the vicinity.

Lamont 4.4^0 N 23.7^0 E
A ghost crater outlined by two concentric wrinkle ridges with a wide pattern of radial arms, diameter 106 km. It contains a mascon. Images from Lunar Orbiters show that the brighter zone around Lamont is full of small impact pits.

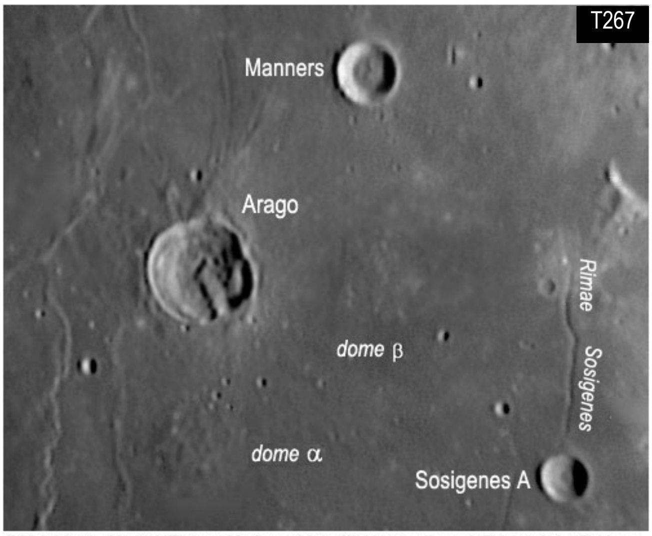


Apollo 11 Landing Module (picture corner) and the Laser Ranging Retro-reflector Array.
The reflector was left by Apollo 11 crew on the landing site, and is still used by the McDonald Observatory in the United States to monitor the precise Earth-Moon distance. A total of three such reflectors were installed on the Moon by Apollo 11, 14 & 15; and two in the unmanned Soviet rovers.

Ross 11.7^0 N 21.7^0 E
A 24-km crater. It should not be confused with ***Rosse*** in Mare Nectaris. (Image T049C)

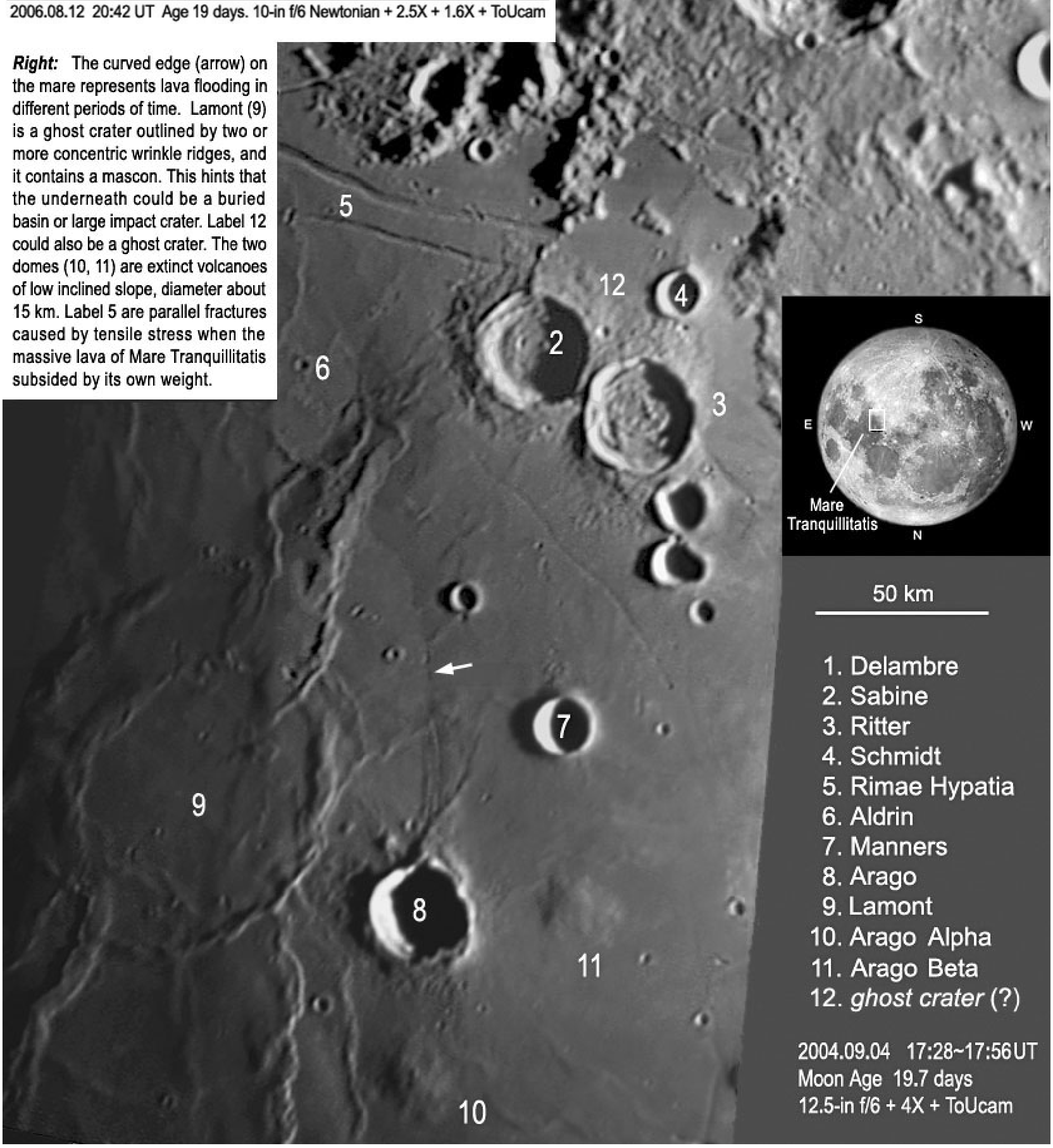


1. Lamont 2. Manners 3. Arago 4. Maclear 5. Rimae Maclear 6. Rimae Sosigenes 7. Ross 8. Carrel 9. Maskelyne 10. Diamondback Rille (*nickname*) 2004.10.03 21:40 UT Age 19 days. 10-in f/6 + 2.5X + ToUcam



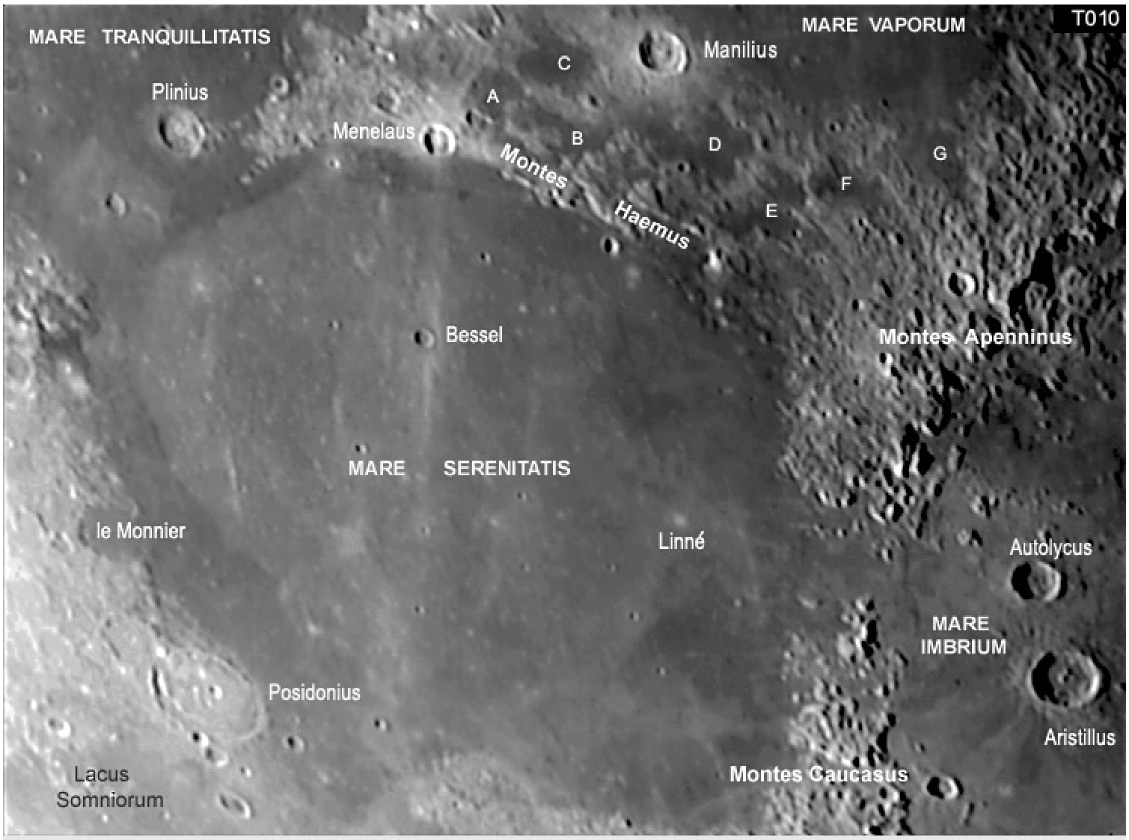
2006.08.12 20:42 UT Age 19 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam

Right: The curved edge (arrow) on the mare represents lava flooding in different periods of time. Lamont (9) is a ghost crater outlined by two or more concentric wrinkle ridges, and it contains a mascon. This hints that the underneath could be a buried basin or large impact crater. Label 12 could also be a ghost crater. The two domes (10, 11) are extinct volcanoes of low inclined slope, diameter about 15 km. Label 5 are parallel fractures caused by tensile stress when the massive lava of Mare Tranquillitatis subsided by its own weight.



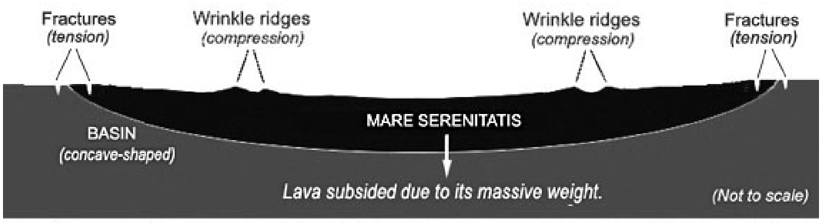
Serpentine Ridge, Plinius, Posidonius, Menelaus, Manilius

Hatfield 1, 3
Rükl 23, 24, 25, 14, 15



Mare Serenitatis 2004.06.26 14:54 UT Age 9 days. 10-in f/6 Newtonian + ToUcam at prime focus, 1/100 sec.
A. Lacus Hiemalis (Winter Lake) B. Lacus Gaudii (Lake of Joy) C. Lacus Lenitatis (Lake of Tenderness) D. Lacus Doloris (Lake of Sorrow) E. Lacus Odii (Lake of Hate) F. Lacus Felicitatis (Lake of Happiness) G. Sinus Fidei (Bay of Faith)

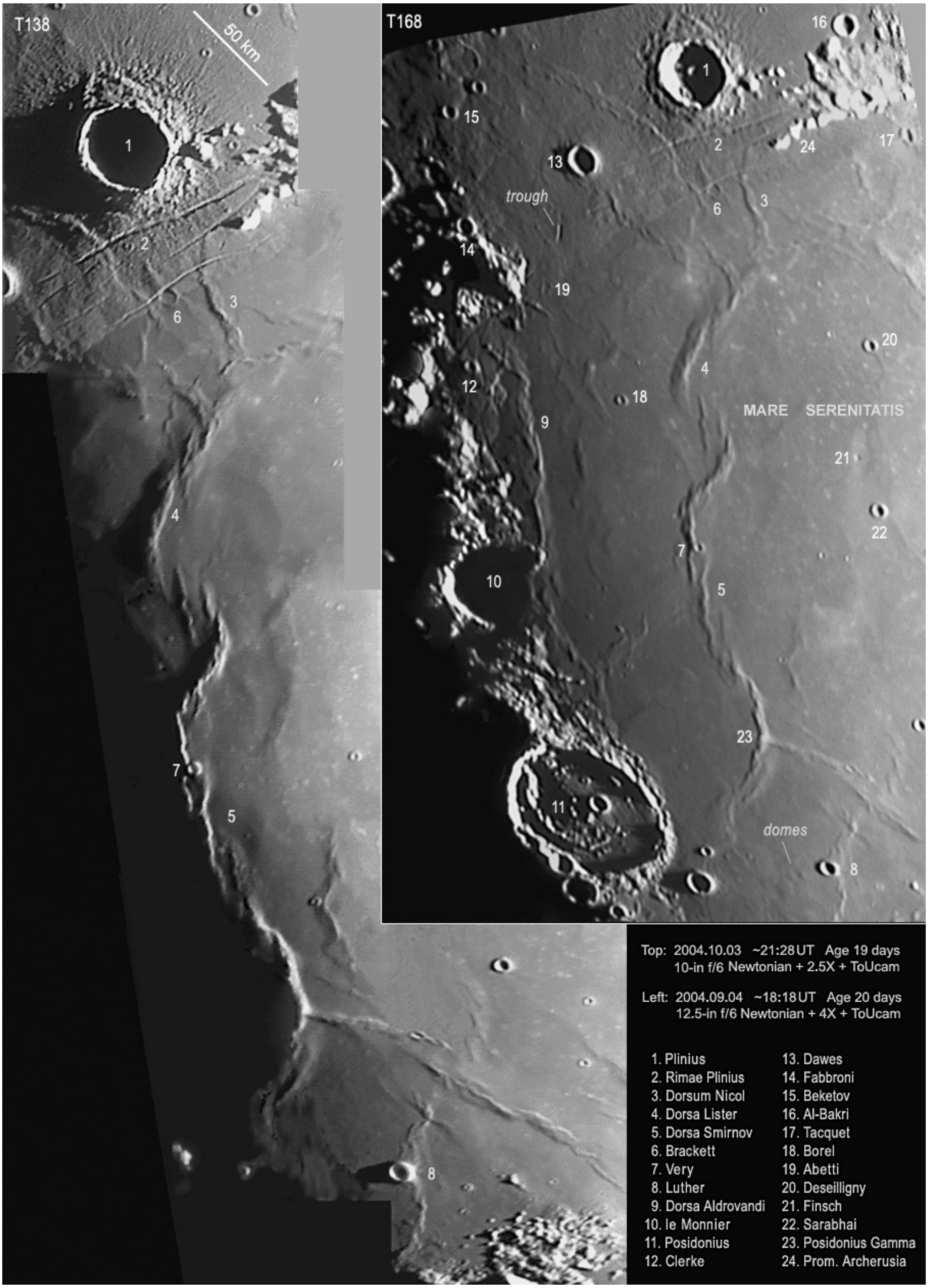
T010 shows the overall view of Mare Serenitatis. It is a vast, near-circular lava plain, size about 500 x 700 km and contains a mascon. The inner collar of the mare looks somewhat darker, suggesting richer in metallic composition (iron, titanium) and earlier in eruption than the central part of the floor. The eastern floor is crossed by ***Serpentine Ridge***, a system of snaky wrinkle ridges which are shown more prominently in next page. Serpentine Ridge is composed of two main sections, Dorsa Lister and Dorsa Smirnov. Each of them is about 10 km wide and meanders quite a long distance. They are surface folds caused by lateral compression during the subsidence of massive lava in the Serenitatis basin. Wrinkle ridges are generally below 200 m in height, so they are distinctive only under very oblique sunlight.

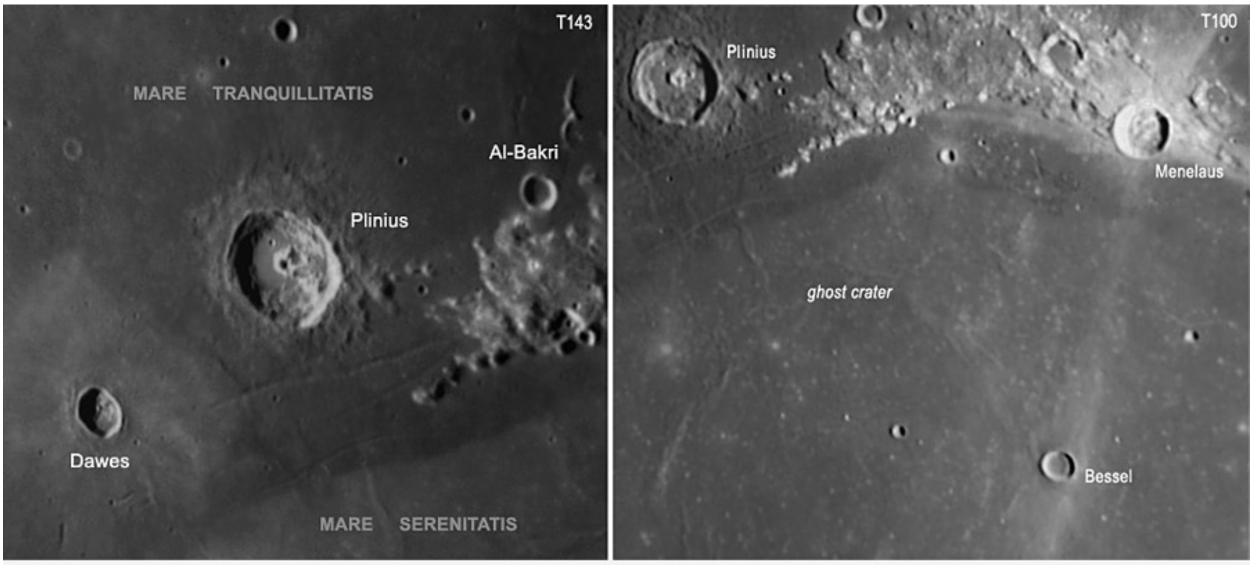


When the massive lava of Mare Serenitatis subsided, wrinkle ridges such as **Serpentine Ridge** formed by lateral compression on the mare surface. Fractures such as **Rimae Plinius** also formed under tension at the basin-mare border.

The southwest edge of Mare Serenitatis is bounded by Montes Haemus. It is part of the rim of the Serenitatis basin. In the vicinity are six irregular lava "lakes", labeled A to F. A channel of mare lava between Montes Apenninus and Montes Caucasus connects Mare Serenitatis with Mare Imbrium.

Image T138 & T168: **Serpentine Ridge** is a former name. Its main body consists of Dorsa Lister and Dorsa Smirnov, total length about 400 km. It is prominent only under low Sun angle. To the south are **Plinius** (43 km) and the intersecting **Rimae Plinius** (124 km). **Very** (5 km) sits on the middle of the ridge.



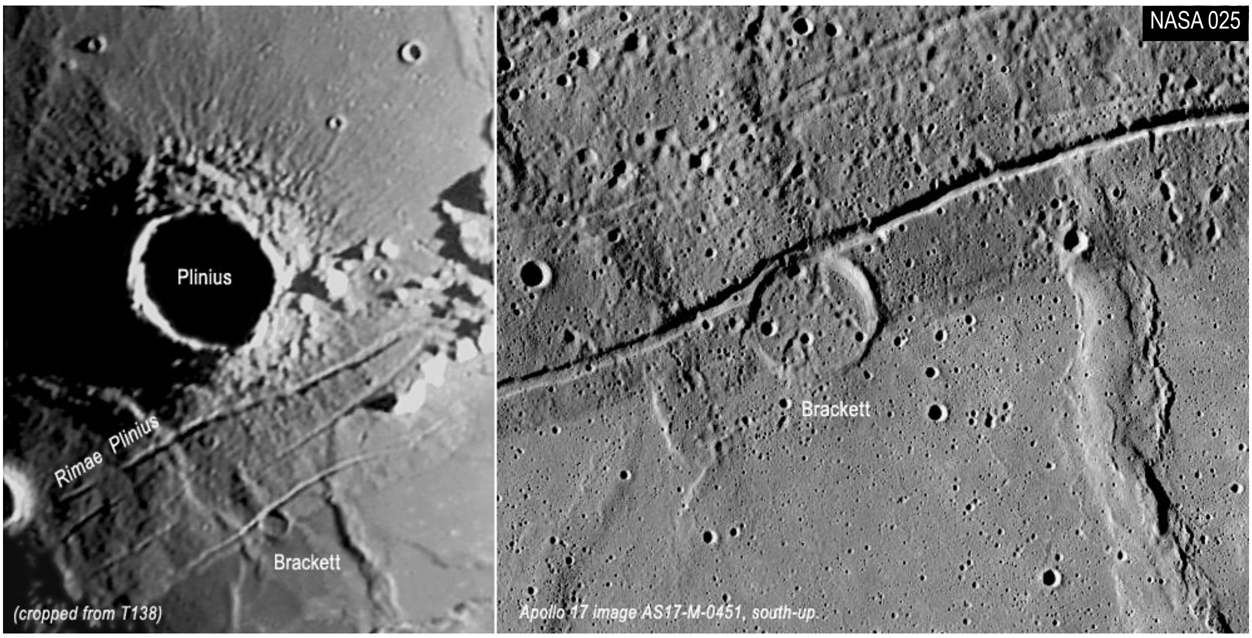


Two views of Plinius Left: 2009.11.24 10:35 UT Age 7.6 days. 10-in f/6 Newtonian + 4X + DMK31AF03 Right: 2006.08.12 19:49 UT Age 18 days. 10-in f/6 Newtonian + 4X + ToUcam

Plinius 15.4^0 N 23.7^0 E
A sharp rimmed crater between Mare Serenitatis and Mare Tranquillitatis, diameter 43 km. Its interior has two crater-like hills with broken slopes. A system of parallel rilles (***Rimae Plinius***, 124 km) lies on the crater north and intersects the wrinkle ridges on the mare. These rilles are grabens formed by tension as the lava sagged towards the center of the Serentitatis basin.

Plinius is a Roman general and naturist, also the author of the encyclopedia "Historia Naturalis". He died in the witness of the massive eruption of Mount Vesuvius, a volcano in Italy that destroyed the City of Pompeii in AD79.

Brackett 17.9^0 N 23.6^0 E
A flooded crater, diameter 8 km. Its southern rim touches a rille of Rimae Plinius. Brackett is visible only under oblique illumination, but it is clearly resolved in the Apollo 17 image. The crater is probably older than Rimae Plinius because the trend of the rille is influenced by the crater rim.



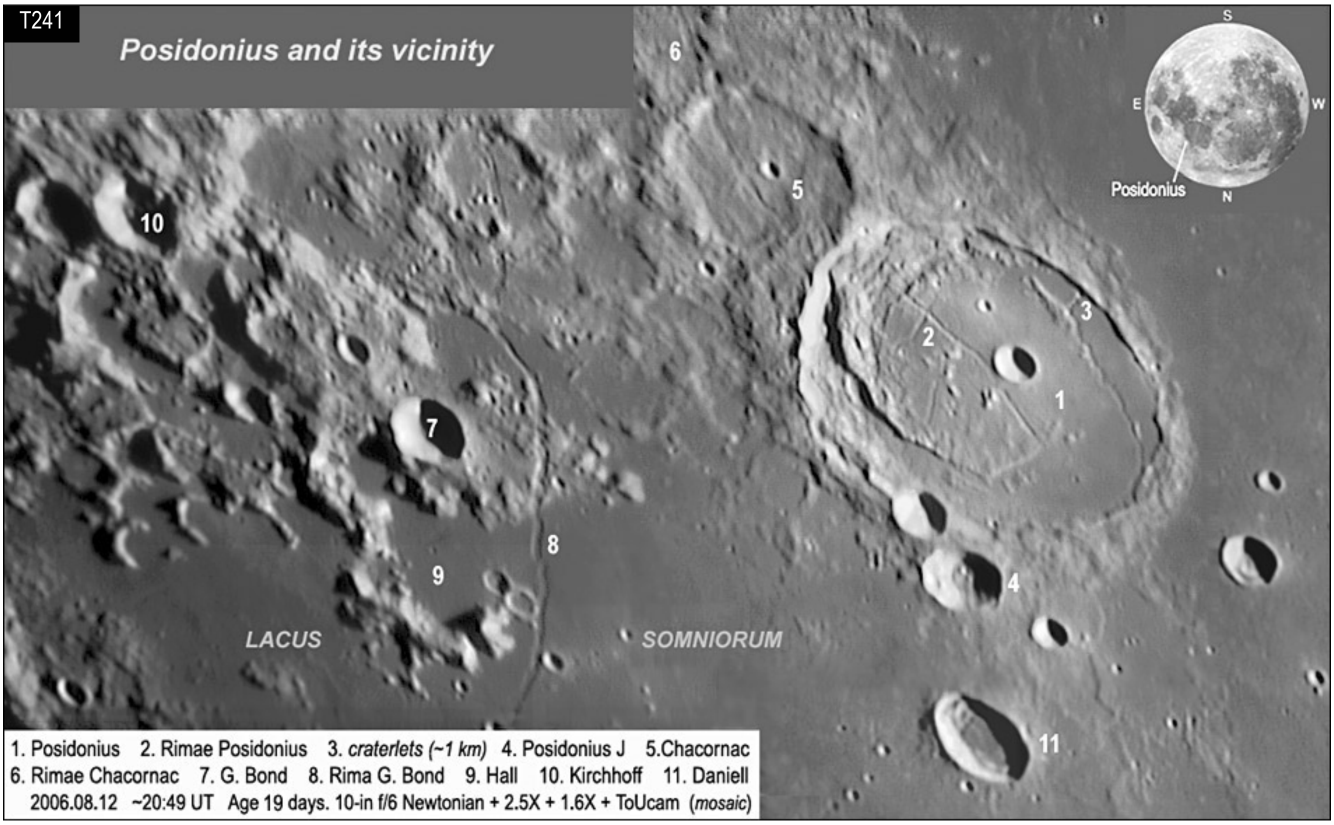
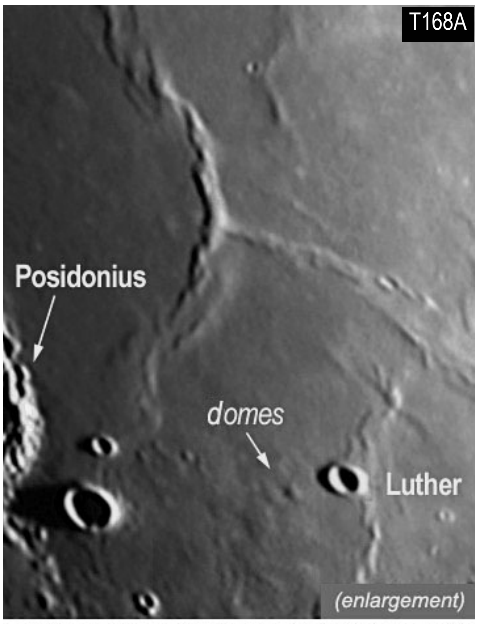


Image T241:

Posidonius 31.8^{0} N 29.9^{0} E A spectacular FFC (floor-fractured crater) at the eastern edge of Mare Serenitatis, diameter 95 km. Its floor is uplifted, which likely produced the internal ***Rimae Posidonius***. There are prominent ridges caused by slippage along the eastern wall. Near first quarter, the crater resembles "a thin pancake" on the dark mare. Label 3 in T241 indicates a short chain of craterlets, barely resolvable in 10-inch telescopes.

In T168A, three small domes are distinguishable between Posidonius and ***Luther*** **(**diameter 9 km).



2004.10.03 21:36 UT Age 19 days. 10-in f/6 Newtonian + 2.5X + ToUcam

Three domes near Luther

Chacornac 29.8^{0} N 31.7^{0} E
A disintegrated crater adjoining Posidonius. It is 51 km in diameter, with hexagonal walls and a small off-center crater. Few rilles (***Rimae Chacornac***) on the floor are visible under high magnifications. Chacornac appears as the little brother of Posidonius.

Rima G. Bond 33.3^{0} N 35.5^{0} E
A graben from Montes Taurus to Lacus Somniorum, length 168 km, width up to 4 km.

Hall 33.7^{0} N 37.0^{0} E
A crescent-like flooded crater, diameter 35 km. Its exposed walls are heavily worn.

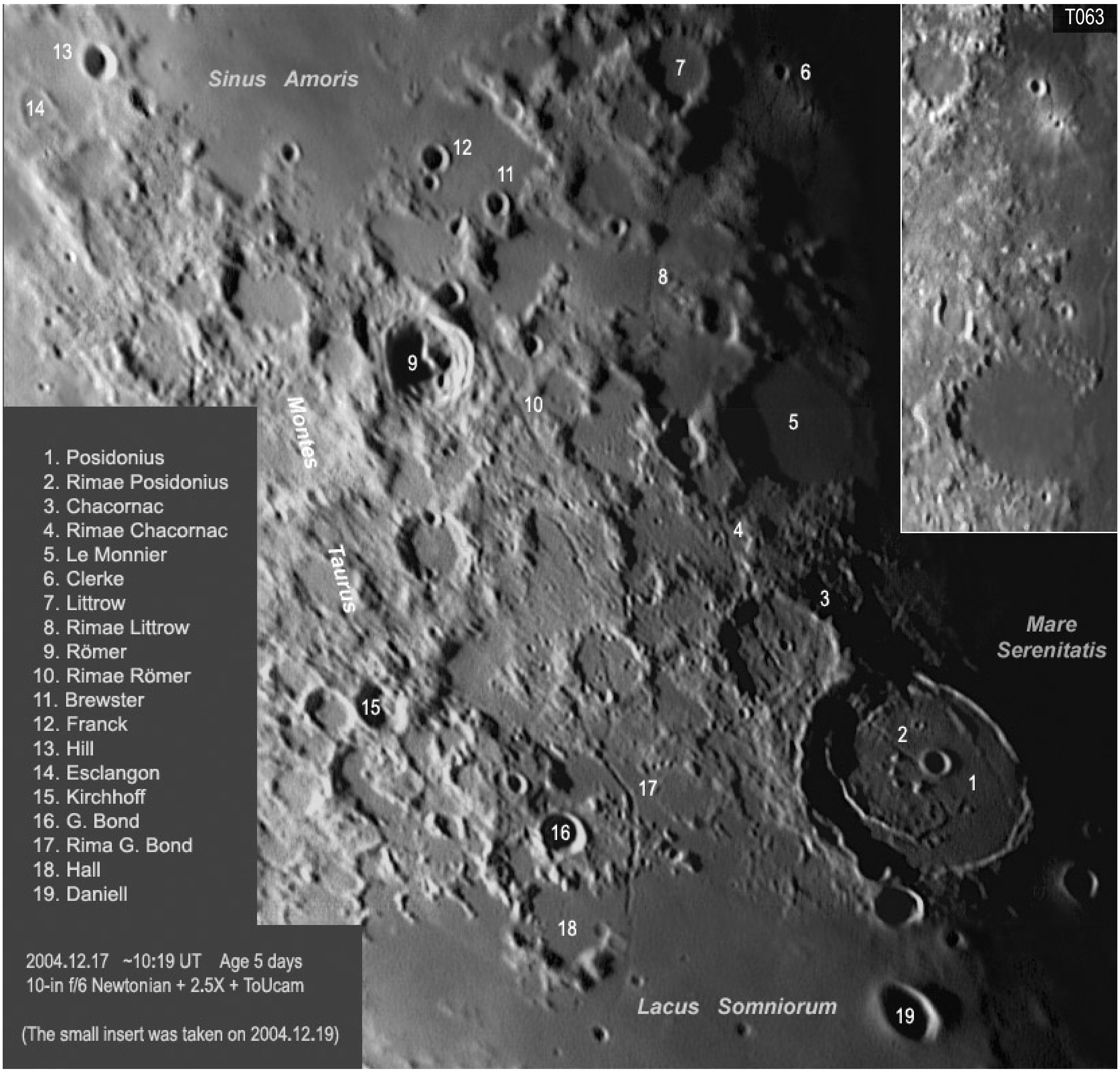


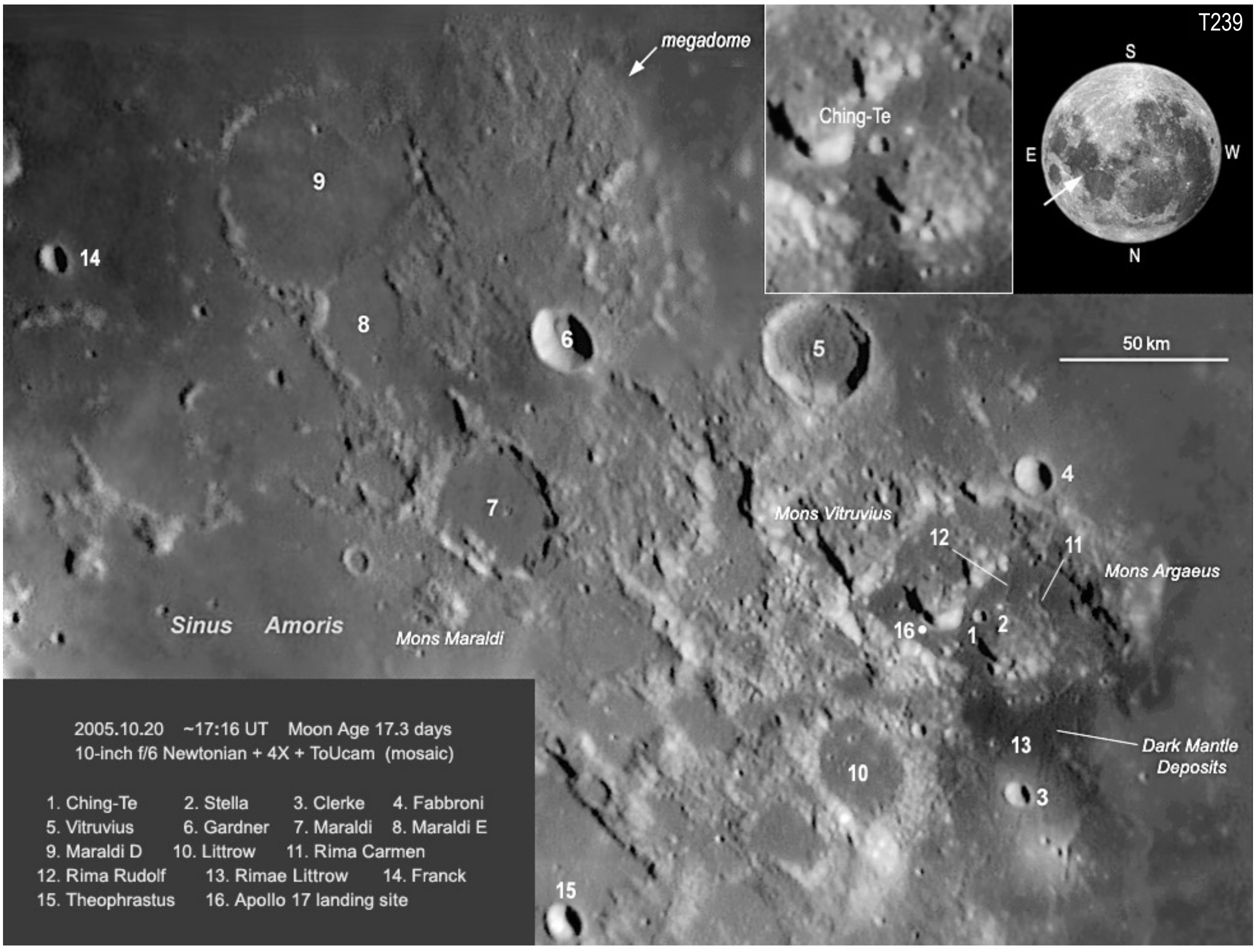
Image T063:

Montes Taurus 28.4^0 N 41.1^0 E
Montes Taurus (Bull Mountains) is in the east of Mare Serenitatis. It rises to 3000 m peak, spanning about 200 km between Sinus Amoris (Bay of Love) and Lacus Somniorum (Lake of Dreams). Its coverage is not well defined. Montes Taurus holds the fairly prominent crater ***Römer,*** the longitudinal rilles ***Rimae Römer*** and part of ***Rima G. Bond***. These rilles rely on low angles of sunlight to be distinctive.

Römer 25.4^0 N 36.4^0 E
A sharp rimmed crater, diameter 39 km. It has terraced walls and a relatively large central peak.

le Monnier 26.6^0 N 30.6^0 E
A bay-like flooded crater opened to Mare Serenitatis, diameter 60 km. Its floor is featureless.

Clerke 21.7^0 N 29.8^0 E
A crater named after Agnes Mary Clerke, a woman astronomer in the 19th Century, diameter 6 km. Note the bright tiny crater-pair close to Clerke (picture insert).



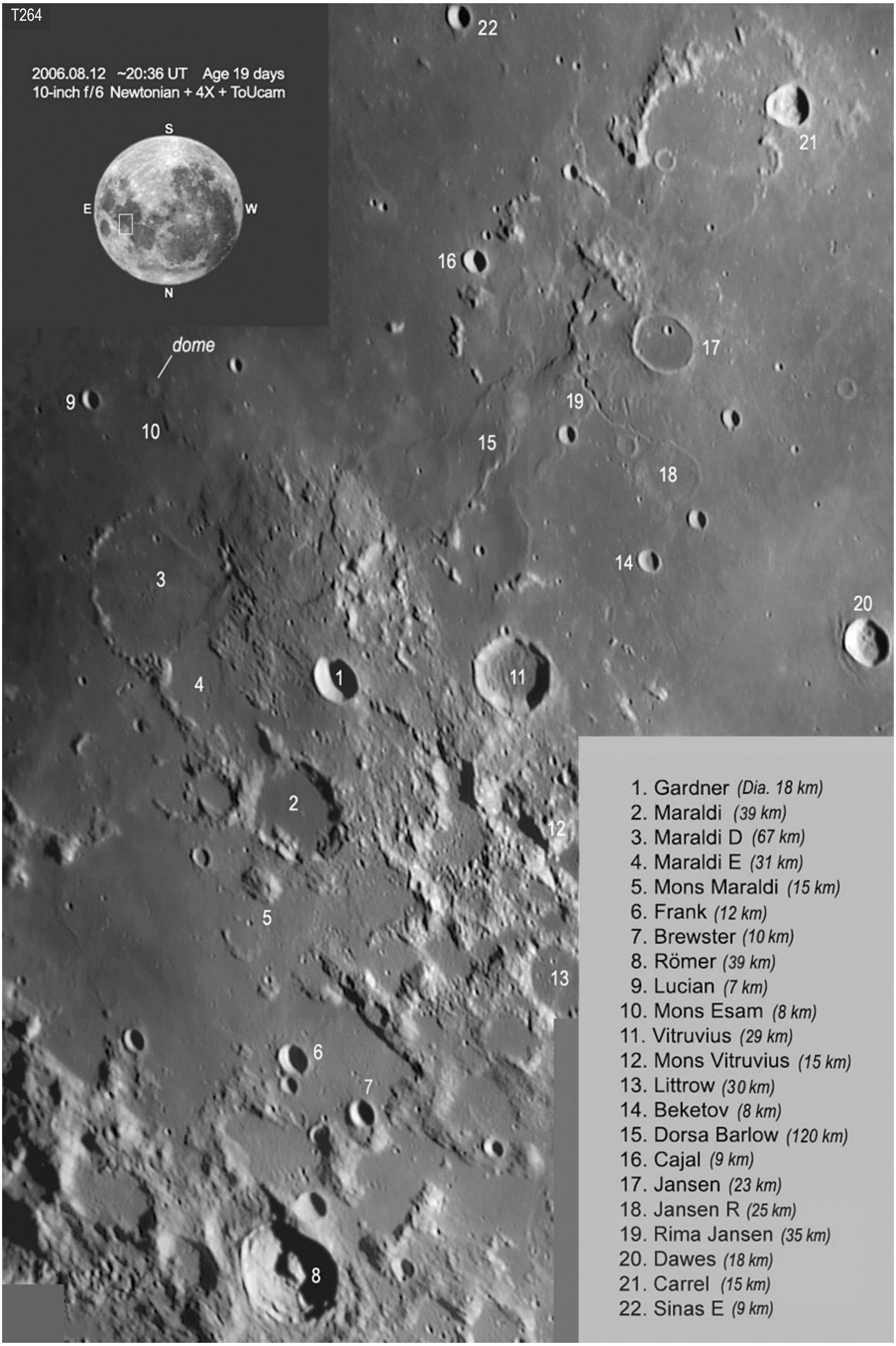
Ching-Te 20.0^0 N 30.0^0 E
Ching-Te (Chinese male name) is a small crater close to Mons Argaeus, diameter 4 km. It is an obscure object for small telescopes and is likely hidden when the Sun angle is not appropriate. The surroundings of Ching-Te are massifs. Apollo 17 landed on the other side of the massifs on December 11, 1972, about 18 km east of Ching-Te.

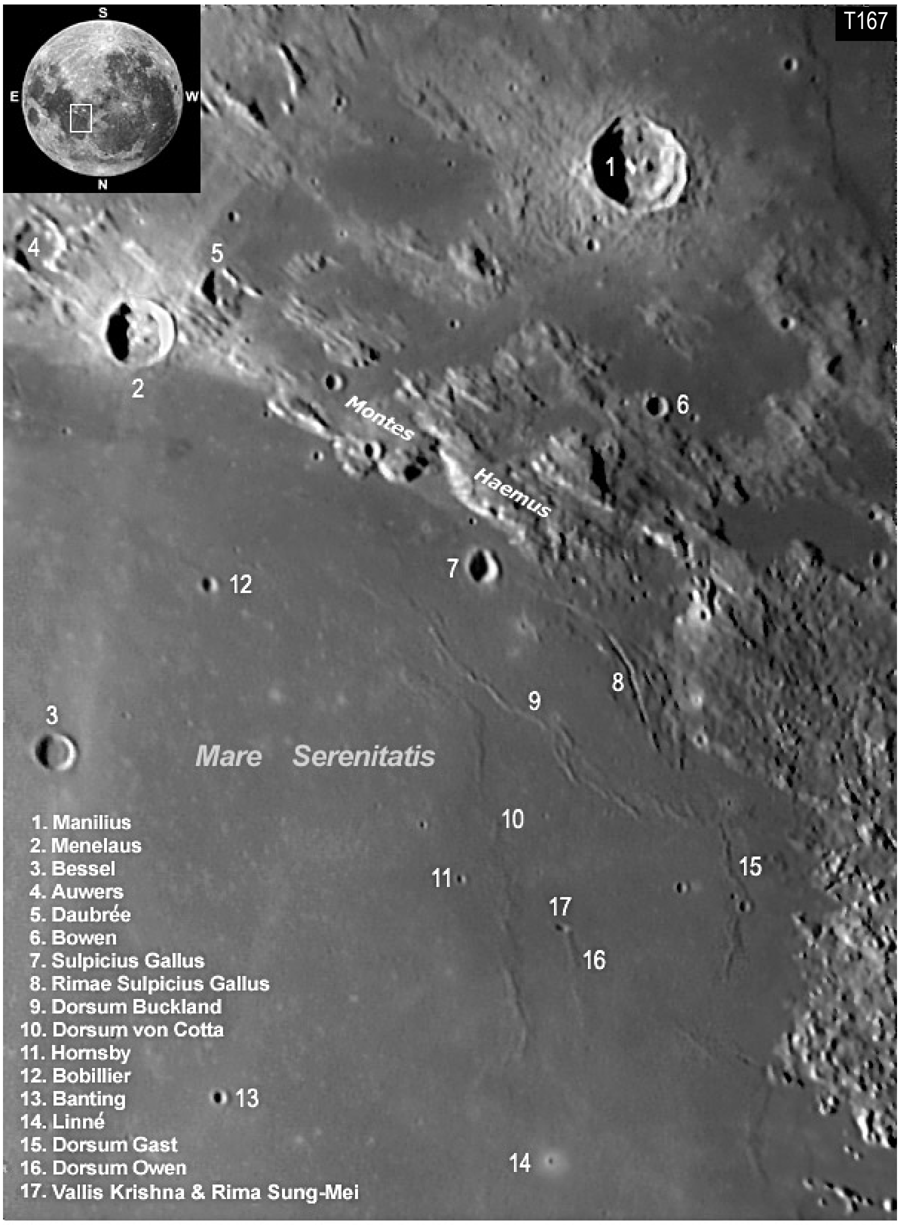
Near Ching-Te is a remarkably dark patch, so called DMD (dark mantle deposit). It is a land of volcanic ashes rich in submillimeter glassy black/orange beads. The Apollo soil samples indicate they are quickly cooled droplets of magma similar to the products of fire fountains in Hawaii. Other DMDs are found in the regions of Rimae Sulpicius Gallus Map 9, Alphonsus Map 12, Mare Vaporum and the Apenninus Map 13, 14, Aristarchus Plateau Map 21 and Doppelmayer Map 24.

Littrow 21.5^0 N 31.4^0 E
A flooded crater with worn walls, diameter 30 km. It has an adjacent system of rilles ***Rimae Littrow.***

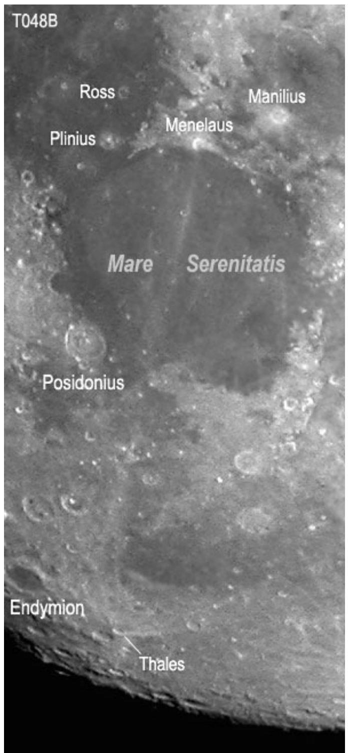
Gardner 17.7^0 N 33.8^0 E
An 18-km crater on a dome-shaped peninsula plateau (informally termed "megadome") where elusive rilles, ridges and irregularities are found. The plateau is flanked by ***Maraldi*** and two ghost craters ***Maraldi D*** & ***E***. T264 in next page shows more details. Note the dome near ***Lucian*** and the snaky ***Rima Jansen*** (*Label 19*) connecting the ghost crater ***Jansen R***.

A volcanic fountain in Hawaii. The arching rises to 10 m, much less energetic than a geologist's impression of lunar volcanic eruption where dark mantle deposits are found. (Imaged by J. D. Griggs, 1983.)


T264
2006.08.12 ~20:36 UT Age 19 days
10-inch f/6 Newtonian + 4X + ToUcam
S
E
W
N
dome
1. Gardner (Dia. 18 km)
2. Maraldi (39 km)
3. Maraldi D (67 km)
4. Maraldi E (31 km)
5. Mons Maraldi (15 km)
6. Frank (12 km)
7. Brewster (10 km)
8. Römer (39 km)
9. Lucian (7 km)
10. Mons Esam (8 km)
11. Vitruvius (29 km)
12. Mons Vitruvius (15 km)
13. Littrow (30 km)
14. Beketov (8 km)
15. Dorsa Barlow (120 km)
16. Cajal (9 km)
17. Jansen (23 km)
18. Jansen R (25 km)
19. Rima Jansen (35 km)
20. Dawes (18 km)
21. Carrel (15 km)
22. Sinas E (9 km)



Manilius, Menelaus & Bessel 2005.11.09 11:45 UT Age 7 days. 10-in f/6 Newtonian + 2.5X + ToUcam (*mosaic*)



Rays of Menelaus sweeping Mare Serenitatis and beyound 2003.09.11 16:11 UT Age 15 days

Image T167:

Montes Haemus 19.9^0 N 9.2^0 E
A 560 km-long mountain range forming the southwest rim of the Serenitatis basin. It rises to 2.4 km peak. Several small "lakes" lie along the southwest face of the range. See also T247.

Menelaus 16.3^0 N 16.0^0 E
A remarkably bright rayed crater. It has sharp rim and central peaks, diameter 26 km. One of its rays extends into Mare Serenitatis and beyond. Other rays are traceable from the outer rim of the crater, between ***Auwers*** and ***Daubrée*** (Label 4, 5 in T167).

Bessel 21.8^0 N 17.9^0 E
A small but prominent crater in Mare Serenitatis, diameter 15 km. The bright rays of Menelaus happen to pass over the western half of Bessel, making the latter to mimic a rayed crater.

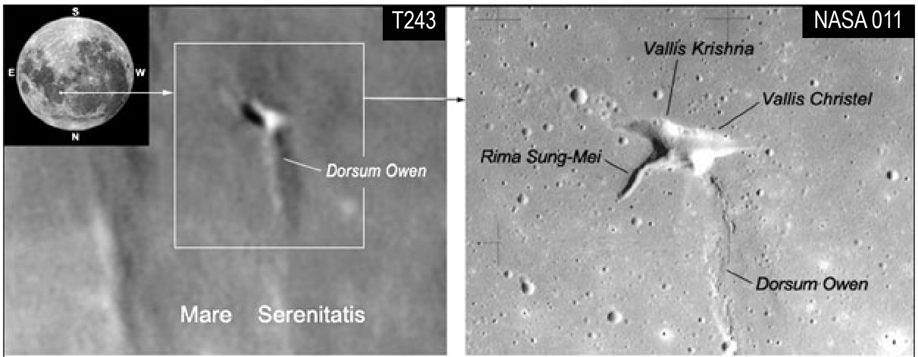
Rimae Sulpicius Gallus 21.0^0 N 10.0^0 E
A system of fractures running through a region of DMD (dark mantle deposit), length 90 km.

Linné 27.7^0 N 11.8^0 E

A small young crater surrounded by bright ejecta. Linné is only 2.4 km or one arcsecond in diameter, yet it is easily recognized through telescopes as a bright spot under high illumination. In the second half of the 19^{th} century, many weird changes of Linné were reported; they were controversial and could be illusions from seeing and inadequate telescope optics.

Rima Sung-Mei 24.6^0 N 11.3^0 E

Rima Sung-Mei is a 4-km long narrow rille. It is one of the three prongs in a small depression near Dorsum Owen at Mare Serenitatis. The prongs are elusive to spot in 10-inch telescope. In the Apollo-15 flyover image, they are named as ***Rima Sung-Mei***, ***Vallis Krishna*** and ***Vallis Christel***. The prongs could have formed from merging three or more volcanic vents on the mare.



Cropped & 200% resized from an image 2005.11.09 12:35 UT taken with 10-in f/6 Newtonian + 4X + ToUcam.

Cropped from Apollo 15 image AS15-M-0407

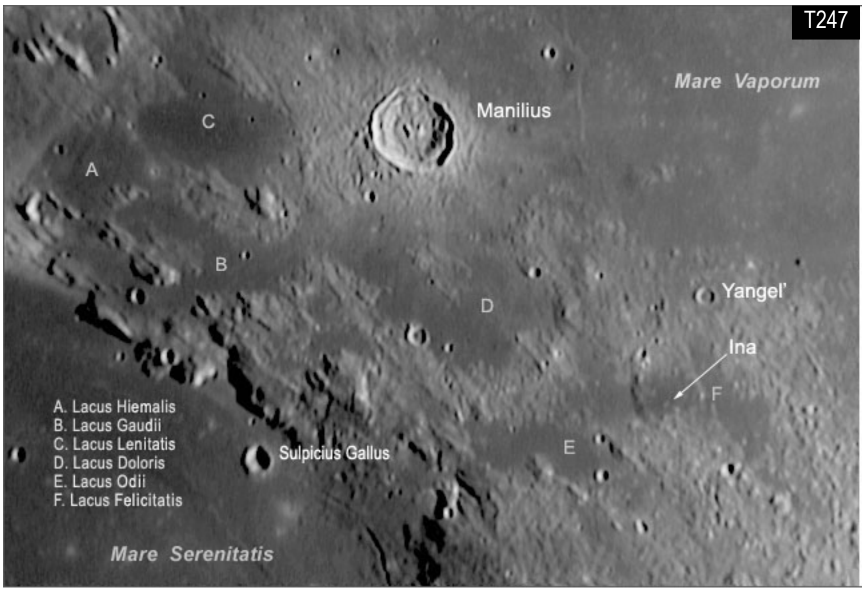
Image T247:

Manilius 14.5^0 N 9.1^0 E

A rayed crater with sharp rim, terraced walls and dual central peaks, diameter 38 km.

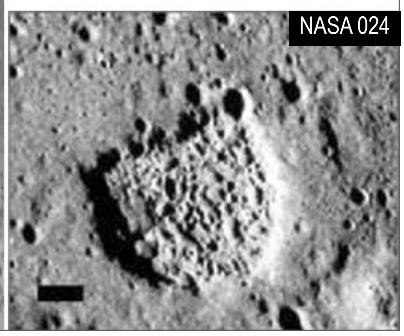
Lacus Felicitatis (Lake of Happiness) 19.0^0 N 5.0^0 E

An irregular lava plain where scientists (*Schultz, Staid and Pieters, 2006*) found evidence for volcanic outgassing that may have happened within the past ten million years ----- and may still be happening today. The evidence was spotted inside ***Ina*** at the rim of Felicitatis. Ina is too small in amateur telescopes, but in the Apollo 15 image it is resolved into a caldera which has many bulbous structures on the floor.



Left: The lava "lakes" near Manilius 2004.10.03 21:00 UT Age 19 days. 10-in f/6 Newtonian + 2.5X + ToUcam

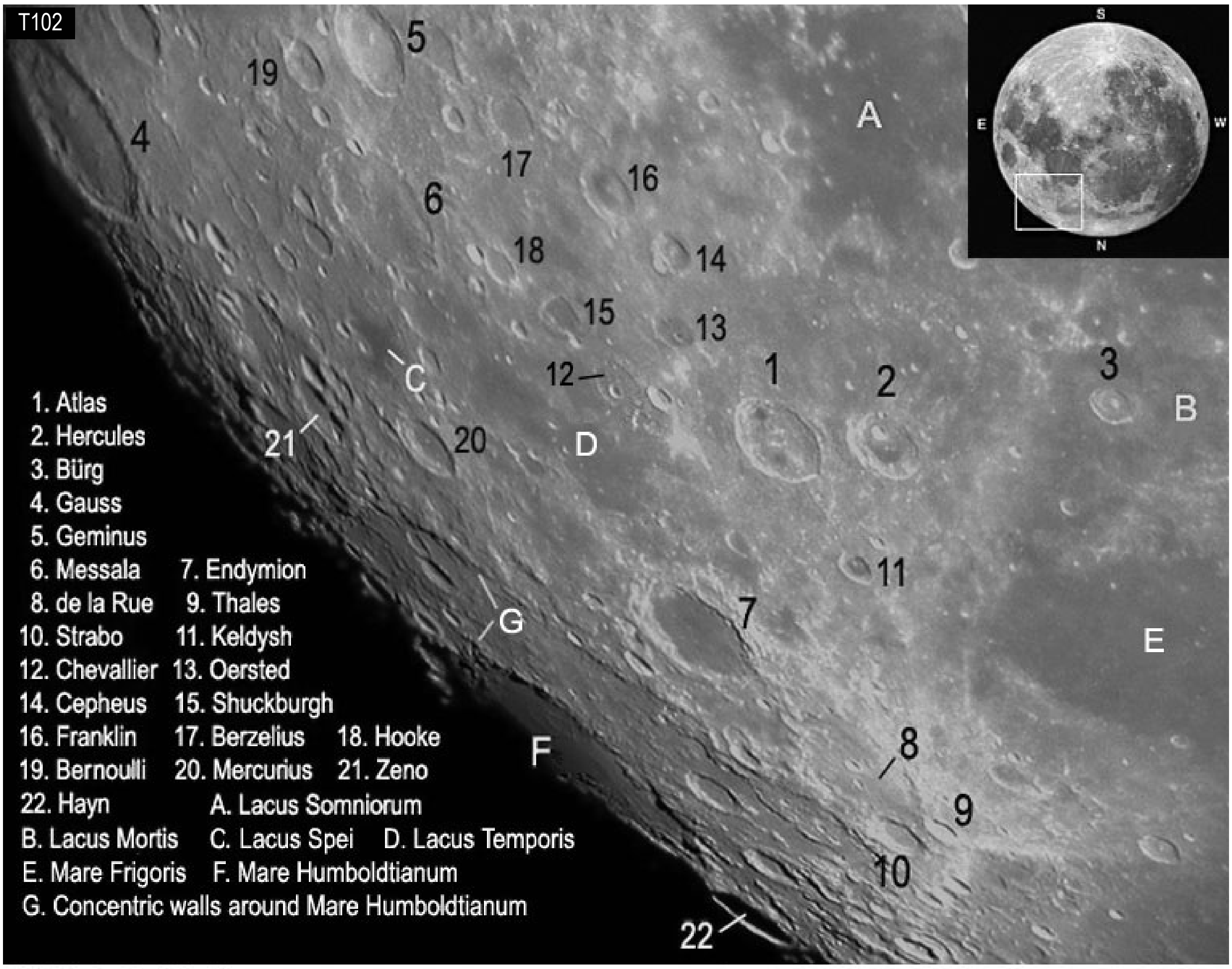
Below: Image of Ina taken in orbit during the Apollo 15 mission, south-up. Ina is a young crater located at 18.6° N 5.3° E, about 3 km in diameter and 50 m deep. *Source: http://www.psrd.hawaii.edu/Nov06/MoonGas.html*



MAP 10

Hatfield 4
Rükl 14, 15, 16, 7, 6

Atlas, Hercules, Bürg, Endymion, Mare Humboldtianum



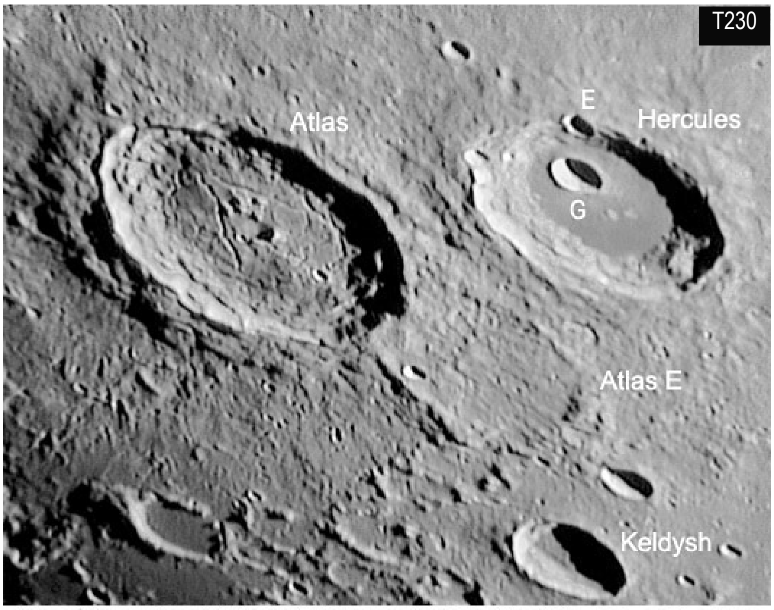
NE limb & vicinity 2004.08.01 14:22 UT Age 15 days. Libration 4.9° (long.) 6.9° (lat.) FS128 + LE12.5 + CP990 at 1/38 sec.

Atlas 46.7° N 44.4° E
Hercules 46.7° N 39.1° E

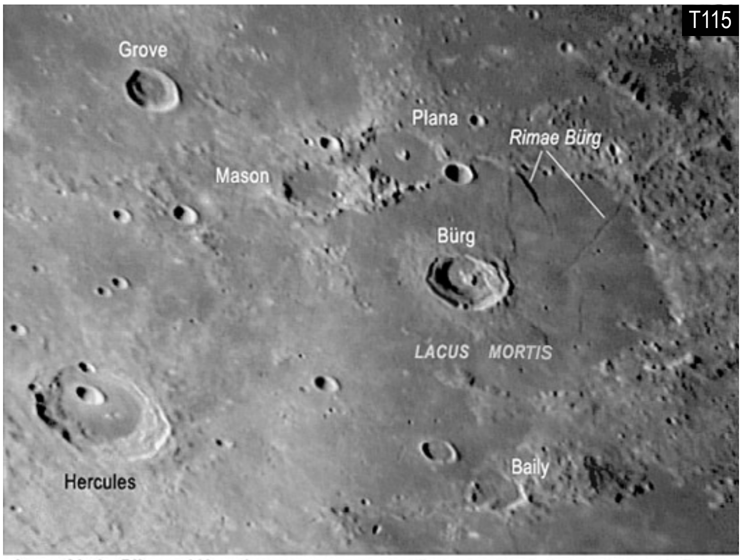
Atlas is a typical example of ‘floor-fractured crater’. By contrast, Hercules is not. They form a fine pair on the Moon’s north-west limb.

Atlas is 87 km in diameter, with a small central peak and terraced walls rising to about 3000 m. Its rough floor contains two fairly dark patches and a complex of rilles (***Rimae Atlas***) which are presumably of volcanic origin.

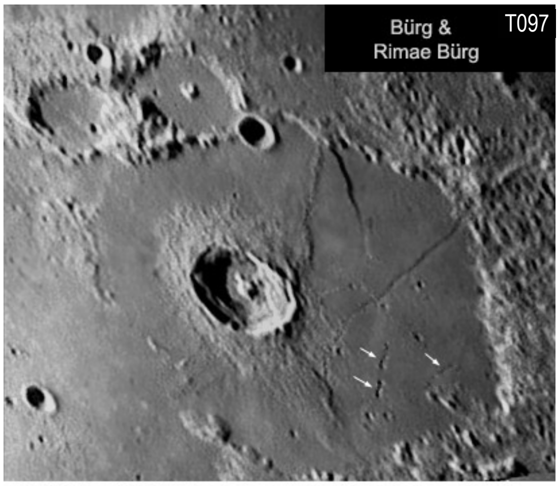
Hercules is a terraced crater with flat floor, diameter 69 km. It has a lava-submerged central peak and contains the bowl-shaped ***Hercules G***. A small crater, ***Hercules E***, hits the rim.



Atlas & Hercules 2005.08.22 19:34 UT Age 17.5 days. 10-in f/6 Newtonian + 4X + ToUcam



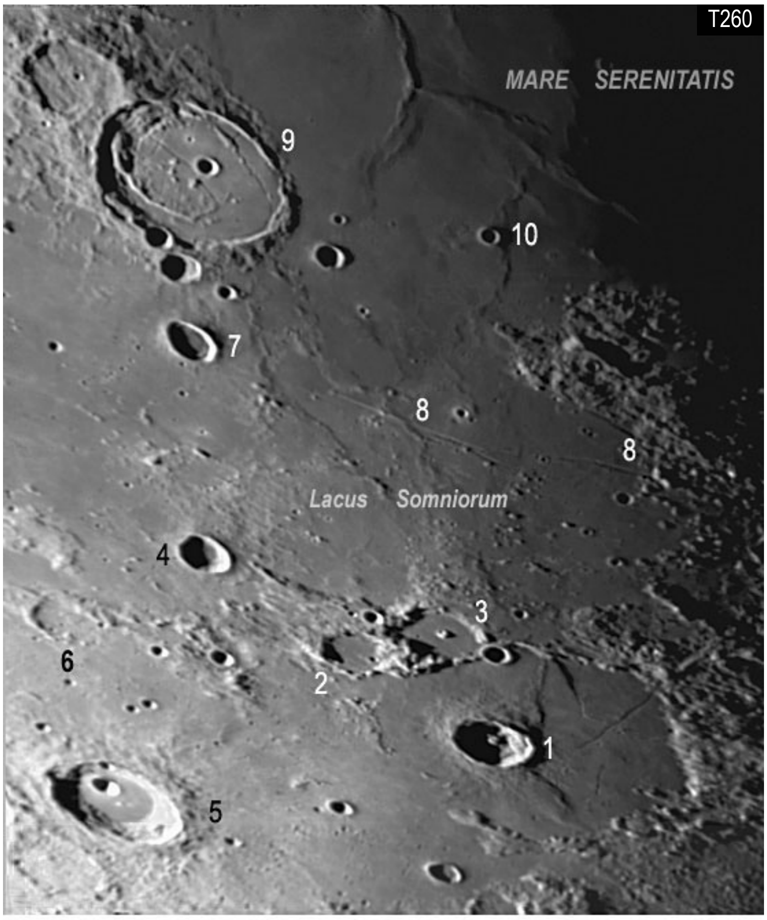
Lacus Moris, Bürg and Hercules 2009.05.02 14:08 UT Age 7 days. 10-in f/6 Newtonian + 2.5X + ToUcam



2005.11.08 ~11:30 UT Age 6 days. 10-inch f/6 Newtonian + 4X + ToUcam
The arrows indicate elusive chains of overlapped craterlets.

Bürg 45.0^0 N 28.2^0 E
Bürg is a sharp-rimmed young crater from the Copernican period, 39 km in diameter, 2200 m deep. It sits inside ***Lacus Mortis*** (Lake of Death) whose predecessor is a much larger crater. Bürg has a large central peak and terraced walls with deep clefts. Its ejecta is partially spilt into two ridges heading north and south from the impact zone. Between these ridges are two segments of rilles (***Rimae Bürg***) that intersect roughly at right angles. The southward segment resembles a fault while the other segment is more like a surface fracture. This is a strange pair lack of adequate explanation. In Lunar Orbiter images, few minor rilles and chains of overlapped craterlets are found to the northwest of Bürg.

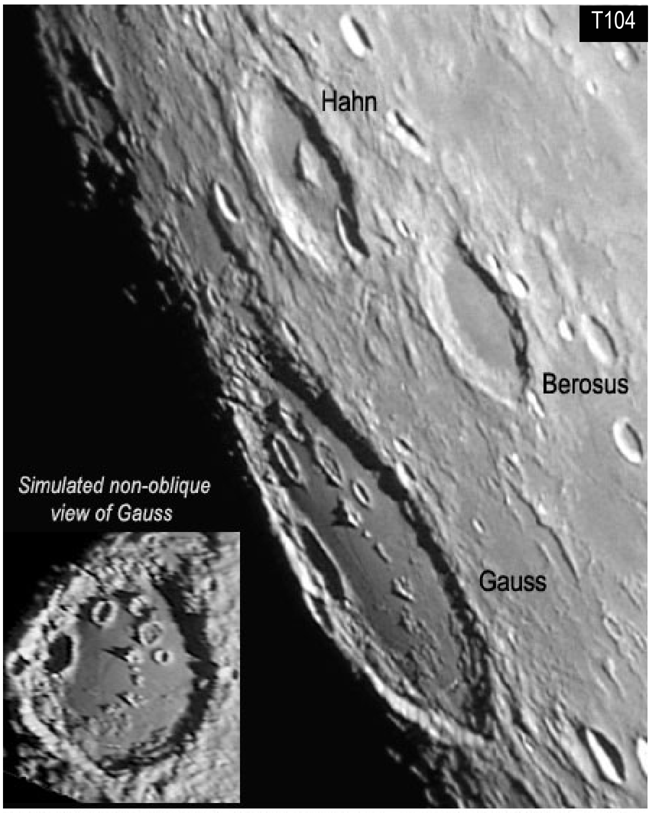
Mason 42.6^0 N 30.5^0 E
Plana 42.2^0 N 28.2^0 E
Manson and Plana are overlapped flooded craters. Mason is 33 X 43 km. Plana is 44 km in diameter with a central peak.



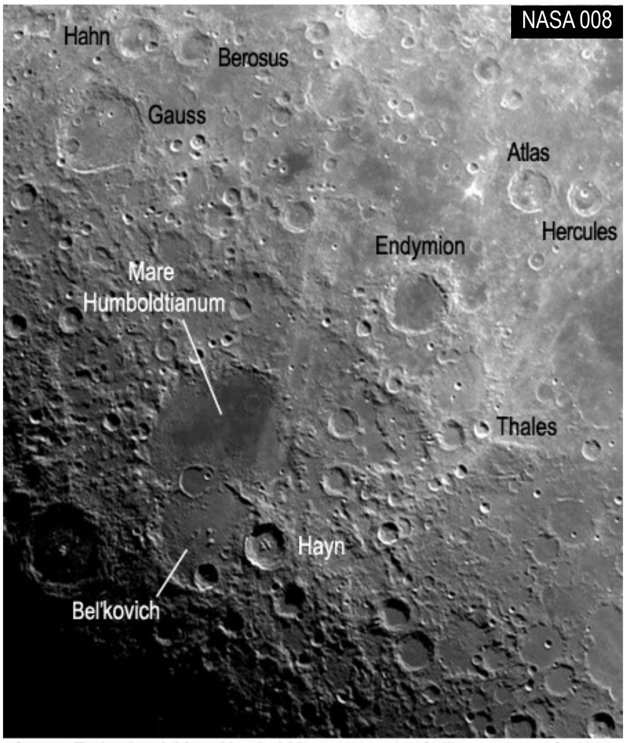
1. Bürg 2. Mason 3. Plana 4. Grove 5. Hercules 6. Williams 7. Daniell 8. Rimae Daniell 9. Posidonius 10. Luther 2006.04.04 11:46 UT Age 6 days. 10-in f/6 + 2.5X + ToUcam (mosaic)

Grove 40.3^0 N 32.9^0 E
A 28-km crater, 2400 m deep. Its inner walls slumped down like a thin ring on the floor.

Daniell 35.3^0 N 31.1^0 E
An oval crater, 23 X 29 km. To the west is ***Rimae Daniell***, a system of rilles 200 km in length. See also Map 9.



Gauss & vicinity 2004.08.01 17:12 UT Age 15 days. 10-in f/6 + 2.5X + ToUcam, 4 frames.



Gauss, Endymion & Mare Humboldtianum seen by Galileo spacecraft, 1992

Gauss 35.7^0 N 79.0^0 E
A vast walled plain, diameter 177 km. Its floor contains small hills and craters which become distinctive under favorable illumination. The largest crater at the inner wall is ***Gauss B*** (37 km).

Hahn 31.3^0 N 73.6^0 E
A mid-sized crater with terraced walls and central peak, diameter 84 km. Its northern rim is interrupted by a small crater.

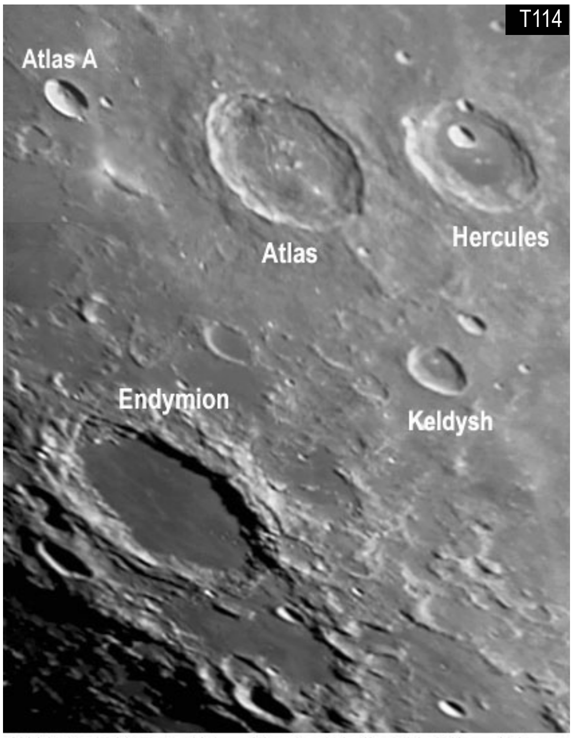
Berosus 33.5^0 N 69.9^0 E
A flooded crater, diameter 74 km. Its flat floor is featureless.

Image T114:

Endymion 53.9^0 N 57.0^0 E
A very prominent crater from the Nectarian period, 123 km in diameter, 2800 m deep. It has smooth, flooded dark floor and fairly slumping walls.

Keldysh 51.2^0 N 43.6^0 E
A crater, diameter 33 km. Its southern floor contains a tiny crater.

Atlas A 45.3^0 N 49.6^0 E
A small satellite crater of Atlas, fairly deep, diameter 22 km. Its rim is interrupted by a sharp craterlet.

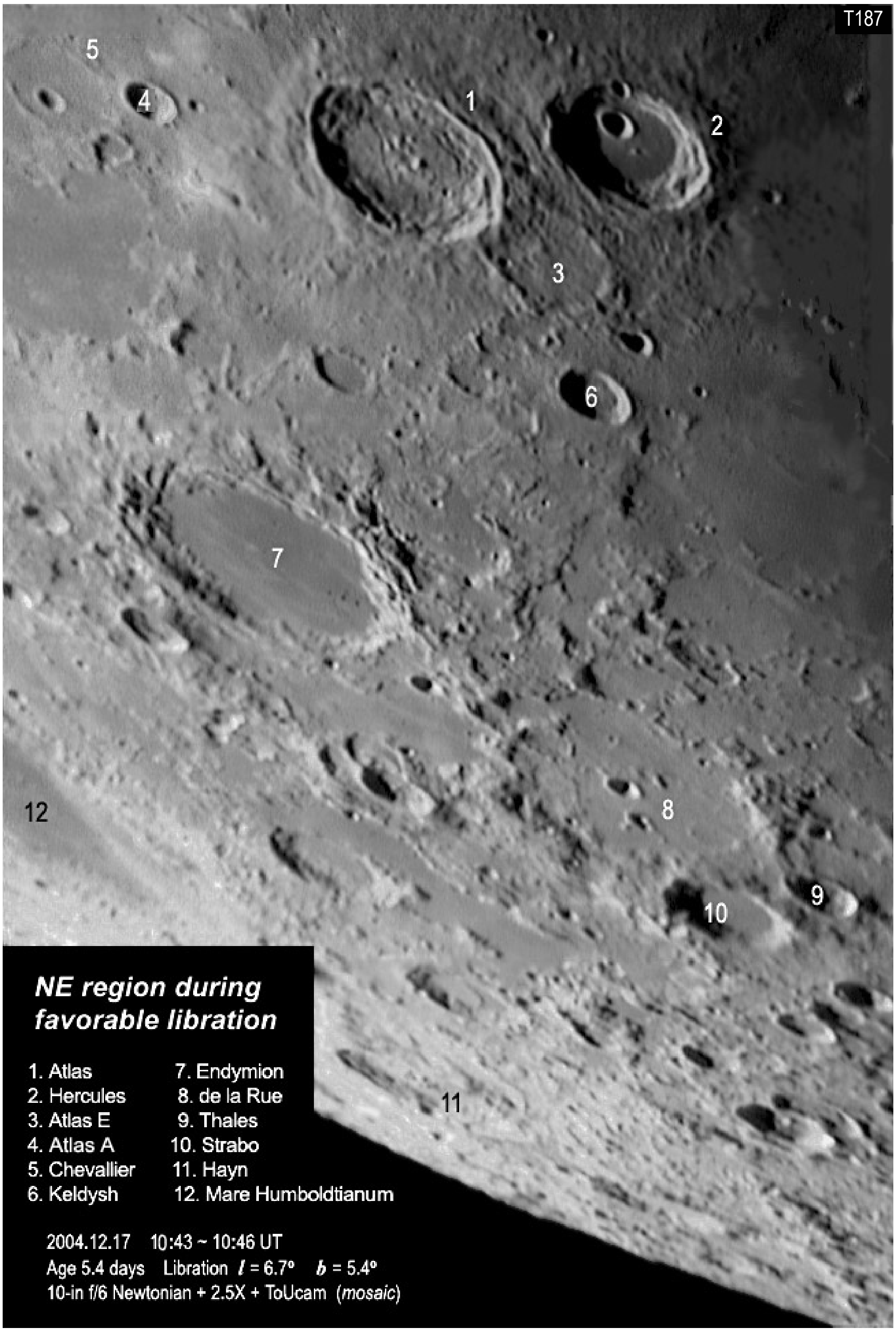


2004.08.02 17:24 UT Age 16 days. Misty sky. 10-in f/6 + 2.5X + ToUcam, 12 frames.

Chevallier 44.9^0 N 51.2^0 E
A heavily flooded walled plain, diameter 52 km. Its floor contains a small deep crater.

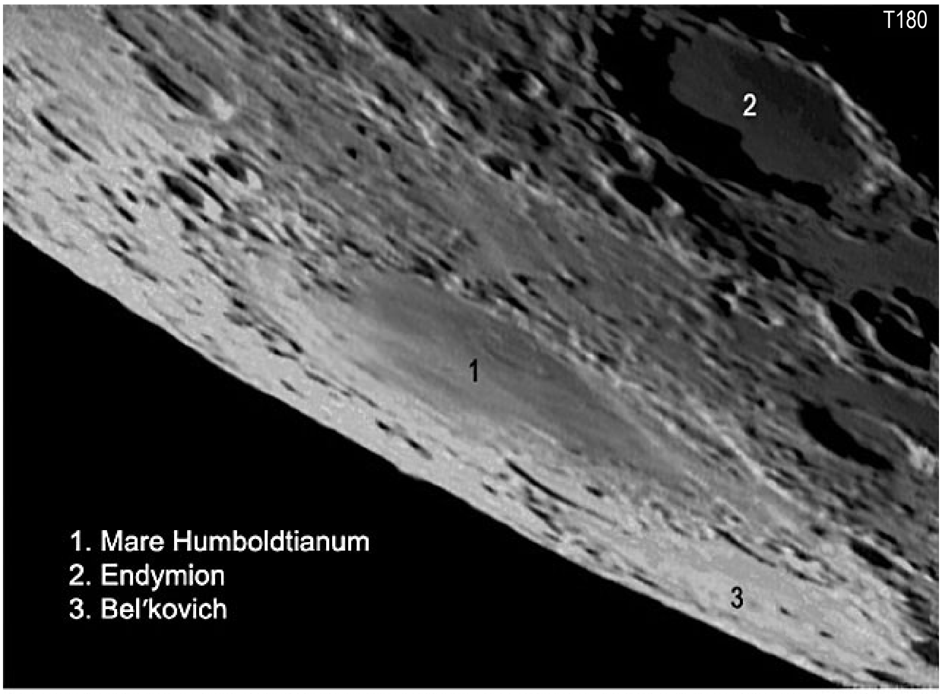
de la Rue 59.1^0 N 52.3^0 E
A disintegrated walled plain with small off-centered craters, diameter 134 km. It is named after the British amateur astronomer Warren de la Rue (1815-89). He was the first to produce a copper plate for printing from a photographic negative of the Moon.

Thales 61.8^0 N 50.3^0 E **Strabo** 61.9^0 N 54.3^0 E
Thales is a rayed crater, diameter 31 km. The neighboring Strabo (55 km) is non-rayed.

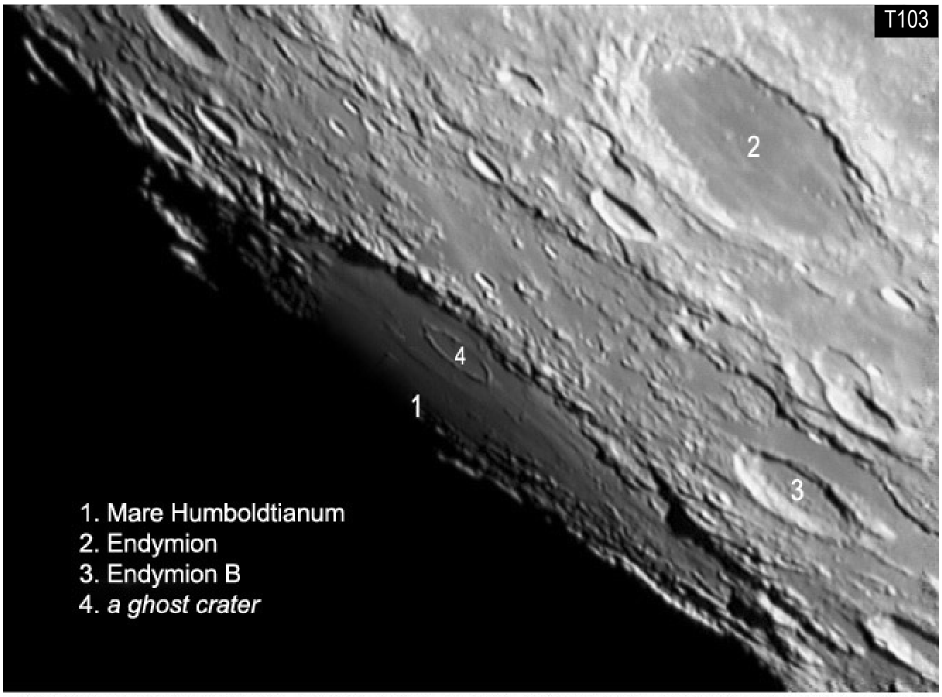


Mare Humboldtianum 56.8^{0} N 81.5^{0} E

Mare Humboldtianum (Humboldt's Sea) is a difficult visual object because its edge extends to the farside of the Moon. A better terrestial view is given below, when the libration was favorable. Mare Humboldtianum is the central lava-flooded portion of a multi-ring impact basin. The lava floor is 270 km in diameter, but the whole basin including the outer rings is 600 km across. Two rings of the basin are recognized in the non-oblique view of Mare Humboldtianum (NASA image in previous page), also seen partially in T180 and T103.



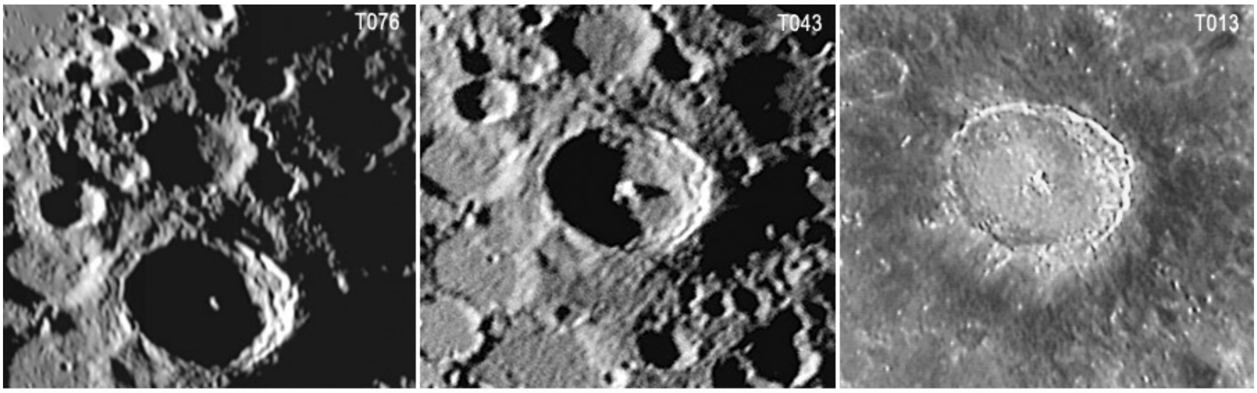
Mare Humboldtianum 2004.12.15 19:13 UT Age 3.4 days. Libration $l = 4.9°$ $b = 6.3°$. 10-in f/6 Newtonian + 2.5X + ToUcam



2004.08.01 16:50 UT Age 15 days. Libration $l = 4.9°$ $b = 6.9°$. 10-in f/6 + 2.5X + ToUcam at 1/100s, 9 frames stacked.

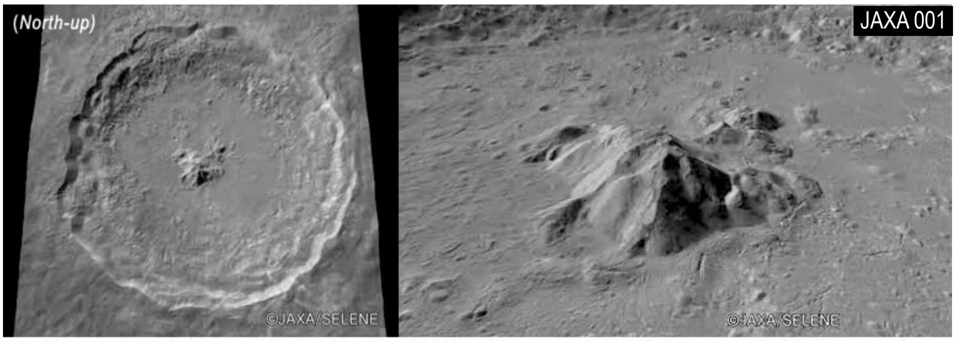
Tycho, Clavius, Maginus, Deslandres, Pitatus, Hesiodus

1. Tycho 2. Magnius 3. Clavius 4. Blancanus 5. Scheiner 6. Deslandres 7. Pitatus 8. Walther 9. Regiomontanus 10. Purbach 11. Aliacensis 12. Werner 13. Sacrobosco 14. Maurolycus 15. Stöfler 16. Wilhelm 17. Longomontanus 18. Moretus 19. Newton 2010.07.01 20:57UT Age 19.4 days. Tak FS128 refractor+Canon 550D at ISO200 1/400s

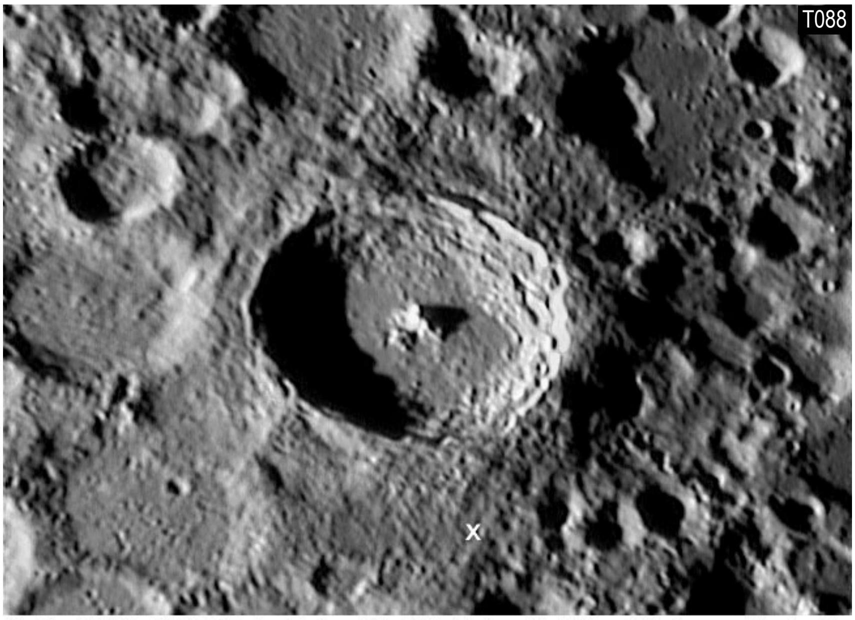


3 views of Tycho 2004.06.26 13:53 UT Age 9 days. 2004.06.27 13:37 UT Age 10 days. 2003.03.17 16:49 UT Age 14 days. 10-in f/6 + 2.5X + ToUcam

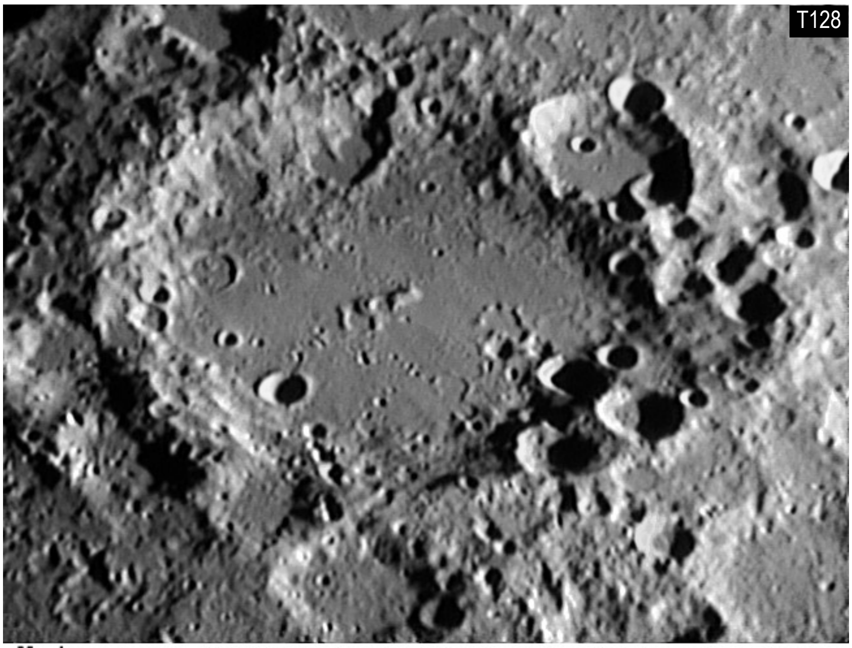
Tycho 43.4^0 S 11.1^0 W
Tycho is a prominent object in the Southern Highlands. It has a nominal diameter of 102 km (cavity 85 km), depth 4600 m. The central peak is 2300 m high. During the full moon, Tycho stands out as the brightest beacon with a system of long rays ranging to 1800 km. It is this system of rays that shows Tycho is a very young impact crater, about 110 million years old. Shortly after the first quarter, Tycho appears as an abyss surrounded by thick walls (T076). The dark halo around Tycho is more prominent at the full moon (T013); it is composed of impact melt, which will be diminished by space weathering over time.



Tycho Imaged by the Japan's Selene lunar probe in Feb 2008 (http://wms.selene.jaxa.jp/selene_viewer/en/observation_mission/tc/tc_012.html)



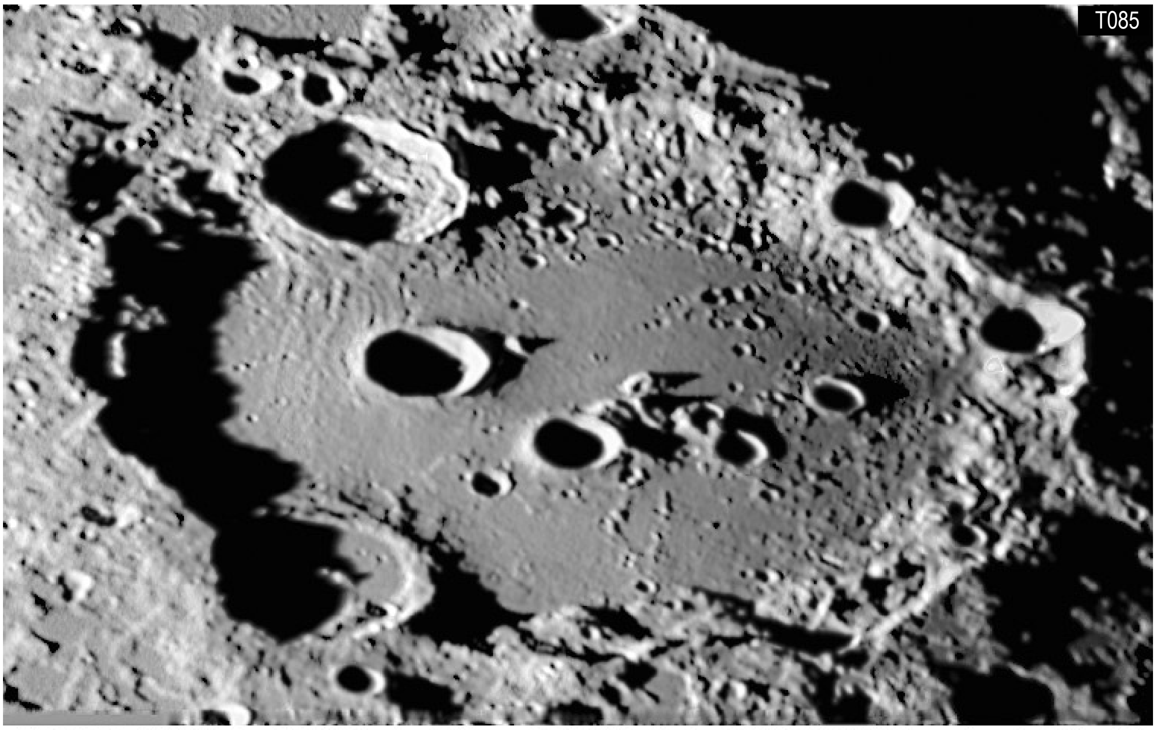
Tycho 2005.04.18 14:56 UT Age 10 days. 10-in f/6 Newtonian + 4X + ToUcam. X is Surveyor 7 landing site.



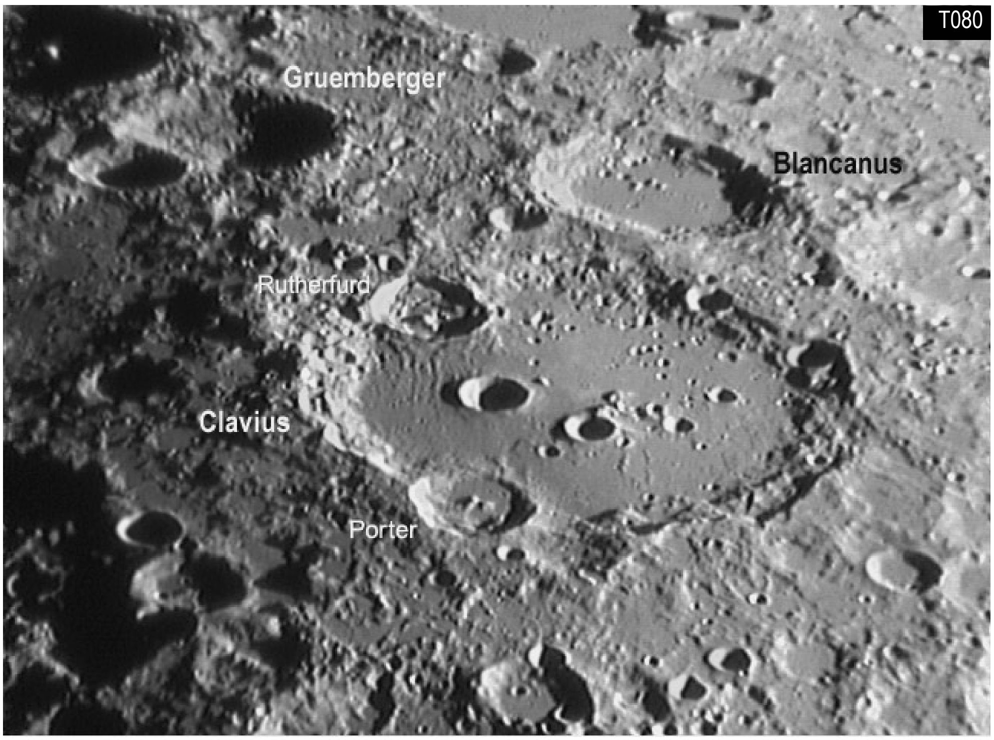
Maginus 2004.09.05 21:18 UT Age 21 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam at 1/25 sec. 47 frames.

Maginus 50.5^{0} S 6.3^{0} W
A large walled plain, diameter 194 km. It is much older than Tycho, as suggested by the eroded rim, the interior peppered with impact craters and the absence of rays.

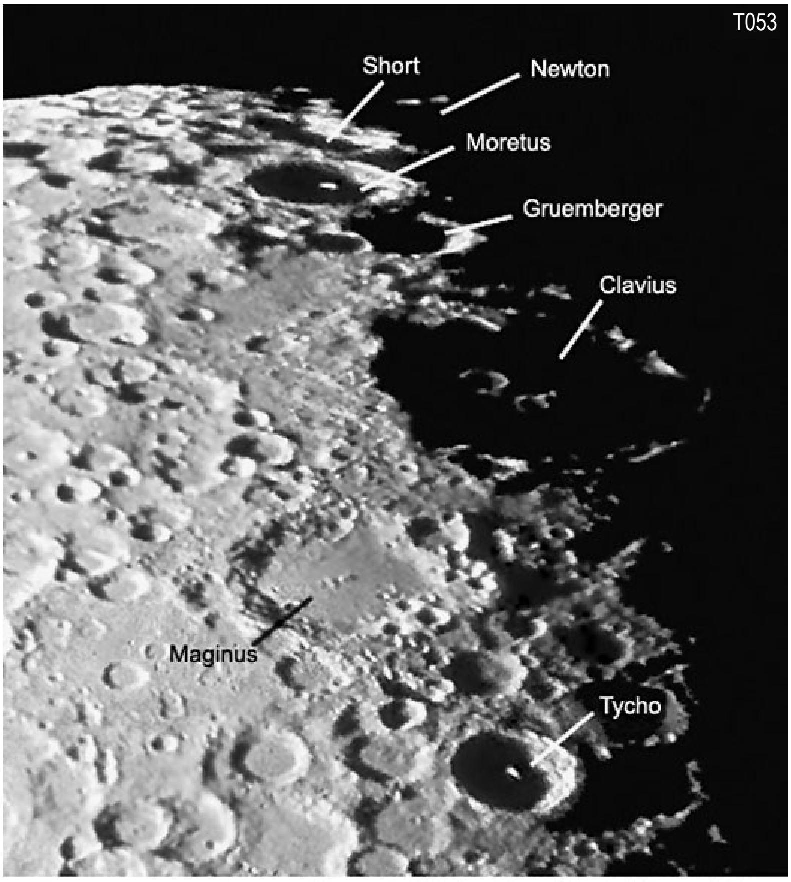
Clavius 58.8^0 S 14.1^0 W
Clavius is a spectacular, vast walled plain from the Nectarian period, diameter 245 km. Its walls are broken by crater ***Rutherfurd*** (48 km) and ***Porter*** (51 km), and there are ridges running between them, see T080 & T085. Note the L-shaped relief near Porter. An arc-array of craters extends across the floor, which also contains many craterlets and small hills. Clavius is best seen shortly after first quarter or before last quarter. It is hardly visible during the full moon.



Clavius 2005.04.18 ~14:53 UT Age 9.8 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam *(mosaic of 2 video clips)*



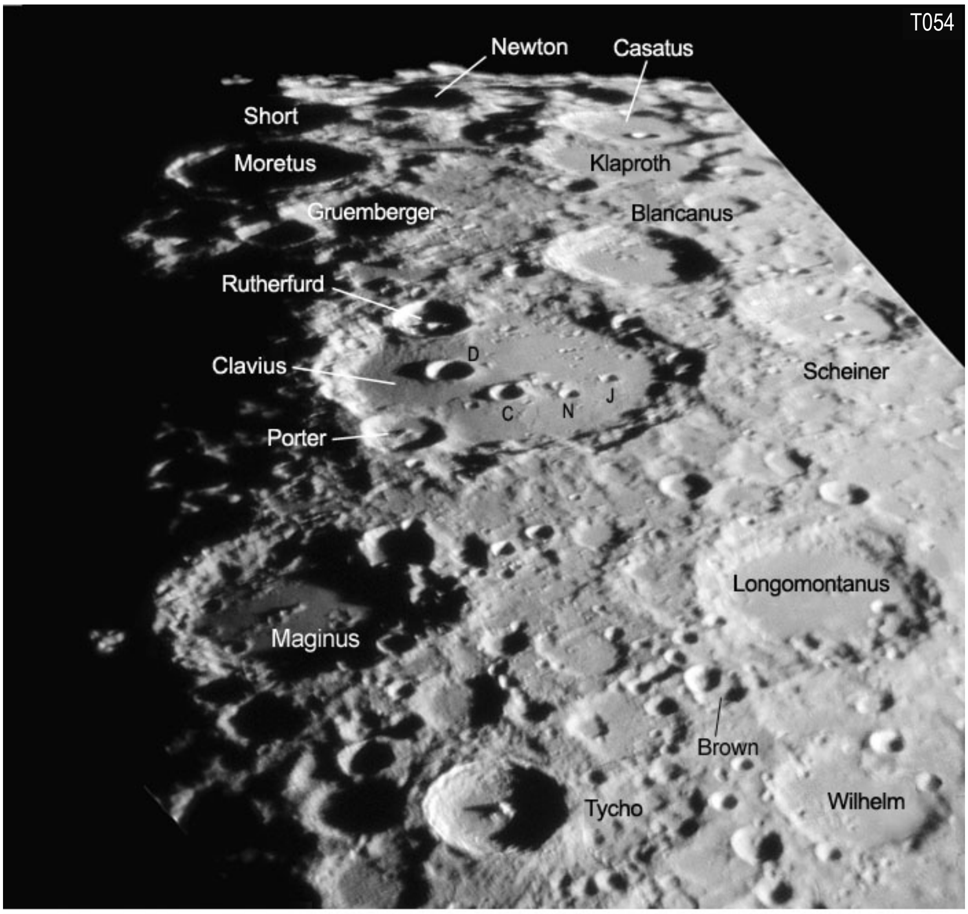
Clavius & Blancanus 2004.08.07 19:48 UT Age 22 days. 10-in f/6 Newtonian + 2.5X + ToUcam at 1/33 sec



Clavius on terminator 2000.11.05 13:50 UT Age 9 days. FS128 + LE12.5 + QV2300

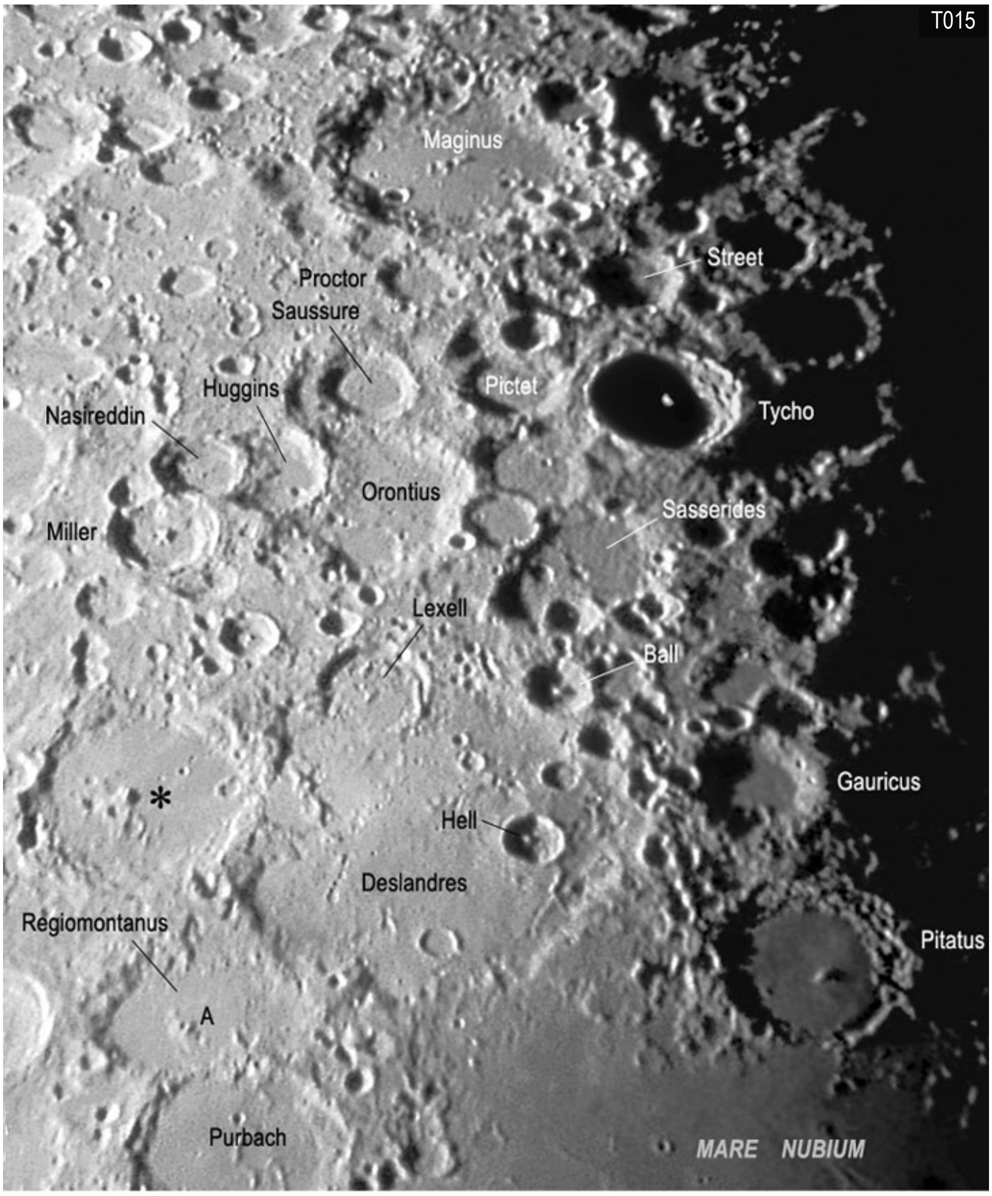
Clavius right on the terminator

It looks like an abyss. The inside craters are Clavius D (larger) and Clavius C.



Clavius outside terminator 2001.08.11 20:21 UT Age 22 days. C9 + LE12.5 + CP990 DSCN9622

Clavius just outside the terminator.

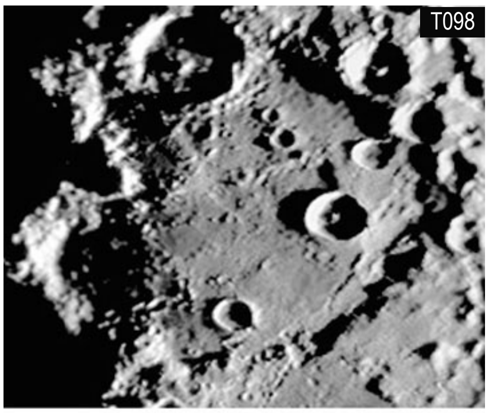


Deslandres to Maginus The * was crater Walter but now renamed as Walther. 2000.11.05 13:35 UT Age 9 days. FS128+LE12.5+QV2300

Deslandres 33.1^0 S 4.8^0 W
A 256-km ruined walled plain from the Pre-Nectarian period. Its floor contains ***Hell*** (33 km), short chains of secondary craterlets and a bright spot. See Image T074.

Walther (formerly ***Walter***) 33.1^0 S 1.0^0 E
A walled plain with mountain massif on its eastern floor, diameter 128 km.

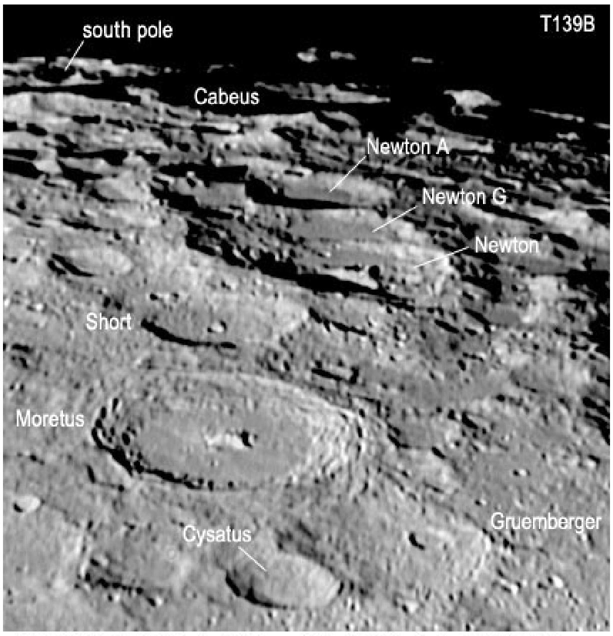
(Remark: This crater is now renamed as **Walther.** The original "**Walter**" is confusingly allocated to a 1-km crater at 28.0^{0}N 33.8^{0}W near Diophantus. See Map 22.)



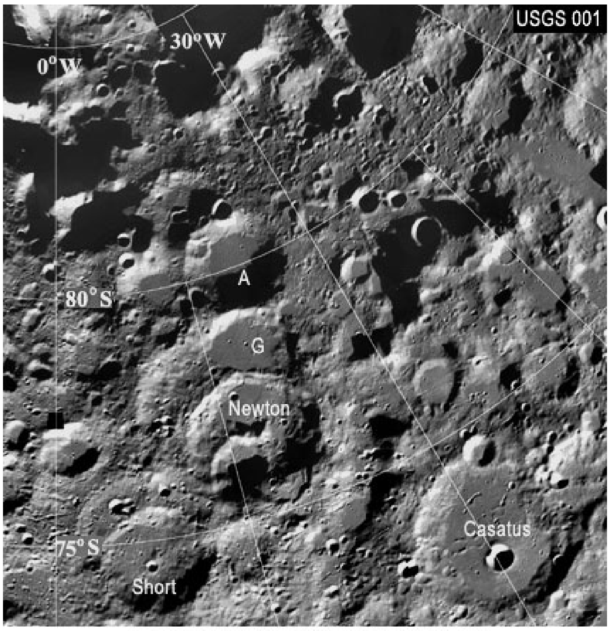
Deslandres in shadow 2001.08.11 21:01UT Age 22 days

Regiomontanus 28.3^0 S 1.0^0 W
A walled plain, 126 x 108 km. It has a summit crater ***Rigiomontanus A*** (6 km) on the central peak.

1. Moretus 2. Newton 3. Gruemberger 2004.09.05 21:16 UT Age 21 days. 10-in f/6 + 2.5X + 1.6X + ToUcam



2005.01.22 15:34 UT Age 12 days. 10-inch f/6 Newtonian + 2.5X + ToUcam

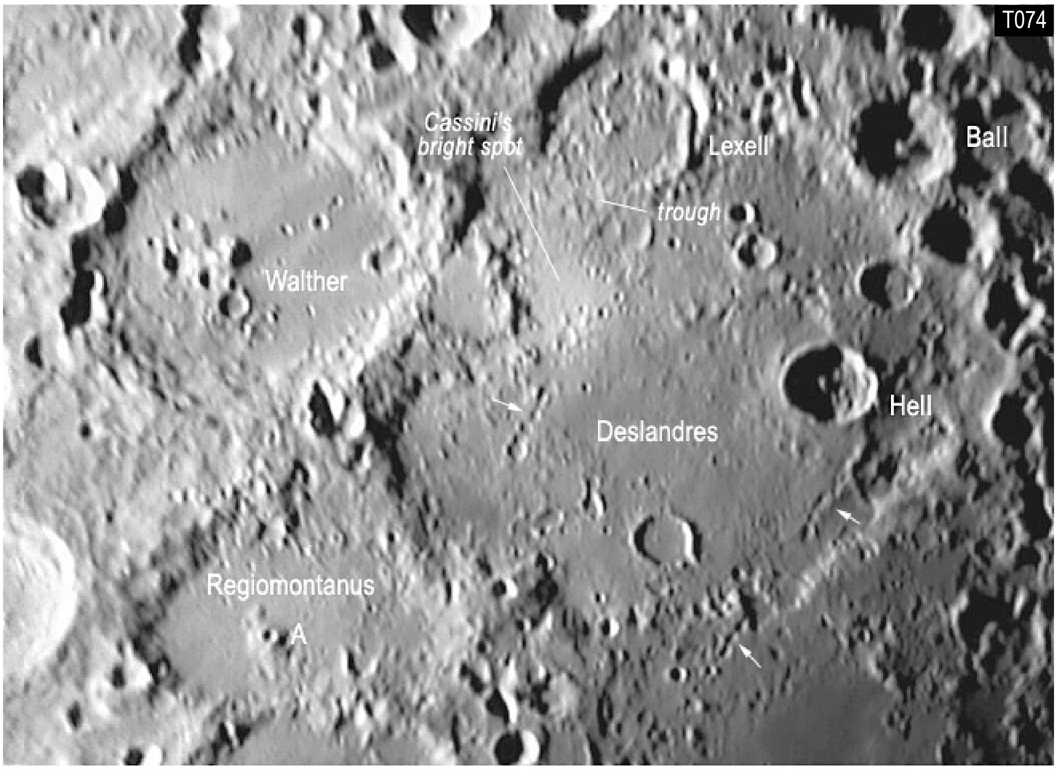


(cropped from Clementine image PIA 00001)

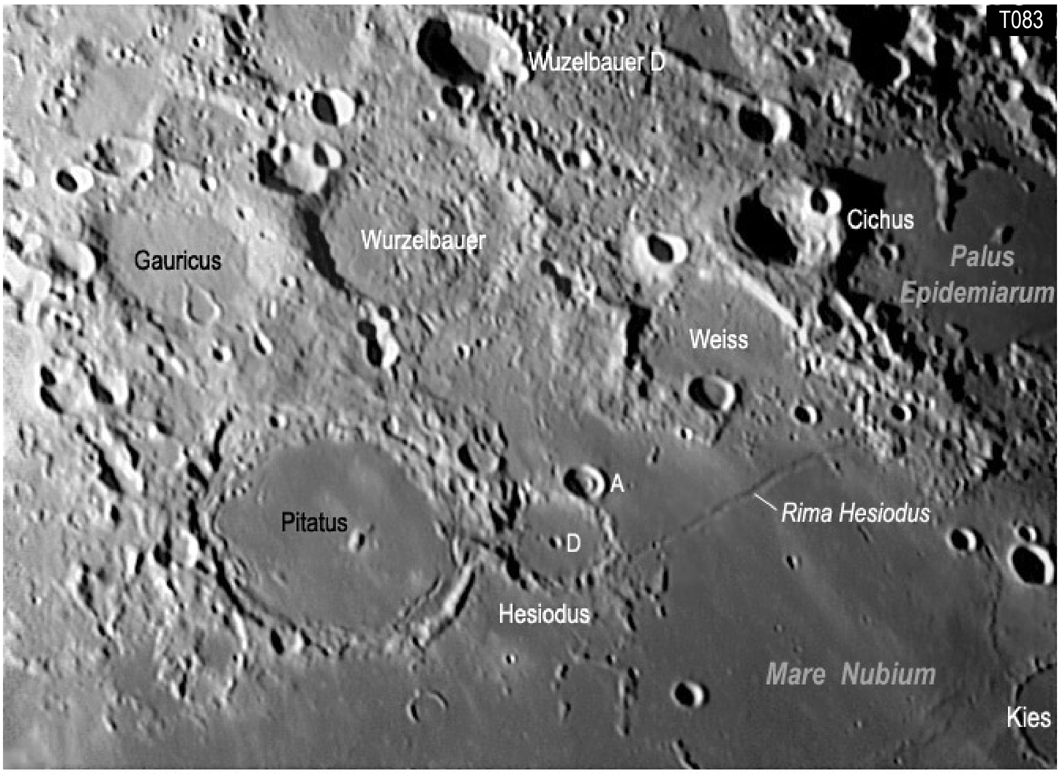
Moretus 70.6^0 S 5.8^0 W
A relatively young, non-rayed crater with well-defined central peak and terraced walls, diameter 111 km. It is likely to form in the Eratosthenian period. On the contrary, the neighboring **Gruemberger** (94 km) is an old crater marked by its eroded appearance.

Newton 76.7^0 S 16.9^0 W
A difficult crater for observation, diameter 78 km, depth unsure. T139B shows its view during favorable libration. The Clementine image at right shows Newton in orbital view.

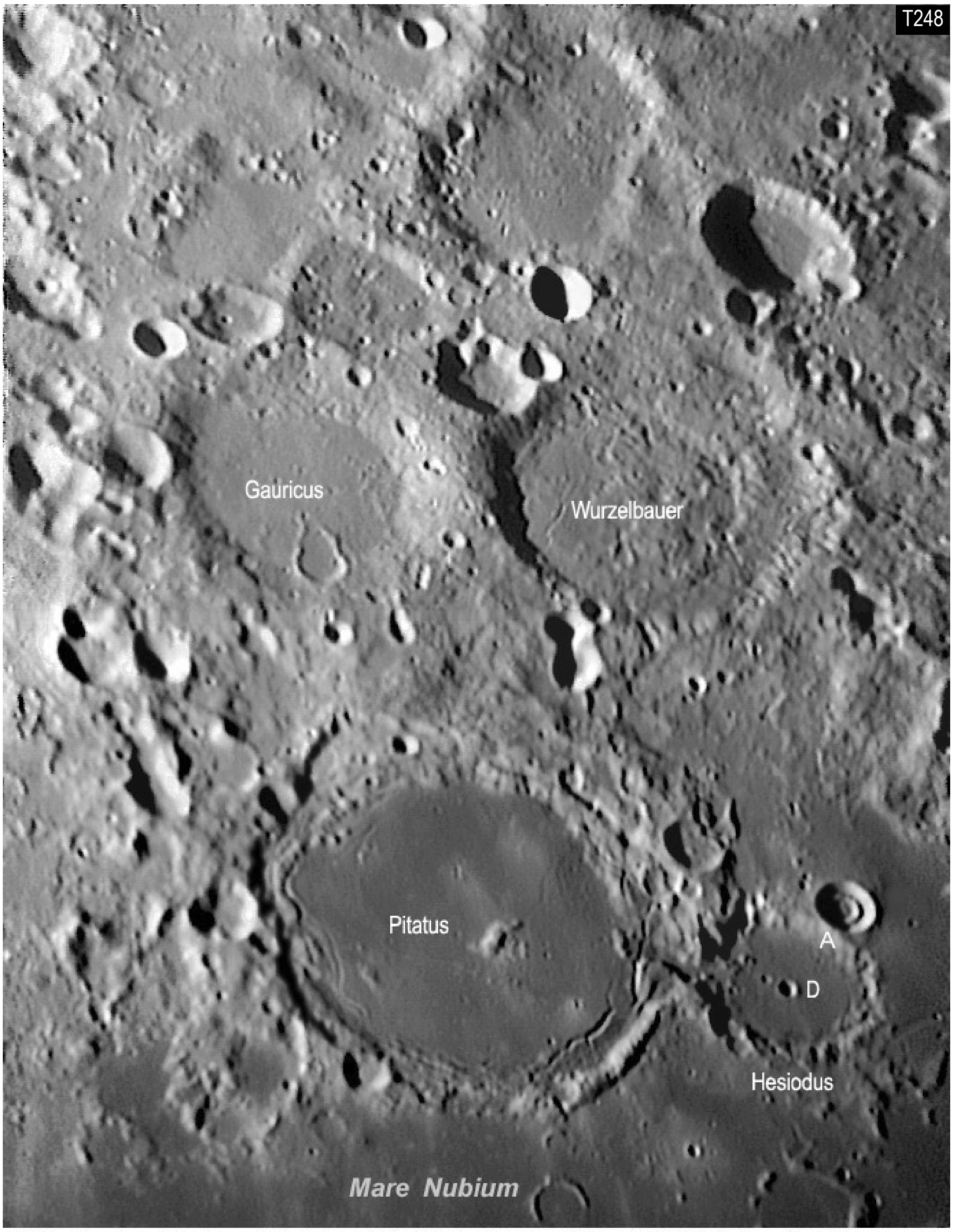
Short 74.6^0 S 7.3^0 W
A 70-km crater with a central low hill, depth 5700 m. A small crater lies on the edge of the hill.



Deslandres and its vicinity 2004.06.26 13:47 UT Age 9 days. 10-inch f/6 Newtonian + 2.5X + ToUcam
Note the "*Cassini's bright spot*" and the chains of craterlets (arrows) on the floor of Deslandres. A shallow valley-like trough intersects the northeastern rim of Lexell.



Pitatus to Palus Epidemiarum 2005.11.11 12:06 UT Age 9.5 days. 10-inch f/6 Newtonian + 2.5X + ToUcam



Pitatus, Gauricus, Wurzelbauer & Hesiodus 2005.11.11 12:19 UT Age 9.5 days. 10-in f/6 Newtonian + 4X + ToUcam (*mosaic*)

Pitatus 29.9^0 S 13.5^0 W
A large flooded FFC (floor-fractured crater) with semi-submerged central peak, diameter 106 km. The fractures along the inner rim (***Rimae Pitatu***s, 94 km) are likely produced by uplift of the floor. The white patches on the floor are deposited materials thrown out from the Tycho impact.

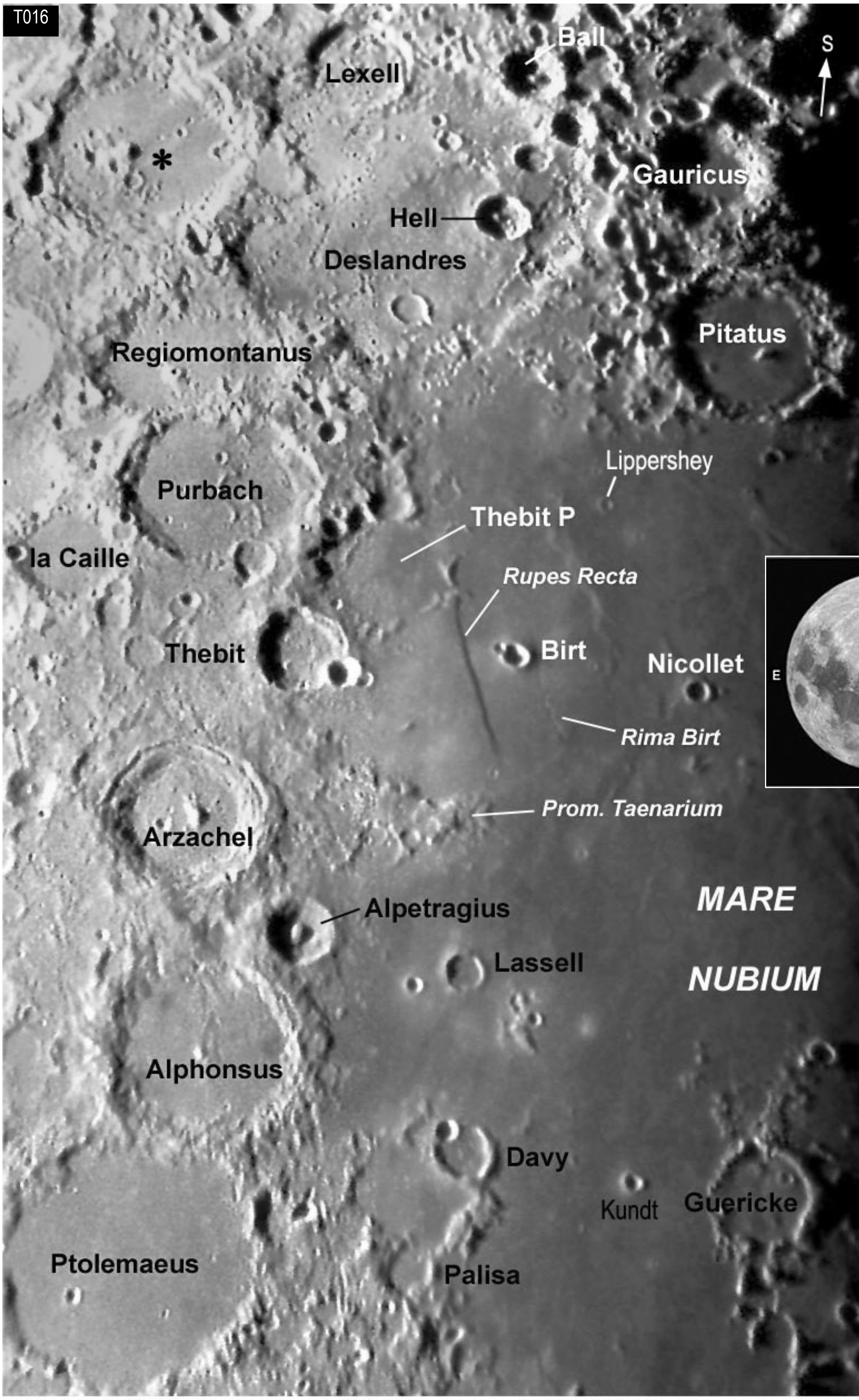
Gauricus 33.8^0 S 12.6^0 W
A heavily eroded crater, diameter 79 km. Its wide wall is encircled by a ring of small craters. The northern floor contains overlapped craters resembling a drop of water.

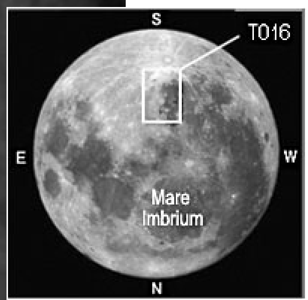
Hesiodus 29.4^0 S 16.3^0 W *(Image T083 & T248)*
A 42-km flooded crater. The center of its floor contains a small crater ***Hesiodus D***. The adjoined crater ***Hesiodus A*** (15 km) has double concentric walls. ***Rima Hesiodus*** is a graben formed by lava subsidence. It runs from Hesiodus into ***Palus Epidemiarum***, 3 km wide, 256 km long.

MAP 12

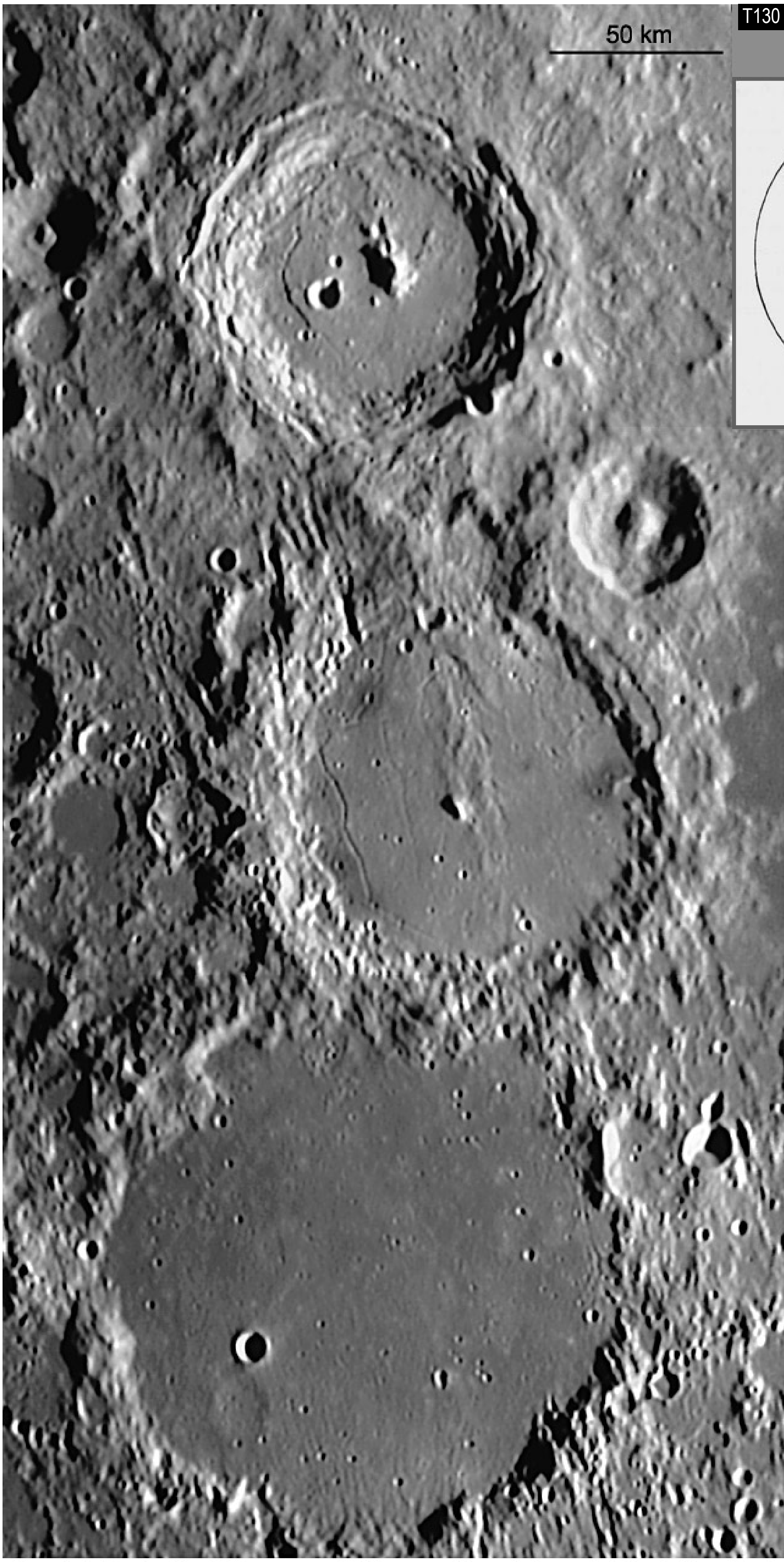
Hatfield 13, 9
Rükl 54, 55, 42, 43, 44

Ptolemaeus, Alphonsus, Purbach, Rupes Recta, Albategnius, Hipparchus, Fra Mauro

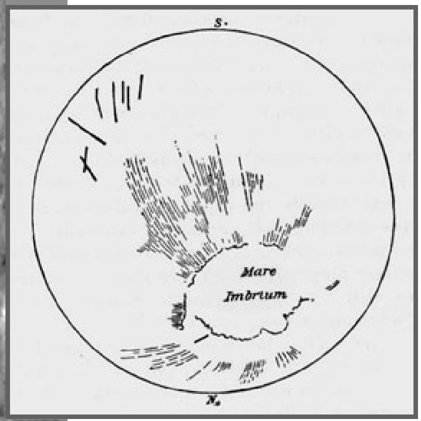




Ptolemaeus to Deslandres The ✱ was crater Walter but now renamed as Walther. 2000.11.05 13:38UT Age 9 days. FS128



Arzachel, Alpetragius, Alphonsus and Ptolemaeus (mosaic from a batch of video clips)
2004.09.05 20:53 ~ 21:11 UT Age 21 days. Very misty sky. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam at 1/25 sec.

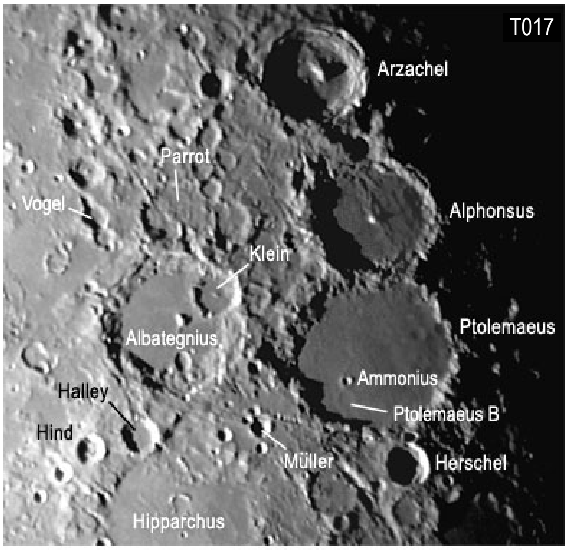


↑ *A sketch of Imbrium Sculpture in a paper by the American geologist Grove Karl Gilbert (1843-1918). It is a terrain of grooves and ridges radial to Mare Imbrium, and affects a large area of the lunar surface. Part of this sculpture is easily seen on the southeast rim of Alphonsus at the middle of T130. Other parts are traceable in T084 and T179 of following pages, also in* *Map 31*.

← *The crater trio from top to bottom:* ***Arzachel, Alphonsus & Ptolemaeus****.*

Comparing their levels of degradation, Arzachel is the youngest and Ptolemaeus is the oldest of the three craters. The flat floor of Ptolemaeus is filled by the ejecta of the Imbrium impact, so the crater looks not dark like maria but bright like highlands at the full moon. Similar ejecta might have created the relatively smooth floor, the bisecting low ridge and the grooved rim of Alphonsus.

Ptolemaeus 9.3^0 S 1.9^0 W
Ptolemaeus is a prominent walled plain, diameter 164 km. Its floor contains a mascon and appears flat, but numerous craterlets and pits are detectable at high powers. ***Ammonius*** (diameter 8 km) is a distinctive crater on the floor; it adjoins a saucer-shaped depression (***Ptolemaeus B***, 17 km). The floor of Ptolemaeus also changes dramatically during a lunation. It is bright at the full moon but appears quite dark at days close to the first and last quarters.



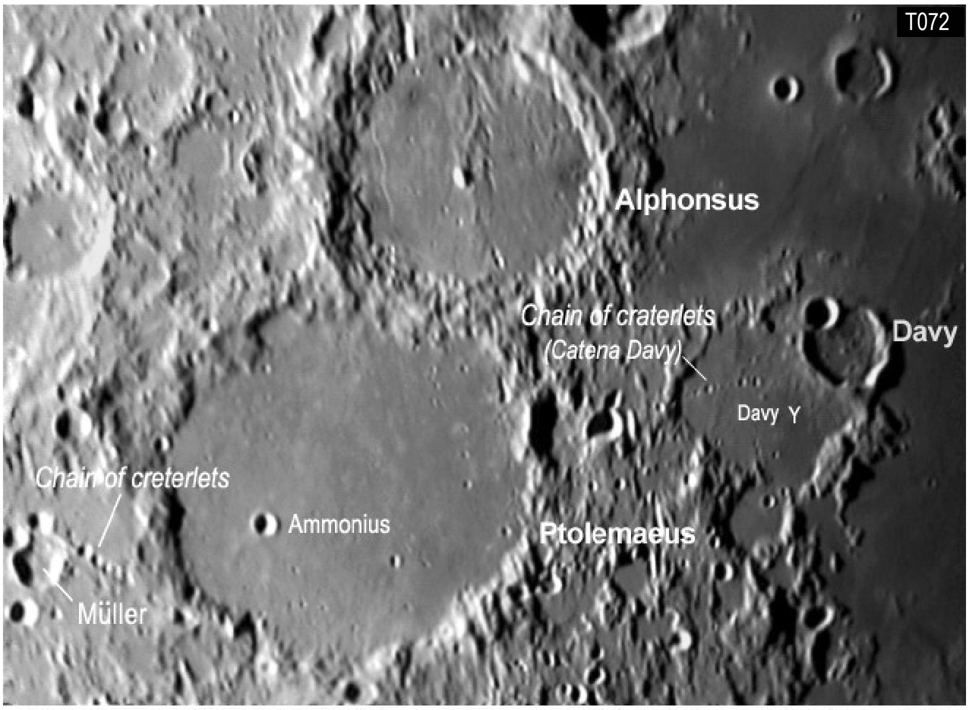
2001.09.25 !2:49 UT Age 8 days. C9 + LE12.5 + CP990 1/2 sec

Ptolemaeus, ***Alphonsus*** (108 km) & ***Arzachel*** (96 km) form an interesting trio. The floor of Arzachel contains a prominent central peak and a system of sharp rilles (***Rimae Arzachel***, length 50 km). Alphonsus, known to form in the Nectarian period, is characterized by ridged floor with dark halo craters and rilles along its inner rim, more details in next page. The NASA Ranger 9 probe made a hard impact on Alphonsus in March 1965. Alphonsus is also an object of LTP (lunar transient phenomena).

Note that in T130, the crater trio and their surroundings are modified by a radial pattern of grooves and ridges known as ***Imbrium Sculpture***, formed from a hurricane of ejecta at low angles during the giant Imbrium impact that occurred 3.85 billion years ago. The flat floor of Ptolemaeus is also caused by the ejecta of the Imbrium impact.

Alpetragius 16.0^0 S 4.5^0 W
A bowl-shape crater, 39 km in diameter, 3900 m deep. It has a central mountain cone, probably oversized by post-volcanic eruptions inside the crater.

Davy 11.8^0 S 8.1^0 W *(Image T072)*
A crater, diameter 34 km. The nearby chain of craterlets is ***Catena Davy***, details in Map 31.



Ptolemaeus, Alphonsus, Davy 2004.06.26 13:32 UT Age 9 days. 10-in f/6 Newtonian + 2.5X + ToUcam

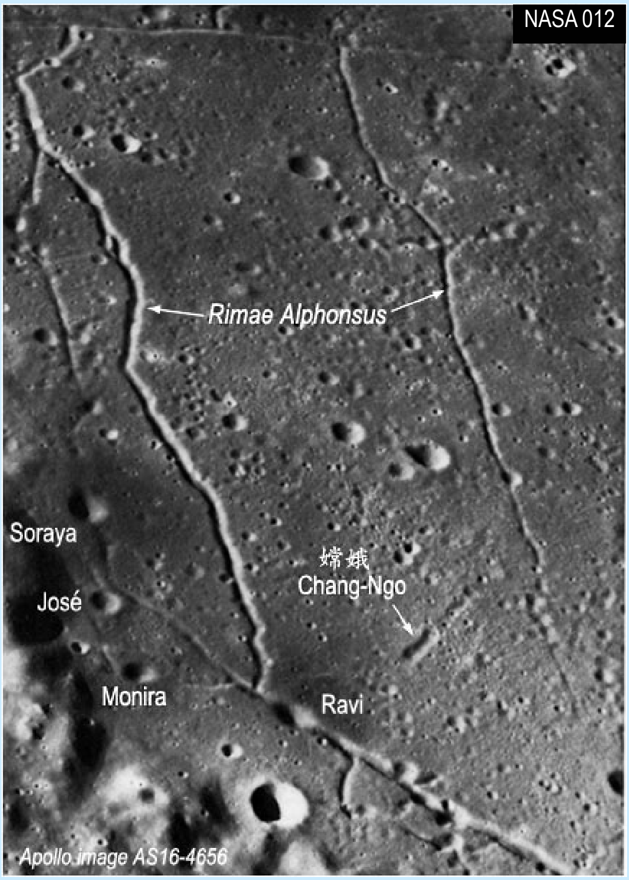
The craters inside Alphonsus

At least 10 *dark halo craters* are inside Alphonsus. Some of them along the eastern inner edge of Alphonsus are highlighted in the right image:

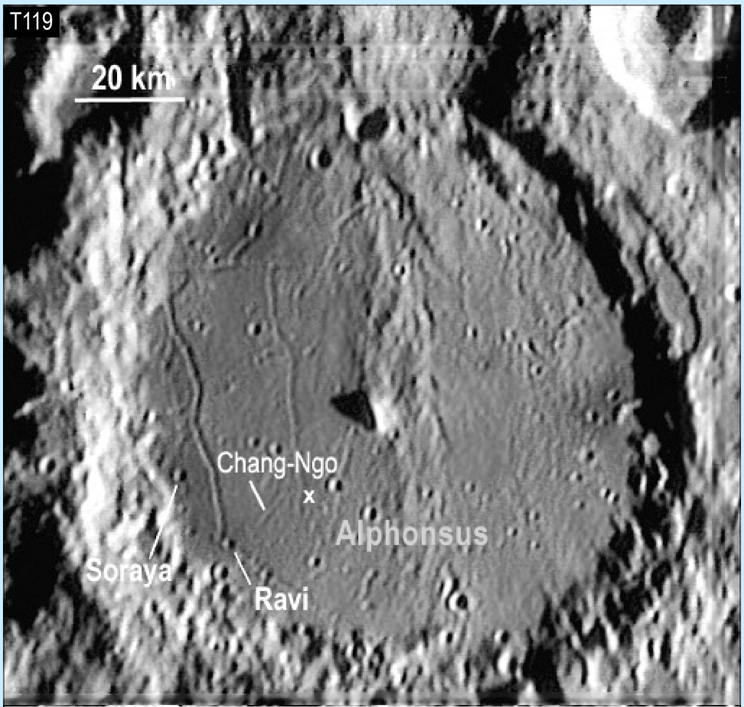
Ravi	12.5^0 S	1.9^0 W	diameter 2.5 km
Monira	12.6^0 S	1.7^0 W	diameter 2 km
José	12.7^0 S	1.6^0 W	diameter 2 km
Soraya	12.9^0 S	1.6^0 W	diameter 2 km

These craters are volcanic. The dark halos around them are DMDs (dark mantle deposits, Map 9). The adjacent rilles are thought to be graben in origin, but they have been modified by post-volcanism as lava channels.

The arrow points to the elongated crater ***Chang-Ngo*** at 12.7^0 S 2.1^0 W, length 3 km. It is impact-originated, probably created by a secondary impact or space debris that intruded the Moon at a grazing angle. The floor of Chang-Ngo appears scalloped. This suggests the impactor was composed of loosely-bounded fragments. During its trajectory, some fragments hit the floor of Alphonsus to form Chang-Ngo; other fragments followed to form the chain of craterlets next to Chang-Ngo.



Above: *Alphonsus belongs to a feature class called FFC (floor-fractured crater), as suggested by Rimae Alphonsus on the crater floor. South is up.*



2004.08.07 ~20:36UT Age 22 days. 10-in f/6 Newtonian + 5X + ToUcam

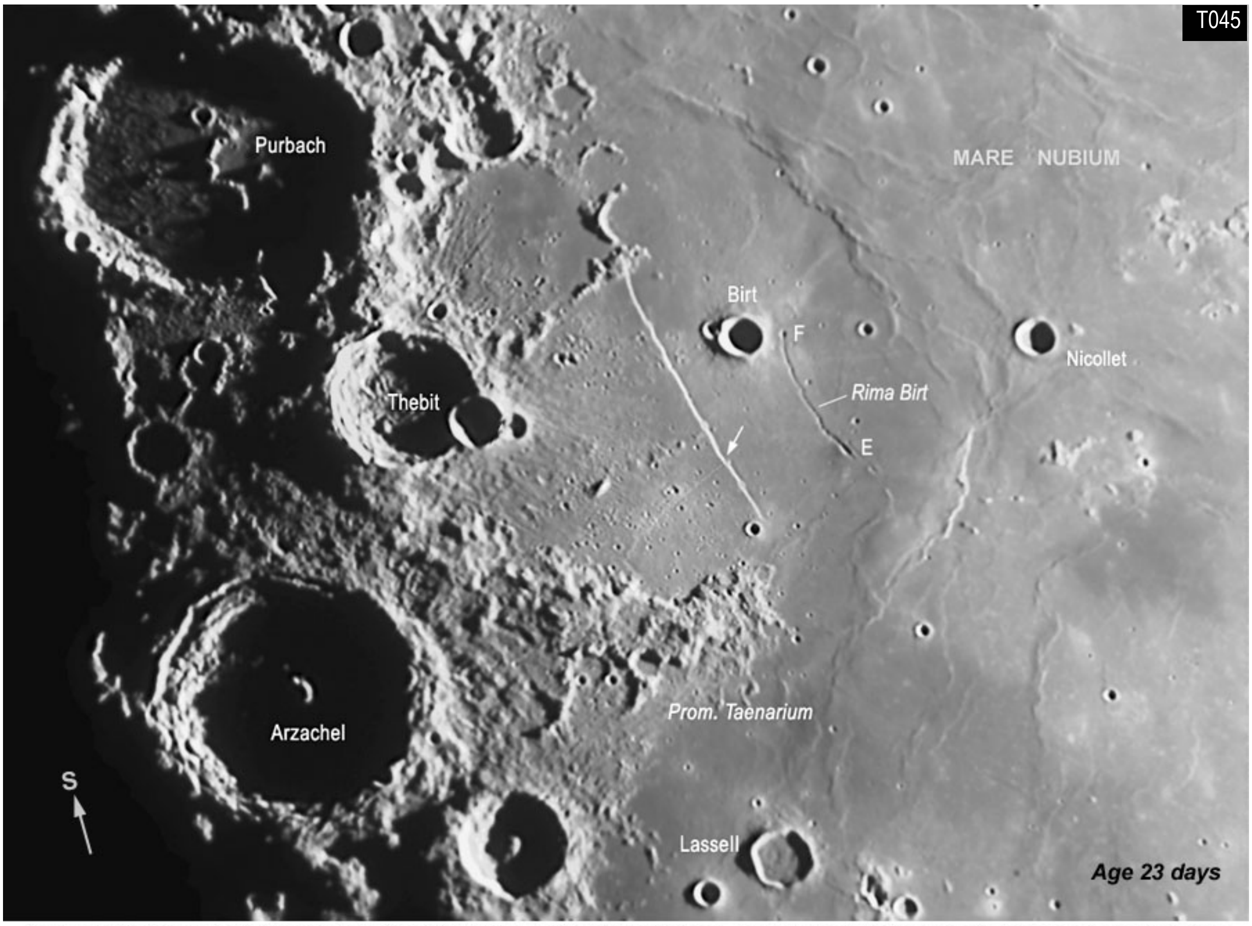
Left: *Crater Chang-Ngo seen from a 10-inch telescope. It is named after a lady in a Chinese myth. The* ***X i****ndicates the impact site of Ranger 9 probe.*

Rupes Recta (The Straight Wall) 22.1^0 S 7.8^0 W

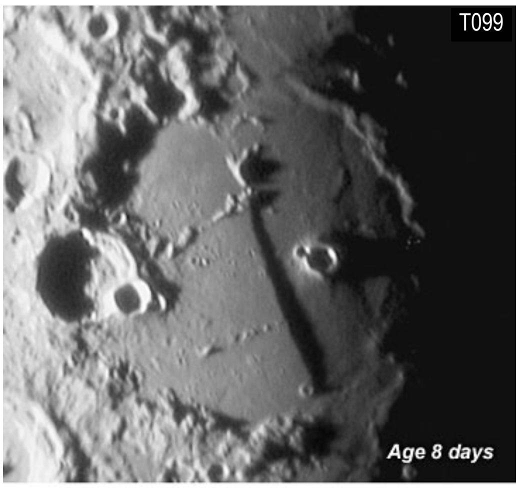
Rupes Recta is a fault, length 130 km. Its western side slopes down by 300 m at average gradient of about 10^0. The fault is possibly triggered by shock waves of the Imbrium impact, and later activated by the lava loading in Mare Nubium. Shortly after the first quarter, Rupes Recta casts striking shadows (T099). During the last quarter, a faint rille is seen intersecting the fault (T045).

Rima Birt 21.0^0 S 9.0^0 W

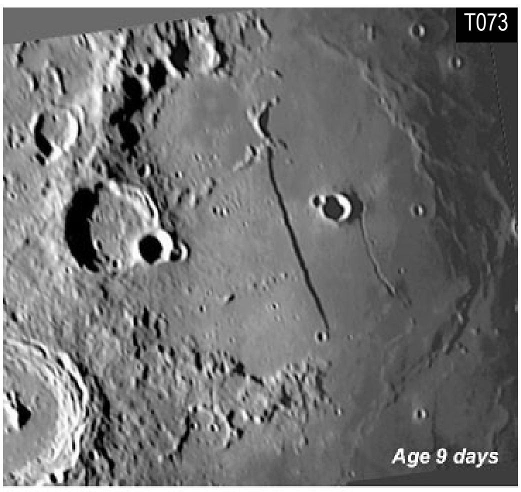
A 50-km rille almost parallel to Rupes Recta. Its south end connects ***Birt F***. Its north end connects ***Birt E*** which rests on a low dome and appears as an outlet of lava flow. ***Birt*** (16 km) is a rayed crater under high illumination. To the south, Birt's ray system mingles with Tycho's rays.



Arrow indicates ***Rupes Recta*** intersected by a faint rille during the last quarter. 2009.11.09 ~21:45 UT Age 22.7 days. 10-in f/6 Newtonian + 2.5X + DMK31AF03.



Rupers Recta 2004.07.25 12:16UT Age 8 days. 10-in f/6 Newtonian+2.5X+ToUcam



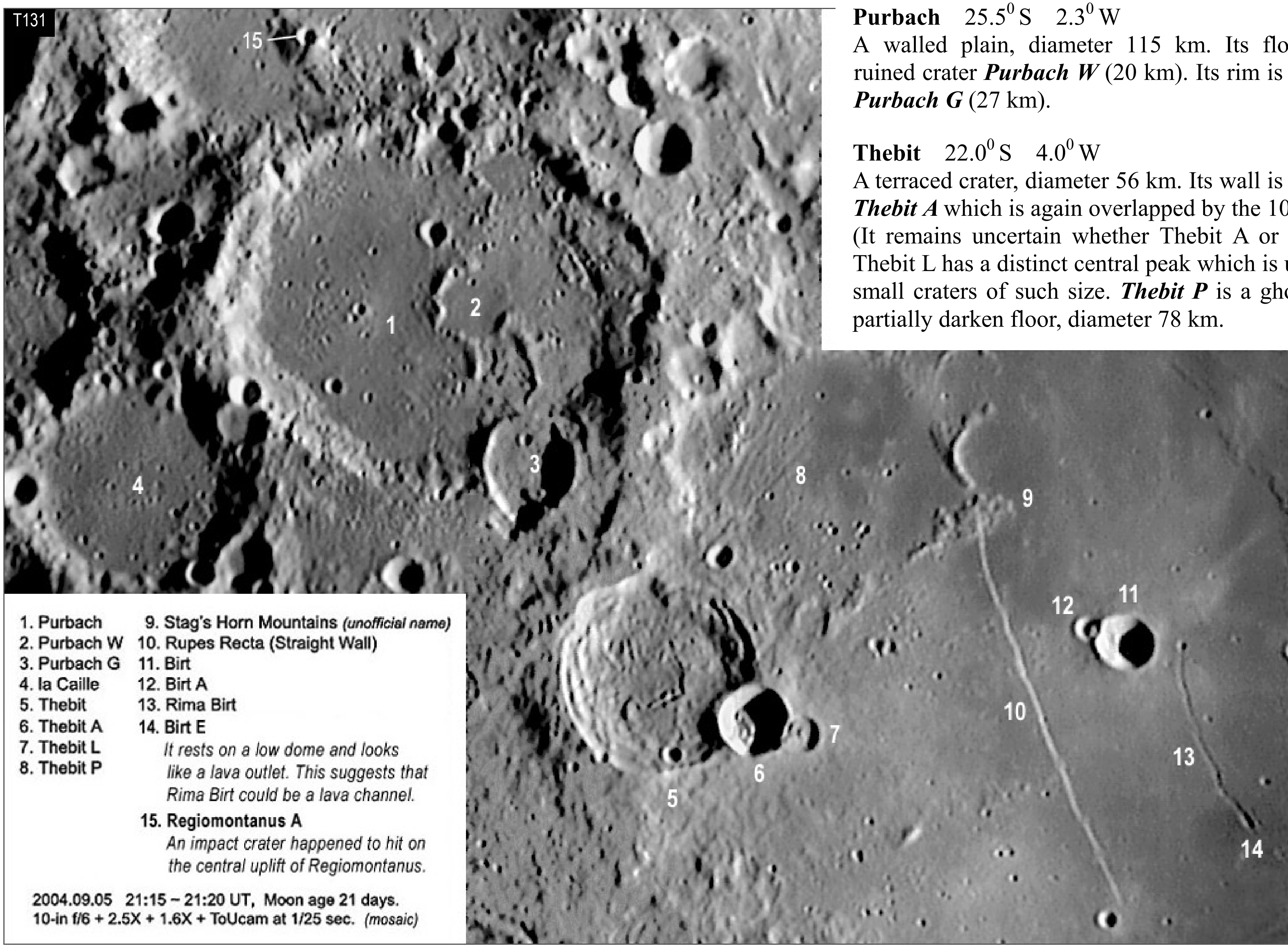
Rupes Recta 2004.06.26 13:59UT Age 9 days. 10-in f/6 Newtonian+2.5X+ToUcam

Purbach 25.5^0 S 2.3^0 W

A walled plain, diameter 115 km. Its floor contains a ruined crater ***Purbach W*** (20 km). Its rim is interrupted by ***Purbach G*** (27 km).

Thebit 22.0^0 S 4.0^0 W

A terraced crater, diameter 56 km. Its wall is overlapped by ***Thebit A*** which is again overlapped by the 10-km ***Thebit L***. (It remains uncertain whether Thebit A or L came first.) Thebit L has a distinct central peak which is uncommon for small craters of such size. ***Thebit P*** is a ghost crater with partially darken floor, diameter 78 km.



MAP 12

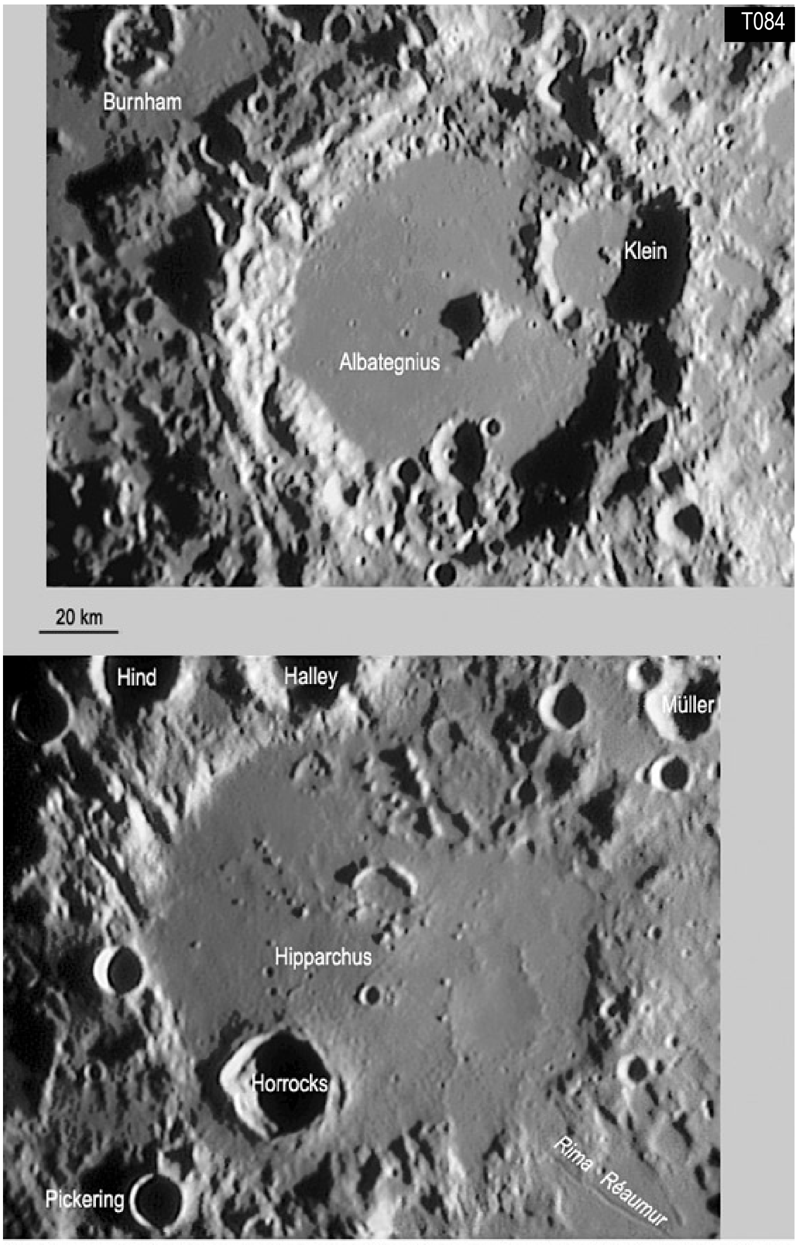
Burnham 13.9^0 S 7.3^0 E
A 24-km crater with broken wall.

Albategnius 11.7^0 S 4.3^0 E
A prominent ring mountain with central peak, internal submerged craters and flatten floor, diameter 114 km. Its inner wall is heavily eroded with landslides, valleys and impact craters including ***Klein*** (44 km). In May 1962, a laser beam was aimed at the Moon and Albategnius became the first lunar object to bounce an Earth-based laser.

Hipparchus 5.1^0 S 5.2^0 E
A vast old walled plain from the Pre-Nectarian period, 138 km in diameter, about 3000 m deep. The eastern wall is cut by a pair of deep clefts, which are part of the ***Imbrium Sculture***. The western wall is fairly disintegrated, with a gap opened to ***Rima Réaumur*** (length 30 km). The floor of Hipparchus contains small hills, ghost craters and ***Horrocks***.

Image T179, next page:

Herschel 5.7^0 S 2.1^0 W
A terraced crater with rough floor and central peak, diameter 40 km.



Two big craters: **Albategnius** from the Nectarian period and **Hipparchus** from the Pre-Nectarian period. Their floors are covered by the ejecta from the Imbrium impact. 2004.09.05 ~21:49 UT Age 21 days. 10-in f/6+4X+ToUcam.

Lalande 4.4^0 S 8.6^0 W
A 24-km rayed crater under high illumination.

Mösting 0.7^0 S 5.9^0 W
A crater with terraced walls and rough floor, diameter 24 km.

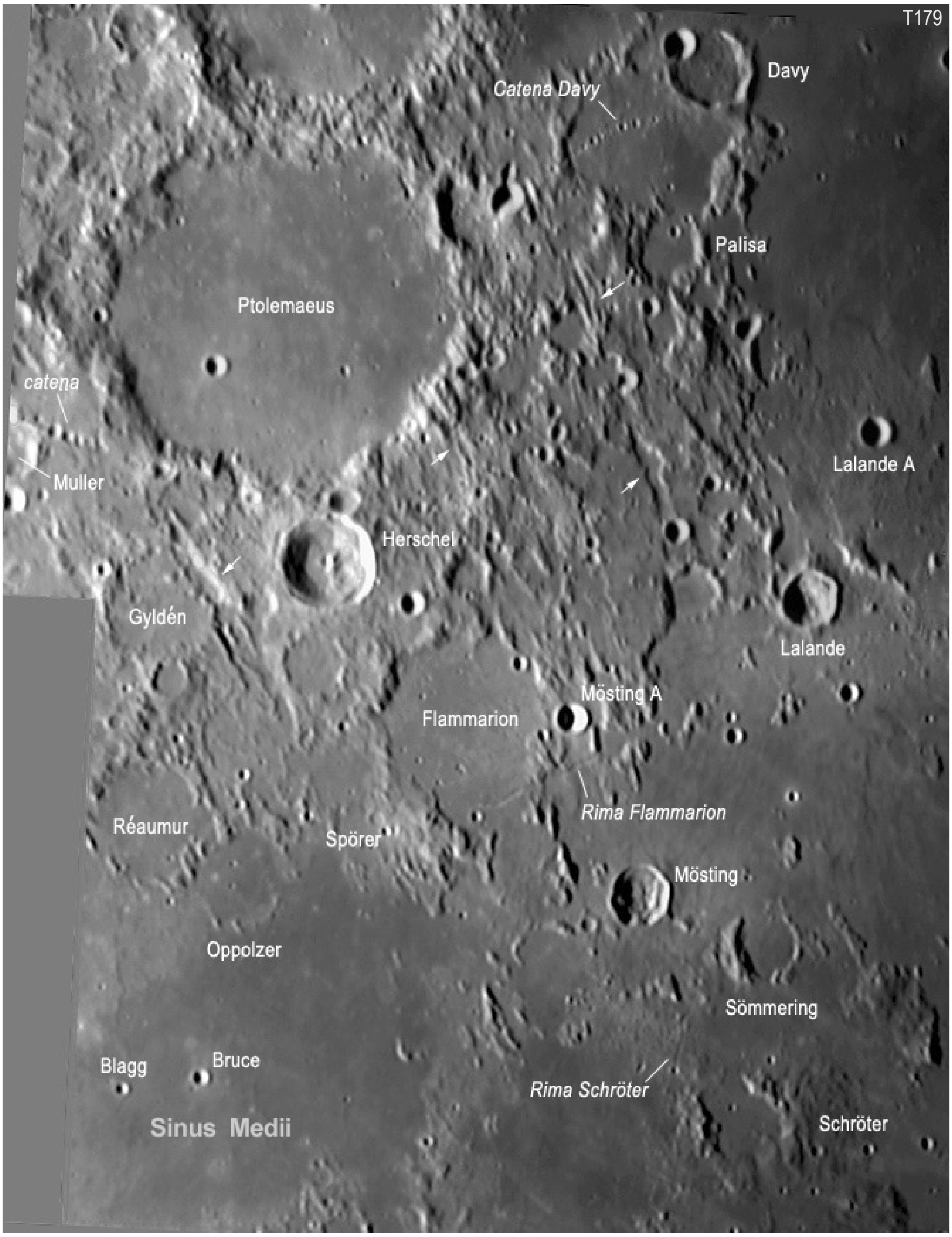
Sömmering 0.1^0 N 7.5^0 W
A ruined flooded crater, diameter 28 km. Wide gaps exist on the north and south rims.

Flammarion 3.4^0 S 3.7^0 W
A walled plain, diameter 74 km. Its northern wall is lava flooded and crossed by ***Rima Flammarion*** (length 80 km). Its western wall is interrupted by a 13-km crater ***Mösting A*** whose selenographic position (3^0 12’ 43.2” S 5^0 12’ 39.6”W) is a reference standard.

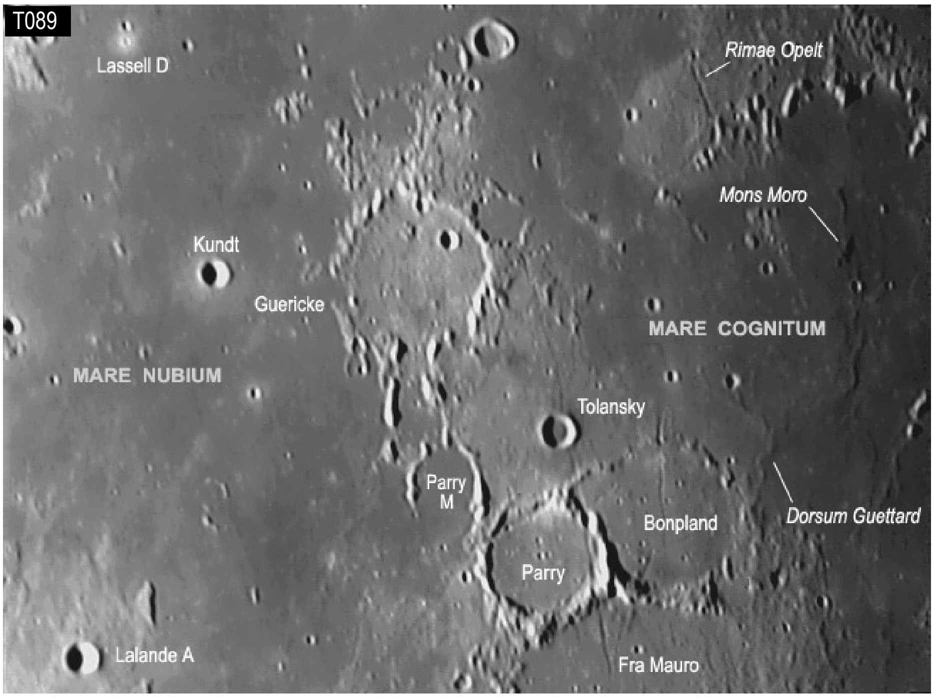
Rima Schröter 1.0^0 N 6.0^0 W
An inconspicous rille near crater ***Schröter*** (diameter 35 km), 40 km long.

Gyldén 5.3° S 0.3° E
A disintegrated crater, diameter 47 km. Its southwestern wall is interrupted by a valley which is part of the Imbrium Sculpture.

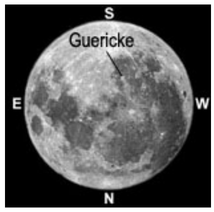
Réaumur 2.4° S 0.7° E diameter 52 km
Oppolzer 1.5° S 0.5° W diameter 40 km
A pair of adjoined crater. See also Map 13.

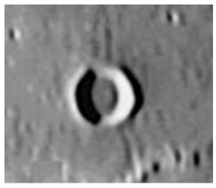


Ptolemaeus and northern vicinity 2005.04.18 ~13:49 UT Age 10 days. 10-in f/6 Newtonian + 2.5X + ToUcam
The arrows indicate traces of the *Imbrium Sculpture*.



Guericke, Tolansky, Parry and Bonpland 2004.06.27 13:30 UT Age 10 days. 10-in f/6 Newtonian + 2.5X + ToUcam





Tolansky *(enlargement)*

The floor of Tolansky is rather flat but looks a bit convex at Moon age of about 10 days, when the Sun illumination is still oblique (~15⁰ from ground).

Lassell D 14.5⁰ S 10.5⁰ W *(Image T089)*
A bright halo crater, with moderate rays, diameter 2 km.

Rimae Opelt Details in T258, Map 23.

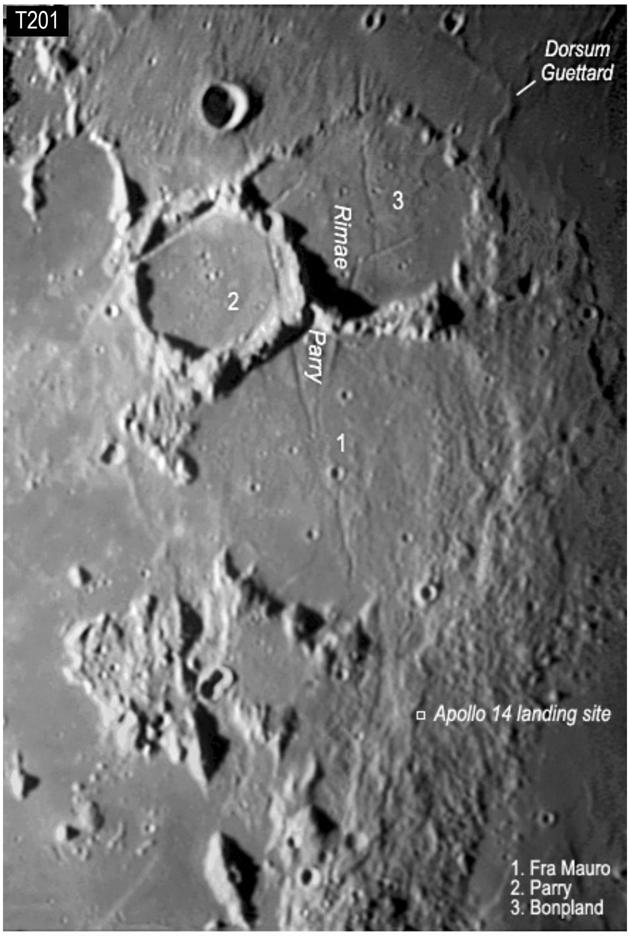
Mons Moro 12.0⁰ S 19.7⁰ W
A low hill on a wrinkle ridge, base size 10 km.

Tolansky 9.5⁰ S 16.0⁰ W
A 13-km crater. Its floor is rather flat but looks a bit convex under oblique illumination.

Guericke 11.5⁰ S 14.1⁰ W
Parry 7.9⁰ S 15.8⁰ W
Guericke is the remains of a walled plain, diameter 63 km. Its southwest rim adjoins ***Guericke F*** (21 km). Parry (47 km) is linked to Guericke, giving an impression of a *g*-shaped crater pair. A complex of fractures (***Rimae Parry***) runs across Parry, Bonpland and Fra Mauro.

Bonpland 8.3⁰ S 17.4⁰ W
A shallow walled plain, diameter 60 km.

Fra Mauro 6.1⁰ S 17.0⁰ W *(Image T201)*
A ruined walled plain, diameter 101 km. Its western half is covered by the Imbrium ejecta, see also T178 in Map 19. The rocks sampled by the Apollo 14 in this region indicated that the Imbrium impact occurred 3.85 billion years ago.



Fra Mauro Formation (hummocky patch at right side of picture) is part of the ejecta from the Imbrium impact. 2005.04.18 11:58 UT Age 10 days. 10-in+4X+ToUcam

Rima Ariadaeus, Rima Hyginus, Rimae Triesnecker, Agrippa

Hatfield 1, 13
Rükl 33, 34, 44

A rima is a rille, an open or slumped channel on the Moon's surface. Rilles are classified according to their appearance. *Sinuous rilles* are found generally in maria. They are running lava (now solidified) and hence become narrower as they flow downslope; fine examples are ***Rima Hadley*** in Map 14 and ***Rima Marius*** in Map 20. *Linear or arcuate rilles* appear mostly in mare-highland boundaries; they are likely surface fractures caused by stress but could be volcanic in other cases. An example of surface fractures is ***Rimae Hippalus*** in Map 24 where the ground has been torn slightly apart by the weight of massive lava in Mare Humorum.

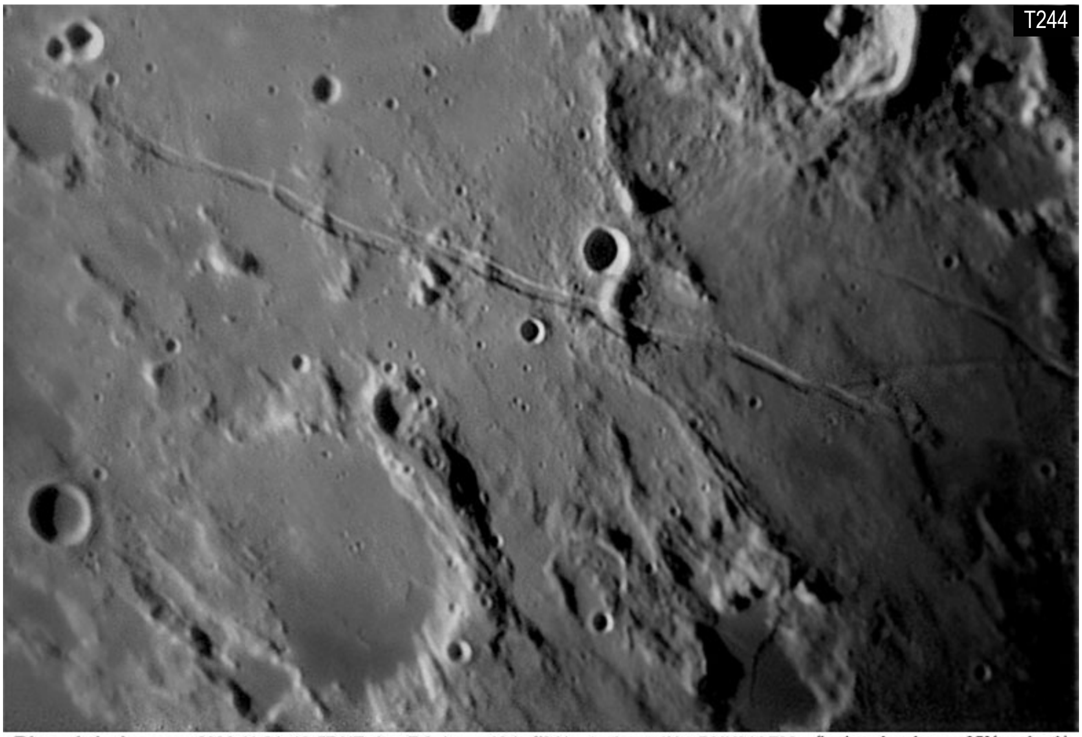
There are three prominent rille systems in this map, all visible in small telescopes:

Rima Ariadaeus 6.4^{0}N 14.0^{0}E
A 250-km linear rille, width about 5 km. It is a graben (sunken floor between parellel faults) radial to the Imbrium basin. A section of it is interrupted by a ridge extending from ***Silberschlag***.

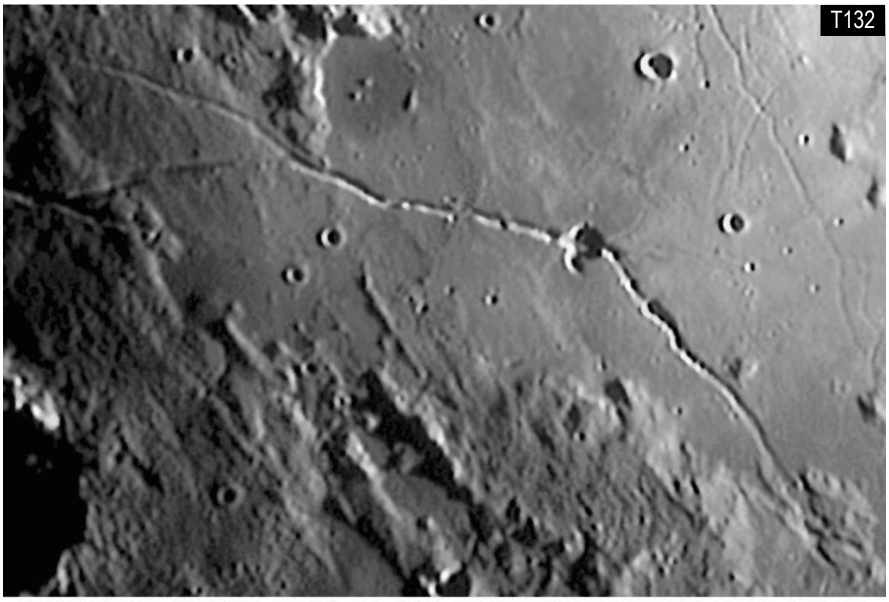
Rima Hyginus 7.4^{0}N 7.8^{0}E
It is composed of two linear segments jointed at ***Hyginus*** (9 km), total length 220 km, 3~5 km wide, 400 m deep. In T132 of next page, Hyginus is supposed volcanic, the rille segments could be lava channels and the tiny craters along the rille could be individual events of lava collapse. There are dark mantle deposits in the regions near Hyginus and Mare Vaporum (T077).

Rimae Triesnecker 4.3^{0}N 4.6^{0}E
A complex of rilles spanning 210 km. Possibly they are tubes channeling the lava that formed Sinus Medii. ***Triesnecker***, a 26-km rayed crater, happens to sit in. See also T077.

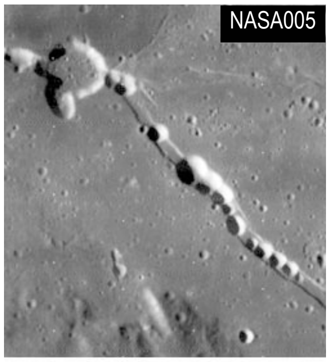
To the north of Hyginus is a small spiral mountain resembling a rotated letter "e", as marked by the arrow in T164. Observers call it ***Mount Schneckenberg***. To the east of this mountain is the disintergrated crater ***Boscovich*** (46 km) and ***Rimae Boscovich*** composed of short rilles. ***Julius Caesar*** (90 km) is a flooded crater with partially darkened floor; it has a heavily worn wall.



Rima Ariadaeus 2009.11.24 10:57 UT Age 7.6 days. 10-in f/6 Newtonian + 4X + DMK31AF03 *(bad seeing, image 85% resized.)*



Rima Hyginus 2004.09.05 21:23 UT Age 21 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam, 47 frames. The crater in the middle of the rille is Hyginus. It has flat floor and non-crested rim; hence appears volcanic more than impact-created. Presumably Hyginus is volcanic, it would be a lava outlet and the rille would be a lava channel. The dark patches on both sides of the rille are DMDs (Dark Mantle Deposits, Map 9).



Craterlets on Rima Hyginus
(cropped from Lunar Orbiter 4 - 4097)

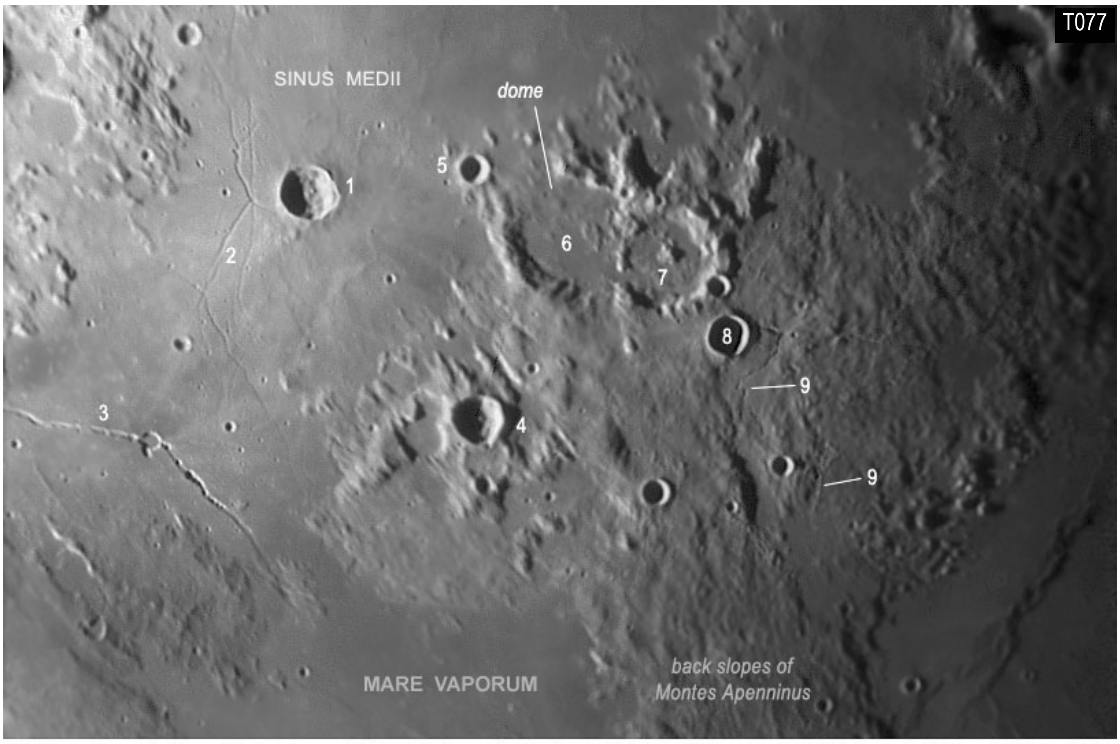
Pallas 5.5^0 N 1.6^0 W **Murchison** 5.1^0 N 0.1^0 W *(Images in next page)*
A pair of joined craters near Sinus Medii. They appear like the Greek alphabet Φ. Both have disintegrated walls. Pallas is 46 km in diameter. Murchison is 57 km with an internal dome.

Bode 6.7^0 N 2.4^0 W
A crater, diameter 18 km. ***Rimae Bode*** (length 70 km) runs northwards from this crater.

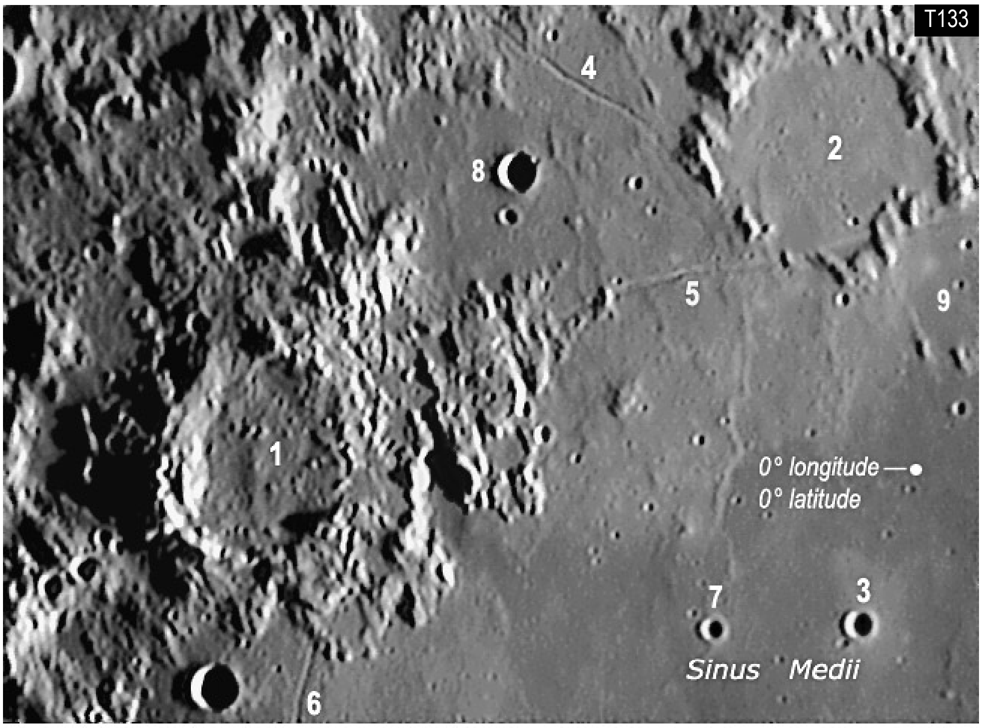
Rhaeticus 0.0^0 N 4.9^0 E
A crater with ruined wall, 45 km in diameter, 1600 m deep.

Bruce 1.1⁰ N 0.4⁰ E
A bowl-shaped crater in Sinus Medii nearest to the zero-point coordinates, diameter 6 km.

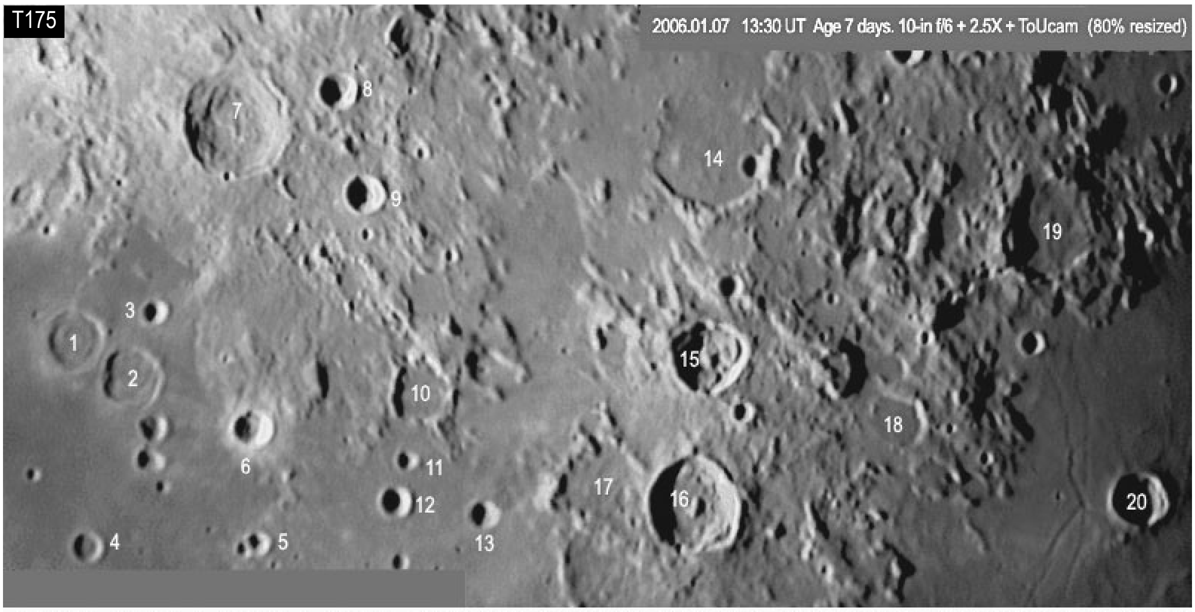
Réaumur 2.4⁰ S 0.7⁰ E
Remains of a crater, diameter 52 km. Part of its rim is lava-flooded and interupted by ***Rima Réaumur*** (30 km) and ***Rima Oppolzer*** (94 km). Both rilles are surface fractures.



1. Triesnecker 2. Rimae Triesnecker 3. Rima Hyginus 4. Ukert 5. Chladni 6. Murchison 7. Pallas 8. Bode 9. Rimae Bode
2009.11.25 10:47 UT Age 8.6 days. 10-inch f/6 Newtonian + 2.5X + DMK31AF03 at 30 frames/sec. (bad seeing, image 80% resized.)



1. Rhaeticus 2. Réaumur 3. Bruce 4. Rima Réaumur 5. Rima Oppolzer 6. Rimae Triesnecker *(partial)*
7. Blagg 8. Seeliger 9. Oppolzer *(partial)* 2004.09.05 21:46UT Age 21 days. 10-in f/6 + 2.5X + 1.6X + ToUcam



1. Sabine 2. Ritter 3. Schmidt 4. Manners 5. Ariadaeus 6. Dionysius 7. Delambre 8. Theon Junior 9. Theon Senior 10. d'Arrest 11. de Morgan 12. Cayley 13. Whewell 14. Lade 15. Godin 16. Agrippa 17. Tempel 18. Dembowski 19. Rhaeticus 20. Triesnecker

Godin 1.8^0 N 10.2^0 E
A rayed crater under high illumination, diameter 34 km. It is fairly irregular, with rough floor and a central peak.

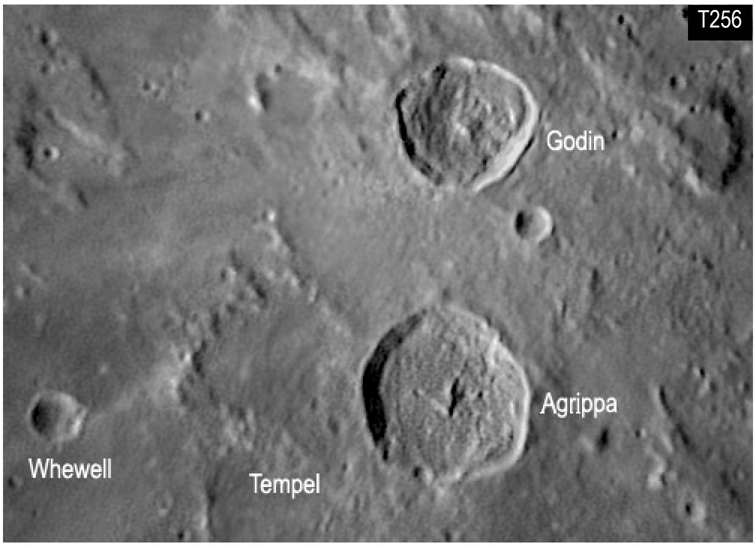
Agrippa 4.1^0 N 10.5^0 E
A crater with central peak from the Eratosthenian period, diameter 44 km. Its north rim is broken by a small crater.

Tempel 3.9^0 N 11.9^0 E
An irregular disintegrated crater adjoining Agrippa, diameter 45 km.

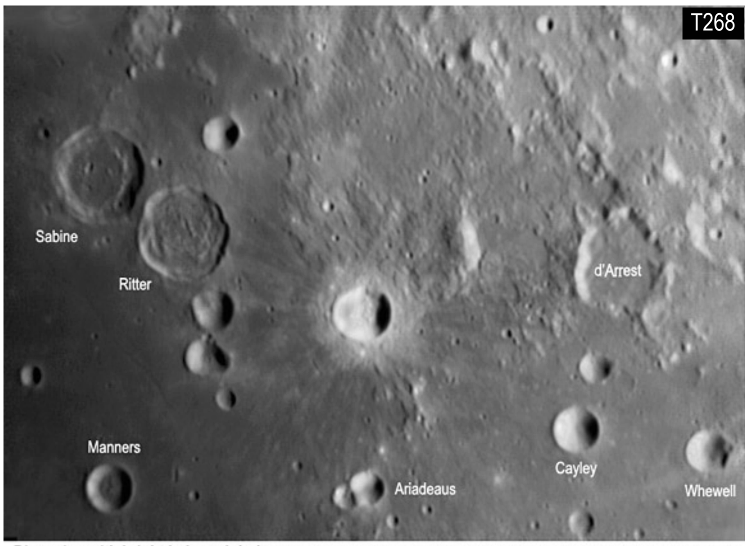
Lade 1.3^0 S 10.1^0 E
A pentagonal flooded crater, diameter 55 km. Its southern wall is nearly overwhelmed in lava. The Moon's equator lies between Lade and Godin.

Dionysius 2.8^0 N 17.3^0 E
A crater with a white halo, very bright during the full moon. It is 18 km in diameter. Close inspection reveals that an additional pattern of 'dark rays' is beneath the white halo. One arm of the dark rays extends across Ritter to the outer rim of Sabine. See also Map 33.

Cayley 4.0^0 N 15.1^0 E
A 14-km bowl-shaped crater, 3 km deep.



Godin & Agrippa 2006.03.09 13:56 UT Age 9.6 days. 10-in f/6 Newtonian + 4X + ToUcam

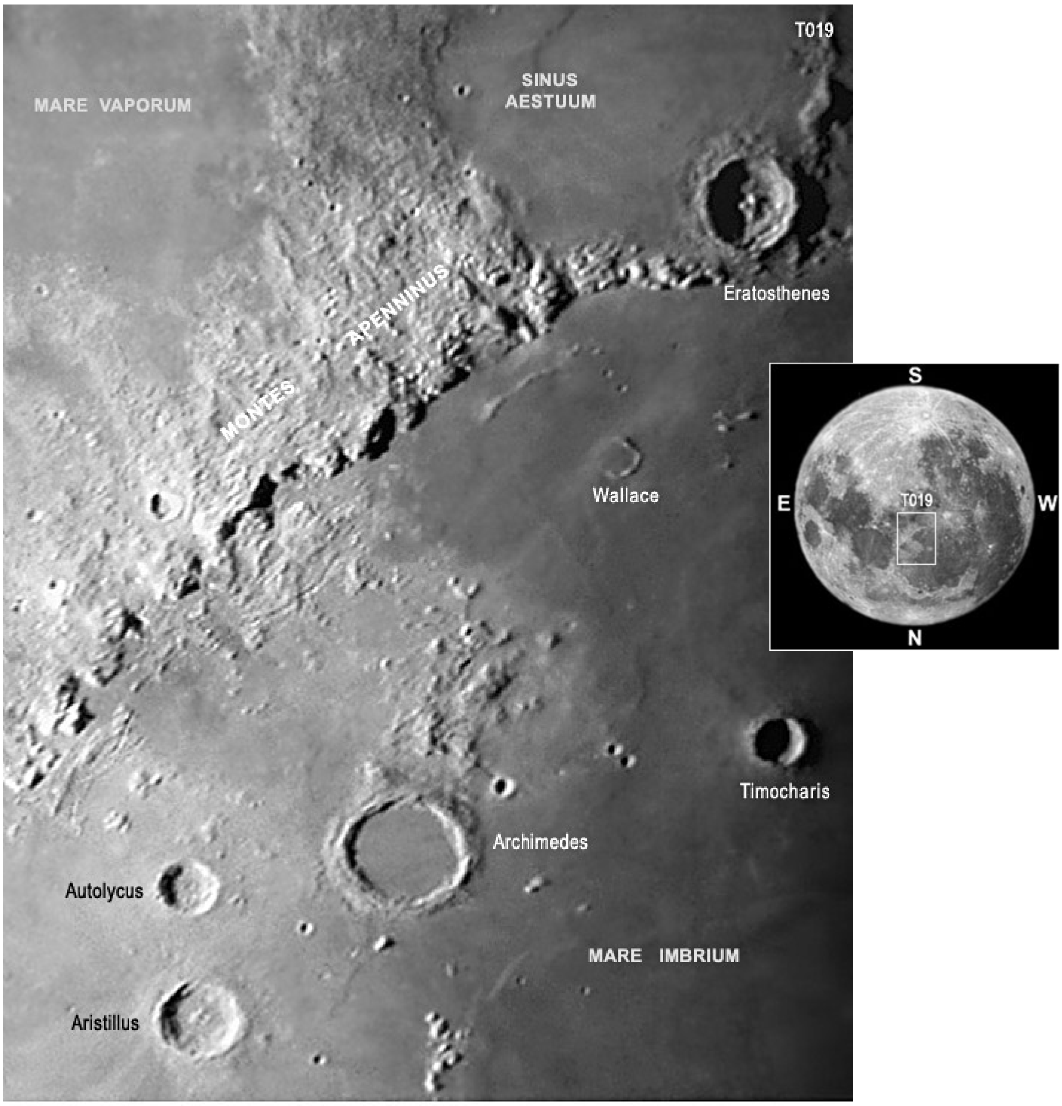


Dionysius with bright halo and dark rays 2006.08.12 20:27 UT Age 19 days. 10-in f/6 Newtonian + 4X + ToUcam

MAP 14

Hatfield 1, 5
Rükl 22, 21 12

Montes Apenninus, Rima Hadley, Archimedes, Aristillus

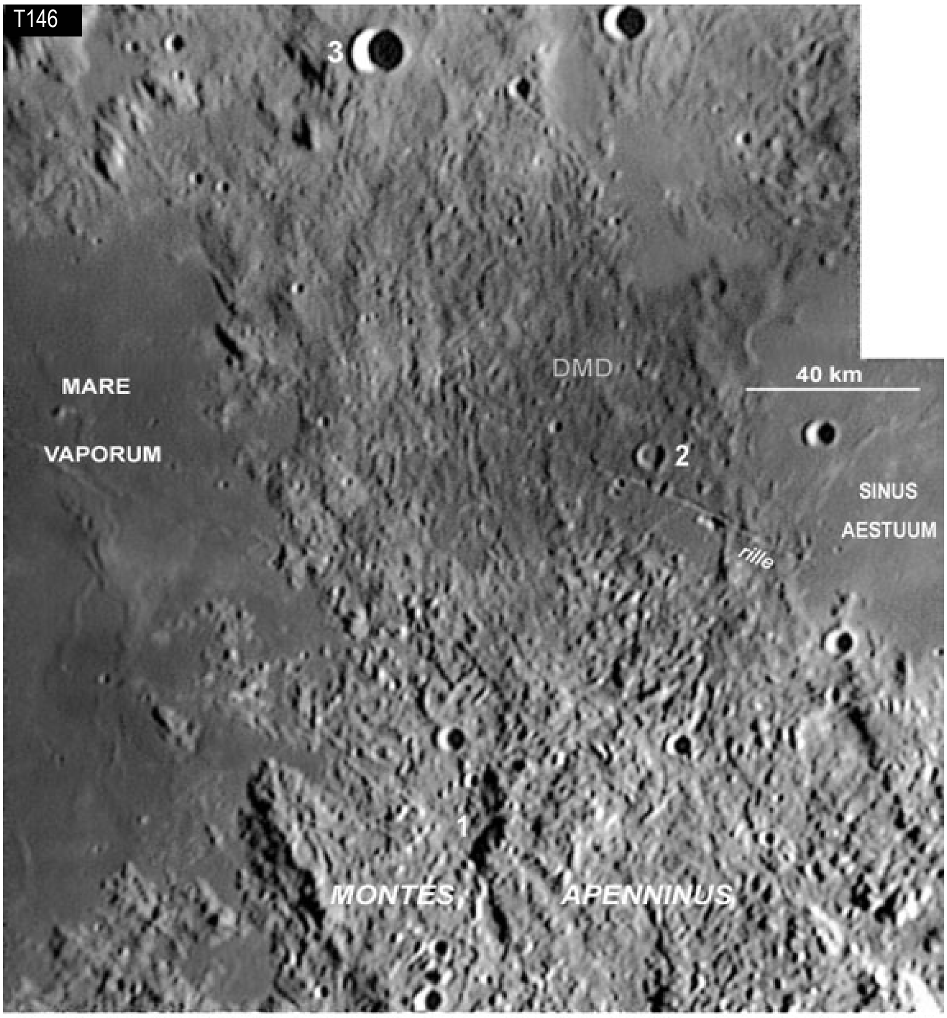


Montes Apenninus & Archimedes 2000.11.05 13:58 UT Age 9 days. FS128 + LE12.5 + QV2300

Montes Apenninus 18.9^0 N 3.7^0 W
The largest mountain range on the nearside of the Moon, named by the Polish astronomer and selenographer Hevelius (1611-1687). It is part of the rising rim of the impact basin that holds Mare Imbrium. Apenninus measures about 450 km end-to-end, 5000 m peak. The mountain slopes facing Mare Imbrium are rather steep (roughly 30^o) but the back slopes towards south are gradual. The back slopes are believed to be massive deposits of ejecta from the Imbrium impact that occurred 3.85 billion years ago.

In T146, the back slope of Apenninus facing Sinus Aestuum contains a linear rille and is darkened by DMD (dark mantle deposits).

> ***Apenninus Bench** refers to the extended terrain between Montes Apenninus and Archimedes in T019. It is noted for its mare-like appearance but not as dark and smooth as Mare Imbrium. The "basalts" sampled by the Apollo 15 near this region show that they do not carry as much iron or titanium, hence have lighter tone than mare basalts. More intricately, these basalts contain the radioactive KREEP elements which are incompatible to common rock-forming process. They indicate non-mare volcanic flows occurring after the Imbrium impact but before the formation of Mare Imbrium. The KREEP basalts, so called afterwards, clearly show volcanism on the Moon is complex.*



Back slopes of Montes Apenninus 1. Macro Polo 2. Bode E 3. Bode A DMD = Dark Mantle Deposit
2004.09.05 21:42 ~ 21:43 UT Age 21 days. 10-in f/6 + 2.5X + 1.6X + ToUcam at 1/25 sec. Mosaic of 2 video clips.

Image T075:

Sinus Aestuum 10.9^0 N 8.8^0 W
Sinus Aestuum (Bay of Billows) is a mare-like lowland where its eastern edge is the slopes of Montes Apenninus, diameter 290 km. Its floor contains concentric wrinkle ridges.

Conon 21.6^0 N 2.0^0 E
A prominent crater on Apenninus, diameter 21 km. Some observers guessed it could be an “oversized” secondary crater produced by the gigantic Imbrium impact. The fairly sinuous ***Rima Conon*** (length 30 km) runs in the south of Conon along the edge of ***Sinus Fidei*** (Bay of Faith).

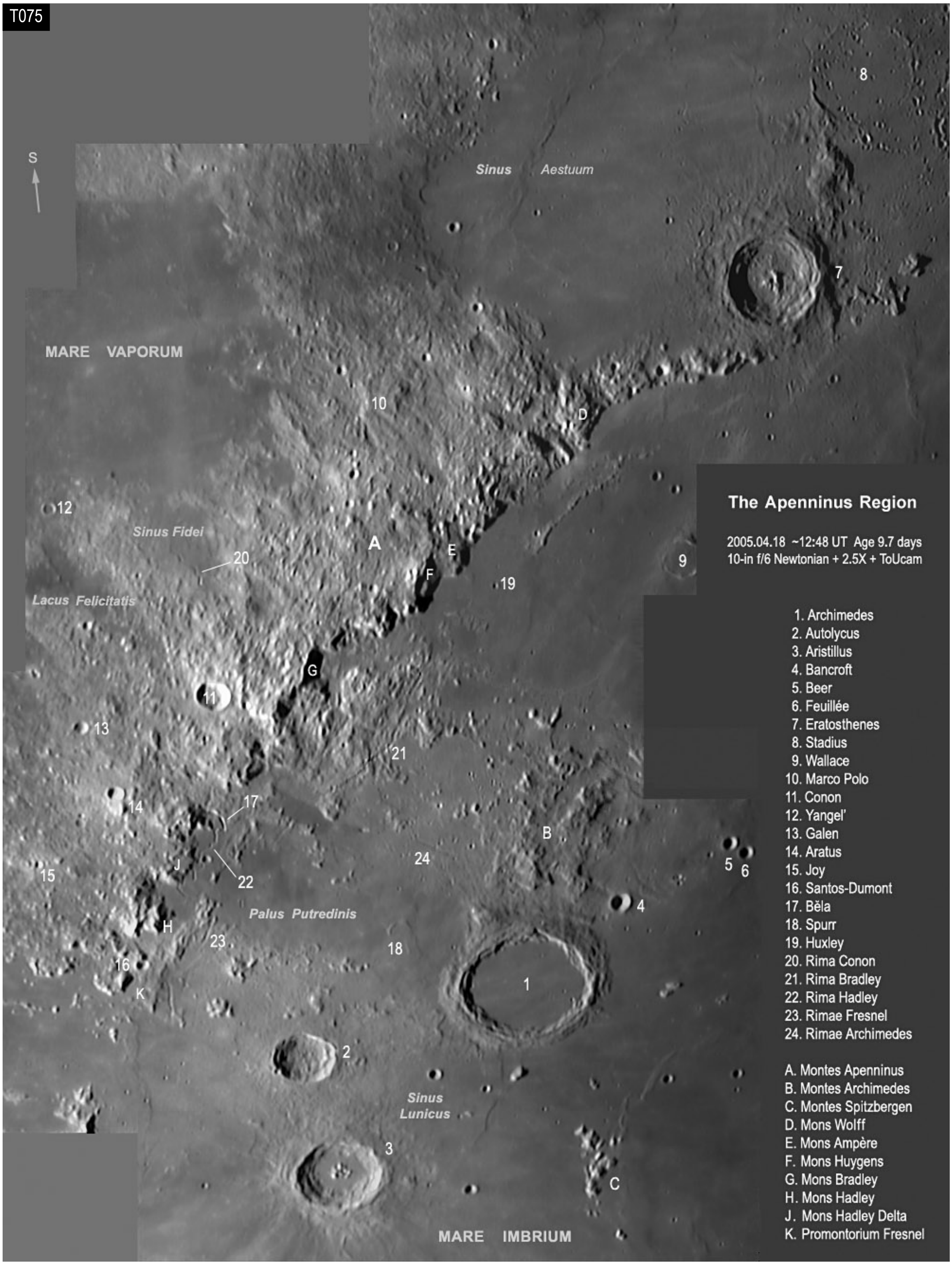
Marco Polo 15.4^0 N 2.0^0 W
An irregular shallow crater on the southern slope of Montes Apenninus, 21 x 28 km.

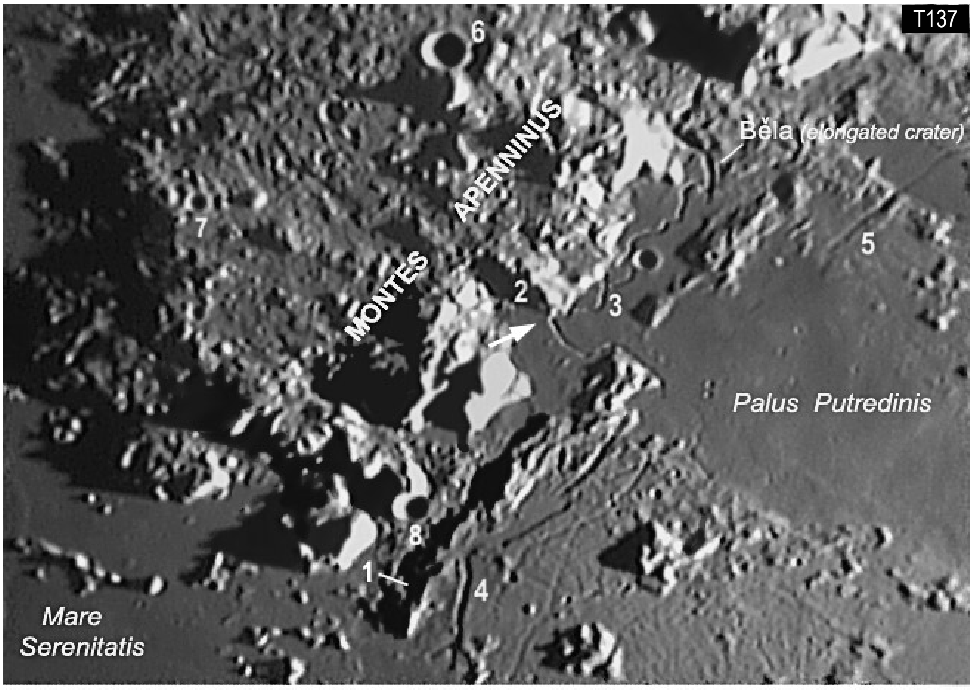
Rima Bradley 23.8^0 N 1.2^0 W
A rille in parallel with Montes Apenninus, length 160 km. It is a fracture caused by stress.

Rimae Fresnel 28.0^0 N 4.0^0 E
A complex of rilles which ends near the spiky cape ***Promontorium Fresnel***, length 90 km. A closer view is shown in T137. It appears to be a continuation of Rima Hadley, but actually it is not.

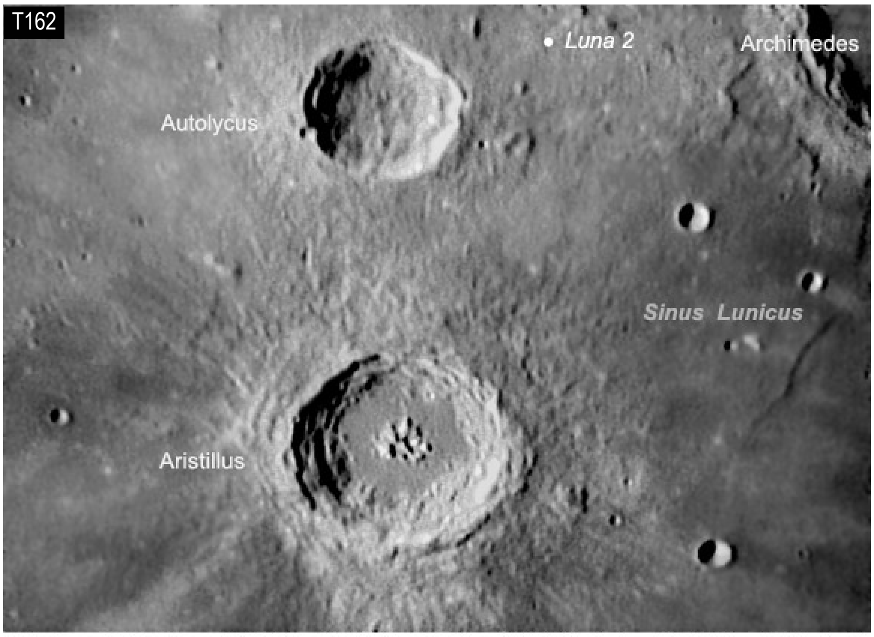
Rima Hadley 25.0^0 N 3.0^0 E

A sinuous rille which begins at the elongated crater ***Běla*** (2 x 11 km). It is a typical lava channel, 80 km long, 1~2 km wide, 300 m deep. On 1971.07.30, two Apollo 15 astronauts landed near this rille. They took its photographs but did not explore because of steep slopes. See also T137.





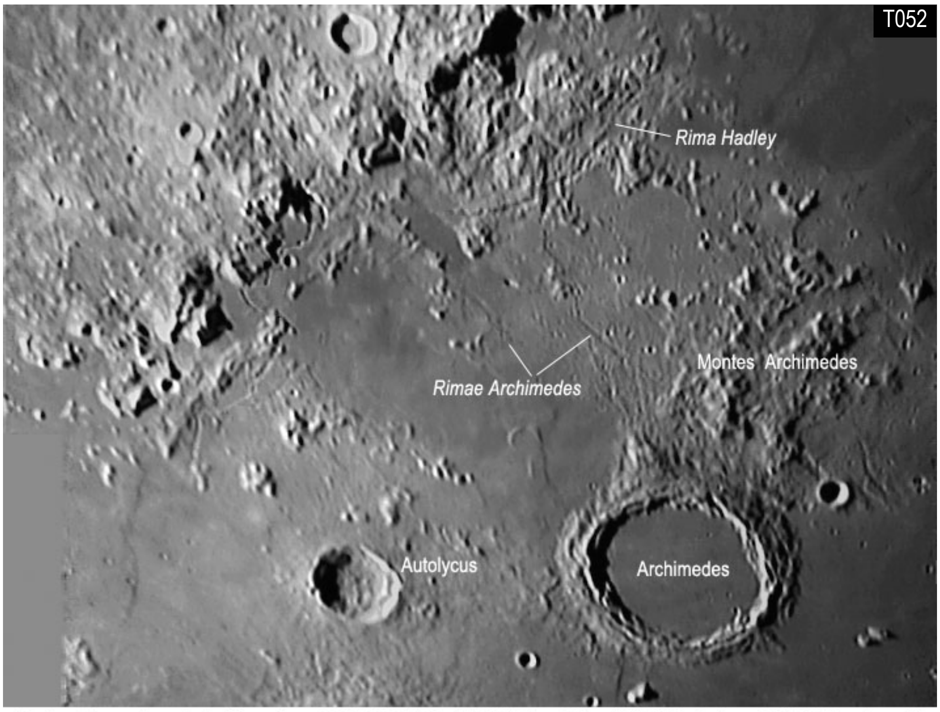
1. Promontorium Fresnel 2. Mons Hadley Delta 3. Rima Hadley 4. Rimae Fresnel 5. Rima Bradley (partial)
6. Aratus 7. Joy 8. Santos-Dumont 2004.09.05 21:26 UT Age 21 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam
(The arrow points to the landing site of Apollo 15.)



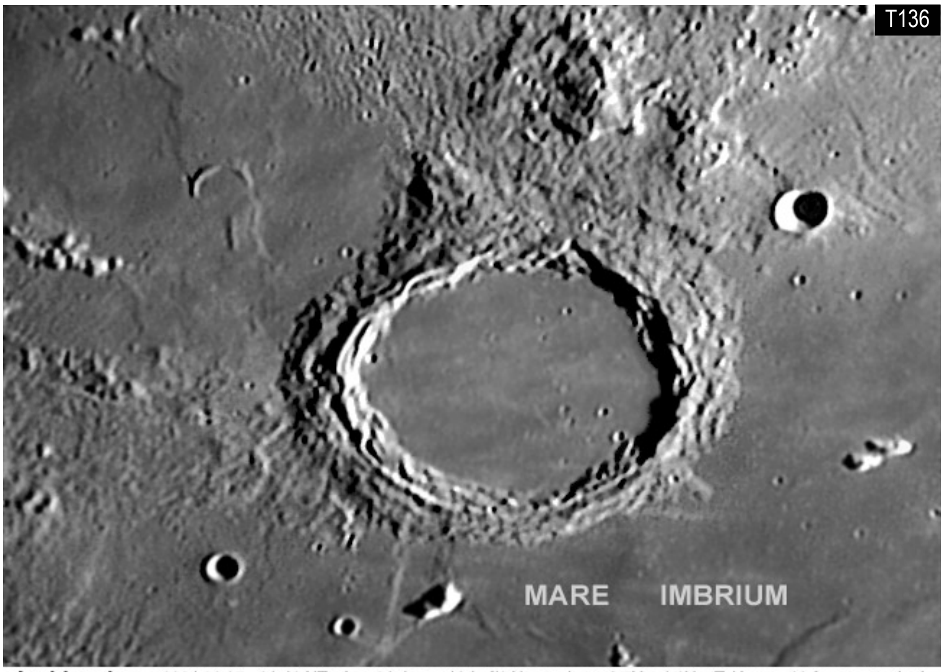
Autolycus & Aristillus 2005.11.11 13:04 UT Age 9.5 days. 10-in f/6 Newtonian + 4X + ToUcam (85% resized)

Autolycus 30.7^{0}N 1.5^{0}E **Aristillus** 33.9^{0}N 1.2^{0}E
A prominent crater pair in the Apenninus region. Autolycus has a rough floor with disintegrated central peaks, diameter 39 km. Aristillus has wide ejecta blanket, terraced inner walls and multiple central peaks, diameter 55 km. A ghost crater is also beneath the ejecta blanket of Aristillus (shown in T120, Map 15.) Both craters are centers of bright rays under high illumination.

In 1959, the Soviet probe Luna 2 hit the Moon on the edge of ***Sinus Lunicus*** (Bay of Luna) near Autolycus. Luna 2 is the first man-made object to reach the Moon surface.



Montes Apenninus & Archimedes 2004.06.26 14:06~14:09 UT Age 9 days. 10-in f/6 Newtonian + 2.5X + ToUcam (*mosaic*)



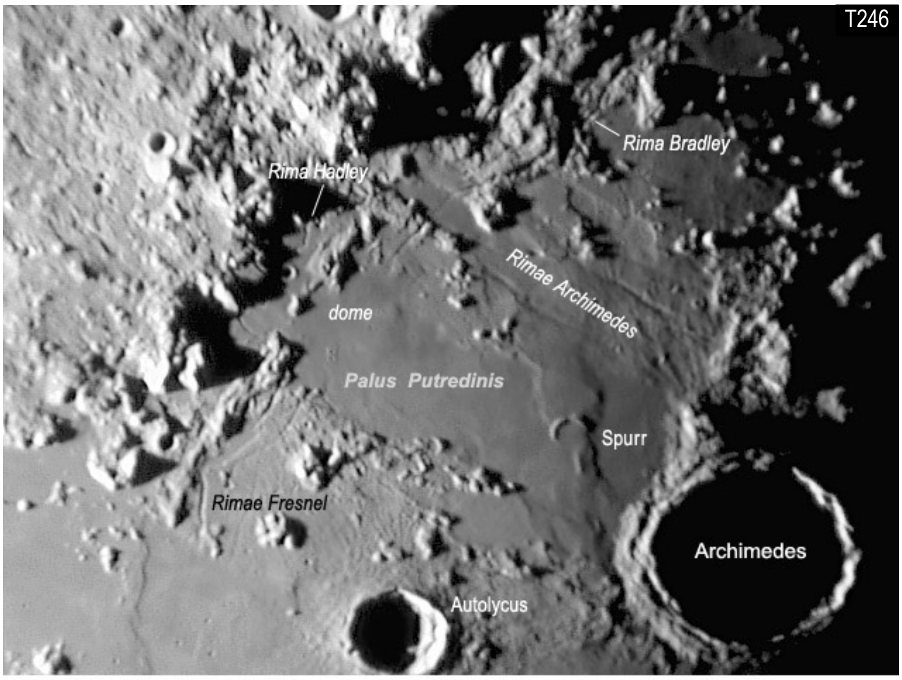
Archimedes 2004.09.05 21:40 UT Age 21 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam, 69 frames stacked.

Archimedes 29.7^0 N 4.0^0 W
A large flooded crater in the early Imbrium period. It has terraced walls, diameter 82 km and depth 2100 m. Its size suggests central peaks once existed, but they were buried by the same lava in Mare Imbrium. The ejecta blanket of Archimedes is also buried partially in lava. This makes the crater rim to look bulgy. A prominent triangular cape extends 30 km almost connecting ***Montes Archimedes***.

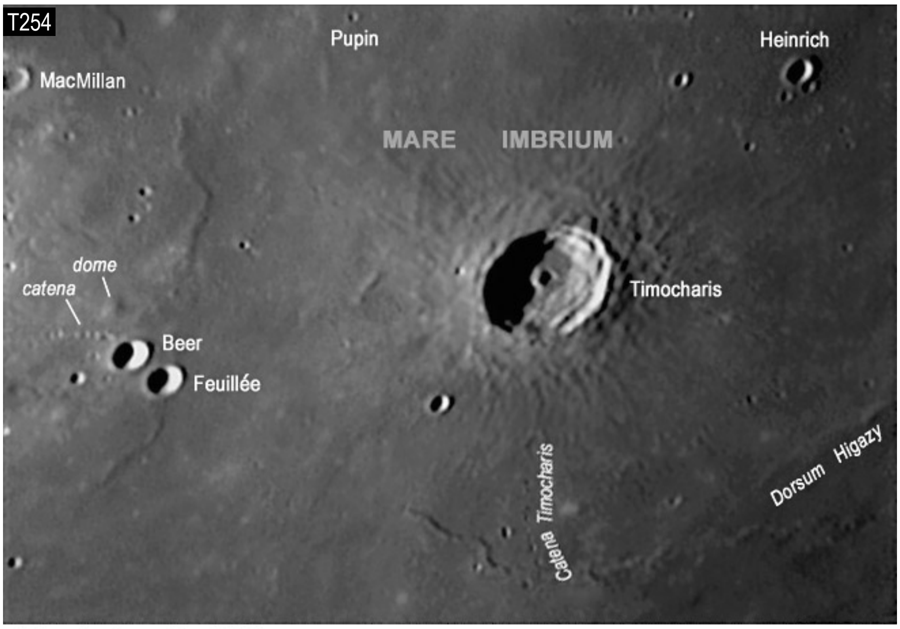
Rimae Archimedes 26.6^0 N 4.1^0 W
A system of thin rilles running between the cap of Archimedes and Montes Apenninus, length 170 km. At least two rilles are visible in small telescopes.

Palus Putredinis 26.5^0 N 0.4^0 E

Palus Putredinis (Marsh of Decay) is a small mare facing Montes Apenninus, 160 km east-west. Note the dome and the thicker lava flow to the south of ***Spurr***, the remains of a flooded crater.



Palus Putredinis 2005.11.09 12:41 UT Age 7 days. 10-in f/6 Newtonian + 4X + ToUcam



Timocharis and its vicinity 2006.03.09 13:26 UT Age 9.6 days. 10-inch f/6 Newtonian + 4X + ToUcam

Timocharis 26.7^0 N 13.1^0 W

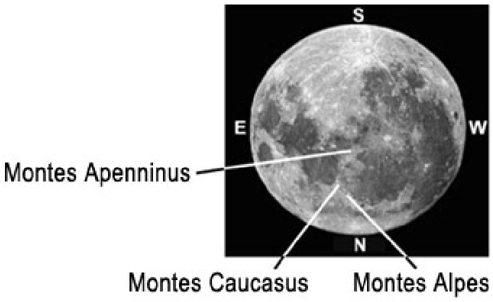
A sharp rim crater at the west of Archimedes, diameter 33 km. It has terraced walls and a small crater on the central floor. To the north is ***Catena Timocharis***, a chain of craterlets barely resolved under low Sun angles. Timocharis emits bright rays under high illumination.

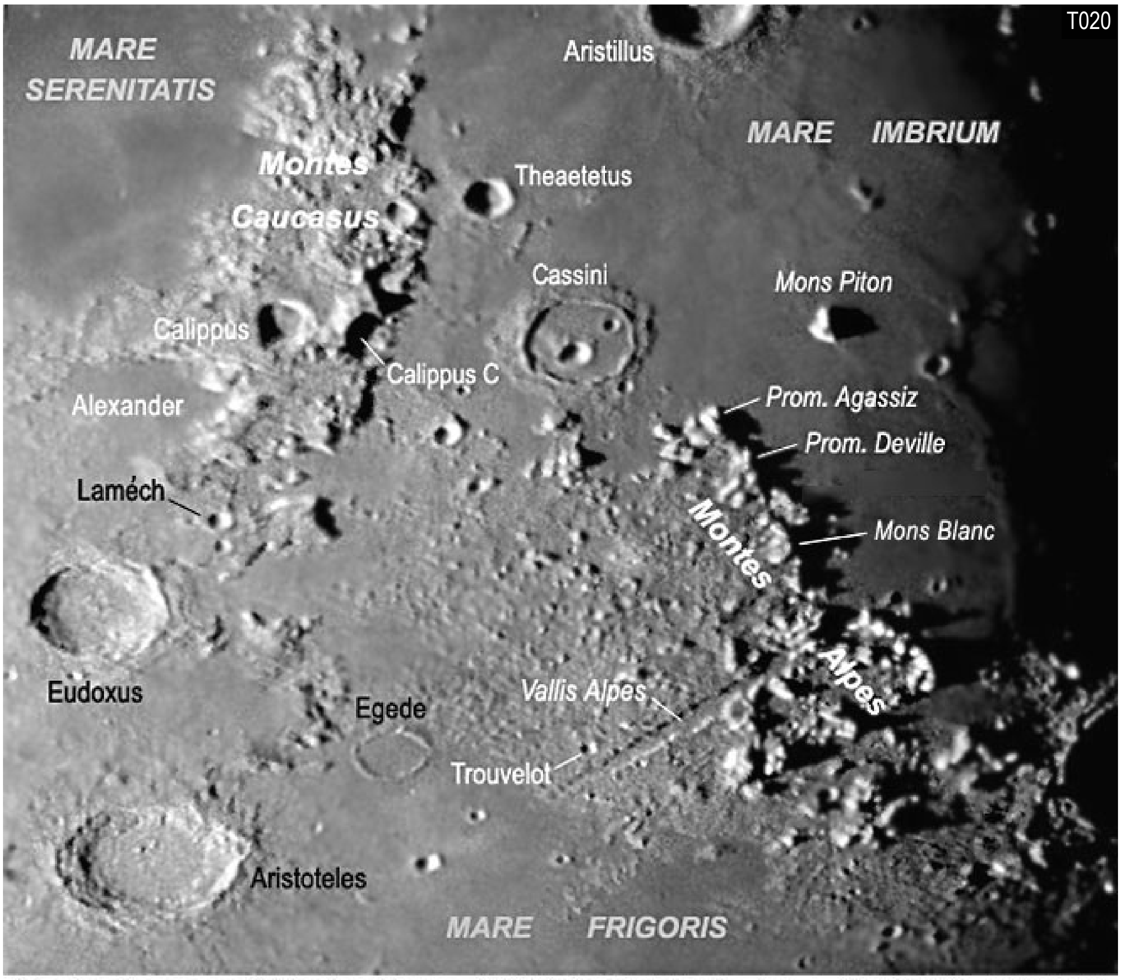
Beer 27.1^0 N 9.1^0 W **Feuillée** 27.4^0 N 9.4^0 W

A close pair of bowl-shaped craters, each about 9 km in diameter. A dome and a catena can be spotted near Beer under very oblique sunlight.

Montes Caucasus, Calippus, Eudoxus, Aristoteles, Montes Alpes, Vallis Alpes, Cassini

Hatfield 2
Rükl 13,12, 5, 4



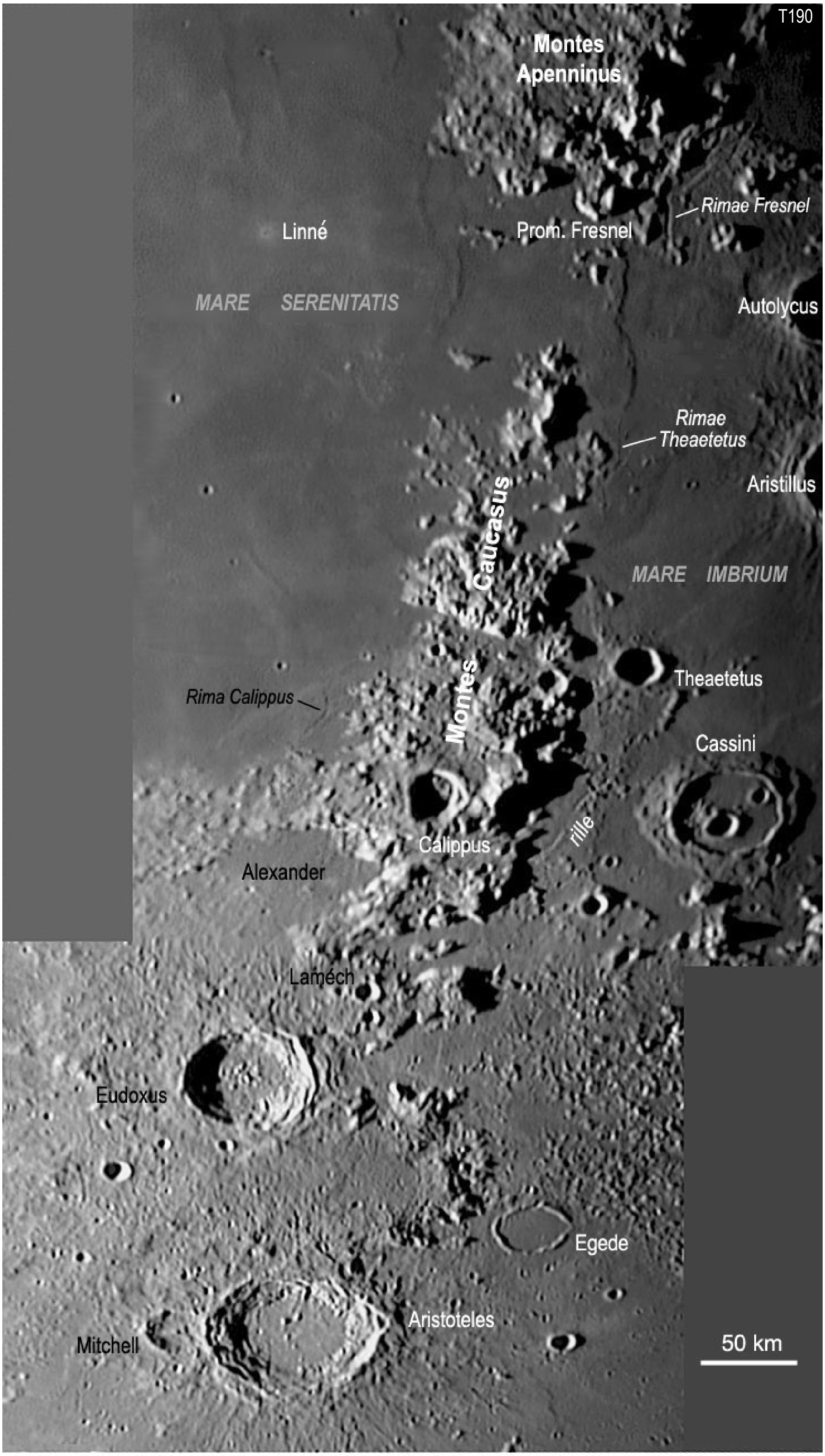


Montes Caucasus & Montes Alpes 2001.09.25 12:57 UT Age 8 days. C9 + CP990 (*DSCN9804*)

Montes Caucasus 38.4^{0}N 10.0^{0}E

A rugged mountain range between Mare Serenitatis in the east and Mare Imbrium in the west. The southern half of the range has several breaks intruded by mare lava. It measures 445 km north-south, height up to 6000 m. It is the highest montes on the nearside of the Moon. Standing on the highest peak, an observer could see distant land at least 140 km away*, including part of Cassini which has a raised floor. Montes Caucasus appears once united with Montes Apenninus but a channel of mare lava separated them subsequently, see Image T190 in next page.

** Horizon radius ≈ square root of (altitude of eye-level* x *diameter of the Moon)*



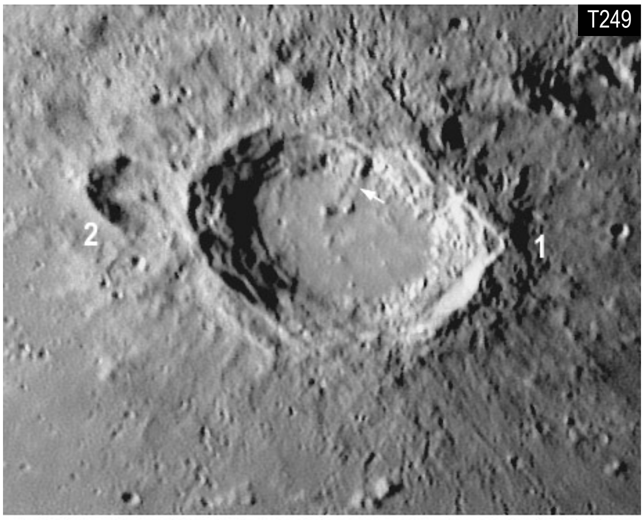
Montes Caucasus, Cassini, Eudoxus & Aristoteles 2004.12.19 ~13:09 UT Age 7 days. 10-in f/6 + 2.5X + ToUcam (*mosaic*)

Calippus 38.9^{0} N 10.7^{0} E
A crater on the highlands of Montes Caucasus, diameter 32 km. Its eastern wall looks linear. Its western wall is slided. ***Calippus C*** (40 km) is a bay-shaped crater facing Mare Imbrium.

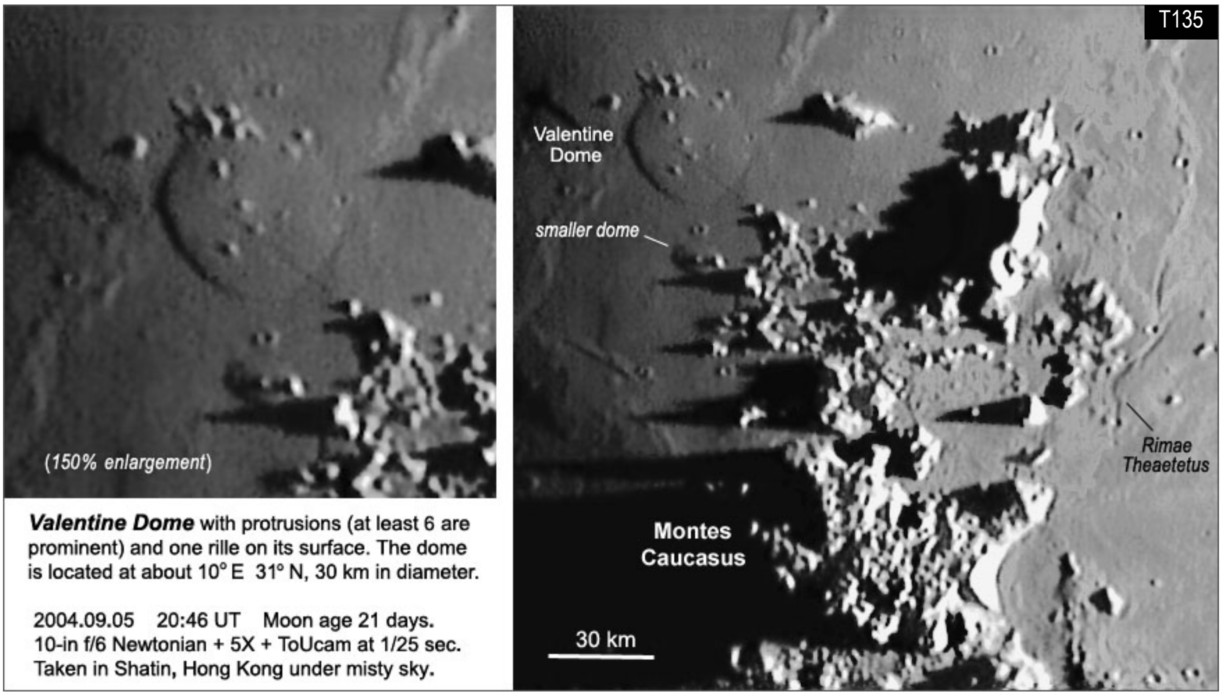
Alexander 40.3^{0} N 13.5^{0} E
A heavily eroded walled plain, diameter 81 km. Its northeastern wall is obliterated.

Eudoxus 44.3^{0} N 16.3^{0} E
A crater with terraced walls and small irregularties on the floor, 67 km in diameter, 3400 m deep. It is often described with Aristoteles as a twin.

Aristoteles 50.2^{0} N 17.4^{0} E
A crater from the Eratosthenian period, with terraced walls and small central peaks, 87 km in diameter, 3300 m deep. A triangular landslide is found on the western wall. The southern wall is interuppted by a weird chain of craterlets. The eastern wall adjoins ***Mitchell*** (30 km) which has a central rise on its floor.



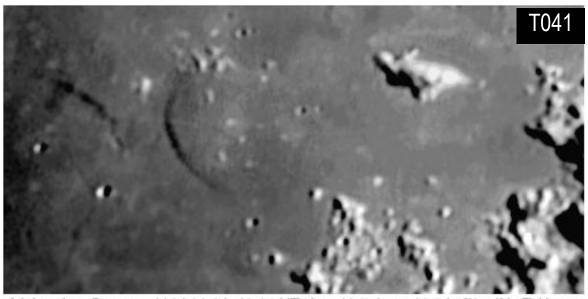
1. Aristoteles **2. Mitchell** The arrow points to a chain of craterlets.
2005.11.09 11:04 UT Age 7.4 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam.



Valentine Dome with protrusions (at least 6 are prominent) and one rille on its surface. The dome is located at about 10° E 31° N, 30 km in diameter.

2004.09.05 20:46 UT Moon age 21 days.
10-in f/6 Newtonian + 5X + ToUcam at 1/25 sec.
Taken in Shatin, Hong Kong under misty sky.

Valentine Dome (nickname)
A very low-height, circular plateau near the southern end of Montes Caucasus. Together with the nearby smaller dome, they are noticeable only at very low Sun angles. T135 was taken one day after T041.

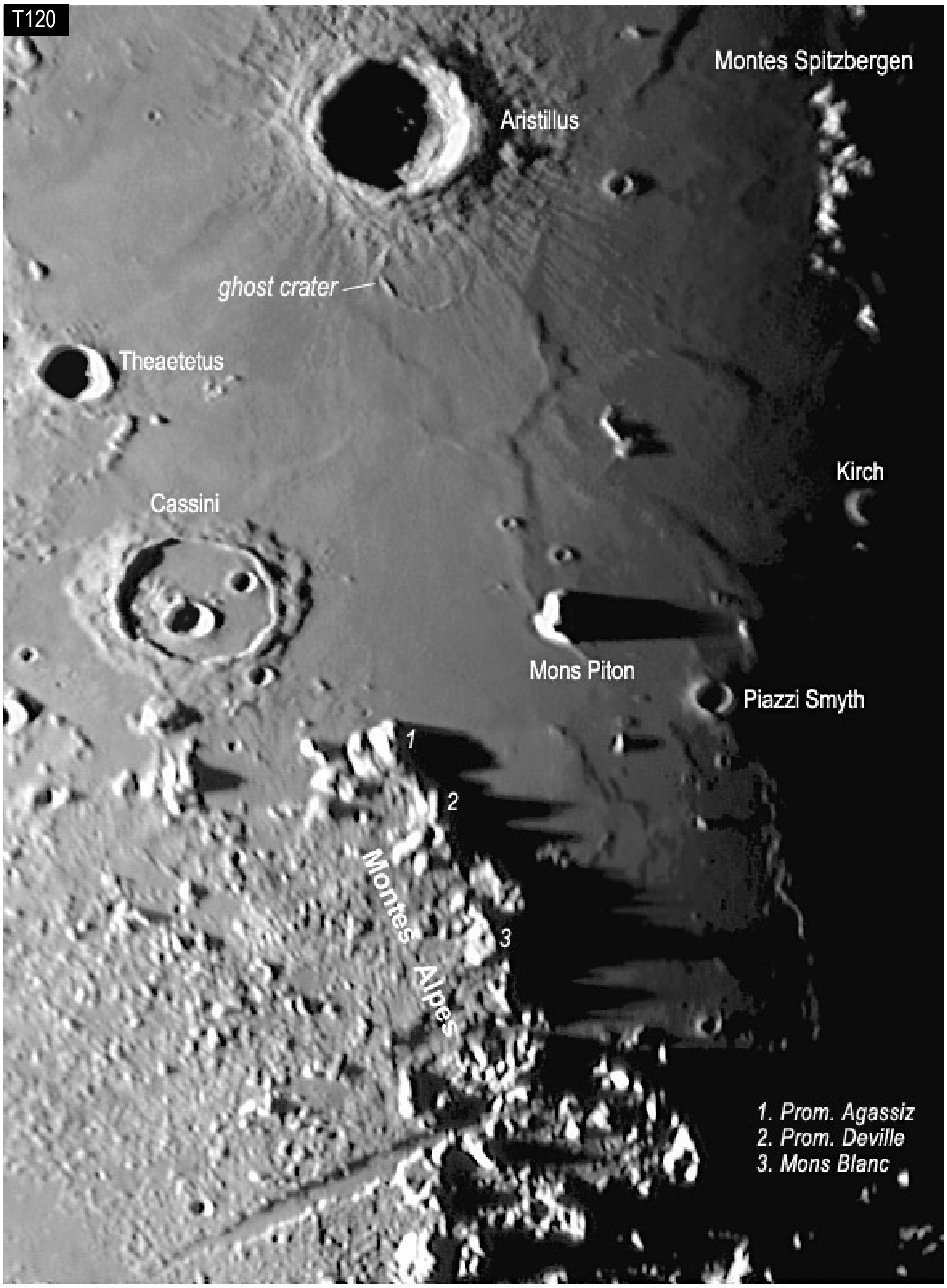


Valentine Dome 2004.09.04 19:21 UT Age 19.7 days. 12.5-in f/6+4X+ToUcam

Montes Alpes 46.4^0 N 0.8^0 W
A mountain range named by the Polish astronomer Hevelius (1611-1687) on the northeast edge of Mare Imbrium, length 280 km and average height 2400 m. It is part of the rising rim of the Imbrium basin. The southern section of Montes Alpes has two capes named ***Promontorium Agassiz*** and ***Promontorum Deville***. Under low Sun angles, the mountain peaks cast a forest of spectacular spiky shadows.

Mons Blanc (Mont Blanc) 45.0^0 N 1.0^0 E
The highest mountain in Montes Alpes, as suggested by the longest shadow in T120. It rises 3600 m peak, base 25 km.

Mons Piton 40.6^0 N 1.1^0 W
An isolated mountain on Mare Imbrium, 2300 m high, base 25 km. It casts a long shadow under low illumination. In T120, note the ghost crater on the ejecta blanket of Aristillus.

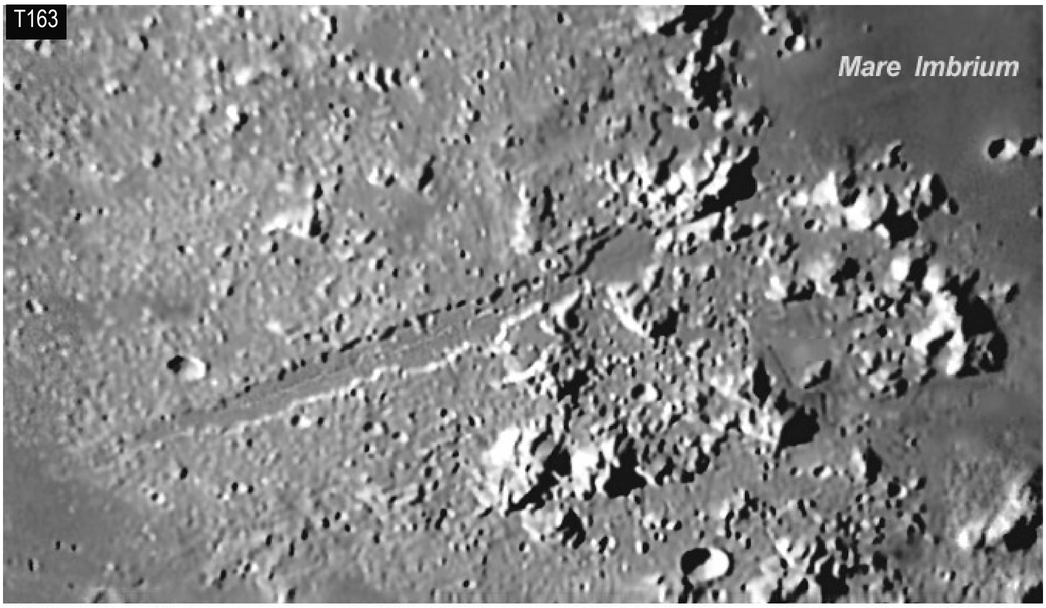


Shadows of Montes Alpes and Mons Piton 2005.11.09 12:00UT Age 7.4 days. 10-in f/6 + 2.5X + ToUcam

Vallis Alpes 48.5^0 N 3.2^0 E

Vallis Alpes is a prominent landmark, length 166 km and width up to 11 km. It is radial to Mare Imbrium, appearing like a blade to bisect Montes Alpes. Under appropiate illumination and good seeing condition, a very narrow central cleft can be spotted with an 8-inch telescope. Vallis Alpes is a graben (sunken area between faults) produced at the time of the Imbrium basin-forming impact. The valley was subsequently filled by volcanic material. The central cleft is roughly 500 m in width and could be a lava channel running downhill along the back slope of Alpes.

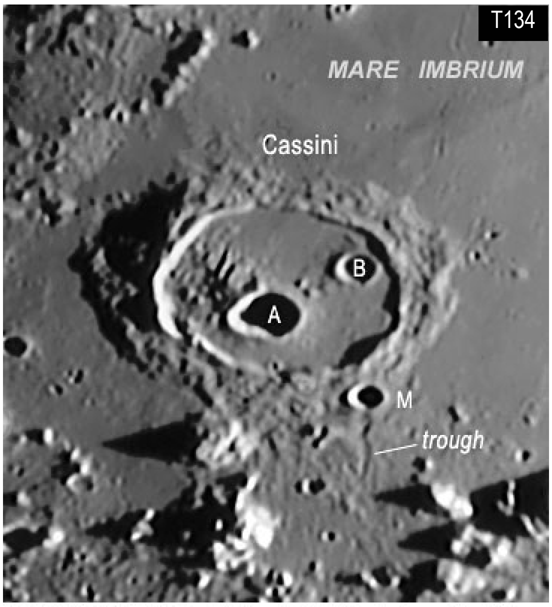
Vallis Alpes 2004.09.05 21:31 ~ 21:33 UT Age 21 days. 10-in f/6 + 2.5X + 1.6X + ToUcam



Vallis Alpes & its narrow central cleft. 2005.11.11 13:22 UT Age 9.5 days. 10-in f/6 Newtonian + 4X + ToUcam

Cassini 40.2^0 N 4.6^0 E

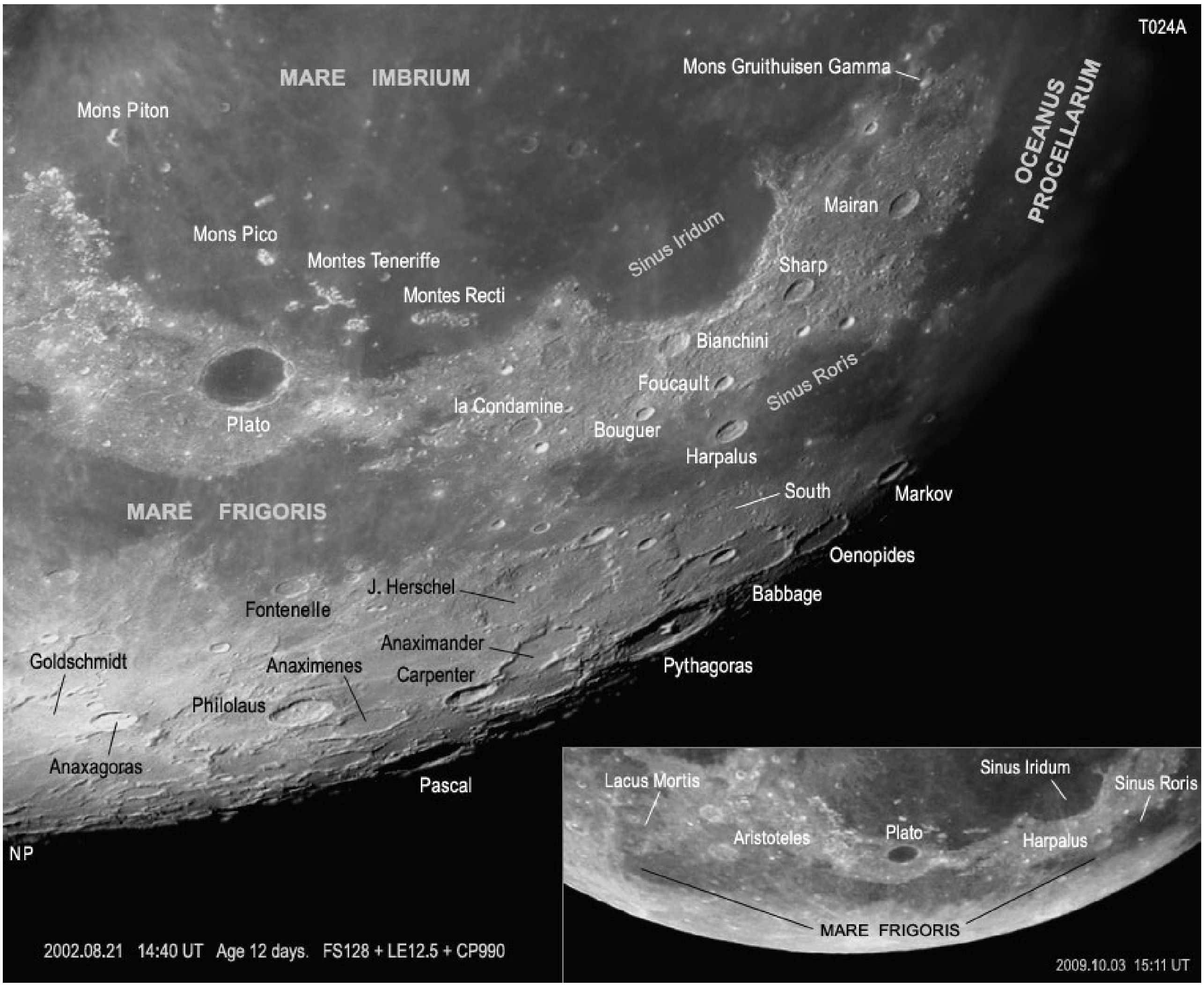
A prominent crater between Montes Caucasus and Montes Alpes, diameter 56 km. Its outer ejecta blanket is submerged in lava; hence the crater rim looks bulgy. The floor is flooded and slightly raised, leaving a hilly ridged area between the rim and the internal crater ***Cassini A*** (15 km). ***Cassini B*** (9 km) is another internal crater. ***Cassini M*** (8 km) is located on the ejecta blanket where a prong-shaped trough extends northward for a distance of some 20 km. A broken rille is located between Cassini and Calippus (Image T190).



2004.09.05 21:30 UT Age 21 days. 10-in f/6 Newtonian + 4X + ToUcam

Mare Frigoris, Plato, Mons Pico, W. Bond, Meton, NP Region

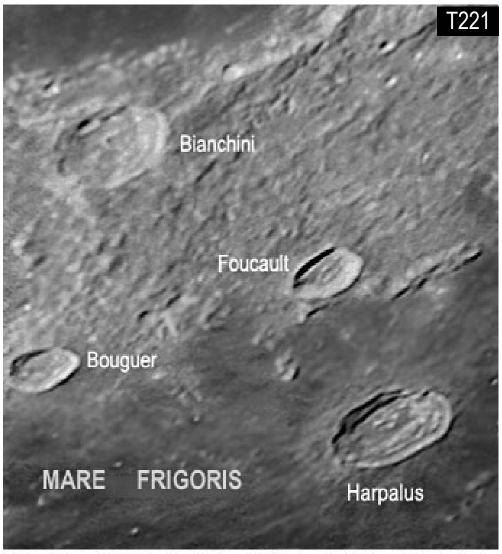
Hatfield 6, 2
Rükl 5, 4, 3, 2, 11



2002.08.21 14:40 UT Age 12 days. FS128 + LE12.5 + CP990

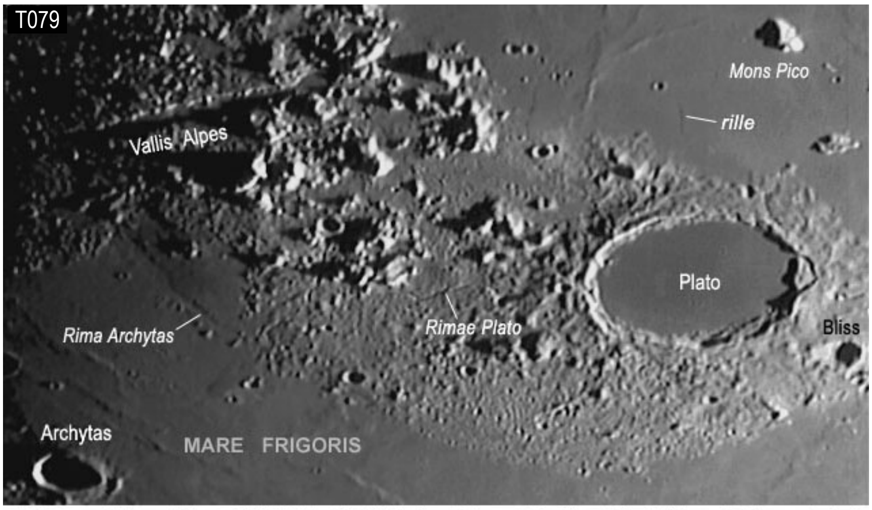
2009.10.03 15:11 UT

Mare Frigoris (Sea of Cold) 56.0^0 N 1.4^0 E
While lunar maria generally tend to be circular in shape, Mare Frigoris is not. It extends roughly 300 km north-south and 1,600 km east-west between Lacus Mortis and Sinus Roris, see the inlet of Image T024A. The formation of Mare Frigoris is not ascertained. Some geologists suggested that it could be part of the lava-filled depression that belongs to the outmost circumference of the gigantic Imbrium impact; the other parts of depression including Mare Vaporum, Sinus Aestuum and perhaps, the eastern portion of Oceanus Procellarum. There is no notable crater within Mare Frigoris except ***Aristoteles*** (87 km) in the east and ***Harpalus*** (39 km) in the west.



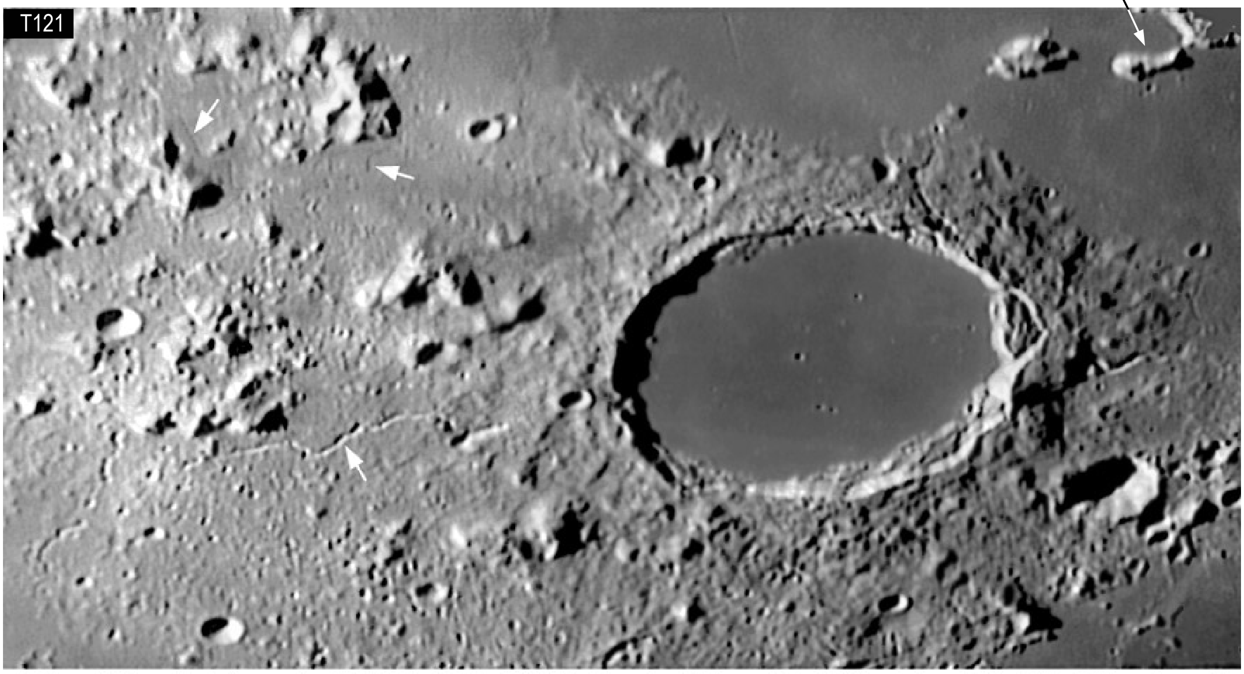
2005.05.22 15:02UT Age 14 days. 10-in f/8+5X+ToUcam (70% resized)

Sinus Roris (Bay of Dew) 54.0^0 N 56.6^0 W
A dark lava plain between Mare Frigoris and Oceanus Procellarum, size up to about 200 km.



Plato and Mons Pico 2004.08.07 20:27 UT Age 22 days. 10-in f/6 + 2.5X + ToUcam. 27 frames stacked.

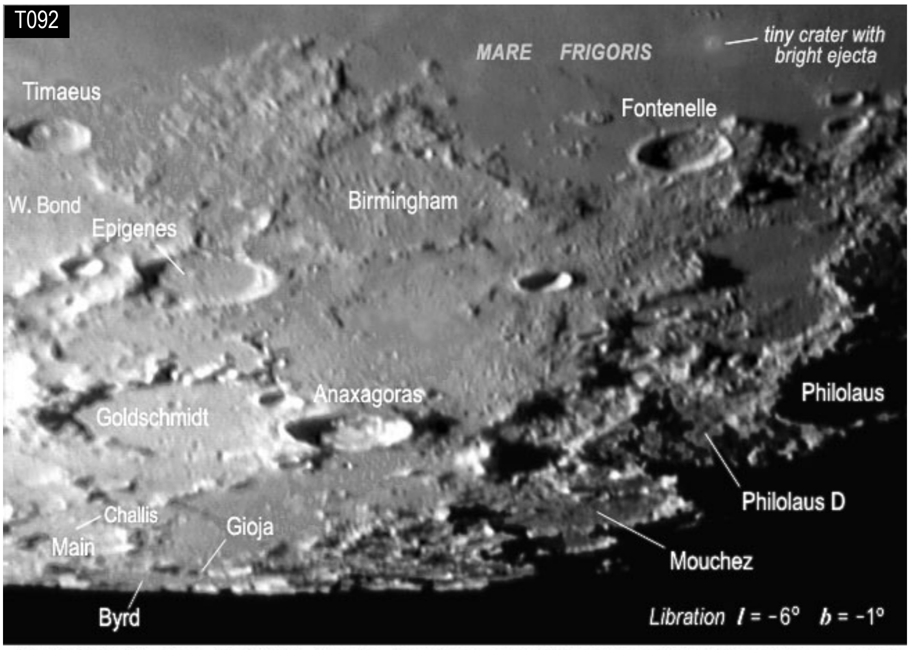
2004.06.27 14:23UT Age 10 days (10-in f/6)



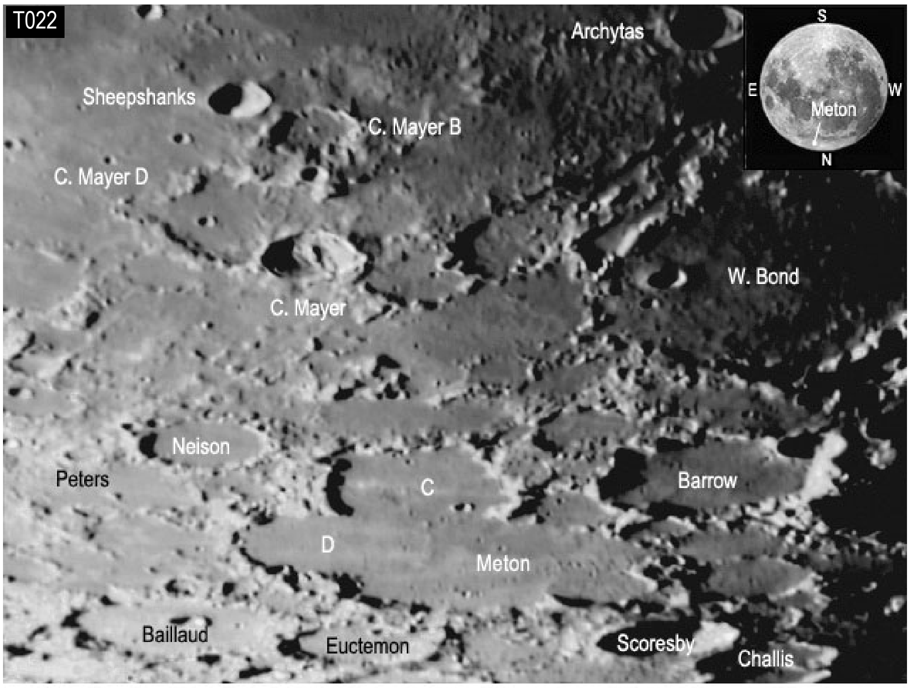
Plato and Rimae Plato (*arrows*) 2005.11.11 13:08 ~ 13:10 UT Moon Age 9.5 days. 10-inch f/6 Newtonian + 2.5X + 1.6X + ToUcam (*mosaic*)

Plato 51.6^0 N 9.4^0 W
Plato is a walled plain nicknamed the 'Great Black Lake', 109 km in diameter, 1000 m deep. It is one of the darkest surface features, even in the full moon. Its lava-filled floor looks flat and blank, but tens of craterlets are detectable using big telescopes under good seeing. When the terminator approaches Plato, spiky shadows cast on the floor. There are two triangular landslides on Plato's rim; similar landslides also seen in Aristoteles Map 15 and Gassendi Map 24. ***Rimae Plato*** (T121) is a system of rilles in three isolated sections. The main section is nearest to Plato, length 87 km. It is thought to be a tributary of lava flow.

To the south of Plato is an oval ghost ring known as 'Ancient Newton' in the past. (Note: The modern 'Newton' refers to a crater near the south pole, Map 11). ***Mons Pico*** (15x25 km, height 2400 m) just sits on the ghost ring. ***Montes Teneriffe*** is a small group of mountains with similar height. In T024A, the arcuate alignment of Mons Piton, Mons Pico, Montes Teneriffe and Montes Recti suggests they could be the highland remnants from a submerged ring of the Imbrium basin.



North Pole Region 2004.06.27 14:25 UT Age 10 days. 10-in f/6 Newtonian + 2.5X + ToUcam, 3 frames stacked.



Meton & Vicinity 2009.05.02 13:47 UT Age 7 days. 10-inch f/6 Newtonisn + 2.5X + ToUcam

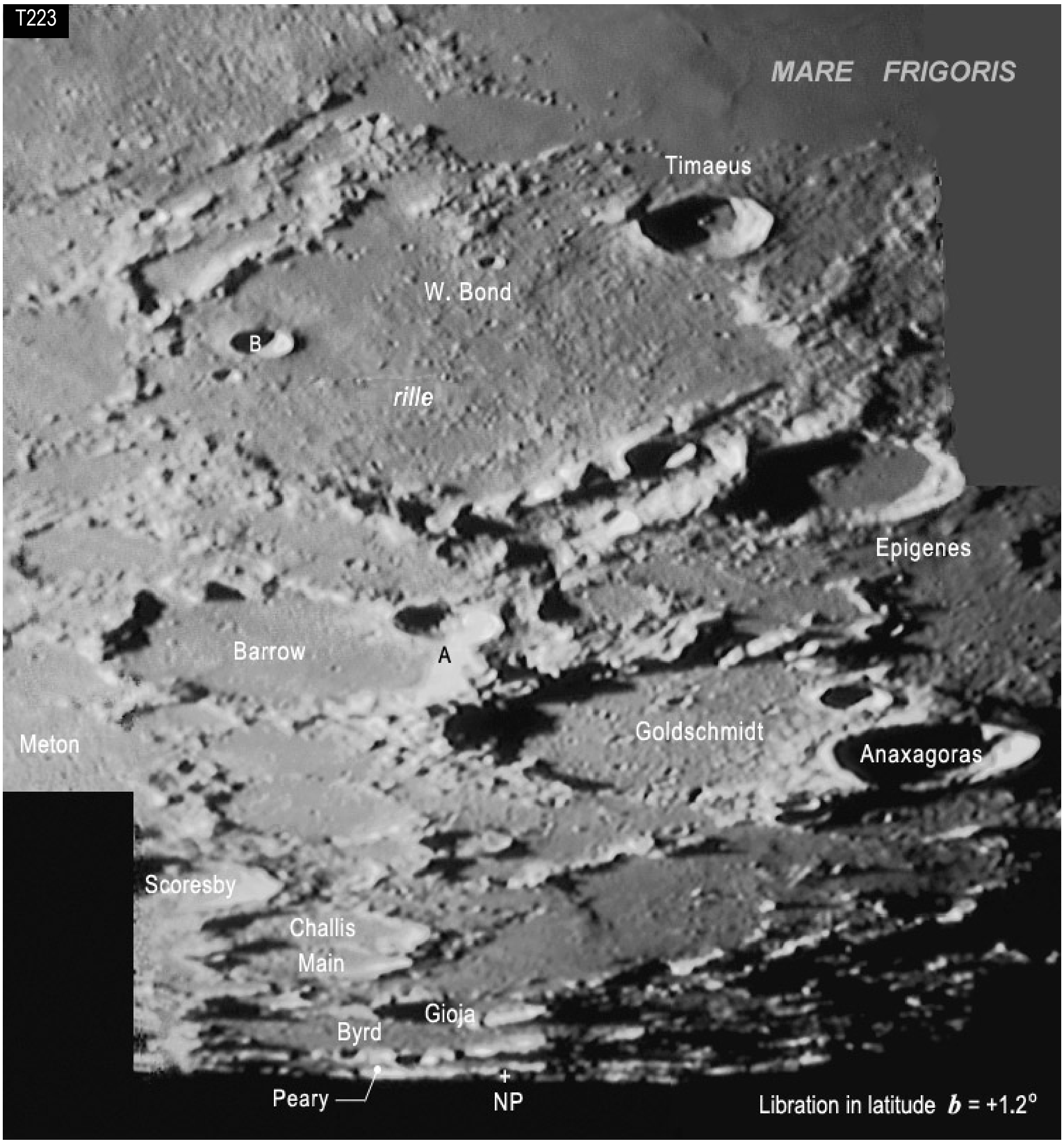
Fontenelle 63.4^0 N 18.9^0 W
A 38-km crater with notched rim and small peaks. It looks oval due to foreshortening.

Birmingham 65.1^0 N 10.5^0 W
A heavily ruined crater, diameter 92 km.

Epigenes 67.5^0 N 4.6^0 W
A crater with off-centered peaks, diameter 55 km.

Meton 73.6^0 N 18.8^0 E
Remains of a vast walled plain, diameter 130 km.
It overlaps with 2 flooded craters, ***Meton C*** (77 km) and ***Meton D*** (78 km).

Remark: *Meton is a Greek astronomer in the fifth century BCE. He is best known for the discovery of “Metonic cycle”, a period of 19 solar years or 235 lunar months after which the Moon’s phases repeat on approximately the same calendar dates.*



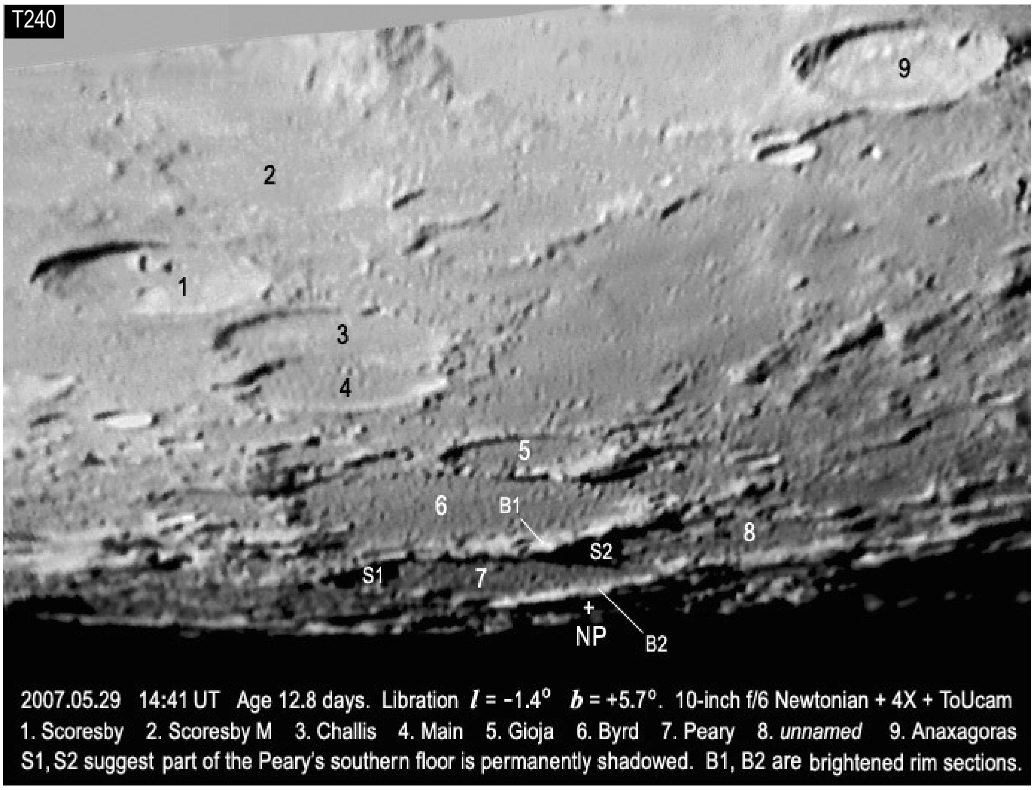
W. Bond & North Pole Region 2007.05.25 ~11:43 UT Age 8.7 days. 10-in f/6 Newtonian + 4X + ToUcam.

W. Bond 65.4^0 N 4.5^0 E
A vast walled plain, diameter 156 km. Its southwest rim is interrupted by ***Timaeus*** (32 km). A large part of its floor is covered by debris ejected from the gigantic Imbrium impact. The floor also contains a nameless rille.

Barrow 71.3^0 N 7.7^0 E
A 92-km walled plain. Its southwest rim is interrupted by ***Barrow A*** (28 km).

Anaxagoras 73.4^0 N 10.1^0 W
A 50-km crater. At high illumination, it emits bright rays up to Plato (Image T024A).

Goldschmidt 73.2^0 N 3.8^0 W
A 113-km crater interrupted by Anaxagoras. Its outer walls are very rugged. In 2009, scientists found the regolith of this crater carrying traces of water molecules although their abundance was not known precisely.



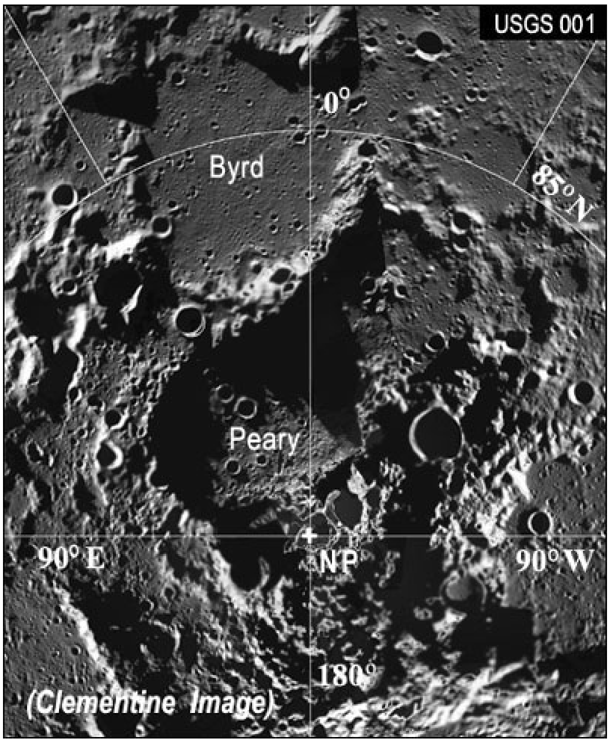
(Reference: http://www.lpi.usra.edu/meetings/lpsc2004/pdf/1387.pdf)

Scoresby 77.7^0 N 14.1^0 E
A 55-km crater with two low hills and a small crater inside the floor. Scoresby M (54 km) is a shallow crater in the south-west vicinity.

Gioja 83.3^0 N 2.0^0 E
A 41-km crater. Its western rim is heavy eroded.

Byrd 85.3^0 N 9.8^0 E
A 93-km walled plain connecting Gioja. It eastern and western walls are heavily eroded. Its floor is peppered with craterlets.

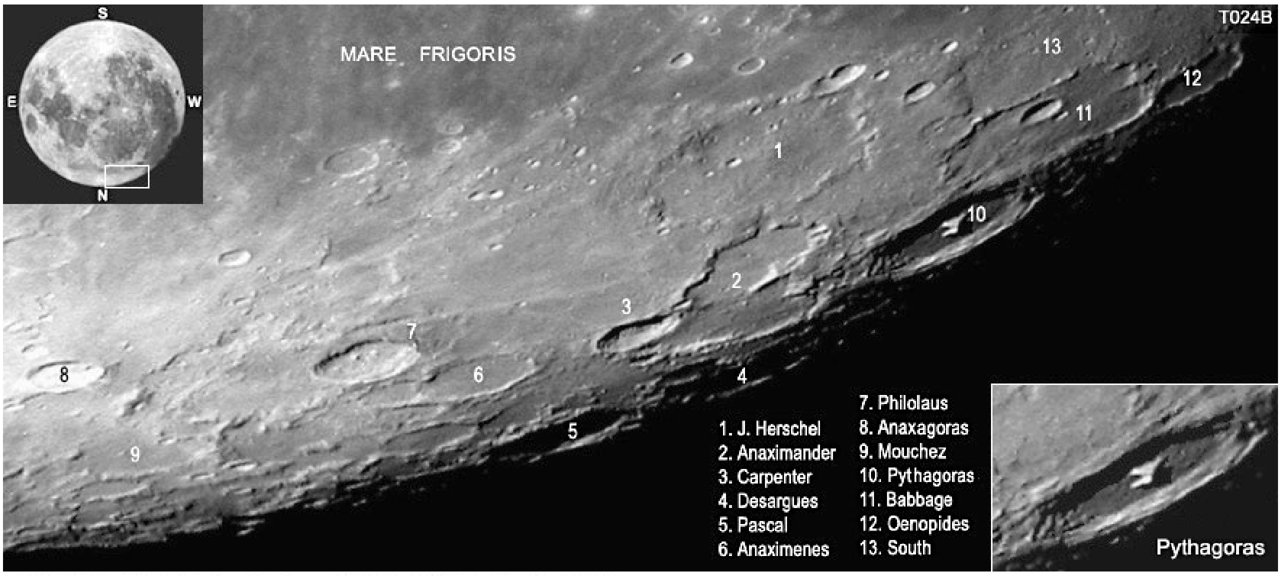
Peary 88.6^0 N 33.0^0 E
A 73-km crater nearest to the north pole, visible in T240 which was taken in favorable libration. The crater is in fact circular but looks much elongated due to extreme foreshortening. A wide portion of its southwestern circumference is opened to an unnamed feature (No. 8). Part of Peary's southern floor remains in permanent shadows (S1, S2). Two sections of its rim (B1, B2) seem to be brightened during the full season of the lunar summer. This is because the Moon's rotation axis is almost perpendicular to orbit, hence the Sun illuminates Peary at grazing angles most of the time. Compare T240 with the Clementine image at right.



MAP 17

J. Herschel, Anaximander, Philolaus, Pythagoras, Babbage

Hatfield 6
Rükl 3, 2, 1



2002.08.21 14:40 UT Age 12 days. FS128 + LE12.5 + CP990 at 1/28 sec.

J. Herschel 62.0^{0} N 42.0^{0} W
Remains of a walled plain, dia.165 km. Its floor is heavily covered by the Imbrium impact ejecta.

Anaximander 66.9^{0} N 51.3^{0} W
A 67-km broken crater between two larger craters ***Anaximander B*** & ***D.*** Details in T157, next page. The formation connects with ***Carpenter*** (59 km).

Pascal 74.6^{0} N 70.3^{0} W
A 115-km crater, visibility subject to libration.

Anaximenes 72.5^{0} N 44.5^{0} W
An 80-km crater with worn walls and flat floor.

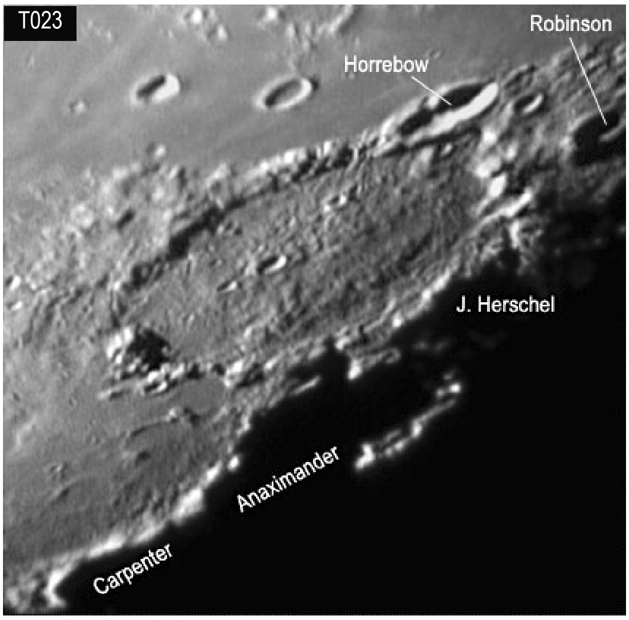
Philolaus 72.1^{0} N 32.4^{0} W
A crater with terraced walls and double central peaks, diameter 70 km.

Pythagoras 63.5^{0} N 63.0^{0} W
A 142-km crater with conspicuous central peak.

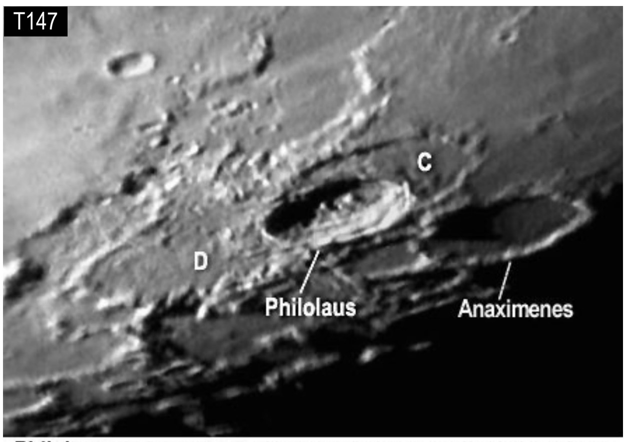
Babbage 59.7^{0} N 57.1^{0} W
A 143-km walled plain. Its floor contains a bowl-shaped crater (***Babbage A***, 32 km).

Oenopides 57.0^{0} N 64.1^{0} W
A 67-km crater with few tiny craters on the rim.

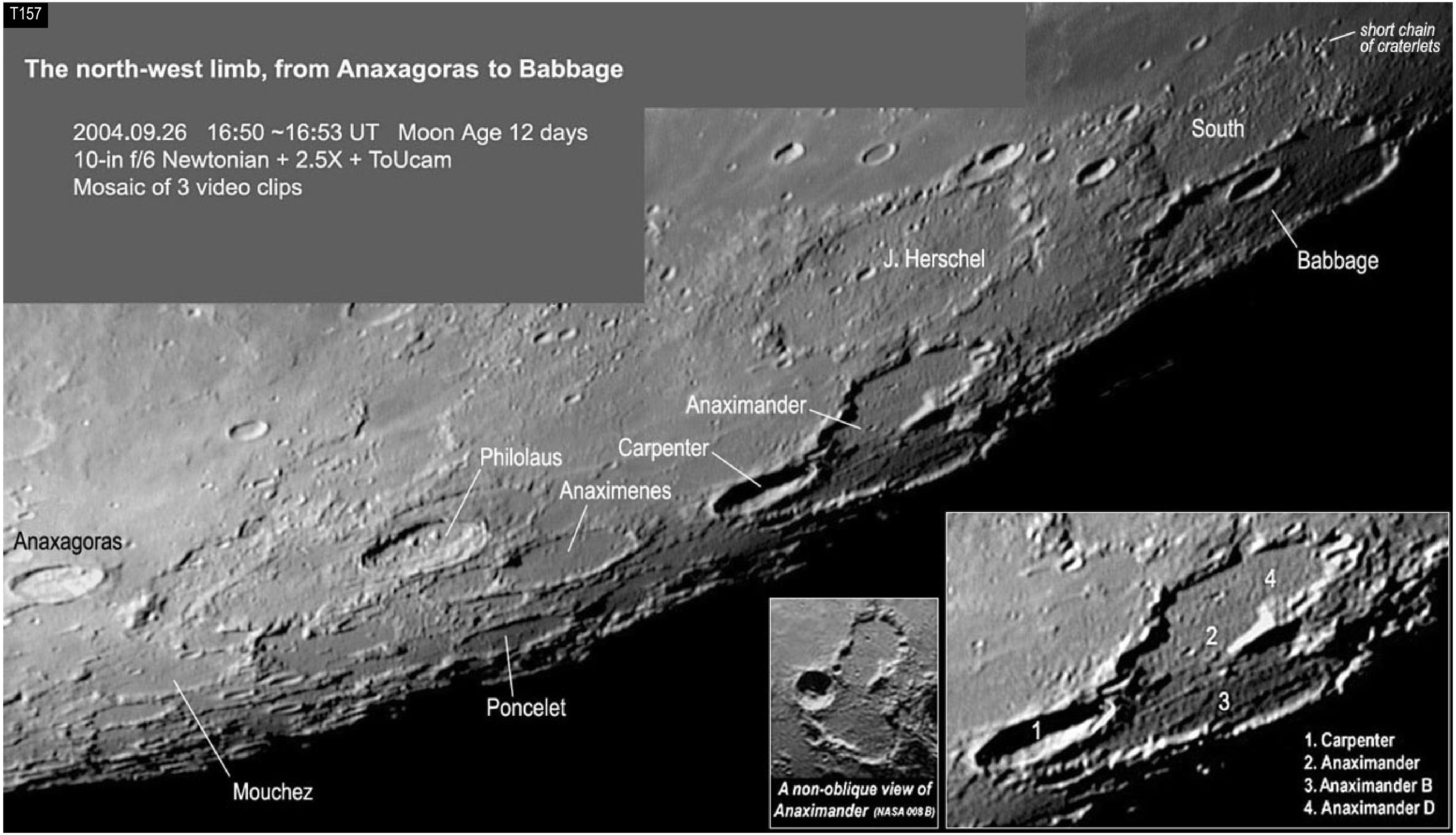
South 58.0^{0} N 50.8^{0} W
Remains of a ruined crater, diameter 104 km. Note the short chain of craterlets at its rim (T157).



J. Herschel 2004.09.25 14:10 UT Age 11 days. 10-in f/6 + 2.5X + ToUcam



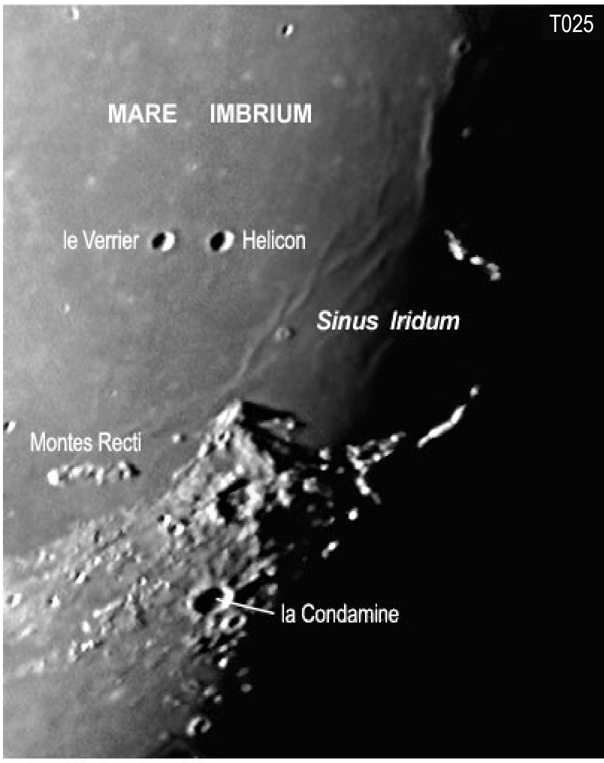
Philolaus 2004.09.25 14:12 UT Age 11 days. 10-in f/6 + 2.5X + ToUcam


T157
The north-west limb, from Anaxagoras to Babbage
2004.09.26 16:50 ~16:53 UT Moon Age 12 days
10-in f/6 Newtonian + 2.5X + ToUcam
Mosaic of 3 video clips
short chain of craterlets
South
J. Herschel
Babbage
Anaximander
Carpenter
Philolaus
Anaximenes
Anaxagoras
Poncelet
Mouchez
A non-oblique view of Anaximander (NASA 008 B)
1
2
3
4
1. Carpenter
2. Anaximander
3. Anaximander B
4. Anaximander D

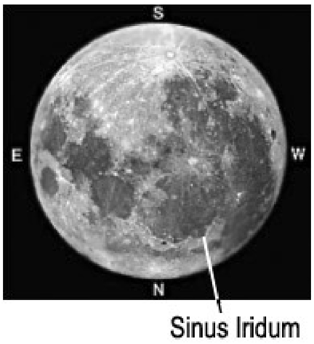
MAP 17

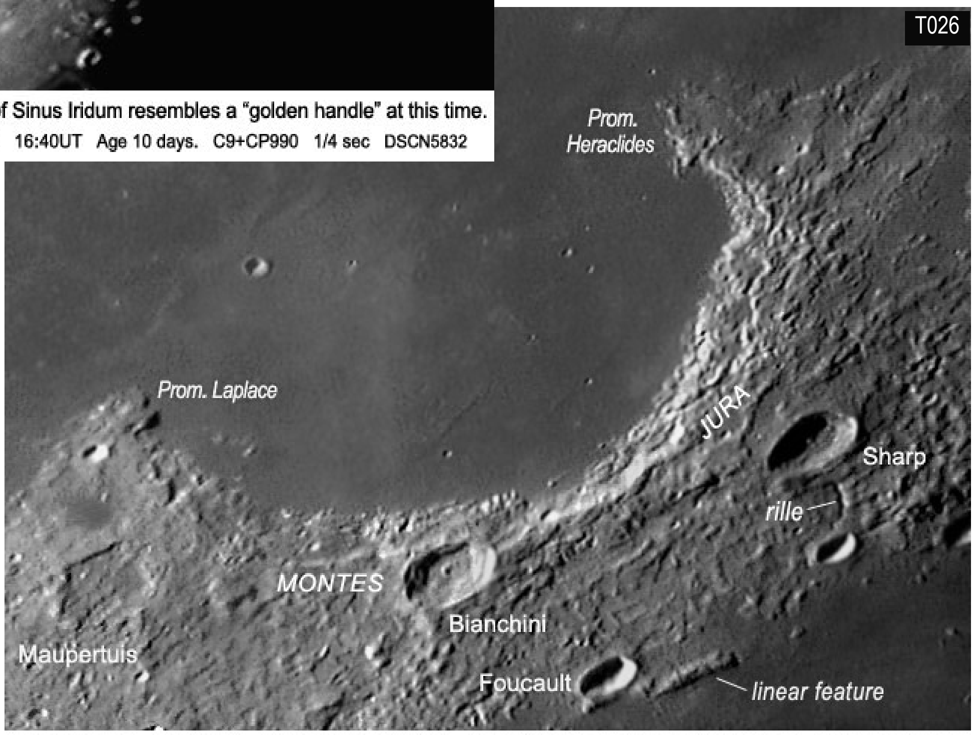
Sinus Iridum, Montes Recti, Bianchini, Sharp, Maupertuis

Hatfield 6
Rükl 10, 11, 20



The edge of Sinus Iridum resembles a "golden handle" at this time.
2002.12.14 16:40UT Age 10 days. C9+CP990 1/4 sec DSCN5832



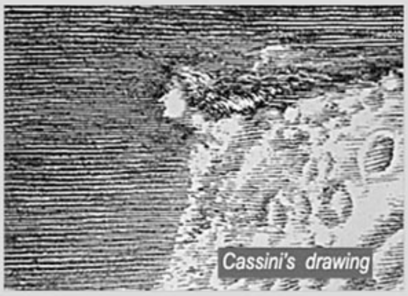


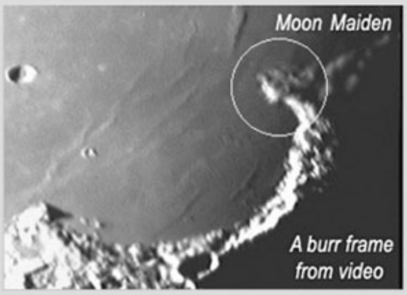
Sinus Iridum 2002.12.16 14:02UT Age 12 days. 10-in f/6 Royce mirror+2.5X+ToUcam, 2 frames stacked.

Sinus Iridum 44.1^0 N 31.5^0 W

Sinus Iridum (Bay of Rainbows) is a distinct landmark on the north-western edge of Mare Imbrium. It measures 230 km between two capes named ***Promontorium Laplace*** (height 2600 m) and ***Promontorium Heraclides*** (height 1700 m). Its origin is believed a vast crater but large part of the walls is overwhelmed by Mare Imbrium. Under low Sun angles, the floor of Sinus Iridum is crossed by wrinkle ridges, and ***Montes Jura*** (the semicircular mountain range along the shore) resembles a "golden handle" of a teapot. In the 17th century, Promontorium Heraclides was nicknamed the "Moon Maiden" by the French astronomer Cassini.

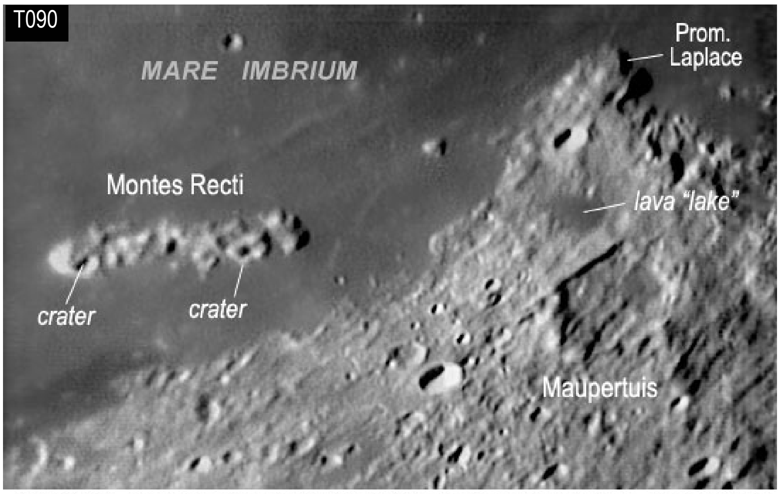
The Moon Maiden When the Italian-born French astronomer Cassini observed Sinus Iridum in the 17th century, he depicted Promontorium Heraclides (circled) as the "Moon Maiden", complete with face and waving hair. Cassini's "Moon Maiden" is in fact an illusion and may not show up all the time. The trick to knowing it is to view it on a night when seeing is not that good; this exaggerates the illusion!





Bianchini 48.7^0 N 34.3^0 W (dia. 38 km) **Sharp** 45.7^0 N 40.2^0 W (39 dia. km)
A pair of "eyes" guarding Sinus Iridum. Note the teeth-shaped rille in Image T026.

Maupertuis 49.6^0 N 27.3^0 W
A pentagon-shaped disintegrated crater close to Promontorium Laplace, 45 km across. A small lava "lake" is just in the south.



2006.05.09 15:03 UT Age 12 days. 10-in f/6 Newtonian + 4X + ToUcam (*80% resized*)

Montes Recti 48.0^0 N 20.0^0 W
A straight mountain range with a small crater at each end, 20 x 90 km, height 1800 m. It is a high remnant of the Imbrium basin's inner ring, but lava flooding failed to cover it.

Image T065, next page:

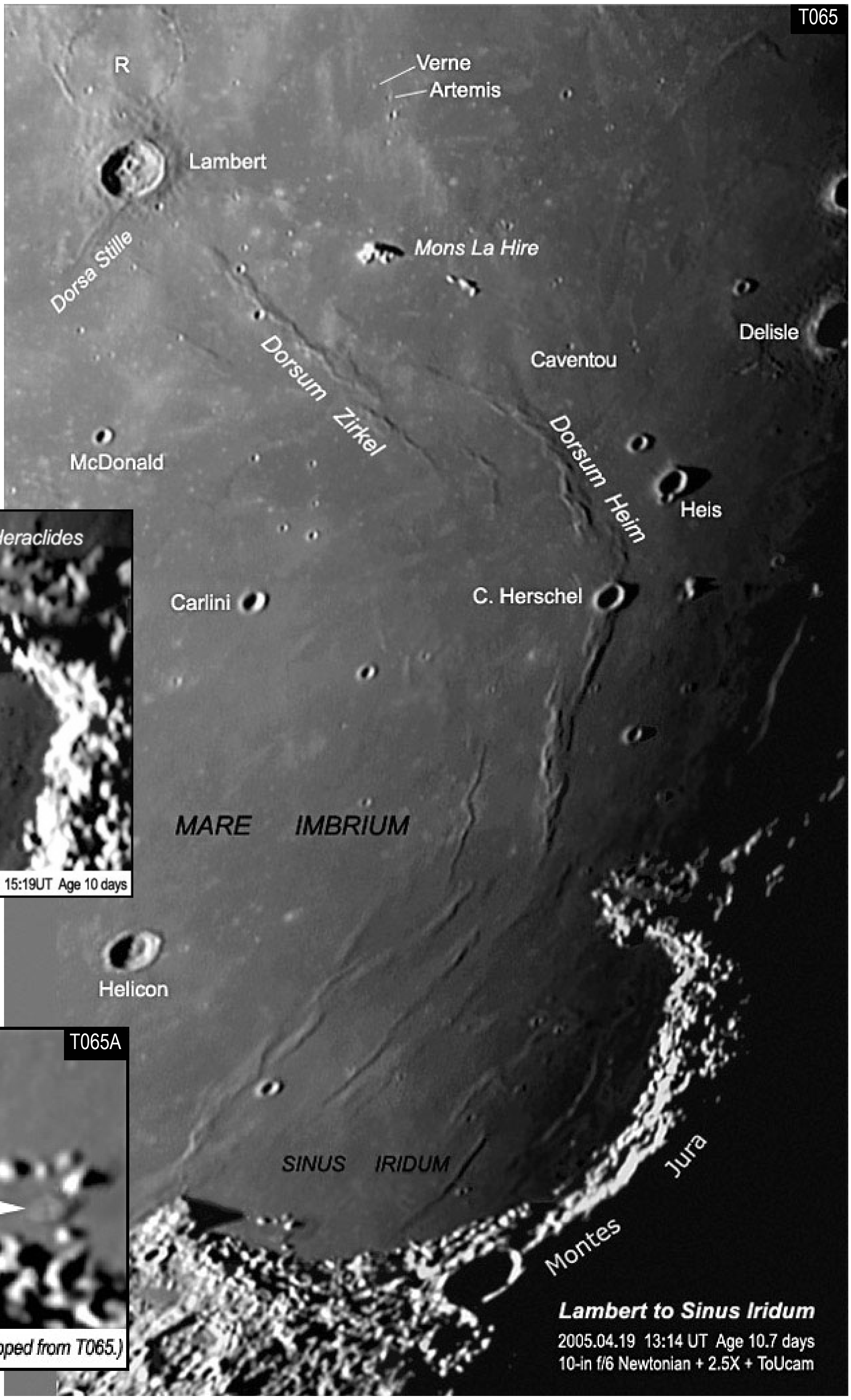
Lambert 25.8^0 N 21.0^0 W
A crater with terraced walls, diameter 30 km. Its immediate south is the ghost crater ***Lambert R*** (55 km). See also Image T177 in Map 19.

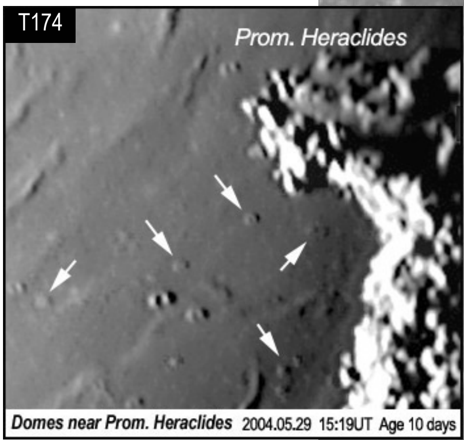
C. Herschel 34.5^0 N 31.2^0 W
A 13-km crater named after Caroline Herschel, the sister of the German-born English astronomer William Herschel who discovered Uranus in 1781. She assisted her brother lifetime and was the first woman to discover a comet.

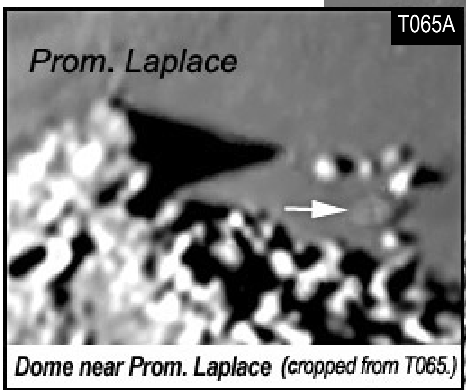
Mons La Hire 27.8^0 N 25.5^0 W
An isolated mountain, base about 11 x 25 km, peak height 1500 m. It is a highland remnant partially submerged in lava. A fly-over view from the Apollo-15 mission is given in Map 1.

Dorsum Zirkel 28.1^0 N 23.5^0 W **Dorsum Heim** 32.0^0 N 29.8^0 W
They are wrinkle ridges on the western floor of Mare Imbrium, which probably mark the the buried inner ring of the Imbrium basin. Dorsum Zirkel is 190 km long. Dorsum Heim is 150 km long, followed by few more unnamed wrinkle ridges that extend northwards into Sinus Iridum.

Sunrise over Sinus Iridum



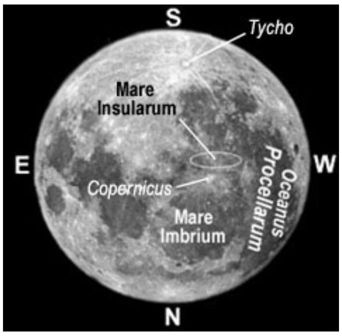


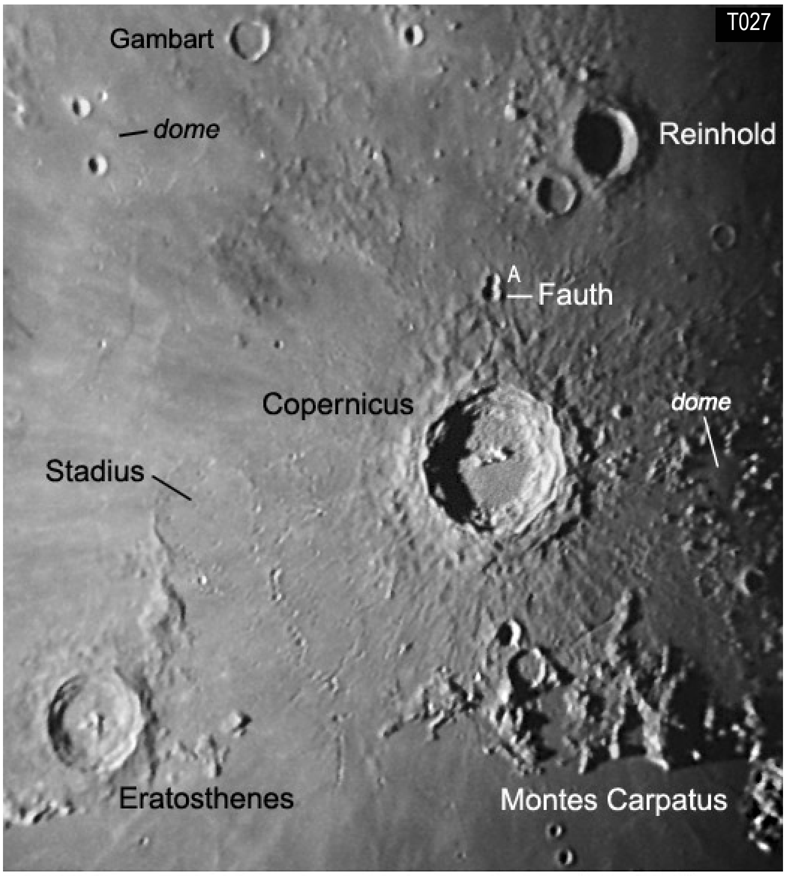


The wrinkle ridges on the floor of Sinus Iridum are particularly prominent when the terminator passes over them. To emphasize the profile of these ridges, Montes Jura (the mountain range under illumination) is inevitably over-exposed in Image T065. Sunlight comes from the east, suggesting that an observer on the shore of Sinus Iridum would experience sunrise at this time.

Helicon is a crater resembling a bowl, 24 km in diameter and 1900 m deep. The cape-like feature that casts triangular shadow is Promontorium Laplace. It rises 2600 m high and has an indistinctive dome in the west (T065A). Other domes exist near Promontorium Heraclides (T174), but they are noticeable only under very low illumination angles.

Copernicus, Eratosthenes, Stadius, Montes Carpatus, Euler, Lambert, Hortensius, Milichius





2002.11.14 14:58UT Age 9 days. C9+LE12.5+CP990 1/7 sec DSCN5818

(Image T027)

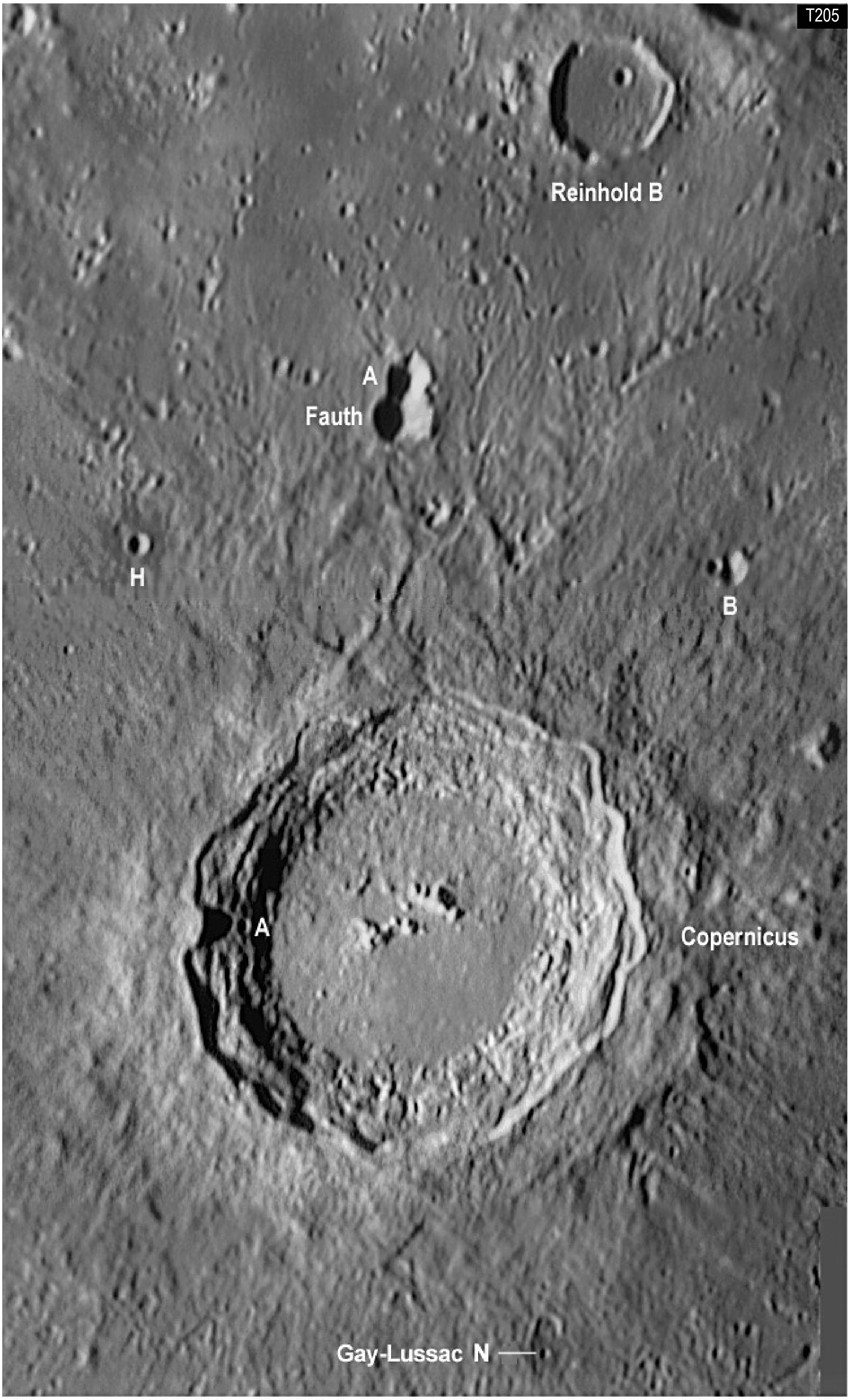
Copernicus 9.7^{0}N 20.1^{0}W

Copernicus is a fine example of a young ring mountain, formed about 800 million years ago. It is located between the south of Mare Imbrium and the north of a loosely bounded plain named ***Mare Insularum*** (Sea of Isles). Copernicus is 93 km in diameter, with a group of central peaks and terraced walls 3700 m above the floor. The depth-diameter ratio of Copernicus is 1:25; this makes the crater to resemble a pie pan rather than a bowl. The southern half of the floor is full of small hills but the northern half is relatively flat. At Moon age of 9 ~10 days, a faint dome is barely notable about one diameter west of the crater. Numerous secondary craterlets and pits also spread like raisin holes in the north-east vicinity. Extensive bright rays emit from the crater at days close to the full moon.

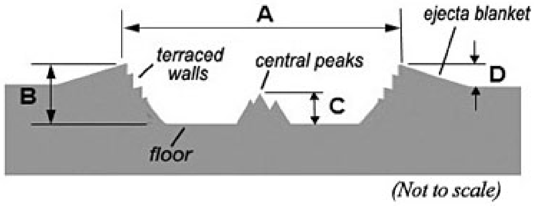
The terraced walls of Copernicus look somewhat hexagonal and segmented. The number of central peaks is a challenge to observation. Three peaks of height up to 1200 m are visible in small telescopes, however bigger telescopes may show more small “bumps”. The central peaks were reported rich in olivine, a subsurface rock-forming mineral but uplift owing to the impact. The radial scars around the outer walls are ejecta deposits. Two small overlapping craters, ***Fauth*** (12 km) and ***Fauth A*** (10 km), are located in the exact south of Copernicus; the trio is a good indicator for north-south orientation. Fauth and Fauth A could be secondary craters, possibly created by the gigantic Imbrium impact.

(Image T205, next page)

Landslides, possibly triggered by the shock waves of the younger Tycho’s impact, are seen along the east rim of Copernicus. Outside the rim are two small dark halo craters --- ***Copernicus H***, diameter 5 km and ***Gay-Lussac N***, diameter 2 km. They pierced into the ejecta blanket of Copernicus. Presumably these craters formed from secondary impact, the dark halo could be the deposits of mare basalt excavated from beneath the ejecta blanket. The impact was supposed not too energetic, so only an insignificant (relatively) amount of dark basalt was excavated.



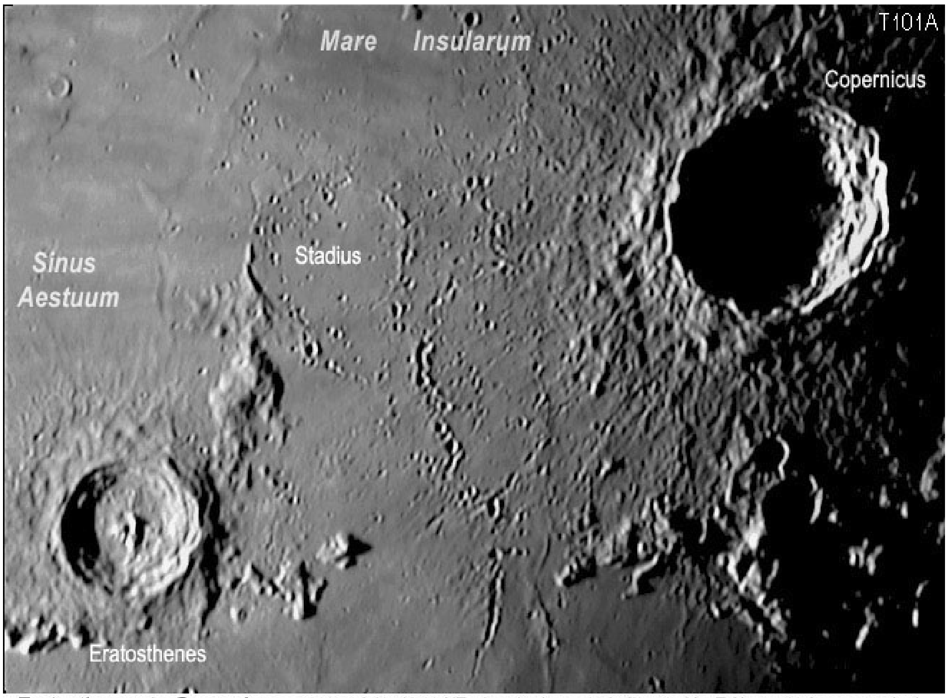
Copernicus 2005.04.19 ~12:39 UT Age 10.7 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam (*mosaic*)



Cross-section of Copernicus

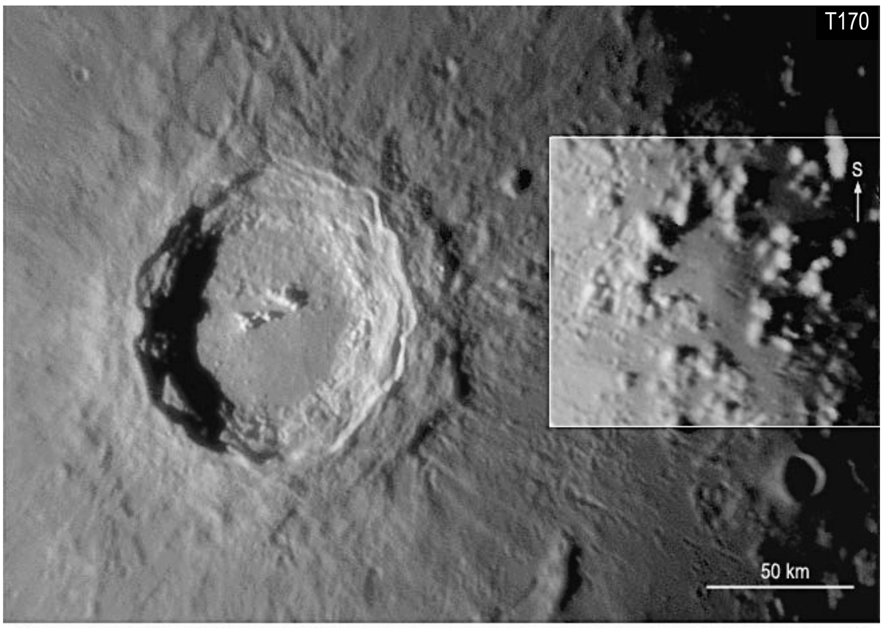
*Diameter **A** = 93 km* *Height of central peaks **C** = 1200 m*
*Depth of floor **B** = 3700 m* *Height of outer walls **D** = 1400 m*

Small impact craters (diameter less than about 15 km) do not have central peaks. They tend to have simple bowl shape whereas in a large crater like Copernicus, slumping of material off the inner walls helps to flatten the crater floor. Note also that B is greater than D, and the inner walls are always steeper than the outer ejecta blanket.



Eratosthenes to Copernicus 2005.04.18 11:29 UT Age 10 days. 10-in f/6 + 2.5X + ToUcam, 33 frames stacked.

Above: *Copernicus is heavily shadowed. To the east is a wide pattern of small secondary craters produced mostly by the ejecta of the Copernicus impact. Secondary craters are often noncircular due to the low velocities (typically 1 ~ 2 km per second) and low inclination trajectories. Some of them even formed sinuous chains as the result of interference between close pairs of ejecta which formed nearly simultaneously.*

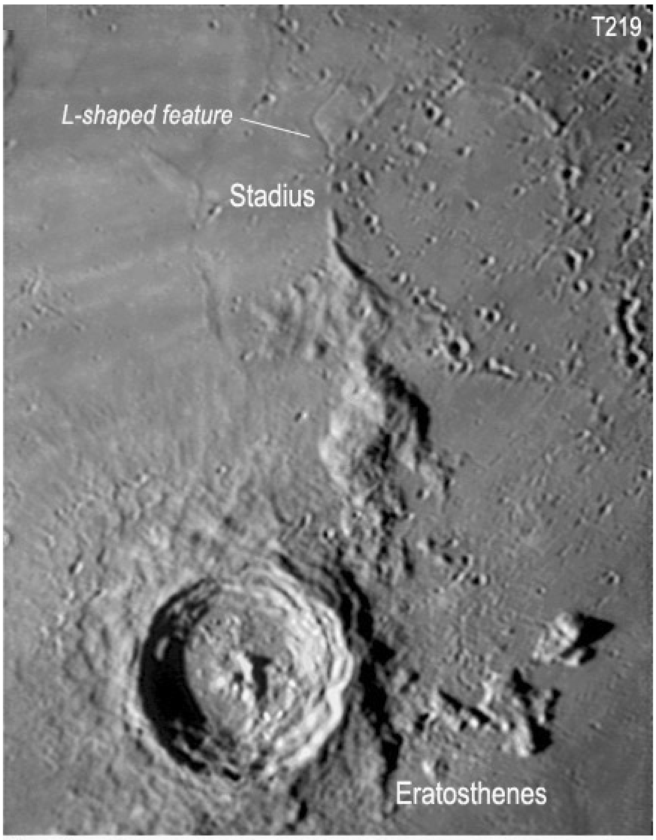


The dome at the west of Copernicus, deliberately highlighted to show its low convex profile.

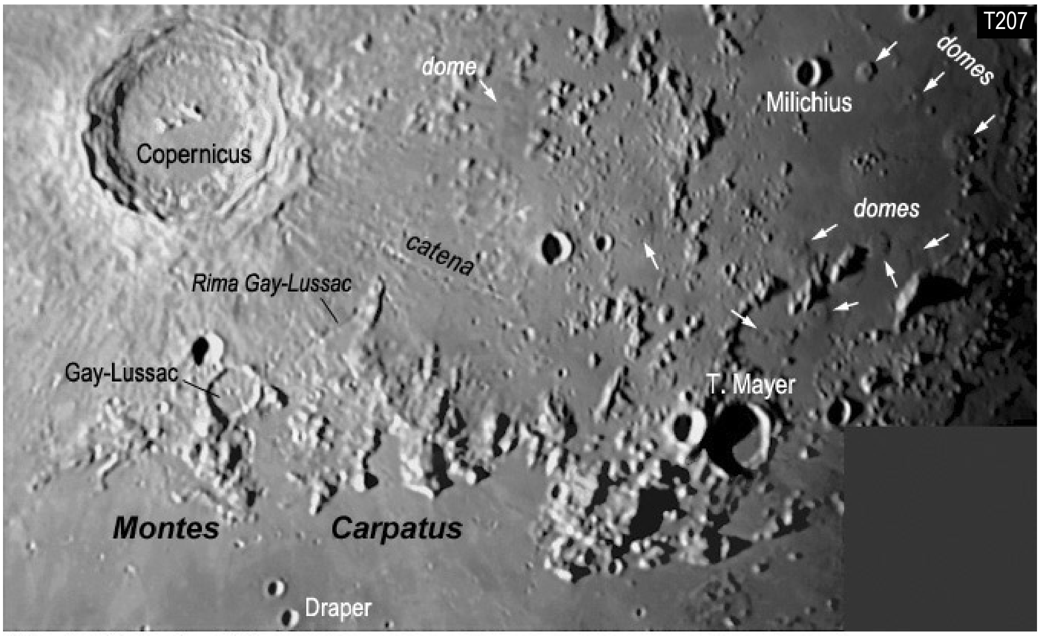
The dome (deliberately brightened) at the west of Copernicus. 10-in f/6 Newtonian + 4X + DMK31AF03 at 1024 x 768. 2008.04.15 ~14:03 UT Moon age 9.4 days. Taken in Shatin, Hong Kong. Image is 67% resized due to poor seeing.

Eratosthenes 14.5^0 N 11.3^0 W
An impact crater close to Copernicus, 58 km in diameter and 3600 m deep. It has a well-defined rim, terraced walls and three central peaks rising to some 1500 m. Eratosthenes changes in appearance during a lunation. At full moon it almost disappears. The lack of bright rays around the crater suggests that the rays were washed out by space weathering, so Eratosthenes must be older than Copernicus and is determined to have formed 3.2 billion years ago (the beginning of the *Eratosthenian* period). The adjacent land relief is interesting; it resembles an elephant with an upward swirling nose.

Stadius 10.5^0 N 13.7^0 W
A ghost depression with incomplete low walls, diameter 69 km. It is peppered with secondary craterlets and pits. A L-shaped feature (possibly composed of a catena and a rille) extends from the southeast rim. The height of the northeast wall is 600 m.

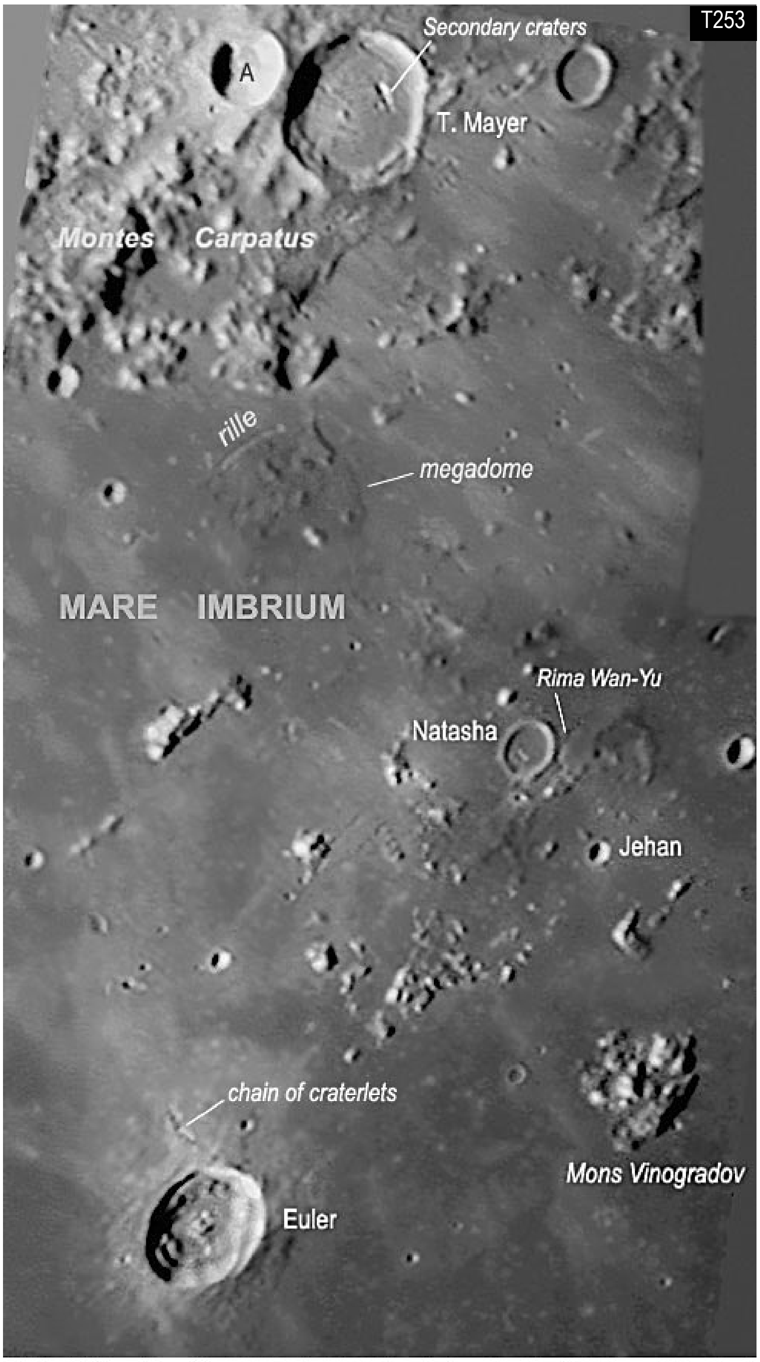


Eratosthenes 2005.04.18 11:53UT Age 9.8 days. 10-in f/6 + 4X + ToUcam, 85% resized.



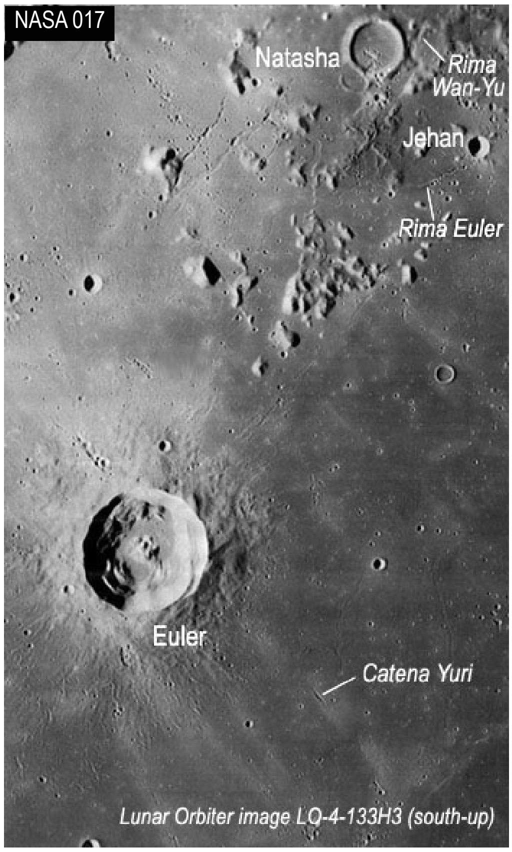
Montes Carpatus & Copernicus 2005.04.19 13:40 UT Age 10.7 days. 10-in f/6 Newtonian + 2.5X + ToUcam

Montes Carpatus 14.5^0 N 24.4^0 W
A mountain range, length 360 km with peak height 2300 m. It is one of the montes that form the rising rim of Mare Imbrium. It holds crater ***T. Mayer*** (diameter 33 km), ***Gay-Lussac*** (26 km), and one rille (***Rima Gay-Lussac***, 40 km) that runs across the ejecta blanket of Copernicus. Some chains of craterlets and volcanic domes can be spotted in the southern vicinity, see T206 at end page of this map.



Euler & Rima Wan-Yu 2006.05.09 13:37 UT Age 12 days. 10-in f/6 + 5X + ToUcam (88% resized)

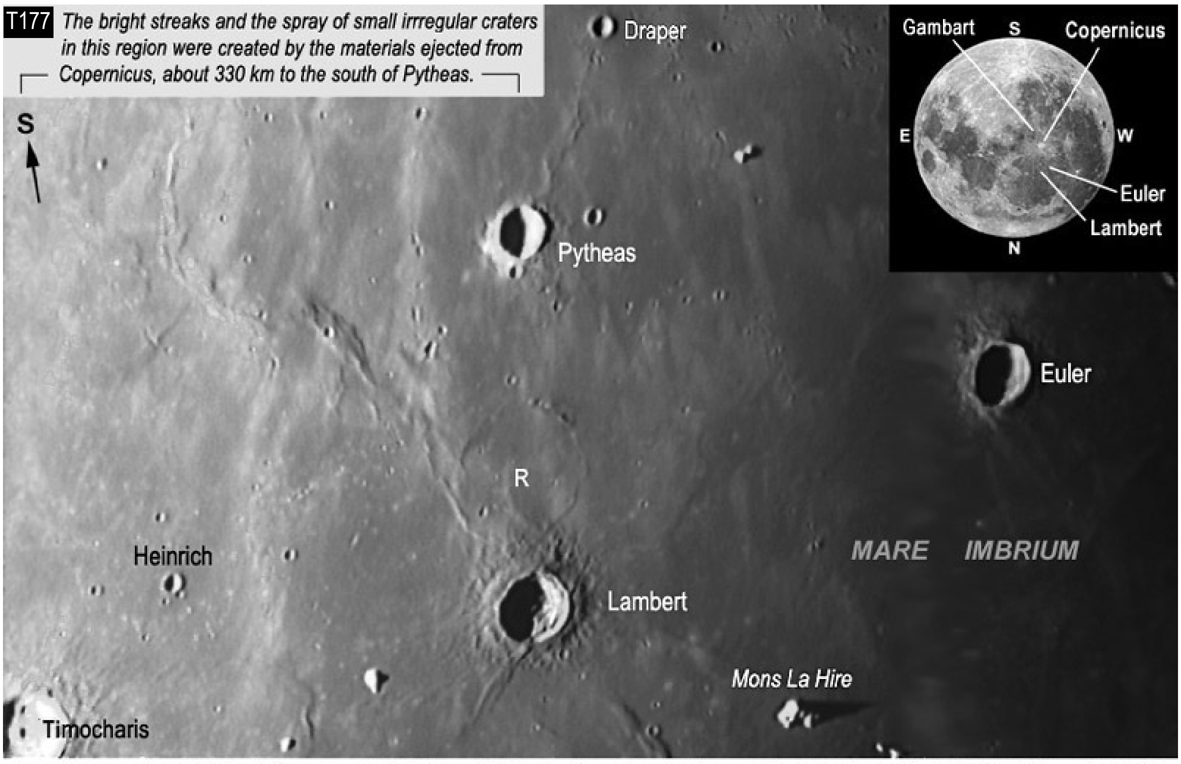
Megadome at north of T. Mayer (Apollo 17 image)



Euler 23.3^0 N 29.2^0 W
A terraced crater with central peak and slumped inner rim, diameter 27 km. A short chain of craterlets runs near the south-east rim of Euler. ***Catena Yuri*** (5 km) and ***Rima Euler*** (90 km) are not seen in T253 but resolved marginally in the Lunar Orbiter image.

Mons Vinogradov 22.4^0 N 32.4^0 W
An irregular mountain rising up to 1400 m, base width 25 km.

Natasha 20.0^0 N 31.3^0 W
An inconspicous crater, diameter 12 km. ***Rima Wan-Yu*** (20.0^0 N 31.5^0 W , length 12 km) is an elusive rille very close to the west rim of Natasha.



Lambert and wrinkle ridges 2005.11.11 ~11:49 UT Moon Age 9.5 days. 10-inch f/6 Newtonian + 2.5X + ToUcam (mosaic)

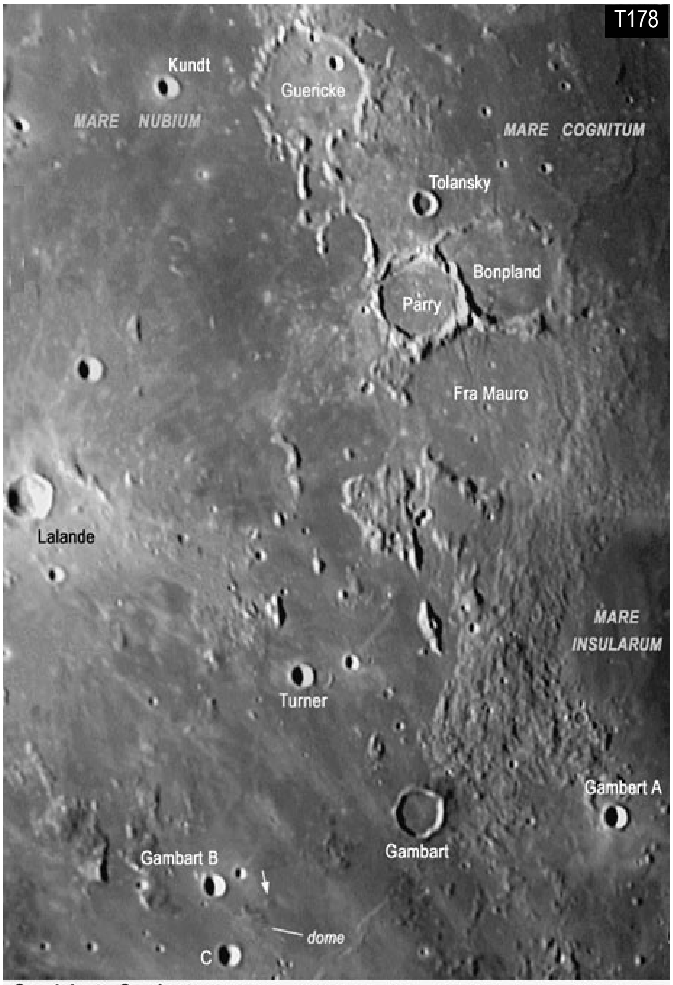
Lambert 25.8^{0} N 21.0^{0} W *(Image T177)*
A terraced crater, diameter 30 km. It adjoins the ghost crater ***Lambert R*** (55 km) which is almost buried beneath the mare floor. To the southeast of Lambert is a nameless network of wrinkle ridges.

Pytheas 20.5^{0} N 20.6^{0} W
A crater with sharp rim, diameter 20 km. Note the bright streaks east of Pytheas.

Gambart 1.0^{0} N 15.2^{0} W (*Image T178)*
A ring-shaped flooded crater, diameter 25 km. To its southwest is an ejecta deposit of the Imbrium impact known as 'Fra Mauro Formation'. ***Gambart A*** (12 km) is a rayed crater. A dome (~10 km) is located close to ***Gambart B*** and ***C***. The arrow points to another skeptical dome.

Turner 1.4^{0} N 13.2^{0} W
A crater, 11 km in diameter, 2600 m deep.

Lalande 4.4^{0} S 8.6^{0} W
A bright rayed crater under high illumination, diameter 24 km. It is probably less than 2.8 billion years old. See also T179 Map 12.



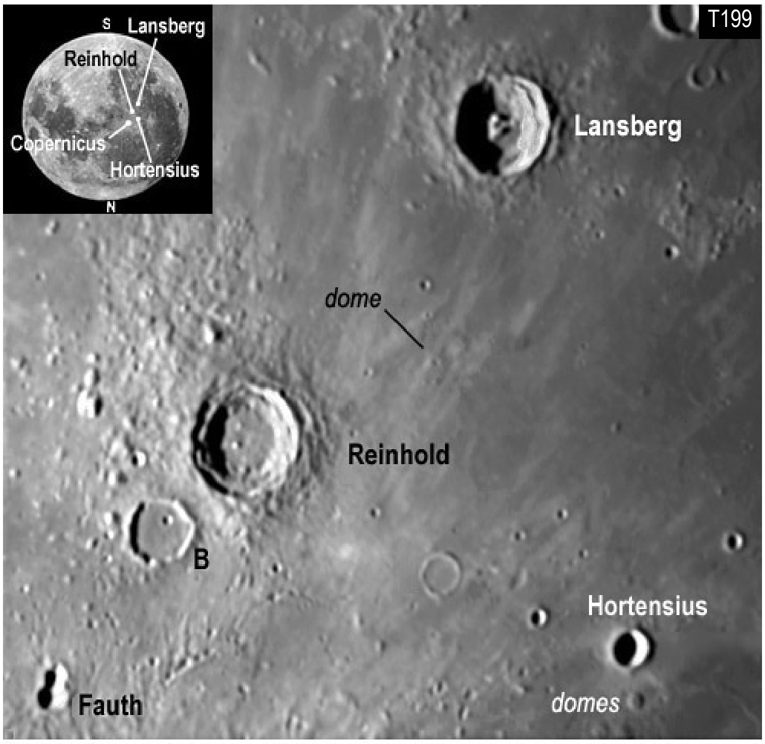
Guericke to Gambart 2004.10.23 ~14:19 UT Age 10 days. 10-in f/6 Newtonian + 2.5X + ToUcam

Image T199:

Lansberg 0.3^0 S 26.6^0 W
A terraced crater with multiple central peaks, diameter 38 km.

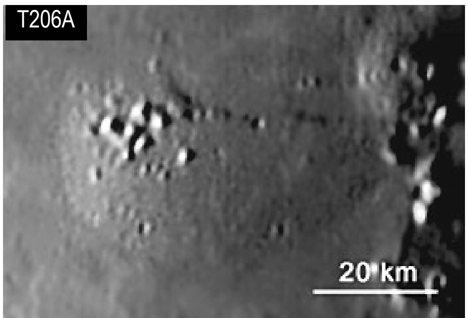
Reinhold 3.3^0 N 22.8^0 W
A terraced crater with a small central peak, diameter 42 km. Between this crater and Lansberg is a volcanic dome that has a summit pit.

Reinhold B 4.3^0 N 21.7^0 W
A flood crater with a conspicuous craterlet on the floor, diameter 26 km. Although it is close to Reinhold, its interior is completely different from Reinhold. See the larger image in T205, previous page.

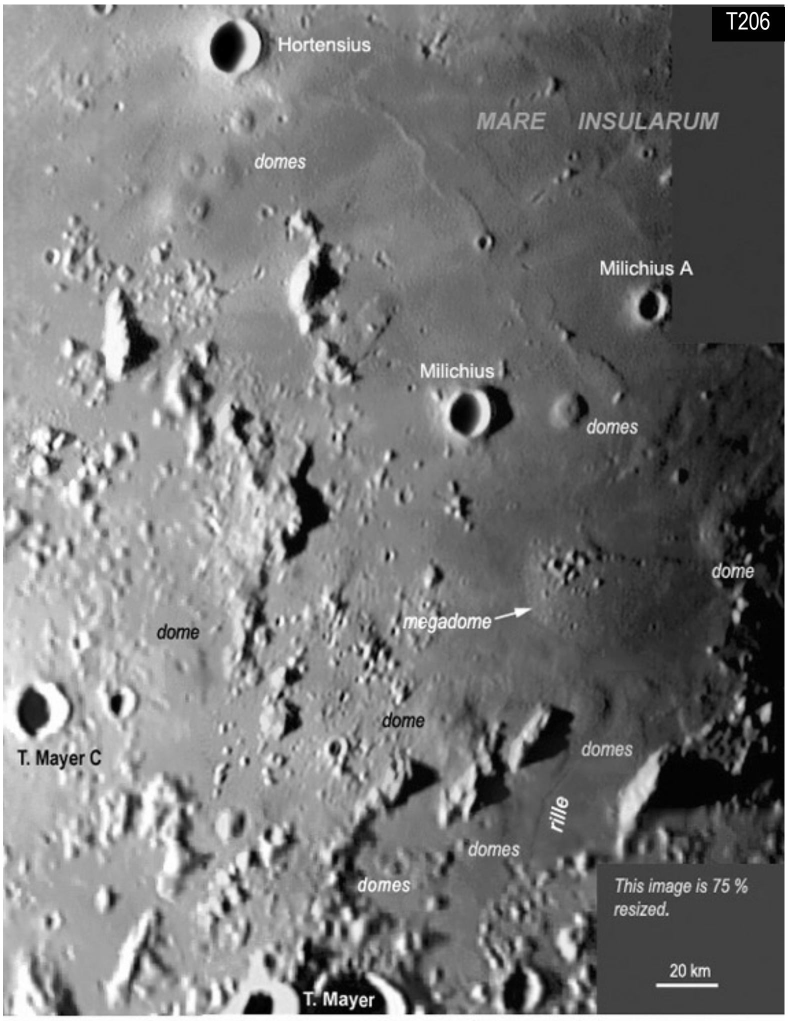


Reinhold & Lansberg 2005.04.19 13:36 UT Age 11 days. 10-in f/6 Newtonian + 2.5X + ToUcam

Hortensius 6.5^0 N 28.0^0 W
Milichius 10.0^0 N 30.2^0 W
In T206, Copernicus is beyond the left edge of the frame. Hortensius (dia. 14 km) and Milichius (12 km) are well-known for the clusters of volcanic domes in their vicinity. These domes range from about 5 to 15 km in diameter and are few hundred meters high. They are visible only under very low Sun angles. The summits of some domes have single or even double pits. Six domes are clustered at the immediate north of Hortensius, and at least ten domes spread in the region between Milichius and T. Mayer. Note also the nameless rille and the "megadome" marked in T206.



The "megadome" (dome-shaped plateau)

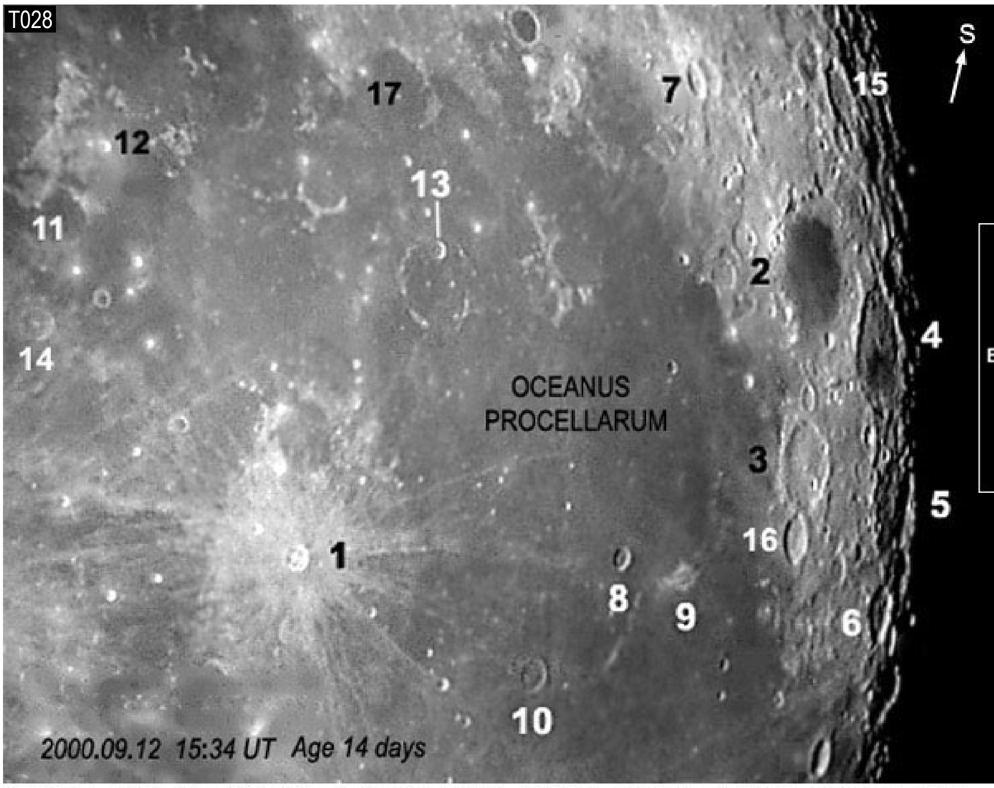


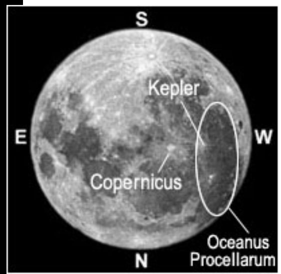
Domes near Hortensius & Milichius 2005.04.19 ~12:35 UT Age 10.7 days. 10-in f/6 + 5X + ToUcam (*mosaic*).

MAP 20

Hatfield 7, 11
Rükl 30, 29, 28, 18
Rükl 40, 41, 42

Oceanus Procellarum (Kepler, Marius, Montes Riphaeus, Flamsteed, Letronne, Reiner Gamma)





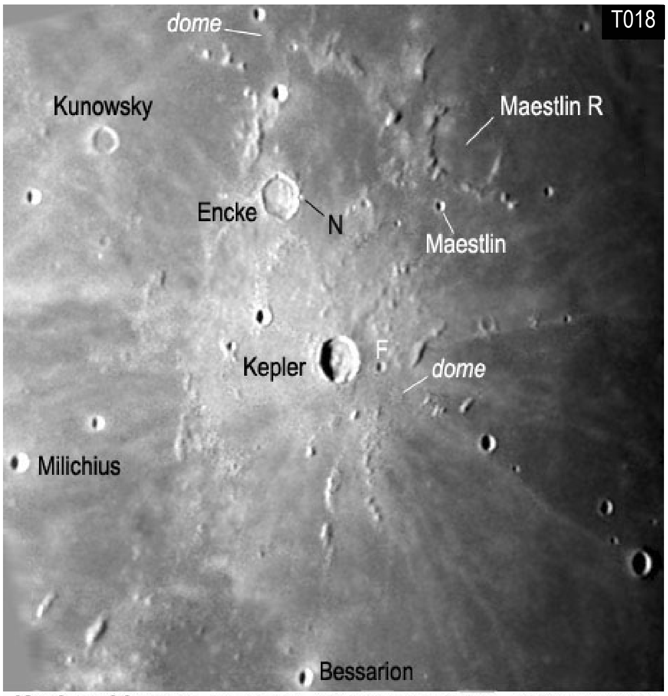
1. Kepler 2. Grimaldi 3. Hevelius 4. Riccioli 5. Hedin 6. Olbers 7. Sirsalis 8. Reiner 9. Reiner Gamma 10. Marius 11. Montes Riphaeus 12. Euclides 13. Flamsteed 14. Lansberg 15. Rocca 16. Cavalerius 17. Letronne

This map covers the southern part of Oceanus Procellarum (Ocean of Storms) which is a very large mare stretching 2500 km north-south. Oceanus Procellarum is not contained within a single well-defined impact basin, so its origin from a proposed "Procellarum basin" remains controversial. Kepler (and Aristarchus in Map 21) are the most prominent craters in the oceanus.

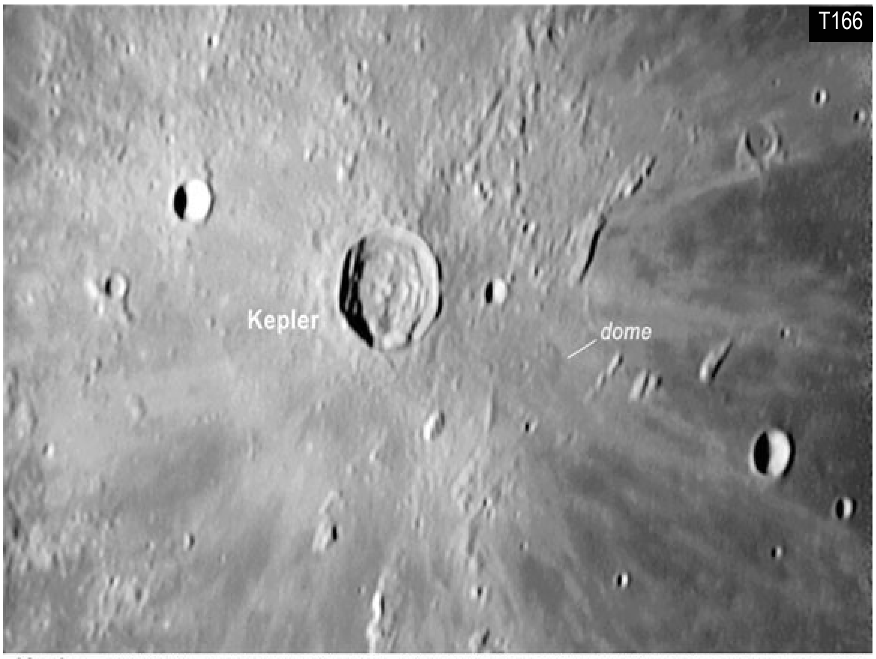
Kepler 8.1^{0}N 38.0^{0}W
A terraced crater with central peaks, diameter 31 km. It is also a center of prominent bright rays. A faint dome is barely visible in the northwest of Kepler.

Encke 4.6^{0}N 36.6^{0}W
A slightly polygonal crater with uneven floor, diameter 28 km. Its rim is interrupted by craterlet ***Encke N***. During the full moon, Encke is overwhelmed by the bright rays from Kepler.

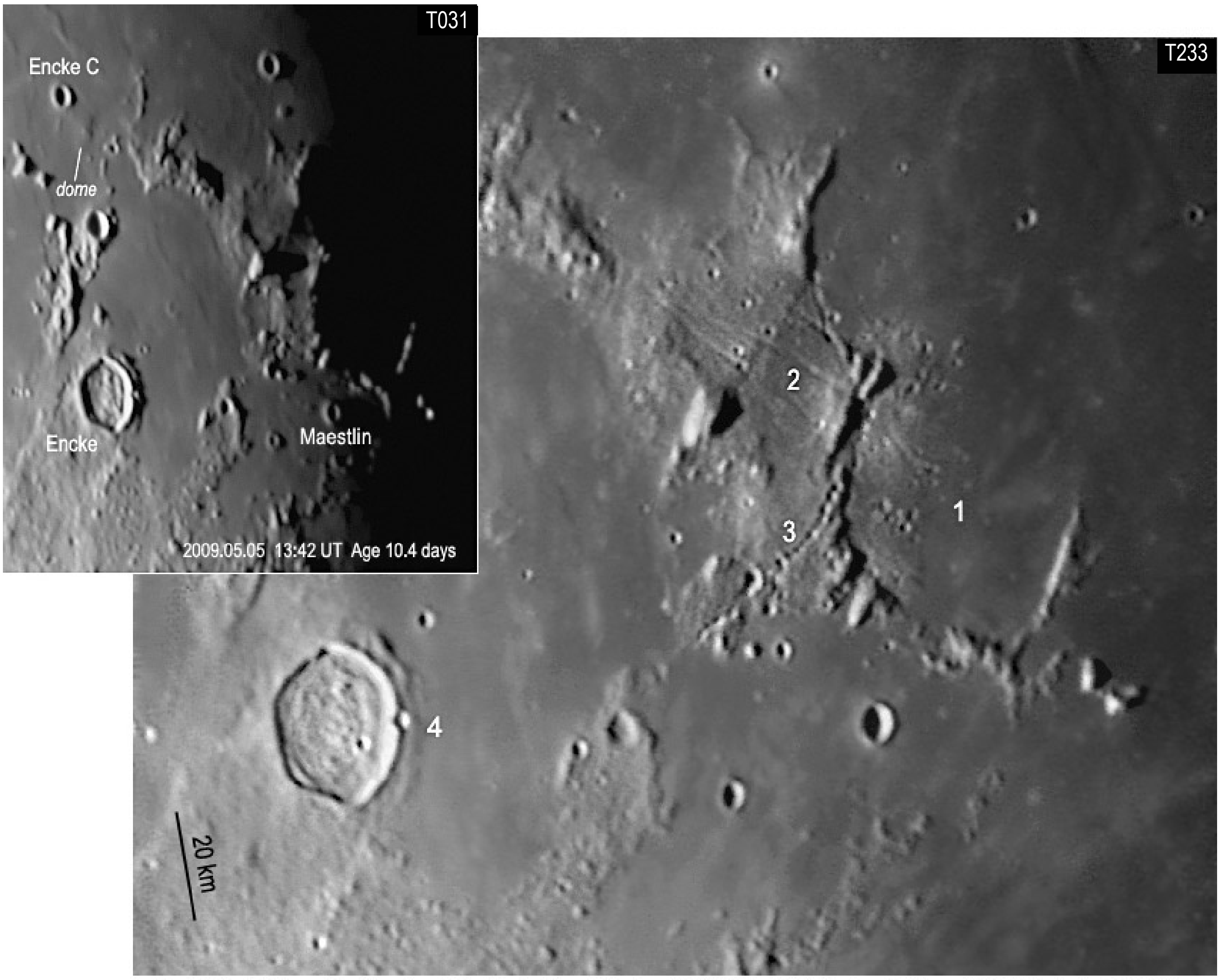
Maestlin R 3.5^{0}N 41.5^{0}W
A crater remnant, diameter 61 km. A chain of craterlets extends outward from the east wall of Maestlin R. A system of rilles (***Rimae Maestlin***, 80 km) intersects the southeast wall, see T233.



Kepler with rays 2001.01.06 15:17 UT Age 11 days. FS102 + QV2300

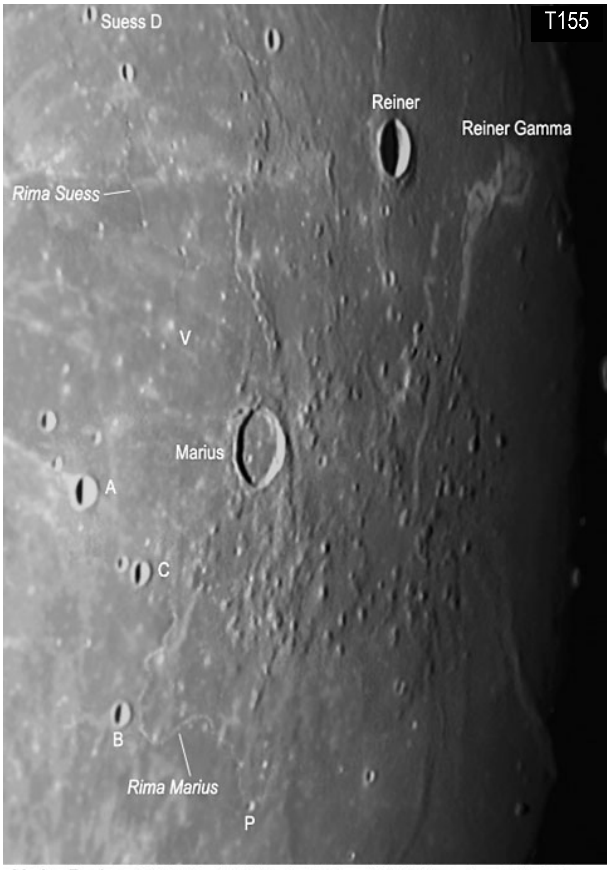


Kepler 2005.04.21 14:42 UT Age 12.5 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam, 75 frames stacked.

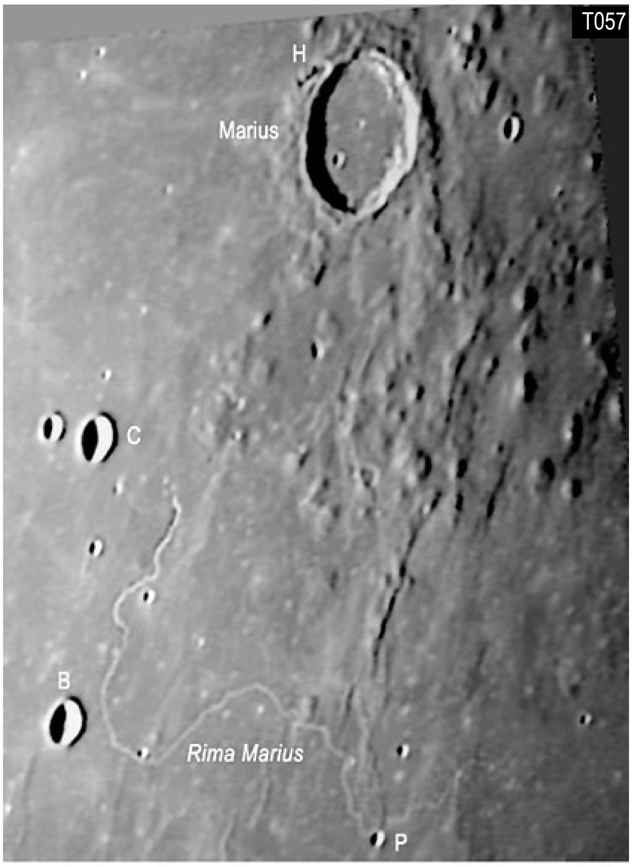


1. Maestlin R 2. Rimae Maestlin 3. *a chain of craterlets* 4. Encke 2006.05.09 ~13:48UT Age 11.8 days. 10-in f/6 Newtonian+5X+ToUcam.

Above: *The Maestlin Region appears as a low elevated plateau that holds the remnant of crater Maestlin R, Rimae Maestlin and a nameless chain of craterlets. It is located on the southeast region of Oceanus Procellarum near Kepler and Encke, size about 100 km north-south. The smaller image was taken in another day when the lunar terminator was crossing Maestlin R.*



Marius Region 2004.09.26 ~15:36 UT Age 12 days. 10-in f/6 Newtonian + 2.5X + ToUcam



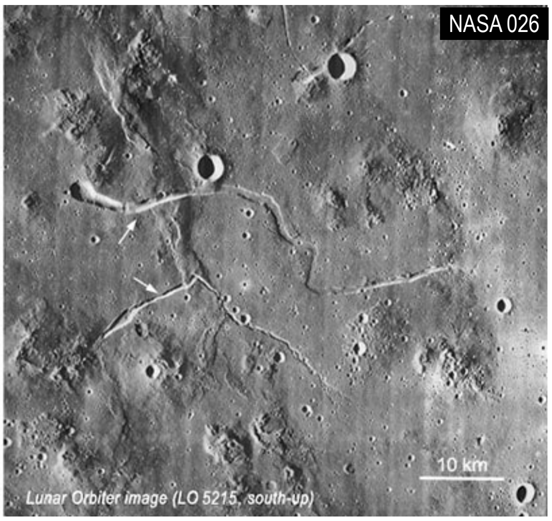
Rima Marius 2005.04.21 14:17 UT Age 12.5 days. 10-in f/6 + 4X + ToUcam

Marius 11.9^0 N 50.8^0 W

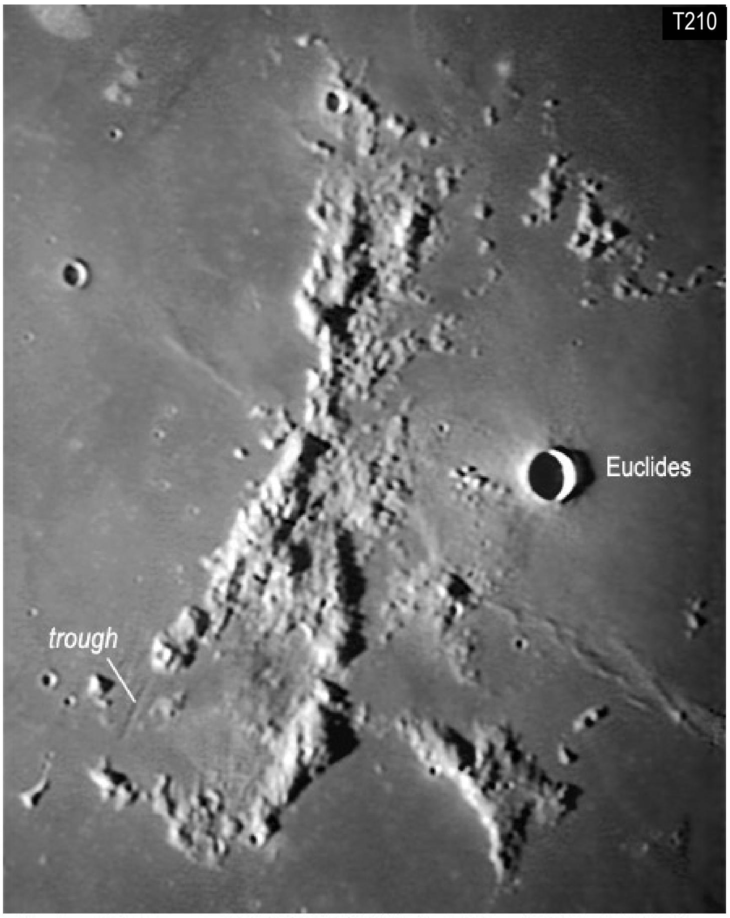
A crater in the middle of Oceanus Procellarum. It has a flat floor, diameter 41 km. Its rim is stuck by a small elongated crater ***Marius H***. The vicinity of Marius is rich in wrinkle ridges and dome hills, best seen at Moon age of 12~13 days. About 300 domes of few hundred meters high were estimated in this area. They are believed to form from concentrated rise of magma within the crust at the later stages of lunar volcanism. ***Rima Marius***, a sinuous lava channel, begins near Marius C and ends beyond the west of Marius P, total length 250 km, width up to 2 km. See also "Lava Channels" in Map 1.

Remark *Few more sinuous rilles are found in the Marius region, but they are too faint to be resolved in the author's 10-inch telescope. These rilles appear in Rürl's Map 29. One of them is* ***Rima Suess*** *(6.7^0 N 48.2^0 W), partially imaged in T155. It meanders between Suess D and Marius V, length 165 km. The other rilles are located near 14^0 N 57^0 W. They are nameless and are marked by arrows in the following images.*

Marius & domes 2009.10.31 14:47 UT Age 13 days. 10-in f/6 Newtonian + 4X + ToUcam



Lunar Orbiter image (LO 5215, south-up)



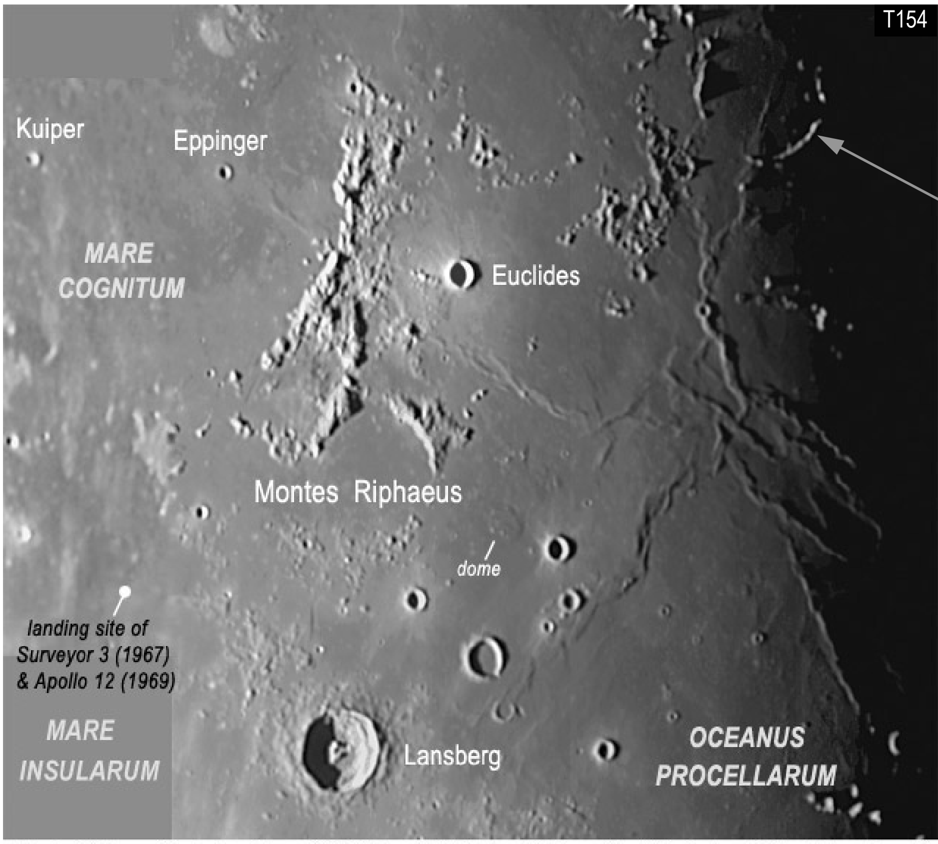
Montes Riphaeus 2005.04.19 12:58 UT Age 11 days. 10-in f/6 + 5X + ToUcam

Image T210:

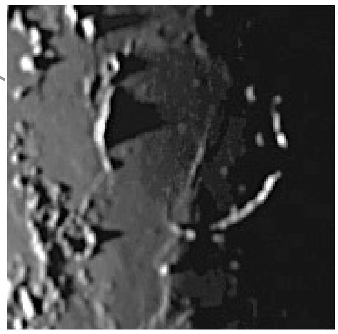
Montes Riphaeus 7.7^{0} S 28.1^{0} W

A mountain range between Oceanus Procellarum and Mare Cognitum (Known Sea), length 190 km, peak height about 1000 m. It consists of several long narrow mountains, giving the impression that resembles a hunter armed with a spear (wrinkle ridge) and a torch when viewed with south up. The "torch" is the rayed crater ***Euclides***, diameter 11 km. An inconspicuous trough (length 40 km) is located in the north-east side of Montes Riphaeus.

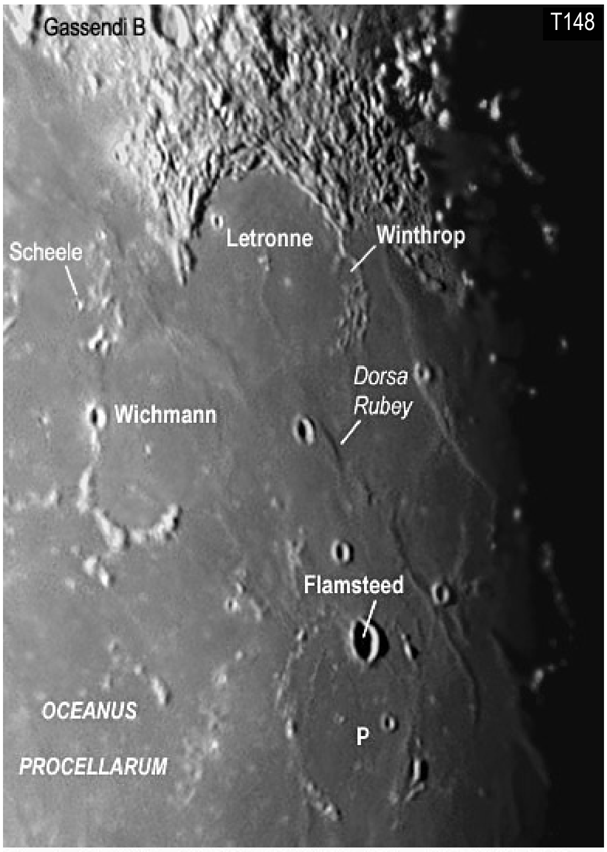
Image T154 shows the landing site of the American unmanned probe *Surveyor 3* (April 1967). The manned *Apollo 12* visited the same site in November 1969, about 360 m away from Surveyor 3. The network of wrinkle-ridges in the west of Montes Riphaeus looks like an alien creature fighting with the "hunter".



Montes Riphaeus & wrinkle ridges 2005.04.19 ~13:33 UT Age 10.7 days. 10-in f/6 Newtonian + 2.5X + ToUcam (*mosaic*)



🡐 The wrinkle ridges in Oceanus Procellarum become prominent near the terminator. Note also the dome and the ghost ring at the picture corner.



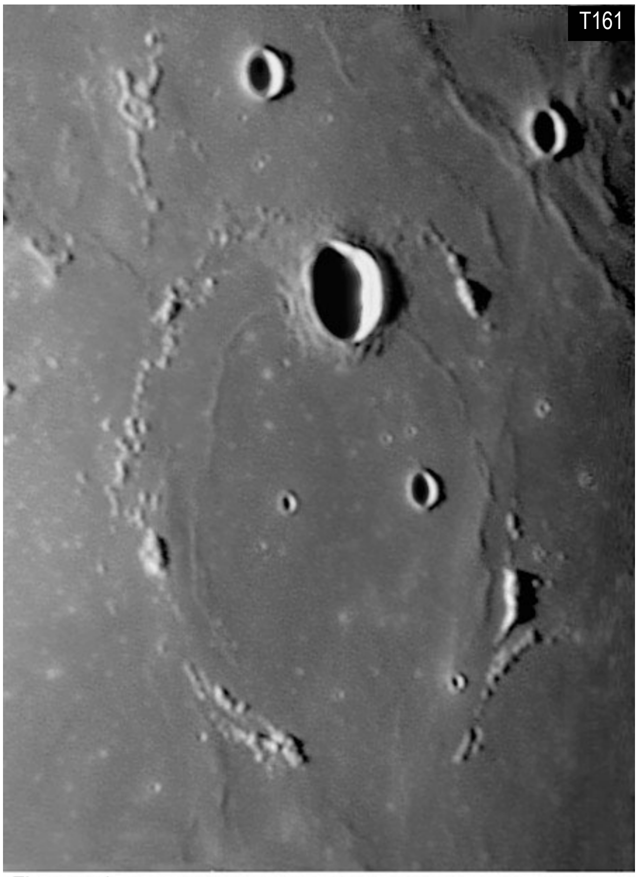
Flamsteed & vicinity 2004.09.25 ~14:44UT Age 11 days. 10-in f/6 + 2.5X + ToUcam

Flamsteed 4.5^0 S 44.3^0 W
A crater, diameter 20 km. It is just inside the ghost ring formation ***Flamsteed P***. This ring has incomplete wall of diameter 112 km, and is believed an ancient impact crater flooded by lava during the formation of Oceanus Procellarum.

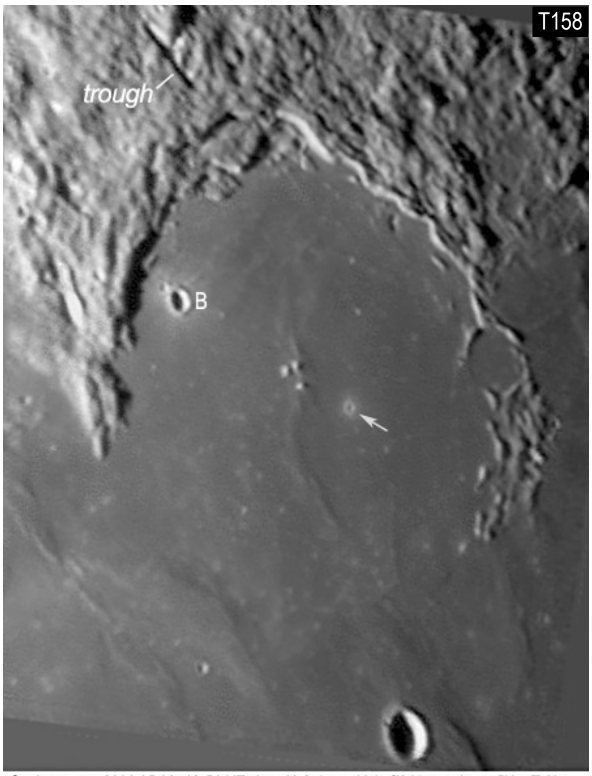
Letronne 10.8^0 S 42.5^0 W
Remains of a flooded crater, diameter 116 km. It appears like a bay which opens to Oceanus Procellarum. Three small central peaks and a white halo craterlet are distinguishable on the floor. Letronne B (5 km) is also a white halo crater. A trough feature is in the immediate south of Letronne.

Winthrop 10.7^0 S 44.4^0 W
Remains of a flooded crater lying on the western rim of Letronne, diameter 17 km.

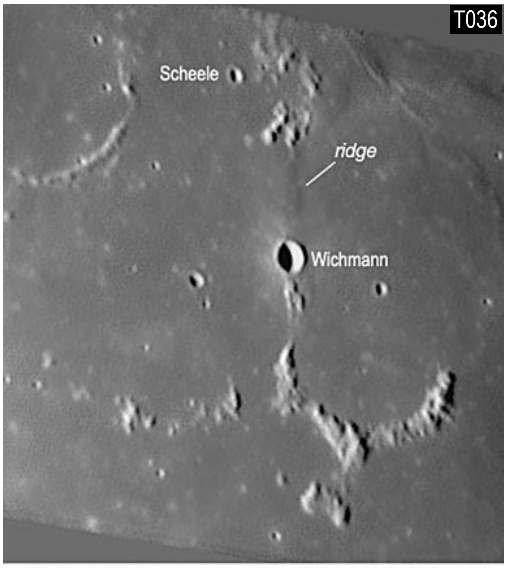
Dorsa Rubey 10.0^0 S 42.0^0 W
A system of wrinkle ridges extending outward from Letronne, length 100 km.



Flamsteed 2006.05.09 13:50 UT Age 11.8 days. 10-in f/6 Newtonian + 5X + ToUcam



Letronne 2006.05.09 13:56 UT Age 11.8 days. 10-in f/6 Newtonian + 5X + ToUcam
The arrow points to a white halo craterlet close to three central peaks.
Letronne B is also a white halo crater, diameter 5 km. Its rim adjoins a craterlet.

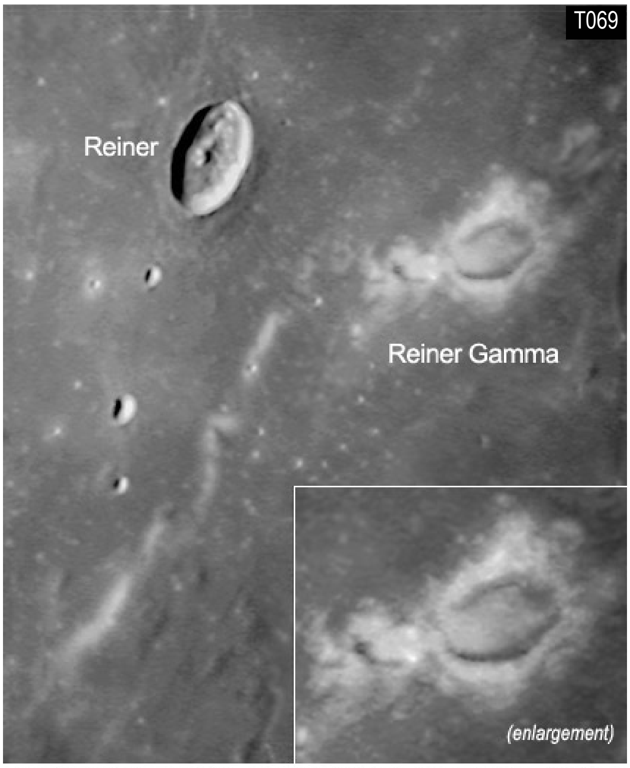


Wichmann 2006.05.09 14:40 UT Age 12 days. 10-in f/6 Newtonian + 4X + ToUcam

Wichmann 7.5^0 S 38.1^0 W
A bowl-shaped crater, diameter 10 km. Its northern rim connects to an arc-shaped mountain which could be the rim of a half-submerged crater. Its southern rim is linked to an irregular mountain through a ridge. A narrow arc-shaped mountain also exists to the east of ***Scheele*** (4 km).

Image T069:

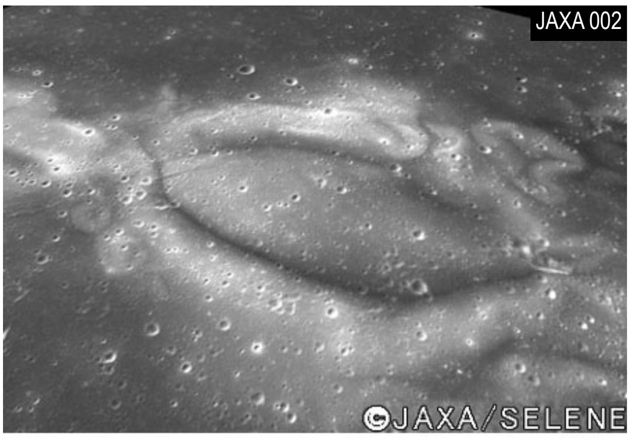
Reiner 7.0^0 N 54.9^0 W
An isolated crater in the middle of Oceanus Procellarum, with central peak and fairly rough floor, diameter 29 km. It is circular in shape but appears oval due to foreshortening.



Reiner Gamma 2005.04.22 16:00 UT Age 13.8 days. 10-in f/6 + 4X + Toucam

Reiner Gamma 7.5^0 N 59.0^0 W
A swirling deposit of bright material near Reiner on Oceanus Procellarum. It measures about 70 km east-west, with the central part resembling an oval dome. Together with the adjacent bright tail formation, Reiner Gamma resembles the head of a white snake. Visually the snake has two tails, but only one tail prominent at a time. The "east tail" is shown in T069 (Moon age 14 days); the "west tail" is shown in T155 of previous page (Moon age 12 days).

In general the lunar surface is lack of magnetic field, but Reiner Gamma is one of the few known anomalies. A model suggests that the early Moon still preserved a weak magnetic field. It happened that some fragments of a low-density comet fell on the Moon and ploughed up the regolith. Their interaction strengthened the local magnetic field while the global magnetic field faded more quickly in time. As magnetic field deflects the charged particles in solar wind which are known to darken the lunar surface, it may account for the high albedo (brightness) of Reiner Gamma against the dark mare background. Another model proposed that shock waves produced from a meteoroid impact on the farside of the Moon may have forced lighter matetials to the location of Reiner Gamma. At present the puzzle of lunar swirls remains unanswered. See also ***Mare Ingenii*** in Farside.

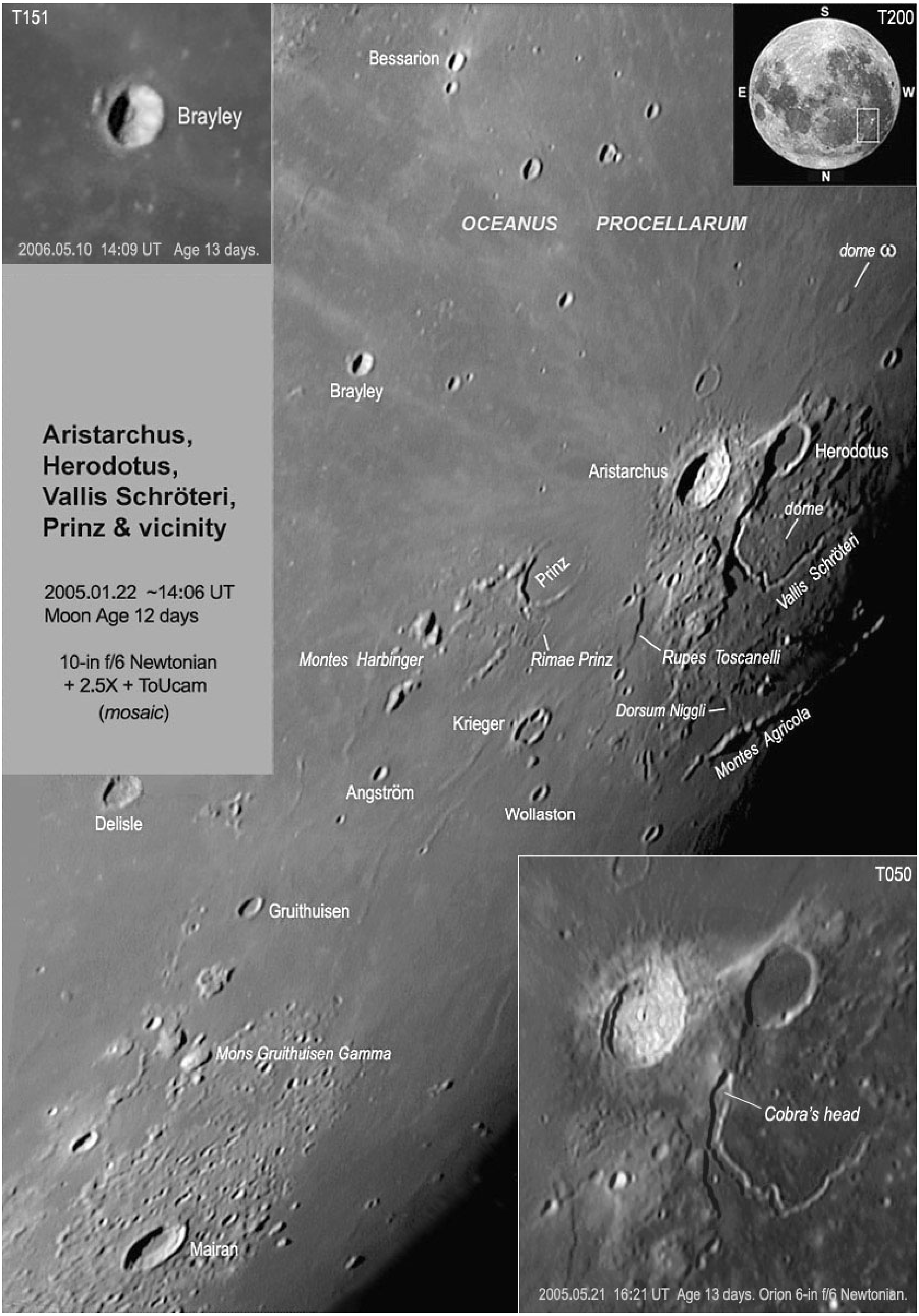


Reiner Gamma imaged by the Japan's Selene lunar probe in 2009

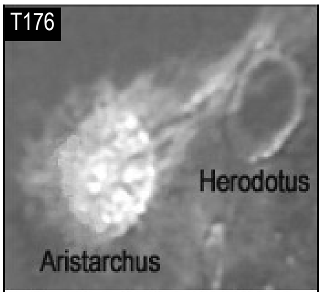
MAP 21

Aristarchus, Herodotus, Vallis Schröteri, Prinz

Hatfield 8
Rükl 18, 19



Aristarchus, Herodotus and Vallis Schröteri form an interesting feature group on a diamond-shaped plateau in Oceanus Procellarum. Near the terminator shortly before the full moon, the feature resembles the face of a cat (or an owl) viewed with south up.



Aristarchus during the full moon on 2005.04.23. Radial dark bands extend up the inner terraced walls of the crater.

Aristarchus 23.7^0 N 47.4^0 W

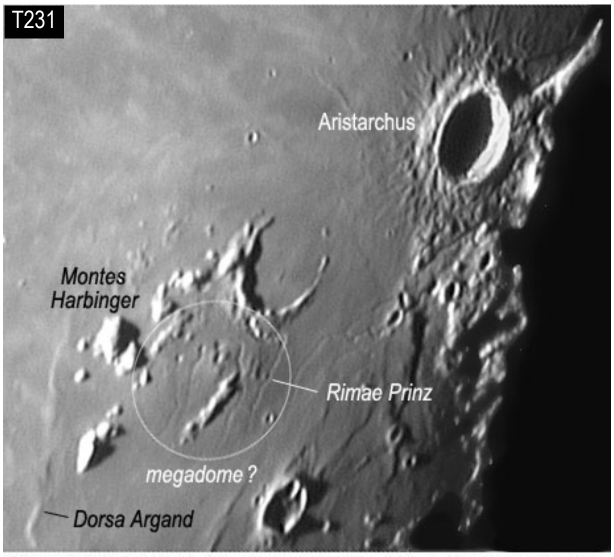
A rayed crater with terraced walls and small central peak, diameter 40 km. Its depth is 3000 m, deep enough to expose the bright anorthosite rock of the lunar crust. Indeed its brightness is even detectable in the earthshine portion of a Moon crescent, Event 3. Aristarchus is very young, formed about 500 million years ago. The Aristarchus region is a site of LTP (lunar transient phenomena) glows, probably caused by gases released from decay of radioactive elements. The Apollo-15 and Lunar Prospector flyover also detected the radioactivity of radon gas. The inner walls of Aristarchus are shaded with radial dark bands near the full moon (T176).

Herodotus 23.2^0 N 49.7^0 W

A flooded crater with flat floor, diameter 34 km. Dome ω is in the south of Herodotus (T200).

Vallis Schröteri (Schröter's Valley) 26.2^0 N 50.8^0 W

This is the largest sinuous valley on the Moon. It starts about 30 km north of Herodotus on a diamond-shaped plateau (Aristarchus plateau), then bends through nearly 180^0 to the west before opening out onto Oceanus Procellarum. The starting end joins with a 6-km diameter crater; nicknamed the ***Cobra's head***. Vallis Schröteri is 168 km long, up to 11 km wide and 1000 m deep. Current theory suggests that the entire valley, including the head, is a lava channel. Note the dome with summit craterlet in the west of Vallis Schröteri (arrow in T159, next page).



Aristarchus (in shadow) 2005.10.14 14:14UT Age 11 days. 10-in f/6 + 2.5X + ToUcam

Rupes Toscanelli 27.4^0 N 47.5^0 W

A fault, length 70 km.

Montes Agricola 29.1^0 N 54.2^0 W

A straight narrow mountain range, 140 km long.

Prinz 25.5^0 N 44.1^0 W *(Image T231)*

The remains of a flooded crater, diameter 46 km. A complex of lava flow (***Rimae Prinz***, 80 km) runs northward from the crater wall.

Montes Harbinger 27.0^0 N 41.0^0 W

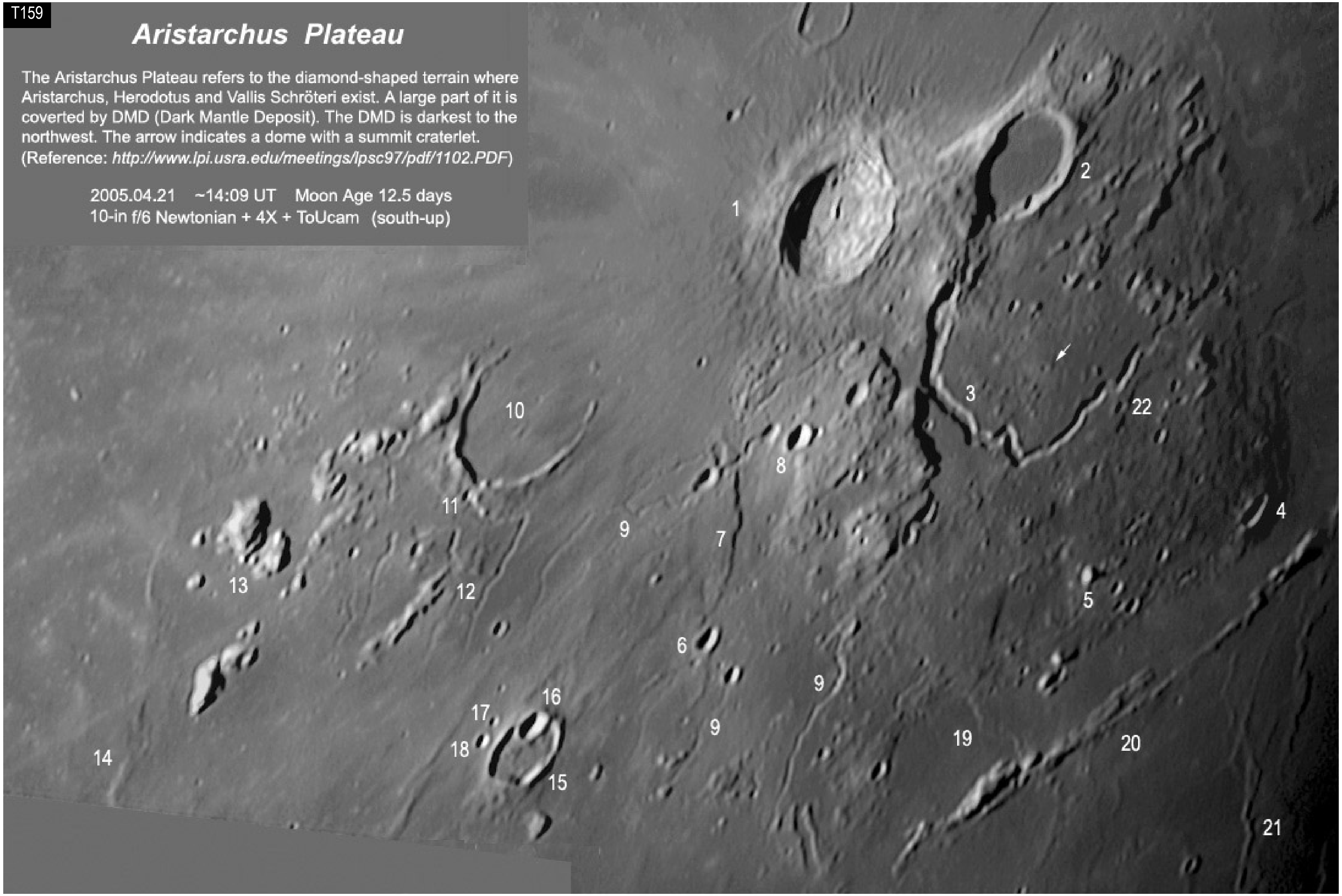
A group of isolated mountains spanning 90 km south-north, peak height 2500 m. Some observers speculated that the Harbinger region is a "megadome" (large uplifted piece on lunar mare) similar to the diamond-shaped Aristarchus plateau. However this remains unconfirmed because its very low elevation is elusive to observe.

Rimae Aristarchus 26.9^0 N 47.5^0 W

A wide system of sinuous rilles close to Aristarchus and Prinz, length 120 km.

Brayley 20.9^0 N 36.9^0 W *(Image T151, previous page.)*

A bowl-shaped crater, diameter 14 km. Its depth is as great as 1/5 of the diameter. Like Aristarchus under high illumination, the inner walls of Brayley are shaded by radial dark bands.



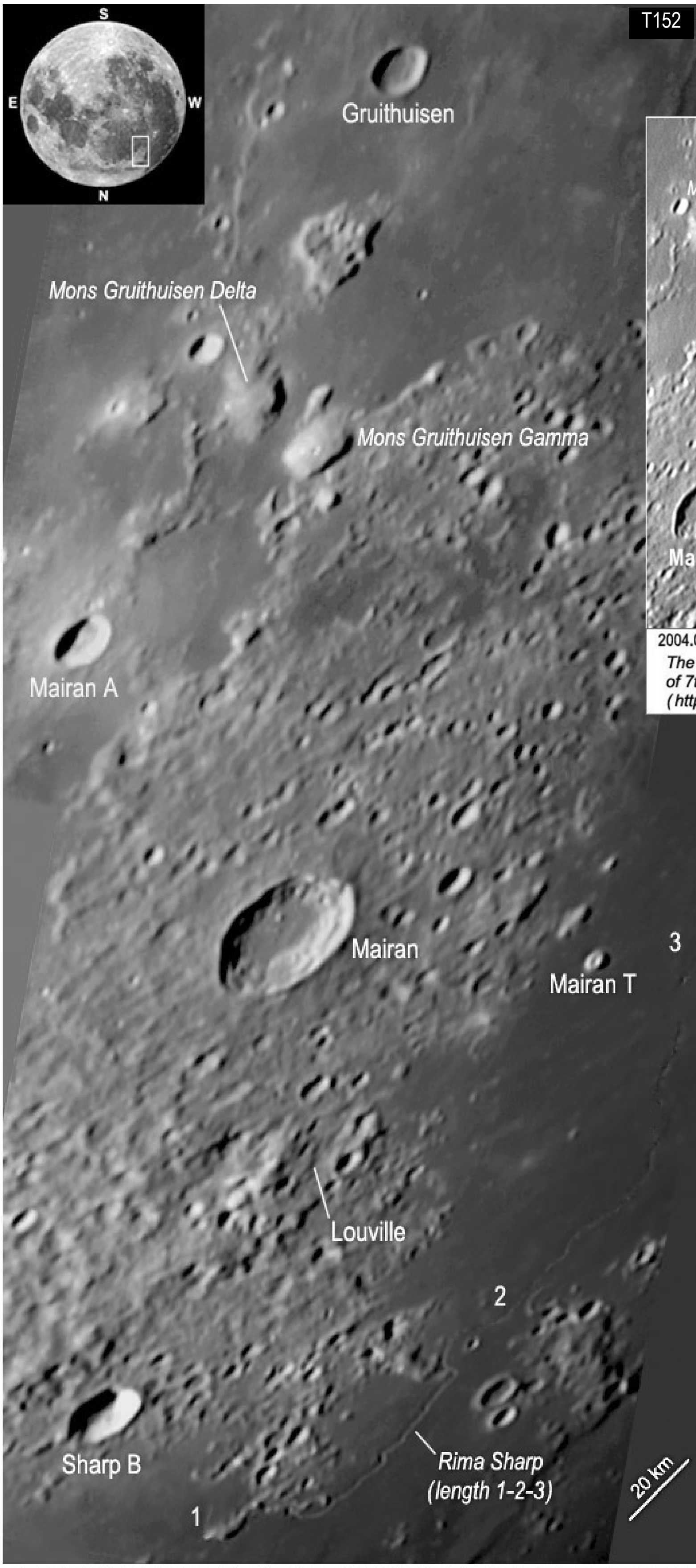
1. Aristarchus 2. Herodotus 3. Vallis Schröteri 4. Raman 5. Mons Herodotus 6. Toscanelli 7. Rupes Toscanelli 8. Väisälä 9. Rimae Aristarchus 10. Prinz 11. Vera 12. Rimae Prinz 13. Montes Harbinger 14. Dorsa Argand 15. Krieger 16. Van Biesbroeck 17. Ruth 18. Rocco 19. Dorsum Niggli 20. Montes Agricola 21. Dorsa Burnet 22. Freud

MAP 21

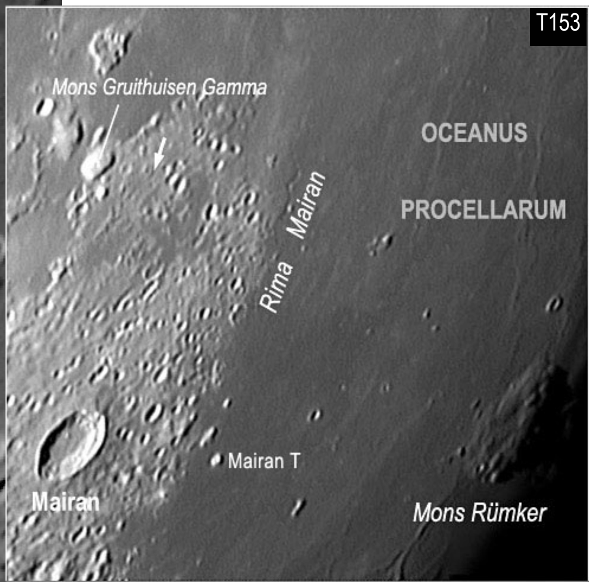
MAP 22

Hatfield 8
Rükl 9, 8, 19

Mairan, Gruithuisen, Mons Rümker, Mons Delisle

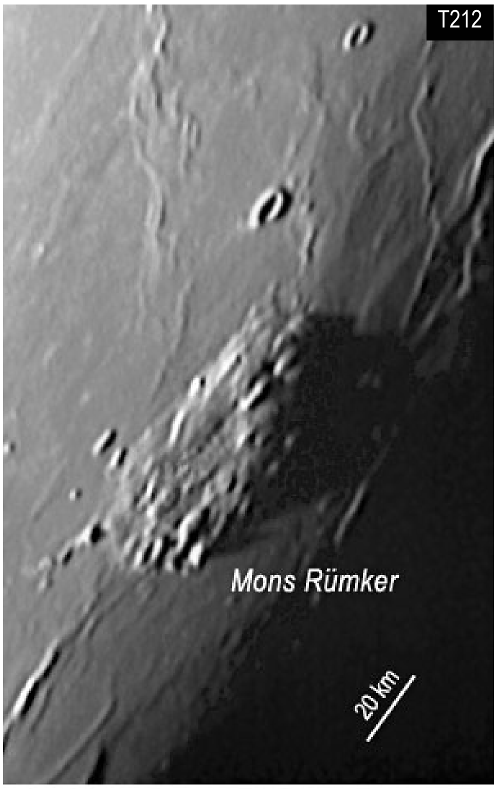


Mairan Region 2006.05.10 15:06 UT Age 12.8 days. 10-in f/6 Newtonian + 4X + ToUcam



2004.09.26 14:22 UT Age 12 days. 10-inch f/6 Newtonian + 2.5X + ToUcam

The arrow points to a "LTP" site where a flash (meteoroid impact) of 7th magntude was captured by NASA / MFSC on 2005.11.07. (http://science.nasa.gov/headlines/y2005/22dec_lunartaurid.htm)



2005.04.21 14:29 UT Age 12.5 days. *(10-in f/6 scope)*

Mairan 41.6^0 N 43.4^0 W
A 40-km crater with sharp rim and a tiny off-centered peak. ***Mairan T*** (3 km) is a small bright dome with a summit craterlet. ***Rima Mairan*** (90 km) is a faint rille south of Mairan T. To the north of Mairan is ***Louville***, a 36-km heavily ruined crater. It is quite obscure to spot from the rugged background.

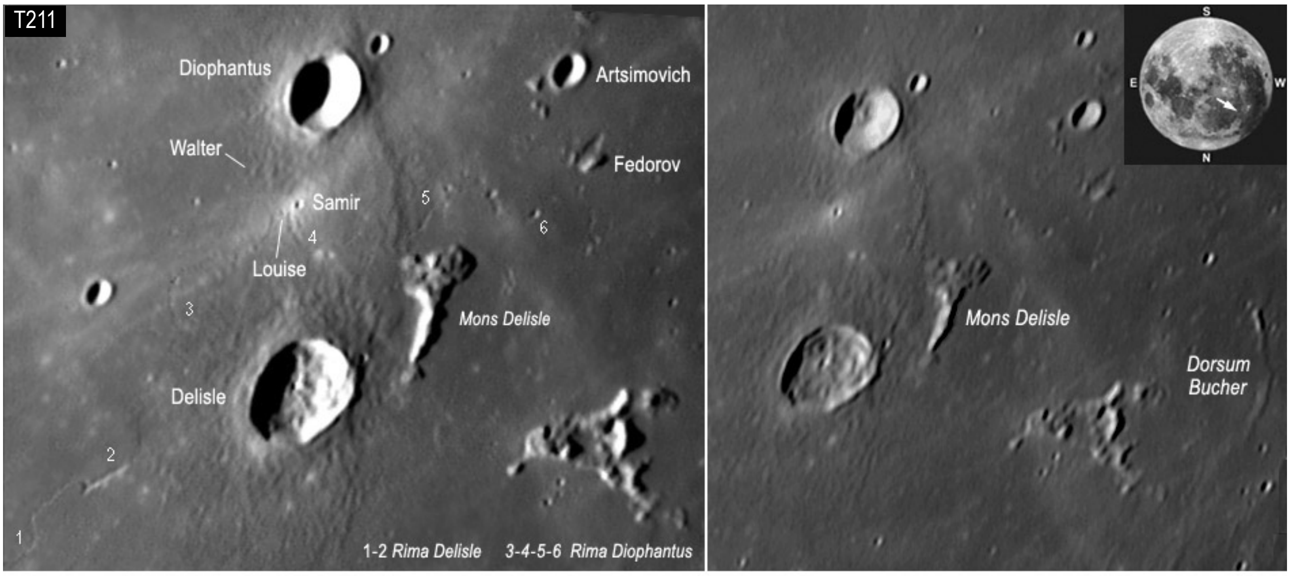

Novarupta volcanic dome in Alaska (base size ~ 2 km, height 840 km)
Image credit: C. G. Reyes, 2003.

Rima Sharp 46.7^0 N 50.5^0 W
A faint sinuous rille, length 190 km. (*107 km by IAU.*)

Mons Gruithuisen Gamma 36.6^0 N 40.5^0 W
A dome mountain between Mairan and ***Gruithuisen*** (diameter 15 km). It measures 20x20 km, height 1 km. The dome is somewhat elongated due to foreshortening, hence appears like an "upturned bathtub". The summit has a 1-km craterlet and an elusive pit, both are good tests for the resolution of 10-in telescopes. Compare this lunar dome with the Novarupta dome in Alaska.

Mons Gruithuisen Delta 36.0^0 N 39.5^0 W
A mountain similar to Mons Gruithuisen Gamma in nature but irregular in shape, base 20 km.

Mons Rümker 40.8^0 N 58.1^0 W
A volcanic complex of dome mountains on Oceanus Procellarum, base 70 km, height 500 m. Its top contains a shallow depression sculptured by clefts and craterlets. At low Sun angles, wrinkle ridges are seen in the vicinity.



Diophantus & Delisle *Left:* 2006.05.09 13:31 UT Age 12 days. 10-in f/6 Newtonian+5.5X+ToUcam *Right:* 2005.04.21 15:04 UT Age 13 days. 10-in f/6 Newtonian+4X+ToUcam

Diophantus 27.6^0 N 34.3^0 W **Delisle** 29.9^0 N 34.6^0 W *(Image T211)*
To the southeast of Gruithuisen is a pair of sharp rimmed craters, Diophantus (17 km) and Delisle (25 km). Diophantus has a low central rise. Delisle has uneven floor with a central broken craterlet. ***Mons Delisle*** is an isolated highland remnant, length 30 km. It has a bulgy southern head but narrows down to the north like a fish-tail. ***Samir*** (2 km) is a tiny rayed crater with ***Louise*** (0.8 km) at neighborhood. Two faint sinuous rilles, ***Rima Diophantus*** (150 km) and ***Rima Delisle*** (60 km), are barely recognized; they appear clearer in the Lunar Orbiter images. ***Walter*** (1 km) is an obscure craterlet and should not be confused with ***Walther*** in Map 11.

Capuanus, Ramsden, Marth, Bullialdus, Kies, Opelt

Hatfield 9
Rükl 52, 53, 54, 63

This map covers the west zone of ***Mare Nubium*** (Sea of Clouds). The complete mare is irregular in shape and does not have definite boundary traceable to a typical impact basin. Probably it is an extension of lava flooding that had spread over vast surface including Mare Cognitum, Mare Insularum and perhaps as far as Oceanus Procellarum. (These maria are shown in T001 of Map 1.)

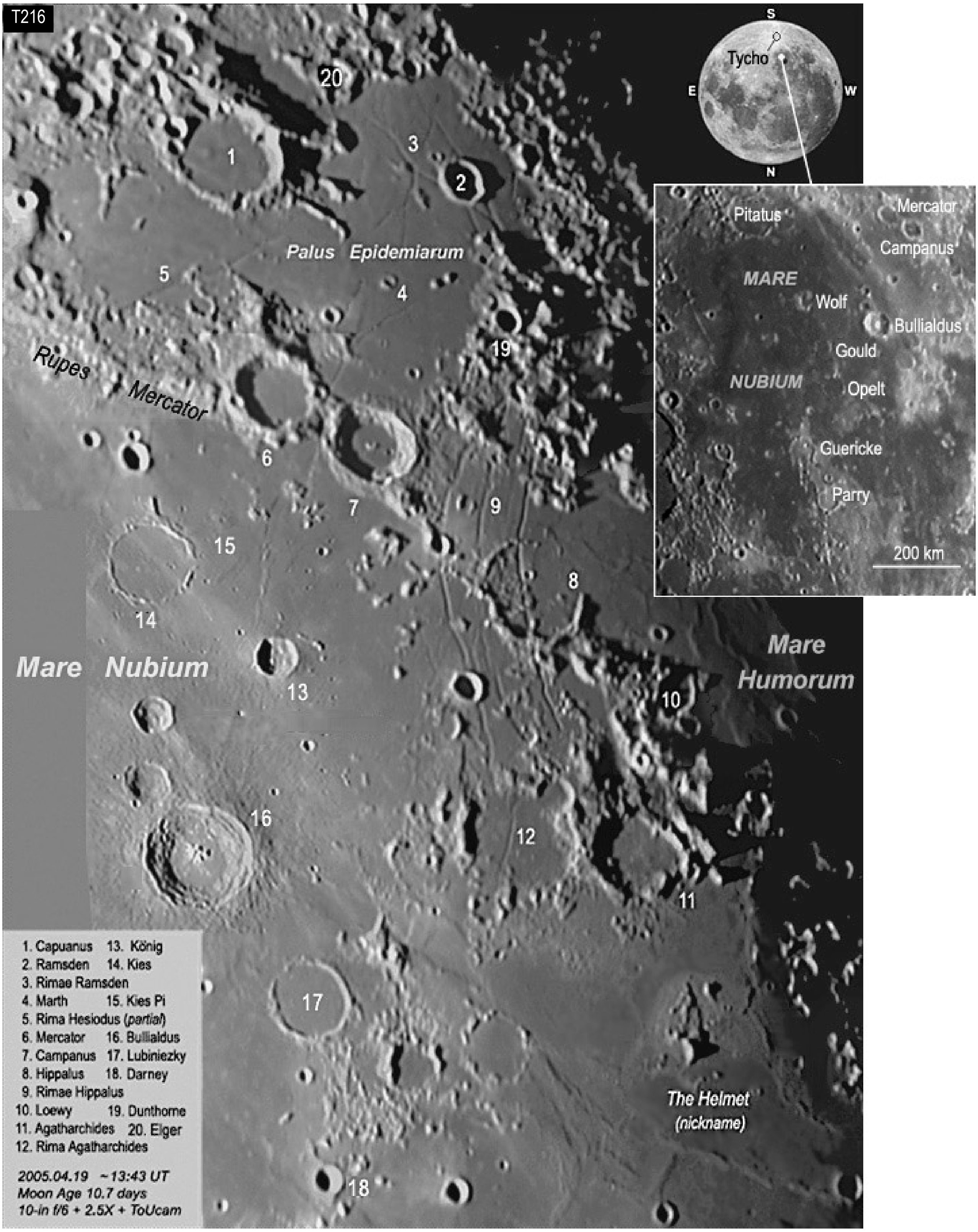
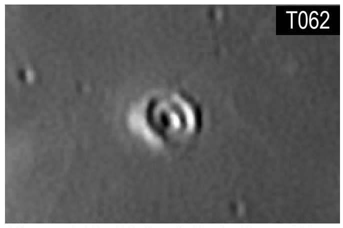


Image T216, previous page:

Capuanus 34.1^0 S 26.7^0 W
A flooded crater, diameter 59 km. Its floor contains low ridges and dome-like features.

Mercator 29.3^0 S 26.1^0 W **Campanus** 28.0^0 S 27.8^0 W
Adjoining craters of almost same size (46~48 km). The twin resembles a pair of spectacles. Campanus has a small, arc-shaped central peak. Two segments of inconspicuous rilles extend south-north from the junction wall between Mercator and Campanus.

Ramsden 32.9^0 S 31.8^0 W
A 24-km crater in the irregular plain ***Palus Epidemiarum*** (Marsh of Epidemics). It sits on a complex of fractures (***Rimae Ramsden***, 110 km).



Marth 2004.04.30 14:05UT Age 11 days

Marth 31.1^0 S 29.3^0 W
A double-walled crater in Palus Epidemiarum, diameter 6 km.

Rimae Hippalus 25.5^0 S 29.2^0 W
A spectacular system of arcuate rilles. See Map 24.

Rima Hesiodus 30.0^0 S 20.0^0 W
A graben, 250 km in length, 3 km in width. Part of it enters into Palus Epidemiarum. See also T083, Map 11.

2005.11.11 12:43 UT Age 9.5 days. 10-in f/6 Newtonian + 4X + ToUcam, 85% resized (*mosaic*)

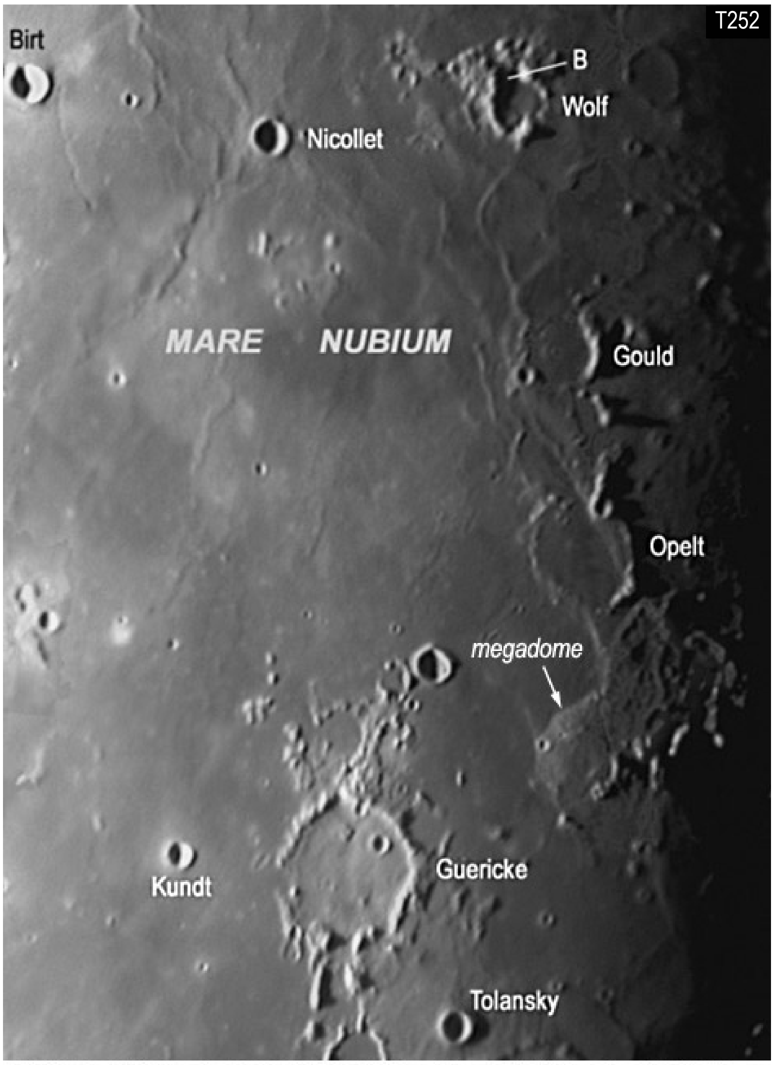
Image T081:

Rupes Mercator 31.0^0 S 22.3^0 W
A fault on the southern edge of Mare Nubium, length 93 km. An adjacent nameless rille runs in parallel.

Bullialdus 20.7^0 S 22.2^0 W
A terraced crater with multiple central peaks and radial ejecta blanket outside the rim, 60 km in diameter, 3500 m in depth. It looks like a "small version" of Copernicus (Map 19) but has no rays.

Kies 26.3^0 S 22.5^0 W
A flooded crater with a spiky cape, diameter 45 km. To the west is ***Kies*** π, a volcanic dome with summit craterlet. Pi is about 12 km in diameter.

König 24.1^0 S 24.6^0 W
A crater, diameter 23 km, fairly deep (2400 m). Its rim is brightened by the rays from Tycho.



Wolf, Gould & Opelt 2006.02.07 ~12:00 UT Age 9 days. 10-in f/6 Newtonian + 2.5X + ToUcam

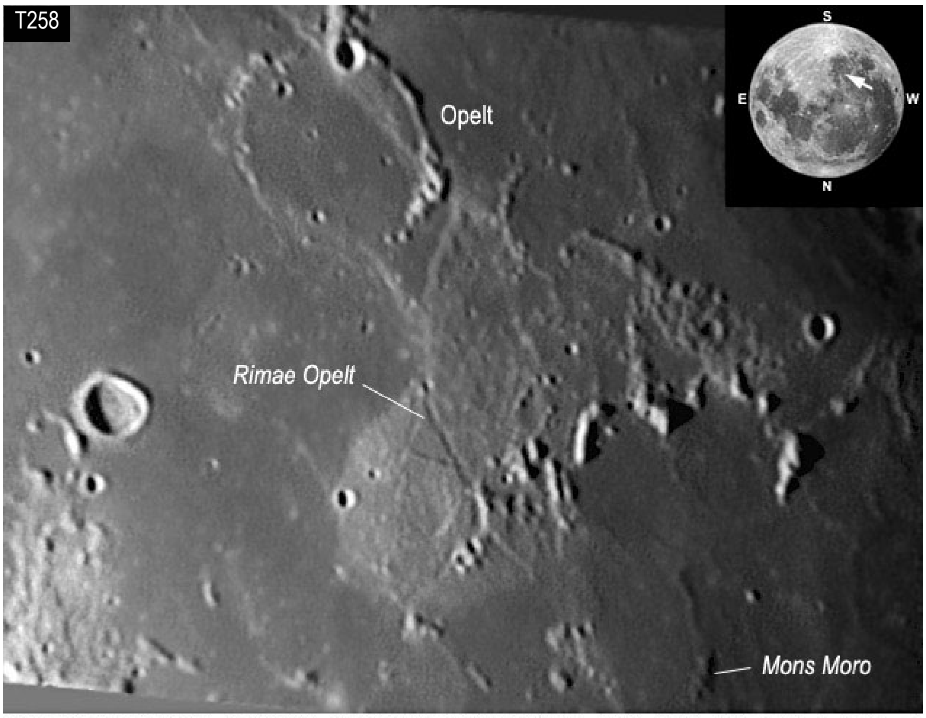
Image T252 & T258:

Wolf 22.7^0 S 16.6^0 W
Remains of a flooded crater sitting on a small low elevation, diameter 25 km. Its southern wall is heavily interrupted by ***Wolf B***.

Gould 19.2^0 S 17.2^0 W
Remains of a flooded crater, diameter 34 km. Its floor mingles with the wrinkle ridges on Mare Nubium.

Opelt 16.3^0 S 17.5^0 W
Remains of a flooded crater, diameter 48 km. Its northern wall is connected to a dome-shaped low plateau (megadome) of diameter about 60 km. The plateau is sculptured by a complex of rilles (***Rimae* Opelt**, length 70 km), see details in T258. This megadome, together with Opelt, Gould and Wolf, form an interesting quartet on the terminator.

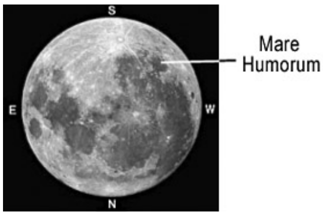
Guericke 11.5^0 S 14.1^0 W
A 63-km crater with "horns" at the rim, shown also in T089, Map 12.

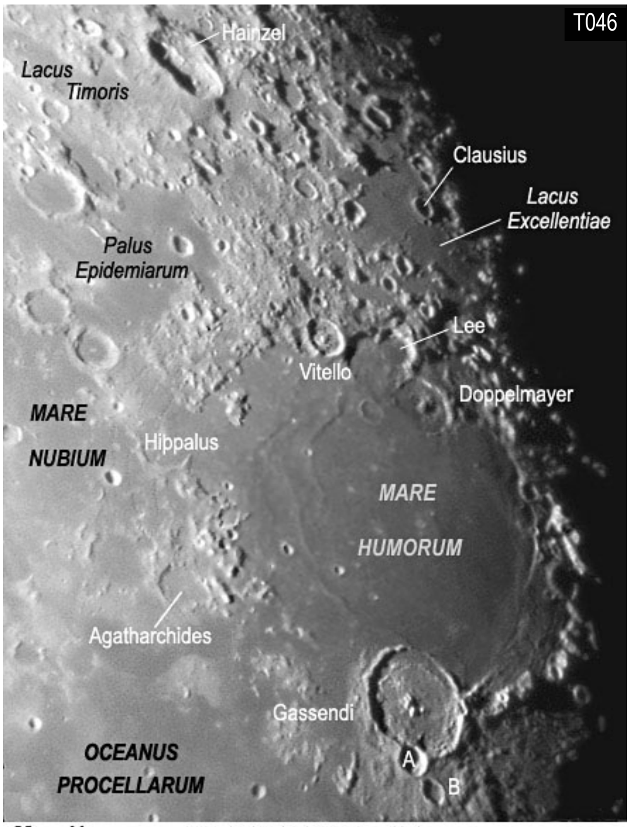


Megadome near Opelt 2006.03.09 ~15:30 UT Age 9.6 days. 10-in f/6 + 2.5X + 1.6X + ToUcam (*stack of 3 videos*)

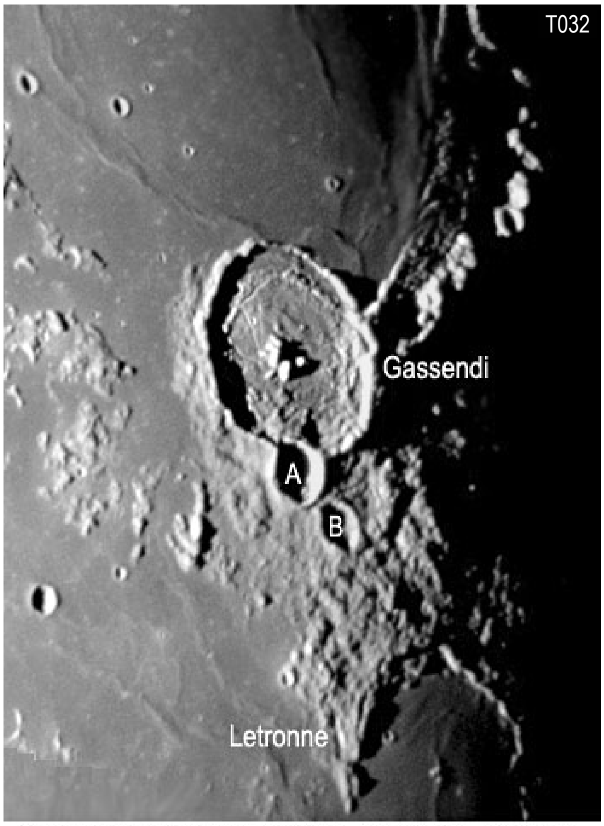
Hatfield 11
Rükl 51, 52, 53, 62

Mare Humorum, Gassendi, Lacus Excellentiae, Rimae Hippalus, Vitello, Doppelmayer, Mersenius





Mare Humorum 2000.12.07 14:16UT Age 11 days. QV2300-20001207-0002

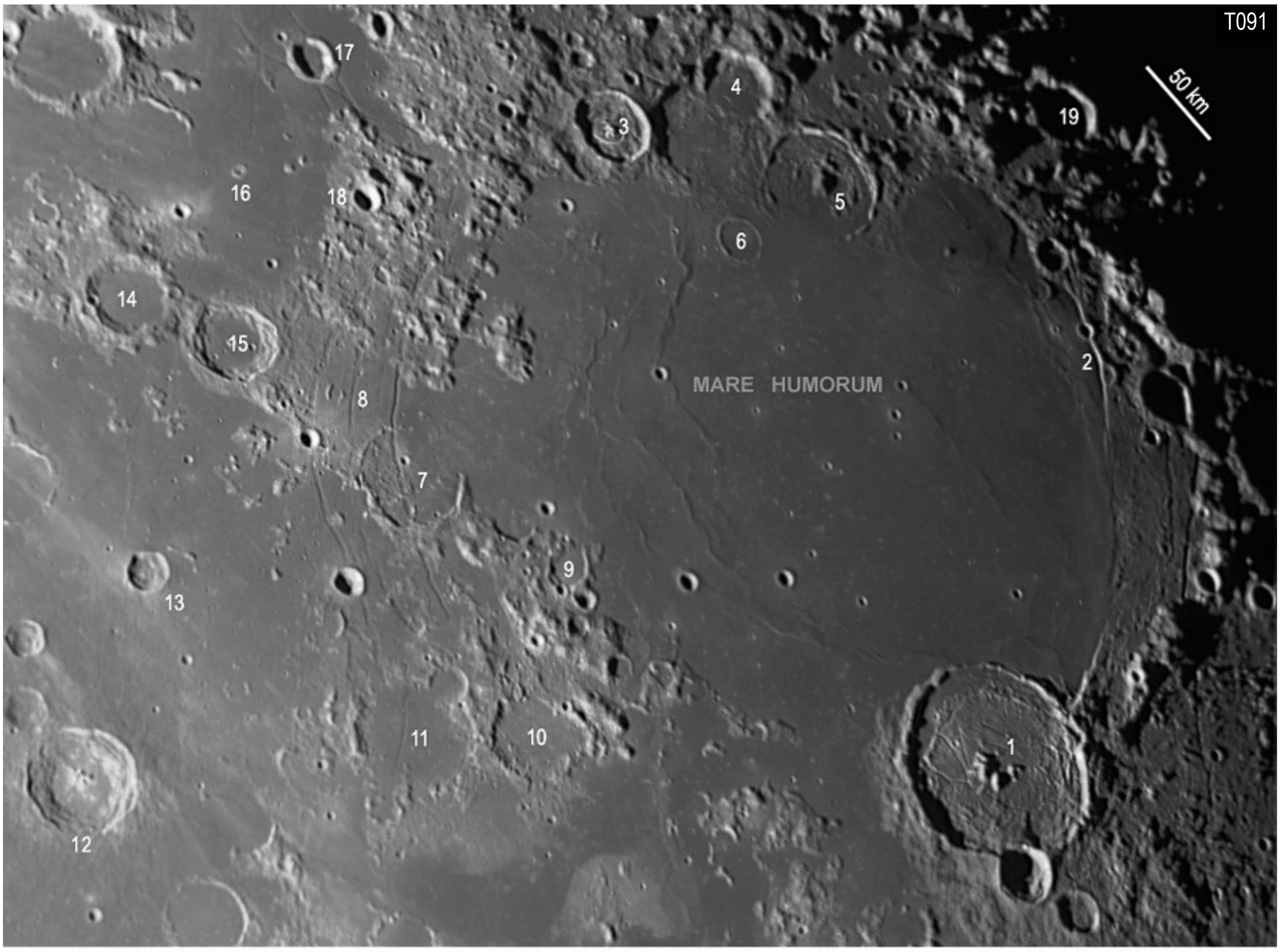


Gassendi 2002.06.21 13:30UT Age 10 days. C9+CP990

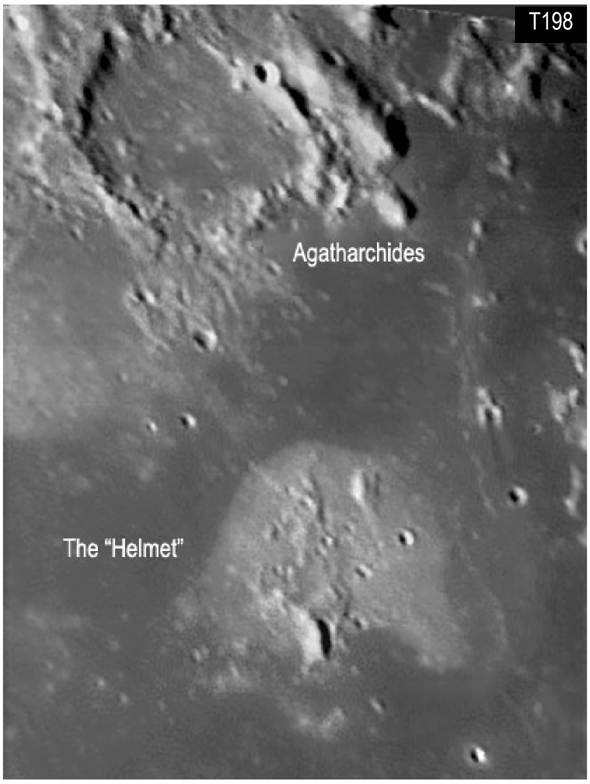
Mare Humorum 24.4^0 S 38.6^0 W
Mare Humorum (Sea of Moisture) is a fairly small lava plain, about 380 km in diameter. It is inside an impact basin formed in the Nectarian period (3.8~3.9 billion years ago). The mare contains a mascon. The lava depth is 3 km or more at the floor center. Under low illuminations, concentric wrinkle ridges are seen along the inner circumference. To the south are ***Palus Epidemiarum*** (Marsh of Epidemics), ***Lacus Excellentiae*** (Lake of Excellence) and ***Lacus Timoris*** (Lake of Fear).

Gassendi 17.6^0 S 40.1^0 W
Gassendi is a prominent FFC (floor-fractured crater) on the edge of Mare Humorum, diameter 101 km, depth 1800 m. In 2006, the European Smart-1 probe determined the crater formed 3.6 ± 0.7 billion years ago. Part of its floor was lava-flooded during the formation of Mare Humorum, leaving behind the crater rim and a jumble of central peaks. The floor is heavily fractured (***Rimae Gassendi***, T261), possibly by upward pressure of lava on a melt sheet. The western wall of Gassendi is broken by a triangular landslide. The northern wall is interrupted by a smaller but deeper crater, ***Gassendi A*** (33 km).

Letronne 10.8^0 S 42.5^0 W
A semi-circular relief just north of Gassendi. It is the remains of a large flooded crater, diameter 116 km. Letronne together with Gassendi resemble a “lobster”. See also T158, Map 20.



1. Gassendi 2. Rupes Liebig 3. Vitello 4. Lee 5. Doppelmayer 6. Puiseux 7. Hippalus 8. Rimae Hippalus 9. Loewy 10. Agatharchides 11. Agatharchides P 12. Bullialdus 13. König 14. Mercator 15. Campanus 16. Marth 17. Ramsden 18. Dunthorne 19. Palmieri 2009.11.28 12:48 UT Age 12 days. 10-in f/6 Newtonian + 1.6X + DMK31AF03



Agatharchides & the *Helmet* 2006.05.09 14:10 UT Age 12 days. 10-in f/6 + 5X + ToUcam

Gassendi 2006.05.09 14:02 UT Age 12 days. 10-in f/6 Newtonian + 5X + ToUcam

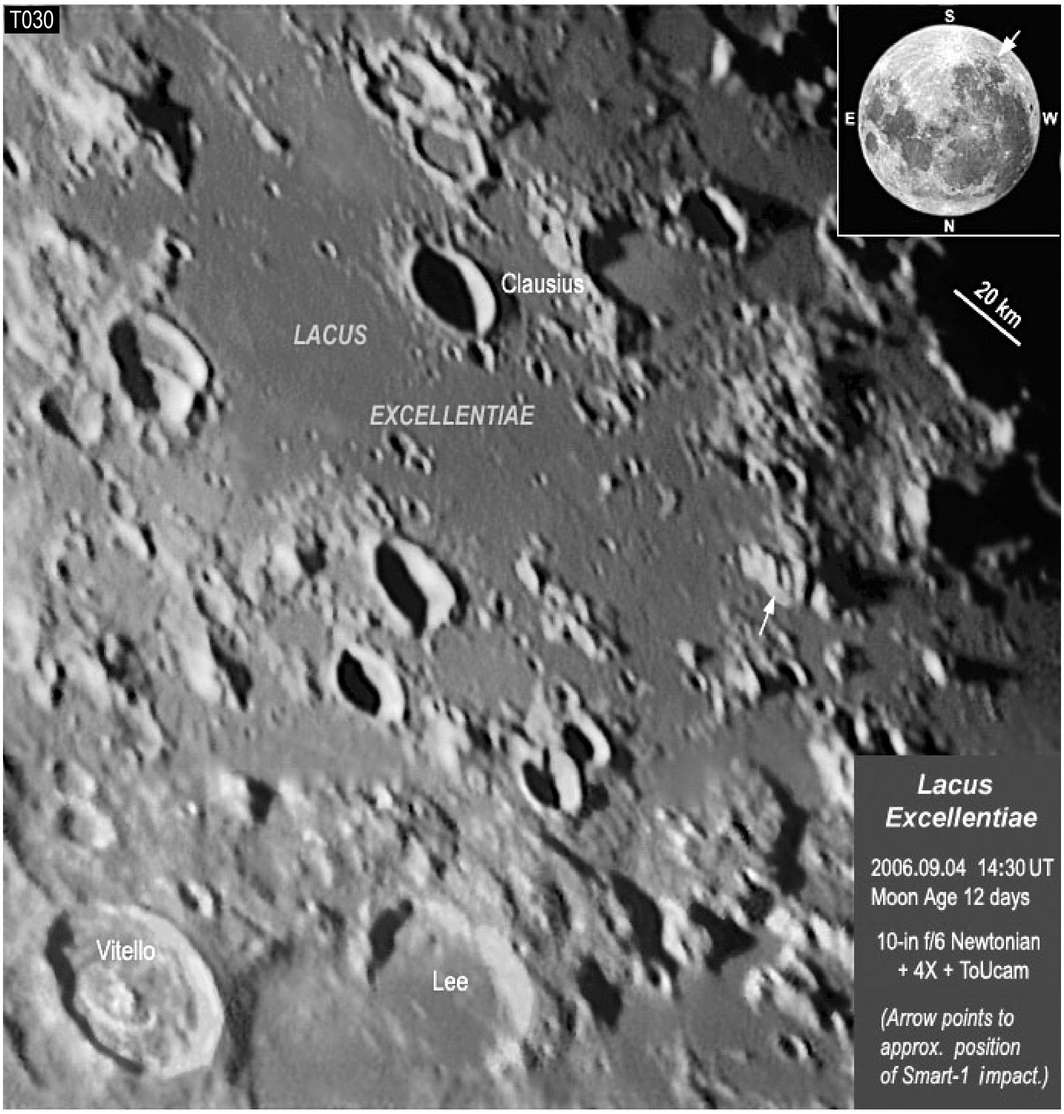
(Image T091 & T198, previous page)

Agatharchides 19.8^0 S 30.9^0 W
A ruined-wall flooded crater, diameter 48 km. To its east is ***Agatharchides P*** (66 km) intersected by a rille (***Rima Agatharchides,*** length 50 km).

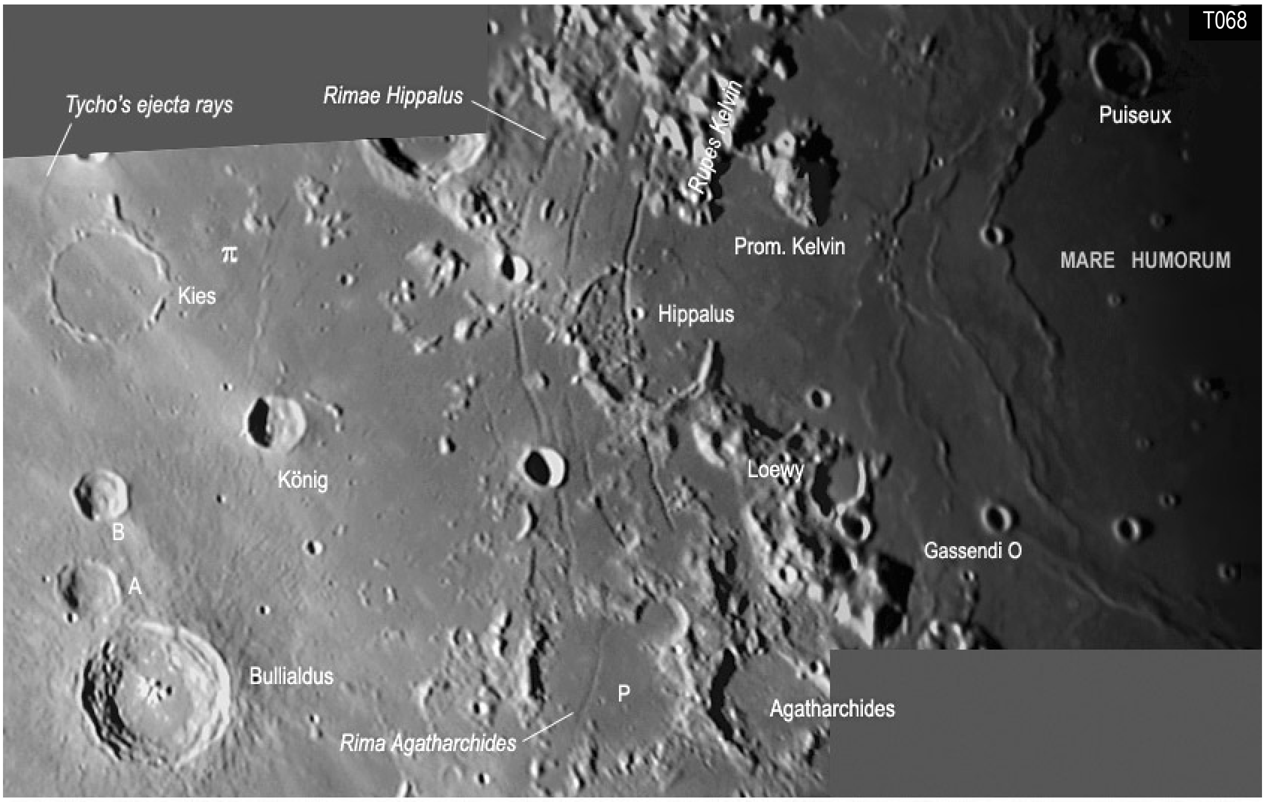
The Helmet 16.7^0 S 31.5^0 W*)*
A fairly bright dome-shaped plateau (megadome) nicknamed by the Apollo-16 crew, size about 60 km. Its top is ridged and cratered.

(Image T030)

Lacus Excellentiae 35.4^0 S 44.0^0 W
Lacus Excellentiae (Lake of Excellence) is an irregular strip of mare on the rugged terrain of the Southern Highlands. Its boundary is ill-defined, roughly 180 km north-south. ***Clausius*** is the only notable crater in this region, diameter 24 km. On 2006.09.03, the European lunar orbiter Smart-1 ended its mission with a controlled crash onto the northern end of Lacus Excellentiae. The 3.6-m CFHT (Canada-France-Hawaii Telescope) on Mauna Kea in Hawaii captured an infrared picture of a bright flash as Smart 1 hit its target.



Rimae Hippalus and wrinkle ridges in Mare Humorum

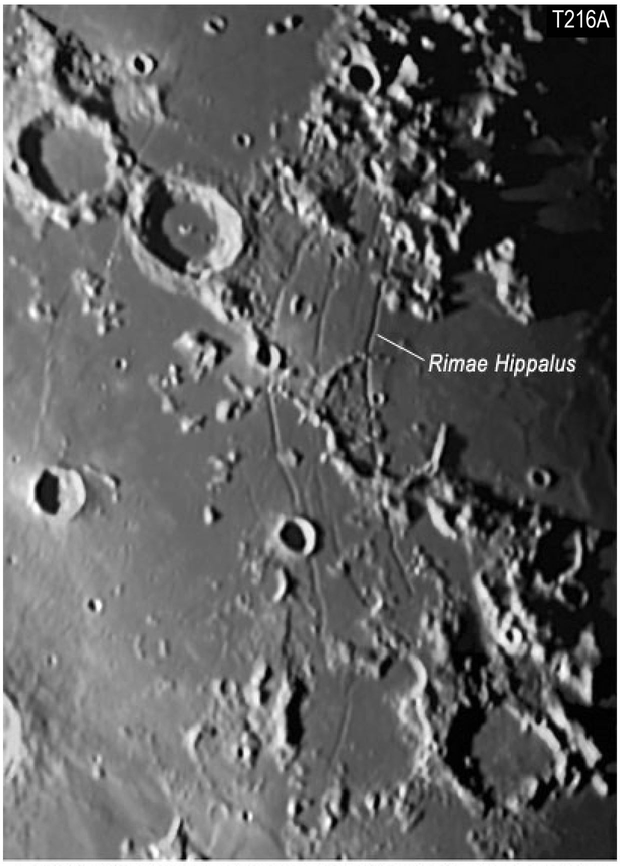


East Region of Mare Humorum 2004.04.30 13:06~13:27 UT Age 11 days. 10-in f/6 Newtonian + 2.5X + ToUcam (*mosaic*)

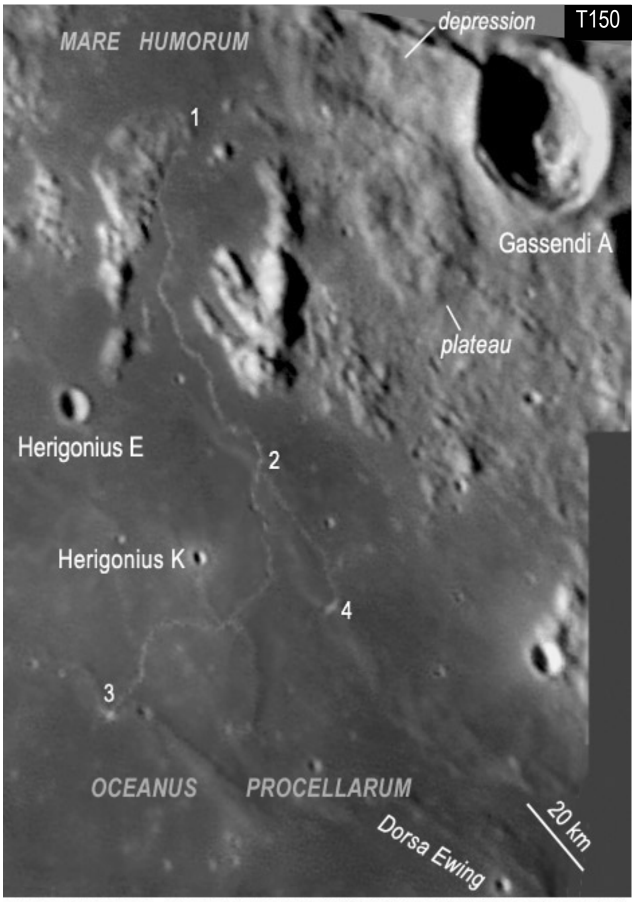
Rimae Hippalus 25.5^{0} S 29.2^{0} W
A spectacular system of rilles crossing the ruined crater ***Hippalus***, length 190 km. The system is dominated by three arcuate rilles, each about 2 km wide and visible in small telescopes. They appear as concentric fractures along the outer circumference of Mare Humorum, and are caused by the subsidence of immense lava masses in the Humorum basin.

Promontorium Kelvin 27.0^{0} S 33.0^{0} W
A cape almost detached from ***Rupes Kelvin***, base width 50 km.

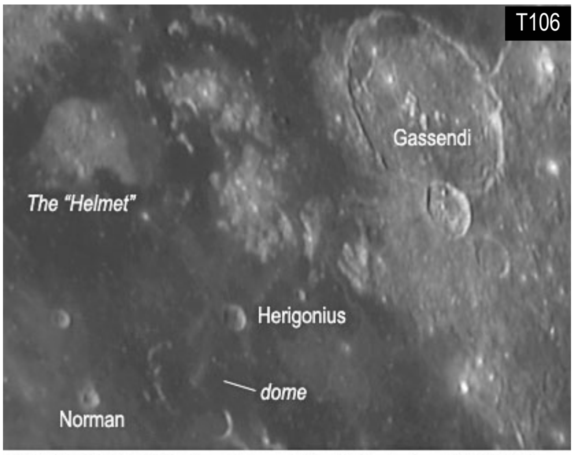
Loewy 22.7^{0} S 32.8^{0} W
Puiseux 27.8^{0} S 39.0^{0} W
Both craters are 24 km in diameter. They are named after the co-authors of the *Atlas Photographique de la Lune*, first published by Paris Observatory in 1896-1910. Puiseux is deeply submerged; only the top part of its rim remains above the mare surface.



2005.04.19 13:43 UT Age 11 days. 10-in f/6 Newtonian + 2.5X + ToUcam



Rimae Herigonius, composed of section 1-2-3 & 2-4, length 100 km. **Gassendi A** (dia. 33 km) is at top corner. 2006.05.09 14:14UT Age 12 days. 10-in f/6+5X+ToUcam

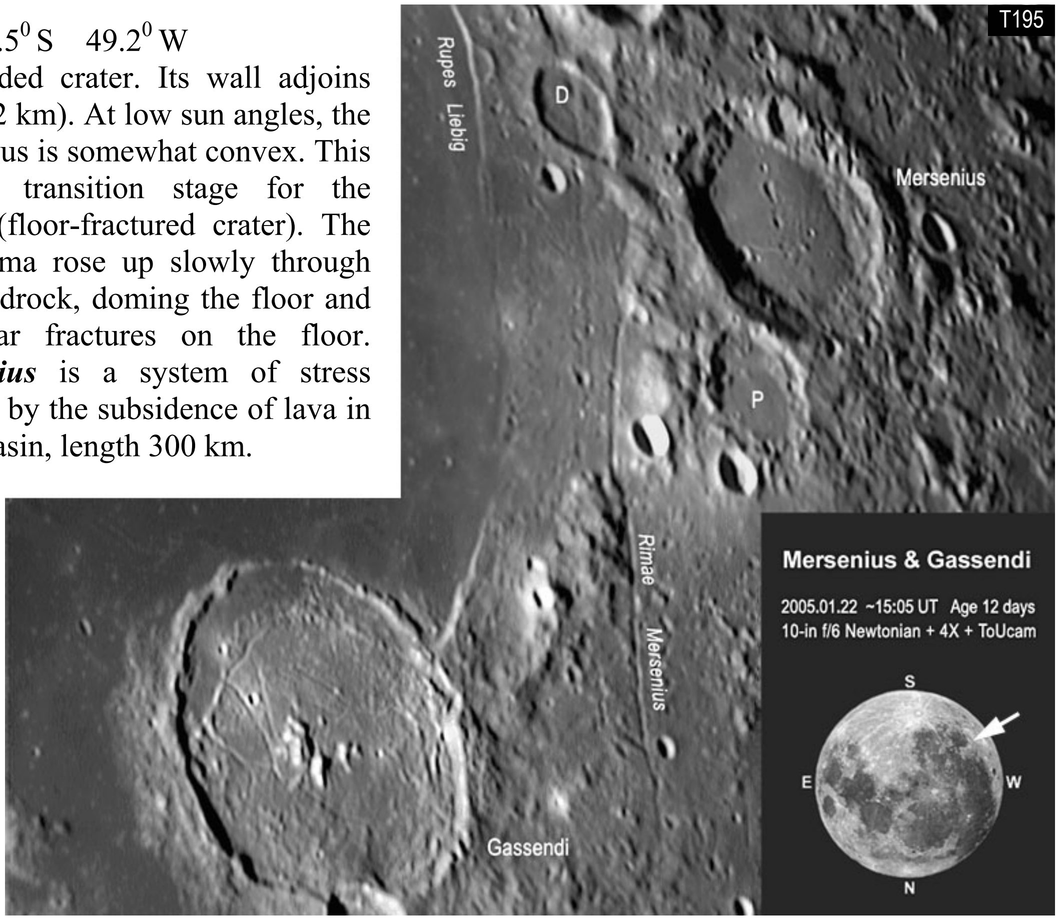


2009.06.06 15:52 UT Age 13 days. 10-in f/6 Newtonian + 2.5X + ToUcam

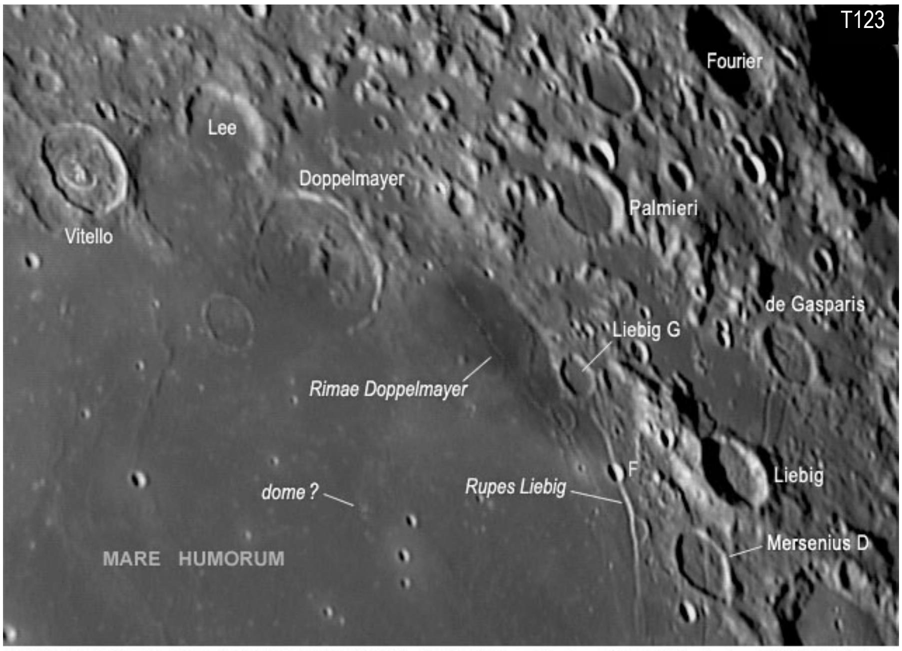
Herigonius 13.3^0 S 33.9^0 W
An inconspicuous crater, diameter 15 km. A dome exists in the northeast of the crater.

Rimae Herigonius 13.0^0 S 37.0^0 W
A system of sinuous rilles (lava channels) meandering between Mare Humorum and Oceanus Procellarum, length 100 km. Note the rectangular depression and plateau feature between Rimae Herigonius and Gassendi A. The plateau top appears rugged and somewhat depressed.

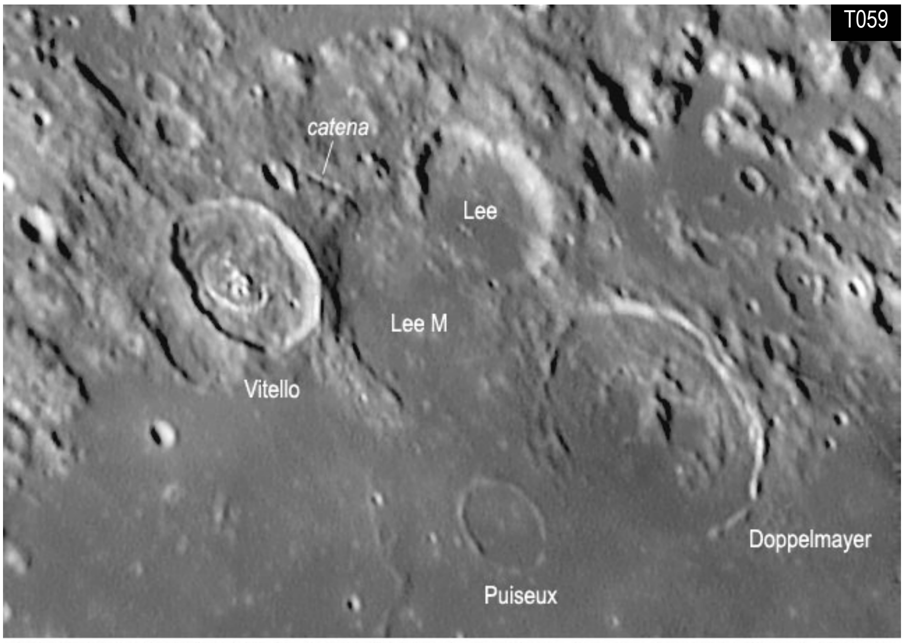
Mersenius 21.5^0 S 49.2^0 W
An 84-km flooded crater. Its wall adjoins ***Mersenius P*** (42 km). At low sun angles, the floor of Mersenius is somewhat convex. This is probably a transition stage for the so-called FFC (floor-fractured crater). The subsurface magma rose up slowly through cracks in the bedrock, doming the floor and making irregular fractures on the floor. ***Rimae Mersenius*** is a system of stress fractures caused by the subsidence of lava in the Humorum basin, length 300 km.



Mersenius & Gassendi
2005.01.22 ~15:05 UT Age 12 days
10-in f/6 Newtonian + 4X + ToUcam



Rimae Doppelmayer & Rupes Liebig 2005.01.22 15:45 UT Age 12 days. 10-in f/6 Newtonian + 2.5X + ToUcam

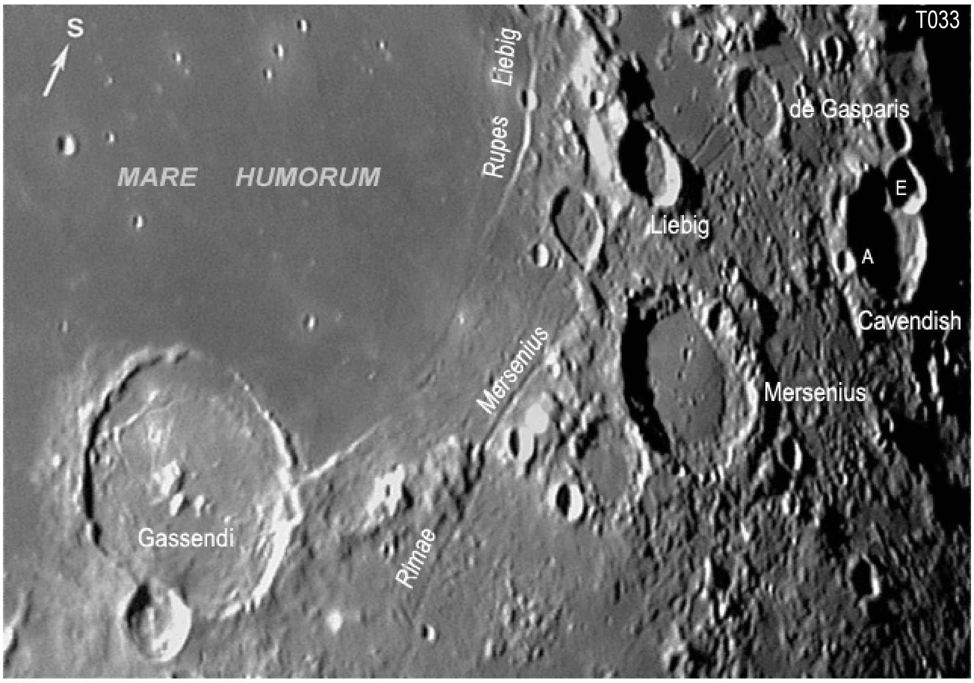


Vitello, Lee and Doppelmayer 2005.01.22 15:10 UT Age 12 days. 10-in f/6 + 2.5X + 1.6X + ToUcam, 68 frames

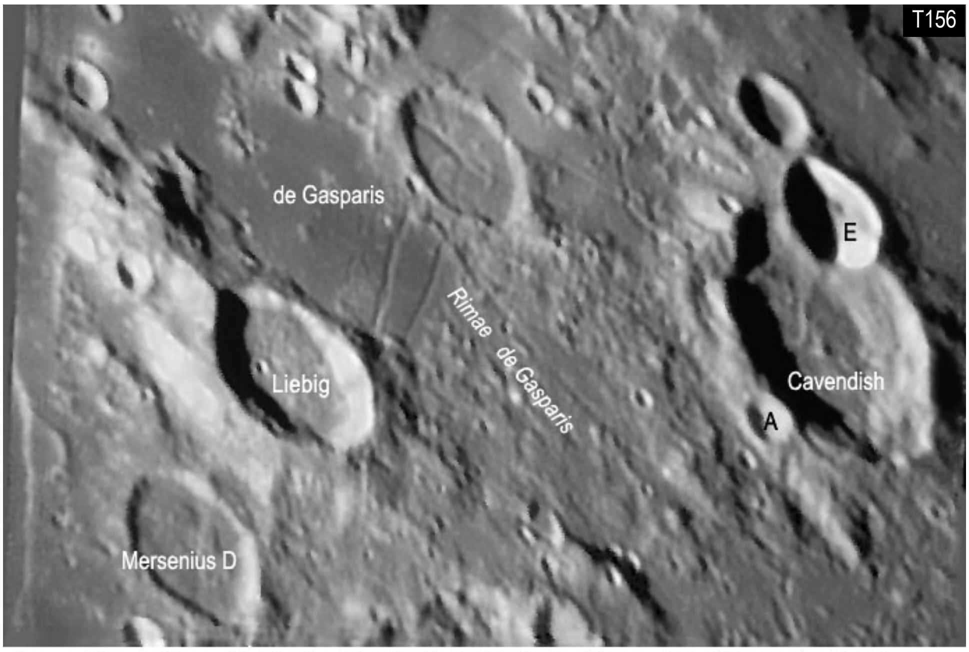
Vitello 30.4^0 S 37.5^0 W
A crater on the southern edge of Mare Humorum, diameter 42 km. Its central peak is encompassed by a C-shaped cleft. A catena (short chain of caterlets) intersects the adjacent flooded crater ***Lee M*** (77 km).

Doppelmayer 28.5^0 S 41.4^0 W
A ruined crater with fairly large central peak, diameter 63 km. ***Rimae Doppelmayer*** runs along the mare edge through a region of dark mantle deposit, length 160 km. The rille origin is unclear.

Rupes Liebig 25.0^0 S 46.0^0 W
A prominent scarp at the edge of Mare Humorum, length 180 km. Its middle section is interrupted by craters including ***Liebig G*** and ***Liebig F***.



West of Gassendi 2002.12.16 15:12 UT Age 12 days. 10-in f/6 Royce mirror + 2.5X + ToUcam, 7 frames stacked.



Cavendish, de Gasparis, Liebig 2006.05.10 14:35 UT Age 13 days. 10-in f/6 Newtonian + 5X + ToUcam

Cavendish 24.5^0 S 53.7^0 W
A 56-km worn crater. Its rim is interrupted by ***Cavendish A*** (10 km) and ***Cavendish E*** (24 km).

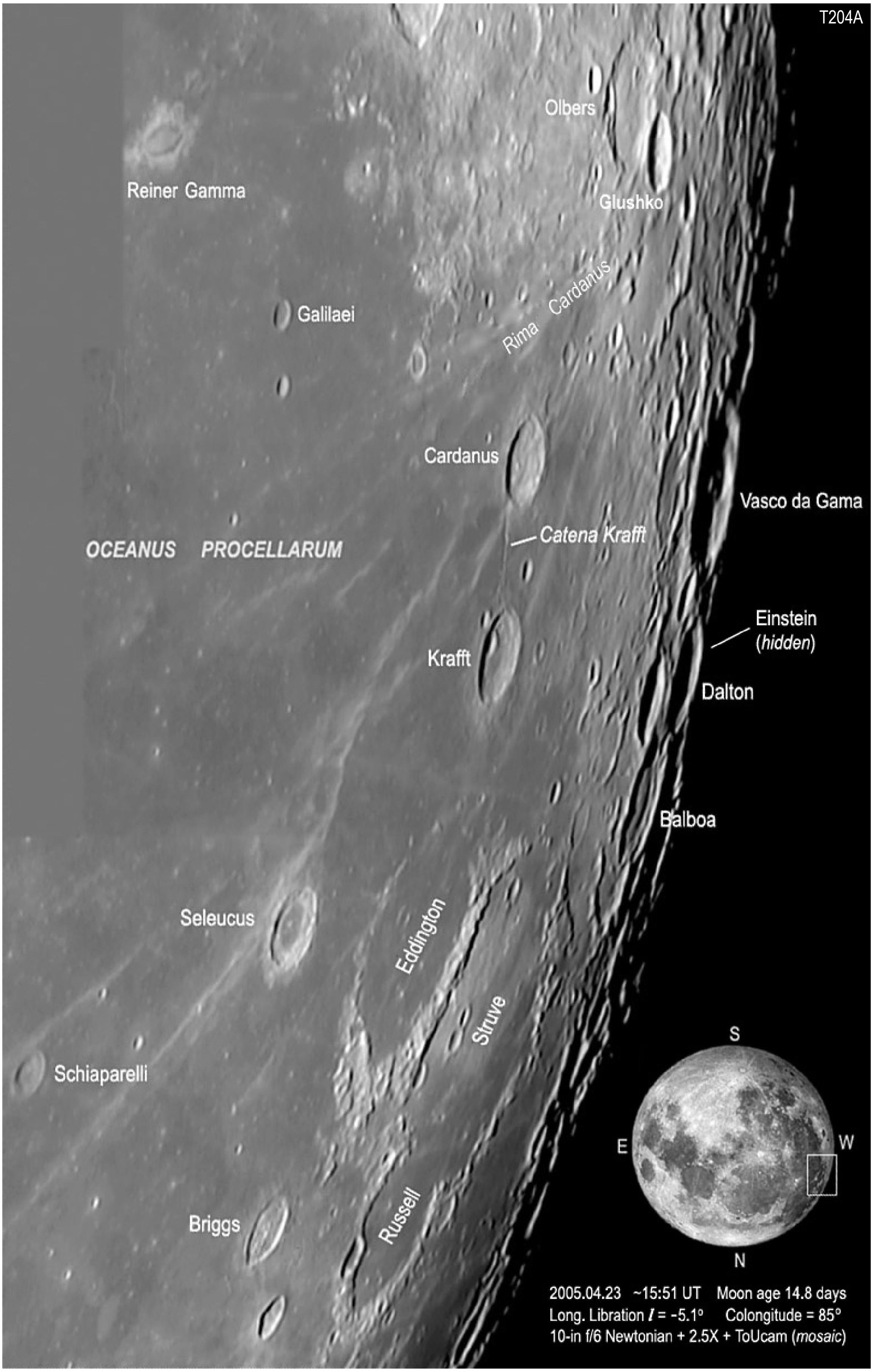
de Gasparis 25.9^0 S 50.7^0 W
A 30-km flooded crater. ***Rimae de Gasparis*** (a wide-pattern of surface fractures, 90 km) runs through the crater floor.

Liebig 24.3^0 S 48.2^0 W
A 37-km crater. Its outer rim looks bulgy because the crater sits on a low uprise. The floor is nearly featureless except for a few tiny craterlets.

MAP 25

Hatfield 7
Rükl 17, 18, 28

Eddington, Struve, Russell, Seleucus, Olbers, Einstein



Eddington 21.3^0 N 72.2^0 W, **Struve** 22.4^0 N 77.1^0 W, **Russell** 26.5^0 N 75.4^0 W
These are fine examples of the remains of flooded walled plains, named to honor three astrophysicists in the early 20th Century. They are located near the north-west limb, visible as long as lunar libration is favorable. Their diameters are 118 km, 164 km and 103 km respectively. The longitude of 80^0 W passes through Struve's western rim.

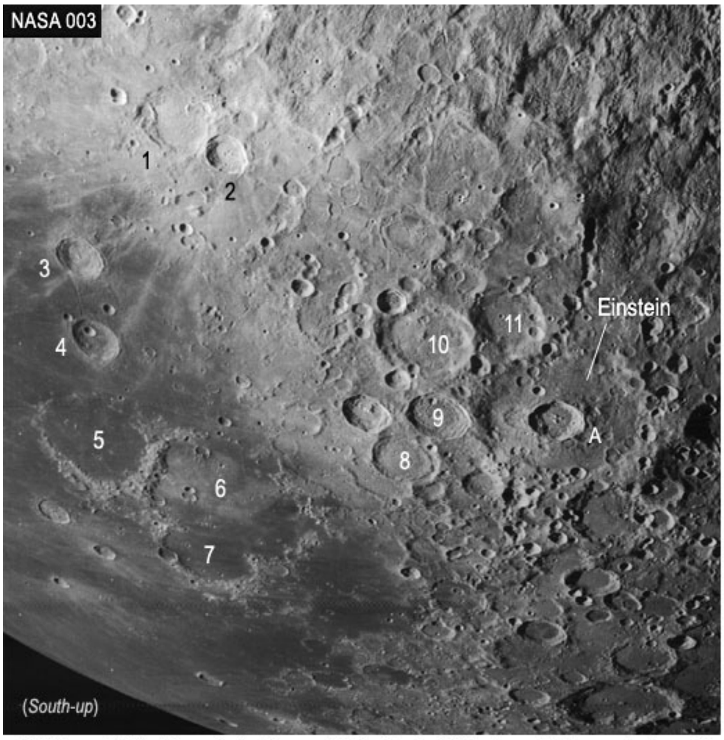
Seleucus 21.0^0 N 66.6^0 W
A crater with terraced walls and a small central peak, diameter 43 km. Its rim is interrupted by a bright ray emitted from the distant crater ***Glushko*** (formerly called ***Olbers A***, 43 km).

Schiaparelli 23.4^0 N 58.8^0 W
A crater, diameter 24 km. It is named after the 19th century Italian astronomer. His description of "canali" (channels) on Mars was misinterpreted as "canals" by other astronomers of his times.

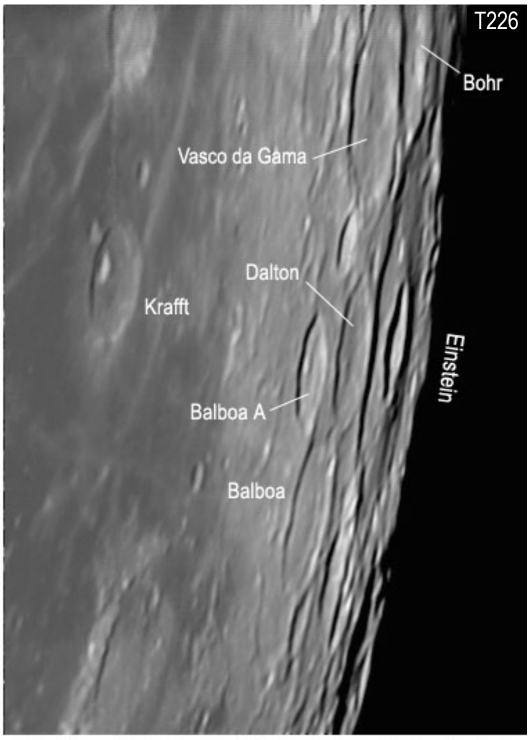
Briggs 26.5^0 N 69.1^0 W
A 37-km crater with ridged floor.

Olbers 7.4^0 N 75.9^0 W
A 74-km crater with fairly flat floor. Its wall is interrupted by Glushko, a center of bright rays under illumination. A long ray of Glushko touches Seleucus and extends beyond Schiaparelli.

Dalton 17.1^0 N 84.3^0 W **Einstein** 16.3^0 N 88.7^0 W
Dalton is 60 km in diameter. Its western wall adjoins the walled plain Einstein which is visible only at very favorable libration. Einstein is truly circular in shape, diameter 198 km and contains a central crater ***Einstein A*** (51 km). The Lunar Orbiter image indicates that Einstein A has a small central peak, but the peak does not appear in T226 due to inadequate libration.



1. Olbers 2. Glushko 3. Cardanus 4. Krafft 5. Eddington 6. Struve 7. Russell
8. Balboa 9. Dalton 10. Vasco da Gama 11. Bohr (*Lunar Orbiter image LO-4187M*)



Einstein 2005.05.23 14:52 UT Age 15 days. Libration *l* = -4.7°
10-in f/6 Newtonian+2.5X+ToUcam, 68 frames stacked.

Vasco da Gama 13.6^0 N 83.9^0 W *(Image T204A)*
A crater with central peak, diameter 83 km.

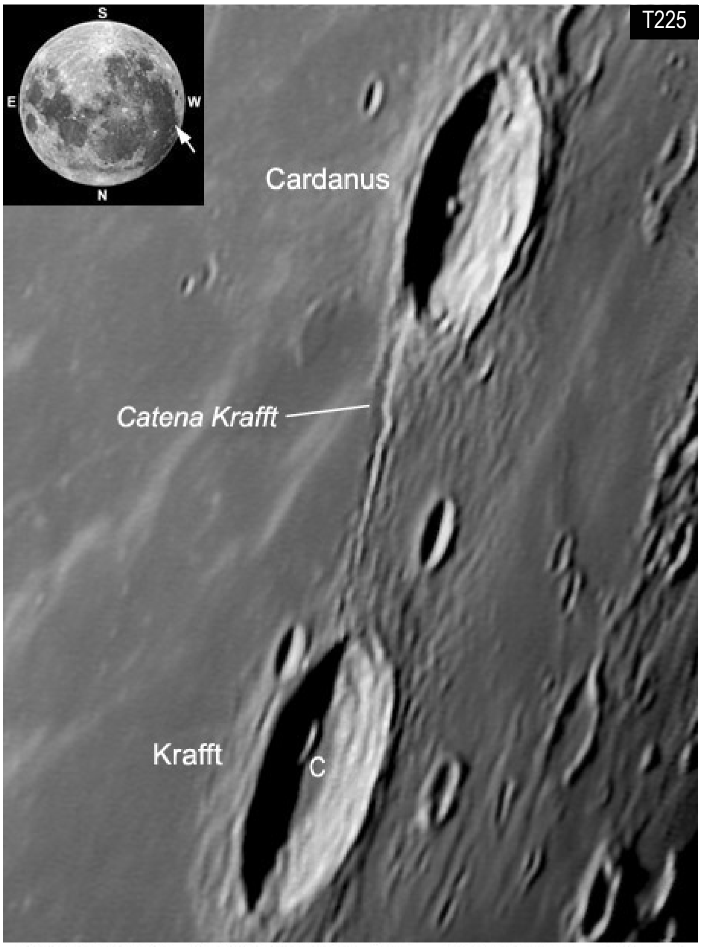
Rima Cardanus 11^0 N 71^0 W *(Image T204A)*
A linear rille in the northeast of Olbers and Glushko, length about 170 km. It is indistinctive, especially when the bright rays of Glushko happen to sweep over it.

(Image T225)

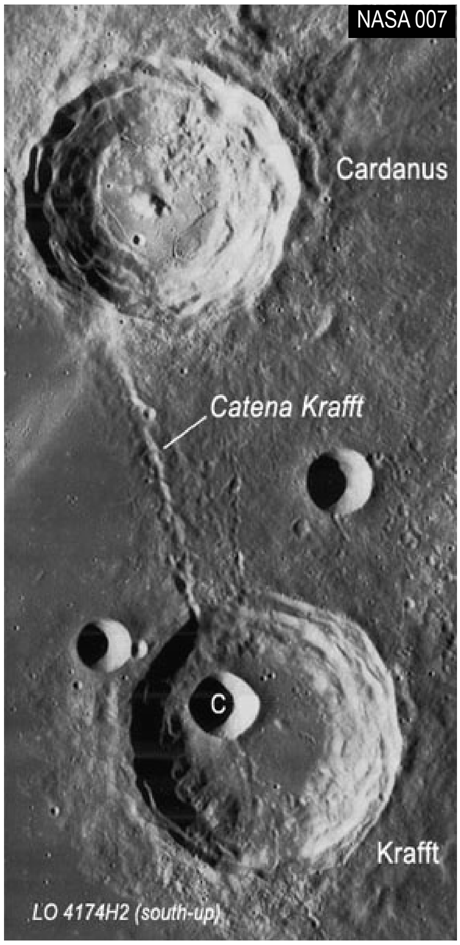
Cardanus 13.2^0 N 72.5^0 W
A sharp-rimmed terraced crater with a small central peak, diameter 49 km. A ghost ring lies outside the northeast rim of Cardanus. The LO image shows the crater floor is fractured.

Krafft 16.6^0 N 72.6^0 W
A sharp-rimmed terraced crater similar to Cardanus, diameter 51-km. It contains a small internal crater ***Krafft C*** (13 km).

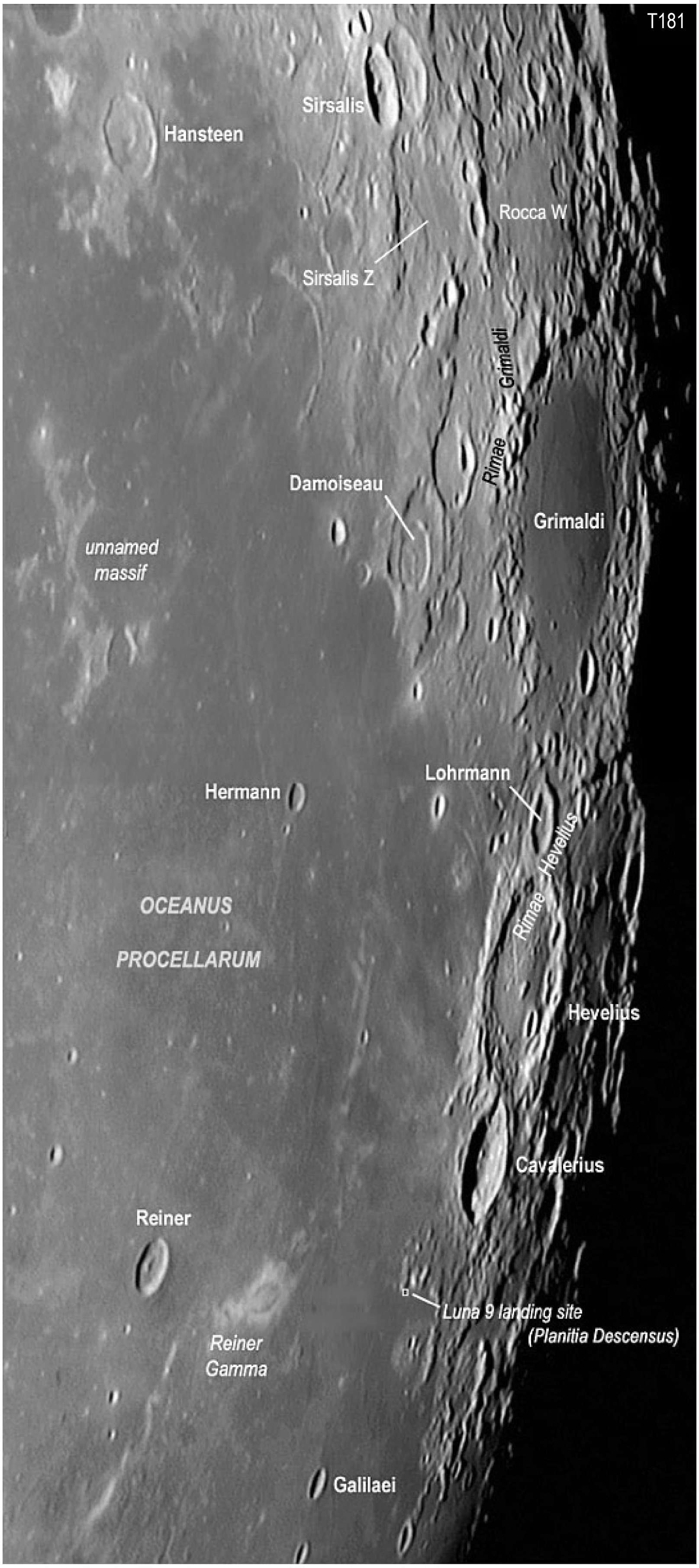
Catena Krafft 15.0^0 N 72.0^0 W
A chain of tiny, eroded overlapping craters which connects Cardanus and Krafft. In Image T225, foreshortening of the Moon's limb makes the chain not as clear as the flyover view from spacecraft (LO-4174H2). Actually, the catena runs into Krafft's floor and bisects Krafft C, total length 60 km. The width of Catena Krafft is tapered from south to north.



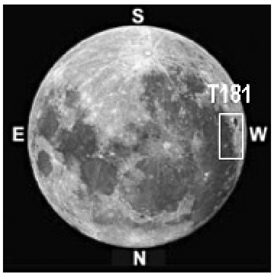
Catena Krafft 2005.05.22 15:11 UT Age 14.3 days. 10-in f/6+5X+ToUcam, 95% resized.

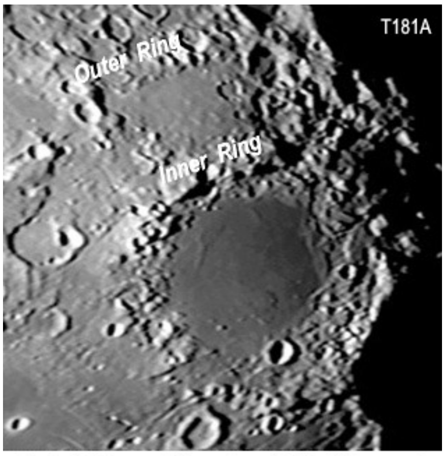


Grimaldi, Hevelius, Cavalerius, Riccioli, Hedin



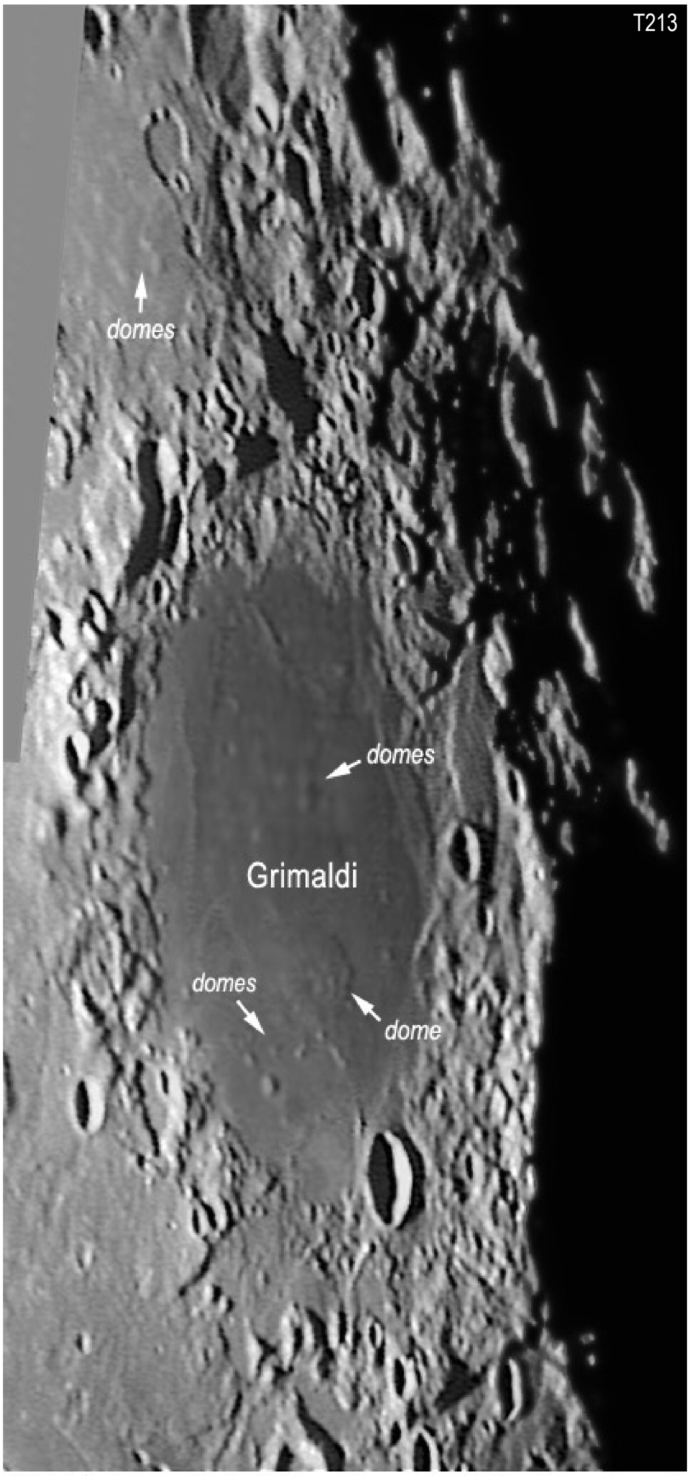
Grimaldi to Reiner Gamma 2004.11.25 16:42-16:45 UT Age 13 days. 10-in f/6 Newtonian + 2.5X + ToUcam



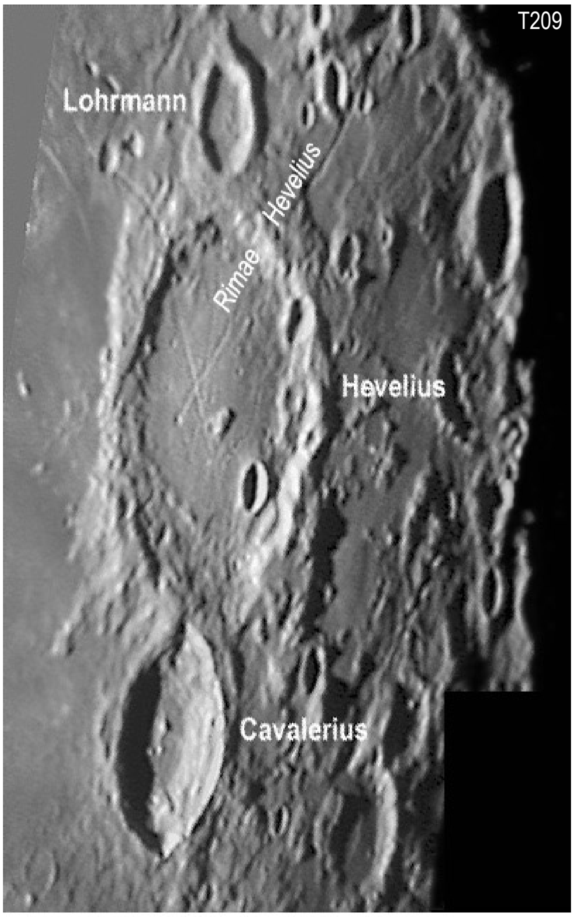


A simulated non-oblique view of Grimaldi, cropped from T181 and rescaled horizontally. Note the concentric ring mountains around the lava floor.

Grimaldi in shadow. The arrows indicate Rimae Grimaldi. 2009.10.31 15:52 UT Age 13.4 days. (*image cropped from T125*)



Grimaldi 2005.04.22 16:32UT Age 14 days. 10-in f/6+4X+ToUcam (*mosaic*)



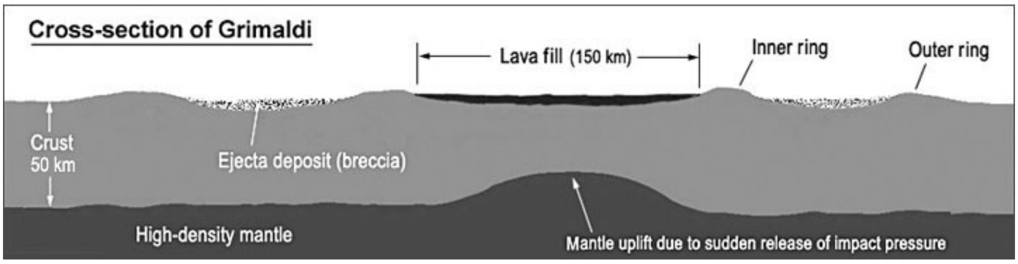
2005.04.22 ~16:25 UT Age 13.8 days. 10-in f/6 + 4X + ToUcam (mosaic)

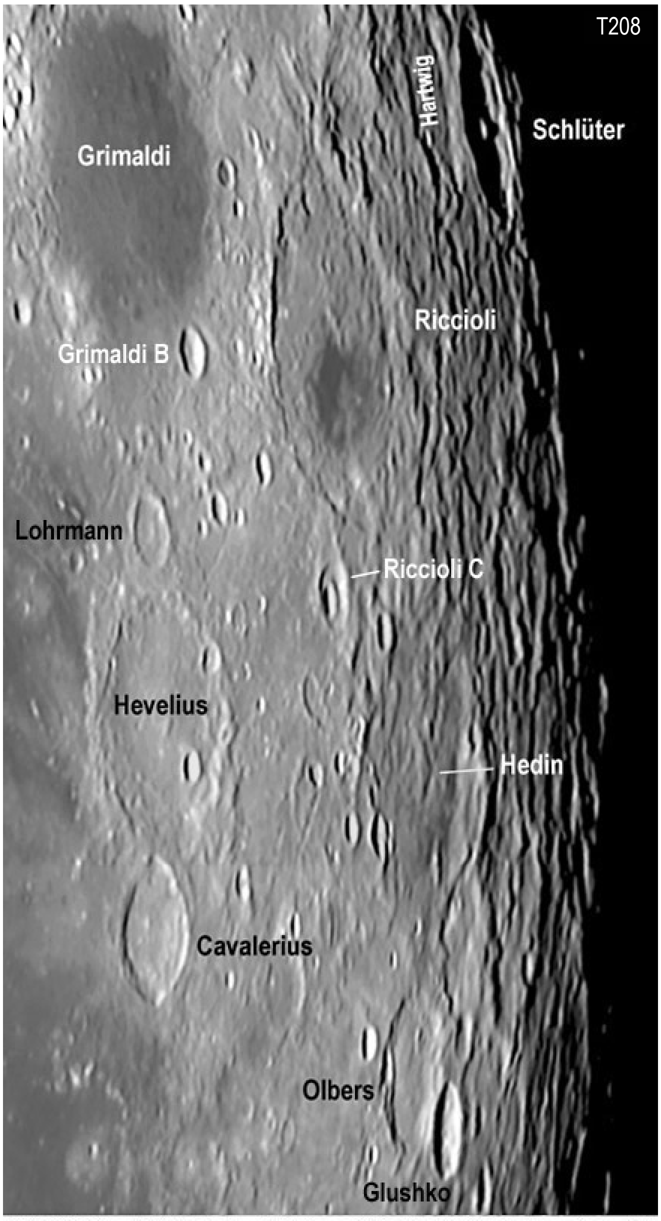
Hevelius 2.2^0 N 67.6^0 W
A walled plain with small central peak, 115 km in diameter. Its floor is cratered and marked by an X-pattern of fractures (***Rimae Hevelius***, span 180 km).

Cavalerius 5.1^0 N 66.8^0 W
A 57-km crater adjoining Hevelius, 3000 m in depth. It has a tiny central peak. The inner walls are terraced.

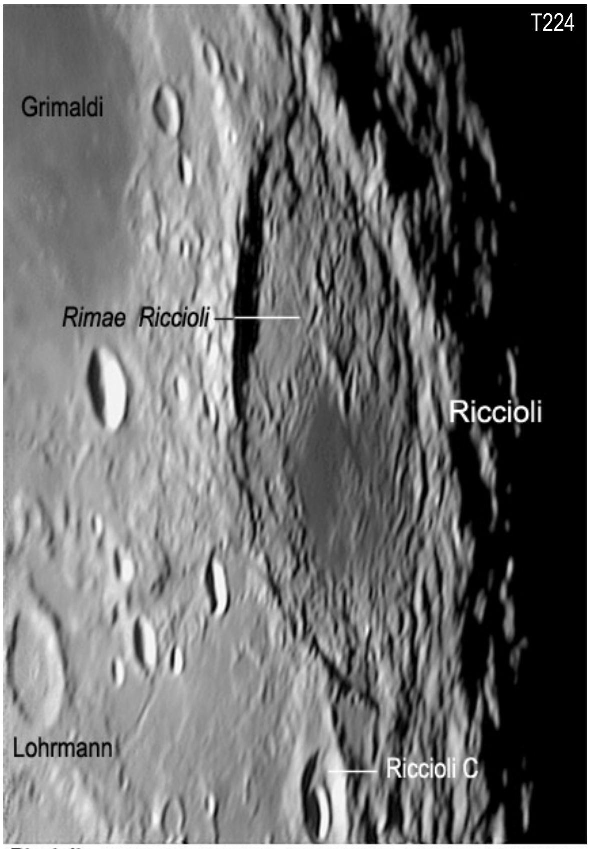
Lohrmann 0.5^0 S 67.2^0 W
A 30-km crater. Its floor is relatively flat and has few low hills.

Grimaldi 5.5^0 S 68.3^0 W
Grimaldi looks like a lava-flooded impact basin more than a crater. It is encircled by two concentric mountain rings, see Image T181A. The outer ring is partially ruined, about 400 km across. The inner ring is 200 km and the lava floor is 150 km. The nominal diameter of Grimaldi is 172 km. Faint surface fractures (***Rimae Grimaldi***, length 230 km) emerge from the south-east wall. In T213, a blade of dark shadow appears to cut along the northern rim of Grimaldi. A dome with summit pits exists in the northern part of the floor; few smaller domes are also spotted under good seeing. Grimaldi contains a mascon caused by local uplift of dense mantle into the lunar crust during the impact. See the illustration in next page.





2005.04.23 ~15:38 UT Age 14.8 days. 10-in f/6 + 2.5X + ToUcam (mosaic)



Riccioli 2005.05.22 ~14:31 UT Age 14.3 days. 10-in f/6 + 5X + ToUcam

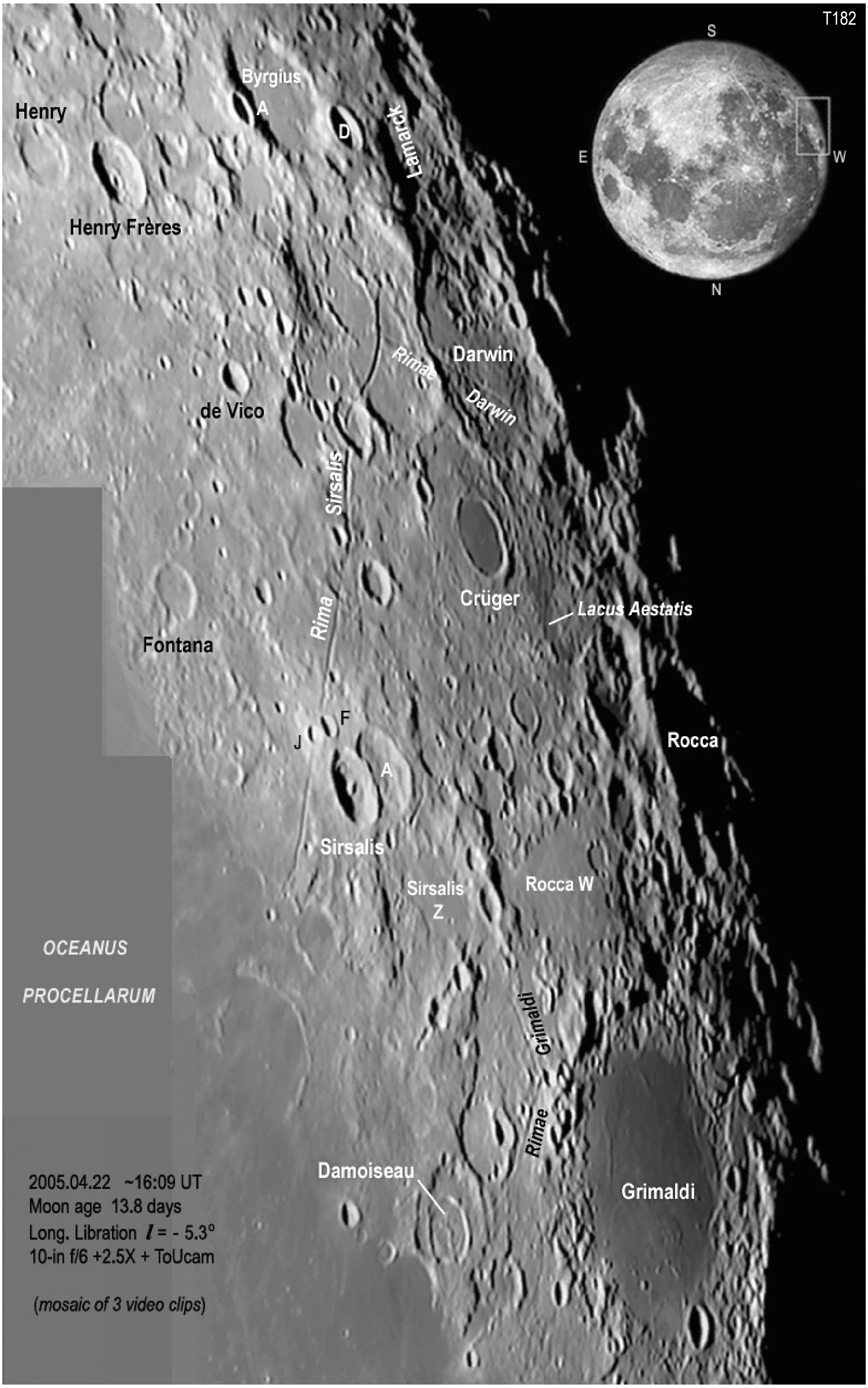
Riccioli 3.3^0 S 74.6^0 W
Riccioli (1598-1671) is an Italian priest and observer who first named lunar craters after philosophers and astronomers. The crater is a walled plain, 139 km in diameter. Images from spacecraft show that Riccioli was modified by the ejecta from the Orientale impact at the farside. Its southern floor contains a complex of fractures (***Rimae Riccioli***, 400 km). The northern floor is lava-flooded. ***Riccioli C*** is a 31-km concentric crater.

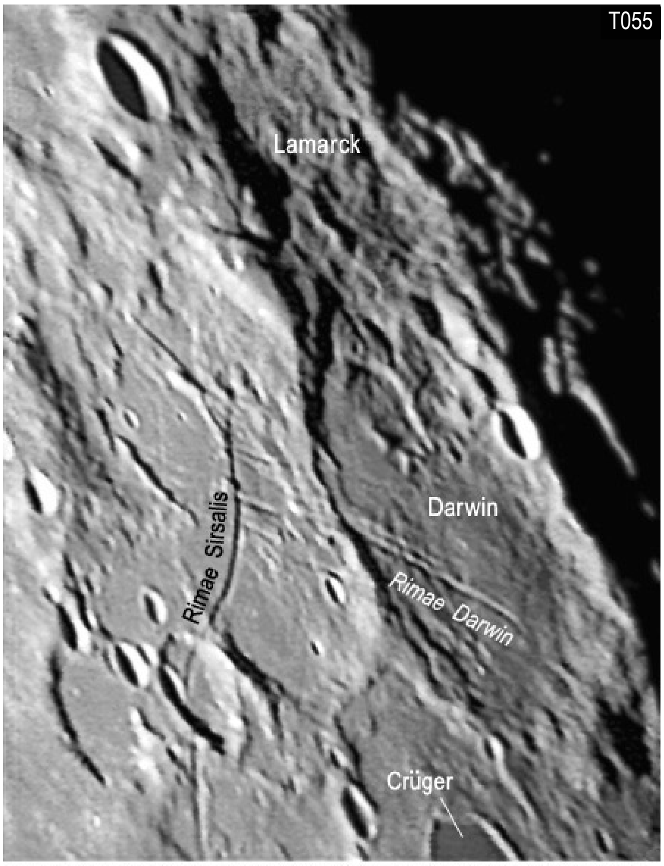
Hedin 2.0^0 N 76.5^0 W
A heavily obliterated walled plain, diameter 150 km. Its floor is covered by the ejecta of the Orientale impact.

Schlüter 5.9^0 S 83.3^0 W
An 89-km crater with terraced walls and central peaks. It is flanked by ***Hartwig*** (79 km).

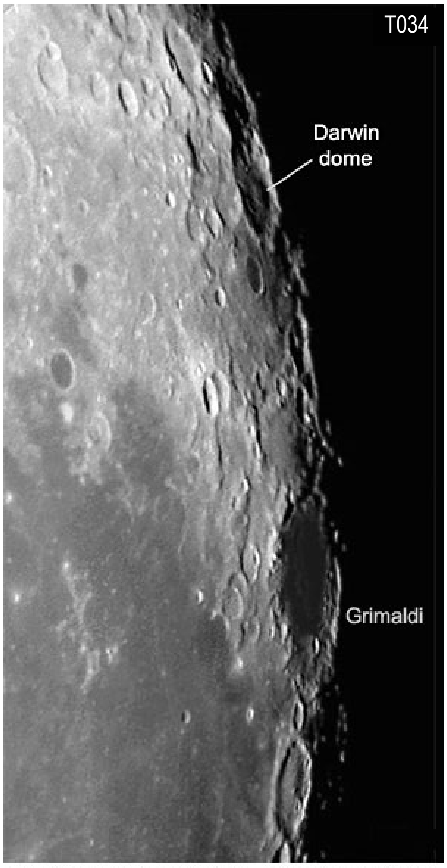
Darwin, Byrgius, Rimae Sirsalis, Crüger, Billy, Hansteen

Hatfield 11
Rükl 50, 51, 39, 40





Darwin & Rimae Darwin 2005.04.22 16:34UT Age 13.8 days. 10-in f/6+4X+ToUcam



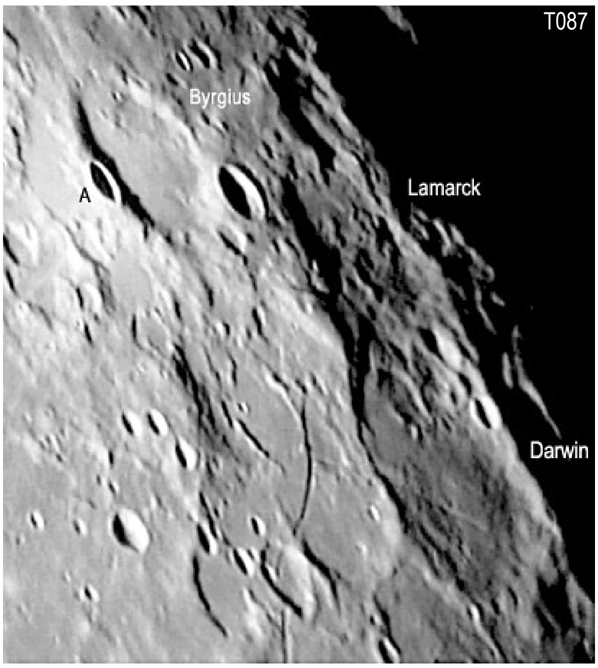
2000.06.15 14:36 UT Age 13 days. ET90+PL16+CP950, 1/15s

Darwin 20.2^0 S 69.5^0 W
Darwin is a complex disintegrated walled plain, diameter 120 km. A cluster of smaller craters is located on its southern floor. Its eastern wall is intersected by ***Rimae Darwin*** (length 140 km). The floor contains a weird dome hill which is visible only under appropriate illumination, see T034 or T087). When Darwin is near the terminator, it resembles one wing of a butterfly while the other wing is an unnamed feature.

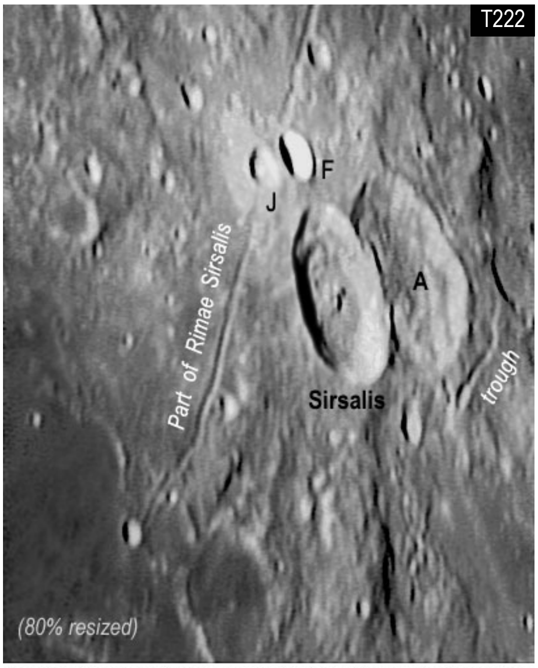
Lamarck 22.9^0 S 69.8^0 W
A disintegrated, rugged crater sharing the walls with Darwin, diameter 100 km.

Byrgius 24.7^0 S 65.3^0 W
An 87-km crater. Its floor is fairly flat and white due to the ejecta splashed from the rayed ***Byrgius A*** (19 km) on the rim.

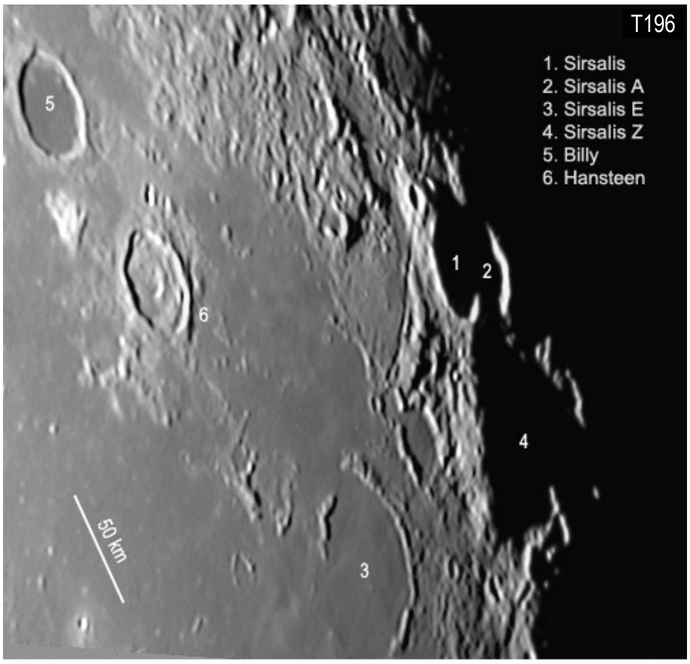
Henry Frères 23.5^0 S 58.9^0 W *(T182)*
A 42-km crater with an off-center smaller crater (~ 7 km) on the floor. It is circular but looks oval due to foreshortening.



Byrgius & Darwin 2008.09.13 15:52 Age 14 days. 10-in f/6+2.5X+ToUcam



Sirsalis 2005.05.22 15:42UT Age 14 days. 10-in f/6 Newtonian+5X+ToUcam



Shadow of Sirsalis Z 2004.09.26 16:35 UT Age 12 days. 10-in f/6 + 2.5X + ToUcam

Sirsalis 12.5^0 S 60.4^0 W

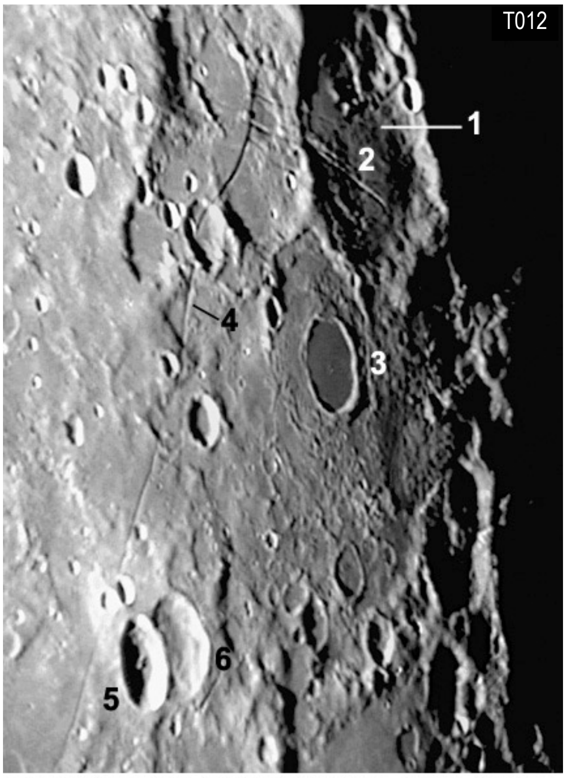
A 42-km crater with small central peak. It intersects with ***Sirsalis A*** (once known as ***Bertaud***, diameter 49 km). A trough feature lies just outside Sirsalis A. ***Sirsalis J*** is a rayed crater, diameter 12 km.

In Image T196, Sirsalis is shadowed by the terminator and hence appears like a black hole. A strip of ridge extends from the northern rim of Sirsalis. This ridge forms the eastern rim of the irregular crater ***Sirsalis Z*** (91 km); it casts a weird triangular shadow around Moon age of 12 days.

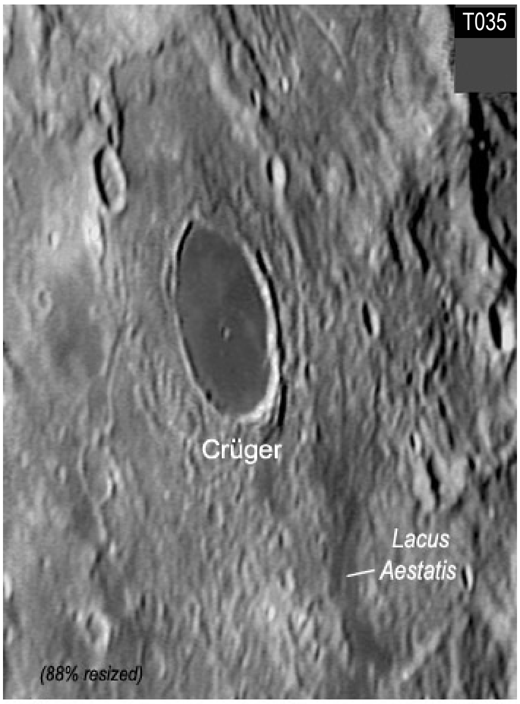
Rimae Sirsalis 15.7^0 S 61.7^0 W

A system of rilles, length 426 km. The most prominent section is ***Rima Sirsalis*** which starts at the edge of Oceanus Procellarum near Sirsalis, cuts across highlands and ends up among the smaller rilles near Darwin (Label 4 in T012). The section at the highlands is deeply grooved. This suggests the rilles are surface faults most likely caused by the Orientale impact on the farside.

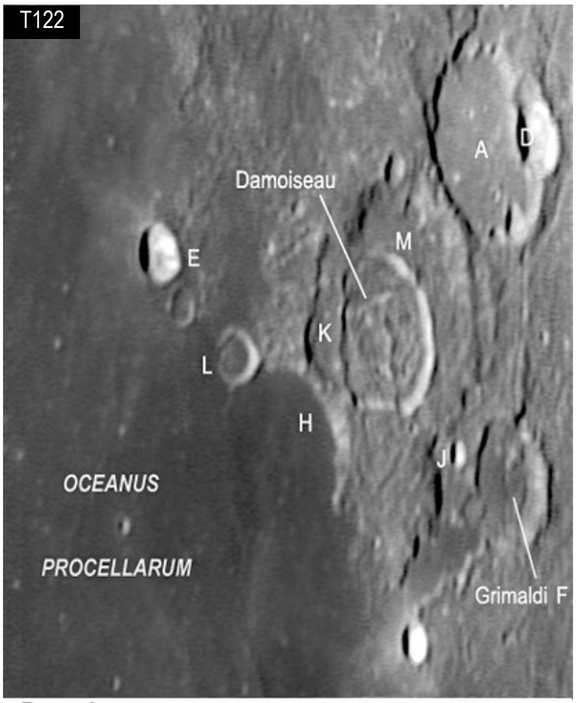
Rimae Sirsalis is the longest rille system on the nearside of the Moon. It is visible even in small telescopes.



1. Darwin 2. Rimae Darwin 3. Crüger 4. Rimae Sirsalis 5. Sirsalis 6. Sirsalis A
2003.03.16 15:55 UT Age 13 days. 10-inch f/6 Newtonian + 2.5X + ToUcam



Crüger 2005.05.22 15:26UT Age 14 days. 10-in f/6+5X+ToUcam



Damoiseau 2005.05.22 15:44UT Age 14 days. 10-in f/6+5X+ToUcam

Crüger 16.7^0 S 66.8^0 W
A flooded crater with a central craterlet on the dark-flat floor, diameter 45 km. To its immediate north is ***Lacus Aestatis*** (Summer Lake), a curved strip of dark lava, size about 90 km.

Damoiseau 4.8^0 S 61.1^0 W
A shallow crater with rough ridged floor, diameter 36 km. It is encompassed by crater ***Damoiseau K*** and ***Damoiseau M***.

Image T037, next page:

Billy 13.8^0 S 50.1^0 W
A dark-floor crater almost identical to Crüger, diameter 45 km; but Billy does not have a central craterlet. ***Rima Billy*** (length 70 km) is in the south-east; it looks like a surface fracture.

Hansteen 11.5^0 S 52.0^0 W
A crater with fractured floor and internal hills, diameter 44 km. It is flanked by the short rille ***Rima Hansteen*** (length 25 km).

Mons Hansteen 12.1^0 S 50.0^0 W
A triangular hand-shaped mountain, base 30 km. Very bright but its cause is unknown.

Zupus 17.2^0 S 52.3^0 W
Remains of a lava-flooded craters, diameter 38 km. Its floor is darkened and featureless. Its eastern rim looks straight and is considerably higher than the western surroundings.

Rimae Zupus 15.0^0 S 53.0^0 W
A system of thin rilles, 120 km long. It runs between ***Zupus C*** and Hansteen, difficult to spot.

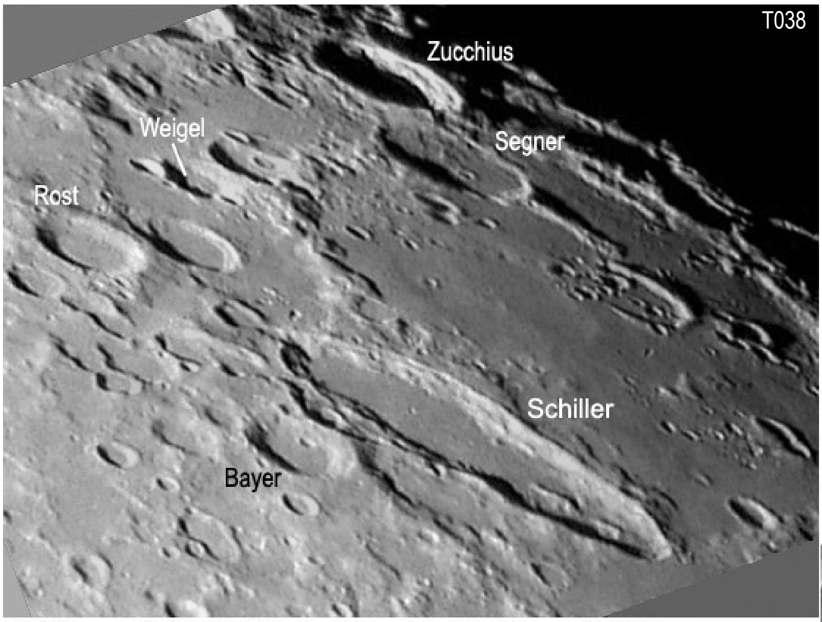
Fontana 16.1^0 S 56.6^0 W
A 31-km crater with internal low hills. Its northeast rim is broken.

Billy, Hansteen and southern vicinity

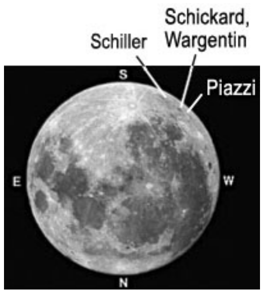
1. Billy 2. Rima Billy 3. Hansteen 4. Rima Hansteen 5. Mons Hansteen 6. Zupus 7. Rimae Zupus 8. Zupus C 9. Fontana 10. de Vico 2006.05.10 14:52 UT Age 13 days. 10-in f/6 Newtonian + 4X + ToUcam

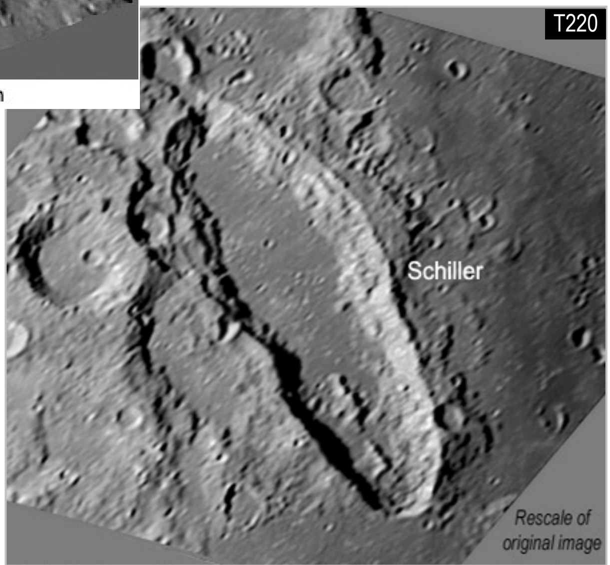
Schiller, Schickard, Phocylides, Wargentin, Piazzi, Vieta

Hatfield 11, 12
Rükl 71, 70, 62, 61, 51



Schiller 2002.12.16 !5:17UT Age 12 days. 10-in f/6 Newtonian + 2.5X + ToUcam





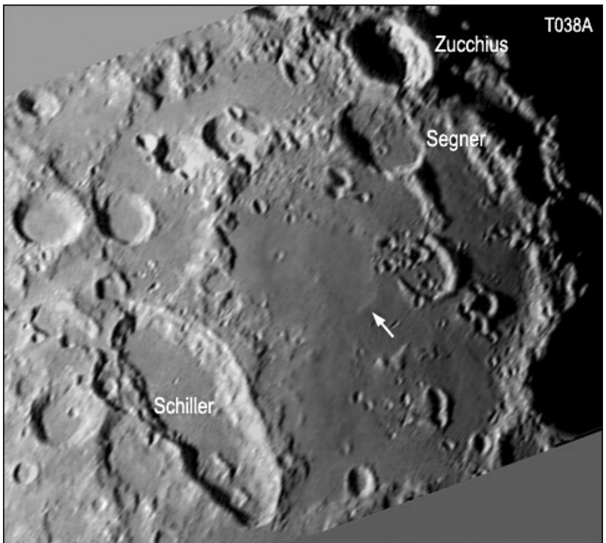
A simulated non-oblique view of Schiller. The picture center line is 40° W.
2005.04.21 13:56UT Age 12.5 days. 10-in f/6+4X+ToUcam, 65 frames stacked.

Schiller 51.9^0 S 39.0^0 W
A truly elongated crater, about 70 x 180 km. The southern half of the floor is fairly flat but the northern half is rough and contains two mountain peaks. It seems Schiller's predecessor consisted of two or more near-sized and overlapped craters. Based on NASA laboratory experiment, these overlapped craters could be fused together by a high-speed grazing impactor, which was probably an Earth-orbiting debris spiraling into the Moon and hitting the Moon at very low angle (few degrees measured from ground).

Segner 58.9^0 S 48.3^0 W
A shallow crater with rough floor, 67 km in dia.

Zucchius 61.4^0 S 50.3^0 W
A terraced crater, diameter 64 km, depth 3200 m.

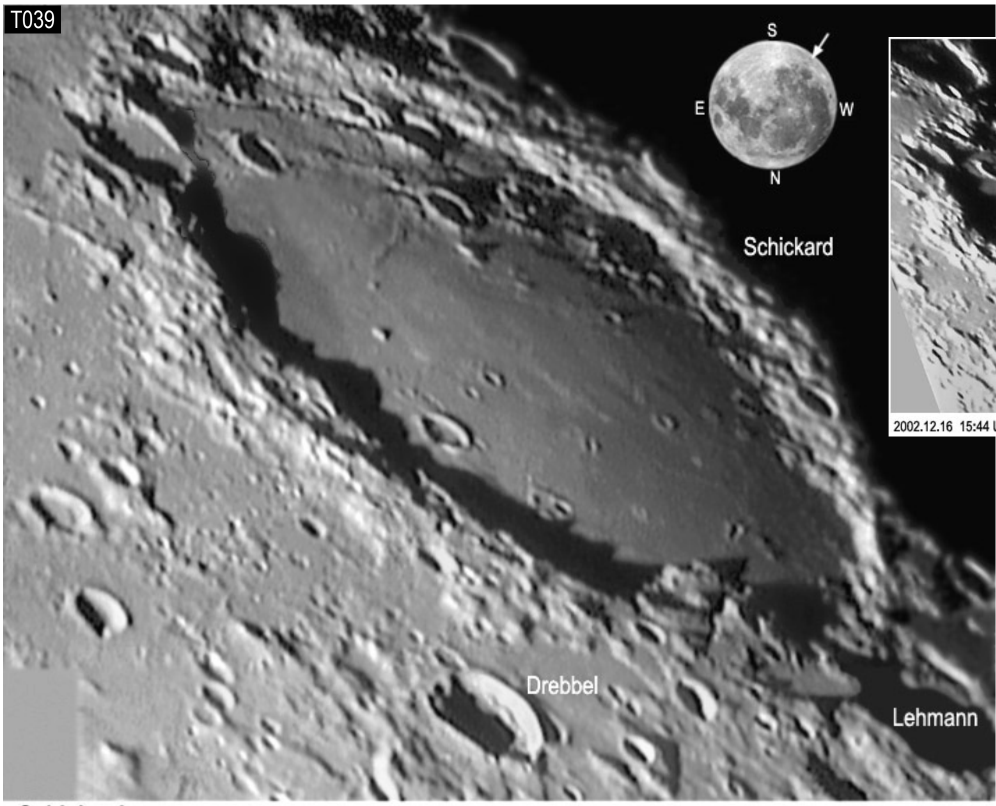
Schiller-Zucchius Basin
The territory between Schiller and Zucchius is an impact basin characterized by two concentric mountain rings. The inner ring (dia. 200 km) intersects Segner; the outer ring (dia. 330 km) intersects Zucchius. There is also the hint of a third ring almost buried beneath the mare floor, as marked by arrow in Image T038A. This basin contains a mascon.



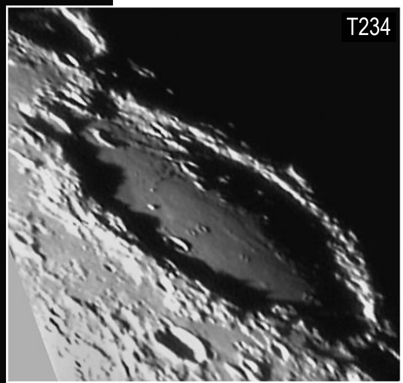
Same image as T038 but rescaled to simulate a non-oblique view of the Schiller-Zucchius Basin.

Schickard 44.3^{0} S 55.3^{0} W
An old vast walled plain, diameter 206 km. The central floor is covered by lighter material ejected from the Orientale impact at the lunar farside. Later, additional lava erupted to cover the northern and southern floor. Sometimes the floor of Schickard looks convex.

Inghirami 47.5^{0} S 68.8^{0} W
A 91-km crater. Its floor was modified by the Orientale impact event. See NASA003 Farside map.

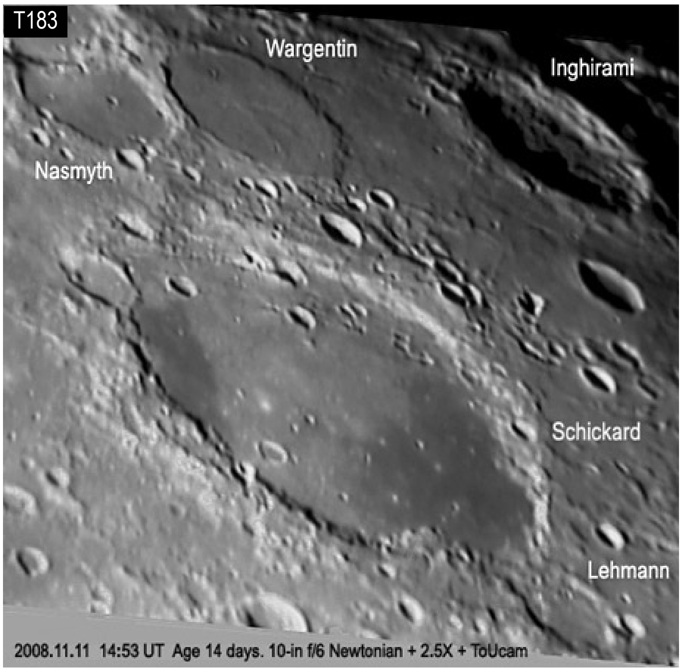


Schickard 2005.01.22 15:17~15:20 UT Age 12.1 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam at 1/25 sec (*mosaic*)

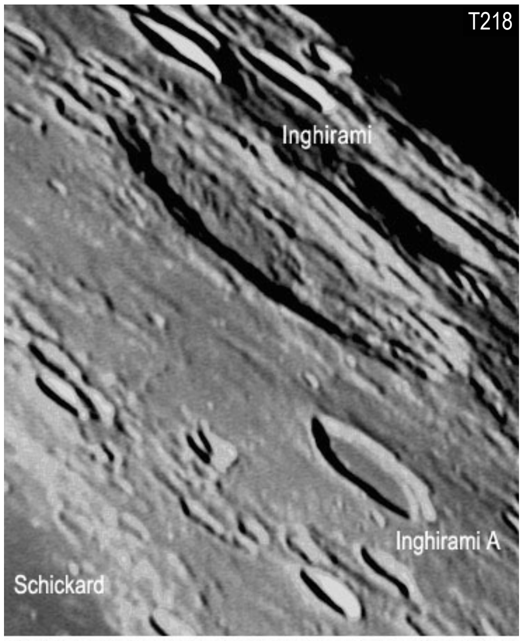


2002.12.16 15:44 UT Age 12 days. 10-in f/6 Newtonisn +2.5X + ToUcam

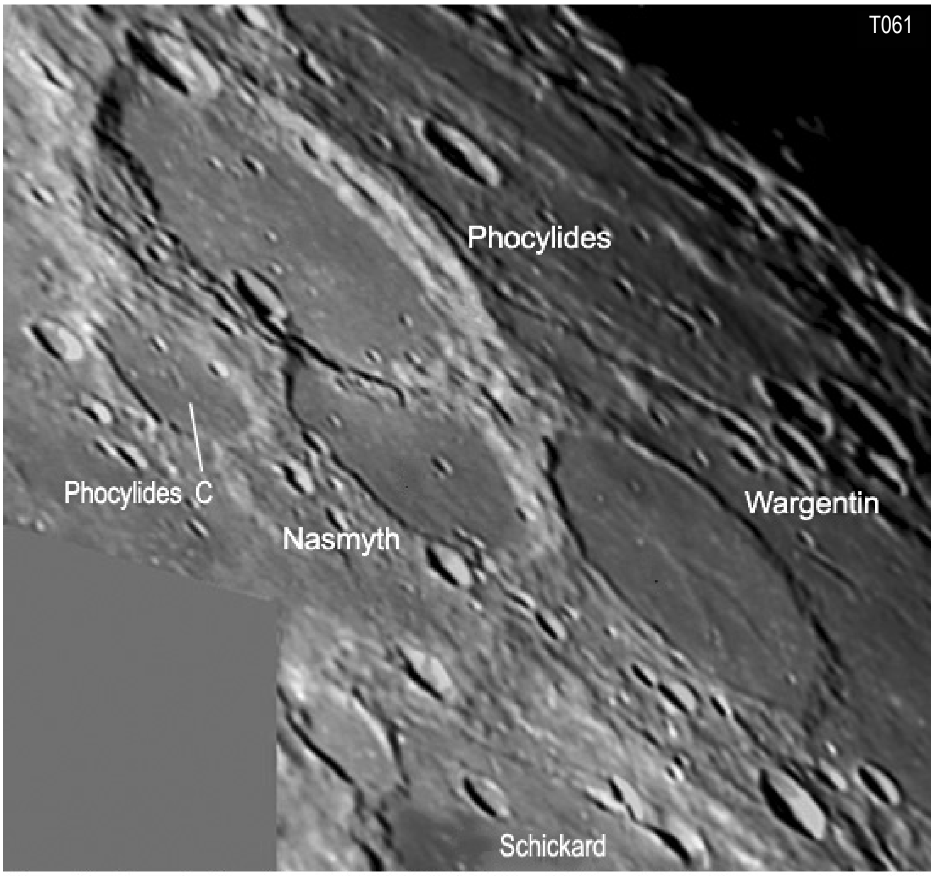
↑ Sometimes the floor of Schickard looks convex with spiky shadows cast by the inner walls.



2008.11.11 14:53 UT Age 14 days. 10-in f/6 Newtonian + 2.5X + ToUcam



Inghirami 2005.05.22 15:42 UT Age 14 days. 10-in f/6 + 5X + ToUcam



Wargentin, Nasmyth, Phocylides 2005.04.22 16:41 UT Age 13.8 days. 10-in f/6 + 4X + Toucam, 85% resized.

Image T061:

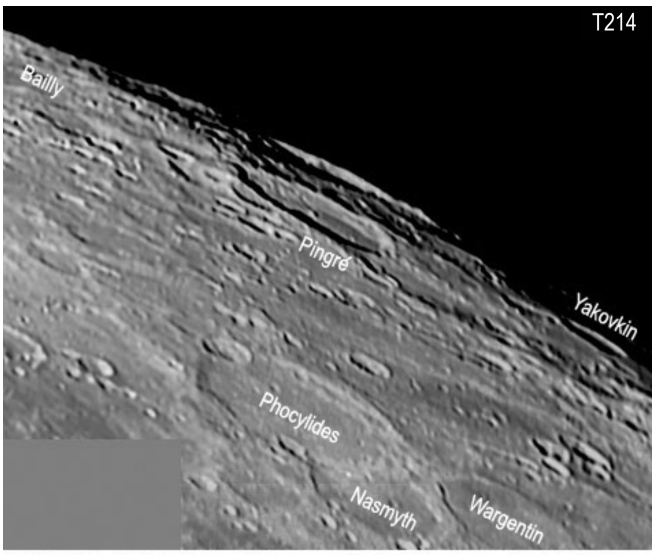
Wargentin 49.6^0 S 60.2^0 W
A rare type of "plateau crater", diameter 84 km. It is filled up with solidified dark lava almost to the top of the rim. The floor is raised 400 m above the surrounding and bears a network of wrinkle ridges. The network joint probably marks the buried central peaks of this crater. A craterlet with dark halo is found on the southern floor.

Phocylides 52.7^0 S 57.0^0 W
A flooded crater, 121 km in diameter, 2100 m in depth. Its eastern wall is eroded and adjoins ***Phocylides C*** (46 km).

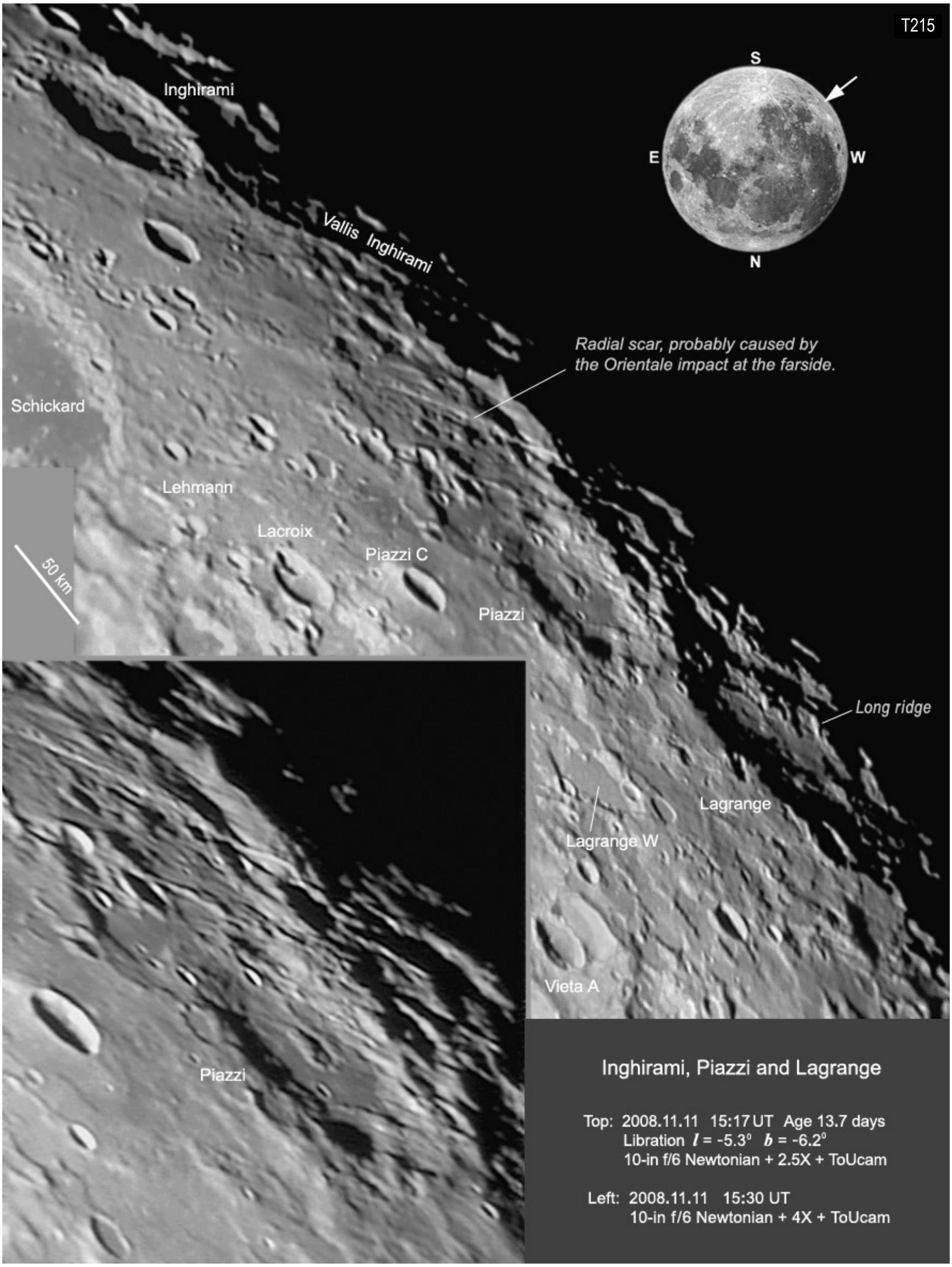
Nasmyth 50.5^0 S 56.2^0 W
A flooded crater, diameter 76 km. Part of its rim is ruined by Phocylides.

Image T214:

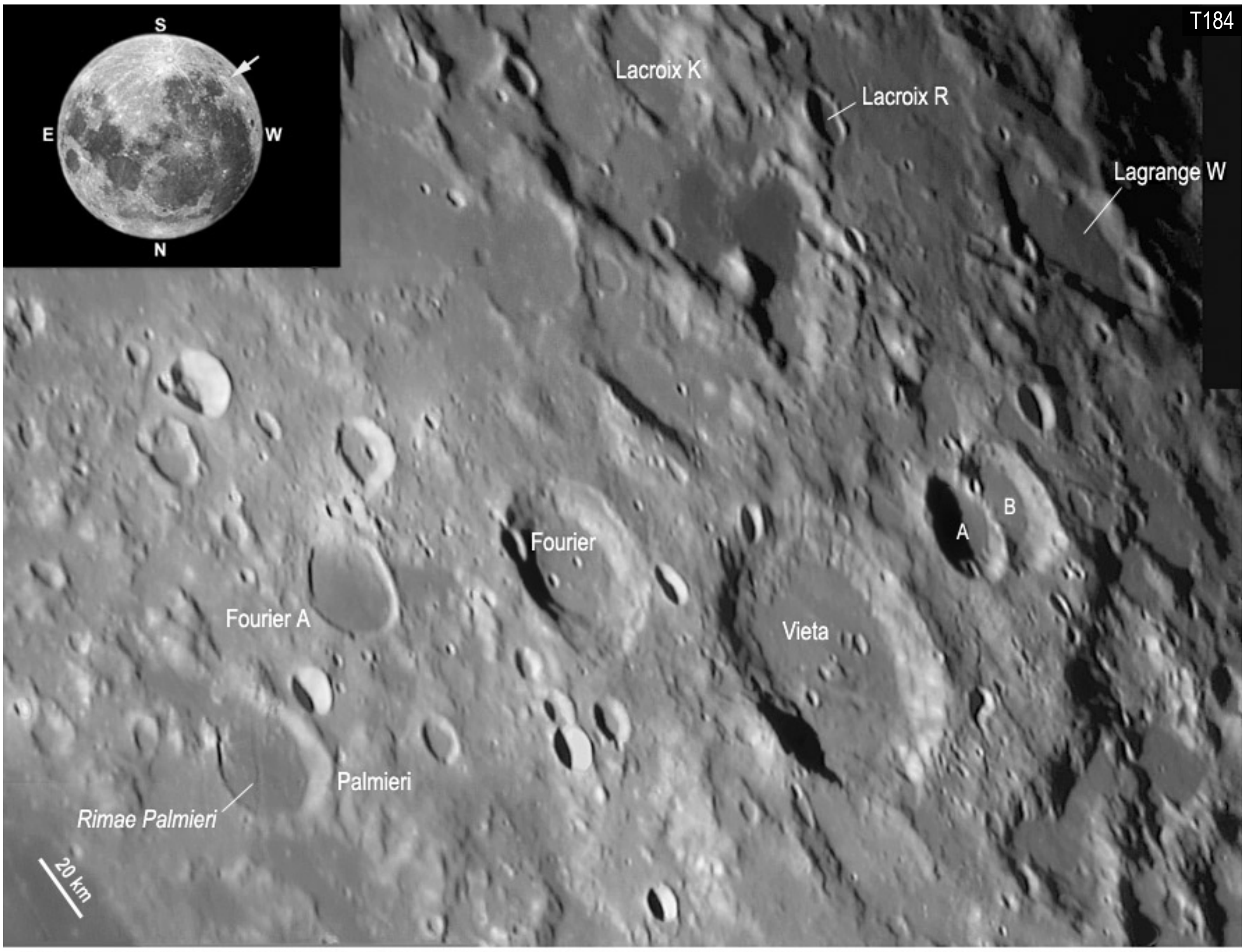
Pingré 58.7^0 S 73.7^0 W
Yakovkin 54.5^0 S 78.8^0 W
Both craters are quite close to the limb and hence best seen in favorable libration. Pingré is 88 km in diameter, Yakovkin is 37 km.



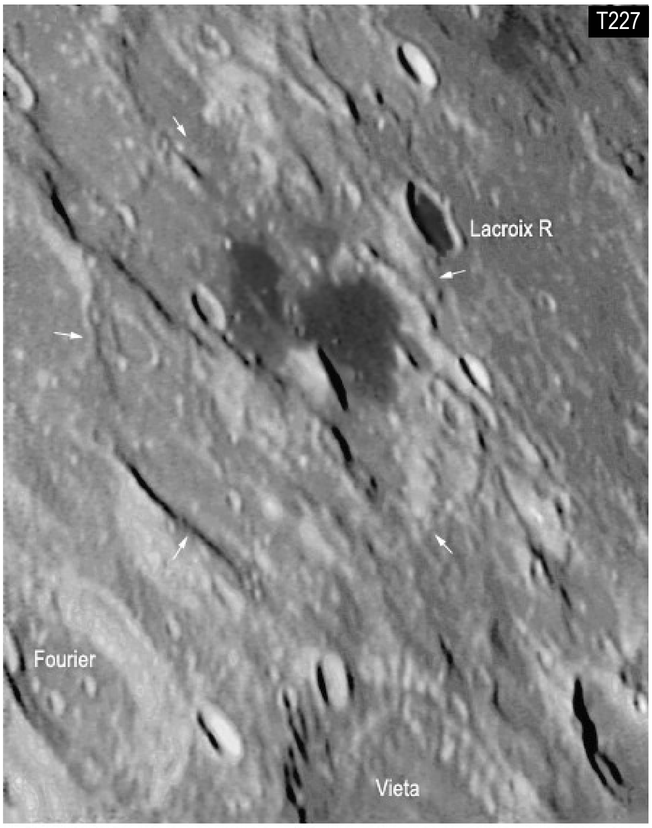
2005.04.23 16:08 UT Age 14.8 days. 10-inch f/6 Newtonian + 2.5X + ToUcam



Piazzi 36.6^0 S 67.9^0 W (diameter 134 km)
Lagrange 32.3^0 S 72.8^0 W (diameter 225 km)
These are adjacent craters heavily modified by the ejecta from the Orientale impact at the farside. A long ridge cuts the southern the floor of Lagrange.



Vieta and its vicinity 2009.10.31 ~15:02 UT Age 13.4 days. 10-inch f/6 Newtonian + 2.5X + 1.6X + ToUcam (*mosaic of 3 video clips*)



South of Vieta 2005.05.22 15:38UT Age 14 days. 10-in f/6 + 5X + ToUcam, 85% resized.

Vieta 29.2^0 S 56.3^0 W
A crater with fairly flat floor but without a central peak, diameter 87 km. A chain of small craters almost bisects the floor. The southern wall has grooved scars caused by the ejecta of some unknown impact. Further south is an isolated, irregular dark patch, about 40 km across (T227). This might be magma leaked out through the local crust fractures. The darkened floor of ***Lacroix R*** might be similar leakage trapped inside the crater.

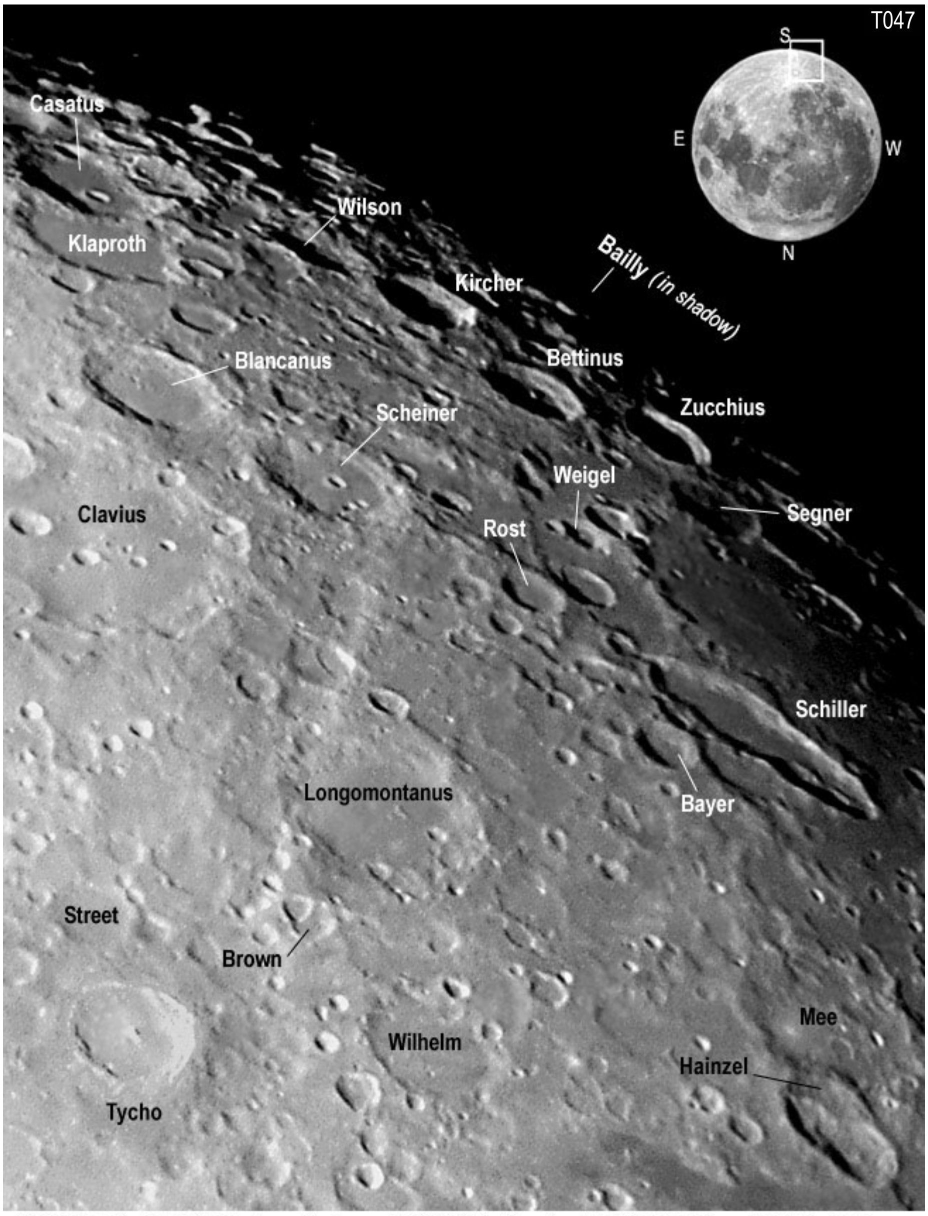
It also appears that the arrow marking in T227 represents the rim of a heavily eroded crater.

Fourier 30.3^0 S 53.0^0 W
A 51-km crater. Its wall is fairly wide.

Palmieri 28.6^0 S 47.7^0 W
A 40-km flooded crater. Its floor is intersected by ***Rimae Palmieri*** (150 km).

Hatfield 12
Rükl 71, 72, 63, 64

Bailly, Longomontanus, Wilhelm, Mee, Hainzel



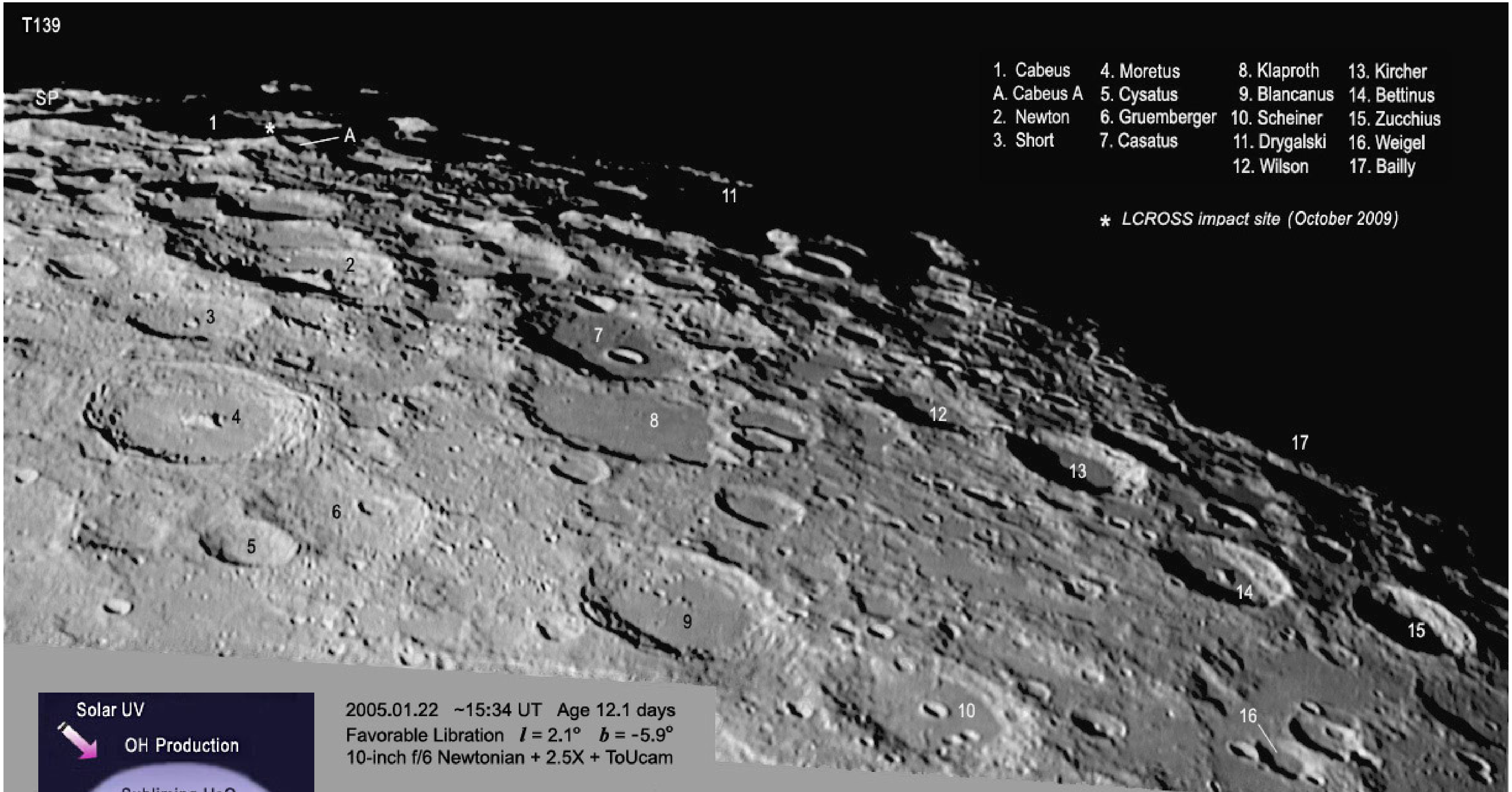
2000.05.15 14:15 UT Age 11 days. FS102 f/8 refractor + LE12.5 + Nikon CP950 1/40 sec.

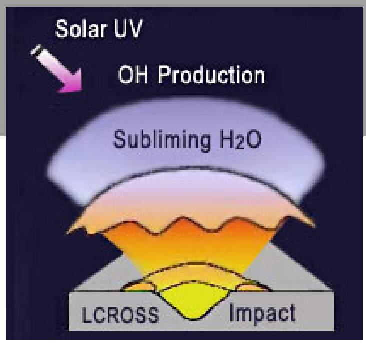
Scheiner 60.5^0 S 27.5^0 W
A crater, diameter 110 km. Its floor contains a small but conspicuous central crater, no central peak. In T047, one arm of Tycho's rays strikes at Scheiner's wall.

Blancanus 63.8^0 S 21.4^0 W
A crater with fairly flat floor and small central peaks, diameter 117 km. Small craters are clustered on the southern floor.

Casatus 72.8^0 S 29.5^0 W
A flooded crater with sharp internal crater, diameter 108 km. Its northwestern rim rises higher than the rest.

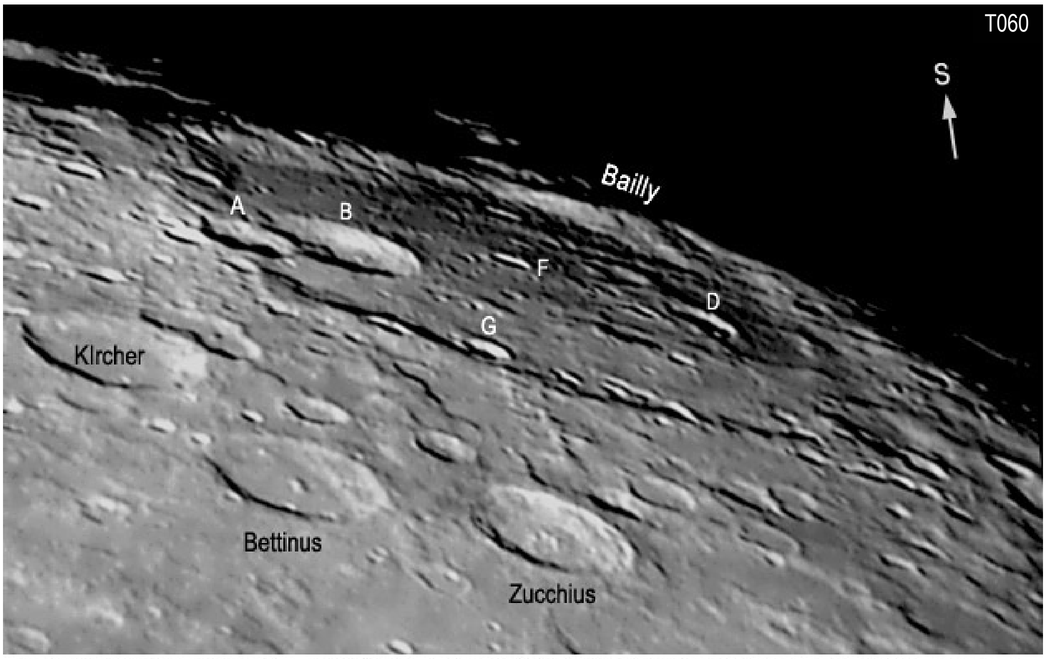
Klaproth 69.8^0 S 26.0^0 W
A flooded walled plain adjoining Casatus, diameter 119 km.





Cabeus 84.9^0 S 35.5^0 W *(Image T139)*
A heavily shadowed crater near the lunar south pole, diameter 98 km. It is also the NASA's LCROSS (Lunar Crater Observation and Sensing Satellite) impact site where signatures of water and hydroxyl (OH) were found.

MAP 29



Bailly 2004.01.06 15:03 UT Age 14 days. Libration l = -2.5° b = -4.7° 10-in f/6 + 2.5X + ToUcam, 48 frames.

Bailly 66.5^0 S 69.1^0 W

The largest crater (walled plain) on the nearside of the Moon, diameter 287 km. It is best seen during favorable libration. Bailly is truly circular but looks oval due to limb foreshortening. The floor is scattered with craters, the largest being ***Bailly A*** (38 km) and ***Bailly B*** (65 km). By geologic classification, Bailly is a "small" impact basin but it has not undergone lava flooding.

Kircher 67.1^0 S 45.3^0 W Diameter 72 km
Bettinus 63.4^0 S 44.8^0 W Diameter 71 km
Zucchius 61.4^0 S 50.3^0 W Diameter 64 km

These craters form a prominent trio outside the rim of Bailly, especially when Bailly is hidden in shadow (T047). Zucchius is a rayed crater in the full moon.

Longomontanus 49.6^0 S 21.8^0 W

An eroded crater with off-centered peaks, 157 km in diameter and interrupting ***Longomontanus Z*** (95 km).

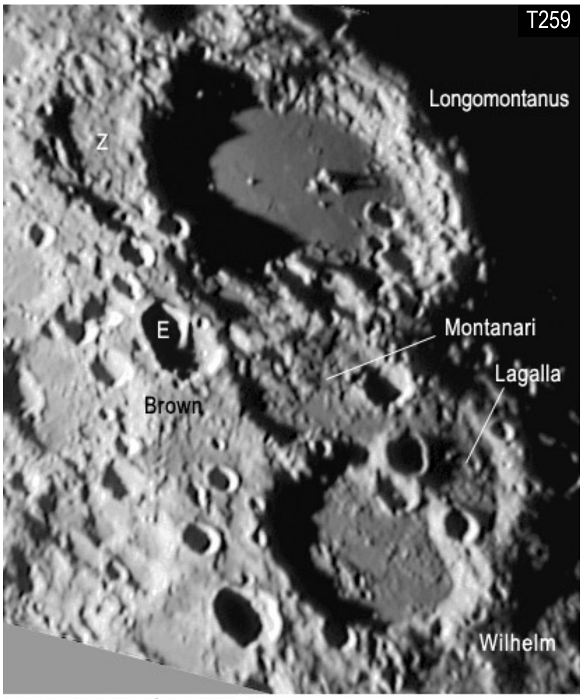
Wilhelm 43.4^0 S 20.4^0 W

An eroded crater with fairly rough floor, 106 km in diameter. It intrudes on two smaller eroded craters, ***Montanari*** (76 km) and ***Lagalla*** (85 km).

Both Wilhelm and Longomontanus do not follow the general rule that small craters are superposed on larger ones.

Brown 46.4^0 S 17.9^0 W

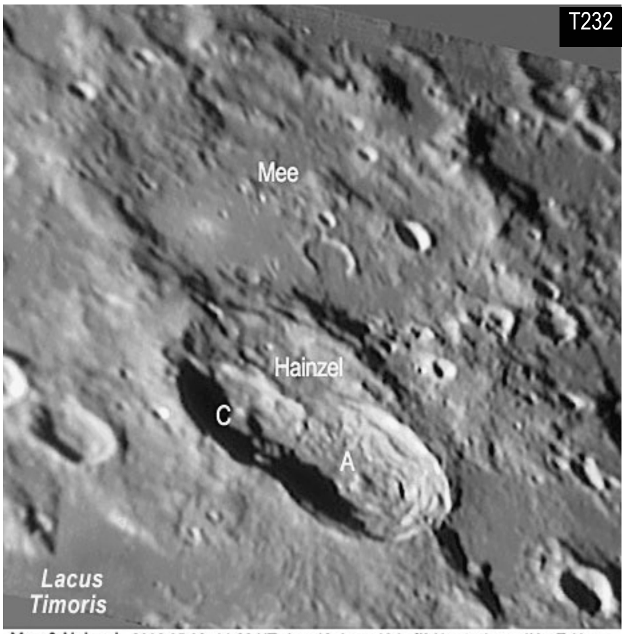
A 34 km crater. Its wall is penetrated by the crater ***Brown E*** (22 km).



Longomontanus & Wilhelm 2006.03.09 14:08 UT Age 9.6 days. 10-in f/6

Mee 43.7^0 S 35.3^0 W
A heavily eroded crater in the Pre-Nectarian period, diameter 126 km. Its floor contains a bright spot probably caused by the ejecta of the Tycho impact. The Lunar Orbiter images show that the bright spot is a tiny crater with a high albedo halo.

Hainzel 41.3^0 S 33.5^0 W
A crater adjoining Mee, diameter 70 km. It is overlapped by ***Hainzel A*** (53 km) and ***Hainzel C*** (38 km). The trio formation resembles the shape of a peanut shell.



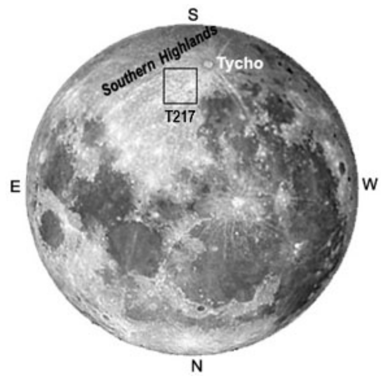
Mee & Hainzel 2006.05.09 14:28 UT Age 12 days. 10-in f/6 Newtonian + 4X + ToUcam

Palus Epidemiarum 32.0^0 S 28.2^0 W (Marsh of Epidemics, width 286 km)
Lacus Timoris 38.8^0 S 27.3^0 W (Lake of Fear, width 117 km)
These are irregular lava plains. See also Map 23

Hainzel to Palus Epidemiarum 2005.01.22 15:38~15:39 UT Age 12 days. 10-in f/6 + 2.5X + ToUcam (*mosaic*)

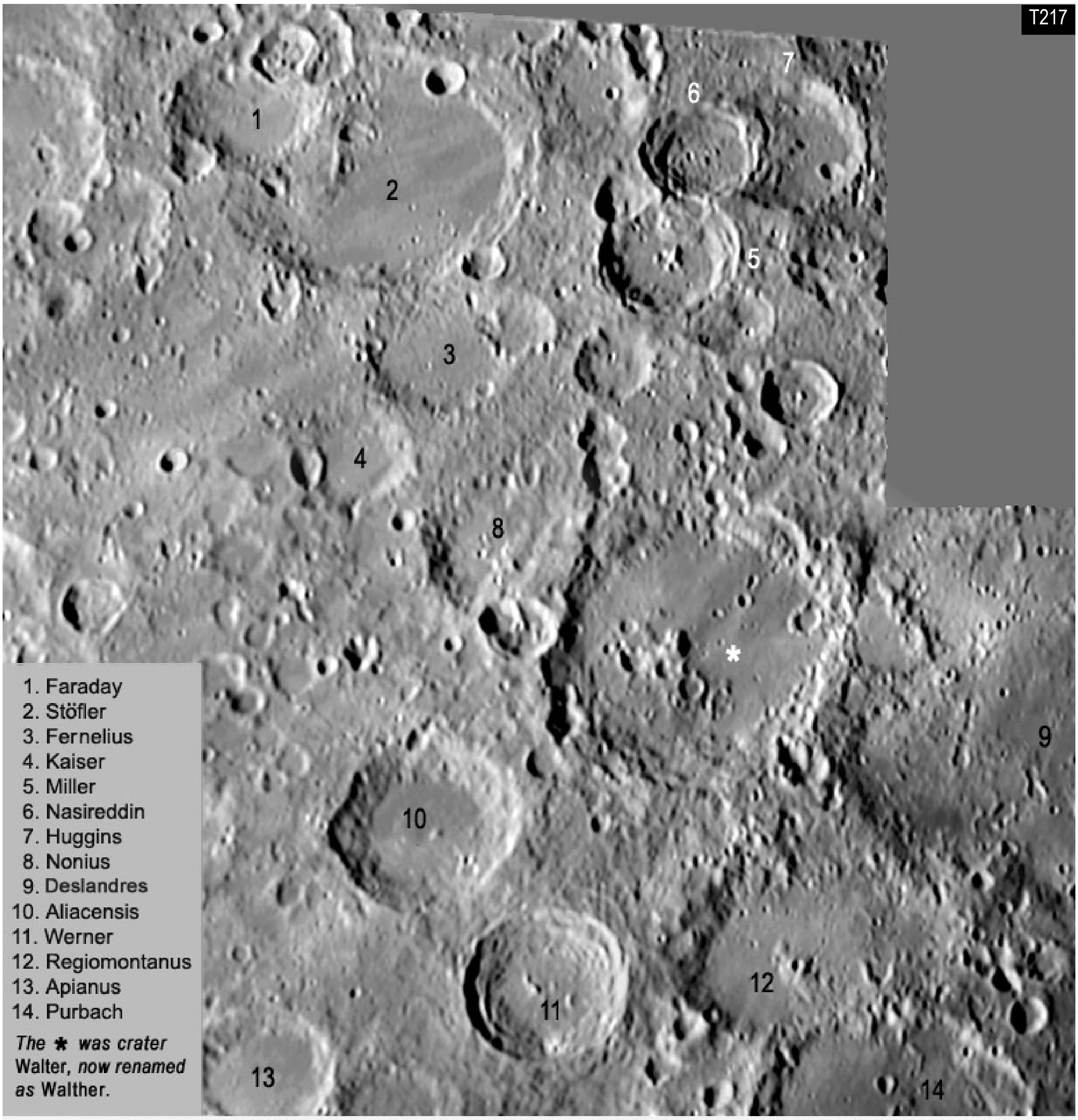
Hatfield 14, 16
Rükl 66, 65, 74, 75, 76

Southern Highlands
(Maurolycus, Faraday, Stöfler, Boussingault, Hommel)

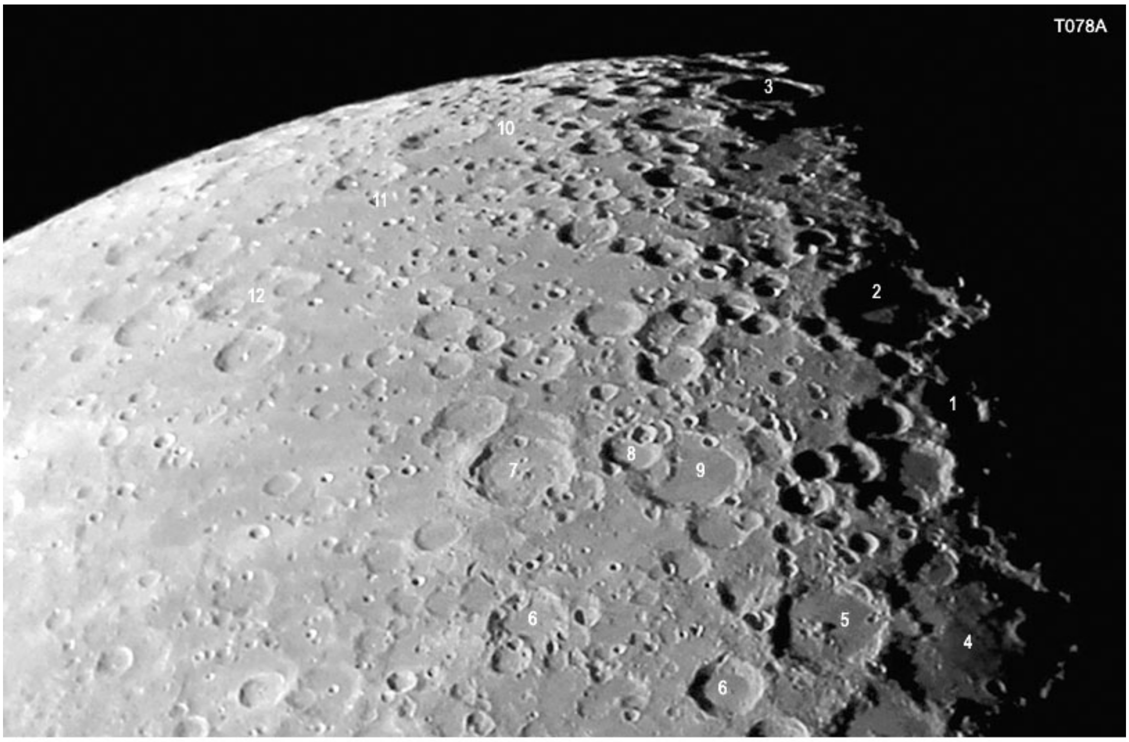


The Southern Highlands is a vast, heavily cratered region where no mare exists. It includes Tycho and its vicinity, the south polar zone, and the broad bright terrain in the southeast quadrant. This region is high because it rises few kilometers above the mare level. It is bright because the lands are dominated by light-colored anorthosite, the most ancient type of Moon rocks briefed in Map 1.

T217 shows a portion of the Southern Highlands. Note that some crater floors are splashed by the deposits of light-colored ejecta, which are traceable to the Tycho impact in 110 million years ago. (Tycho crater is located beyond the top right corner of this frame.)

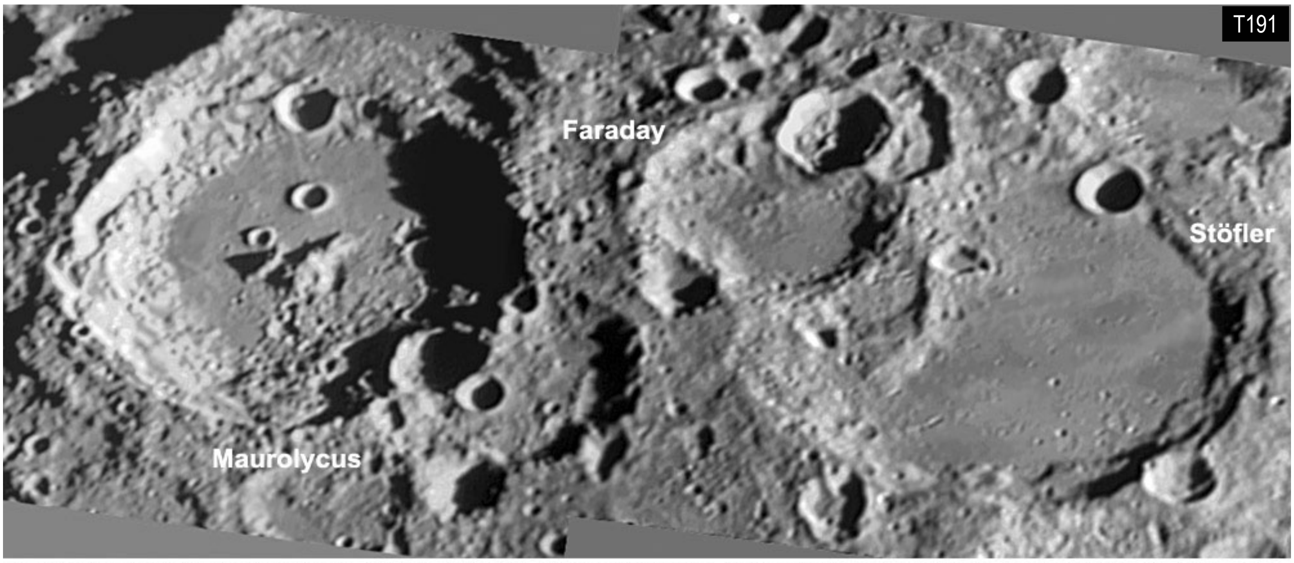


A portion of the Southern Highlands (Stöfler to Regiomontanus) 2005.04.18 ~13:35 UT Age 9.8 days. 10-in f/6 Newtonian + 2.5X + ToUcam



1. Tycho
2. Maginus
3. Moretus
4. Deslandres
5. Walther
6. Aliacensis
7. Maurolycus
8. Faraday
9. Stöfler
10. Manzinus
11. Mutus
12. Hommel

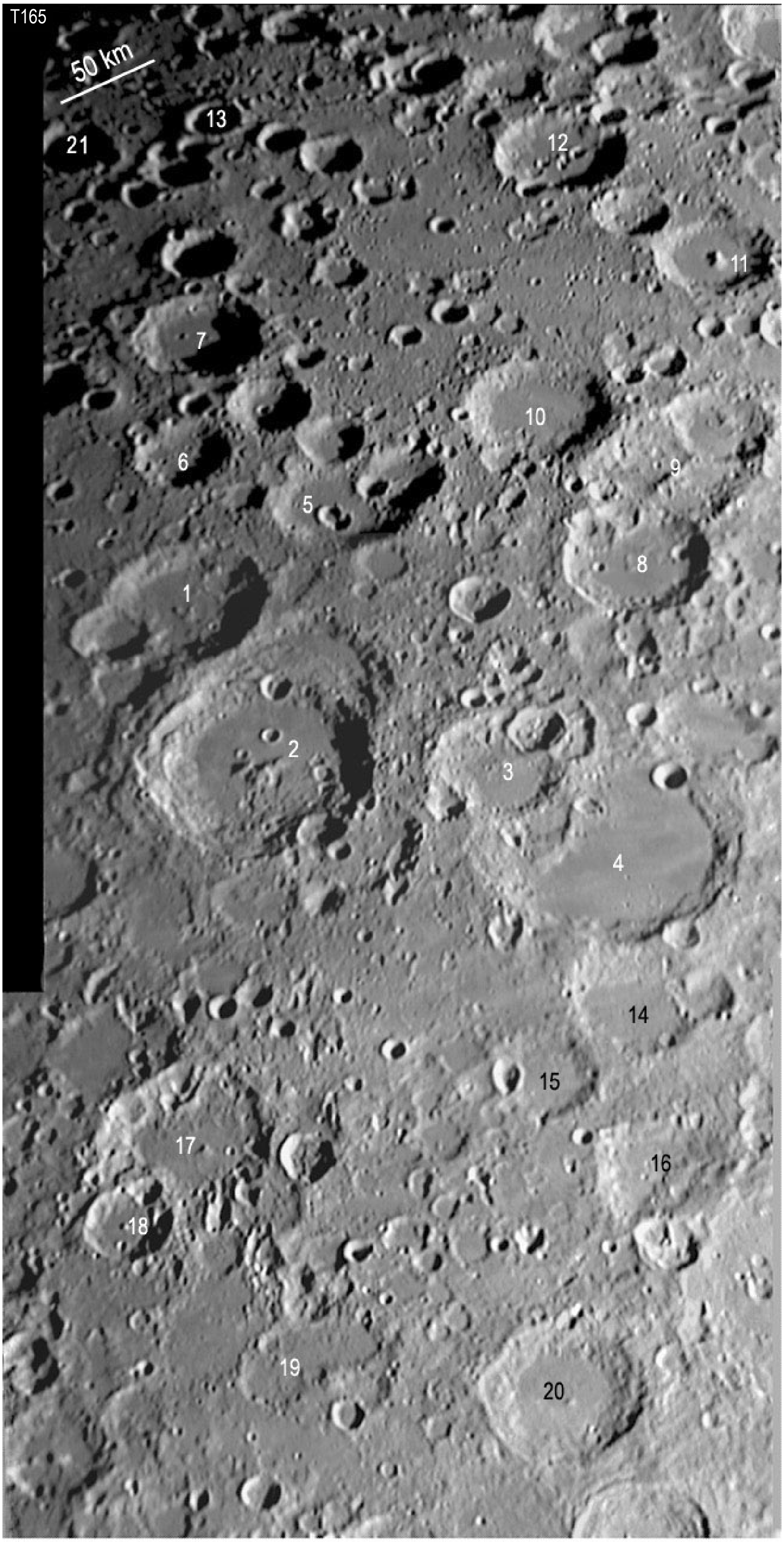
A chaos of craters in the Southern Highlands 2010.07.19 12:36UT Age 8 days. FS128 f/8 + Canon 550D (cropped from T078 & 74% resized.)



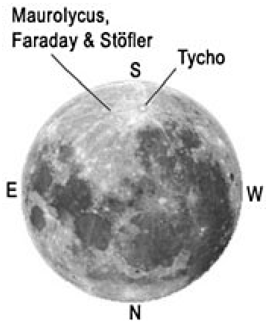
Crater Trio: Maurolycus, Faraday & Stöfler 2004.09.04 ~19:08 UT Age 20 days. 12.5-in f/6 Newtonian + 4X + ToUcam. (*mosaic of 2 video clips, 88% resized.*)

Maurolycus 42.0^0 S 14.0^0 E **Faraday** 42.4^0 S 8.7^0 E **Stöfler** 41.1^0 S 6.0^0 E

These are often depicted as a trio feature in the Southern Highlands. Maurolycus is a typical crater with central mountains and terraced walls, 114 km in diameter, 4700 m deep. The shadow in Image T191 tells that Maurolycus must be the deepest of the trio. Its walls and floor are interrupted by smaller craters. Faraday, likely youngest among the three, lies in the middle of the trio, 69 km in diameter. Its walls are also interrupted by three conspicuous craters. Stöfler is a vast walled plain peppered with secondary craterlets, 126 km in diameter and 2700 m deep. A large portion of Stöfler's floor is flat, but the eastern portion is mountainous suggesting it could be the remains of a crater which was ruined by the Faraday impact. The light-colored strips on Stöfler's floor are the ejecta deposits from the Tycho impact.



Maurolycus & vicinity 2004.10.03 ~21:49 UT Age 19 days. 10-in f/6 + 2.5X + ToUcam



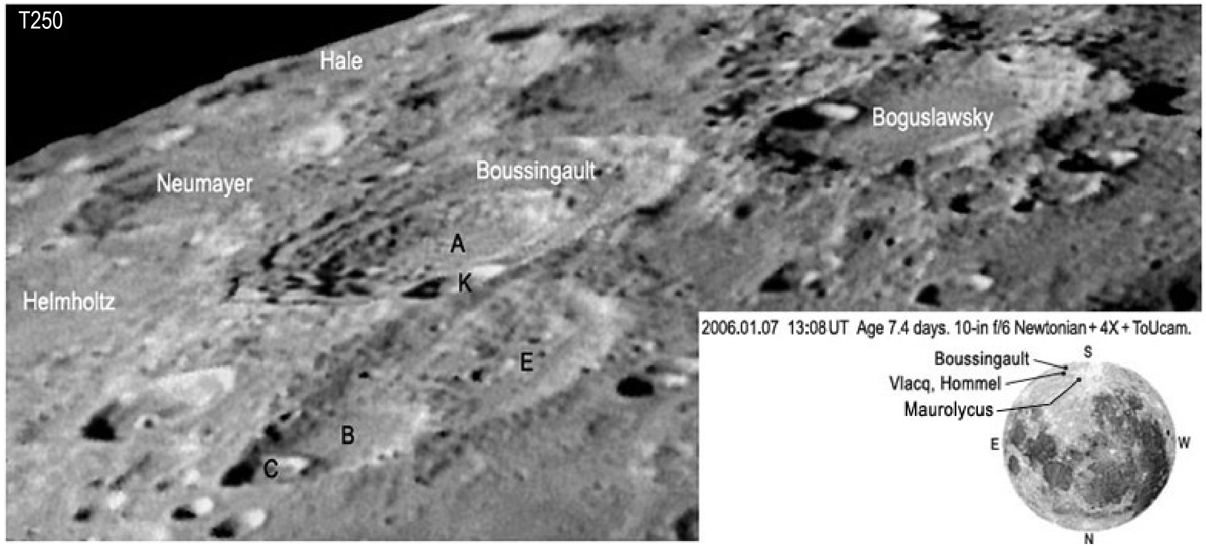
1. Barocius *(Dia. 82 km)*
2. Maurolycus *(114 km)*
3. Faraday *(69 km)*
4. Stöfler *(126 km)*
5. Clairaut *(75 km)*
6. Breislak *(49 km)*
7. Baco *(69 km)*
8. Licetus *(74 km)*
9. Heraclitus *(90 km)*
10. Cuvier *(75 km)*
11. Lilius (61 km)
12. Jacobi *(68 km)*
13. Tannerus *(28 km)*
14. Fernelius *(65 km)*
15. Kaiser *(52 km)*
16. Nonius *(69 km)*
17. Gemma Frisius *(87 km)*
18. Goodacre *(46 km)*
19. Poisson *(42 km)*
20. Aliacensis *(79 km)*
21. Asclepi *(42 km)*

Boussingault 70.2^0 S 54.6^0 E
A terraced crater, diameter 142 km, 3200 m deep. Its floor contains another large crater ***Boussingault A***. The whole formation resembles a triple-walled crater.

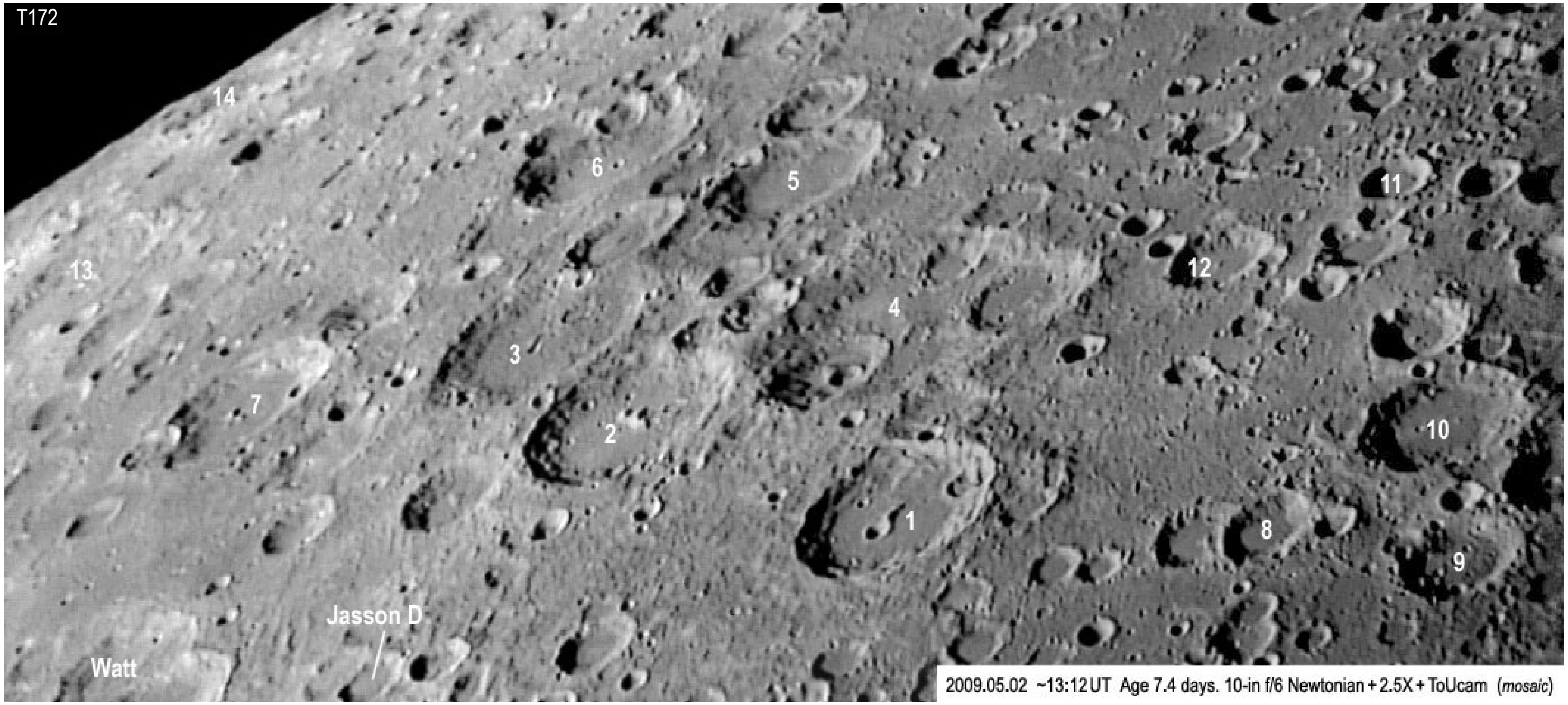
Boguslawsky 72.9^0 S 43.2^0 E
A 97-km crater with fairly worn rim, 3400 m deep.

Vlacq 53.3^0 S 38.8^0 E
A 89-km crater with central peaks, 3000 m deep.

Hommel 54.7^0 S 33.8^0 E
A 126-km crater from the Pre-Nectarian period, 2800 m deep. It has three conspicuous internal craters.



2006.01.07 13:08 UT Age 7.4 days. 10-in f/6 Newtonian + 4X + ToUcam.



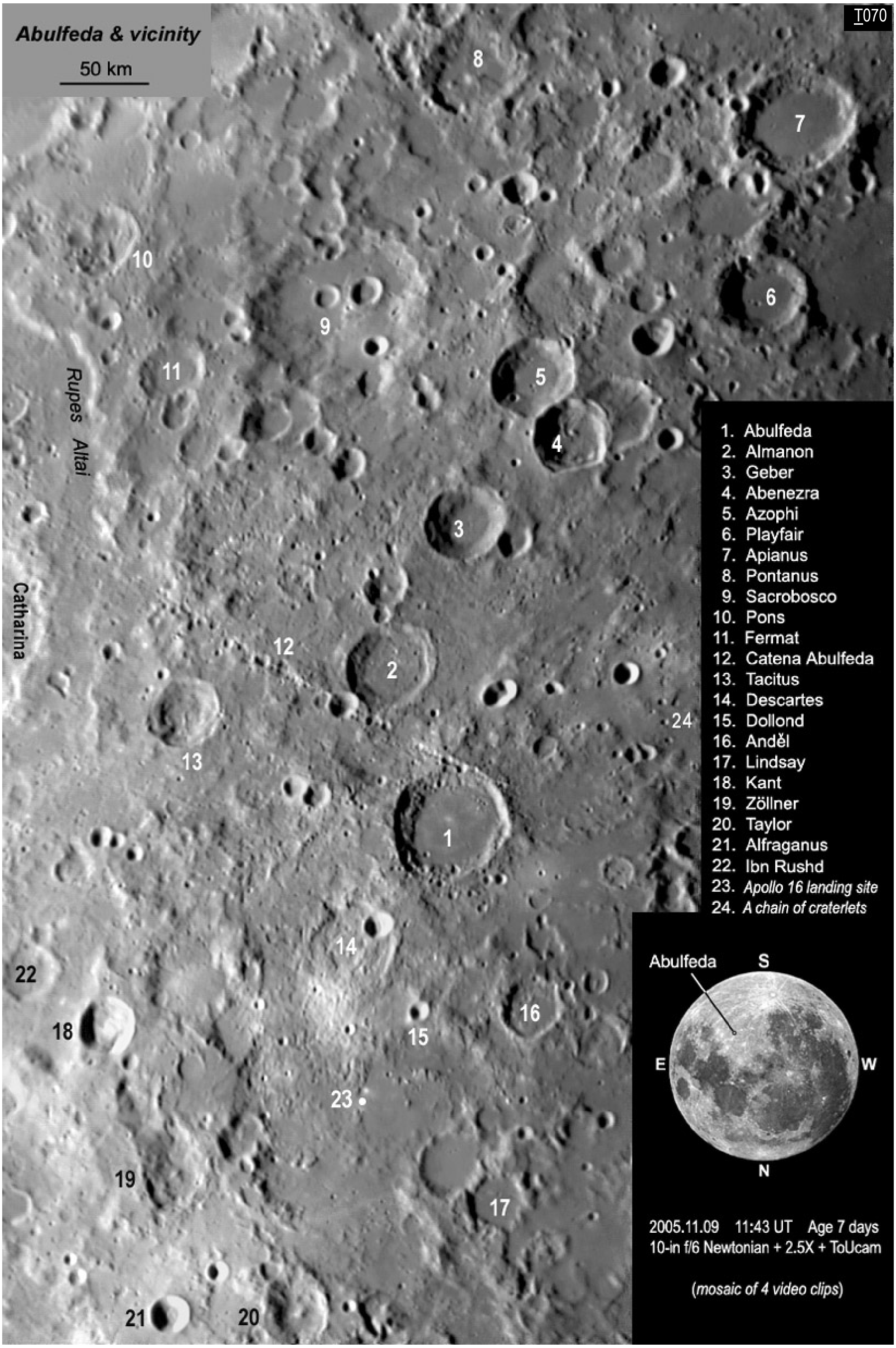
2009.05.02 ~13:12 UT Age 7.4 days. 10-in f/6 Newtonian + 2.5X + ToUcam (*mosaic*)

1. Pitiscus (*82 km*)
2. Vlacq (*89 km*)
3. Rosenberger (*95 km*)
4. Hommel (*126* km)
5. Nearch (*75 km*)
6. Hagecius (*76 km*)
7. Biela (*76 km*)
8. Ideler (*38 km*)
9. Breislak (*49 km*)
10. Baco (*69 km*)
11. Tannerus (*28 km*)
12. Asclepi (*42 km*)
13. Pontécoulant (*91 km*)
14. Gill (*66 km*)

MAP 30

Catena Abulfeda, Catena Davy, Crater Arrays

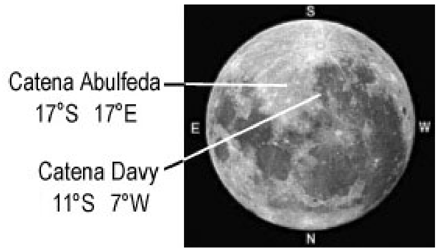
Hatfield 13
Rükl 56, 55, 45, 44, 43

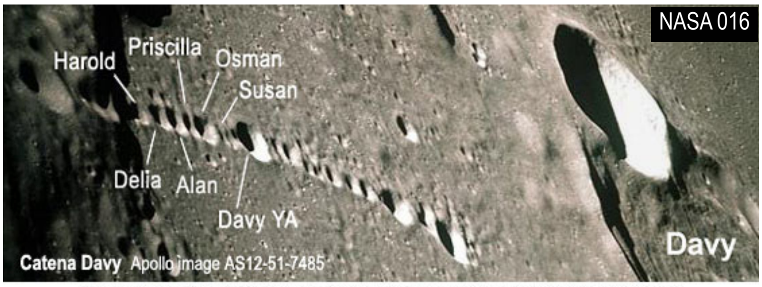


Catena is a chain of small craters, generally resulted from secondary impacts, or from fragmental impacts of a tidally disrupted meteoroid / asteroid. An exception is the chain of tiny craters inside Rima Hyginus Map 13, which appears to be volcanic rather than impact-originated.

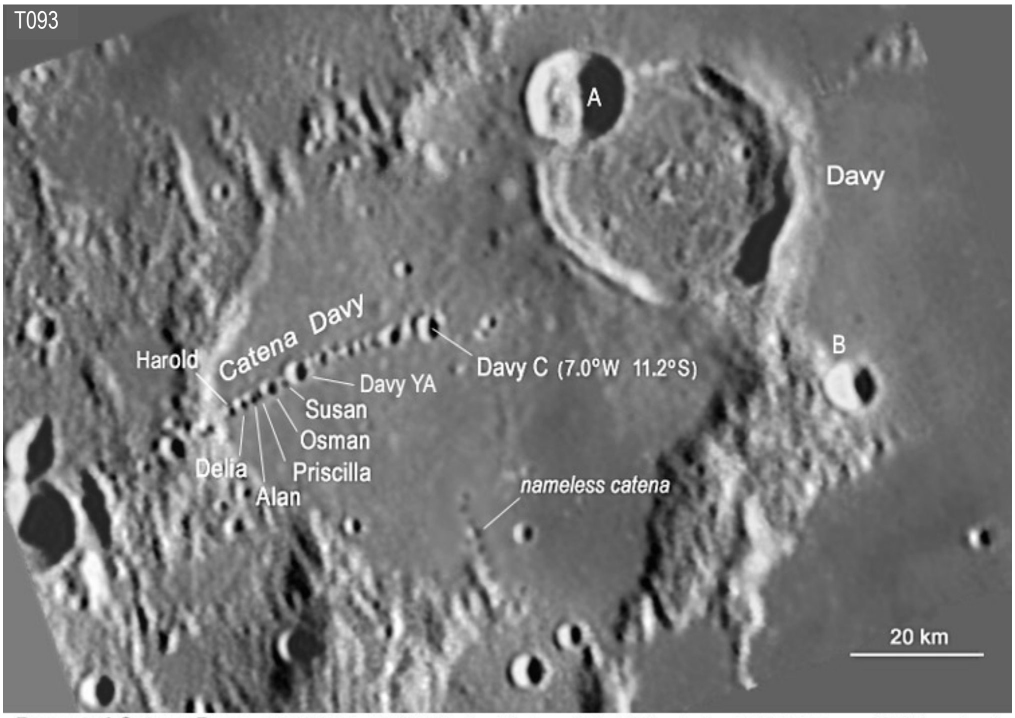
The most known crater chain is ***Catena Abulfeda*** (T070), length 210 km. It runs from the rim of ***Abulfeda*** (diameter 65 km) to the northern end of Rupes Altai. At high power, it resolves to tens of discrete or overlapped craterlets. This suggests that the intruder was partly disrupted and partly gravitationally bound. A short, loose chain of craterlets is also shown by *Label 24* in T070. Note the interesting arc array of craters from ***Abulfeda*** to ***Apianus*** *(1 to 7)*, and ***Descartes*** *(14)* with a bright patch at its rim. This patch consists of impact melts and breccias as found in the Apollo 16 samples, but its origin is a puzzle. In 1999 the Lunar Prospector flew low here and probed a strong subsurface magnetic anomaly. The Descartes region is more enigmatic than ever.

Another crater chain, ***Catena Davy***, is shown below. It requires high power to spot. This chain consists of some 20 craters from 1 to 3 km in diameter, 50 km long. It is likely caused by fragmental impacts of a tidally disrupted "rubble pile" meteoroid / asteroid, because most craters in the chain do not overlap. To the north of ***Davy C*** (3.4 km) is another catena but it is nameless.





(Reference Map: *http://www.lpi.usra.edu/resources/mapcatalog/topophoto/*)

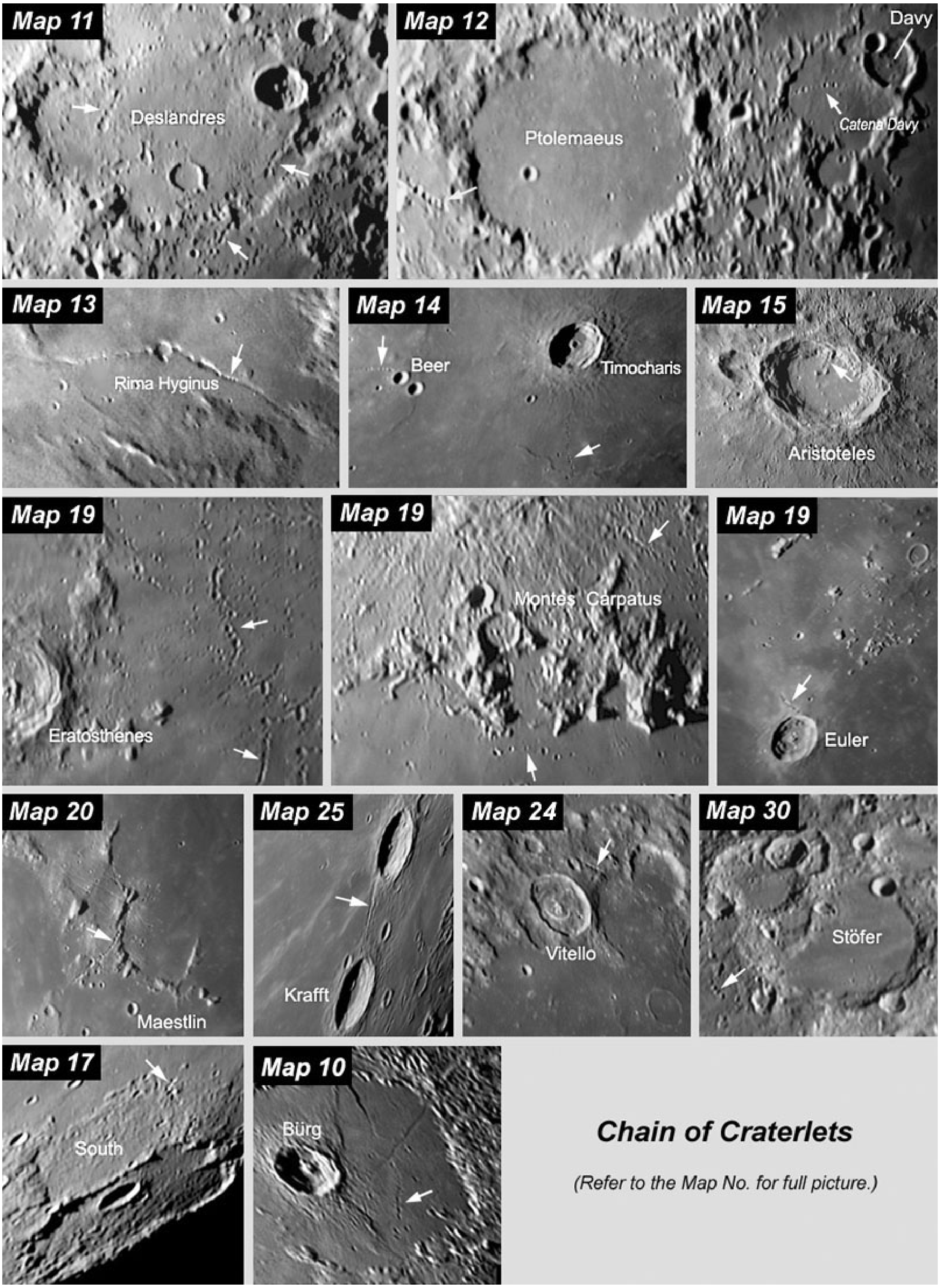


Davy and Catena Davy 2004.09.05 ~20:12 UT Age 21 days. 10-in f/6 Newtonian + 5X + ToUcam (*150% resized*)

Six IAU-named craters are marked along the eastern section of Catena Davy:

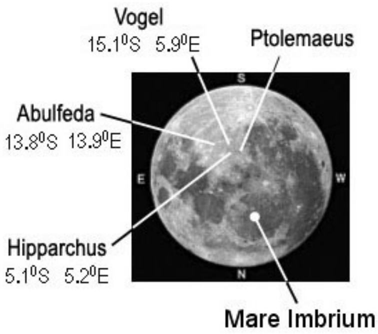
Harold	*(10.9°S 6.0°W 2 km)*	**Alan**	*(10.9°S 6.1°W 2 km)*	**Osman**	*(11.0°S 6.2°W 2 km)*
Delia	*(10.9°S 6.1°W 2 km)*	**Priscilla**	*(10.9°S 6.2°W 1.8 km)*	**Susan**	*(11.0°S 6.3°W 1 km).*

Other chains of craterlets are found in the regions marked by arrows in the guide maps below. Most of them are nameless.

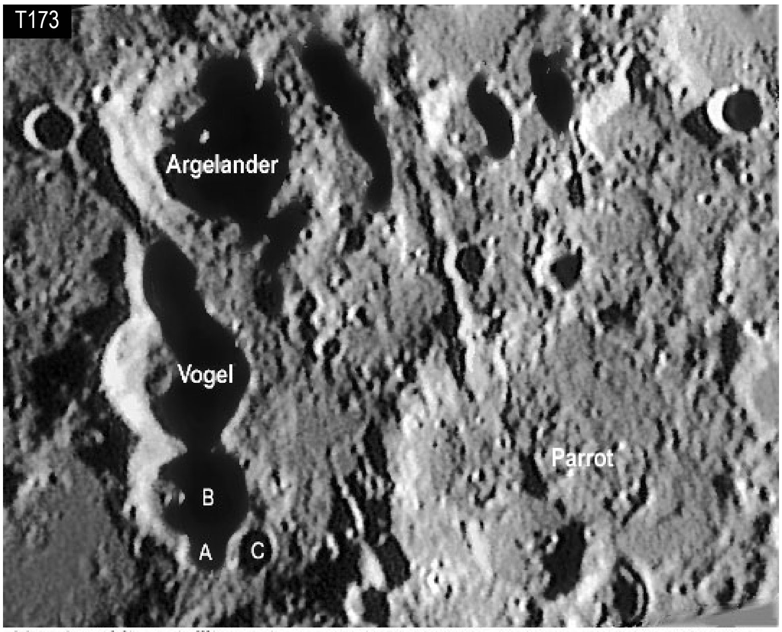


Chain of Craterlets

(Refer to the Map No. for full picture.)

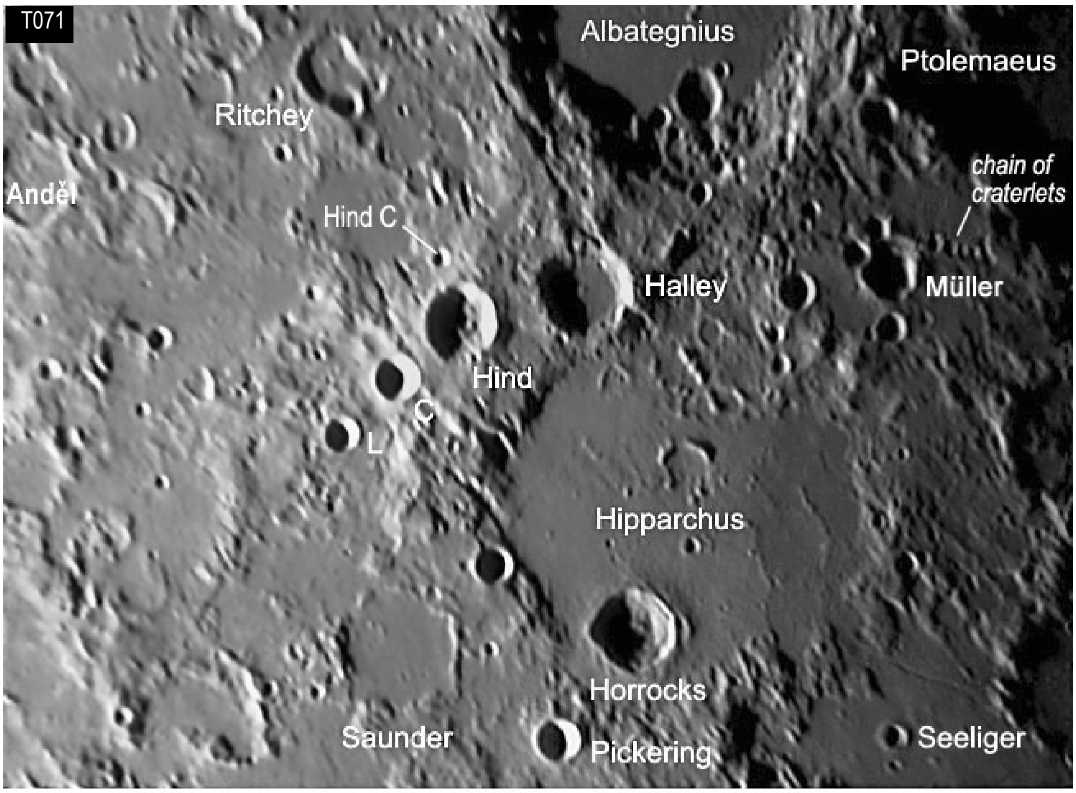


T173 shows a gourd-like crater array composed of ***Vogel*** (26 km), its companion craters A, B and C. Vogel can be spotted with the larger map in next page. The crater array seems to be secondaries from the Imbrium impact.



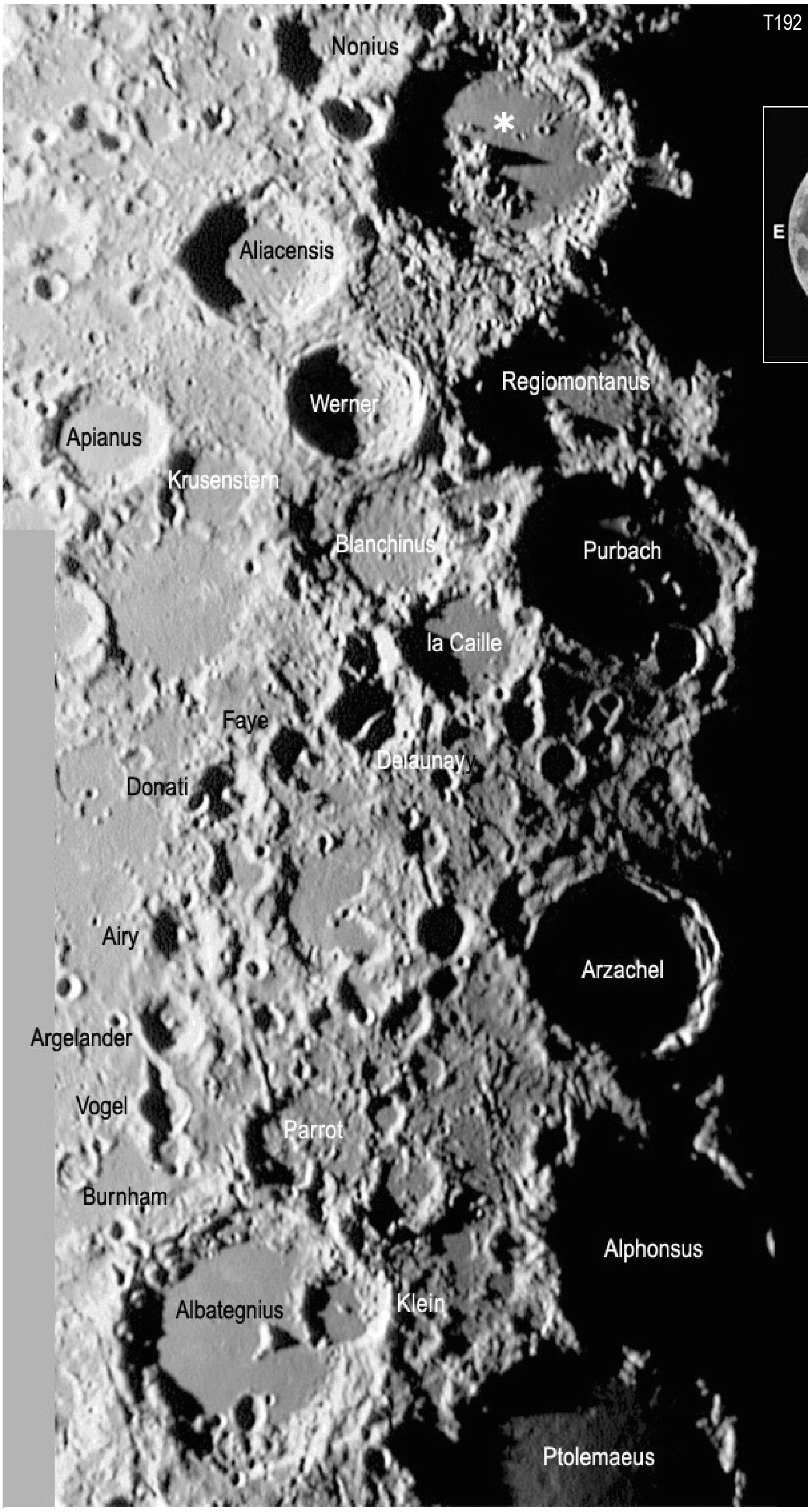
Vogel and its satellite craters 2004.09.05 20:27 UT Age 21 days. 10-in f/6 + 5X + ToUcam

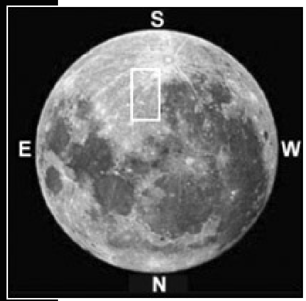
T071 shows a row of diminishing craters, composed of ***Halley, Hind, Hipparchus C*** and ***Hipparchus L***. Hipparchus is a vast walled plain (138 km), shown also in Map 12. Its walls are modified by a pattern of grooves and ridges known as "***Imbrium Sculpture***". This pattern is radial to Mare Imbrium, which affects the lunar surface for more than 1000 km from Imbrium. The same pattern can be seen in the middle of T173. ***Horrocks*** (30 km) is a younger crater within Hipparchus. ***Pickering*** (15 km) is named after E. C. Pickering, the former director of Harvard College Observatory. A chain of craterlets lies between ***Müller*** and Ptolemaeus. The small crater ***Hind C*** emits moderate rays under high illumination.



Hipparchus & vicinity 2004.06.25 12:47 UT Age 8 days. 10-in f/6 Newtonian + 2.5X + ToUcam, 6 frames stacked.

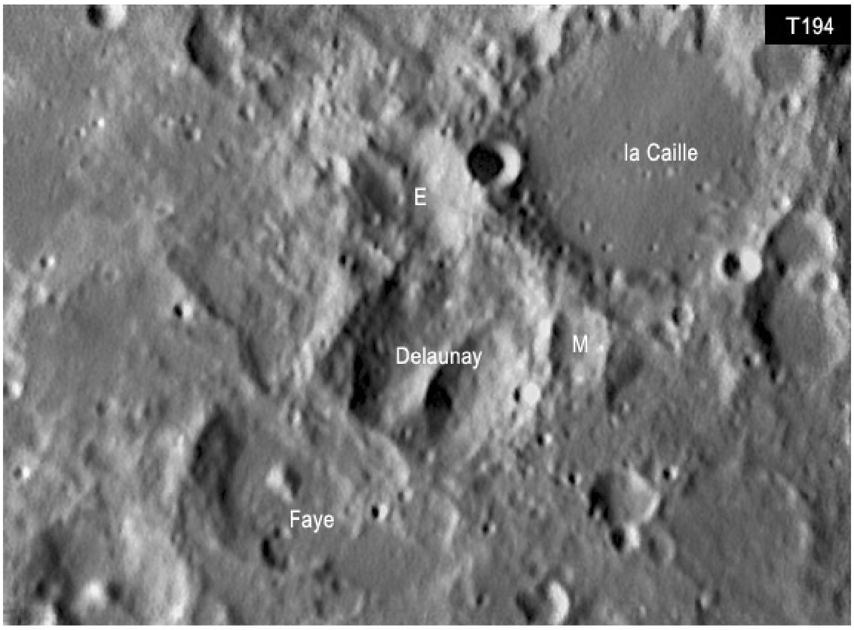
T192: An array of diminishing small craters, composed of ***la Caille*** (diameter 67 km), ***Delaunay*** (46 km), ***Faye*** (36 km), ***Donati*** (36 km), ***Airy*** (36 km), ***Argelander*** (34 km) and ***Vogel*** (26 km).





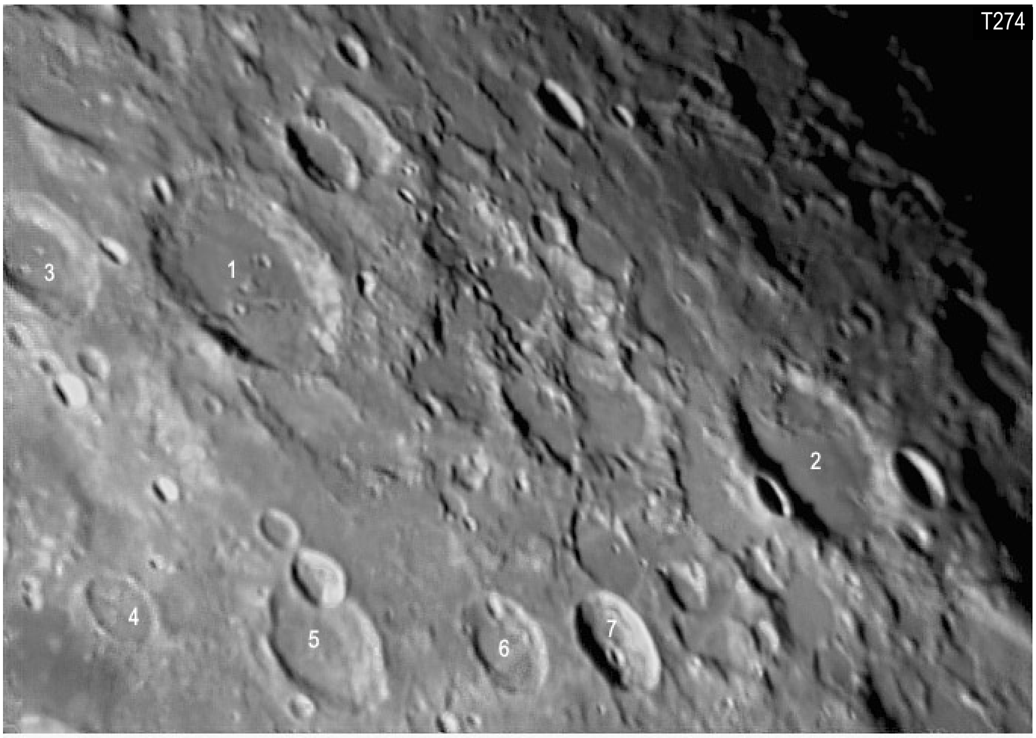
2004.12.19 12:41 UT Age 7 days. 10-in f/6+2.5X+ToUcam. The * was crater Walter, now renamed as Walther.

T194: **Delaunay, la Caille E and la Caille M** form a bell-shaped crater array.
Delaunay is 46 km in diameter. Its floor is divided by a sharp central ridge. la Caille is a 67-km crater with heavily worn rim. These craters are also shown in T192.



Delaunay 2005.01.19 12:18 UT Age 9 days. 10-in f/6 + 5X + ToUcam at 1/25 sec, 88 frames stacked.

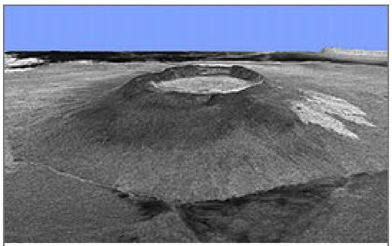
T274: A chaos of overlapped craters between Vieta (Map 28) and Byrgius (Map 27). They are located at the south-west limb of the nearside.



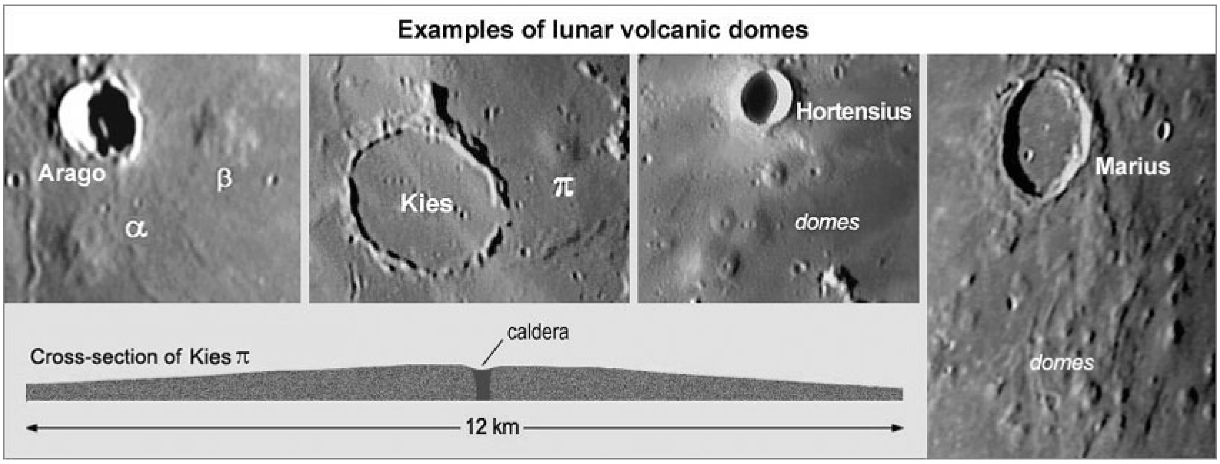
A chaos of overlapped craters between Vieta and Byrgius 2008.11.11 15:22UT Age 14 days. 10-in f/6 Newtonian+2.5X+ToUcam
Craters: 1. Vieta 2. Byrgius 3. Fourier 4. de Gasparis 5. Cavendish 6. Henry 7. Henry Frères

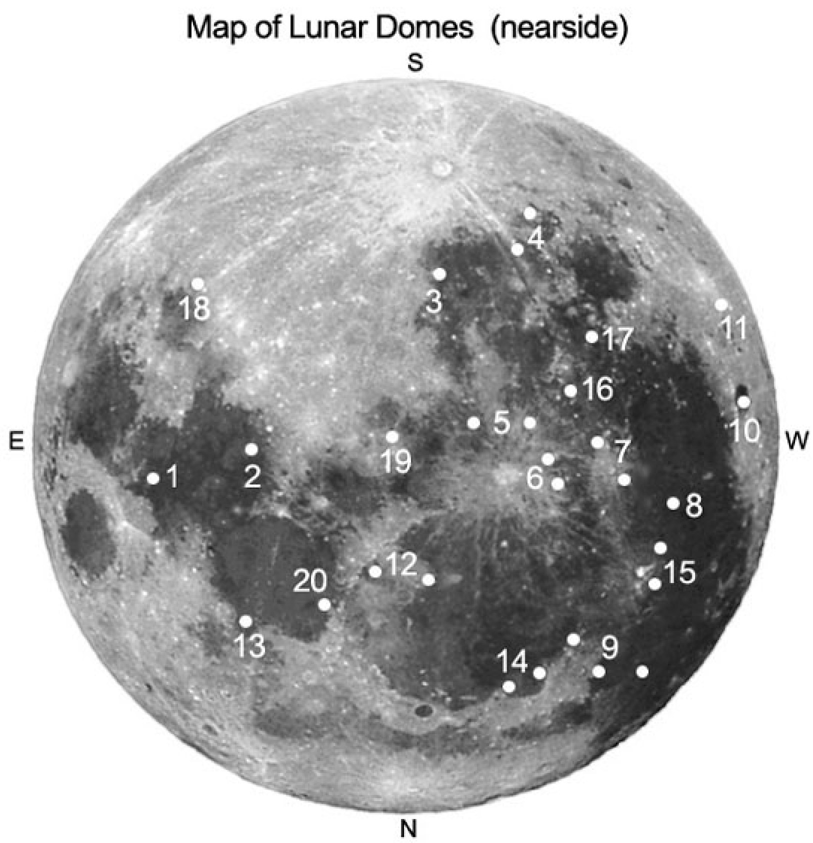
Domes

Domes refer to low rounded elevations found mostly on lunar maria. They are similar to the shield volcanoes on Earth but at small slopes of 1 ~ 3^0 owing to the low viscosity of erupted lava. They are believed to form during the later stages of lunar volcanism, when the temperature and rate of lava extrusion had decreased. Some domes, such as those near Cauchy, Kies and Hortensius, have calderas visible as summit craterlets in telescopes. However the ***megadome***, which is a large uplifted piece of the crust (diameter more than 30 km), is more complex in nature. Lunar domes and megadomes located near a known feature are highlighted in the following maps; they require very oblique sunlight to be seen.



Shield volcano **Darwin** on Isabella Island in Pacific Ocean. It has an exceptionally large summit caldera, dia. 5 km, height 1330 m. (Image made from radar data & elevation data)



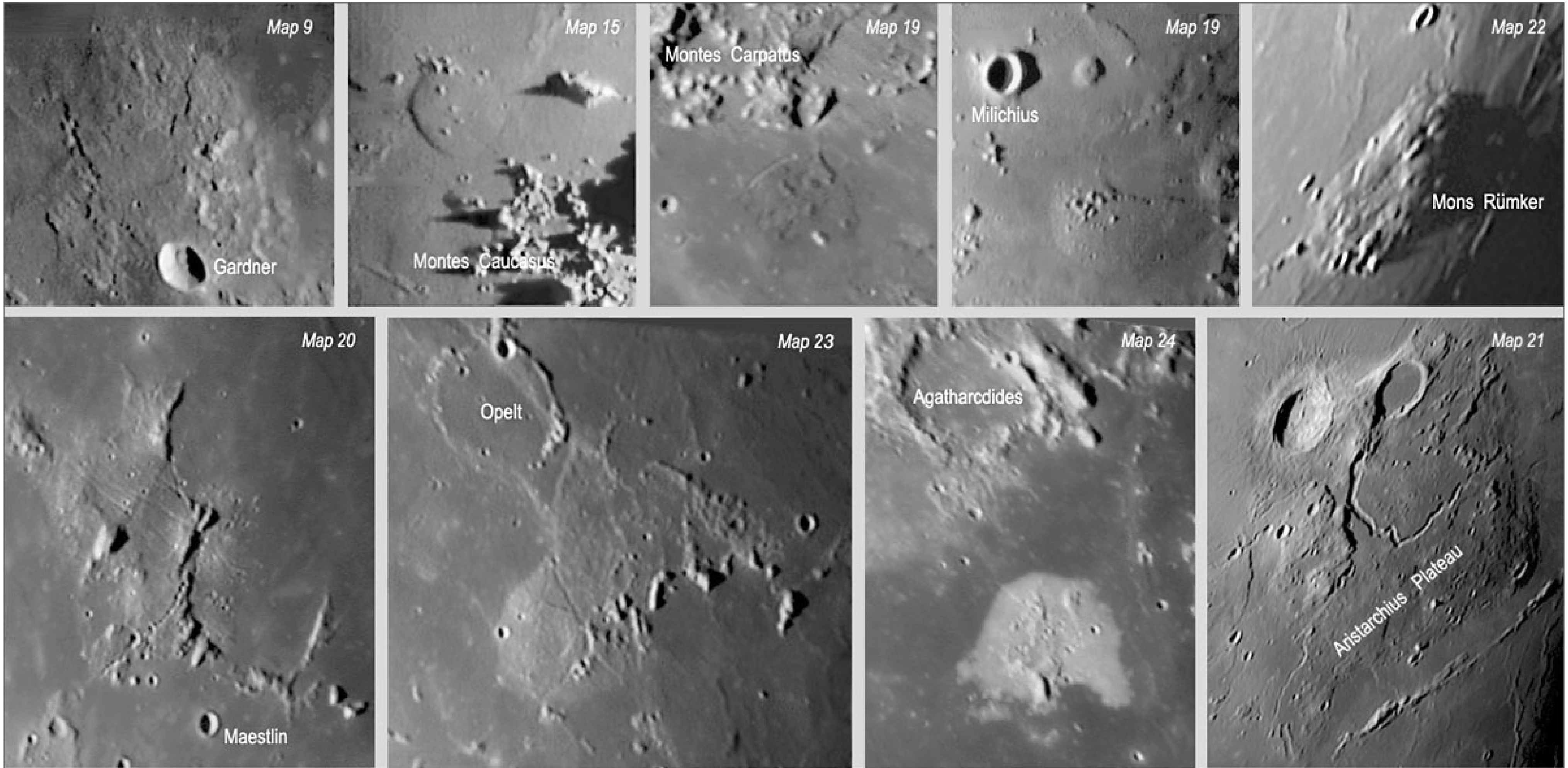


1. Cauchy, Lyell & Lucian Map 6
2. Arago & its northern vicinity Map 8
3. Birt Map 12
4. Capuanus & Kies Map 23
5. Gambart & Reinhold Map 19
6. Copernicus, Hortensius & Milichius Map19
7. Kepler & Encke Map 20
8. Marius Map 20
9. Gruithuisen, Mairan T & Mons Rümker Map 22
10. Grimaldi Map 26
11. Darwin Map 27
12. Palus Putredinis & Beer Map 14
13. Luther Map 9
14. Sinus Iridum Map18
15. Aristarchus & Herodotus Map 21
16. Lansberg Map 20
17. Herigonius Map 24
18. Fracastorius Map 5
19. Murchison Map 13
20. Valentine Dome Map15

Other megadomes are shown in next page.

A longer list of lunar domes (non-consensual) is suggested in the References page.

Megadome is a near-circular plateau or irregular uplift patch on lunar mare. It has diameter more than about 30 km and low elevation of few hundred meters. The plateau surface is textured with protrusions, depressions, ridges, rilles, craterlets etc. The large diameter means it is within the reach of small telescopes. But the trick is that all megadomes are truly low in height and poor in contrast, so they are noticeable only under very oblique sunlight. Megadomes may be volcanic or impact originated, both are not fully understood. For Aristarchus Plateau, it was thought that the formation was originally a low section of the highland region, but was uplifted as a result of the gigantic Imbrium impact. The subsequent lava flooding failed to cover it.



Megadomes on the nearside of the Moon (low elevated plateaus, size greater than 30 km) Aristarchius Plateau is 60% resized. Refer to the Map No. for full picture.

MAP 32

Lunar Rays

When the Sun illumination angle is high enough (e.g. 30^0 or more), bright rays begin to emit from certain craters. The table below lists some craters with noticeable rays. A longer list (non-consensual) is suggested in the References page.

Rayed Craters									
Anaxagoras	(Map 16)	Dionysius	(Map 13)	Kepler	(Map 20)	Messier A	(Map 6)	Taruntius	(Map 6)
Aristarchus	(Map 21)	Euclides	(Map 20)	Lalande	(Map 19)	Petavius B	(Map 3)	Thales	(Map 10)
Aristillus	(Map 14)	Furnerius A	(Map 3)	Langrenus	(Map 3)	Proclus	(Map 2)	Theophilus	(Map 5)
Autolycus	(Map 14)	Gambart A	(Map 19)	Lassell D	(Map 12)	Samir	(Map 22)	Timocharis	(Map 14)
Birt	(Map 12)	Glushko	(Map 25	Lichtenberg	(Event 1)	Sirsalis J	(Map 27)	Triesnecker	(Map 13)
Byrgius A	(Map 27)	Godin	(Map 13)	Manilius	(Map 9)	Snellius	(Map 3)	Tycho	(Map 11)
Copernicus	(Map 19)	Hind C	(Map 31)	Menelaus	(Map 9)	Stevinus A	(Map 3)	Zucchius	(Map 29)

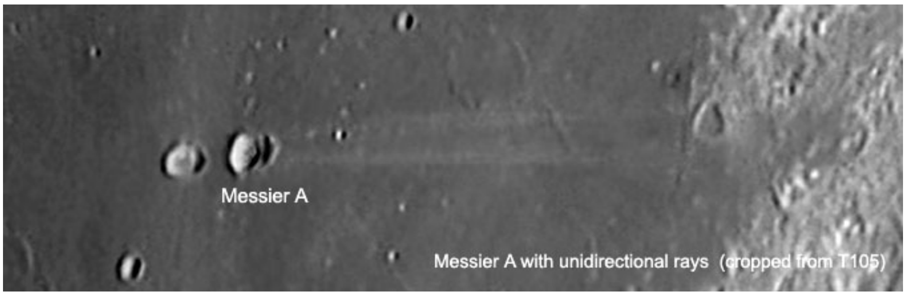
Lunar rays are simply distant ejecta from impact. They are bright due to two separate causes, or a mix of both.

- Some rays are composed of materials ejected from an impact site on the highlands. The highlands are predominately light-color anorthosite (illustrated in Map 1). These rays become bright simply because anorthosite is deposited as projectiles on the darker maria.
- The ray may also contain fine pulverized rock powder created by the energy of the impact. This powder reflects sunlight effectively making the ray (ejecta) bright under illumination. However, the brightness of such powdery ray is weathered away by micrometeoroids, cosmic rays, and solar winds more rapidly than the ejecta that is rich in anorthosite.

In theory all fresh impact craters have rays. As time goes by, both the anorthositic and powdery rays will vanish. This suggests that rayed craters are generally younger than non-rayed craters.

Lunar rays are unique in the following characteristics:

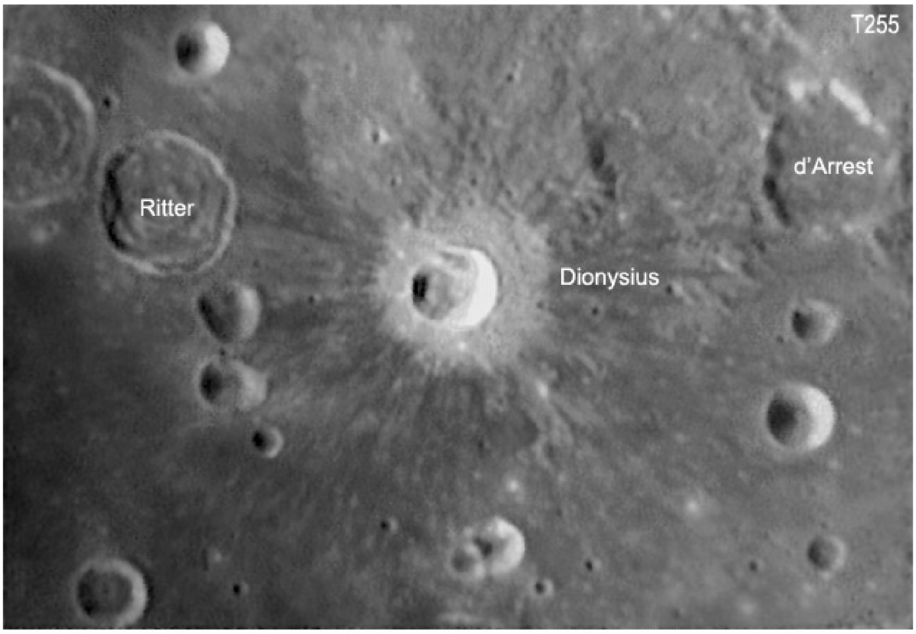
- They do not have fixed pattern. For example in next page, the rays from Tycho are long in multi directions but those from Copernicus and Kepler are wispy. The difference of pattern probably depends on the impact intensity, the viscosity (fluidity) of the ejecta melt and the distribution of secondary craters. (Remember secondary craters can produce weak rays too.)
- The rays may be unidirectional at grazing impact angle (a few degrees from ground).



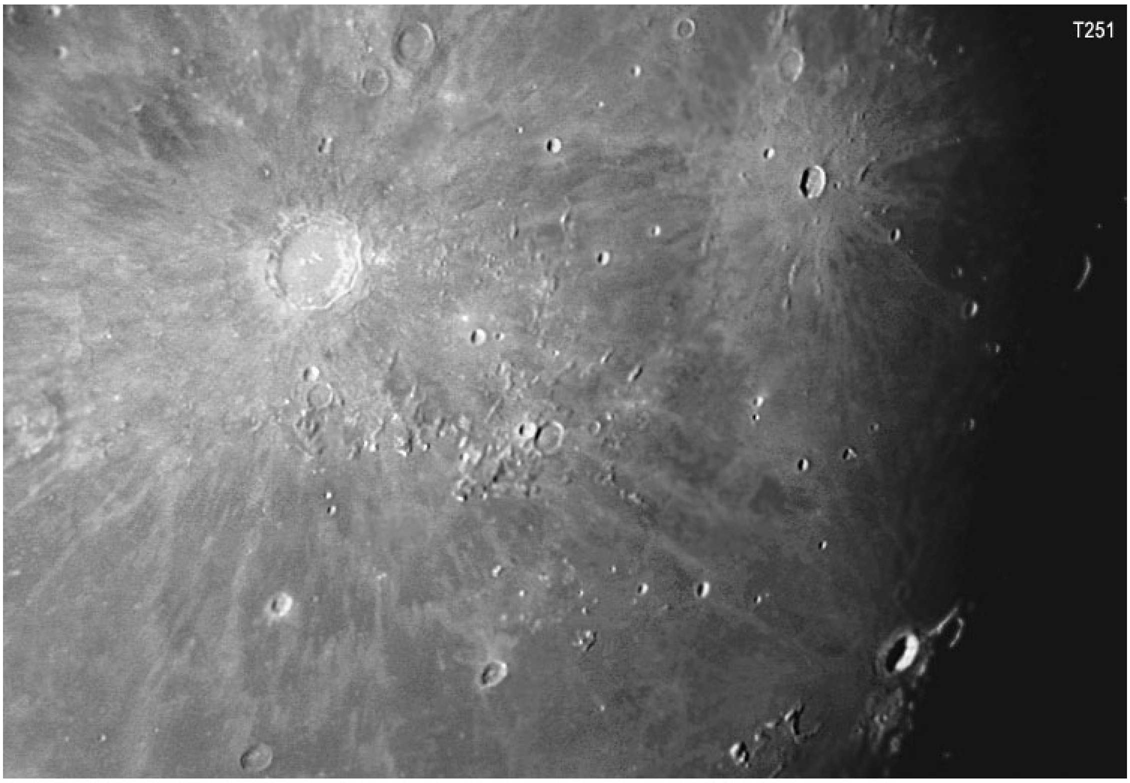
Messier A with unidirectional rays (cropped from T105)

- The rays may not point exactly back to the crater from which they supposedly originated.
- The rays may shift slightly in position during a lunation.
- The rays are not always equally bright when under a similar illumination angle in the lunar morning and evening.

While bright rays are common, there is a rare type of 'dark rays'. In T255, the impact crater ***Dionysius*** (diameter 18 km, Map 13) has a bright halo over a radial pattern of dark rays. The dark rays were first noted by Clementine spacecraft in 1994. They are actually ejecta composed of dark material excavated from the mare basalts. The bright halo is deposits of light-colored anorthosite excavated from the deeper layer.

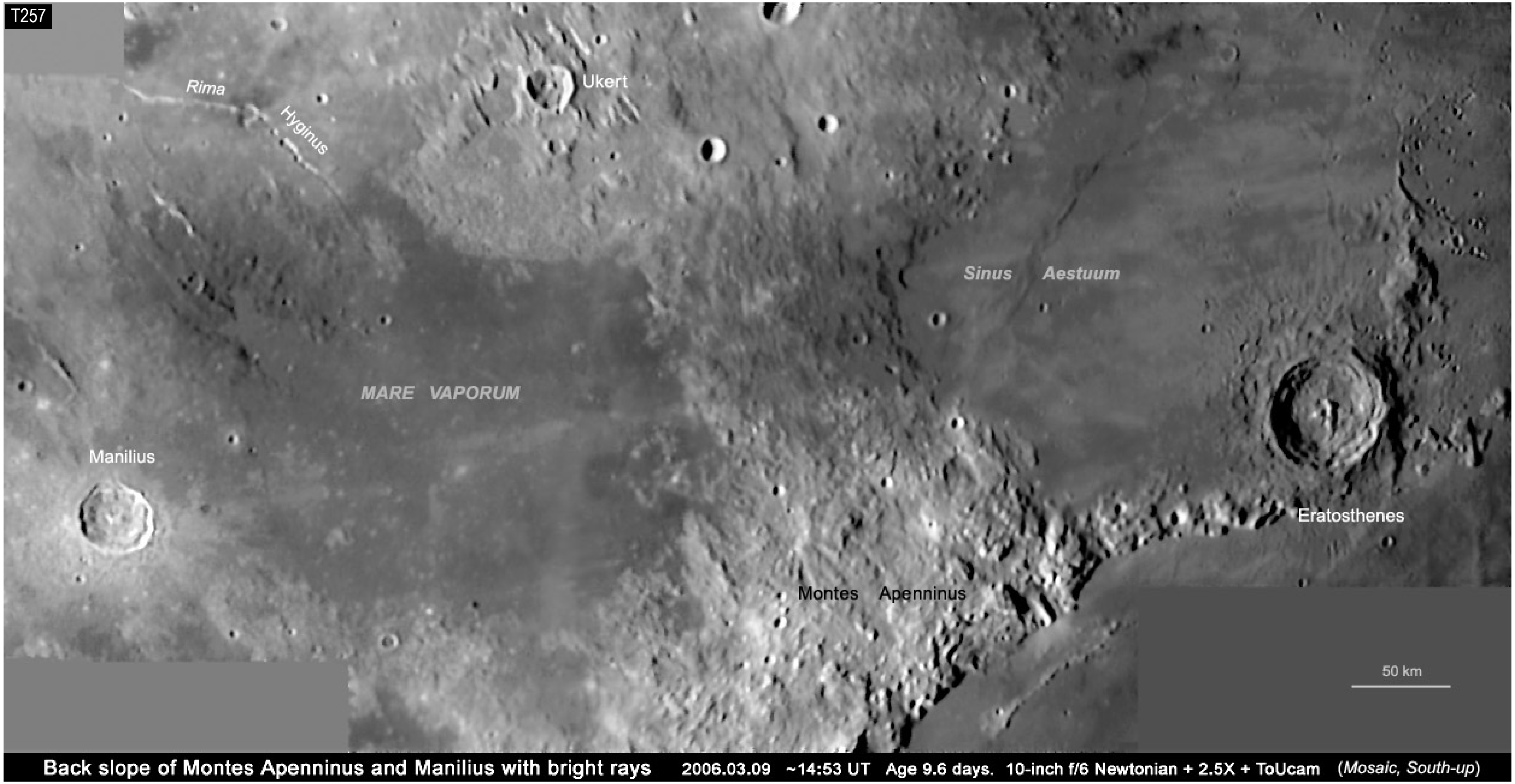


Dionysius with dark rays 2006.03.09 13:48 UT Age 10 days. 10-inch f/6 Newtonian + 5X + ToUcam



Copernicus and Kepler with their systems of rays 2000.05.15 14:02 UT Age 11 days. FS102 f/8 + LE7.5 + CP950 at 1/13 sec.

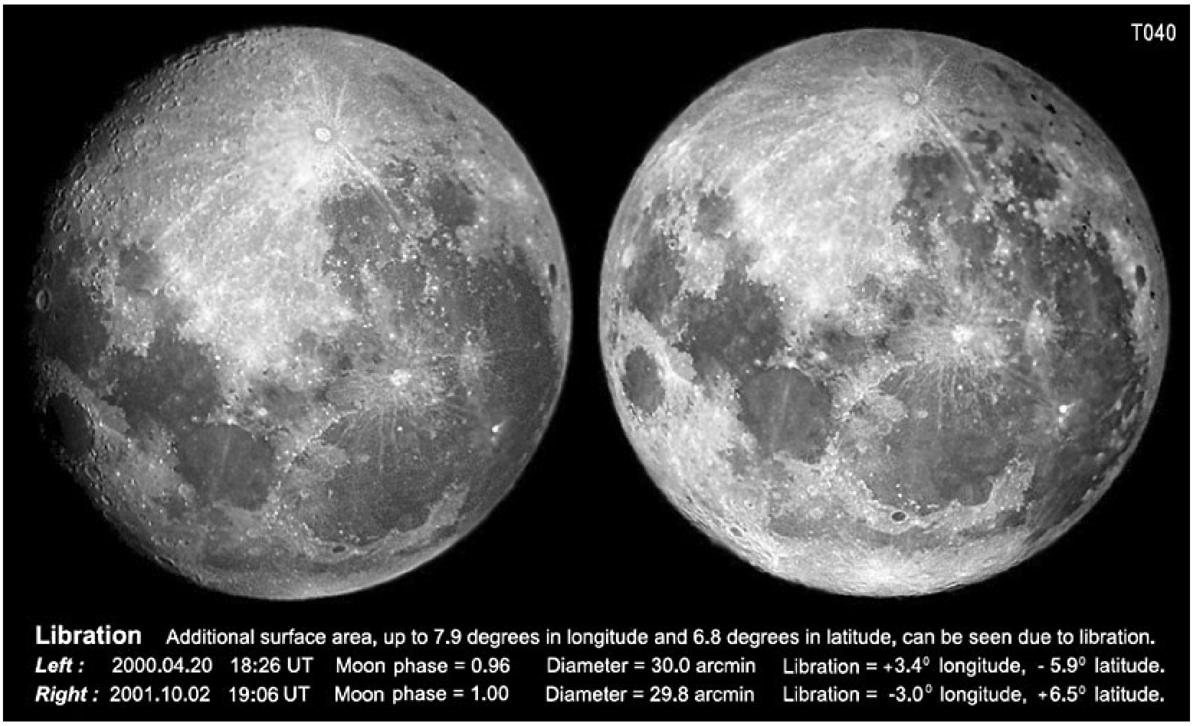
One arm of Tycho's rays stretching about 1500 km into Mare Nectaris (bottom left corner of frame). Note also the "Cassini's bright spot" and the "double ray" north of Tycho. 2010.09.26 16:48 UT Age 18 days. FS128 + Canon 550D, south-up.



One arm of Manilius rays stretches across Mare Vaporum and the back slope of Montes Apenninus. The ray is as long as 450 km, almost penetrating into Sinus Aestuum. Note also the regions of DMD (dark mantle deposits) to the southeast of Mare Vaporum and on the back slopes of the Apenninus.

MAP 33

Libration

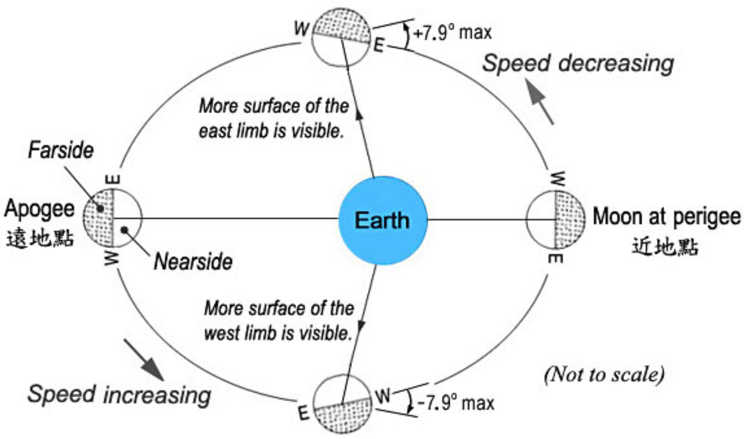


Libration Additional surface area, up to 7.9 degrees in longitude and 6.8 degrees in latitude, can be seen due to libration.
Left : 2000.04.20 18:26 UT Moon phase = 0.96 Diameter = 30.0 arcmin Libration = +3.4° longitude, - 5.9° latitude.
Right : 2001.10.02 19:06 UT Moon phase = 1.00 Diameter = 29.8 arcmin Libration = -3.0° longitude, +6.5° latitude.

Libration (天平動) allows the nearside of the Moon to be seen from slightly different angles at different time, producing an overall view of the lunar surface that adds up, over time, to 59% of the total. It was first noted by the Polish astronomer Johannes Hevelius (1611-1687).

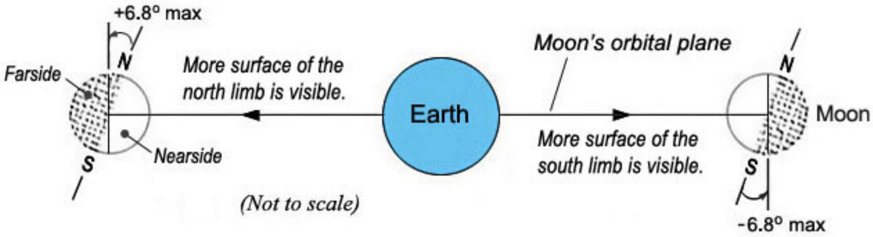
There are 3 types of optical librations, subject to the observer's location relative to the Moon .**

- ***Libration In Longitude*** (經天平動) is due to the fact that the Moon moves faster towards perigee and slower when it approaches apogee, but its axial rotation remains constant. This means that the Moon's rotation is not yet in perfect synchronization with its orbital motion. As a result, the Moon appears to wobble back and forth around its rotation axis. The additional longitudinal surface that can be seen with this libration is $\pm 7.9^0$.

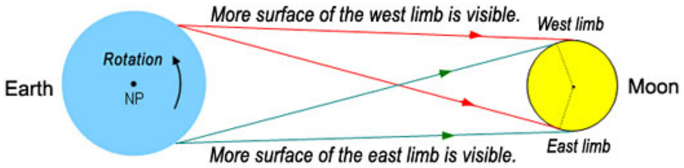


*** Due to irregularities of gravitational pull by the Earth and the Sun, the Moon does librate very slightly by itself; this is known as physical libration. See Appendix –* Moon Data.

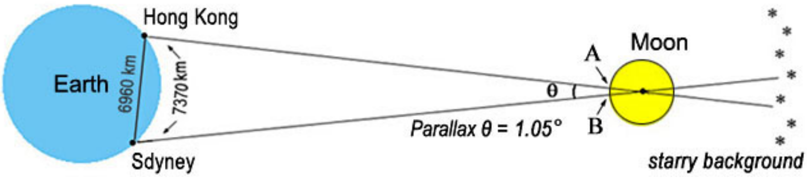
- ***Libration In Latitude*** (緯天平動) is due to the tilt angle of the Moon's equator (or rotation axis) from its orbital plane. As a result, the Moon appears to nod its polar regions towards and away from the Earth as it goes around its orbit. The additional latitudinal surface that can be seen with this libration is ± 6.8^0.



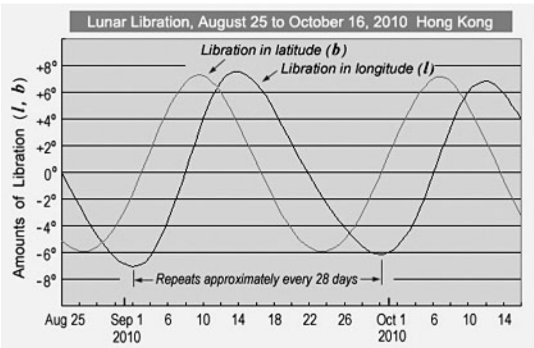
- ***Diurnal Libration*** (周日天平動) happens daily. It gives an extra 1^0 of visible surface round the east or west limb of the Moon, because the Earth's rotation brings a terrestrial observer at slightly different view angles between moonrise and moonset.

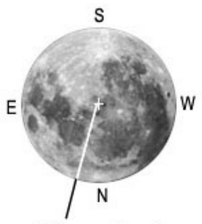


Simultaneous observations of the Moon disc from two cities also produce a parallax, such as θ shown below. An observer in Hong Kong sees the Moon disc center at position A whereas another observer in Sydney sees it offset slightly to B.

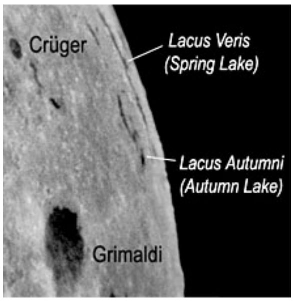


The period of libration in longitude is 27.55455 days (the perigee-to-perigee month). The period of libration in latitude is 27.21222 days (the node-to-node month). Their difference makes the Moon disc's center to librate from the zero coordinates by an amount marked by longitude l and latitude b. A positive value of l or b gives more surface of the east or north limb exposed to Earth. A negative value of l or b gives more exposed surface of the west or south limb.



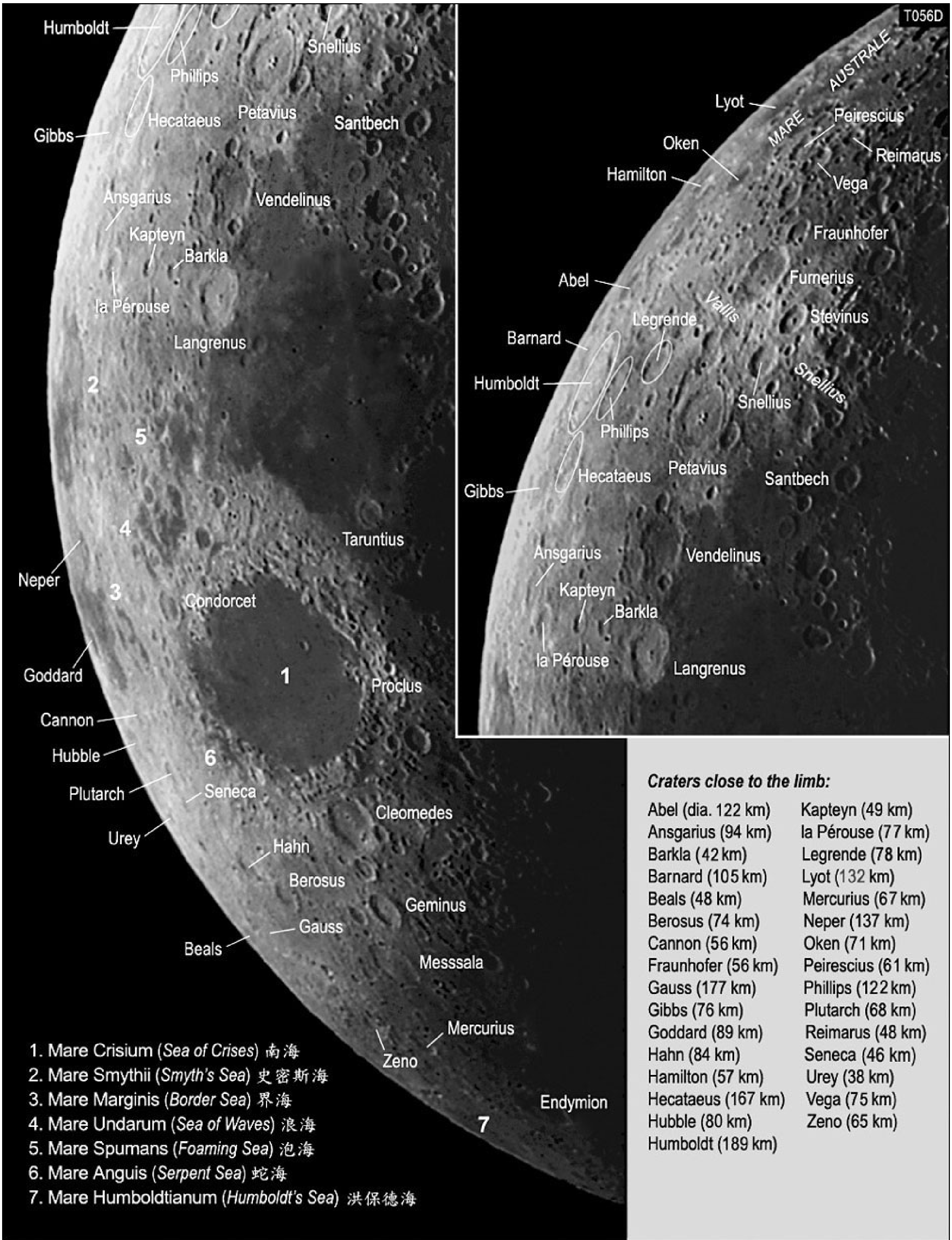


Disc center at longitude l, latitude b (seen from observer's location)



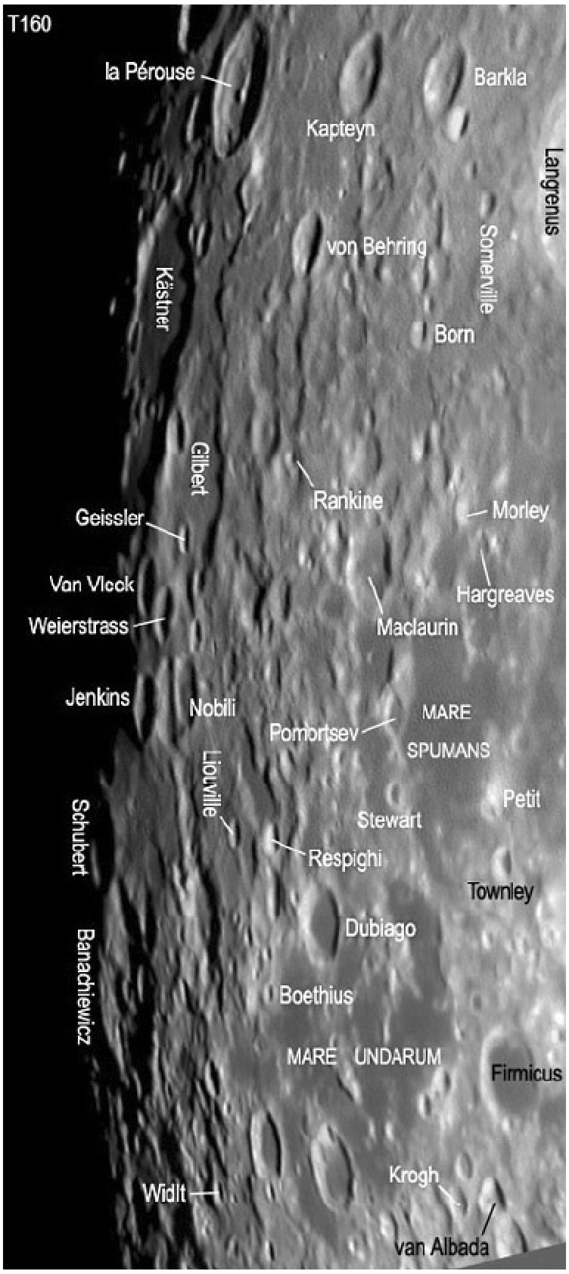
Libration causes lunar features at the limb distort perceptively, or even temporarily out of sight. For instance, Lacus Veris and Lacus Autumni on the west limb are recognized only at favorable libration. The visibility of the Moon's east limb (T056D, next page) are also libration dependent.

The east limb during favorable libration

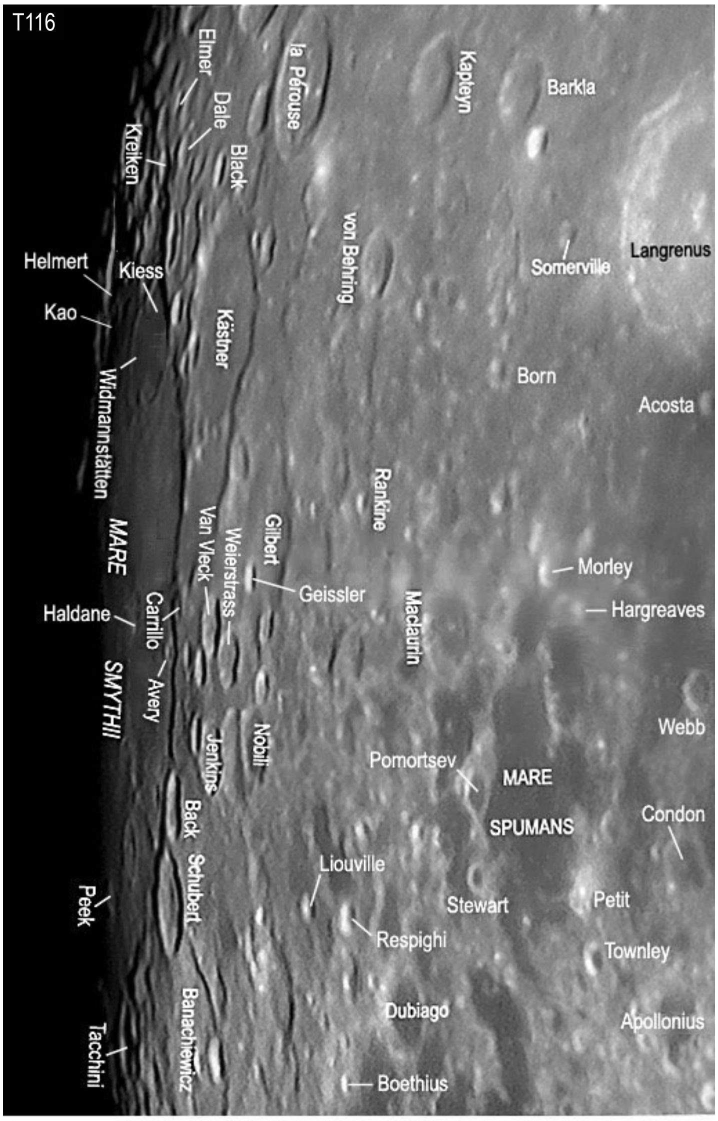


East Limb of the Moon 2001.09.22 11:27 UT Age 5 days. Kenko ED refractor 8cm f/8 + Or18 + Nikon CP990 at 1/8 sec. This day is almost autumnal equinox. It also happened that lunar libration was maximum in longitude (l = +7.8°). *DSCN9724*

The east limb near equator during favorable libration



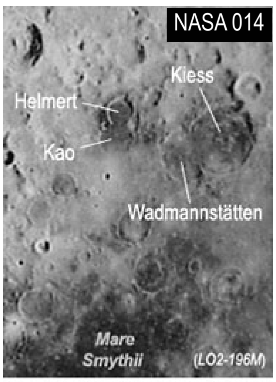
Mare Spumans & Mare Undarum 2004.09.29 ~15:32UT Age 15 days
Libration l = 5.4° b = 1.4° Terminator at 82° E



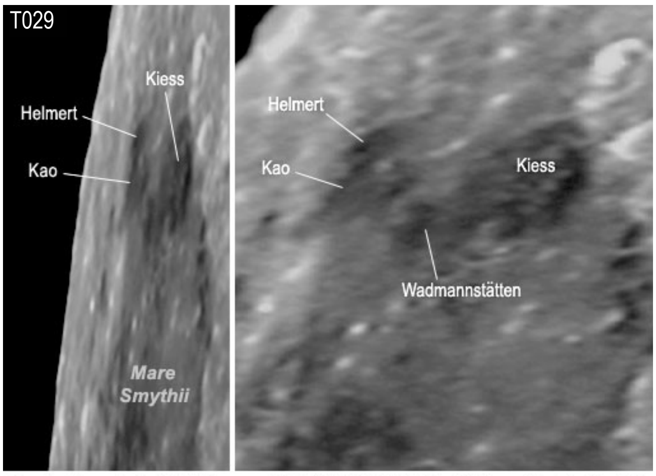
Mare Smythii & Mare Spumans at fairly favorable libration (l = 4.5° b = -1.0°)
2004.10.28 ~14:09 UT Age 15 days. Terminator at 89° E. 10-in f/6 Newtonian + 2.5X +ToUcam

*Craters **Kao** & **Helmert** spotted in telescope but not yet resolved.*

Crater Diameters:
Banachiewicz *(92 km)*
Barkla *(42 km)*
Dubiago *(51 km)*
Firmicus *(56 km)*
Gilbert *(112 km)*
Helmert *(26 km)*
Jenkins *(38 km)*
Kao *(34 km)*
Kapteyn *(49 km)*
Kästner *(108 km)*
Kiess *(63 km)*
la Pérouse *(77 km)*
Maclaurin *(50 km)*
Nobili *(42 km)*
Schubert *(54 km)*
von Behring *(38 km)*
Widmannstätten *(46 km)*

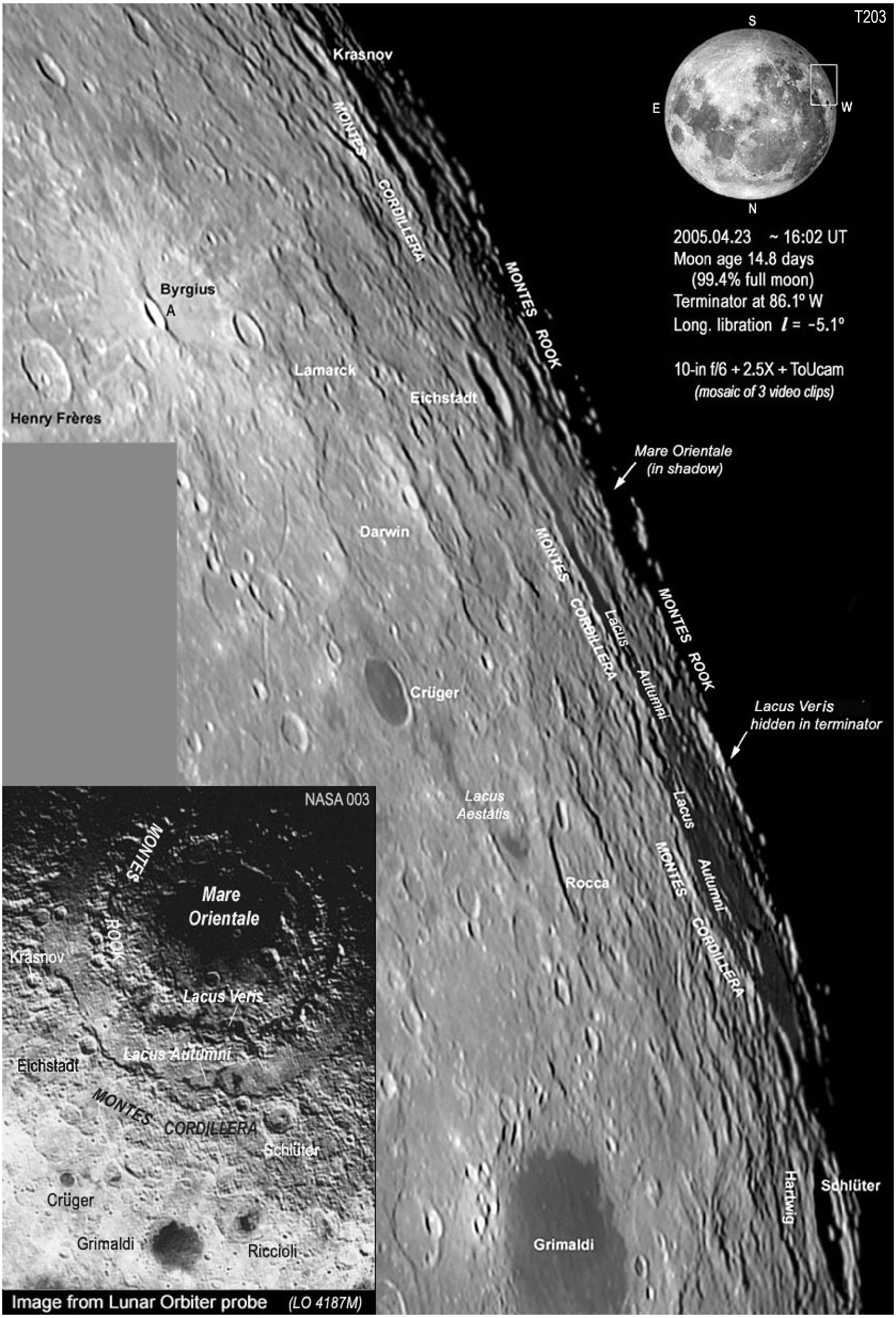


Kao 高平子 (6.7°S 87.6°E, 34 km) & **Helmert** from Lunar Orbiter 2, south-up.

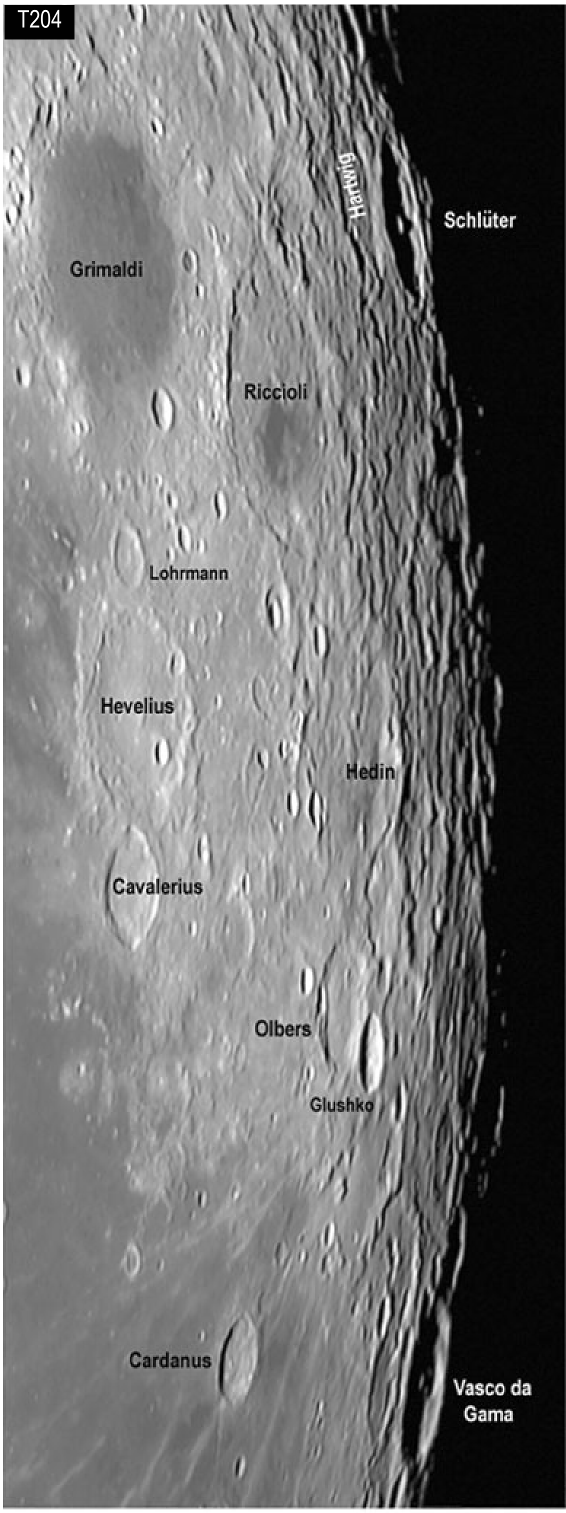


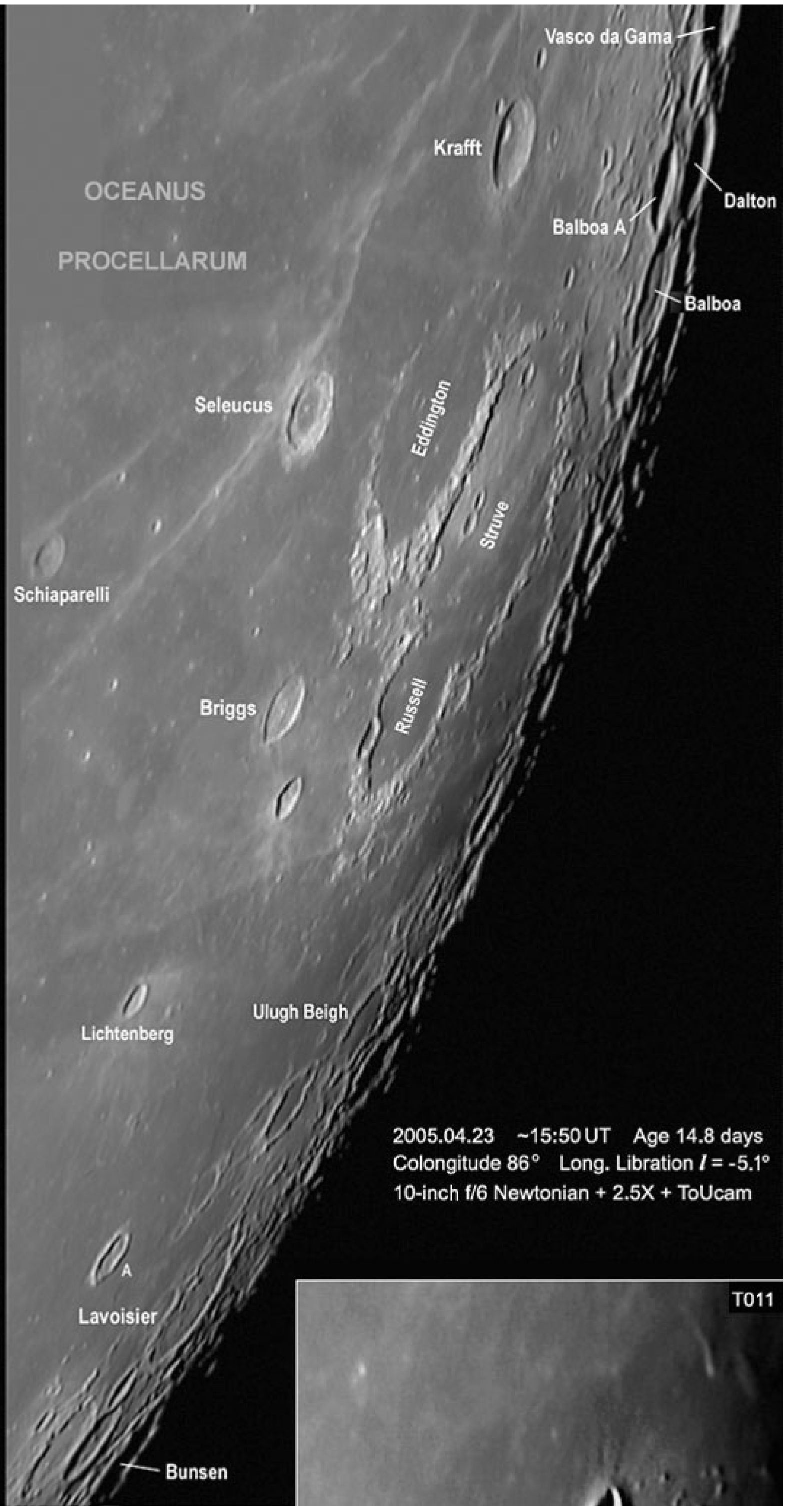
Crater Kao *Left:* Original image 2009.06.30 12:03 UT Age 7.7 days Libration l = 7.1°
10-inch f/6 Newtonian + 2.5X + ToUcam. *Right :* Image with 4X-enlarged horizontal scale.

The west limb during favorable libration (from 31° S to 4° S)



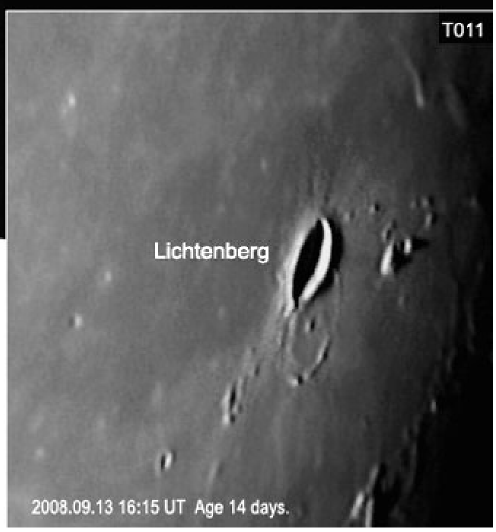
The west limb during favorable libration (from 9^0 S to 42^0 N)





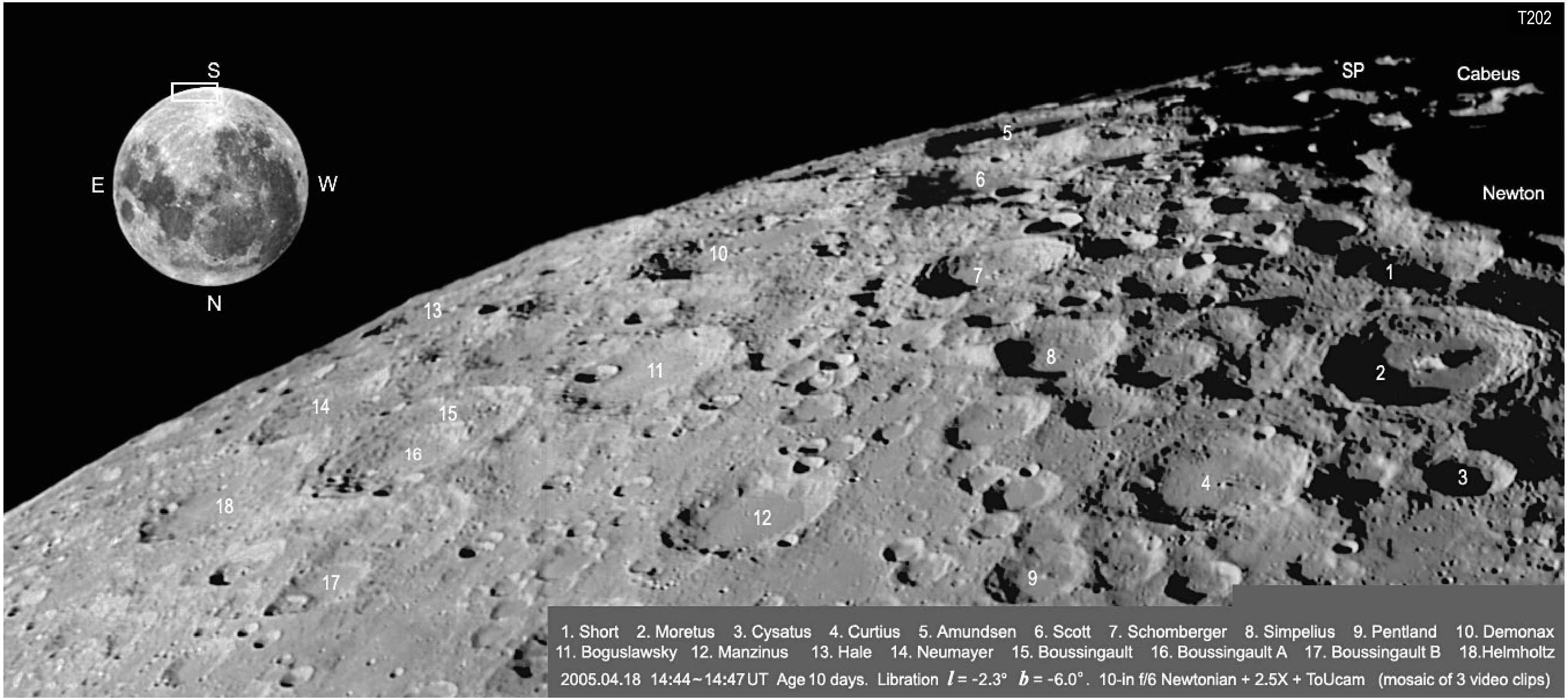
Right Image: With moderate ray emission, Lichtenberg is a fairly young crater formed in the Copernican period (~1 billion years ago), diameter 20 km. It sits on the rim of a ghost crater. The rays extend to the north, south and west, but the rays to the east are hidden anomalously by a darker deposit of mare lava, which is obviously younger than Lichtenberg. This hints that lava eruption might last to the Copernican period, although rock samples from the Apollo indicated lunar volcanism likely ceased 2.5 billion years ago. Some scientists cited an age of 0.9 billion years for the Lichtenberg lava, the youngest in its type.

While the Lichtenberg lava was anomalously young, dating of a lunar meteorite suggested that mare basalt could be as old as 4.35 ± 0.15 billion years.
(Reference: http://www.psrd.hawaii.edu/Dec07/cryptomareSample.html)



South pole and its eastern region during favorable libration

The south pole is marked SP. *Crater Cabeus (diameter 98 km) and Newton (78 km) are hidden in the dark side of the terminator. Amundsen (Label 5, 101 km) located at 84.3^{0}S 85.6^{0}E is not visible usually but it is recognizable in this image. See also the* Farside *map for non-oblique views of these craters.*

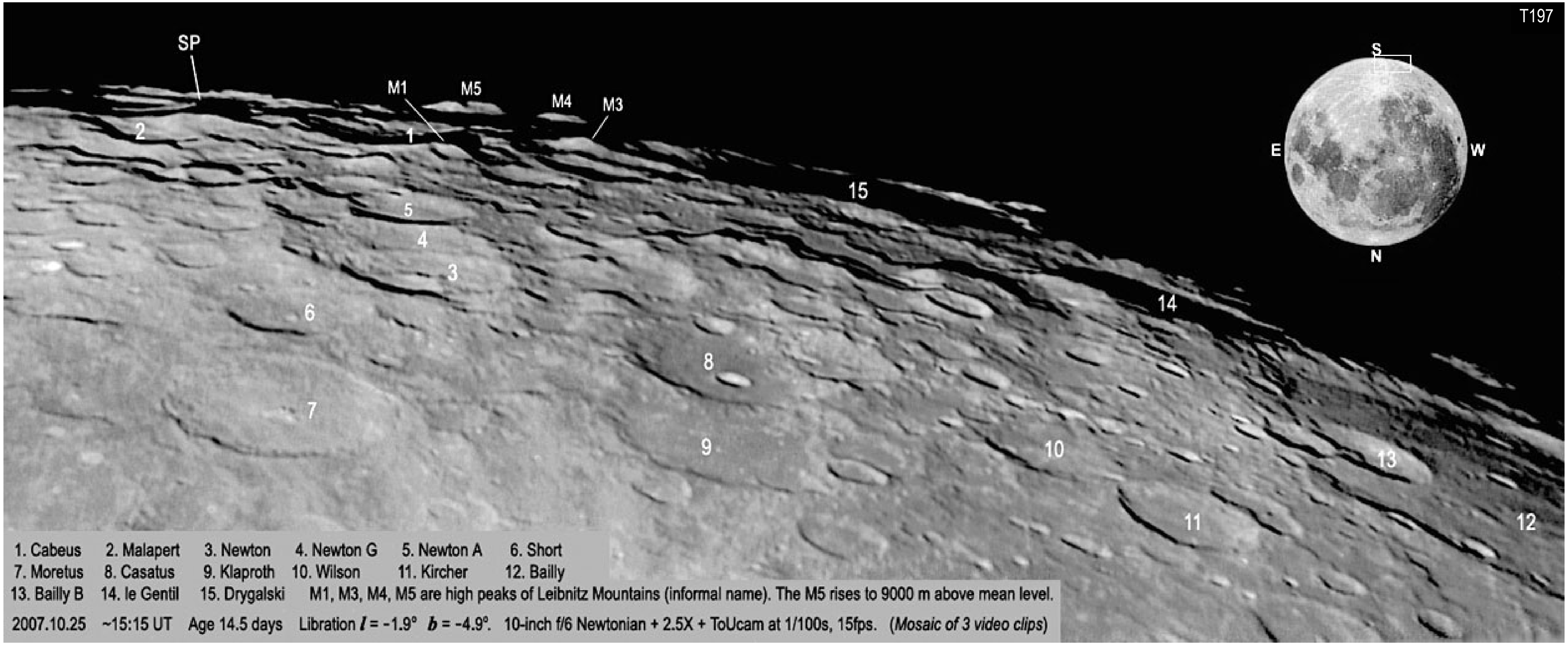


Hatfield 14, 16 Rükl 73, 74, 75

EVENT 1

South pole and its western region during favorable libration

The south pole SP, crater le Gentil and Drygalski (Nos. 14, 15) are heavily shadowed. Newton (No. 3, diameter 78 km) is shown together with satellite craters A and G. M1, M3, M4 and M5 are the high peaks of ***Leibnitz Mountains*** *(informal name). They are actually the peaks on the outer rim of SPA (South Pole-Aitken basin, Farside map). The M5 rises to 9,000 m above mean level; it is the highest surface feature on the entire Moon.*

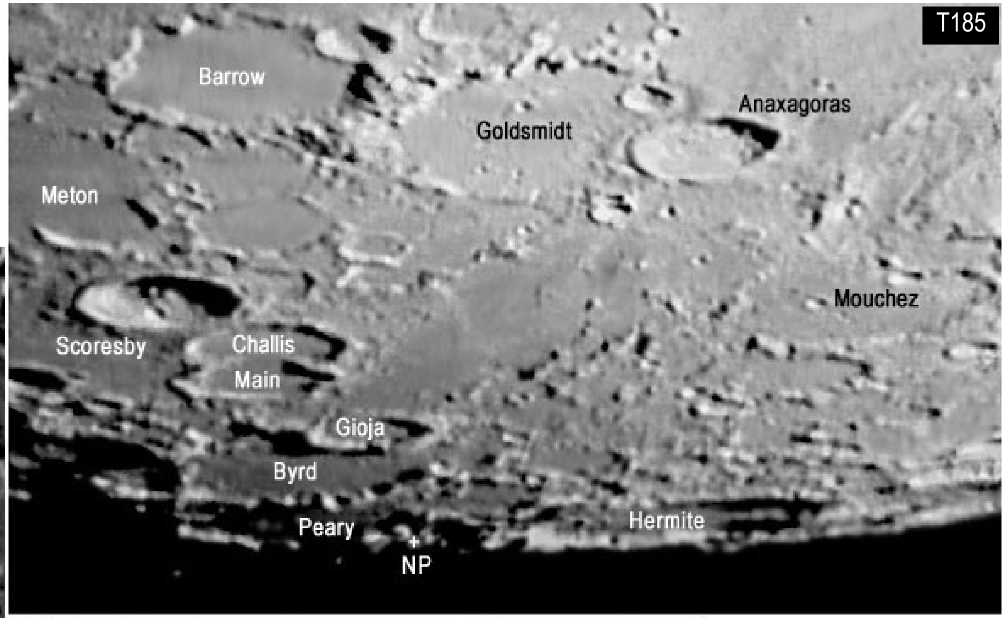


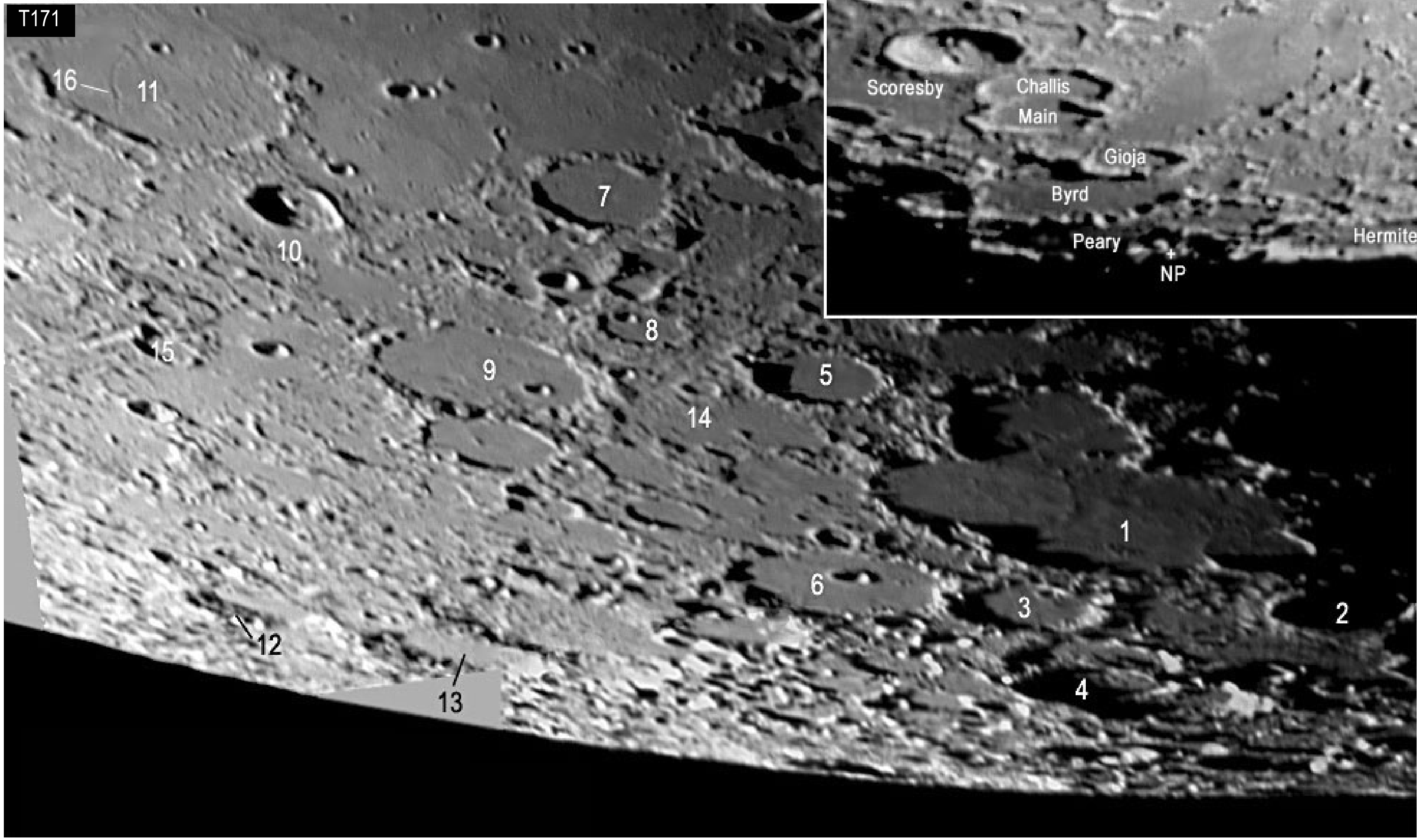
Hatfield 10 Rükl 73, 72, 71

EVENT 1

North pole region during favorable libration

Below: 2004.09.20 11:06 UT Age 6 days. Latitudinal Libration +4.3°
10-inch f/6 Newtonian + 2.5X + ToUcam (mosaic of 2 video clips)
1. Meton 2. Scoresby 3. Euctemon 4. de Sitter 5. Neison 6. Baillaud 7. Kane 8. Moigno 9. Arnold 10. Democritus 11. Gärtner 12. Cusanus 13. Petermann 14. Peters 15. Schwabe 16. Rima Gärtner





Top:
2009.03.14 20:27 UT
Age 18 days (*poor seeing*)
Latitudinal Libration +6.7°
10-in f/6 + 2.5X + ToUcam

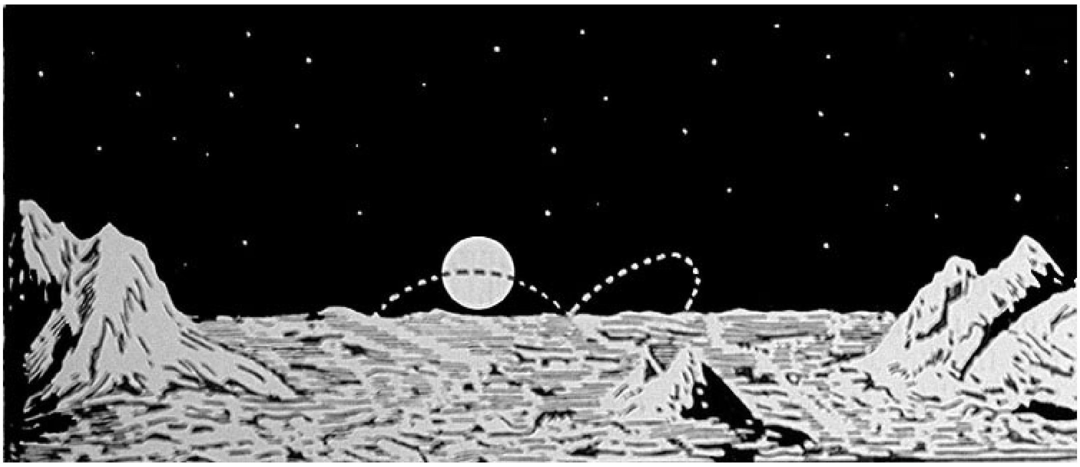
The north pole (NP) lies on the ouer rim of crater Peary. See also ***Map 16***.

Hatfield 2 Rükl 4, 5, 6

EVENT 1

Artist's impression of libration

To an observer at a given place on the nearside of the Moon, the Earth would seem to be almost fixed in the sky. Lunar libration, however, produces an additional peculiar motion of the Earth. Whenever on the Moon the Earth is seen above horizon, it will seem to set and then rise again, as indicated by the broken curves. This peculiar rising or setting of the Earth at the horizon follows the period of libration, which repeats approximately every 27~28 days. (Sketch from Perelman's Astronomy For Entertainment, Moscow, 1958.)

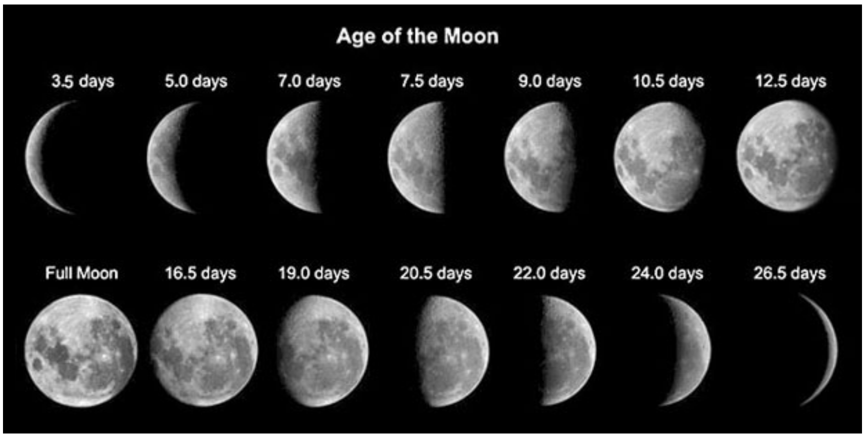


A partially illuminated Earth rises above the lunar horizon

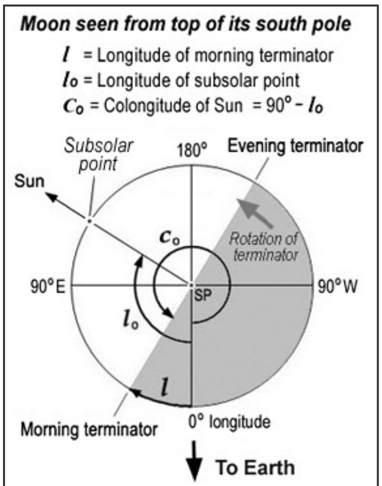
Taken by Apollo 11 crew flying over Mare Smythii, July 20, 1969. Mare Smythii is on the east limb of the Moon's nearside. If the crew landed on Smythii and stayed there long, they would find the Earth wandering very slowly above the horizon, similar to the above sketch.

Terminator

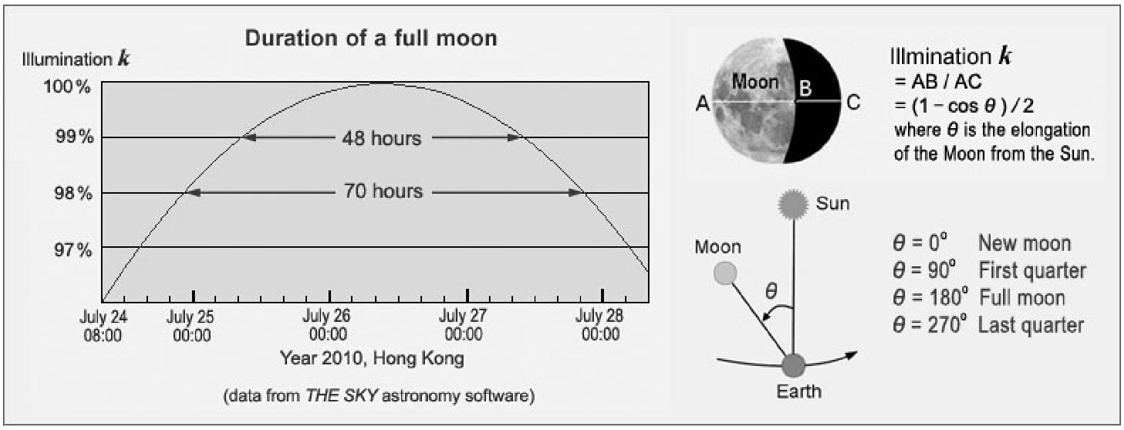
The terminator is the border line between the illuminated and dark portions of the Moon. It is the line of sunrise or sunset. At the morning terminator, the Sun is rising over that part of the Moon; at the evening terminator, the Sun is setting. Precisely the line of sunrise is specified by the Sun's *colongitude*. It is equal to the angular position of the morning terminator measured from the selenographic longitude of 0^0 in the same direction as the advancing terminator. Thus the colongitude is approximately 0^0 at the first quarter, 90^0 at the full moon, 180^0 at the last quarter and 270^0 (= 90^0E) at the new moon. In some ephemerides, colongitude is measured relative to the mean center of the lunar disc, not accounting for any effect of libration. This may cause the observer to notice a deviation between the actual terminator position and the position quoted by the ephemeris. To avoid such ambiguity, this book marks the terminator position simply in terms of the "Age of the Moon" or the fractional "Illumination ***k***", although both parameters are not exact indication of the sunlight angle. See the following illustrations.



Mosaic from various images, south is up and east is left. The top row (before full moon) gives the morning terminator; the bottom row (after full moon) gives the evening terminator. Note that Moon age less than 2 days or greater than 27 days is very difficult to trace due to close proximity to the Sun. Practically the Moon crescent is not visible if it is less than 7^0 from the Sun.



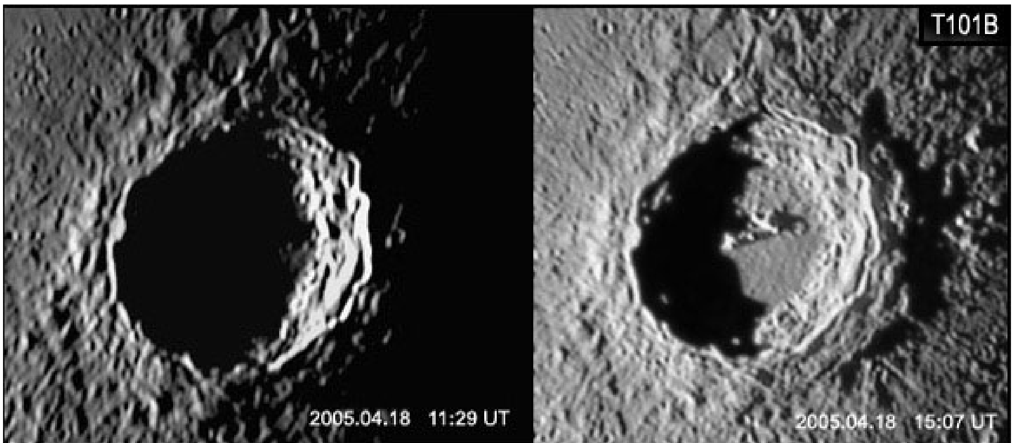
Viewing from top of the lunar south pole, the terminator always rotates anticlockwise at 29.27 ~29.83 days per revolution. The average period is 29.53 days, generally known as the Synodic Month.



The daily shift of terminator along the Moon's equator is slow at days close to the full moon. This is illustrated by astronomy software in the above diagram. There is no visible terminator at exact full moon (***k*** = 100 %), and the Moon remains "pretty full" (***k*** > 98 %) in 70 hours.

The movement of terminator is detectable in telescopes. One observation through a 4-inch refractor at low power indicates that the movement is barely distinguishable in interval as short as 10 minutes (Image T040B). When the terminator is crossing Copernicus, its movement can even be detected in a couple of minutes under high power (T101B).

The lunar terminator has moved very slightly in duration as short as 10 min. FS102+K25+CP950 at 1/322s



Two views of Copernicus on the lunar terminator, separated by 3.5 hours (11:29 to 15:07 UT)

The lunar terminator produces many intriguing but momentary views. Some examples are

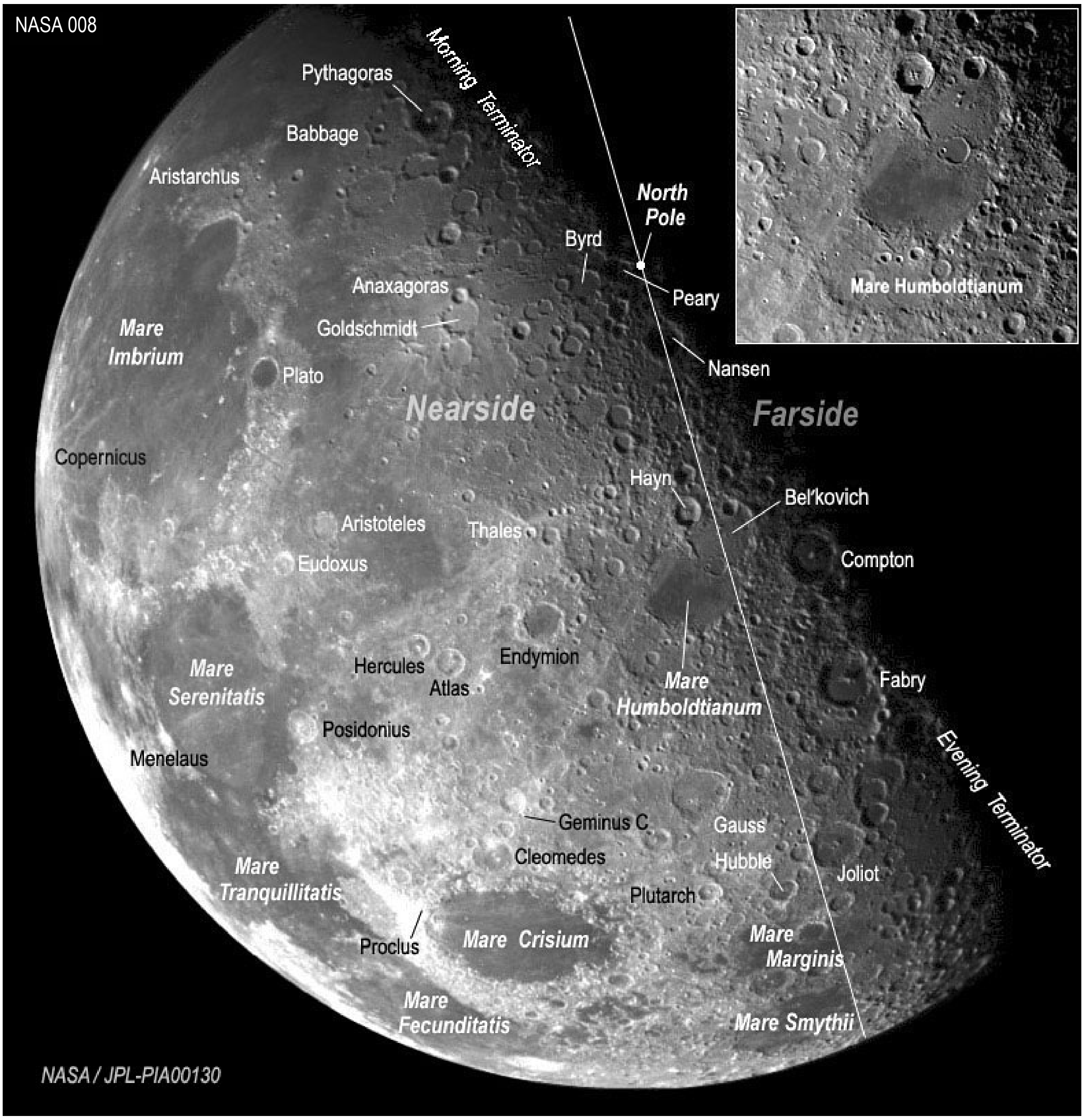
Map 5	The tortoise-shaped shadow on the floor of Cyrillus F, Moon age ~ 19 days.
Map 9	The snaky Serpentine Ridge intersected by Rimae Plinius, Moon age ~20 days.
Map 15	Valentine Dome with surface sculpture.
Map 18	The edge of Sinus Iridum (Montes Jura) that brightens up like a “golden handle” of a teapot.
Map 20	The Maestlin region that resembles an “ET” (Extraterrestrial) face.
Map 27	The triangular shadow cast by Sirsalis Z.

EVENT 2

Terminator seen by Galileo spacecraft as it flew by the Moon

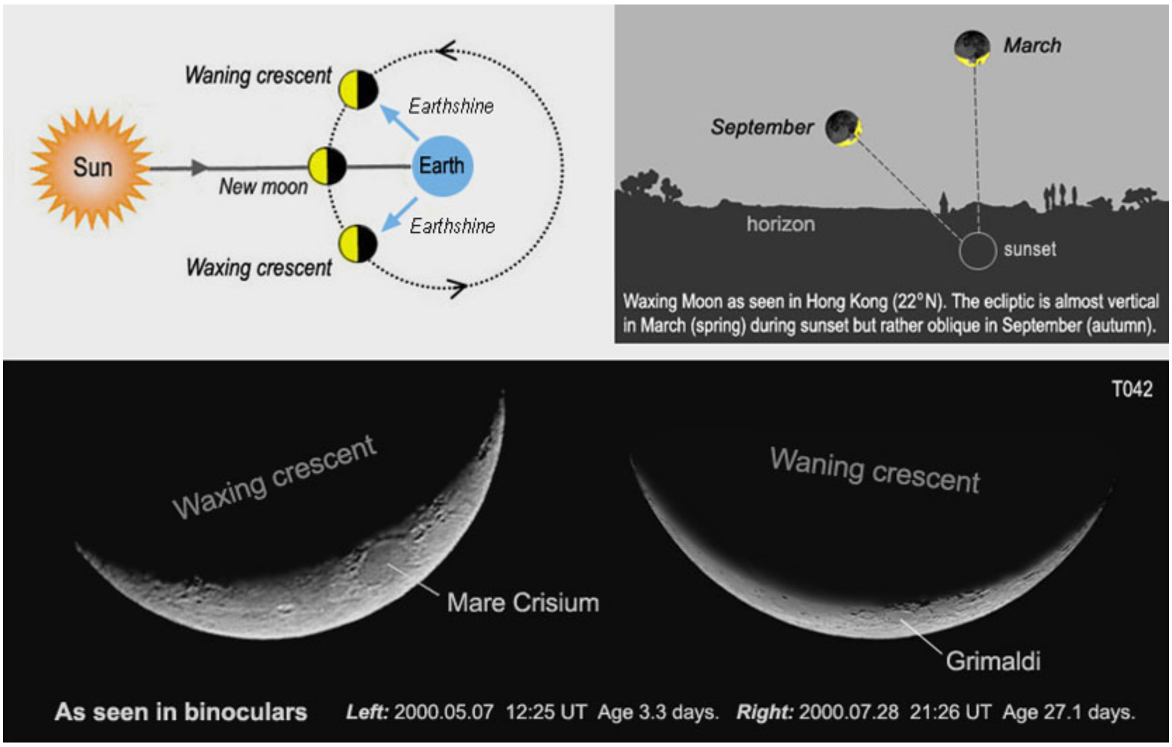
Below is a mosaic of 18 images from the spacecraft's camera through a green filter on 1992.12.07, when the Moon was 94% full and with the illuminated portion approximately facing the Earth. The lunar north pole is on the outer rim of crater ***Peary****. This crater is 73 km in diameter and lies just inside the shadow zone next to* ***Byrd****. To a terrestrial observer,* ***Mare Humboldtianum*** *is a difficult object on the northeast limb of the Moon but here it is seen clearly with two concentric mountain rings. Note the bright ray stretching from Geminus C to the floor of Mare Humboldtianum. The shapes of Mare Tranquillitatis, Mare Fecunditatis and Mare Crisium also change dramatically from their usual impressions.*

The straight line through the north pole separates the nearside from the farside of the Moon. The morning terminator rotates clockwise in time. It indicates the Sun is rising over that part of region. At the evening terminator, the Sun is setting. Because the Moon has no atmosphere, there is no Earth-like twilight. The day and night transition over a lunar place occurs quite instantly. During daytime (which lasts about 2 weeks by Earth calendar), the surface temperature at the equatorial zone can reach 130^{0}C maximum. During nighttime (which also lasts about 2 weeks), it falls to -180^{0}C or even lower at the polar regions. The temperature at depth of 1 m under surface, however, is relatively constant, around -35^{0}C. This suggests that the lunar regolith is a good thermal insulator.



Crescent

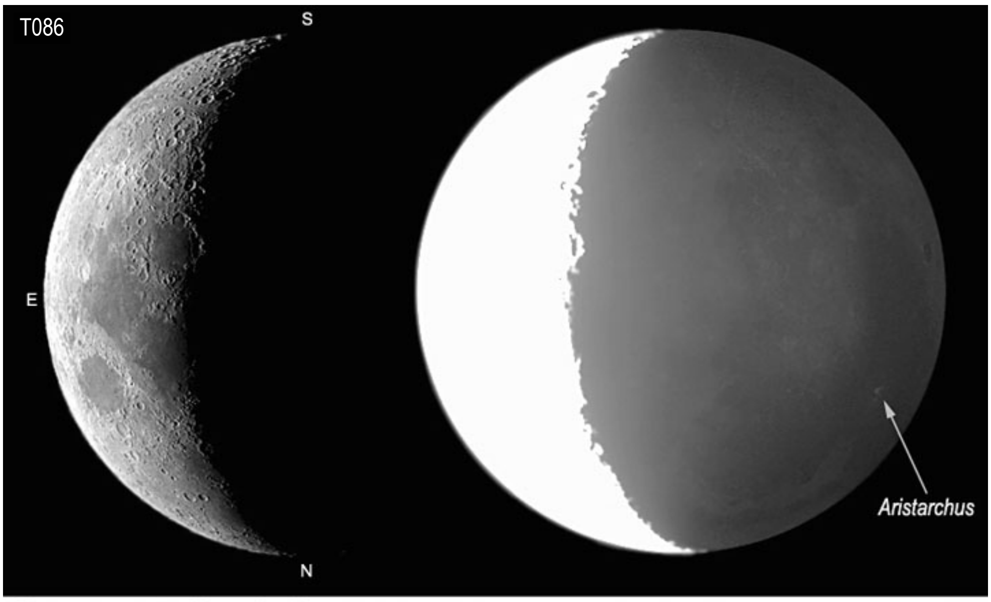
When the Moon is a crescent, its sky position is not far away from the Sun. The ***Waxing Crescent*** indicates that the Moon phase is increasing; it always sinks low in the western sky after sunset. The ***Waning Crescent*** indicates that the Moon phase is decreasing; typically it rises few hours before daybreak.



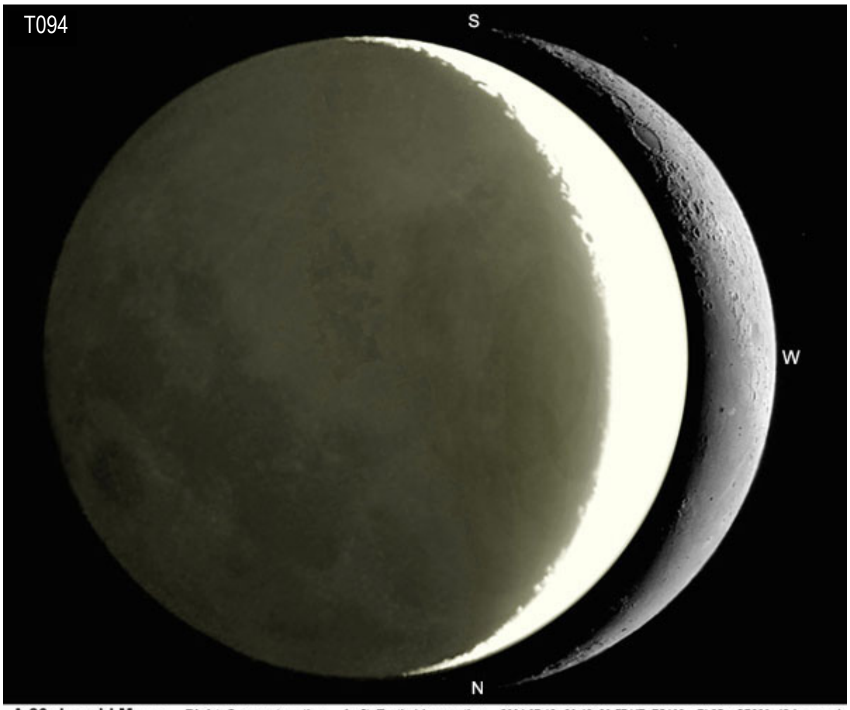
Waxing Moon as seen in Hong Kong (22°N). The ecliptic is almost vertical in March (spring) during sunset but rather oblique in September (autumn).

As seen in binoculars *Left:* 2000.05.07 12:25 UT Age 3.3 days. *Right:* 2000.07.28 21:26 UT Age 27.1 days.

Thin crescents often appear with ***Earthshine***, as shown in T086 and T094. Earthshine refers to a faint illumination of the dark portion of the crescent, caused by sunlight reflected from the Earth. Surface features in a photograph of thin crescent (e.g. T095) are likely lack of contrast, because the light reflection of Earth illuminates on the crescent as well.



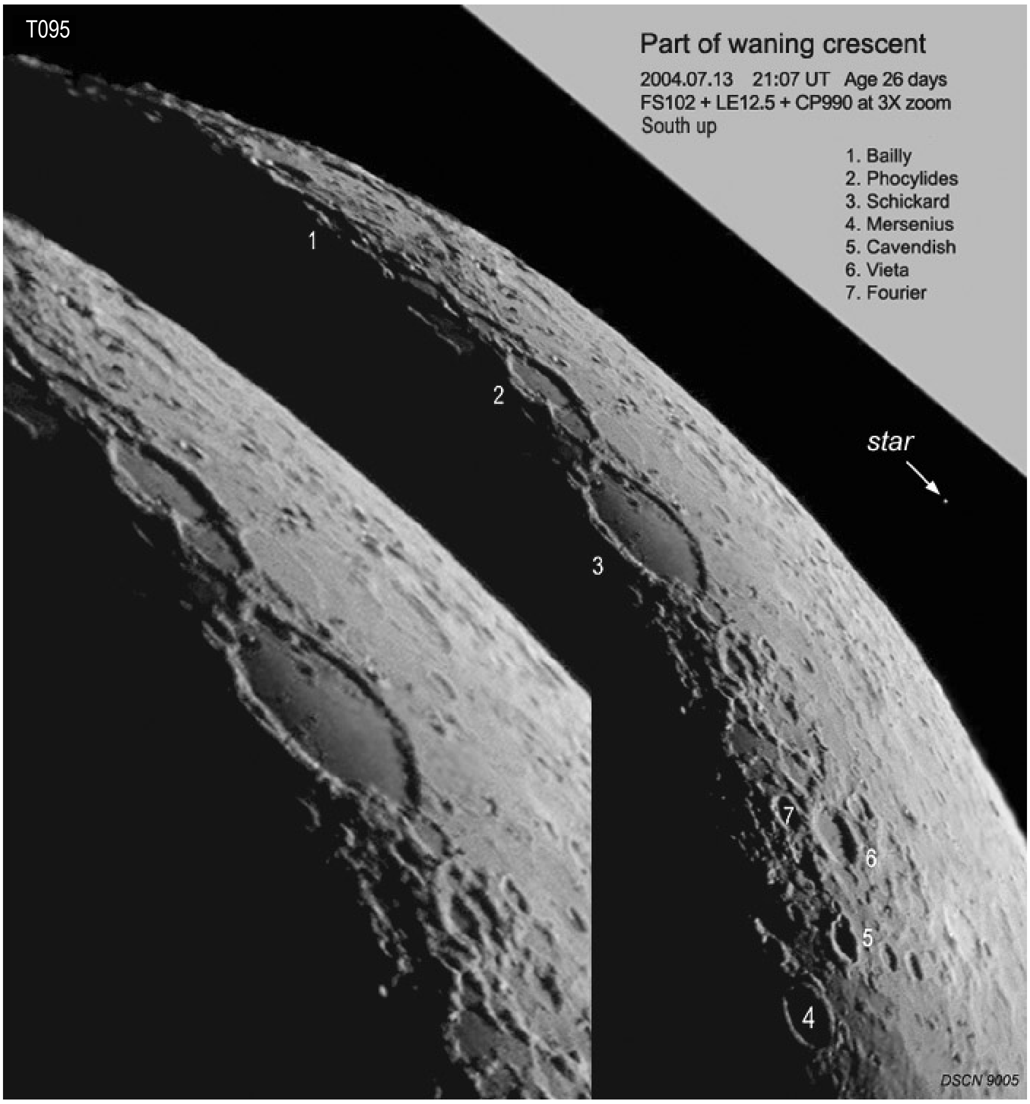
Moon crescent with earthshine 2002.08.13 ~12:00 UT Age 4 days. FS102 + Or 25 + CP990. The right image is deliberately overexposed to show the earthshine. Note that Aristarchus, a truly bright crater near the west limb, is visible even in earthshine.



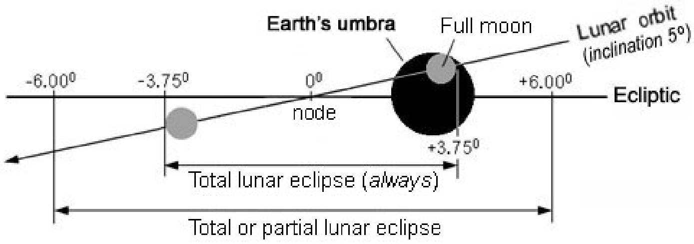
A 26-day old Moon **Right:** Crescent portion **Left:** Earthshine portion 2004.07.13 20:42~20:57 UT. FS102 + PL25 + CP990 (2 images)

Waning Crescent with Earthshine

(Taken on 2004.07.13 when it was 27 degrees above horizon)

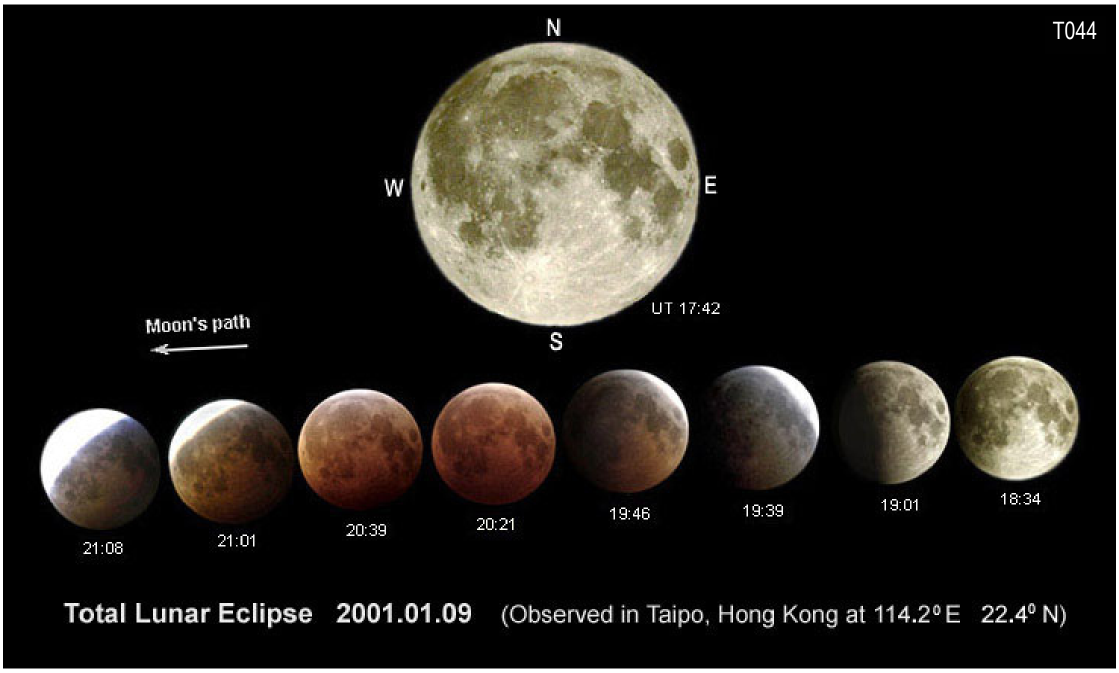


Eclipse



The condition for total lunar eclipse is shown at right. Whenever the full moon comes within 3.75^0 on either side of the node of orbits, it must be completely shadowed by the Earth's umbra. A total lunar eclipse will be seen on Earth. Lunar and solar eclipses are also related to the **Saros**, a period of 223 lunations (6585.32 days or 18.03 years) which was known in ancient Babylonian times. After one Saros, the Sun, Earth, Moon and nodes of the orbits return to almost the same alignment; hence a lunar or solar eclipse with passage (duration and obscured portion) resembling its predecessor will recur.

The total lunar eclipse on 2001.01.09 is shown in T044. It represents the view in binoculars at different intervals. The color and brightness of the Moon did not change much in the Earth's penumbra (18:34 UT). As the Moon entered the Earth's umbra, its color changed gradually and dimmed to dull red at eclipse maximum (20:21 UT). The brightness drop during total eclipse was about 1 **:** 10000, as plotted in next page. It also happened that Delta Geminorum, a 3.5-magnitude star, was almost occulted by the Moon in this event. See T044A.

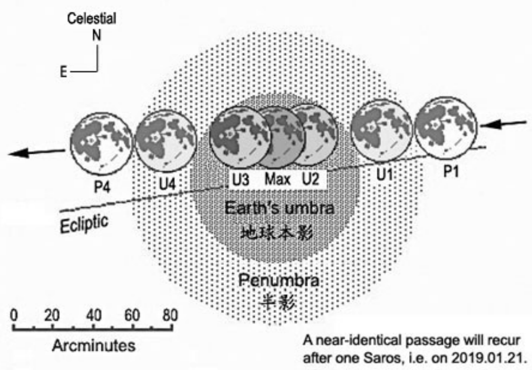


Passage of the Moon through the Earth's shadows *2001.01.09*

Stage of Lunar Eclipse		2001.01.09 (UT)	Moon's Altitude
P1	食始	17:43	71^0
U1	初虧	18:42	58^0
U2	食既	19:50	43^0
Max	食甚	20:21	36^0
U3	生光	20:52	29^0
U4	復圓	21:59	15^0
P4	食終	22:58	3^0

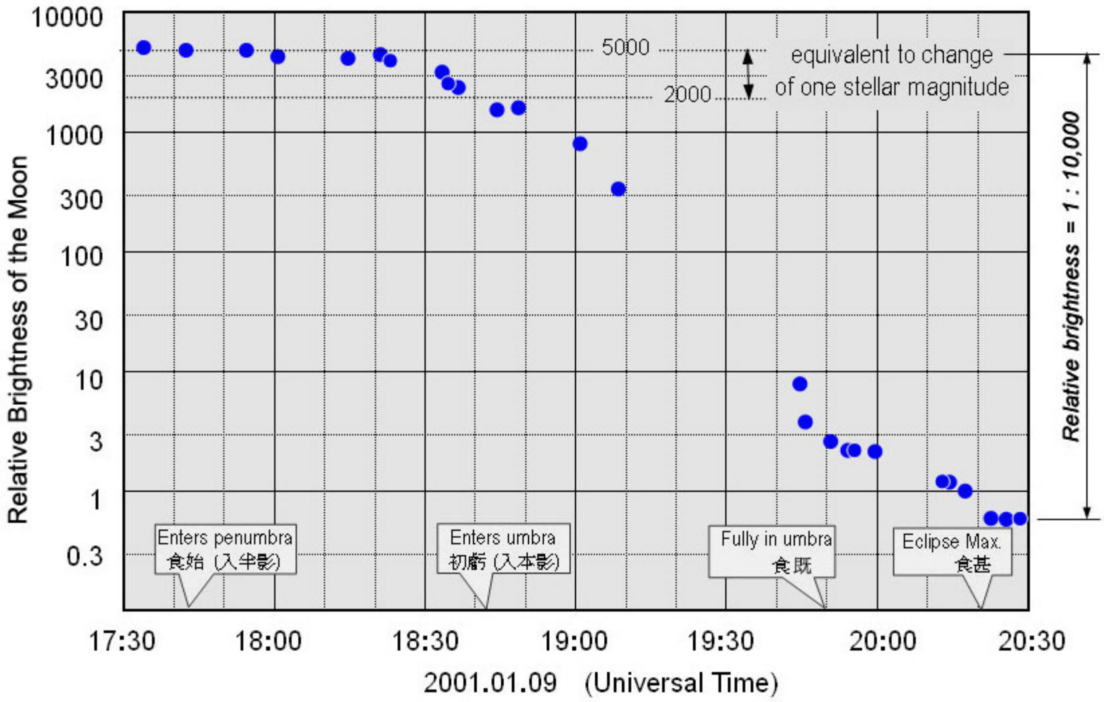
P1 - Lunar eclipse begins with the west limb of the Moon entering the Earth's penumbra.

Duration of Moon in Earth's umbra = 62 min.



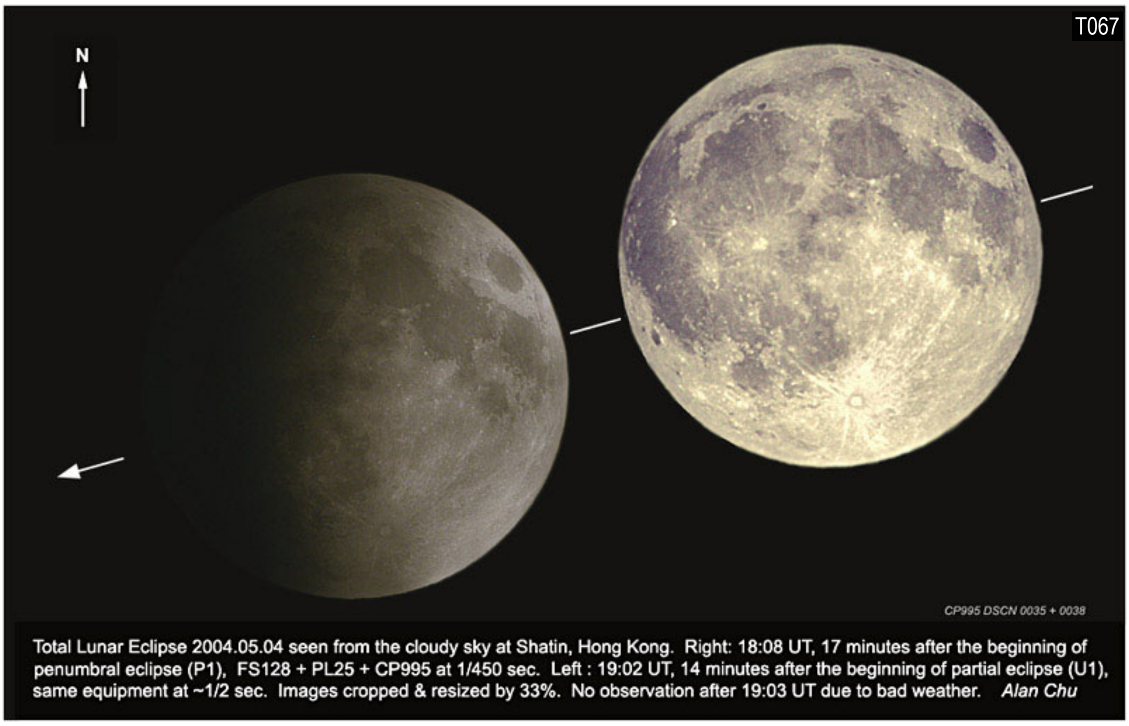
Brightness of the eclipsed Moon, 2001.01.09

The relative brightness is deduced by comparing the exposure readings of different images captured by Casio QV2300 digital camera during the eclipse. For example, at fixed magnification and ISO sensitivity, a non-manual exposure of f/5.6 1/20 sec means the image is 40 times brighter than f/2.8 1/2 sec.



The eclipsed Moon and Delta Geminorum (3.5-magnitude star) in near-occultation on 2001.01.09 19:45 UT. The closest separation is 0.9 arcmin between the star and the Moon's west limb. Observed in Hong Kong.

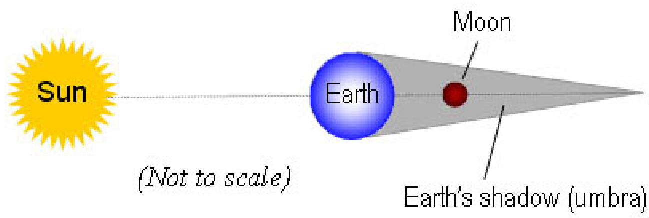
T067 was taken in another total lunar eclipse, occurred on 2004.05.04 and observed in Hong Kong. When the eclipse began, the sky was overcast for rain. Only this picture is available in the full course of the event. Note that lunar eclipse always begins with the west limb of the Moon.



Total Lunar Eclipse 2004.05.04 seen from the cloudy sky at Shatin, Hong Kong. Right: 18:08 UT, 17 minutes after the beginning of penumbral eclipse (P1), FS128 + PL25 + CP995 at 1/450 sec. Left : 19:02 UT, 14 minutes after the beginning of partial eclipse (U1), same equipment at ~1/2 sec. Images cropped & resized by 33%. No observation after 19:03 UT due to bad weather. *Alan Chu*

Lunar and solar eclipses at the same time

Credit: **David A. Hardly** *http://www.astroart.org*

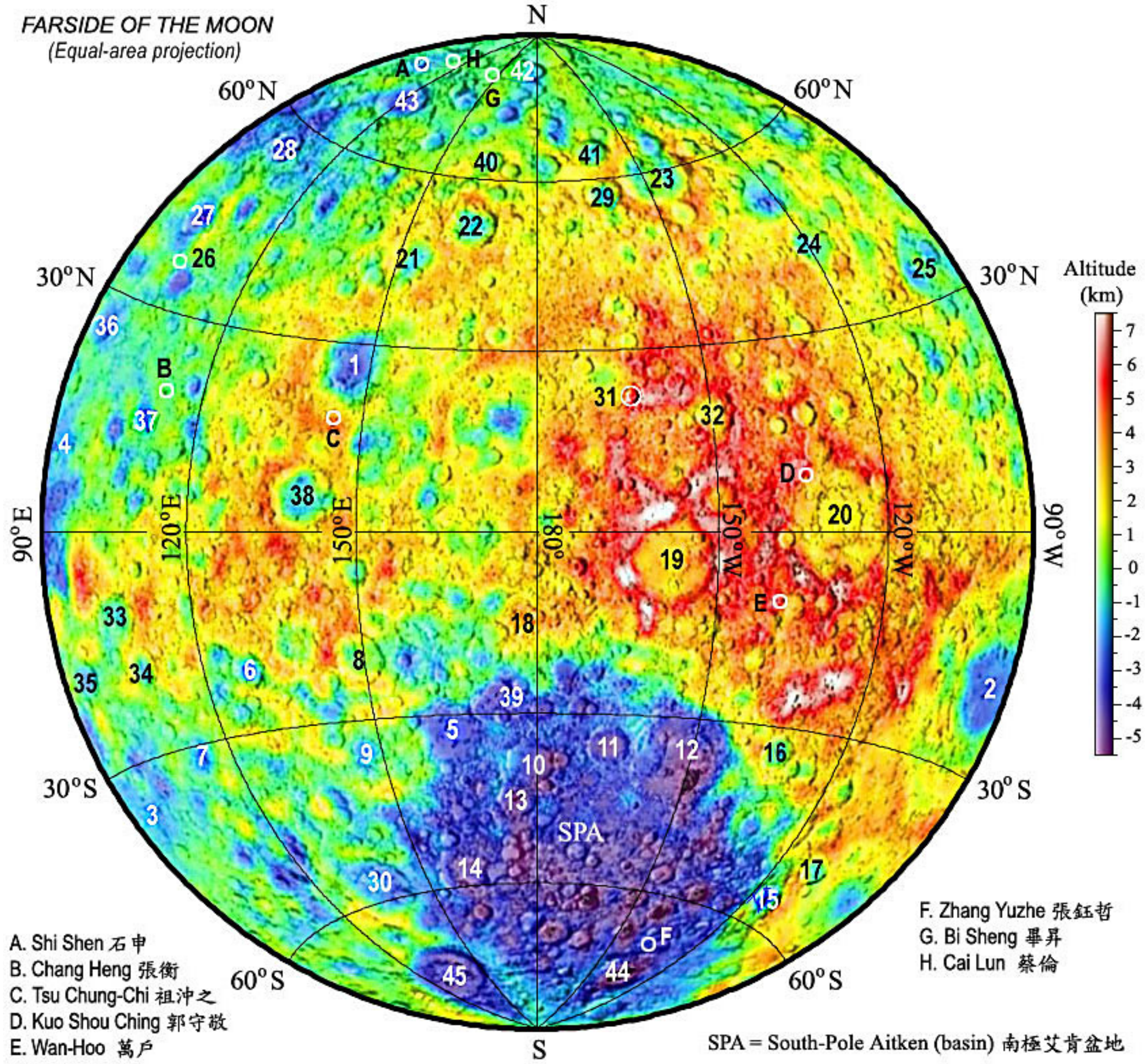


Above: *While watchers on the Earth see a lunar eclipse, watchers on the Moon could experience a solar eclipse as well. As the Moon passes through the umbra (darkest portion) of the Earth's shadow, the total solar eclipse seen from the Moon can last up to 1.7 hours, much longer than the duration of any solar eclipse seen from the Earth.*

Left: *A space painting which depicts an eclipse of the Sun by Earth as seen from the Moon. From here the Earth looks four times larger than the solar disc; hence the corona (extremely hot ionized gas surrounding the Sun) would not be seen. The Earth's atmosphere forms a "ring of fire" as sunlight is refracted by it, giving a typical coppery tint. The bright red glow at the ring bottom is caused by "sunset" (diamond ring) effect. The Moon also turns red by the illumination of the Earth's atmosphere.*

(This explains why the eclipsed Moon in T044A looks red.)

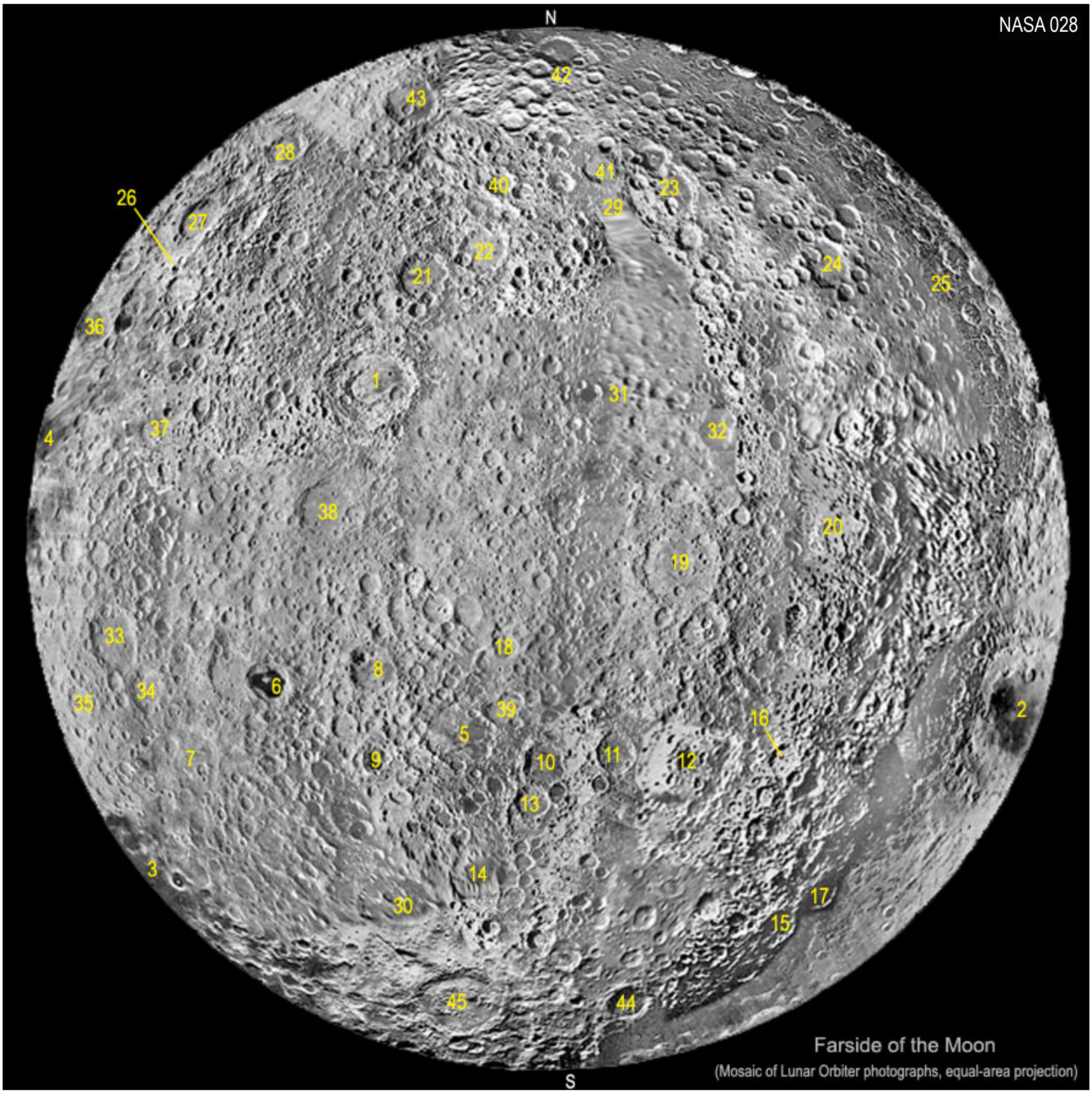
3. Farside of the Moon

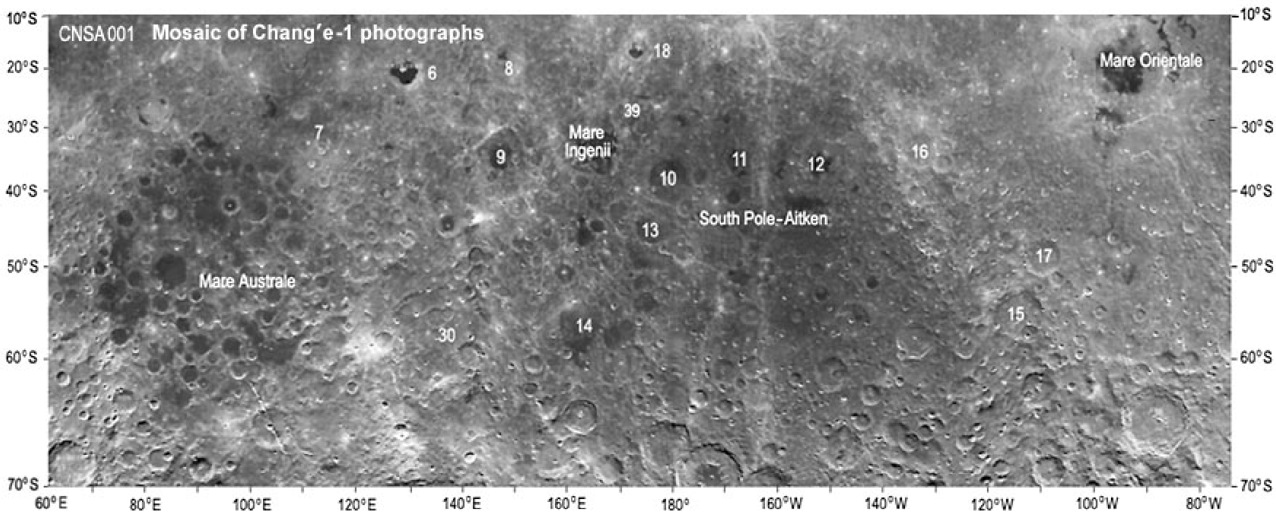


	Feature Name	Lat. (deg.)	Long. (deg.)	Dia. (km)		Feature Name	Lat. (deg.)	Long. (deg.)	Dia. (km)
1	Mare Moscoviense	27.3 N	147.9 E	277	23	Birkhoff 伯克霍夫	58.7 N	146.1 W	345
	(Moscow Sea) 莫斯科海				24	Landau 蘭道	41.6 N	118.1 W	214
2	Mare Orientale (*Eastern Sea*) 東海	19.4 S	92.8 W	327	25	Lorentz 勞蘭斯 (勞倫斯)	32.6 N	95.3 W	312
3	Mare Australe (*Southern Sea*) 南海	38.9 S	93.0 E	603	26	Giordano Bruno 左丹奴布魯諾	35.9 N	102.8 E	22*
4	Mare Marginis (*Border Sea*) 界海	13.3 N	86.1 E	420	27	Fabry 法布里	42.9 N	100.7 E	184
5	Mare Ingenii (*Sea of Ingenuity*) 智海	33.7 S	163.5 E	318	28	Compton 康普頓	55.3 N	103.8 E	162
6	Tsiolkovskiy 齊奧爾科夫斯基	21.2 S	128.9 E	185	29	Rowland 勞蘭德	57.4 N	162.5 W	171
7	Milne 米爾恩	31.4 S	112.2 E	272	30	Planck 普朗克	57.9 S	136.8 E	314
8	Gagarin 加加林	20.2 S	149.2 E	265	31	Jackson 杰克遜	22.4 N	163.1 W	71*
9	Jules Verne 朱爾斯・維恩	35.0 S	147.0 E	143	32	Mach 馬赫	18.5 N	149.3 W	180
10	Leibnitz 萊布尼茲	38.3 S	179.2 E	245	33	Pasteur 巴士德	11.9 S	104.6 E	224
11	Oppenheimer 奧本海默	35.2 S	166.3 W	208	34	Hilbert 希爾伯特	17.9 S	108.2 E	151
12	Apollo 阿波羅	36.1 S	151.8 W	537	35	Sklodowska 居里夫人	18.2 S	95.5 E	127
13	Von Kármán 卡曼	44.8 S	175.9 E	180	36	Joliot 約里奧	25.8 N	93.1 E	164
14	Poincaré 龐加萊	56.7 S	163.6 E	319	37	Fleming 費萊明	15.0 N	109.6 E	106
15	Lippmann 李普曼	56.0 S	114.9 W	160	38	Mendeleev 門德列夫	5.7 N	140.9 E	313
16	Chebyshev 車比雪夫	33.7 S	133.1 W	178	39	Van de Graaff 范德格拉夫	27.4 S	172.2 E	233
17	Mendel 門德爾	48.8 S	109.4 W	138	40	Avogadro 亞佛加德羅	63.1 N	164.9 E	139
18	Aitken 艾肯	16.8 S	173.4 E	135	41	Sommerfeld 薩默菲爾德	65.2 N	162.4 W	169
19	Korolev 科羅列夫	4.0 S	157.4 W	437	42	Plaskett 普拉斯基特	82.1 N	174.3 E	109
20	Hertzsprung 赫茨普隆	2.6 N	129.2 W	591	43	Schwarzschild 史瓦西	70.1 N	121.2 E	212
21	Campbell 坎貝爾	45.3 N	151.4 E	219	44	Zeeman 塞曼	75.2 S	133.6 W	190
22	D' Alembert 阿蘭伯特	50.8 N	163.9 E	248	45	Schrödinger 施羅丁格爾	75.0 S	132.4 E	312

* *rayed crater*

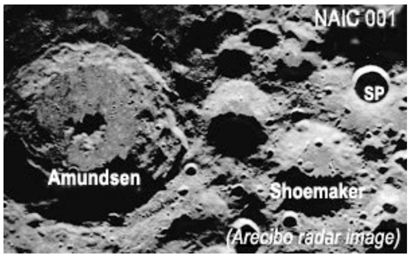
Farside of the Moon *(Features labeled as last page)*



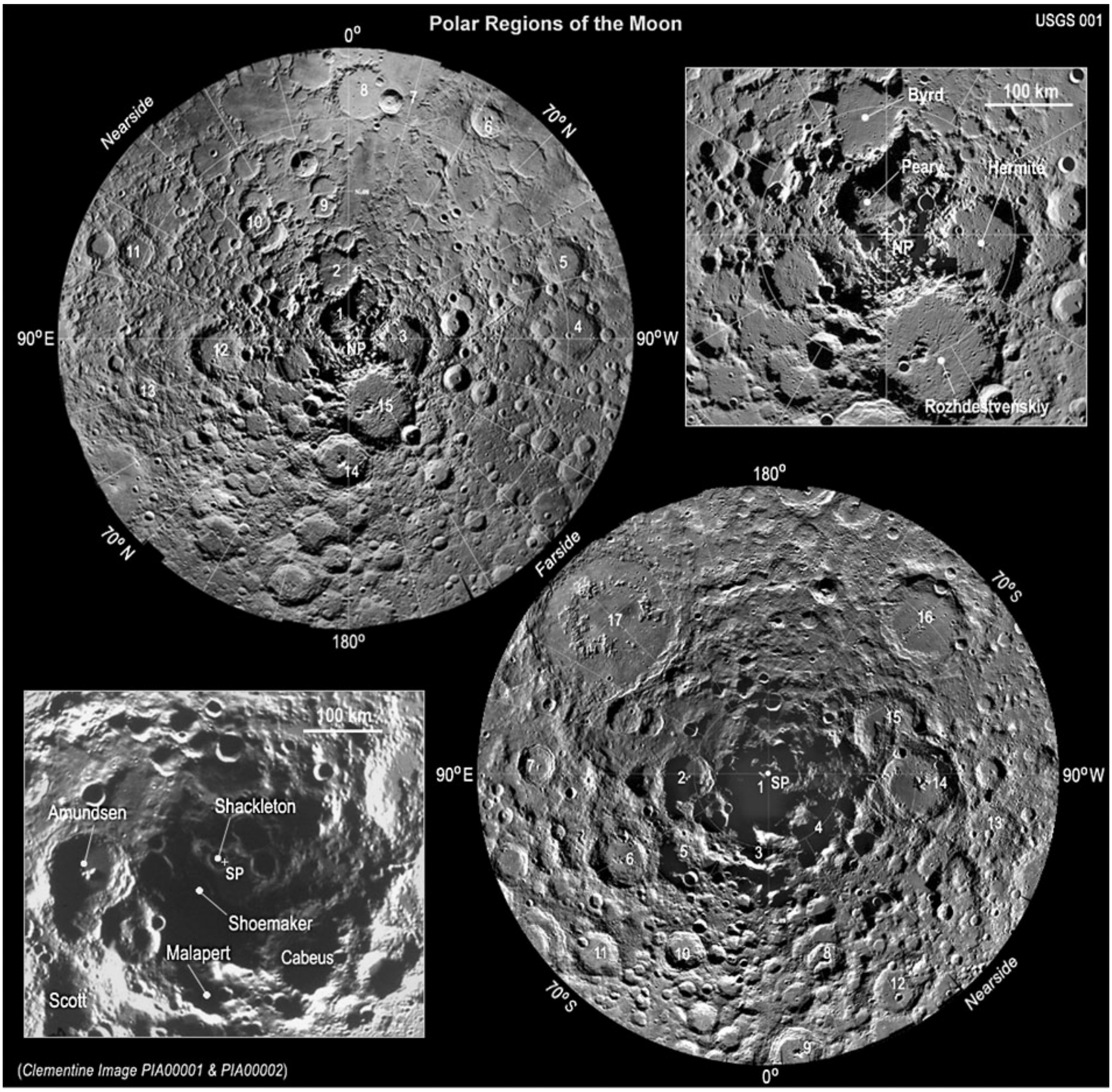


The farside ranges from 90^0E to 90^0W via the 180^0 longitude. It was first photographed by the Soviet Luna 3 probe in 1959. Compared to the nearside, the farside is full of craters and basins, has few smaller maria and mascons.

The north pole lies on the outer rim of crater ***Peary***, details in Map 16. *The south pole is inside* ***Shackleton****, a 19-km crater on a heavily shadowed depression and is so deep that sunlight probably never reaches the bottom. The cold interior of this depression has been thought to trap water-ice shed by comet impacts. Next to Shackleton is* ***Shoemaker****, a 51-km crater where the* ***Lunar Prospector*** *probe ended its mission by impact in 1999. The crater is named after the planet geologist Eugene Shoemaker (1928-1997). He discovered the fragmented comet SL-9 with his amateur colleague David Levy. SL-9 collided on Jupiter during July 16 - 22, 1994.*



The ***South Pole-Aitken*** *(SPA) is an impact basin, diameter 2300 km and depth 12 km, so named for its location between the lunar south pole and crater Aitken. It appears darker and contains more iron and titanium than the highlands. The crust under SPA is not supposed thick (~30 km), yet there are abnormally few maria in the basin. Some scientists hypothesized that the SPA was not caused by a typical impact, but may instead have been formed by a low-velocity projectile that hit at a low angle (30^0 less), and hence did not dig deeply into the Moon. Such an oblique impact would have provided a source of "secondary" projectiles to make other lunar basins and craters. The outer rim of SPA can be glimpsed from Earth as "Leibnitz Mountains", see Image T197 in* Event 1 *pages.*



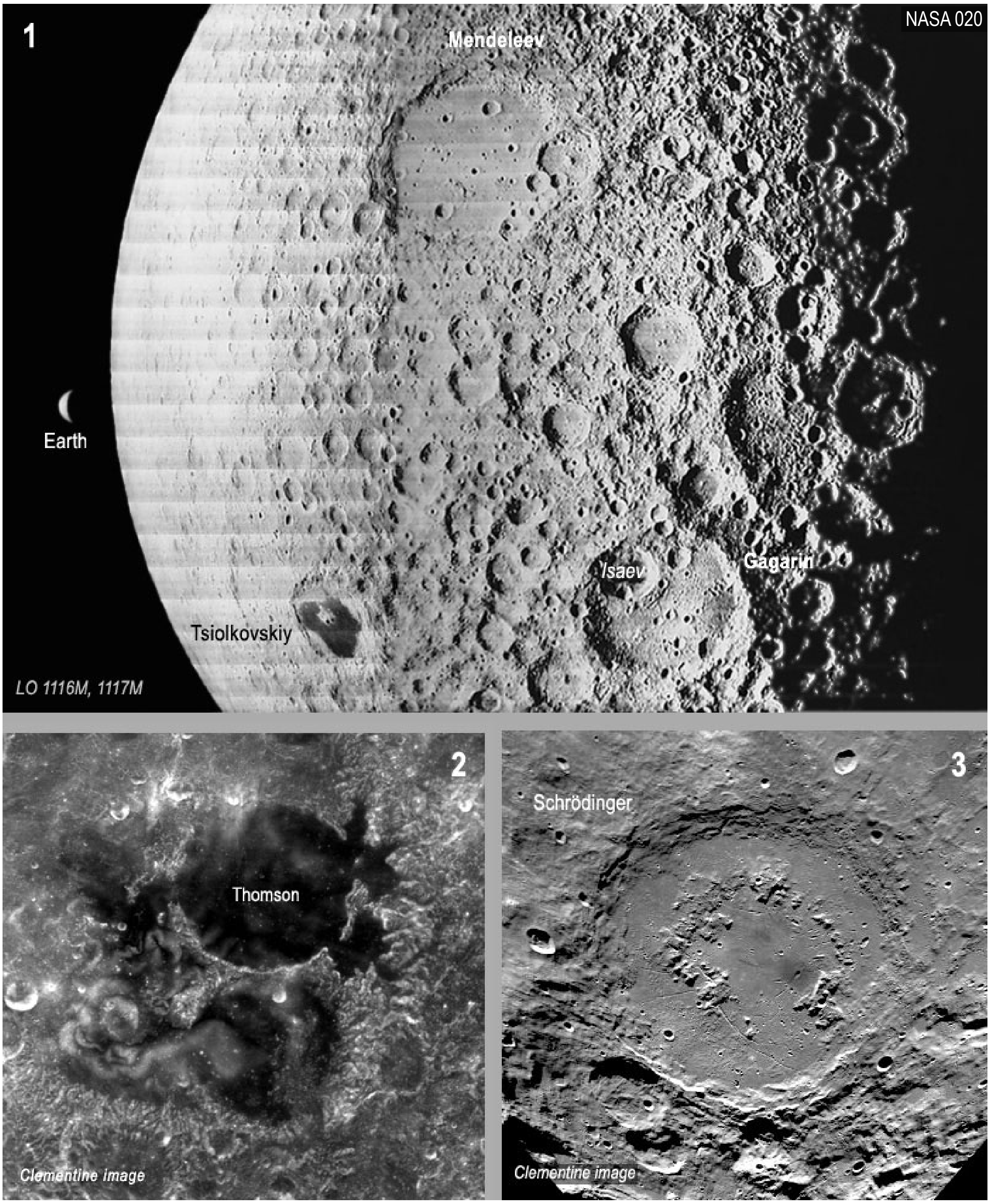
NP Region: 1. Peary 2. Byrd 3. Hermite 4. Brianchon 5. Pascal 6. Philolaus 7. Anaxagoras 8. Goldschmidt 9. Main 10. de Sitter 11. Petermann 12. Nansen 13. Shi Shen 14. Plaskett 15. Rozhdestvenskiy ***SP Region:*** 1. Shackleton 2. Amundsen 3. Malapert 4. Cabeus 5. Scott 6. Demonax 7. Hale 8. Newton 9. Moretus 10. Schomberger 11. Boguslawsky 12. Casatus 13. le Gentil 14. Drygalski 15. Ashbrook 16. Zeeman 17. Schrödinger

Features on the farside of the Moon

1. The western region: The Earth is in crescent. ***Mendeleev*** *is a large walled plain, diameter 313 km.* ***Tsiolkovskiy*** *is a prominent feature that appears partially crater and partially mare, diameter 185 km. The crater itself is fairly circular, but its dark mare-like floor is distinctly not circular.* ***Gagarin*** *is a Pre-Nectarian crater named after the Russian astronaut who first orbited the Earth, diameter 265 km. Its floor is intruded by the lava-flooded crater Isaev. The chain of small craters next to Gagarin is possibly created by the ejecta of the Ingenii impact.*

2. Mare Ingenii *sits in an impact basin, diameter 320 km. Half of the mare is dominated by crater* ***Thomson****. The floor contains swirling deposits of brighter material which are magnetic anomalies similar to Reiner Gamma in Map 20.*

3. Schrödinger *is an impact crater-basin formed in the Imbrium period, diameter 312 km. At this size, it may develop an internal ring instead of central peak due to fluidized waves during the impact. The floor of Schrödinger is fractured with a distinctive dark-halo crater.*

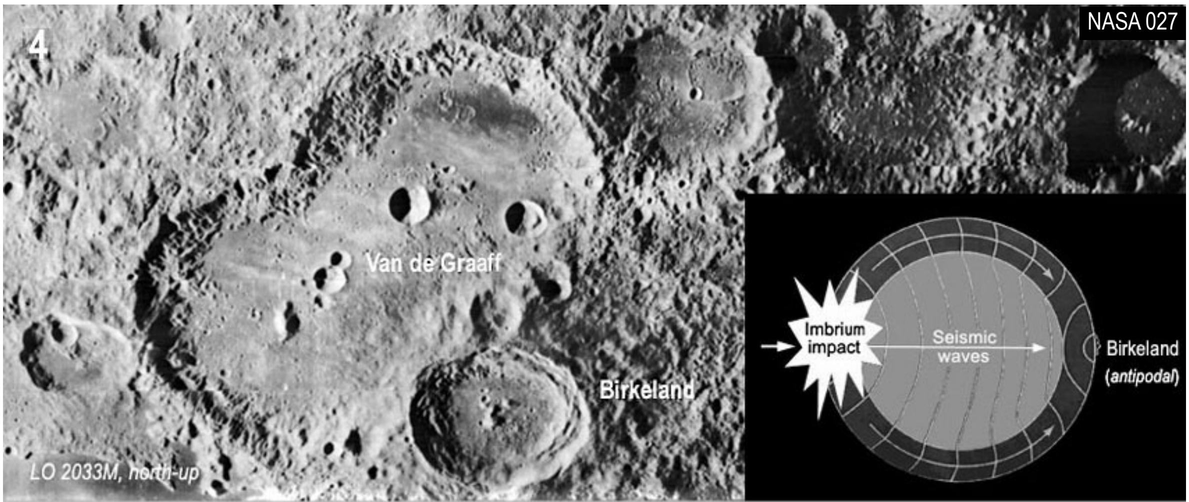


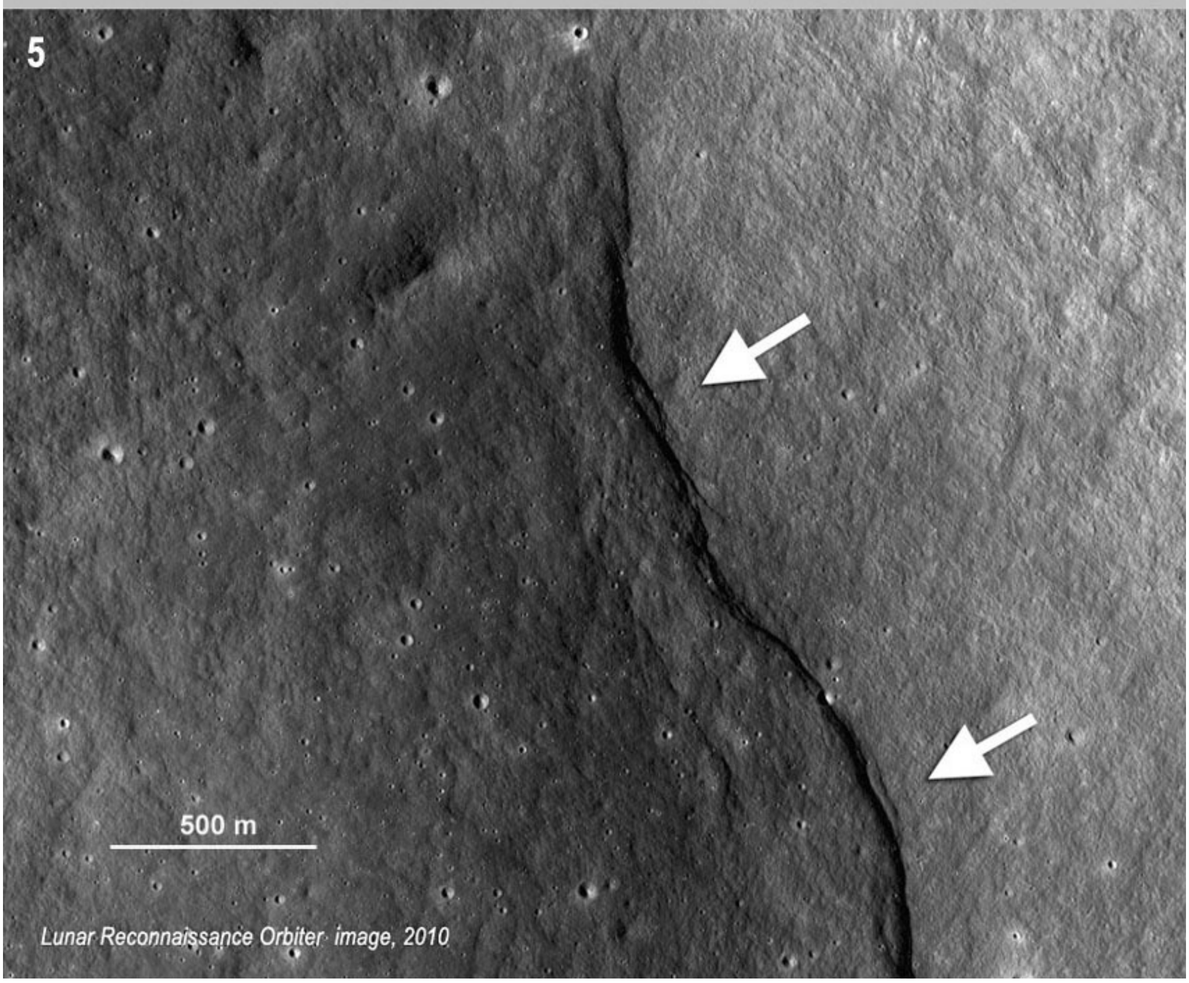
(All images north-up)

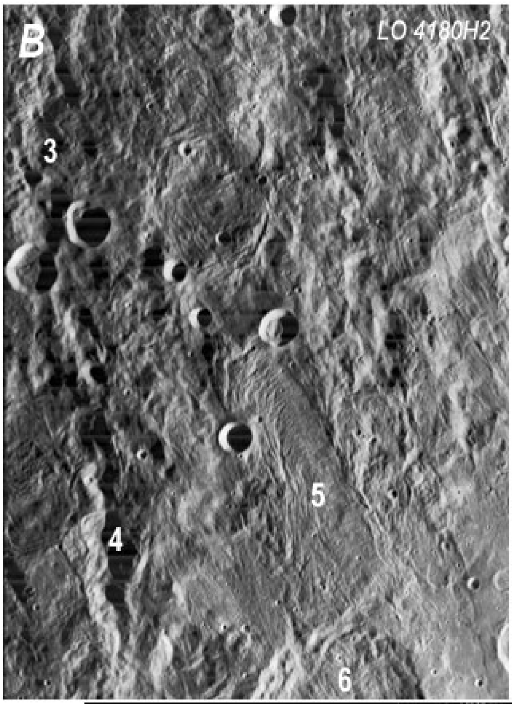
Features on the farside of the Moon

*4. **Birkeland** is an 82-km crater at 30^{0} S 174^{0} E. It is antipodal to the giant Imbrium basin at the nearside. The converged focusing of seismic waves from the Imbrium impact may have created the weird grooves along the crater's inner rim. **Van de Graaff** is a large "twin crater" interrupted by Birkeland, which partly accounts for the figure-8 shape. This site was also known for its unusual level of radioactive and magnetic anomalies.*

5. A lobate scarp at the side of the farside impact crater named Gregory (2°N 127°E). As the Moon cooled and contracted in its evolution, thrust faults formed in the crust where a section of the land juts out over another. The resulting scarps are often lobe-shaped and so called "lobate scarps". They were first discovered from the Apollo lunar images and later in the mapping of Mercury by Mariner 10 in 1974, but the lobate scarps on the Moon are limited and are much smaller than Mercury's.



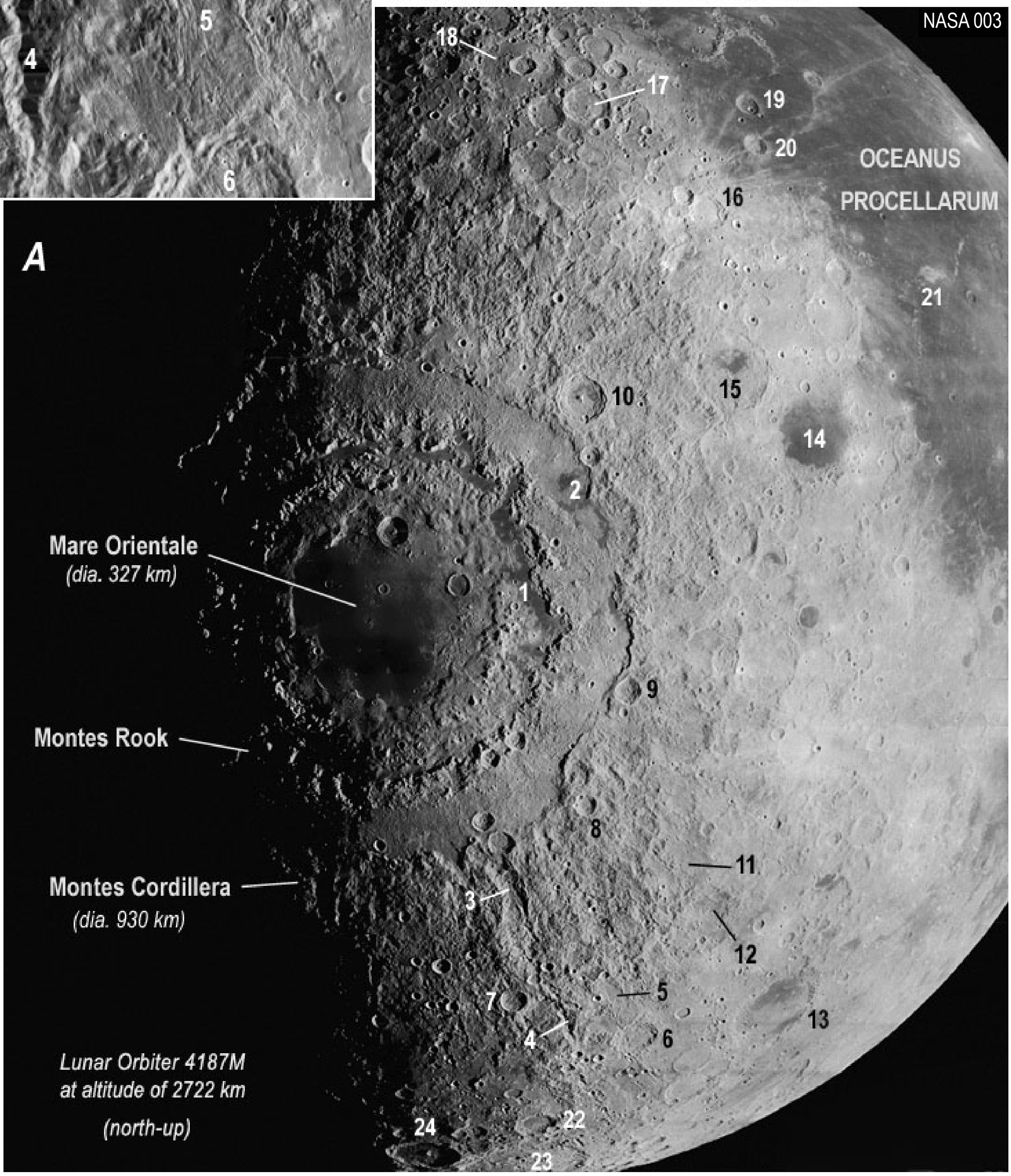




Orientale Basin

A: *Orientale is a prominent impact basin at the farside (19°S 93°W), diameter about 930 km. It comprises at least four concentric rings including Montes Rook and Montes Cordillera which rises 6 km above the basin floor.* ***B:*** *The ruins of the Orientale impact, seen as radial valleys or grooves, are distinctive in this region.*

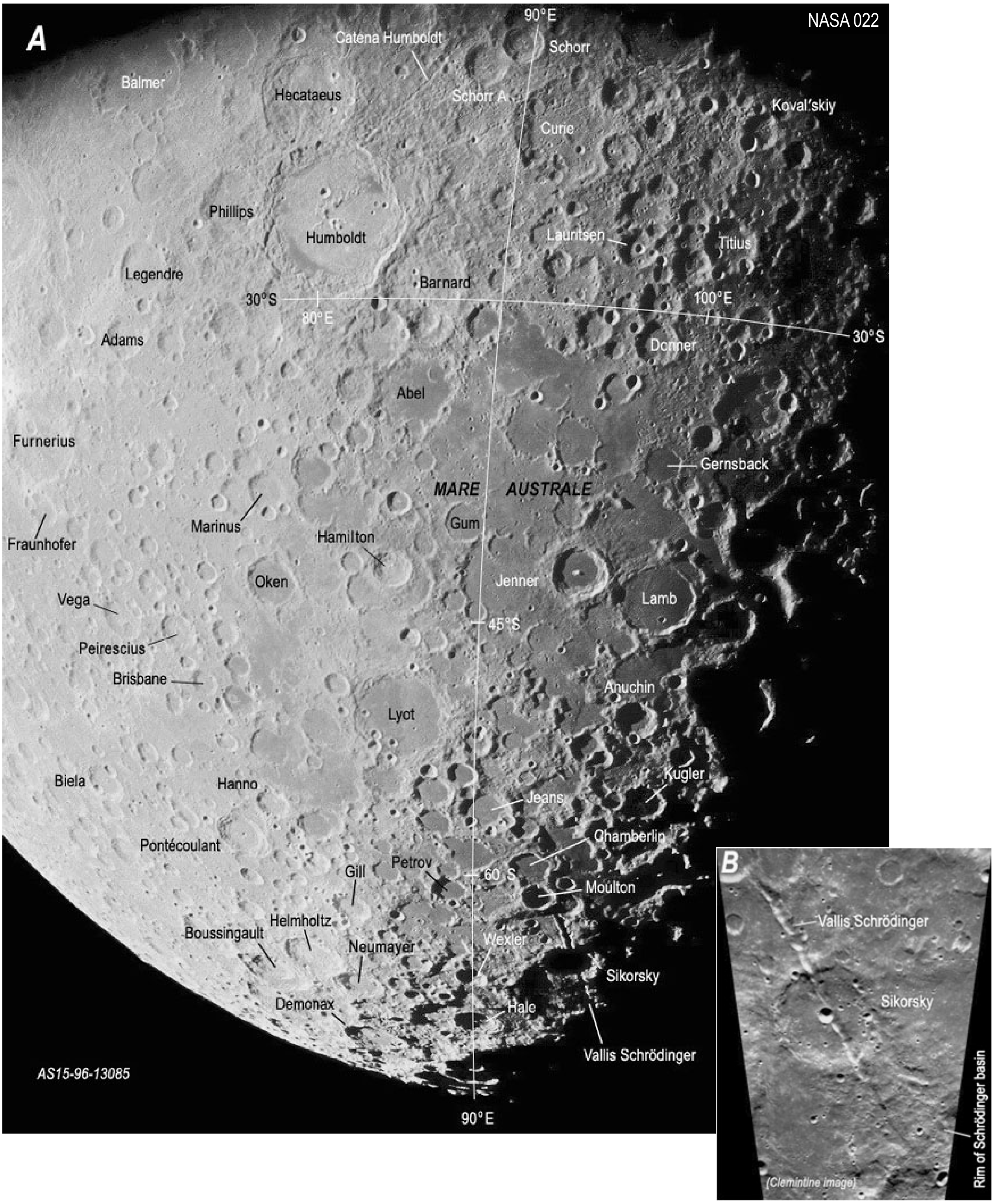
1. Lacus Veris (Spring Lake)
2. Lacus Autumni (Autumn Lake)
3. Vallis Bouvard (284 km)
4. Vallis Baade (203 km)
5. Vallis Inghirami (148 km)
6. Inghirami (91 km)
7. Baade (55 km)
8. Krasnov (40 km)
9. Eichstadt (49 km)
10. Schlüter (89 km)
11. Lagrange (225 km)
12. Piazzi (134 km)
13. Schickard (206 km)
14. Grimaldi (172 km)
15. Riccioli (139 km)
16. Olbers (74 km)
17. Vasco da Gama (83 km)
18. Einstein (198 km)
19. Krafft (51 km)
20. Cardanus (49 km)
21. Reiner Gamma
22. Pingré (88 km)
23. Bailly (287 km)
24. Hausen (167 km)



Mare Australe and Vallis Schrödinger

A. *This image by Apollo 15 is rotated north-up. Mare Australe (Southern Sea) is about 600 km across. It occupies a large old impact basin, but the basin was not totally lava-flooded and so a large number of pre-existing craters remain on the basin floor. The largest crater in this mare is* ***Lyot*** *(132 km). It is a flooded walled plain, visible in telescope under favorable libration. See also T188 in* *Map 4*. ***Jenner*** *and* ***Lamb*** *are prominent crater pair, but they are on the farside and hence invisible from Earth.* ***Humboldt*** *is a large walled plain just outside Mare Australe, diameter 189 km.* ***Catena Humboldt*** *is a chain of craterlets running between Humboldt and* ***Schorr A****, length 165 km.*

B. ***Vallis Schrödinger*** *captured by the Clementine lunar probe. It bisects crater* ***Sikorsky****, 310 km in length. The valley is in fact a chain of small overlapping craters radial to the Schrödinger basin, and was thought to form by the ejecta during the Schrödinger impact.*



Lunar features named after Chinese

There are 13 lunar features named after Chinese, 5 on the nearside and 8 on the farside.

Feature Name	Year Adopted	Lat. *(deg.)*	Long. *(deg.)*	Dia.* *(km)*	Origin	Image / Where
Crater						
Bi Sheng 畢昇	2010	78.3 N	148.4 E	55	Inventor, 990 - 1051	See next page or Farside map, Label G.
Cai Lun 蔡倫	2010	80.1 N	113.8 E	43	Inventor, 57 - 121	See next page or Farside map, Label H.
Chang Heng 張衡	1970	19.0 N	112.2 E	43	Astronomer, 78 - 139	See next page or Farside map, Label B.
Chang-Ngo 嫦娥	1976	12.7 S	2.1 W	3	Female in Chinese myth	Inside crater Alphonsus, Map 12.
Ching-Te 敬德 #	1976	20.0 N	30.0 E	4	Generic male name	Southwest of crater Littrow, Map 9.
Kao (Ping-Tse) 高平子	1982	6.7 S	87.6 E	34	Astronomer, 1888 - 1970	See Event 1 (Image T116).
Kuo Shou Ching 郭守敬	1970	8.4 N	133.7 W	34	Astronomer, 1231 - 1316	See next page or Farside map, Label D.
Shi Shen 石申	1970	76.0 N	104.1 E	43	Astronomer, ~ 300 B.C.	See next page or Farside map, Label A.
Tsu Chung-Chi 祖沖之	1970	17.3 N	145.1 E	28	Mathematician, 429 - 500	See next page or Farside map, Label C.
Wan-Hoo 萬戶	1970	9.8 S	138.8 W	52	Inventor, ~ 1500	See next page or Farside map, Label E.
Zhang Yuzhe 張鈺哲	2010	69.0 S	137.7 W	37	Astronomer, 1902 - 1986	See next page or Farside map, Label F.
Rille						
Rima Sung-Mei 宋梅月溪 #	1985	24.6 N	11.3 E	4	Generic female name	On the western floor of Mare Serenitatis, Map 9.
Rima Wan-Yu 萬玉月溪 #	1976	20.0 N	31.5 W	12	Generic female name	Almost at the west rim of crater Natasha, Map 19.

*Names in native language are not yet ascertained.　　* *Diameter or long-side dimension*

Shi Shen 石申 ~ 300 B.C.

石申 (石申夫) 是戰國時代魏國人。他和楚國人甘德各自編過一本星表，後人將石申編的資料歸納成《石氏星經》，此書已失，但唐朝《開元占經》輯錄了大量片斷內容。《石氏星經》主要記錄了二十八宿距星和 121 顆星體的赤道座標位置，可以說是中國古代天體測量工作的基礎。

Cai Lun 蔡倫 57 - 121

東漢人，他改進了當時的造紙技術，相傳發明造紙術。

Chang Heng 張衡 78 - 139

東漢人，字平子。少年時代醉心於文學，三十歲後開始從事天文與科技的工作。三十八歲任太史令，主管曆法機構，晚年任尚書。他研創用水力運作的「渾天儀」和顯示地震方位的「候風地動儀」，也可能造過記里鼓車、自飛木雕的機械裝置 (後漢書 • 張衡列傳)。他正確指出月球反射太陽光和日月食的成因，算出圓周率約等於 92 / 29。主要著作有《靈憲》、《渾天儀圖注》、《算罔論》等。

Tsu Chung-Chi 祖沖之 429 - 500

南北朝时代南朝人。他把圓周率精確地算至 3.1415926 和 3.1415927 之間，在 33 歲時創制了《大明曆》，採用一年的天數，跟現代回歸年值只多出 54 秒，《大明曆》又首次引入了歲差，每隔 391 年設 144 個閏月。這些做法，都是對前代曆法的重大改革，可惜《大明曆》遲至祖沖之死後十年才獲朝廷同意實行。在制曆過程中，祖沖之發明了用圭表測量正午時日影長度以定冬至時刻的方法，這個方法為後世長期採用。

Bi Sheng 畢昇 990 - 1051

北宋人，發明世界上最早的活字印刷技術。

Kuo Shou Ching 郭守敬 1231 - 1316

元代河北人，他在全國各地設立 27 個觀測站進行大規模的天文和地理測量，北至西伯利亞，南至西沙群島，並且首次運用海拔概念，比歐洲的同樣概念還要早；他主編的《授時曆》，一年的周期 (365.2425 天) 與現代公曆幾乎相同，另外，他創造和改進了十餘種天文儀器，包括著名的「簡儀」、登封觀星台的巨型圭表、「景符」及「窺幾」等等，他又主持多項國家工程，集防洪、灌溉、航運為一體。天文數學著作有十四種共 105 卷，可惜已遺失。

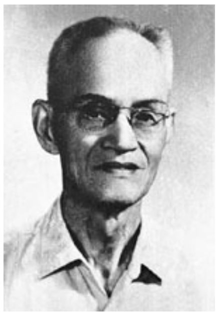
Wan-Hoo 萬戶 ~1500

據傳原是木匠，後在明朝軍營擔任兵器技藝的開發。他的姓名不詳，萬戶可能是一軍階的名謂，也可能不是軍階。他曾把多枚火箭捆綁在自己的座椅上，並且手持風箏試圖飛天，可惜點火後火箭爆炸喪命。外國稱他是「最早乘搭火箭的人」。

Kao (Ping-Tse) 高平子 1888 - 1970

原叫高均，江蘇人，對張衡十分敬仰，故又名平子。他沒有接受正規的天文教育，震旦學院畢業後入徐家匯天文台及佘山天文台，隨法國神父從事太陽黑子、小行星及雙星的觀測，工餘自修天文。1924 年他代表中國接管由日本人佔用的青島觀象台，1926 年參加國際經緯度的測定工作，他也曾主持編算天文年曆及協建南京紫金山天文台。抗日時期避居上海租界研究中國古天文，1948 年遷居台灣，著作有《史日長編》、《圭表測景論》等。

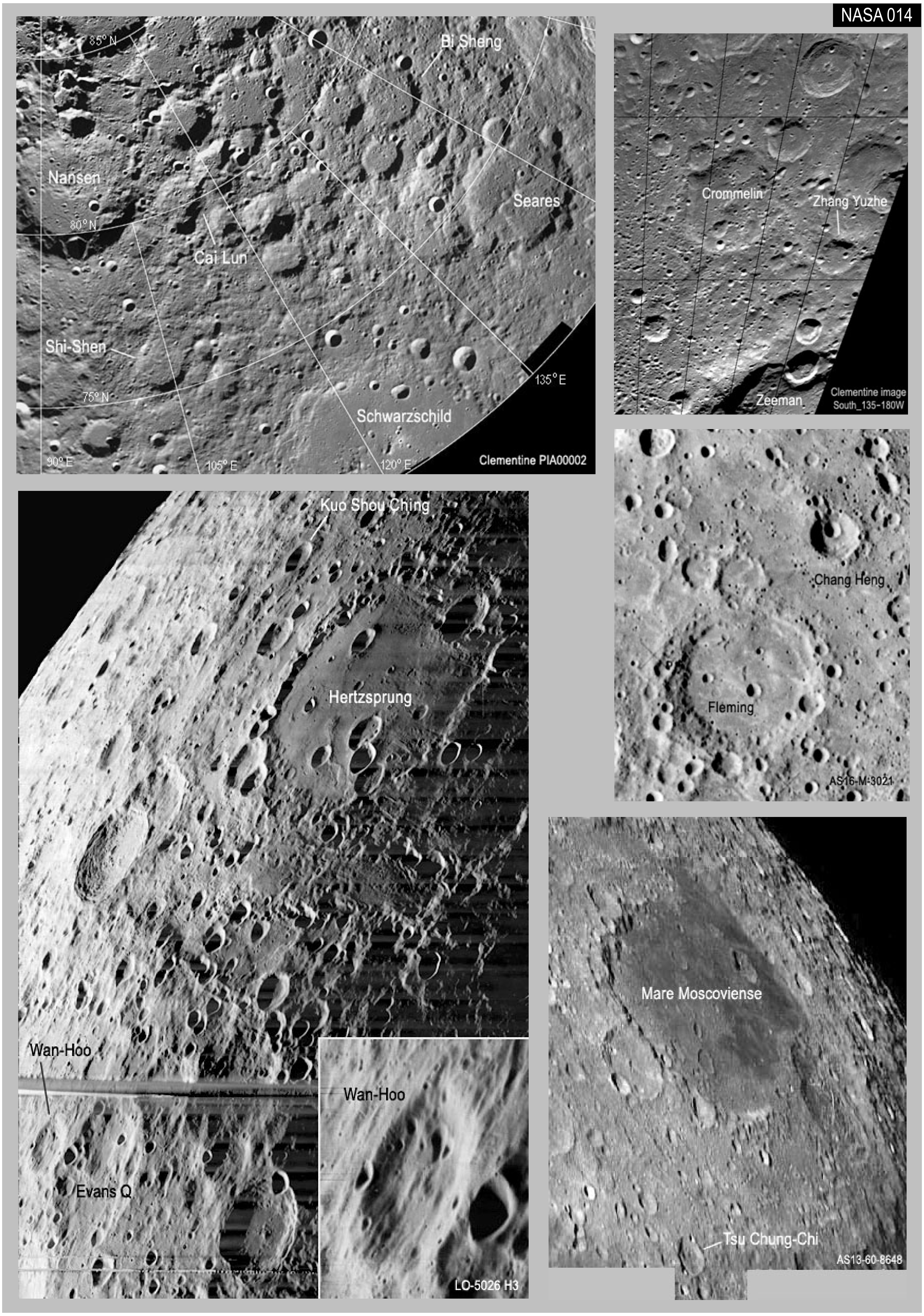
Zhang Yuzhe 張鈺哲 1902 - 1986



中國天文學家，福建人，1919 年入讀清華學堂（今名清華大學），1923 年入芝加哥大學，1928 年在美國葉凱士天文台發現一顆小行星，命名為中華，1929 年獲該台博士學位，同年回國在國立中央大學 (今名南京大學) 講授天文學。1941 年任中央研究院天文研究所所長，1946-1948 年赴美研究交食雙星光譜，1950-1984 年任南京紫金山天文台台長。

張長期致力於小行星和彗星的軌道計算工作，第 2051 號小行星就是以他的名字 (張 Chang) 來命名的。

Farside craters named in Chinese *(All images north-up)*



4. Lunar Spacecraft

Since 1959, over 30 unmanned spacecraft explored the Moon successfully. They are highlighted below:

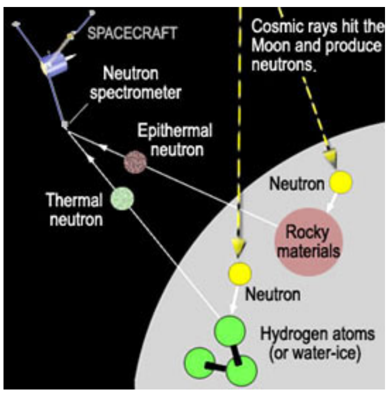
Unmanned Spacecraft	Date of Launch (UT)	Missions / Results
Luna 2, 3, 9 to14, 16, 17, 19 to 24 (Soviet) 「月球號」	1959 September ~ 1976 August	● First succeeded to photograph Moon's farside (Luna 3, 1959). ● Returned a total of 300g soil samples to Earth. http://www.lpi.usra.edu/expmoon/luna/luna.html
Ranger 7, 8, 9 (USA) 「徘徊者」	1964 July ~ 1965 March	● Returned closeup images before the spacecraft crashed on the Moon. http://www.lpi.usra.edu/expmoon/ranger/ranger.html
Surveyor 1, 3, 5, 6, 7 (USA) 「探測者」	1966 June ~ 1968 January	● Tested or analyzed lunar soils directly on landing sites. ● Transmitted to Earth about 86,000 lunar photographs. http://www.lpi.usra.edu/expmoon/surveyor/surveyor.html
Lunar Orbiter 1, 2, 3, 4, 5 (USA) 「月球軌道飛行器」	1966 Aug ~ 1967 Aug (Crash onto the Moon at end of mission)	● Photographed the entire moon surface from orbit. ● Discovered the existence of mascons. http://www.lpi.usra.edu/resources/lunar_orbiter/
Clementine (USA) 「克萊門泰」	1994.01.25 (Signal too weak to receive after 5 months from launch)	● Mapped the entire Moon at multi-wavelengths from which scientists deduced the abundance of elements on the lunar surface without coming into direct contact with it (the so-called remote sensing technique). http://www.cmf.nrl.navy.mil/clementine/
Lunar Prospector (USA) 「月球勘探者」	1998.01.07 (Controlled crash onto the Moon, 1999.07.31)	● Went into polar orbit around the Moon to survey the composition of lunar crust; searched water-ice at the poles. ● Mapped the Moon's gravity and magnetic fields. ● Monitored volcanic emission. http://lunar.arc.nasa.gov/
Smart-1 (Europe) 「智能一號」	2003.09.27 (Controlled crash onto the Moon, 2006.09.03)	● Testing and proving of an ion drive engine and miniaturized instruments, along with investigations of lunar geochemistry and a search for water-ice at the lunar South Pole. http://sci.esa.int/science-e/www/area/index.cfm?fareaid=10
Selene, also known as Kaguya (Japan) 「月亮女神」	2007.09.14 (Controlled crash onto the Moon, 2009.06.10)	● Carried two subsatellites; took HDTV images on lunar landscapes. http://www.jaxa.jp/projects/sat/selene/index_e.html
Chang'e-1, 2 (China) 「嫦娥一號、二號」	2007 Oct, 2010 Oct (Chang'e-1 crashed onto the Moon, 2009.03.01)	● To obtain the Moon's 3D images and elemental distribution; to investigate lunar regolith and the space weather (solar wind) en route to the Moon. http://www.clep.org.cn/
Chandrayaan-1 (India) 「印度月船一號」	2008.10.22 (Stopped sending signals, 2009.08.29)	● Went into polar orbit around the Moon. The on-board NASA radar found deposits of water ice in some shadowed craters at the north pole. http://www.isro.org/chandrayaan/htmls/home.htm
LRO - Lunar Reconnaissance Orbiter; LCROSS - Lunar Crater Observation and Sensing Satellite (USA)	2009.06.18 (LRO launched together with LCROSS)	● LRO – Surface imaging with 1-m resolution; investigations that support future human return to the Moon. http://lunar.gsfc.nasa.gov/ ● On 2009.10.09, LCROSS hit crater Cabeus near the lunar south pole where signatures of water were found. http://lcross.arc.nasa.gov/

The on-board instruments generally include the multi-band cameras, radar, laser ranging / altimeter and the following types:

X-ray Spectrometer – It determines the abundance of elements Al, Si, Mg, Fe etc. through X-ray fluorescence spectrometry by irradiation of solar X-rays.

Gamma-ray Spectrometer – It determines the abundance of uranium, thorium, potassium etc. (radioactive or light elements) by measuring the energy spectra of gamma-rays from the lunar surface.

Alpha-particle Spectrometer – It detects the alpha particles emitted by radioactive gases, such as radon and polonium, leaking out of the lunar interior. It also detects the abundance of cosmic ray particles from space. [Remark: An alpha particle consists of 2 protons and 2 neutrons bound together, identical to a helium nucleus. Cosmic rays are energetic particles; typically consist of 90% protons, 9% helium nuclei (alpha particles) and 1% electrons.]

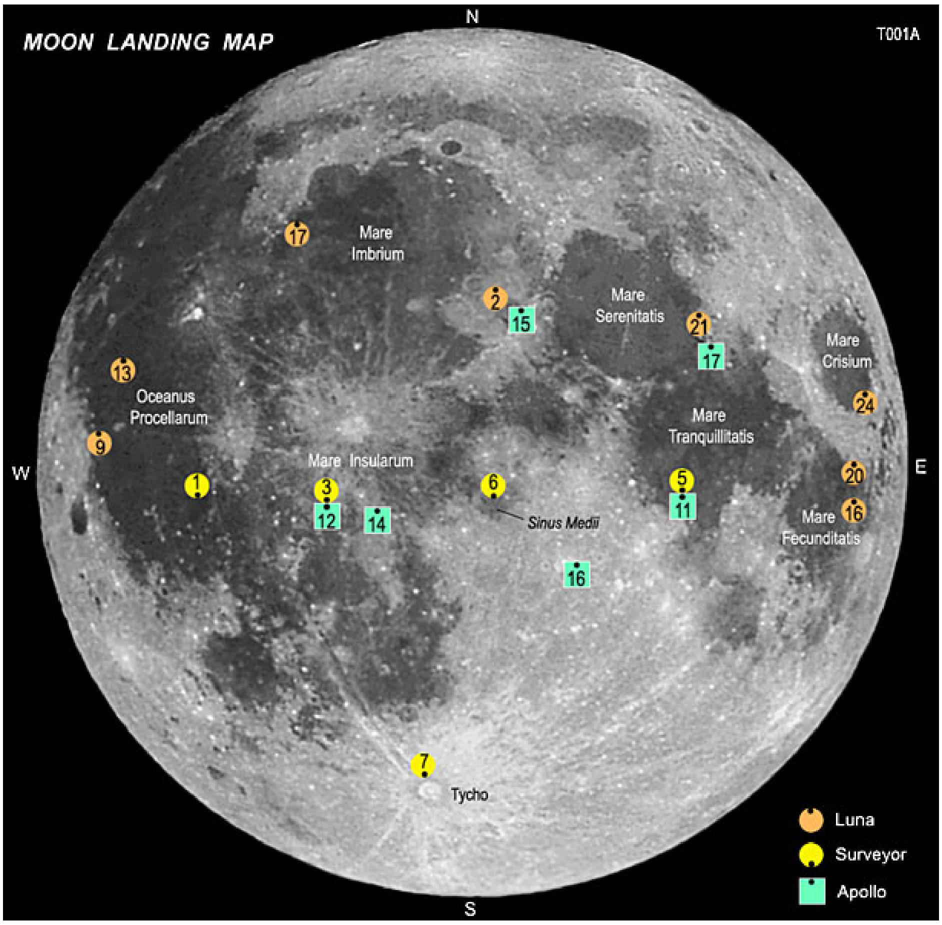


Neutron Spectrometer – It is specially designed to detect hydrogen atoms, since hydrogen is a good marker for water existence. It does not detect hydrogen directly, but looks for "thermal" neutrons --- neutrons that have bounced off a hydrogen atom somewhere on the lunar surface. See the illustration at right.

Magnetometer / Electron Reflectometer – The magnetometer works commonly on "fluxgate" principle in which the magnetic field passes through arrays of electric coils. The intensity and direction of the magnet field on the Moon are mapped by the current variations in the coils. Electron reflectometer, however, detects magnetic field through counting of electrons reflected from localized magnetic materials (if any). [Remark: The electrons are originated from solar wind bombardment on the lunar surface.]

Gravity Measurement – As the spacecraft orbits the Moon, its speed is determined by the Doppler effect. Surface gravity of the Moon can be derived from the speed variations.

The first manned landing began with the Apollo 11 mission when Neil Armstrong and Edwin Aldrin set foot on Mare Tranquillitatis (Sea of Tranquility) on July 20, 1969. Meanwhile Michael Collins orbited in the command module. Apollo is a NASA program to land humans on the Moon. A total of six Apollo landing modules including 12 astronauts succeeded in landing between 1969 and 1972, see the Moon Landing Map. Since then no human landed on the Moon but surveys by unmanned spacecraft continued. The best rewards from the Apollo are the human experience on the airless low-gravity lunar surface, the collection of 382 kg of Moon rocks and the on-site experiments about solar wind, cosmic ray, lunar atmosphere, heat flow, magnetic field, seismometry and laser ranging. The Moon rocks played the key role to reveal the lunar evolution. By analyzing the rocks with radiometric dating, the Moon was determined 4.5 ~ 4.6 billion years old, virtually same age as the Earth.

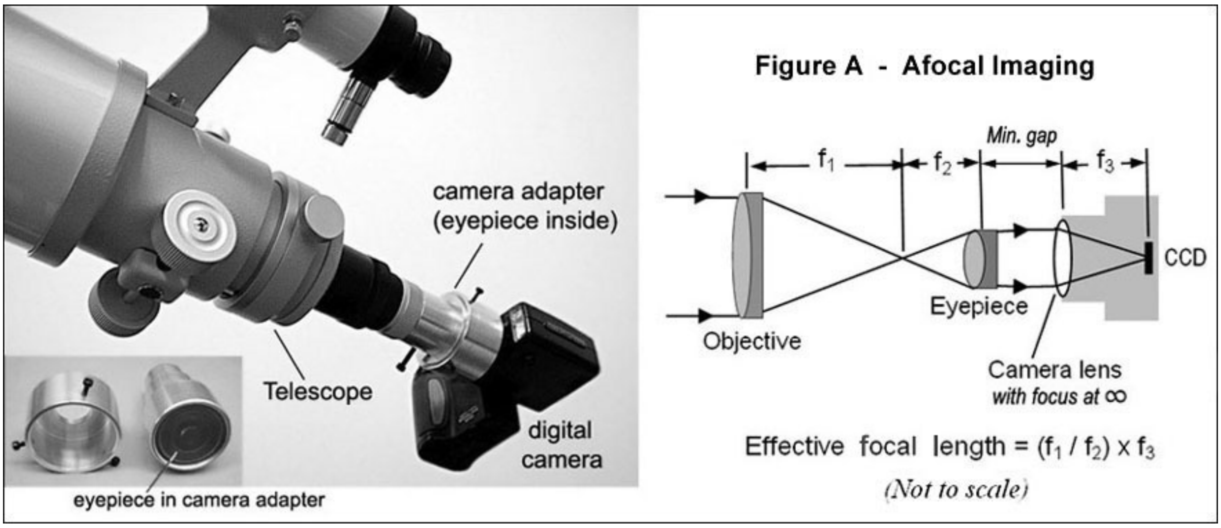


Spacecraft	Date of Landing	Results	Spacecraft	Date of Landing	Results
Luna Probes (Soviet)			**Apollo Missions (USA)**		
Luna 2	1959.09.13	Hit Moon near Palus Putredinis.	Apollo 11	1969.07.20	Landing 0.7⁰ N 23.5⁰ E, Mare Tranquillitatis, Map 8. Collected 22 kg basalts and breccias.
Luna 9	1966.02.03	Soft-landed in Oceanus Procellarum.	Apollo 12	1969.11.19	Landing 3.0⁰ S 23.4⁰ W, Mare Insularum, Map 20. Collected 34 kg, almost all basalts.
Luna 13	1966.12.24	Soft-landed in Oceanus Procellarum.	Apollo 14	1971.02.05	Landing 3.6⁰ S 17.5⁰ W, Fra Mauro, Map12. Collected 43 kg ejecta breccias.
Luna 16	1970.09.20	Returned 100g soil from M. Fecunditatis.	Apollo 15	1971.07.30	Landing 26.1⁰ N 3.6⁰ E, Rima Hadley, Map 14. Collected 77 kg basalts and Highland rocks traceable to birth of Moon.
Luna 17	1970.11.17	Landed one rover in Mare Imbrium.	Apollo 16	1972.04.21	Landing 9.0⁰ S 15.5⁰ E, Descartes, Map 31. Collected 95 kg breccias from highlands.
Luna 20	1972.02.21	Returned 30g soil from Crisium highlands.	Apollo 17	1972.12.11	Landing 20.2⁰ N 30.8⁰ E, Taurus-Littrow, Map 9. Collected 111 kg, mostly basalts, some highland rocks.
Luna 21	1973.01.15	Landed one rover in Mare Serenitatis.	Remark: Apollo 13 (April 1970) aborted in the 3rd day of the mission.		
Luna 24	1976.08.18	Returned 170g soil from Mare Crisium.			
Surveyor Probes (USA)					
Surveyor 1	1966.06.02	Soft-landed in Oceanus Procellarum.			
Surveyor 3	1967.04.20	Tested soil in Mare Insularum, Later visited by Apollo 12 astronauts.			
Surveyor 5	1967.09.11	Tested soil in Mare Tranquillitatis.			
Surveyor 6	1967.11.10	Tested soil in Sinus Medii.			
Surveyor 7	1968.01.10	Tested soil near crater Tycho.			

5. Methods of Imaging

The author of this book applied two methods to image the Moon — the afocal method and the video method.

5.1 Afocal Method



This is implemented by coupling a digital camera to the telescope's eyepiece, Figure A. The camera's focus mechanism is fixed at infinity (hence the term "afocal"). Actual focusing is adjusted on the telescope while watching the camera LCD screen.

The effective focal length of an afocal system is equal to the telescope magnification times the focal length of the camera's front lens.

<u>Example</u>

Telescope focal length, f_1 = 1040 mm
Eyepiece focal length, f_2 = 12.5 mm
Telescope magnification, f_1 / f_2 = 1040 / 12.5 = 83
Camera lens focal length, f_3 = 24 mm
Effective focal length for afocal imaging = 83 x 24 ≈ 2000 mm

The frame FOV (field of view) is equal to the FOV of the camera lens divided by telescope magnification. If the FOV of the camera lens is 15 x 11 degrees (which can be estimated from its specifications), then following the above example, the frame FOV will be 11 x 8 arcminutes. This covers about 1/3 ~ 1/4 diameter of the Moon disc.

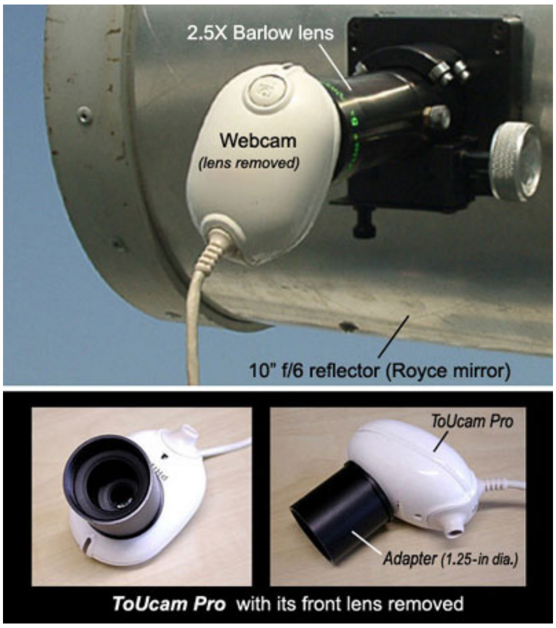
The afocal method is very flexible while image quality is quite promising. Changing the eyepiece, zooming the camera lens, rotating the camera body, and/or using telescopes of different sizes virtually satisfy all needs of wide-field and close-up images of the Moon. However, there is a limit of telescope magnification. Under average seeing, the author controls the telescope magnification not to exceed 25X per inch aperture (10X per cm). 40X per inch (16X per cm) is used only during very good seeing. The author also avoids using eyepieces longer than 30mm focal length, because they produce excessive darkening of the frame corners.

The telescopes used depend on instant availability, see Figure B. The digital cameras have 3~4X optical zoom, including the early models of Nikon Coolpix-9xx and Casio QV2300. These cameras incorporate a twistable lens head with CCD pixel around 3.5 x 3.5 µm.

Typically a raw image from any digital camera looks flat. The author enhances it with the editing software ***Photoshop***.

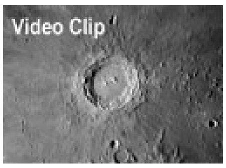
Figure B - Telescopes Used for Afocal Imaging

Figure C - Video Method



5.2 Video Method

The default setup of this method is illustrated in Figure C. It includes a 10-inch (254 mm) f/6 Newtonian reflector in which the prime mirror was produced by the specialist Robert F. Royce (http://www.rfroyce.com/), a Tele Vue 2.5X Barlow lens, a webcam with its front lens removed and a computer that controls the webcam exposure. The webcam is ***Philips ToUcam Pro***. It incorporates a CCD chip (Sony ICX098BQ at 640 x 480, 5.6 x 5.6 µm per pixel) and allows video frames to be captured at 1/25 second or faster shutter speed. The whole setup is quite powerful for high magnification works, for maximum possible speed can be chosen to offset image jittering, and the image resolution can reach ~ 0.3 arcsecond per pixel. Each frame covers a FOV of 3.2 x 2.4 arcminutes or roughly 1/10 of a lunar diameter. In theory this 10-inch telescope resolves round objects to 0.45 arcsecond or lunar craters as small as 800 m in diameter. Linear objects like clefts can be detected to 400 m or less in width subject to their contrast and the atmospheric seeing.



Typical ToUcam settings

To produce Image T064 in Figure F:

Video Format = I-420, Frame Size = 640x480 pixels, Frame Rate = 10 frames/sec,
Color = off (B&W only), Audio = off, Gamma = 1/5 full scale, Gain = 1/3 full scale, Shutter = 1/50 sec.
All other settings at default values.

After video capturing, the sharper raw frames are extracted and stacked with the free image processing software ***RegiStax*** (http://www.astronomie.be/registax/). Stacking is a technique to reduce image noise inherent in CCD. RegiStax can sort out the sharper frames automatically while the user determines by preference the number of frames stacked. No more than 500 frames are stacked, for over-stacking leads to loss of image details. In general, good seeing allows less stacking and bad seeing requires more stacking. RegiStax also provides a sharpening tool, the so called wavelet filter where image sharpness is adjustable on individual layers. However, the author prefers the use of Photoshop whereas the wavelets serve only as ancillary tool. Note that this method, though superior, demands heavy CPU power. A high-speed PC is recommended to run RegiStax.

An alternative of RegiStax is ***AviStack*** (http://www.avistack.de/). It supports a wide range of AVI codecs as well as MOVs and MPEGs.

Figure D - The 10-inch f/6 Newtonian

Figure D shows the full view of the 10-inch f/6 Newtonian, equipped with a Barlow lens and a motorized Crayford focuser. When seeing is good, a 4X or even a 5X Barlow lens is used instead of the 2.5X. The 4X is supposed an optimal choice according to Nyquist sampling theory. At 4X, the effective focal length of the telescope is 6100 mm. A lunar feature of angular size equals to the telescope's resolution (i.e. 0.45 arcsecond) thus projects an image length = 6100 *sin* (0.45 / 3600) = 13 µm at the focal plane. This covers approximately two pixels on each side of the CCD chip in ToUcam ----- a fitted Nyquist sampling. However the 4X is not always useable due to unfavorable seeing.

The choice of afocal or video method is a matter of FOV and seeing consideration. For instance in Figure E, a wide field like T019 is obtained with the afocal method. High magnification like T118 in Figure F is obtained with the video method. The image is rotated "south-up" like an eyepiece view in Newtonian telescope placed in the northern hemisphere.

This Moon book adopts magnified images more than wide-fields. Therefore much of the imaging works were done with the video method. Sometimes, frames from multiple video clips were combined to make a mosaic. Those who wish to capture the Moon at larger frames may refer to other commercial cameras, e.g. DMK31AF03 (1024 x 768 pixels) and DMK 41AU02 (1280 x 960 pixels) from ***The Imaging Source***, or the ***Canon*** digital-single-lens-reflex EOS 550D (5184 x 3456 pixels). See their image examples in Figure G and H. It is also possible to replace the Barlow lens with a projection eyepiece (e.g. 9 mm focal length) for high-power imaging.

Figure E - Imaging by afocal method

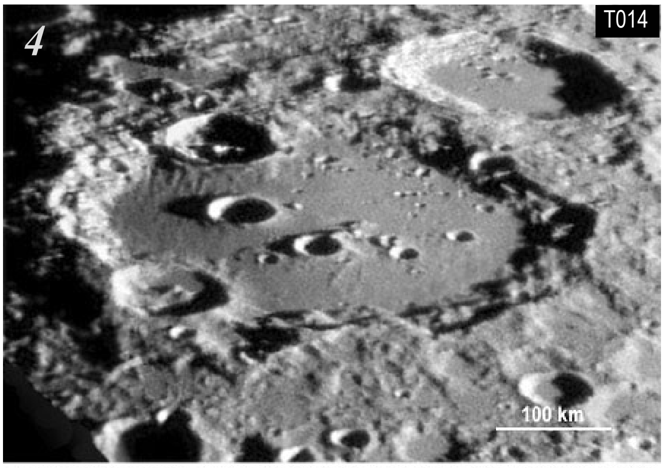
Digital camera coupled to:

1. *4-inch (102 mm) f/8 refractor + 6.7 mm eyepiece.*
2. *4-inch (102 mm) f/8 refractor + 25 mm eyepiece.*
3. *9.25-inch (235 mm) f/10 Schmidt-Cassegrain + 12.5 mm eyepiece.*
4. *9.25-inch (235 mm) f/10 Schmidt-Cassegrain + 7.5 mm eyepiece.*

2000.02.11 13:24 UT Age 6 days. FS102 + PL6.7 mm + CP950 at 1/30 s, 65 % resized.

Total Lunar Eclipse 2001.01.09 20:39 UT FS102 + Or25 + QV2300 at 4 sec. North-up.

Rupes Recta 2001.08.11 20:19 UT Age 22 days. C9 + LE12.5 + CP990 at 1/8 s



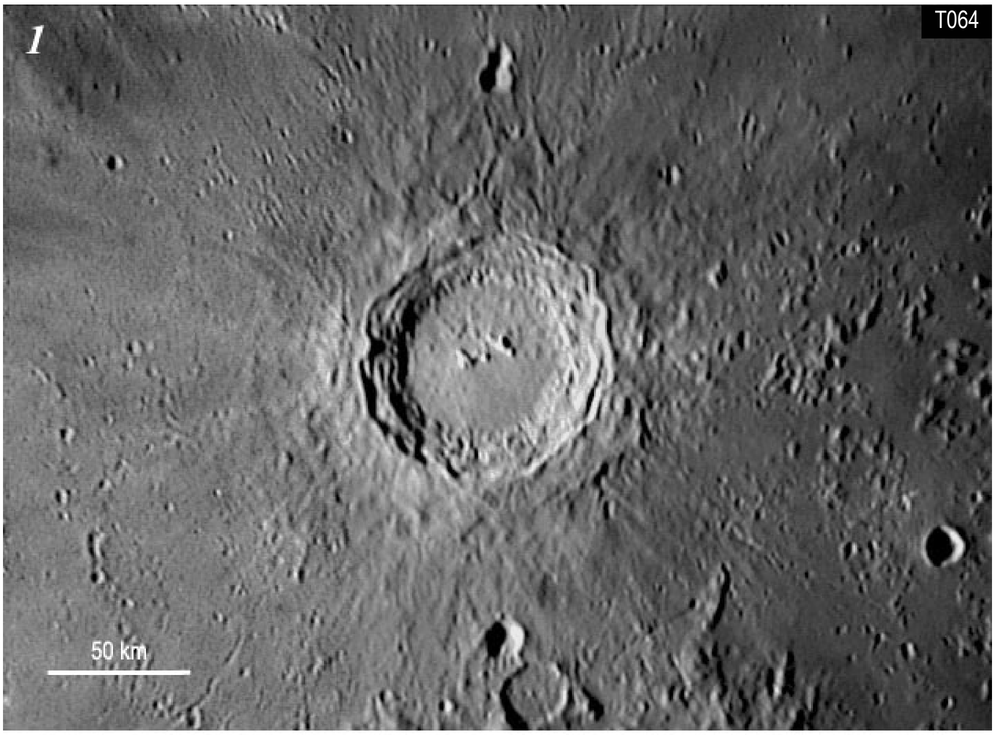
Clavius & Blancanus 2001.08.11 20:42 UT Age 22 days. C9 + LE7.5 mm + CP990

Figure F - Imaging by video method (ToUcam)

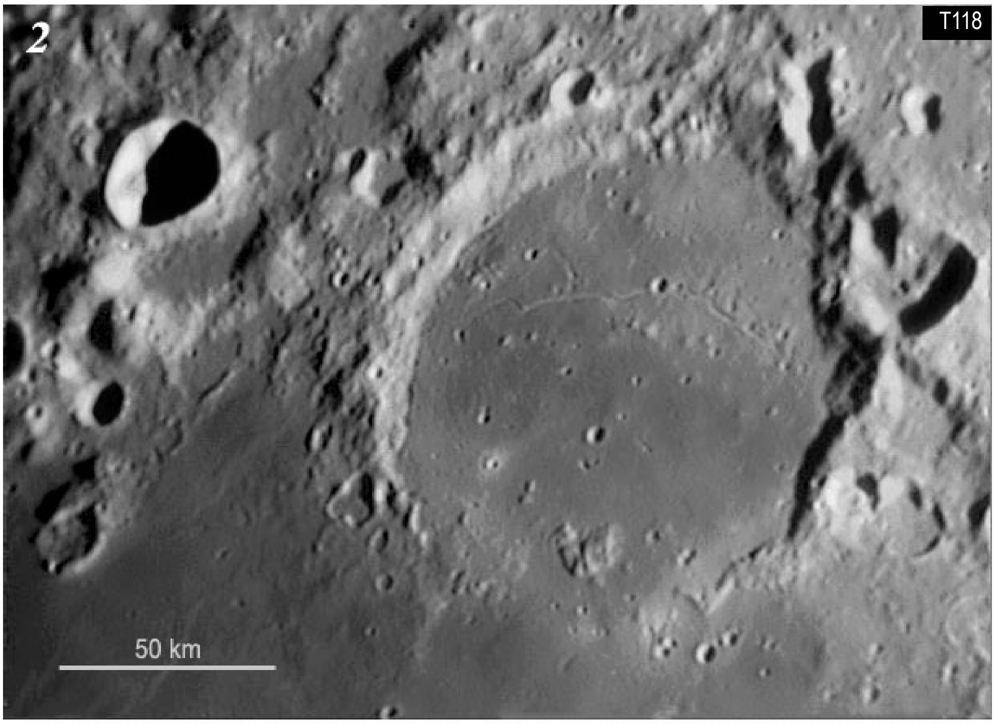
ToUcam coupled to:

1: *Royce 10-inch (254 mm) f / 6 Newtonian + 2.5X Barlow lens, effective f / 15.*
2: *Royce 10-inch (254 mm) f / 6 Newtonian + 2.5X + 1.6X Barlow lenses in cascade, effective f / 24.*

(All images are south up.)



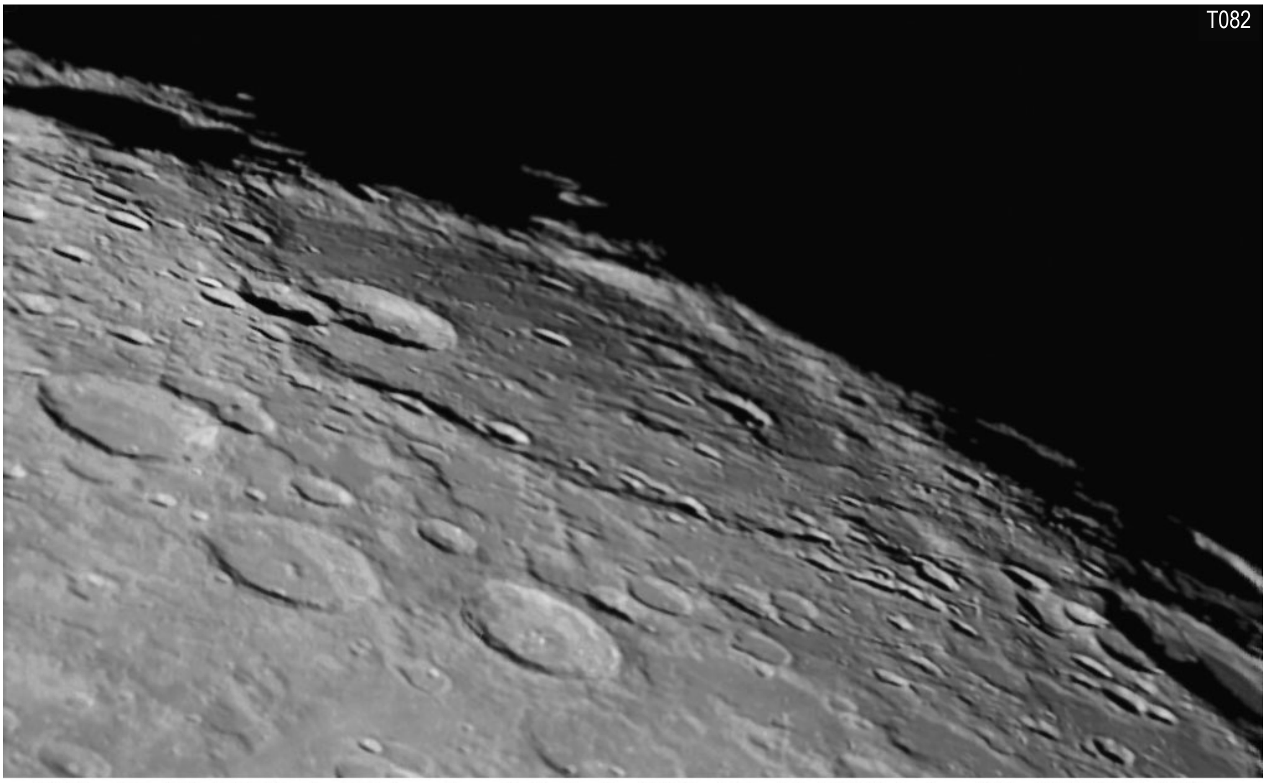
Copernicus 2004.05.29 ~15:20 UT 10-in f/6 Newtonian + 2.5X + ToUcam at 1/50s, 2 frames stacked (1 frame each from 2 video clips).



Fracastorius & vicinity 2006.08.12 21:31 UT Age 19 days. 10-in f/6 Newtonian + 2.5X + 1.6X + ToUcam

Figure G - Imaging by video method (DMK31AF03)

The west limb of the Moon on 2009 October 31 15:52 UT Age 13.4 days. Grimaldi is in deep shadow. 10-inch f/6 Newtonian + 2.5X + DMK31AF03 at 30 fps.



Bailly 2009.11.01 15:29 UT Age 14.4 days. Favorable libration ***l*** = -5.1° ***b*** = -6.4°. 10-inch f/6 Newtonian + 2.5X + DMK31AF03 at 30 fps.

Figure H - Imaging by digital-single-lens-reflex camera

Taken with a Canon DSLR camera coupled to a 5-inch (128-mm) f/8 apochromatic refractor. The moon disc in the original frame is 1480 pixels in diameter. Image processed by Photoshop.

The Moon in Mid-Autumn Festival, Hong Kong. 2009.10.03 15:11 UT, 15 hours before exact full moon. FS128 f/8 refractor + Canon EOS350D at ISO100, 1/250s

5.3 Other Considerations

It should be noted that the brightness of the Moon changes significantly with its age in a lunation. This implies that when shooting the Moon, a wide range of camera shutter speed is required. Typically the shutter speed is a fraction of a second at crescent to about 1/500 second for a full moon. If the frame includes both very bright and very dark features, the exposure is compromised by trials. Today's technology makes exposure rather easy, because the trials can be judged from the digital camera or PC screen any time.

Precise focusing is a must. In close-up images taken by the video method, a motorized focuser has been found extremely useful. It also avoids telescope vibration as focusing is made.

Object tracking is important to create image mosaic from a multiple of video clips, otherwise the post-work of stacking and mosaicking are complicated by any excessive drift of the object in field. The author tracks the Moon's R.A. and Declination with the ***Vixen New Atlux*** mount; it virtually locks the object in field during the entire video session.

For high magnification works, it is essential to ensure proper collimation of the optics and allow them to reach thermal equilibrium.

5.4 Environment and Image Archives

All lunar images in this book and taken by the author are traceable from the Image Data in next pages. The images were taken mostly in City One Shatin of Hong Kong where the author's observing site is located. The night sky above the site is heavily light-polluted, and there are hundreds of air conditioners in the windows of the neighbor buildings. The site is also blocked in the east direction, hence much of the imaging were done in phases before the last quarter.

In the list of Image Data, the **Moon Age** is expressed in rounded number, e.g. *15* means the age of the Moon is about *15 days*. The **Equipment Used** are abbreviated, e.g. *FS102 f/8 + K25 + QV2300* = Takahashi FS102 f/8 refractor with Kellner 25mm eyepiece and Casio QV2300 digital camera. All digital cameras are set to ~ ISO100 and full resolution for maximum available pixels. When the ToUcam was used, not all video clips were archived; only the stack of raw frames were saved.

Figure I - The Night Sky

A light-polluted sky like this is disappointing to explore deep sky objects but still manageable for lunar and planetary observations.

Data of Lunar Images

The following data apply to lunar images taken by the author in Hong Kong; each image is identified by a T code *at the frame corner.*

Image Code	Date / Time (UT)		Moon Age	Equipment Used	Exposure (sec)	Raw Image
T001	2000.09.13	14:39	15 days	FS102 f/8 + K25 + QV2300	1/265	QV2300-20000913-0072
T002	2000.04.20	17:52	15	FS102 f/8 + LE5 + CP950	1/3	CP950-DSCN 1589
T003	2000.09.15	15:25	16	MK67 (6-in f/12) + PL16 + CP950	1/11	CP950-DSCN 4013
T004, A	2006.11.08	20:06	18	ETX90 Maksutov + LE24 + CP990	1/20	CP990-DSCN 9738 (2)
T005	2000.06.15	16:28	13	FS102 f/8 + LE7.5 + CP950	1/21	CP950-DSCN 2989
T006	2000.09.15	15:52	17	MK67 (6-in f/12) + K25 + CP950	1/42	CP950-DSCN 3997
T007	2000.04.20	17:58	15	FS102 f/8 + LE5 + CP950	1/4	CP950-DSCN 1591
T008,	2000.11.02	12:14	6	FS128 f/8 + LE12.5 + QV2300	1/6	QV2300-20001102-0044
T009	2001.05.12	18:20	19	C9 + LE12.5 + CP990	?	CP990-DSCN 9080
T010	2004.06.26	14:54	9	10-in f/6 + ToUcam at prime focus	1/100	38 frames stacked
T011	2008.09.13	16:15	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	90 frames stacked
T012	2003.03.16	15:55	13	10-in f/6 Royce + 2.5X + ToUcam	1/25	50 frames stacked
T013	2003.03.17	16:49	14	10-in f/6 Royce + 2.5X + ToUcam	1/500	60 frames stacked
T014	2001.08.11	20:42	22	C9 + LE7.5 + CP990	?	CP990-DSCN 9642
T015	2000.11.05	13:35	9	FS128 f/8 + LE12.5 + QV2300	1/10	QV2300-20001105-0018
T016	2000.11.05	13:38	9	FS128 f/8 + LE12.5 + QV2300	1/8	QV2300-20001105-0020
T017	2001.09.25	12:49	8	C9 + LE12.5 + CP990	1/2	CP990-DSCN 9797
T018	2001.01.06	15:17	11	FS102 f/8 + LE7.5 + QV2300	1/8	QV2300-20010106-0041
T019	2000.11.05	13:58	9	FS128 f/8 + LE12.5 + QV2300	1/8	QV2300-20001105-0029
T020	2001.09.25	12:57	8	C9 + LE12.5 + CP990	1/4	CP990-DSCN 9804
T021	2004.09.05	~21:31	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Stacked from 2 video clips
T022	2009.05.02	13:47	7	10-in f/6 Royce + 2.5X + ToUcam	1/33	190 frames stacked
T023	2004.09.25	14:10	11	10 in f/6 Royce + 2.5X + ToUcam	1/50	16 frames stacked
T024, A, B	2002.08.21	14:40	12	FS128 f/8 + LE12.5 + CP990	1/28	CP990-DSCN 5490
T025	2002.12.14	16:40	10	C9 + Or25 + CP990	1/4	CP990-DSCN 5832
T026	2002.12.16	14:02	12	10-in f/6 Royce + 2.5X + ToUcam		2 frames stacked
T027	2002.11.14	14:58	9	C9 + LE12.5 + CP990	1/7	CP990-DSCN 5818
T028	2000.09.12	15:34	14	MK67 (6-in f/12) + PL16 + QV2300	1/10	?
T029	2009.06.30	12:03	8	10-in f/6 Royce + 2.5X + ToUcam	1/50	220 frames stacked
T030	2006.09.04	~14:30	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T031	2009.05.05	13:42	10	10-in f/6 Royce + 2.5X + ToUcam	1/25	158 frames stacked
T032	2002.06.21	13:30	10	C9 + LE12.5 + CP990	1/3	CP990-DSCN 4483 (lost)
T033	2002.12.16	15:12	12	10-in f/6 Royce + 2.5X + ToUcam	1/33	7 frames stacked
T034	2000.06.15	14:36	13	ETX90 Maksutov + PL16 + CP950	1/15	CP950-DSCN 2964
T035	2005.05.22	15:26	14	10-in f/6 Royce + 5X + ToUcam	1/25	82 frames stacked
T036	2006.05.09	14:40	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	120 frames stacked
T037	2006.05.10	~14:52	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T038,	2002.12.16	15:17	12	10-in f/6 Royce + 2.5X + ToUcam		2 frames stacked
T039	2005.01.22	~15:17	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T040, A, B	2000.04.20	18:26	16	FS102 f/8 + K25 + CP950	1/322	CP950-DSCN 1596
	2001.10.02	19:06	15	Kenko 8cm f/8 + Or18 + CP990	1/140	CP990-DSCN 9823
T041	2004.09.04	19:21	20	12.5-in f/6 Royce + 4X + ToUcam	1/25	78 frames stacked
T042	2000.05.07	12:25	3	7x50 finderscope + CP950 at 3X	1/4	CP950-DSCN 1958
	2000.07.28	21:26	27	FS102 f/8 + K25 + CP950	1/7	CP950-DSCN 3399
T043	2001.04.03	10:08	9	FS128 f/8 + LE12.5 + CP990	?	CP990-DSCN 8764
T044, A, B	2001.01.09	Total lunar eclipse		FS102 f/8 + Or25 + QV2300		Mosaic from a batch of images
T045	2009.11.09	~21:45	23	10-in f/6 Royce + 2.5X + DMK31AF	1/44	Stack of 2 video clips
T046	2000.12.07	14:16	11	?	1/8	QV2300-20001207-0002
T047	2000.05.15	14:15	11	FS102 f/8 + LE12.5 + CP950	1/40	CP950-DSCN 2350
T048, A, B	2003.09.11	16:11	15	FS128 f/8 + PL25 + CP995	1/416	CP995-DSCN 9883
T049, A – C	2010.09.15	11:12	7	FS128 f/8 + 1.4X + Canon 550D	1/200	Single frame Img0212
T050	2005.05.21	16:21	13	Orion 6-in f/8 + 4X + ToUcam	1/25	68 frames stacked
T051	2004.08.31	19:07	15	10-in f/6 + ToUcam + IR Blocker	1/500	12 frames stacked
T052	2004.06.26	14:09	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	11 frames stacked
T053	2000.11.05	13:50	9	FS128 f/8 + LE12.5 + QV2300	1/8	QV2300-20001105-0024
T054	2001.08.11	20:21	22	C9 + LE12.5 + CP990	?	CP990-DSCN 9622
T055	2005.04.22	16:34	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/33	69 frames stacked
T056, A – D	2001.09.22	11:27	5	Kenko 8cm f/8 + Or18 + CP990	1/8	CP990-DSCN 9724
T057	2005.04.21	14:17	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	64 frames stacked
T058	2005.01.22	~15:38	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T059	2005.01.22	15:10	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	68 frames stacked
T060	2004.01.06	15:03	14	10-in f/6 Royce + 2.5X + ToUcam	1/50	48 frames stacked
T061	2005.04.22	~16:41	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T062	2004.04.30	14:05	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	19 frames, cropped, 2X resized.
T063	2004.12.17	~10:19	5	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T064	2004.05.29	15:20	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	2 frames stacked
T065, A	2005.04.19	~13:14	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 3 video clips
T066	2000.02.11	13:24	6	FS102 f/8 + PL6.7 + CP950	1/30	CP950-DSCN 0060
T067	2004.05.04	Total lunar eclipse		FS128 f/8 + PL25 + CP995		CP995-DSCN 0035 + 0038
T068	2004.04.30	~13:06	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 2 video clips
T069	2005.04.22	16:00	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	88 frames stacked
T070	2005.11.09	~11:43	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips

Data of Lunar Images

Image Code	Date / Time (UT)		Moon Age	Equipment Used	Exposure (sec)	Raw Image
T071	2004.06.25	12:47	8 days	10-in f/6 Royce + 2.5X + ToUcam	1/50	6 frames stacked
T072	2004.06.26	13:32	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	10 frames stacked
T073	2004.06.26	13:59	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	14 frames stacked
T074	2004.06.26	13:47	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	5 frames stacked
T075	2005.04.18	~12:48	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 5 video clips
T076	2004.06.26	13:53	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	12 frames stacked
T077	2009.11.25	10:47	9	10-in f/6 Royce + 2.5X + DMK31AF	1/60	30 frames/sec
T078, A	2010.07.19	12:36	8	FS128 f/8 + Canon 550D at ISO200	1/400	Single frame Img0164
T079	2004.08.07	20:27	22	10-in f/6 Royce + 2.5X + ToUcam	1/25	27 frames stacked
T080	2004.08.07	19:48	22	10-in f/6 Royce + 2.5X + ToUcam	1/33	9 frames stacked
T081	2005.11.11	~12:43	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T082	2009.11.01	15:29	14	10-in f/6 Royce + 2.5X + DMK31AF	1/90	30 frames/sec
T083	2005.11.11	12:06	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	97 frames stacked
T084	2004.09.05	~21:49	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Two adjacent images
T085	2005.04.18	~14:53	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T086	2002.08.13	~12:00	4	FS102 f/8 + Or25 + CP990		CP990-DSCN 4967 + 5021
T087	2008.09.13	13:52	14	10-in f/6 Royce + 2.5X + ToUcam	1/25	100 frames stacked
T088	2005.04.18	14:56	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/33	52 frames stacked
T089	2004.06.27	13:30	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	18 frames stacked
T090	2006.05.09	15:03	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	130 frames stacked
T091	2009.11.28	12:48	12	10-in f/6 Royce + 1.6X + DMK31AF	1/74	30 frames/sec
T092	2004.06.27	14:25	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	3 frames stacked
T093	2004.09.05	~20:12	21	10-in f/6 Royce + 5X + ToUcam	1/25	Stacked from 3 video clips
T094	2004.07.13	~20:42	26	FS102 + PL25 + CP990, 2X zoom	1 sec	CP990-DSCN 8992+9000(2)
T095	2004.07.13	21:07	26	FS102 + LE12.5 + CP990, 3X zoom	1/8	CP990-DSCN 9005 (2)
T096	2004.09.20	~11:13	6	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T097	2005.11.08	~11:30	6	10 in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T098	2001.08.11	21:01	22	C9 + LE7.5 + CP990	?	CP990-DSCN 9648
T099	2004.07.25	12:16	8	10-in f/6 Royce + 2.5X + ToUcam	1/50	9 frames stacked
T100	2006.08.12	19:49	18	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	180 frames stacked
T101, A, B	2005.04.18	11:29	10	10-in f/6 Royce + 2.5X + ToUcam	1/33	33 frames stacked
T102	2004.08.01	14:22	15	FS128 f/8 + LE12.5 + CP990	1/38	CP990-DSCN 9081(2)
T103	2004.08.01	16:50	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	9 frames stacked
T104	2004.08.01	17:12	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	4 frames stacked
T105, A, B	2004.08.02	17:53	16	10-in f/6 Royce + 2.5X + ToUcam	1/50	16 frames stacked
T106	2009.06.06	15:52	13	10-in f/6 Royce + 2.5X + ToUcam	1/50	Note: 1/4 FOV blocked
T107	2004.08.31	17:14	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T108	2004.08.31	17:04	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T109	2004.08.31	17:27	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T110	2004.08.31	17:16	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T111	2004.08.31	16:53	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T112	2004.08.31	18:38	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	9 frames stacked
T113	2004.08.31	18:54	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	25 frames stacked
T114	2004.08.02	17:24	16	10-in f/6 Royce + 2.5X + ToUcam	1/100	12 frames stacked
T115	2009.05.02	14:08	7	10-in f/6 Royce + 2.5X + ToUcam	1/33	102 frames stacked
T116	2004.10.28	~14:09	15	10 in f/6 Royce + 2.5X + ToUcam	1/100	Mosaic of 2 video clips
T117, A	2004.08.07	19:04	22	FS128 f/8 + LE24 + CP990	1/30	CP990-DSCN 9131 (2)
T118	2006.08.12	21:31	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	160 frames stacked
T119	2004.08.07	~20:36	22	10-in f/6 Royce + 5X + ToUcam	1/25	50 frames (from 5 video clips)
T120	2005.11.09	~12:00	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T121	2005.11.11	~13:08	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T122	2005.05.22	15:44	14	10-in f/6 Royce + 5X + ToUcam	1/25	81 frames stacked
T123	2005.01.22	15:45	12	10-in f/6 Royce + 2.5X + ToUcam	1/33	150 frames stacked
T124, A	2004.08.02	~17:53	16	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T125, A	2009.10.31	15:52	13	10-in f/6 Royce + 2.5X + DMK31AF	1/60	30 frames/sec
T126	2004.08.31	17:38	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	16 frames stacked
T127, A	2010.09.26	16:48	18	FS128 f/8 + Canon 550D at ISO200	1/400	Single frame Img0225
T128	2004.09.05	21:18	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	47 frames stacked
T129	2004.09.05	21:16	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	64 frames stacked
T130	2004.09.05	~20:53	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 6 video clips
T131	2004.09.05	~21:15	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T132	2004.09.05	21:23	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	47 frames stacked
T133	2004.09.05	21:46	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	41 frames stacked
T134	2004.09.05	21:30	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	68 frames stacked
T135	2004.09.05	20:46	21	10-in f/6 Royce + 5X + ToUcam	1/25	90 frames stacked
T136	2004.09.05	21:40	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	69 frames stacked
T137	2004.09.05	21:26	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	87 frames stacked
T138	2004.09.04	~18:18	20	12.5-in f/6 Royce + 4X + ToUcam	1/25	Mosaic of 5 video clips
T139	2005.01.22	~15:34	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T140	2004.12.17	~10:04	5	10 in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips

Data of Lunar Images

Image Code	Date / Time (UT)		Moon Age	Equipment Used	Exposure (sec)	Raw Image
T141	2004.09.20	~12:00	6 days	10 in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T142	2004.09.20	~11:17	6	10 in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T143	2009.11.24	10:35	8	10-in f/6 Royce + 4X + DMK31AF	1/44	30 frames/sec
T144	2006.08.12	21:43	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	180 frames stacked
T145	2004.09.04	~17:28	20	12.5 in f/6 +2.5X + 1.6X + ToUcam	1/25	Mosaic of 4 video clips
T146	2004.09.05	~21:42	21	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T147	2004.09.25	14:12	11	10-in f/6 Royce + 2.5X + ToUcam	1/50	22 frames stacked
T148	2004.09.25	~14:44	11	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T149	2001.08.11	20:19	22	C9 + LE12.5 + CP990	1/8	CP990-DSCN9620
T150	2006.05.09	14:14	12	10-in f/6 Royce + 5X + ToUcam	1/25	190 frames stacked
T151	2006.05.10	14:09	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	200 frames stacked
T152	2006.05.10	~15:06	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T153	2004.09.26	14:22	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	34 frames stacked
T154	2005.04.19	~13:33	11	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T155	2004.09.26	~15:36	12	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 2 video clips
T156	2006.05.10	14:35	13	10-in f/6 Royce + 5X + ToUcam	1/25	200 frames stacked
T157	2004.09.26	~16:50	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T158	2006.05.09	13:56	12	10-in f/6 Royce + 5X + ToUcam	1/25	176 frames stacked
T159	2005.04.21	~14:09	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T160	2004.09.29	~15:32	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	Mosaic of 3 video clips
T161	2006.05.09	13:50	12	10-in f/6 Royce + 5X + ToUcam	1/25	108 frames stacked
T162	2005.11.11	13:04	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	98 frames stacked
T163	2005.11.11	13:22	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	99 frames stacked
T164	2004.12.19	~12:29	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T165	2004.10.03	~21:49	19	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T166	2005.04.21	14:42	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	75 frames stacked
T167	2005.11.09	~11:45	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T168, A	2004.10.03	~21:28	19	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T169	2004.10.03	21:40	19	10-in f/6 Royce + 2.5X + ToUcam	1/50	48 frames stacked
T170	2008.04.15	14:03	9	10-in f/6 Royce + 4X + DMK31AF	1/50	Stack of 3 video clips
T171	2004.09.20	~11:06	6	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 2 video clips
T172	2009.05.02	~13:12	7	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 2 video clips
T173	2004.09.05	20:27	21	10-in f/6 Royce + 5X + ToUcam	1/25	67 frames stacked
T174	2004.05.29	15:19	10	10-in f/6 Royce + 2.5X + ToUcam	1/33	18 frames stacked
T175	2006.01.07	~13:30	7	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 2 video clips
T176	2005.04.23	16:15	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	68 frames stacked
T177	2005.11.11	~11:49	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T178	2004.10.23	~14:19	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T179	2005.04.18	~13:49	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T180	2004.12.15	19:13	3	10-in f/6 Royce + 2.5X + ToUcam	1/50	68 frames stacked
T181, A	2004.11.25	~16:42	13	10-in f/6 Royce + 2.5X + ToUcam	1/100	Mosaic of 3 video clips
T182	2005.04.22	~16:09	14	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T183	2008.11.11	14:53	14	10-in f/6 Royce + 2.5X + ToUcam	1/50	290 frames stacked
T184	2009.10.31	~15:02	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T185	2009.03.14	20:27	18	10-in f/6 Royce + 2.5X + ToUcam	1/33	250 frames stacked
T186	2004.12.17	~10:54	5	10-in f/6 Royce + 2.5X + ToUcam	1/50	Stack of 4 video clips
T187	2004.12.17	~10:43	5	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T188	2006.03.09	~14:11	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T189	2004.12.19	~12:13	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T190	2004.12.19	~13:09	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T191	2004.09.04	~19:08	20	12.5-in f/6 Royce + 4X + ToUcam	1/25	Mosaic of 2 video clips
T192	2004.12.19	~12:41	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T193	2004.12.17	~10:14	5	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T194	2005.01.19	12:18	9	10-in f/6 Royce + 5X + ToUcam	1/25	88 frames stacked
T195	2005.01.22	~15:05	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of a batch of video clips
T196	2004.09.26	16:35	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	50 frames stacked
T197	2007.10.25	~15:15	14	10-in f/6 Royce + 2.5X + ToUcam	1/100	Mosaic of 3 video clips
T198	2006.05.09	14:10	12	10-in f/6 Royce + 5X + ToUcam	1/25	171 frames stacked
T199	2005.04.19	13:36	11	10-in f/6 Royce + 2.5X + ToUcam	1/50	78 frames stacked
T200	2005.01.22	~14:06	12	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T201	2005.04.18	~11:58	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T202	2005.04.18	~14:44	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 3 video clips
T203	2005.04.23	~16:02	15	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T204, A	2005.04.23	~15:50	15	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 6 video clips
T205	2005.04.19	~12:39	11	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T206, A	2005.04.19	~12:35	11	10-in f/6 Royce + 5X + ToUcam	1/25	Mosaic of 3 video clips
T207	2005.04.19	13:40	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	78 frames stacked
T208	2005.04.23	~15:38	15	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T209	2005.04.22	~16:25	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T210	2005.04.19	12:58	11	10-in f/6 Royce + 5X + ToUcam	1/25	54 frames stacked

Data of Lunar Images

Image Code	Date / Time (UT)		Moon Age	Equipment Used	Exposure (sec)	Raw Image
T211	2005.04.21	15:04	13 days	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	68 frames stacked
	2006.05.09	13:31	12	10-in f/6 Royce + 5.5X + ToUcam	1/25	198 frames stacked
T212	2005.04.21	14:29	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	88 frames stacked
T213	2005.04.22	~16:32	14	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T214	2005.04.23	16:08	15	10-in f/6 Royce + 2.5X + ToUcam	1/50	57 frames stacked
T215	2008.11.11	~15:17	14	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 3 video clips
T216, A	2005.04.19	~13:43	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	Mosaic of 3 video clips
T217	2005.04.18	~13:35	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T218	2005.05.22	15:42	14	10-in f/6 Royce + 5X + ToUcam	1/25	75 frames stacked
T219	2005.04.18	11:53	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	67 frames stacked
T220	2005.04.21	13:56	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	65 frames stacked
T221	2005.05.22	15:02	14	10-in f/6 Royce + 5X + ToUcam	1/33	68 frames stacked
T222	2005.05.22	15:42	14	10-in f/6 Royce + 5X + ToUcam	1/33	75 frames stacked
T223	2007.05.25	~11:43	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T224	2005.05.22	~14:31	14	10-in f/6 Royce + 5X + ToUcam	1/25	Mosaic of 2 video clips
T225	2005.05.22	15:11	14	10-in f/6 Royce + 5X + ToUcam	1/25	85 frames stacked
T226	2005.05.23	14:52	15	10-in f/6 Royce + 2.5X + ToUcam	1/100	68 frames stacked
T227	2005.05.22	15:38	14	10-in f/6 Royce + 5X + ToUcam	1/25	88 frames stacked
T228	2005.08.22	~18:56	17	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 3 video clips
T229	2005.08.22	19:07	17	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	93 frames stacked
T230	2005.08.22	19:34	17	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	88 frames stacked
T231	2005.10.14	14:14	11	10-in f/6 Royce + 2.5X + ToUcam	1/33	97 frames stacked
T232	2006.05.09	14:28	12	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	180 frames stacked
T233	2006.05.09	~13:48	12	10-in f/6 Royce + 5X + ToUcam	1/25	Mosaic of 2 video clips
T234	2002.12.16	15:44	12	10-in f/6 Royce + 2.5X + ToUcam	1/33	11 frames stacked
T235	2005.10.19	16:08	16	10 in f/6 Royce + 2.5X + ToUcam	1/50	92 frames stacked
T236	2004.08.02	18:15	16	10 in f/6 Royce + 2.5X + ToUcam	1/50	10 frames stacked
T237	2004.08.02	18:10	16	10 in f/6 Royce + 2.5X + ToUcam	1/50	11 frames stacked
T238	2005.10.19	~16:27	16	10 in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T239	2005.10.20	~17.16	17	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T240	2007.05.29	14:41	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/50	250 frames stacked
T241	2006.08.12	~20:49	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T242	2005.10.21	15:37	18	10-in f/6 Royce + 2.5X + ToUcam	1/50	92 frames stacked
T243	2005.11.09	12:35	7	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	400 frames stacked (testing)
T244	2009.11.24	10:57	8	10-in f/6 Royce + 4X + DMK31AF	1/39	30 frames/sec
T245	2005.11.08	~11:50	6	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T246	2005.11.09	12:41	7	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	150 frames stacked
T247	2004.10.03	21:00	19	10-in f/6 Royce + 2.5X + ToUcam	1/50	48 frames stacked
T248	2005.11.11	~12:19	9	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T249	2005.11.09	11:04	7	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	72 frames stacked
T250	2006.01.07	~13:08	7	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T251	2000.05.15	14:02	11	FS102 f/8 + LE7.5 + CP950	1/13	CP950-DSCN 2354
T252	2006.02.07	~12:00	9	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T253	2006.05.09	~13:37	12	10-in f/6 Royce + 5X + ToUcam	1/25	Mosaic of 2 video clips
T254	2006.03.09	13:26	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	100 frames stacked
T255	2006.03.09	~13:48	10	10-in f/6 Royce + 5X + ToUcam	1/25	Stack of 2 video clips
T256	2006.03.09	13:56	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	190 frames stacked
T257	2006.03.09	~14:53	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 4 video clips
T258	2006.03.09	~15:30	10	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Stack of 3 video clips
T259	2006.03.09	14:08	10	10-in f/6 Royce + 2.5X + ToUcam	1/50	200 frames stacked
T260	2006.04.04	~11:46	6	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T261	2006.05.09	14:02	12	10-in f/6 Royce + 5X + ToUcam	1/25	169 frames stacked
T262	2006.07.02	~12:40	7	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T263	2006.07.31	~12:18	6	10-in f/6 Royce + 2.5X + ToUcam	1/50	Mosaic of 2 video clips
T264	2006.08.12	~20:36	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 6 video clips
T265	2006.08.12	~21:22	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T266	2006.08.12	21:23	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	200 frames stacked
T267	2006.08.12	20:42	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	170 frames stacked
T268, A	2006.08.12	20:27	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	200 frames stacked
T269	2006.08.12	~21:30	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 4 video clips
T270	2006.08.12	~21:11	19	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	Mosaic of 2 video clips
T271	2009.10.31	14.47	13	10-in f/6 + 2.5X + 1.6X + ToUcam	1/25	300 frames stacked
T272	2009.10.03	15:11	15	FS128 f/8 + Canon 350D at ISO100	1/250	Single frame Img3210
T273, A	2010.07.01	20:57	19	FS128 f/8 + Canon 550D at ISO200	1/400	Single frame Img0138
T274	2008.11.11	15:22	14	10-in f/6 Royce + 2.5X + ToUcam	1/50	200 frames stacked

Data of the Moon

Equatorial diameter 赤道直徑	3476 km (0.2725 of Earth's diameter)
Polar diameter 極直徑	2 km less than equatorial
Angular diameter 角直徑	29.4 - 33.5 arcmin (geocentric); 29.8 - 34.1 arcmin (topocentric 地面計)
Axial rotation period 自轉周期	same as sidereal month (1:1 spin-orbit coupling)
Mass 質量	7.348×10^{22} kg (Earth-Moon mass ratio = 81.30)
Mean density 平均密度	3.341 g / cm^3 (0.6 of Earth's density)
Surface gravity 表面引力	1.622 m / sec^2 (1/6 of Earth's gravity), ***Global Map C***.
Surface Escape velocity 表面脫離速度	2.38 km / sec
Albedo 反照率	maria 0.06 highlands 0.17 mean 0.12
Apparent magnitude 目視星等	−12.7 at full moon
Atmosphere 大氣層	very tenuous, ***Note 1***.
Thickness of crust 地殼厚度	average 50 km, generally thicker on farside, ***Global Map A***.
Surface height variation 地形起伏範圍	up to about 16 km, ***Global Map B***.
Surface magnetic field 表面磁場	very weak except few localized anomalies, ***Global Map D***.
Surface temperature 表面溫度	approx. 130^0 C at day to -180^0 C at night
Temperature at 1 m below surface 月面下一米深溫度	-35^0C, approx. constant.
Surface heat flow 表面熱流	average 29 mW / m^2, ***Note 2***.
Tidal Love number 樂甫指數	0.027, ***Note 3***.
Mean distance from Earth 月地平均距離	384 401 km (30 times Earth's diameter)
Increase of distance from Earth 月地距離增加率	3.8 cm / year
Distance of Moon at apogee 遠地點距離	406 700 km (406 712 km on 1984 March 2)
Distance of Moon at perigee 近地點距離	356 400 km (356 375 km on 1912 January 4)
Period of revolution of perigee 近地點移行周期	3232 days (8.85 years)
Mean orbital eccentricity 平均軌道偏心率	0.0549 (variable 0.026 to 0.077), ***Note 4***.
Mean orbital velocity 平均軌道速度	1.023 km / sec
Mean sidereal motion 平均月移行	13.18^0 / day (moving eastward, variable 12^0 to 15^0 / day)
Inclination of orbit to ecliptic 白道與黃道交角	5.14^0 (oscillating between 4.96^0 to 5.31^0 every 173.3 days), ***Note 5***.
Inclination of lunar equator to ecliptic 月球赤道與黃道交角	1.54^0
Inclination of lunar equator to orbit 月球赤道與白道交角	6.68^0

Lunar Months (Epoch J2000)

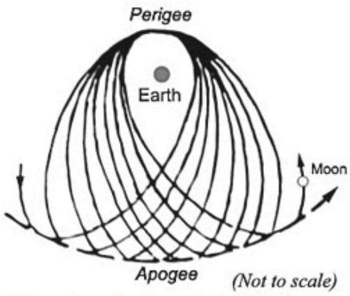
Sidereal month (orbital period) 恆星月	27.321662 days
Synodic month (new moon to new moon) 朔望月	29.530589 days (variable 29.27 to 29.83 days), ***Note 6***.
Anomalistic month (perigee to perigee) 近點月	27.554550 days
Tropical month (equinox to equinox) 分至月	27.321582 days
Draconic month (node to node) 交點月	27.212221 days
Regression of nodes 交點退行	19.34^0 / year (period = 6798 days or 18.61 years), ***Note 7***.

Earth-Moon System

Earth: Moment of inertia about rotation axis 地球慣性矩	$0.331\, M_e R_e^2$ where M_e = Earth's mass & R_e = its radius.
Moon: Moment of inertia about rotation axis 月球慣性矩	$0.394\, M_m R_m^2$ where M_m = Moon's mass & R_m = its radius, ***Note 8***.
Total angular momentum 總角動量	3.48×10^{34} kg・m^2 / sec, ***Note 9***.
Lagrangian points 拉格朗日點	***Note 10***.

Libration of the Moon 月球天平動

	Longitudinal 經天平動	Latitudinal 緯天平動
Optical libration 光學天平動 Displacement (selenocentric) 從月心位移 Period	± 7.88^0 anomalistic month	± 6.85^0 draconic month
Physical libration 物理天平動 Displacement (selenocentric) 從月心位移 Period	± 66" 1 year	± 105" 6 years
Surface area of Moon visible from Earth	59 % maximum	

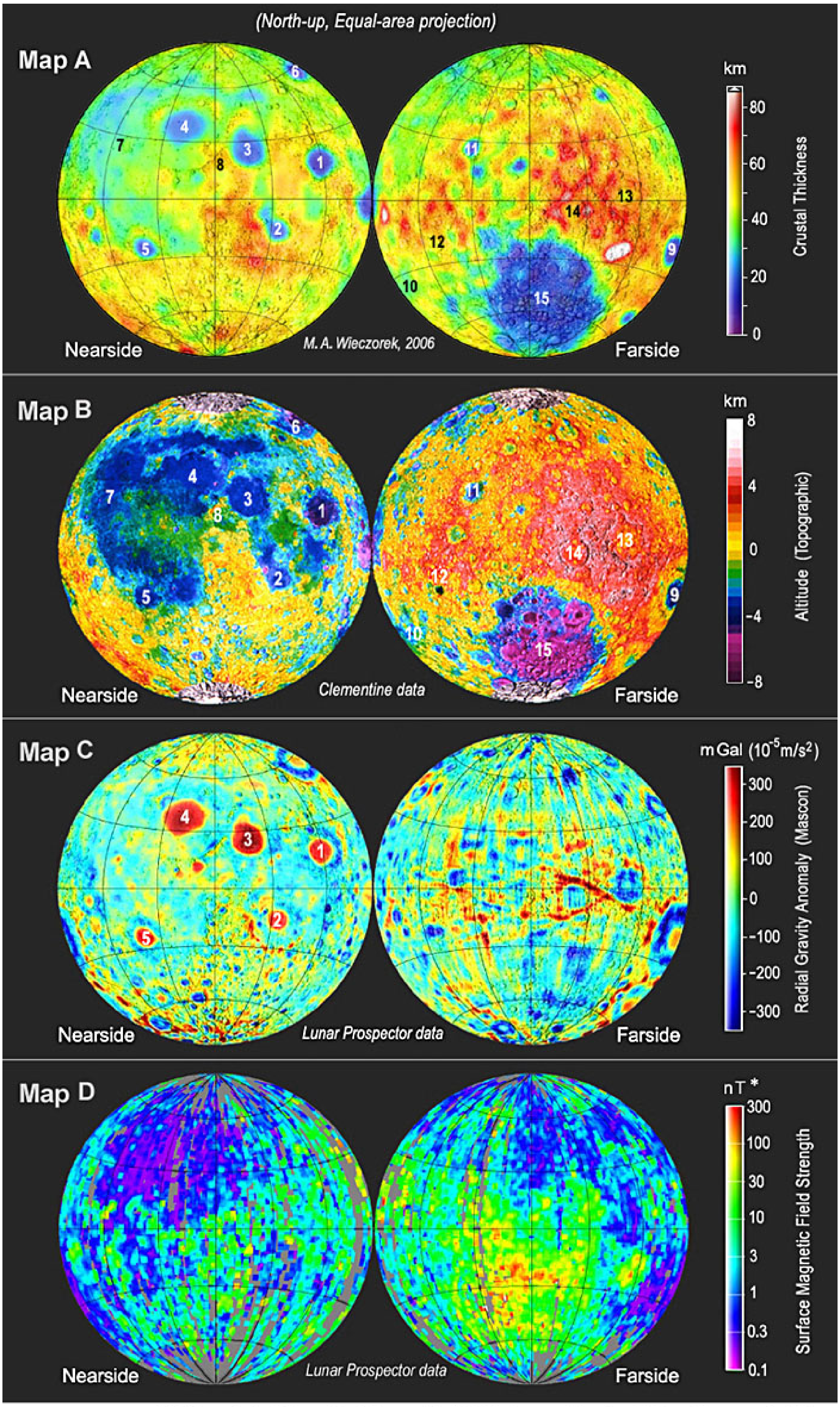


The perigee (and apogee) of the lunar orbit revolves in a period of 8.85 years.

Lunar Geologic Timescale 月球地質紀年

Time (10^9 years ago)	Name of Period	Marking events
4.55 - 4.5		impact debris accretion & melting, global magma ocean
4.5 - 3.92	Pre-Nectarian 前酒海紀	cooling & primary differentiation, crust formation
3.92 - 3.85	Nectarian 酒海紀	intense bombardment , impact basins & highland formation
3.85 - 3.2	Imbrian 雨海紀	volcanism, mare basalt formation
3.2 - 1.1	Eratosthenian 愛拉托遜紀	continuing but less intense bombardment
1.1 - present	Copernican 哥白尼紀	continuing crater formation, regolith

Global Maps — Crustal Thickness, Altitude, Gravity and Magnetic Field



* This scale in nT (nanoTesla) is roughly 10,000 times weaker than the Earth's magnetic field.

Surface features

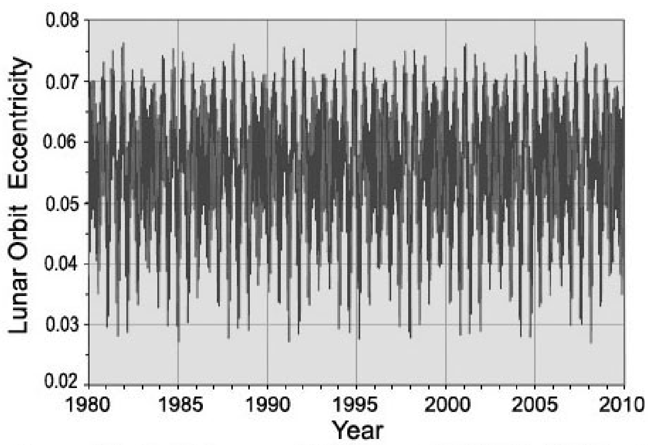
1. Mare Crisium
2. Mare Nectaris
3. Mare Serenitatis
4. Mare Imbrium
5. Mare Humorum
6. Mare Humboldtianum
7. Oceanus Procellarum
8. Montes Apenninus
9. Mare Orientale
10. Mare Australe
11. Mare Moscoviense
12. Tsiolkovskiy
13. Hertzsprung
14. Korolev
15. South Pole-Aitken (*basin, dia. 2300 km*)

Note 1: The Moon has a very tenuous atmosphere whose gases are easily lost to space. It is largely composed of particles from the solar wind and radioactive decay, and atoms from the lunar regolith released by the impacts of meteorites or comets. The main constituents in particles per cubic cm are Helium (^{4}He) - 40000; Neon (^{20}Ne) - 40000; Hydrogen (H_2) - 35000; Argon (^{40}Ar) - 30000. Trace amounts of Methane, Ammonia, Carbon Dioxide, Oxygen, Aluminum, Silicon, Sodium etc were also detected. The atmospheric pressure at night is about 3×10^{-15} bar.

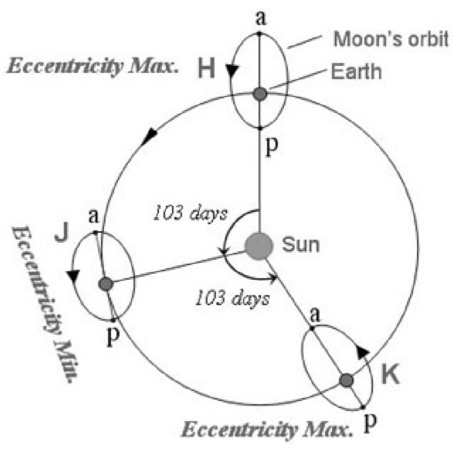
Note 2: The surface heat flow refers to the thermal emission from radioisotopes (mainly ^{40}K, ^{232}Th, ^{235}U and ^{238}U) in the lunar interior to a depth of about 300 km. The data were obtained from the measurements in the Apollo 15 and 17 landing sites. (*Lunar Source Book, 1991.*)

Note 3: The Love number (symbol k_2) is a measure of how a planetary surface and interior move in response to the tidal pull of nearby bodies. The Moon's Love number is 0.027. Its surface is stretched and squeezed as much as 10 cm by the tidal pull of the Earth and Sun. The Earth's surface, with a greater Love number of 0.3, may move as much as 50 cm per day from the pull of the Moon and Sun. The Love number depends on the density and rigidity of the body.

Note 4: According to Jean Meeus (the author of Mathematical Astronomy Morsels), the eccentricity of the Moon's orbit can vary between the extremes 0.026 and 0.077. Eccentricity maximum occurs at position **H** of the attached diagram, where the effect of solar gravity has stretched out the Moon's orbit such that the apogee and perigee line up towards the Sun. Eccentricity minimum occurs 103 days later at position **J**, where the apogee-perigee line are perpendicular to the Sun-Earth line. A new eccentricity maximum is reached again after 103 days at position **K**. Overall the apogee and perigee line up towards the Sun every 206 days or 7 synodic months. Perigean spring tide (greatest high tide) tends to occur every 7 synodic months. Biggest full moon recurs every 14 synodic months.



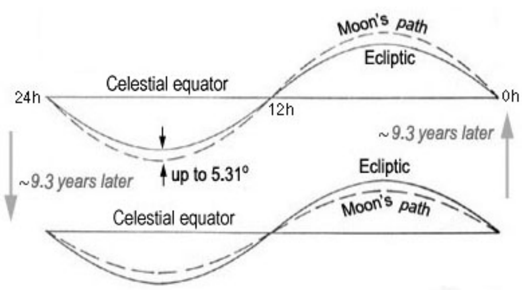
Source: *http://ssd.jpl.nasa.gov/dat/lunar_cmd_2005_jpl_d32296.pdf*



a = apogee p = perigee

The change of lunar orbital eccentricity also results in a displacement of the Moon's ecliptic longitude up to 1.27^0 (over two lunar diameters) with a period of 31.807 days. This displacement was measured by the ancient astronomer Ptolemaeus and is called *Evection* 出差.

Note 5: Due to the regression of the nodes between the lunar orbit and the ecliptic, the Moon's position will vary up to 5.31^0 on either side of the ecliptic, or up to 28.75^0 north or south of the celestial equator. The period of this variation is 18.61 years.

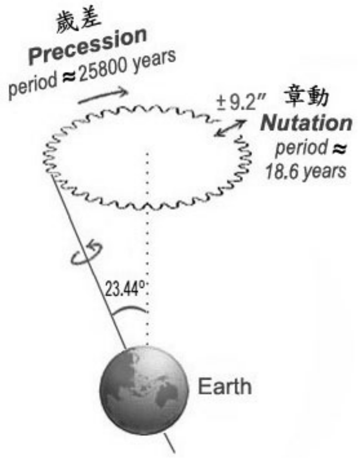


Note 6: The mean value of synodic month is calculated from

1 / synodic month = 1 / sidereal month – 1 / sidereal year,

i.e. 1 / 29.530589 days = 1 / 27.321662 days – 1 / 365.256363 days

Note 7: The positions of the Moon and Sun relative to the Earth are continuously changing. They cause an irregular tidal pull on the Earth's equatorial bulge, and hence a slight periodic oscillation of the Earth's pole superimposed on the precession circle. This slight oscillation, called *Nutation*, has a main amplitude of ± 9.2 arcseconds and a period equal to the regression of the Moon's nodes (18.61 years).



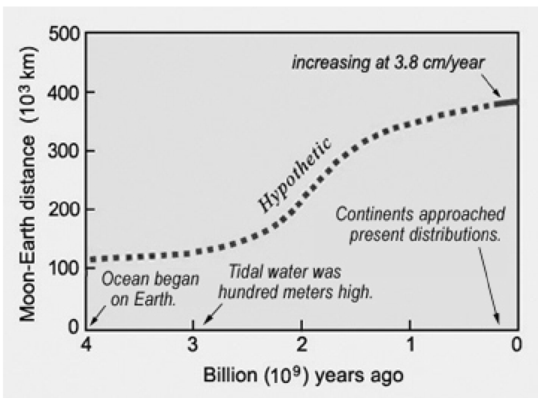
Note 8: The Moon's moment of inertia is slightly below the theoretical value ($^2/_5 \cdot MR^2$) of a homogeneous sphere. It implies that the Moon's interior is not uniform and might contain a small core of denser material.

Note 9: The total angular momentum is theoretically equal to the sum of

the angular momentum of the Moon in its orbit around Earth (2.89×10^{34} kg • m²/s),
the angular momentum of the Earth about its own rotation axes (0.59×10^{34} kg • m²/s), and
the angular momentum of the Moon about its own rotation axes (0.000023×10^{34} kg • m²/s).

The sum is 3.48×10^{34} kg • m²/s. This value is anomalously high compared with that of Mars, Venus or the Earth alone, but is plausible by referring to the giant impact hypothesis of the Moon's origin.

Over time, the movement of continents and ocean water slows down the Earth's rotation. It also causes the Moon to spiral away from Earth by the principle of conservation of angular momentum. The curve at right hypothesizes the change of lunar distance in the past. It is hypothetic because the past distribution of land and sea is unclear. Today the Moon is receding from Earth at average rate of 3.8 cm/year. Total solar eclipses will no longer be possible 0.6 billion years from now.



Note 10: The Lagrangian points refer to 5 points L_1 L_2 L_3 L_4 and L_5 on the orbital plane of the Earth-Moon System. The L_1 L_2 and L_3 are points of quasi-equilibrium. That is, a small perturbation will cause an object in one of these points to drift away. The L_4 and L_5 are points of stable equilibrium.

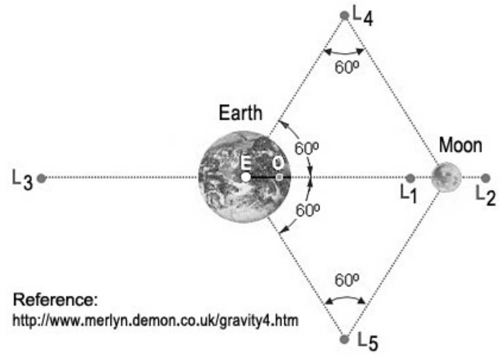
(Assuming circular orbits)

O = center of mass in Earth-Moon system
= 4,700 km from center of Earth

L_1 = 58,000 km from center of Moon V_1 = 0.87 km/s
L_2 = 65,000 km from center of Moon V_2 = 1.20 km/s
L_3 = 381,000 km from center of Earth V_3 = 1.02 km/s

L_4 = 384,400 km from center of Earth V_4 = 1.03 km/s
L_5 = 384,400 km from center of Earth V_5 = 1.03 km/s

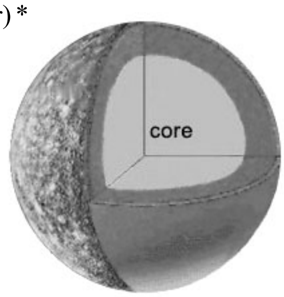
V = Velocity of object (with respect to Earth) to remain on the Lagrangian point



The Moon versus Mercury

The Moon is our nearest celestial companion. Mercury is the planet nearest to the Sun. Despite their similarities in heavily cratered surfaces and wide exposure to the Sun, these two bodies do differ in their courses of development. The following table gives a comparison.

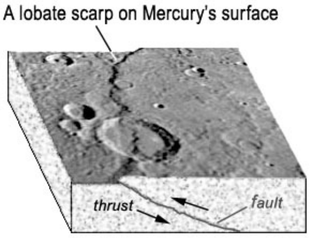
	Moon	**Mercury**
Overall diameter	3476 km	4879 km
Core diameter	< 700 km (?)	3700 km (3/4 overall diameter) *
Mass	7.35×10^{22} kg	33.0×10^{22} kg
Mean density	3.34 g/cc	5.43 g/cc
Orbital period	27.322 days	87.969 days
Orbital eccentricity	0.055	0.206
Orbital inclination	5.1^0	7.0^0
Axial rotation	same as orbital period	2/3 orbital period
Axial tilt	6.7^0	0.0^0
Escape velocity	2.4 km/s	4.3 km/s
Surface gravity (Earth = 1)	0.17	0.38
Surface magnetic field	~ 0.01 % of Earth's	~ 1 % of Earth's
Atmosphere	negligible	negligible
Surface temperature	~ 130^0 C at noon ~ -180^0 C at night	~ 400^0 C at noon (hotter inside Caloris Basin) ~ -180^0 C at night
Regolith	yes	yes
Multi-ring basins	yes	yes
Lava plains	extensive (maria)	not obvious
Lava channels	yes (sinuous rilles)	not obvious
Volcanoes	yes (domes)	not obvious
Craters on highlands	heavily populated	heavily to moderately populated
Central uplift in craters	obvious	relatively low
Secondary craters	widely spread	confined in distribution
Bright rays on surface	yes	yes
Grabens	yes	not obvious
Lobate scarps **	not obvious	yes
Water-ice in polar region	yes	suspicious from radar mapping
Visiting spacecraft	about 40, unmanned (up to 2010 Dec)	Mariner 10 (first flyby: 1974), Messenger (first flyby: 2008)



Mercury's big metallic core

* A model postulated that Mercury was originally larger, with about half the mass of the Earth. A giant impact by another body stripped off a large fraction of Mercury's mantle mass, thus leaving a thinner silicate layer above a now disproportionately large core.

** Lobate scarps are thrust faults on a planetary surface. As the planet contracted, the mantle and surface crust were forced to respond, forming thrust faults where a section of the crust cracks and juts out over another. Many of the resulting cliffs, or scarps, have a semi-circular or lobe-shaped appearance, giving rise to the term "lobate scarps".

A lobate scarp on Mercury's surface


Lobate scarps on Mercury can run for hundreds of kilometers and rise up to 3 km. They are much larger than those found on the Moon. Massive scarps like these lead scientists to believe that Mercury was completely molten in the beginning. If so, Mercury would be expected to shrink more than the Moon as it cooled.

(Reference: The Incredible Shrinking Moon http://www.nasa.gov/mission_pages/LRO/news/shrinking-moon.html)

Glossary

Abundance of Elements 元素豐度 The relative amount of each element in a given object such as a star, planet or satellite.

Accretion 吸積 The increase of mass of a body by the accumulation of smaller objects that collide and stick to it.

Age of the Moon 月齡 The period that has elapsed since the last new moon. It starts at "zero" day (exact new moon).

Albedo 反照率 Fraction of sunlight reflected from a planetary surface. The albedo of lunar maria are 5-10 %; highlands are 12-18 %.

Angular Momentum 角動量 A property of any rotating or revolving body. Its value depends on the distribution of the body's mass and velocity about the axis of rotation or revolution. The total angular momentum of a two-body system (e.g. the Earth and Moon) is constant unless some other body interferes.

Anorthosite 斜長岩 Light-colored rock formed almost solely by plagioclase feldspar, a silicate mineral rich in calcium and aluminum.

Antipode 反極 The point diametrically opposite to another point on a global surface

Apenninus Bench 亞平寧階地 The light-toned, lowly elevated region between the south of Archimedes and the slope of Montes Apenninus facing Mare Imbrium. It is known for the Apollo 15 finding of radioactive non-mare basalts (the so-called KREEP basalts) which represent volcanic flows occurring after the Imbrium impact but before the formation of Mare Imbrium.

Apogee 遠地點 The farthest point on the Moon's orbit from the Earth.

Apollo Missions 阿波羅登月任務 The American NASA (National Aeronautics and Space Administration) program to land humans on the Moon. A total of 12 Apollo astronauts landed on the Moon between July 1969 and December 1972.

Basalt 玄武岩 Dark-colored rock formed from solidified lava. See also **Mare Basalt**.

Bedrock 基岩 The solid rock beneath surface soil (lunar regolith).

Blue Moon 藍月亮 An ambiguous term mistakenly used to denote the second full moon in a calendar month.

Breccia 角礫岩 A rock formed by cementing angular fragments of other rocks during an explosion on impact. The filling material that holds the fragments is called **Matrix** 填質.

Caldera 破火山口 / 塌陷火山口 Crater on the summit of a volcano; collapsed depression over a subsurface magma chamber.

Catena 環形山串 Latin for chain of relatively small craters (plural: catenae).

Colongitude 餘經度 The angular position of the Moon's morning terminator (longitudinal line of sunrise) measured from the selenographic longitude of 0^0 in the same direction of the advancing terminator. Thus the colongitude is approximately 0^0 at the first quarter, 90^0 at the full moon, 180^0 at the last quarter and 270^0 at the new moon.

Complex Crater 複雜環形山 A crater characterized by single or multiple central peaks and terraced walls. Lunar complex craters generally have diameters between 20 and 300 km.

Crater 環形山 / 圓坑 A generic term for circular depression on surface, typically a ring mountain or a walled plain which has relatively large and flat floor. Craters are of either impact in origin or volcanic.

Crescent 娥眉月 The phase of the Moon when it is less than half illuminated as seen from the Earth.

Crust 地殼 The outermost solid layer of a planet or satellite.

Cryptomare 隱蔽月海 "Invisible" pre-existing mare possibly hidden under a layer of breccias.

Crystallization 結晶 Precipitation of minerals out of a cooling magma, sometimes used loosely to mean "differentiation".

Dark Halo Crater 黑暈環形山 Small crater with a halo of dark material. It can be impact in origin or volcanic.

Dark Mantle Deposit 暗地幔覆蓋物 Remarkably dark lava ashes deposited on the lunar surface. In the Apollo soil samples, DMD is rich in submillimeter glassy beads. They are quickly cooled droplets of magma similar to the products of fire-fountains in Hawaii.

Differentiation 分化作用 / 分導 The formation of variety of rock types and layers from an initial single parental magma. Minerals resulted in this process are differentiated by their densities; heavy minerals sink, less dense minerals float.

Dome 拱形小山 / 拱丘 Shield-like gently sloping volcano on the Moon, typically 5 to 20 km in diameter.

Dorsa / Dorsum 皺脊 Latin for wrinkle ridges on a mare, generally formed by lateral compression when the lava subsided in a basin.

Earthshine 地照 / 地球照 The faint illumination on the dark side of a Moon crescent, caused by sunlight reflected from the Earth.

Eccentricity 偏心率 A measure of how far an orbit diverges from a circle. An ellipse gives eccentricity between 0 (exact circle) and 1.

Ejecta 噴出物 Material thrown out from an explosive event, such as a crater-forming impact or volcanic eruption.

Ejecta Blanket 噴出覆蓋物 Ejecta deposited on the area surrounding the rim of an impact crater.

Elongation 距角 The angle between a body and the Sun as seen from Earth. It is measured anticlockwise 0^0 to 360^0 from the Sun.

Equal-area Projection 等面積投影 A method to present a global map in which adjacent grids tend to contain equal surface areas. It reduces the visual distortion associated with Mercator projection (as seen in a regular world map). Commonly used in topography.

Evection 出差 A periodic displacement of the Moon's ecliptic longitude due to changes in the eccentricity of its orbit.

Fra Mauro Formation 弗拉摩洛結構 The hummocky patch on the Fra Mauro region. It is in fact a deposit from the ejecta of the Imbrium impact. Apollo 14 collected its samples from which the impact was determined to occur 3.85 billion years ago.

Farside of the Moon 月背面 The side of the Moon facing away from the Earth.

Fault 斷層 A fracture of surface along which there has been slippage, either vertical or horizontal.

FFC 裂底環形山 Floor-fractured crater, generally big and lying at a mare border. The fractures formed by uplift of subsurface magma.

Fire-Fountain 火泉 A continuous spray of lava from a vent, like a fountain.

First Quarter 上弦 The phase of the Moon that occurs midway between new and full moon, when half of the Moon is illuminated. At first quarter, the Moon has moved 1/4 of its orbit around the Earth and lies 90^0 east of the Sun.

Full Moon 滿月 / 望 The phase of the Moon when it is fully illuminated and 180^0 away from the Sun, as seen from the Earth.

Gal 伽 A unit of gravitational acceleration named after Galileo Galilei. One Gal = 1 cm/sec^2. The Earth has 980 Gal in average.

Ghost Crater 假環形山 The bare hint of a crater formation that has been destroyed or heavily modified by some later action.

Giant Impact Hypothesis 大碰撞論 A popular model for the origin of the Moon from impact debris when a Mars-sized proto-planet collided with the proto-Earth in about 4.5 billion years ago, developed after the Apollo missions.

Graben 地塹 Two parallel faults with a sunken floor between them.

Grazing Impact 掠碰撞 Impact at very low angle, typically few degrees measured from ground.
Harvest Moon 穫月 The full moon closest to the autumnal equinox when it rises at minimum delay time in successive days.
Highlands 高地 Raised areas on the Moon, light-colored, heavily cratered and chemically distinct from the maria.
IAU 國際天文聯合會 International Astronomical Union, an assembly to govern the world of astronomy, founded in 1919.
Igneous 火成的 Referring to processes that involve the formation and solidification of hot, molten magma or lava.
Illumination 照度 Moon phase measured by the fraction of illuminated area of the Moon disc. Full moon gives illumination = 100 %.
Ilmenite 鈦鐵 An iron-titanium enriched mineral ($FeTiO_3$) found in mare basalts; black colored.
Imbrium Sculpture 雨海刻蝕 A pattern of grooves and ridges radial to the Imbrium basin and transecting much of the lunar surface, formed during the Imbrium impact. Because of its wide extent, the trajectories of texture are useful in determining the relative age of rock units far from the basin.
Impact Basin 碰撞盆地 A vast depressed surface of impact origin, size larger than about 300 km, sometimes with visible multi-rings.
Impact Melt 碰撞熔岩 Rocks and debris molten during an impact and then cooled into a smooth, solid deposit.
Isotopes 同位素 Atoms of the same element having same number of protons but different numbers of neutrons in their nuclei.
KREEP 克里普岩 A special type of rock concentrated in Oceanus Procellarum and Mare Imbrium. It is relatively rich in potassium (symbol K), rare-earth elements (REE), phosphorus (P) as well as other radioactive elements such as thorium and uranium.
KREEP Basalt 克里普玄武岩 Unusual non-mare volcanic rock that appears like basalt and contains the KREEP elements.
Lacus 湖 Latin for lake. A "small version" of lunar mare.
Lagrangian Points 拉格朗日點 Five locations in space where a small body (e.g. artificial satellite) can remain in equilibrium despite the gravitational influence of two massive bodies (e.g. the Earth & Moon).
Laser Ranging 激光測距 Establishment of precise Earth-Moon distances by aiming and reflecting laser beams between them.
Last Quarter 下弦 The phase of the Moon that occurs midway between full and new moon, when half of the Moon is illuminated. At last quarter, the Moon has moved 3/4 of its orbit around the Earth and lies 90^0 west of the Sun.
Late Heavy Bombardment 後期猛烈碰撞 The event that postulates the Moon was heavily bombarded around 3.9 billion years ago.
Lava 熔岩 Molten rock that reaches the surface during a volcanic eruption. See also **Magma**.
Lava Tube 熔岩管道 A roofed channel in which lava flows, may form a cave after the flow has cooled or collapse by shock on roof.
Libration 天平動 The apparent vertical or horizontal rocking motions of the Moon as it orbits around the Earth. The amount of libration is measured by the shift of longitude and latitude at the center of the Moon disc.
Lobate Scarp 葉狀懸崖 A lobe-shaped scarp, resulted from lateral thrust on surface cracks as a planet cooled and contracted.
Love Number, Tidal 樂甫指數 A measure of how a planetary surface and interior move in response to the tidal pull of nearby bodies.
LTP 月面暫變現象 Abbreviation for "Lunar Transient Phenomena" or "Transient Lunar Phenomena". A controversial observed phenomena of temporary changes in color, brightness or shape on the lunar surface.
Lunation (Synodic Month) 朔望月 The period of time taken for the Moon to go through a complete cycle of phases.
Magma 岩漿 Subsurface molten rock. When it reaches the surface during a volcanic eruption, it is called *lava*.
Mantle 幔 / 地幔 The layer beneath a planetary crust in which magma resides (if the planet or satellite has not been fully solidified).
Mare 海 / 月海 Latin for sea (plural: maria). The broad dark plain formed from ancient lava outflow from the Moon's interior.
Mare Basalt 月海玄武岩 Dark rock on lunar maria, enriched by heavy metals like iron and titanium. Few samples of mare basalt from the Apollo missions are vesicular; they suggest that trapped gases escaped from the rocks during mare formation.
Mascon 質量瘤 / 重力異常區 Abbreviated from the term "mass concentration". A zone on the Moon composed of relatively dense material, as evidenced by an increased gravitational pull on orbiting spacecraft.
Megadome 大型拱地 Unofficial term. In this book it means a lowly raised plateau with surface sculpture, diameter 30 km or more.
Megaregolith 大規模碎石表層 Broad layer of debris and fractured bedrocks created by impacts on the outmost few kilometers of the lunar crust.
Meteoroid 流星體 Small low-mass interplanetary debris. A meteoroid that hits the Earth's or lunar surface is called **meteorite** 隕石.
Mg-suite 富鎂結晶岩套 A series of magnesium-rich rocks that make up a fraction (perhaps 10%) of the lunar crust, distinct from the anorthosites.
Mineral 礦物 Inorganic solid with a definite composition and crystal structure formed through geologic processes. Minerals are classified according to their chemical compositions. They are the basic components of rock.
Moment of Inertia 慣性矩 A measure of a body's ability to resist changes in its angular velocity about a given axis.
Mons 山 Latin for mountain. A group of isolated mountains or mountain ranges are Latinized as **Montes** 山脈.
Moonquake 月震 Sudden trembling of the Moon caused by the abrupt release of internal energy, meteorite impacts or landslides.
Multi-ring Structure 多環結構 The multiple, concentric mountain rings associated with an impact basin.
Nearside of the Moon 月正面 The side of the Moon facing the Earth.
New Moon 新月 / 朔 The phase of the Moon when it is directly between the Earth and the Sun.
Node 交點 In this book, it refers to one of the intersecting points between the plane of the Moon's orbit and the Earth's orbit (ecliptic).
Oceanus 洋 Latin for ocean. The "large version" of lunar mare. Oceanus Procellarum is the only feature so named.
Olivine 橄欖石 A silicate mineral rich in iron and magnesium; greenish; found in basalts on the Earth and Moon.
Outgassing 釋氣 / 排氣 The release of gases by heating or volcanic activities. Large-scale outgassing may result in an atmosphere.
Palus 沼 Latin for marsh or swamp. A "small version" of lunar mare.
Perigee 近地點 The nearest point on the Moon's orbit from the Earth.
Phase 月相 Illuminated portion of the Moon disc. There are four specific phases: new moon, first quarter, full moon and last quarter.
Pit 小坑 A meter-sized shallow depression on surface, smaller than a craterlet. The distinction between pit and craterlet is arbitrary.
Plagioclase Feldspar 斜長石 A silicate mineral rich in aluminum and calcium; common in anorthosite, the rock of the lunar crust.
Plutonic Rock 深成岩 Rock crystallized at great depth, often coarse-grained due to very slow rates of cooling, e.g. granite 花崗岩.
Promontorium 岬 / 海角 Latin for promontory or cape.
Pyroclastic 火成碎屑 "Fire-broken" fragmental rocks and ashes produced from explosive volcanic eruptions, e.g. a fire-fountain.
Pyroxene 輝石 A silicate mineral rich in iron, magnesium and calcium; brown to black colored; common in mare basalt.

Radiometric Dating 放射性同位素計年 Age-determination of rocks by comparing the decay of radioactive elements such as the isotopes of potassium (^{40}K), rubidium (^{87}Rb) or uranium (^{235}U) embedded in the samples.
Rays, Lunar 月面輻射紋 Streaks (normally bright) radiating from some impact craters of the Moon.
Regolith, Lunar 月壤 / 浮土 / 表層屑 From the Greek for "blanket of stone". A layer of loose and broken rock and dust that exist almost everywhere on the lunar surface. It contains a small amount of tiny, black glass beads produced by micrometeoroid impacts.
Remote Sensing 遙感 Gathering of information without actual physical contact with what is being observed.
Rima 月溪 / 溝紋 Latin for rille (plural: rimae). A loose term for narrow and relatively long cleft, slumped channel, valley, graben or fracture on the lunar surface. Sinuous rilles are solidified lava flow. Linear or arcuate rilles are likely caused by lateral tension.
Ritcher Scale 黎克特地震等級 A scale to determine the magnitude of earthquake and moonquake. Each whole number increase in scale magnitude represents 31.6 times more energy release than the preceding magnitude. Thus magnitude 8.0 releases 1000 times more energy than magnitude 6.0. Magnitudes below about 2.0 are generally not noticed by human.
Roche Limit 洛希極限 The minimum distance from a planet's center at which a satellite will not be disrupted by the planet's tidal force. It is material density dependent. For the current Earth-Moon system, the Roche limit is about 2.9 Earth radii or 19,000 km from Earth's center.
Rock 岩 / 岩石 A solid mass on the crust of a planet or satellite, largely composed of silicates (silicon and oxygen) while the rest may be one or more types of other minerals. Rocks are named by their appearance, or more specifically, by mineral contents.
Rubble Pile 碎石堆 A weak aggregate of large and small debris held together by gravity rather than material strength.
Rupes 懸崖 / 峭壁 / 斷層 Latin for scarp, cliff or fault.
Saros 沙羅周期 A cycle of nearly identical lunar or solar eclipses that recur every 223 lunations (6585.32 days or 18.03 years).
Secondary Craters 次級環形山 / 次級碰撞坑 Impact craters formed by the ejecta of a larger crater.
Seeing 視寧度 A measure of the steadiness of air through which a celestial object is observed.
Seismometry 地震測量 Measurement of seismic waves, such as those produced by earthquakes or moonquakes.
Selenographic 月面的 Belonging or relating to the surface of the Moon. "Selene" is the Greek goddess of the Moon.
Shield Volcano 盾形火山 Volcano that appears in gently sloping cone, constructed of solidified lava flows.
Shock Wave 激波 An abrupt ripple of compression across a medium, due to a fast object hitting on or moving through the medium.
Silicates 硅酸鹽 The most abundant group of rock forming minerals in which silicon tetrahedra (SiO_4) are always the main building blocks. Do not mix silicate with silica (SiO_2).
Simple Crater 簡單圓坑 A bowl-shaped lunar crater with crested rim, generally below 15 km in diameter, depth-diameter ratio 1:5.
Sinus 灣 Latin for bay. A "small version" of lunar mare, usually in the appearance of a bay but can be irregular in shape.
Soil, Lunar 月壤 Unofficial description of the lunar regolith although it is remarkably distinct from the organic soil on Earth.
Solar Wind 太陽風 The wind from the Sun's corona which carries electrons, and (to lesser extent) the nuclei of hydrogen and helium. It has a spiral magnetic field because of the Sun's rotation and the charged particles blowing at high speed of about 50 - 700 km/s.
Spectral Reflectance 頻譜反射 Relative amount of light at specific wavelengths reflected (or absorbed in alternative sense) from a material. This quantity is useful to characterize the element and mineral compositions of a planetary surface.
Spectrometer 頻譜儀 An instrument used to measure the properties of light over a specific portion of the electromagnetic spectrum.
Spring Tide 大潮 The tide at new or full moon that gives maximum difference in water level between high and low tides. It refers to the way that the water level "springs up" to a greater than normal height, and has nothing to do with the yearly season called spring.
Stratigraphy 地層學 The study of stratified (layered) rocks relating to the history of a planet or satellite.
Sub-solar Point 日下點 The ground point where the Sun is at the zenith.
Superposition 疊置 A principle stating that strata (rocky layers) on top are usually younger although subsequent movements or disturbances may overturn the sequence. By this principle, small craters on the Moon are usually superposed on larger ones.
Swirl, Lunar 月面漩渦 The rare lunar feature that is bright and swirling like cream in coffee. Reiner Gamma is the best example.
Taurus-Littrow 金牛山・利特洛區 Lunar region where the Apollo 17 landed and drilled for DMD (dark mantle deposit) samples.
Tectonics 地殼構造作用 Large-scale movements of planetary crust, such as land uplift to form mountains and slipping to form faults.
Terminator 明暗界線 The boundary on the Moon between day and night, or between light and shadow. At the morning terminator, the is rising over that part of the Moon; at the evening terminator, the Sun is setting.
Terraced Wall 台地牆 The inner wall (of a lunar crater) that appears in terrace structure.
Terrain (Terrane) 地體 / 地勢 A generic term referring to any surface area with a distinctive geological character.
Tesla 特斯拉 A unit of magnetic field strength, symbol T. The Earth's surface magnetic field is about 0.00005T or 1/200 of a small bar magnet. The Moon's surface magnetic field is virtually depleted, in order of nano-Tesla or 10,000 times weaker than that of Earth.
Tidal Force 引潮力 / 起潮力 The ability of a celestial body A to raise tides on another body B. It is quantified by the difference of gravitational forces experienced by B between its surface and center, and is inversely proportional to the cube of the distance between the two bodies. The lunar tidal force acting on Earth is 2.2 times greater than the Sun's tidal force.
Topography 地形學 / 地形測量學 The study of the shape and irregularity of a planetary surface.
Umbra 本影 The darker core of the shadow of the Earth, typically cone shaped, and surrounded by a lighter penumbra shadow. Within the umbra, the Moon is completely obscured from direct sunlight; a total lunar eclipse will be seen on Earth.
UT 世界時 Abbreviation for Universal Time, same as Greenwich Mean Time which is the mean solar time on the meridian of Greenwich in England. Hong Kong local time is 8 hours ahead of UT.
Vallis 谷 / 月谷 / 槽 Latin for lunar valley that appears as a broad trough of volcanic origin or a chain of overlapping craters.
Viscosity 粘度 The property of a fluid that resists internal flow. The lunar lava is not rich in silicates ('*mafic*' lava) and hence low in viscosity, like motor-oil. By contrast, the lava on Earth is higher in silicates ('*felsic*' lava), making it more like toothpaste.
Volatile 揮發的 Easy to vaporize. Volatile substances have low boiling points, e.g. water, hydrogen, nitrogen, methane, ammonia, CO_2.
Volcanism 火山作用 The planetary process of interior melting and transfer of internal molten materials and gases to the surface.
Waning Moon 虧月 The (decreasing) phase of the Moon after the full moon and before the new moon.
Waxing Moon 盈月 The (increasing) phase of the Moon after the new moon and before the full moon.
Wrinkle Ridge 皺脊 Sometimes called mare ridges. See **Dorsa / Dorsum**.

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30. Lunar Meteorites http://meteorites.wustl.edu/lunar/howdoweknow.htm
31. Apparent depth/apparent diameter relation for lunar craters http://adsabs.harvard.edu/full/1977LPSC....8.3427P
32. Lunar Gravity, Topography, Crustal Thickness http://www.ipgp.fr/~wieczor/CrustalThicknessArchive/CrustalThickness.html
33. Lunar Constants and Models Document http://ssd.jpl.nasa.gov/dat/lunar_cmd_2005_jpl_d32296.pdf
34. 月球科學概論 Introduction to Lunar Science (Chinese text), China Astronautic Publishing House, ISBN 7-80218-001-5
35. Mapping and Naming the Moon: A History of Lunar Cartography and Nomenclature, Ewen A. Whitaker, 2003.

Other Web Resources

36. A Brief History of Lunar Mapping https://forum.hkas.org.hk/Web/Lunar_mapping_history.doc
37. Determination of Lunar Surface Heights https://forum.hkas.org.hk/Web/Crater_diameter_depth.doc
38. The-Moon Wiki and LPOD (Lunar Photo of the Day) http://the-moon.wikispaces.com
39. Lunar Science Results http://www.lpi.usra.edu/expmoon/science/science_index.html
40. Volcanic Eruption on the Moon (DMDs) http://www.psrd.hawaii.edu/Feb97/PSRD-MoonVolcanics.pdf *
41. Giant Impact Hypothesis: Strengths & Weaknesses http://en.wikipedia.org/wiki/Giant_impact_hypothesis
42. Late Heavy Bombardment http://en.wikipedia.org/wiki/Late_Heavy_Bombardment
43. Lunar Transient Phenomena (LTP) http://en.wikipedia.org/wiki/Transient_lunar_phenomenon
44. Moonquake http://science.nasa.gov/headlines/y2006/15mar_moonquakes.htm
45. Moondust http://science.nasa.gov/headlines/y2006/28dec_truefake.htm
46. Lunar Swirls http://www.lpi.usra.edu/meetings/lpsc2006/pdf/1230.pdf
47. Floor-Fractured Craters http://www.lpod.org/cwm/DataStuff/ffc.htm
48. Water-ice on the Moon http://www.nasa.gov/mission_pages/Mini-RF/multimedia/feature_ice_like_deposits.html
49. Moon's Heart Melted http://www.jpl.nasa.gov/releases/2002/release_2002_37.html
50. Incredible Shrinking Moon http://www.nasa.gov/mission_pages/LRO/news/shrinking-moon.html
51. Selenology Today (Lunar Dome Catalog) http://digilander.libero.it/glrgroup/
52. ALPO List of Lunar Bright Rayed Craters http://www.zone-vx.com/alpo-rays-table.pdf
53. Color of The Moon http://www.colormoon.pt.to/
54. An Amateur's Moon, Alexander Vandenbohede http://users.pandora.be/lunarsite/
55. Past, Present, and Future Eclipses http://eclipse.gsfc.nasa.gov/eclipse.html

* *Recommended primer to lunar science.*

Nearside

Crater Lat. Long. Dia. (+Latitude = North –Latitude = South +Longitude = East –Longitude = West Diameter in km)

Crater	Lat.	Long.	Dia.
Abbot	5.6	54.8	10
Abel	-34.5	87.3	122
Abenezra	-21.0	11.9	42
Abetti	20.1	27.8	1.5
Abulfeda	-13.8	13.9	65
Acosta	-5.6	60.1	13
Adams	-31.9	68.2	66
Agatharchides	-19.8	-30.9	48
Agrippa	4.1	10.5	44
Airy	-18.1	5.7	36
Akis	20.0	-31.8	2
Alan	-10.9	-6.1	2
Al-Bakri	14.3	20.2	12
Albategnius	-11.7	4.3	114
Aldrin	1.4	22.1	3
Alexander	40.3	13.5	81
Alfraganus	-5.4	19.0	20
Alhazen	15.9	71.8	32
Aliacensis	-30.6	5.2	79
Almanon	-16.8	15.2	49
Al-Marrakushi	-10.4	55.8	8
Aloha	29.8	-53.9	3
Alpetragius	-16.0	-4.5	39
Alphonsus	-13.7	-3.2	108
Ameghino	3.3	57.0	9
Ammonius	-8.5	-0.8	8
Amontons	-5.3	46.8	2
Amundsen	-84.3	85.6	101
Anaxagoras	73.4	-10.1	50
Anaximander	66.9	-51.3	67
Anaximenes	72.5	-44.5	80
Anděl	-10.4	12.4	35
Ango	20.5	-32.3	1
Angström	29.9	-41.6	9
Ann	25.1	-0.1	3
Annegrit	29.4	-25.6	1
Ansgarius	-12.7	79.7	94
Anville	1.9	49.5	10
Apianus	-26.9	7.9	63
Apollonius	4.5	61.1	53
Arago	6.2	21.4	26
Aratus	23.6	4.5	10
Archimedes	29.7	-4.0	82
Archytas	58.7	5.0	31
Argelander	-16.5	5.8	34
Ariadaeus	4.6	17.3	11
Aristarchus	23.7	-47.4	40
Aristillus	33.9	1.2	55
Aristoteles	50.2	17.4	87
Armstrong	1.4	25.0	4
Arnold	66.8	35.9	94
Artemis	25.0	-25.4	2
Artsimovich	27.6	-36.6	8
Aryabhata	6.2	35.1	22
Arzachel	-18.2	-1.9	96
Asada	7.3	49.9	12
Asclepi	-55.1	25.4	42
Aston	32.9	-87.7	43
Atlas	46.7	44.4	87
Atwood	-5.8	57.7	29
Autolycus	30.7	1.5	39
Auwers	15.1	17.2	20
Auzout	10.3	64.1	32
Avery	-1.4	81.4	9
Azophi	-22.1	12.7	47
Baade	-44.8	-81.8	55
Babbage	59.7	-57.1	143
Back	1.1	80.7	35
Baco	-51.0	19.1	69
Baillaud	74.6	37.5	89
Bailly	-66.5	-69.1	287
Baily	49.7	30.4	26
Balboa	19.1	-83.2	69
Ball	-35.9	-8.4	41
Balmer	-20.3	69.8	138
Banachiewicz	5.2	80.1	92
Bancroft	28.0	-6.4	13
Banting	26.6	16.4	5
Barkla	-10.7	67.2	42
Barnard	-29.5	85.6	105
Barocius	-44.9	16.8	82
Barrow	71.3	7.7	92
Bartels	24.5	-89.8	55
Bayer	-51.6	-35.0	47
Beals	37.3	86.5	48
Beaumont	-18.0	28.8	53
Beer	27.1	-9.1	9
Behaim	-16.5	79.4	55

Crater	Lat.	Long.	Dia.
Beketov	16.3	29.2	8
Béla	24.7	2.3	11
Bel'kovich	61.1	90.2	214
Bellot	-12.4	48.2	17
Bernoulli	35.0	60.7	47
Berosus	33.5	69.9	74
Berzelius	36.6	50.9	50
Bessarion	14.9	-37.3	10
Bessel	21.8	17.9	15
Bettinus	-63.4	-44.8	71
Bianchini	48.7	-34.3	38
Biela	-54.9	51.3	76
Bilharz	-5.8	56.3	43
Billy	-13.8	-50.1	45
Biot	-22.6	51.1	12
Birmingham	65.1	-10.5	92
Birt	-22.4	-8.5	16
Black	-9.2	80.4	18
Blagg	1.3	1.5	5
Blancanus	-63.8	-21.4	117
Blanchinus	-25.4	2.5	61
Bliss	53.0	-13.5	20
Bobillier	19.6	15.5	6
Bode	6.7	-2.4	18
Boethius	5.6	72.3	10
Boguslawsky	-72.9	43.2	97
Bohnenberger	-16.2	40.0	33
Bohr	12.4	-86.6	71
Boltzmann	-74.9	-90.7	76
Bombelli	5.3	56.2	10
Bonpland	-8.3	-17.4	60
Boole	63.7	-87.4	63
Borda	-25.1	46.6	44
Borel	22.3	26.4	4
Boris	30.6	-33.5	1
Born	-6.0	66.8	14
Boscovich	9.8	11.1	46
Boss	45.8	89.2	47
Bouguer	52.3	-35.8	22
Boussingault	-70.2	54.6	142
Bowen	17.6	9.1	8
Brackett	17.9	23.6	8
Brayley	20.9	-36.9	14
Breislak	-48.2	18.3	49
Brenner	-39.0	39.3	97
Brewster	23.3	34.7	10
Brianchon	75.0	-86.2	134
Briggs	26.5	-69.1	37
Brisbane	-49.1	68.5	44
Brown	-46.4	-17.9	34
Bruce	1.1	0.4	6
Brunner	-9.9	90.9	53
Buch	-38.8	17.7	53
Bullialdus	-20.7	-22.2	60
Bunsen	41.4	-85.3	52
Burckhardt	31.1	56.5	56
Bürg	45.0	28.2	39
Burnham	-13.9	7.3	24
Büsching	-38.0	20.0	52
Byrd	85.3	9.8	93
Byrgius	-24.7	-65.3	87
C. Herschel	34.5	-31.2	13
C. Mayer	63.2	17.3	38
Cabeus	-84.9	-35.5	98
Cajal	12.6	31.1	9
Calippus	38.9	10.7	32
Cameron	6.2	45.9	10
Campanus	-28.0	-27.8	48
Cannon	19.9	81.4	56
Capella	-7.5	35.0	49
Capuanus	-34.1	-26.7	59
Cardanus	13.2	-72.5	49
Carlini	33.7	-24.1	10
Carlos	24.9	2.3	4
Carmichael	19.6	40.4	20
Carpenter	69.4	-50.9	59
Carrel	10.7	26.7	15
Carrillo	-2.2	80.9	16
Carrington	44.0	62.1	30
Cartan	4.2	59.3	15
Casatus	-72.8	-29.5	108
Cassini	40.2	4.6	56
Catalán	-45.7	-87.3	25
Catharina	-18.1	23.4	104
Cauchy	9.6	38.6	12
Cavalerius	5.1	-66.8	57
Cavendish	-24.5	-53.7	56
Caventou	29.8	-29.4	3

Crater	Lat.	Long.	Dia.
Cayley	4.0	15.1	14
Celsius	-34.1	20.1	36
Censorinus	-0.4	32.7	3
Cepheus	40.8	45.8	39
Chacornac	29.8	31.7	51
Challis	79.5	9.2	55
Chang-Ngo	-12.7	-2.1	3
Charles	29.9	-26.4	1
Chevallier	44.9	51.2	52
Ching-Te	20.0	30.0	4
Chladni	4.0	1.1	13
Cichus	-33.3	-21.1	40
Clairaut	-47.7	13.9	75
Clausius	-36.9	-43.8	24
Clavius	-58.8	-14.1	245
Cleomedes	27.7	56.0	125
Cleostratus	60.4	-77.0	62
Clerke	21.7	29.8	6
Collins	1.3	23.7	2
Colombo	-15.1	45.8	76
Condon	1.9	60.4	34
Condorcet	12.1	69.6	74
Conon	21.6	2.0	21
Cook	-17.5	48.9	46
Copernicus	9.7	-20.1	93
Courtney	25.1	-30.8	1
Cremona	67.5	-90.6	85
Crile	14.2	46.0	9
Crozier	-13.5	50.8	22
Crüger	-16.7	-66.8	45
Curie	-22.9	91.0	151
Curtis	14.6	56.6	2
Curtius	-67.2	4.4	95
Cusanus	72.0	70.8	63
Cuvier	-50.3	9.9	75
Cyrillus	-13.2	24.0	98
Cysatus	-66.2	-6.1	48
da Vinci	9.1	45.0	37
Dag	18.7	5.3	0.5
Daguerre	-11.9	33.6	46
Dale	-9.6	82.9	22
Dalton	17.1	-84.3	60
Daly	5.7	59.6	17
Damoiseau	-4.8	-61.1	36
Daniell	35.3	31.1	29
Darney	-14.5	-23.5	15
d'Arrest	2.3	14.7	30
Darwin	-20.2	-69.5	120
Daubrée	15.7	14.7	14
Davy	-11.8	-8.1	34
Dawes	17.2	26.4	18
de Gasparis	-25.9	-50.7	30
de Gerlache	-88.5	-87.1	32
de La Rue	59.1	52.3	134
de Morgan	3.3	14.9	10
de Sitter	80.1	39.6	64
de Vico	-19.7	-60.2	20
Debes	29.5	51.7	30
Dechen	46.1	-68.2	12
Delambre	-1.9	17.5	51
Delaunay	-22.2	2.5	46
Delia	-10.9	-6.1	2
Delisle	29.9	-34.6	25
Delmotte	27.1	60.2	32
Deluc	-55.0	-2.8	46
Dembowski	2.9	7.2	26
Democritus	62.3	35.0	39
Demonax	-77.9	60.8	128
Desargues	70.2	-73.3	85
Descartes	-11.7	15.7	48
Deseilligny	21.1	20.6	6
Deslandres	-33.1	-4.8	256
Diana	14.3	35.7	2
Dionysius	2.8	17.3	18
Diophantus	27.6	-34.3	17
Dollond	-10.4	14.4	11
Donati	-20.7	5.2	36
Donna	7.2	38.3	2
Doppelmayer	-28.5	-41.4	63
Dove	-46.7	31.5	30
Draper	17.6	-21.7	8
Drebbel	-40.9	-49.0	30
Drygalski	-79.3	-84.9	149
Dubyago	4.4	70.0	51
Dunthorne	-30.1	-31.6	15
Eckert	17.3	58.3	2
Eddington	21.3	-72.2	118
Egede	48.7	10.6	37

Crater	Lat.	Long.	Dia.
Eichstadt	-22.6	-78.3	49
Eimmart	24.0	64.8	46
Einstein	16.3	-88.7	198
Elger	-35.3	-29.8	21
Elmer	-10.1	84.1	16
Encke	4.6	-36.6	28
Endymion	53.9	57.0	123
Epigenes	67.5	-4.6	55
Epimenides	-40.9	-30.2	27
Eratosthenes	14.5	-11.3	58
Esclangon	21.5	42.1	15
Euclides	-7.4	-29.5	11
Euctemon	76.4	31.3	62
Eudoxus	44.3	16.3	67
Euler	23.3	-29.2	27
Fabbroni	18.7	29.2	10
Fabricius	-42.9	42.0	78
Fahrenheit	13.1	61.7	6
Faraday	-42.4	8.7	69
Faustini	-87.3	77.0	39
Fauth	6.3	-20.1	12
Faye	-21.4	3.9	36
Fedorov	28.2	-37.0	6
Felix	25.1	-25.4	1
Fermat	-22.6	19.8	38
Fernelius	-38.1	4.9	65
Feuillée	27.4	-9.4	9
Finsch	23.6	21.3	4
Firmicus	7.3	63.4	56
Flammarion	-3.4	-3.7	74
Flamsteed	-4.5	-44.3	20
Fontana	-16.1	-56.6	31
Fontenelle	63.4	-18.9	38
Foucault	50.4	-39.7	23
Fourier	-30.3	-53.0	51
Fra Mauro	-6.1	-17.0	101
Fracastorius	-21.5	33.2	112
Franck	22.6	35.5	12
Franklin	38.8	47.7	56
Franz	16.6	40.2	25
Fraunhofer	-39.5	59.1	56
Fredholm	18.4	46.5	14
Freud	25.8	-52.3	2
Furnerius	-36.0	60.6	135
G. Bond	32.4	36.2	20
Galen	21.9	5.0	10
Galilaei	10.5	-62.7	15
Galle	55.9	22.3	21
Galvani	49.6	-84.6	80
Gambart	1.0	-15.2	25
Gardner	17.7	33.8	18
Gärtner	59.1	34.6	115
Gassendi	-17.6	-40.1	101
Gaston	30.9	-34.0	2
Gaudibert	-10.9	37.8	34
Gauricus	-33.8	-12.6	79
Gauss	35.7	79.0	177
Gay-Lussac	13.9	-20.8	26
Geber	-19.4	13.9	44
Geissler	-2.6	76.5	16
Geminus	34.5	56.7	85
Gemma Frisius	-34.2	13.3	87
Gerard	44.5	-80.0	90
Gibbs	-18.4	84.3	76
Gilbert	-3.2	76.0	112
Gill	-63.9	75.9	66
Gioja	83.3	2.0	41
Glaisher	13.2	49.5	15
Glushko	8.4	-77.6	43
Goclenius	-10.0	45.0	72
Goddard	14.8	89.0	89
Godin	1.8	10.2	34
Goldschmidt	73.2	-3.8	113
Golgi	27.8	-60.0	5
Goodacre	-32.7	14.1	46
Gould	-19.2	-17.2	34
Grace	14.2	35.9	1
Graff	-42.4	-88.6	36
Greaves	13.2	52.7	13
Grimaldi	-5.5	-68.3	172
Grove	40.3	32.9	28
Gruemberger	-66.9	-10.0	93
Gruithuisen	32.9	-39.7	15
Guericke	-11.5	-14.1	63
Gum	-40.4	88.6	54
Gutenberg	-8.6	41.2	74
Gyldén	-5.3	0.3	47
Hagecius	-59.8	46.6	76

Crater	Lat.	Long.	Dia.
Hahn	31.3	73.6	84
Haidinger	-39.2	-25.0	22
Hainzel	-41.3	-33.5	70
Haldane	-1.7	84.1	37
Hale	-74.2	90.8	83
Hall	33.7	37.0	35
Halley	-8.0	5.7	36
Hamilton	-42.8	84.7	57
Hanno	-56.3	71.2	56
Hansen	14.0	72.5	39
Hansteen	-11.5	-52.0	44
Harding	43.5	-71.7	22
Hargreaves	-2.2	64.0	16
Harlan	-38.5	79.5	65
Harold	-10.9	-6.0	2
Harpalus	52.6	-43.4	39
Hartwig	-6.1	-80.5	79
Hase	-29.4	62.5	83
Hausen	-65.0	-88.1	167
Hayn	64.7	85.2	87
Hecataeus	-21.8	79.4	167
Hédervári	-81.8	84.0	69
Hedin	2.0	-76.5	150
Heinrich	24.8	-15.3	6
Heinsius	-39.5	-17.7	64
Heis	32.4	-31.9	14
Helicon	40.4	-23.1	24
Hell	-32.4	-7.8	33
Helmert	-7.6	87.6	26
Helmholtz	-68.1	64.1	94
Henry	-24.0	-56.8	41
Henry Frères	-23.5	-58.9	42
Heraclitus	-49.2	6.2	90
Hercules	46.7	39.1	69
Herigonius	-13.3	-33.9	15
Hermann	-0.9	-57.0	15
Hermite	86.0	-89.9	104
Herodotus	23.2	-49.7	34
Herschel	-5.7	-2.1	40
Hesiodus	-29.4	-16.3	42
Hevelius	2.2	-67.6	115
Hill	20.9	40.8	16
Hind	-7.9	7.4	29
Hippalus	-24.8	-30.2	57
Hipparchus	-5.1	5.2	138
Holden	-19.1	62.5	47
Hommel	-54.7	33.8	126
Hooke	41.2	54.9	36
Hornsby	23.8	12.5	3
Horrebow	58.7	-40.8	24
Horrocks	-4.0	5.9	30
Hortensius	6.5	-28.0	14
Houtermans	-9.4	87.2	29
Hubble	22.1	86.9	80
Huggins	-41.1	-1.4	65
Humason	30.7	-56.6	4
Humboldt	-27.0	80.9	189
Hume	-4.7	90.4	23
Huxley	20.2	-4.5	4
Hyginus	7.8	6.3	9
Hypatia	-4.3	22.6	40
Ian	25.7	-0.4	1
Ibn Battuta	-6.9	50.4	11
Ibn-Rushd	-11.7	21.7	32
Ideler	-49.2	22.3	38
Ina	18.6	5.3	3
Inghirami	-47.5	-68.8	91
Isabel	28.2	-34.1	1
Isidorus	-8.0	33.5	42
Isis	18.9	27.5	1
Ivan	26.9	-43.3	4
J. Herschel	62.0	-42.0	165
Jacobi	-56.7	11.4	68
Jansen	13.5	28.7	23
Jansky	8.5	89.5	72
Janssen	-45.4	40.3	199
Jehan	20.7	-31.9	5
Jenkins	0.3	78.1	38
Jerik	18.5	27.6	1
Jomo	24.4	2.4	7
José	-12.7	-1.6	2
Joy	25.0	6.6	5
Julienne	26.0	3.2	2
Julius Caesar	9.0	15.4	90
Kaiser	-36.5	6.5	52
Kane	63.1	26.1	54
Kant	-10.6	20.1	33
Kao	-6.7	87.6	34

(Latest list in Ref. No. 7)

(+Latitude = North   -Latitude = South   +Longitude = East   -Longitude = West   Diameter in km)

Crater	Lat.	Long.	Dia.
Kapteyn	-10.8	70.6	49
Kästner	-6.8	78.5	108
Kathleen	25.4	-0.7	5
Keldysh	51.2	43.6	33
Kepler	8.1	-38.0	31
Kies	-26.3	-22.5	45
Kiess	-6.4	84.0	63
Kinau	-60.8	15.1	41
Kirch	39.2	-5.6	11
Kircher	-67.1	-45.3	72
Kirchhoff	30.3	38.8	24
Klaproth	-69.8	-26.0	119
Klein	-12.0	2.6	44
Knox-Shaw	5.3	80.2	12
König	-24.1	-24.6	23
Kopff	-17.4	-89.6	41
Krafft	16.6	-72.6	51
Krasnov	-29.9	-79.6	40
Kreiken	-9.0	84.6	23
Krieger	29.0	-45.6	22
Krogh	9.4	65.7	19
Krusenstern	-26.2	5.9	47
Kuiper	-9.8	-22.7	6
Kundt	-11.5	-11.5	10
Kunowsky	3.2	-32.5	18
la Caille	-23.8	1.1	67
la Condamine	53.4	-28.2	37
la Pérouse	-10.7	76.3	77
Lacroix	-37.9	-59.0	37
Lade	-1.3	10.1	55
Lagalla	-44.6	-22.5	85
Lagrange	-32.3	-72.8	225
Lalande	-4.4	-8.6	24
Lallemand	-14.3	-84.1	18
Lamarck	-22.9	-69.8	100
Lambert	25.8	-21.0	30
Lamé	-14.7	64.5	84
Lamèch	42.7	13.1	13
Lamont	4.4	23.7	106
Landsteiner	31.3	-14.8	6
Langley	51.1	-86.3	59
Langrenus	-8.9	61.1	127
Lansberg	-0.3	-26.6	38
Lassell	-15.5	-7.9	23
Lavoisier	38.2	-81.2	70
Lawrence	7.4	43.2	24
Le Gentil	-74.6	-75.7	128
Le Monnier	26.6	30.6	60
Le Verrier	40.3	-20.6	20
Leakey	-3.2	37.4	12
Lebesgue	-5.1	89.0	11
Lee	-30.7	-40.7	41
Legendre	-28.9	70.2	78
Lehmann	-40.0	-56.0	53
Lepaute	-33.3	-33.6	16
Letronne	-10.8	-42.5	116
Lexell	-35.8	-4.2	62
Licetus	-47.1	6.7	74
Lichtenberg	31.8	-67.7	20
Lick	12.4	52.7	31
Liebig	-24.3	-48.2	37
Lilius	-54.5	6.2	61
Linda	30.7	-33.4	1
Lindbergh	-5.4	52.9	12
Lindenau	-32.3	24.9	53
Lindsay	-7.0	13.0	32
Linné	27.7	11.8	2
Liouville	2.6	73.5	16
Lippershey	-25.9	-10.3	6
Littrow	21.5	31.4	30
Lockyer	-46.2	36.7	34
Loewy	-22.7	-32.8	24
Lohrmann	-0.5	-67.2	30
Lohse	-13.7	60.2	41
Longomontanus	-49.6	-21.8	157
Louise	28.5	-34.2	0.8
Louville	44.0	-46.0	36
Lubbock	-3.9	41.8	13
Lubiniezky	-17.8	-23.8	43
Lucian	14.3	36.7	7
Luther	33.2	24.1	9
Lyapunov	26.3	89.3	66
Lyell	13.6	40.6	32
Lyot	-49.8	84.5	132
Maclaurin	-1.9	68.0	50
Maclear	10.5	20.1	20
MacMillan	24.2	-7.8	7
Macrobius	21.3	46.0	64
Mädler	-11.0	29.8	27
Maestlin	4.9	-40.6	7
Magelhaens	-11.9	44.1	40
Maginus	-50.5	-6.3	194
Main	80.8	10.1	46
Mairan	41.6	-43.4	40
Malapert	-84.9	12.9	69
Mallet	-45.4	54.2	58
Manilius	14.5	9.1	38
Manners	4.6	20.0	15
Manuel	24.5	11.3	0.5
Manzinus	-67.7	26.8	98
Maraldi	19.4	34.9	39
Marco Polo	15.4	-2.0	28
Marinus	-39.4	76.5	58
Marius	11.9	-50.8	41
Markov	53.4	-62.7	40
Marth	-31.1	-29.3	6
Mary	18.9	27.4	1
Maskelyne	2.2	30.1	23
Mason	42.6	30.5	33
Maupertuis	49.6	-27.3	45
Maurolycus	-42.0	14.0	114
Maury	37.1	39.6	17
Mavis	29.8	-26.4	1
McClure	-15.3	50.3	23
McDonald	30.4	-20.9	7
Mee	-43.7	-35.3	126
Menelaus	16.3	16.0	26
Menzel	3.4	36.9	3
Mercator	-29.3	-26.1	46
Mercurius	46.6	66.2	67
Mersenius	-21.5	-49.2	84
Messala	39.2	60.5	125
Messier	-1.9	47.6	11
Metius	-40.3	43.3	87
Meton	73.6	18.8	130
Michael	25.1	0.2	4
Milichius	10.0	-30.2	12
Miller	-39.3	0.8	61
Mitchell	49.7	20.2	30
Moigno	66.4	28.9	36
Moltke	-0.6	24.2	6
Monge	-19.2	47.6	36
Monira	-12.6	-1.7	2
Montanari	-45.8	-20.6	76
Moretus	-70.6	-5.8	111
Morley	-2.8	64.6	14
Moseley	20.9	-90.1	90
Mösting	-0.7	-5.9	24
Mouchez	78.3	-26.6	81
Müller	-7.6	2.1	22
Murchison	5.1	-0.1	57
Mutus	-63.6	30.1	77
Naonobu	-4.6	57.8	34
Nasireddin	-41.0	0.2	52
Nasmyth	-50.5	-56.2	76
Natasha	20.0	-31.3	12
Naumann	35.4	-62.0	9
Neander	-31.3	39.9	50
Nearch	-58.5	39.1	75
Neison	68.3	25.1	53
Neper	8.5	84.6	137
Neumayer	-71.1	70.7	76
Newcomb	29.9	43.8	41
Newton	-76.7	-16.9	78
Nicholson	-26.2	-85.1	38
Nicolai	-42.4	25.9	42
Nicollet	-21.9	-12.5	15
Nielsen	31.8	-51.8	9
Nobile	-85.2	53.5	73
Nobili	0.2	75.9	42
Nöggerath	-48.8	-45.7	30
Nonius	-34.8	3.8	69
Norman	-11.8	-30.4	10
Oenopides	57.0	-64.1	67
Oersted	43.1	47.2	42
Oken	-43.7	75.9	71
Olbers	7.4	-75.9	74
Opelt	-16.3	-17.5	48
Oppolzer	-1.5	-0.5	40
Orontius	-40.6	-4.6	105
Osama	18.6	5.2	0.5
Osiris	18.6	27.6	1
Osman	-11.0	-6.2	2
Palisa	-9.4	-7.2	33
Palitzsch	-28.0	64.5	41
Pallas	5.5	-1.6	46
Palmieri	-28.6	-47.7	40
Parrot	-14.5	3.3	70
Parry	-7.9	-15.8	47
Pascal	74.6	-70.3	115
Patricia	25.0	0.3	5
Peary	88.6	33.0	73
Peek	2.6	86.9	12
Peirce	18.3	53.5	18
Peirescius	-46.5	67.6	61
Pentland	-64.6	11.5	56
Petavius	-25.1	60.4	188
Petermann	74.2	66.3	73
Peters	68.1	29.5	15
Petit	2.3	63.5	5
Petrov	-61.4	88.0	49
Pettit	-27.5	-86.6	35
Phillips	-26.6	75.3	122
Philolaus	72.1	-32.4	70
Phocylides	-52.7	-57.0	121
Piazzi	-36.6	-67.9	134
Piazzi Smyth	41.9	-3.2	13
Picard	14.6	54.7	22
Piccolomini	-29.7	32.2	87
Pickering	-2.9	7.0	15
Pictet	-43.6	-7.4	62
Pilâtre	-60.2	-86.9	50
Pingré	-58.7	-73.7	88
Pitatus	-29.9	-13.5	106
Pitiscus	-50.4	30.9	82
Plana	42.2	28.2	44
Plato	51.6	-9.4	109
Playfair	-23.5	8.4	47
Plinius	15.4	23.7	43
Plutarch	24.1	79.0	68
Poisson	-30.4	10.6	42
Polybius	-22.4	25.6	41
Pomortsev	0.7	66.9	23
Poncelet	75.8	-54.1	69
Pons	-25.3	21.5	41
Pontanus	-28.4	14.4	57
Pontécoulant	-58.7	66.0	91
Porter	-56.1	-10.1	51
Posidonius	31.8	29.9	95
Prinz	25.5	-44.1	46
Priscilla	-10.9	-6.2	1.8
Proclus	16.1	46.8	28
Proctor	-46.4	-5.1	52
Protagoras	56.0	7.3	21
Ptolemaeus	-9.3	-1.9	164
Puiseux	-27.8	-39.0	24
Pupin	23.8	-11.0	2
Purbach	-25.5	-2.3	115
Pythagoras	63.5	-63.0	142
Pytheas	20.5	-20.6	20
Rabbi Levi	-34.7	23.6	81
Raman	27.0	-55.1	10
Ramsden	-32.9	-31.8	24
Rankine	-3.9	71.5	8
Ravi	-12.5	-1.9	2.5
Rayleigh	29.3	89.6	114
Réaumur	-2.4	0.7	52
Regiomontanus	-28.3	-1.0	108
Regnault	54.1	-88.0	46
Reichenbach	-30.3	48.0	71
Reimarus	-47.7	60.3	48
Reiner	7.0	-54.9	29
Reinhold	3.3	-22.8	42
Repsold	51.3	-78.6	109
Respighi	2.8	71.9	18
Rhaeticus	0.0	4.9	45
Rheita	-37.1	47.2	70
Riccioli	-3.3	-74.6	139
Riccius	-36.9	26.5	71
Riemann	38.9	86.8	163
Ritchey	-11.1	8.5	24
Ritter	2.0	19.2	29
Robert	19.0	27.4	1
Robinson	59.0	-45.9	24
Rocca	-12.7	-72.8	89
Rocco	28.9	-45.0	4
Römer	25.4	36.4	39
Rosa	20.3	-32.3	1
Rosenberger	-55.4	43.1	95
Ross	11.7	21.7	24
Rosse	-17.9	35.0	11
Rost	-56.4	-33.7	48
Rothmann	-30.8	27.7	42
Runge	-2.5	86.7	38
Russell	26.5	-75.4	103
Ruth	28.7	-45.1	3
Rutherfurd	-60.9	-12.1	48
Sabatier	13.2	79.0	10
Sabine	1.4	20.1	30
Sacrobosco	-23.7	16.7	98
Samir	28.5	-34.3	2
Sampson	29.7	-16.5	1
Santbech	-20.9	44.0	64
Santos-Dumont	27.7	4.8	8
Sarabhai	24.7	21.0	7
Sasserides	-39.1	-9.3	90
Saunder	-4.2	8.8	44
Saussure	-43.4	-3.8	54
Scheele	-9.4	-37.8	4
Scheiner	-60.5	-27.5	110
Schiaparelli	23.4	-58.8	24
Schickard	-44.3	-55.3	206
Schiller	-51.9	-39.0	180
Schlüter	-5.9	-83.3	89
Schmidt	1.0	18.8	11
Schomberger	-76.7	24.9	85
Schorr	-19.5	89.7	53
Schröter	2.6	-7.0	35
Schubert	2.8	81.0	54
Schumacher	42.4	60.7	60
Schwabe	65.1	45.6	25
Scoresby	77.7	14.1	55
Scott	-82.1	48.5	103
Secchi	2.4	43.5	22
Seeliger	-2.2	3.0	8
Segner	-58.9	-48.3	67
Seleucus	21.0	-66.6	43
Seneca	26.6	80.2	46
Shackleton	-89.9	0.0	19
Shaler	-32.9	-85.2	48
Shapley	9.4	56.9	23
Sharp	45.7	-40.2	39
Sheepshanks	59.2	16.9	25
Shoemaker	-88.1	44.9	51
Short	-74.6	-7.3	70
Shuckburgh	42.6	52.8	38
Silberschlag	6.2	12.5	13
Simpelius	-73.0	15.2	70
Sinas	8.8	31.6	11
Sirsalis	-12.5	-60.4	42
Slocum	-3.0	89.0	13
Smithson	2.4	53.6	5
Snellius	-29.3	55.7	82
Somerville	-8.3	64.9	15
Sömmering	0.1	-7.5	28
Soraya	-12.9	-1.6	2
Sosigenes	8.7	17.6	17
South	58.0	-50.8	104
Spallanzani	-46.3	24.7	32
Spörer	-4.3	-1.8	27
Spurr	27.9	-1.2	13
Stadius	10.5	-13.7	69
Steinheil	-48.6	46.5	67
Stella	19.9	29.8	1
Stevinus	-32.5	54.2	74
Stewart	2.2	67.0	13
Stiborius	-34.4	32.0	43
Stöfler	-41.1	6.0	126
Stokes	52.5	-88.1	51
Strabo	61.9	54.3	55
Street	-46.5	-10.5	57
Struve	22.4	-77.1	164
Suess	4.4	-47.6	8
Sulpicius Gallus	19.6	11.6	12
Susan	-11.0	-6.3	1
Swasey	-5.5	89.7	23
Swift	19.3	53.4	10
Sylvester	82.7	-79.6	58
T. Mayer	15.6	-29.1	33
Tacchini	4.9	85.8	40
Tacitus	-16.2	19.0	39
Tacquet	16.6	19.2	7
Taizo	24.7	2.2	6
Talbot	-2.5	85.3	11
Tannerus	-56.4	22.0	28
Taruntius	5.6	46.5	56
Taylor	-5.3	16.7	42
Tebbutt	9.6	53.6	31
Tempel	3.9	11.9	45
Thales	61.8	50.3	31
Theaetetus	37.0	6.0	24
Thebit	-22.0	-4.0	56
Theiler	13.4	83.3	7
Theon Junior	-2.3	15.8	17
Theon Senior	-0.8	15.4	18
Theophilus	-11.4	26.4	110
Theophrastus	17.5	39.0	9
Timaeus	62.8	-0.5	32
Timocharis	26.7	-13.1	33
Tisserand	21.4	48.2	36
Tolansky	-9.5	-16.0	13
Torricelli	-4.6	28.5	22
Toscanelli	27.4	-47.5	7
Townley	3.4	63.3	18
Tralles	28.4	52.8	43
Triesnecker	4.2	3.6	26
Trouvelot	49.3	5.8	9
Tucker	-5.6	88.2	7
Turner	-1.4	-13.2	11
Tycho	-43.4	-11.1	102
Ukert	7.8	1.4	23
Ulugh Beigh	32.7	-81.9	54
Urey	27.9	87.4	38
Väisälä	25.9	-47.8	8
van Albada	9.4	64.3	21
Van Biesbroeck	28.7	-45.6	9
Van Vleck	-1.9	78.3	31
Vasco da Gama	13.6	-83.9	83
Vega	-45.4	63.4	75
Vendelinus	-16.4	61.6	131
Vera	26.3	-43.7	2
Verne	24.9	-25.3	2
Very	25.6	25.3	5
Vieta	-29.2	-56.3	87
Virchow	9.8	83.7	16
Vitello	-30.4	-37.5	42
Vitruvius	17.6	31.3	29
Vlacq	-53.3	38.8	89
Vogel	-15.1	5.9	26
Volta	53.9	-84.4	123
von Behring	-7.8	71.8	38
von Braun	41.1	-78.0	60
Voskresenskiy	28.0	-88.1	49
W. Bond	65.4	4.5	156
Wallace	20.3	-8.7	26
Wallach	4.9	32.3	6
Walter	28.0	-33.8	1
Walther	-33.1	1.0	128
Wargentin	-49.6	-60.2	84
Warner	-4.0	87.3	35
Watt	-49.5	48.6	66
Watts	8.9	46.3	15
Webb	-0.9	60.0	21
Weierstrass	-1.3	77.2	33
Weigel	-58.2	-38.8	35
Weinek	-27.5	37.0	32
Weiss	-31.8	-19.5	66
Werner	-28.0	3.3	70
Wexler	-69.1	90.2	51
Whewell	4.2	13.7	13
Wichmann	-7.5	-38.1	10
Widmannstätten	-6.1	85.5	46
Wildt	9.0	75.8	11
Wilhelm	-43.4	-20.4	106
Wilkins	-29.4	19.6	57
Williams	42.0	37.2	36
Wilson	-69.2	-42.4	69
Winthrop	-10.7	-44.4	17
Wöhler	-38.2	31.4	27
Wolf	-22.7	-16.6	25
Wollaston	30.6	-46.9	10
Wright	-31.6	-86.6	39
Wrottesley	-23.9	56.8	57
Wurzelbauer	-33.9	-15.9	88
Xenophanes	57.5	-82.0	125
Yakovkin	-54.5	-78.8	37
Yangel'	17.0	4.7	8
Yerkes	14.6	51.7	36
Yoshi	24.6	11.0	1
Young	-41.5	50.9	71
Zach	-60.9	5.3	70
Zagut	-32.0	22.1	84
Zähringer	5.6	40.2	11
Zeno	45.2	72.9	65
Zinner	26.6	-58.8	4
Zöllner	-8.0	18.9	47
Zucchius	-61.4	-50.3	64
Zupus	-17.2	-52.3	38

(Latest list in Ref. No. 7)

Crater	Lat.	Long.	Dia.	(+Latitude = North			-Latitude = South			+Longitude = East			-Longitude = West	Diameter in km)	
Abbe	-57.3	175.2	66	Chamberlin	-58.9	95.7	58	Fairouz	-26.1	102.9	3	Icarus	-5.3	-173.2	96
Abul Wáfa	1.0	116.6	55	Champollion	37.4	175.2	58	Fechner	-59.0	124.9	63	Idel'son	-81.5	110.9	60
Aitken	-16.8	173.4	135	Chandler	43.8	171.5	85	Fényi	-44.9	-105.1	38	Il'in	-17.8	-97.5	13
Al-Biruni	17.9	92.5	77	Chang Heng	19.0	112.2	43	Feoktistov	30.9	140.7	23	Ingalls	26.4	-153.1	37
Alden	-23.6	110.8	104	Chant	-40.0	-109.2	33	Fermi	-19.3	122.6	183	Innes	27.8	119.2	42
Alder	-48.6	-177.4	77	Chaplygin	-6.2	150.3	137	Fersman	18.7	-126.0	151	Ioffe	-14.4	-129.2	86
Alekhin	-68.2	-131.3	70	Chapman	50.4	-100.7	71	Fesenkov	-23.2	135.1	35	Isaev	-17.5	147.5	90
Al-Khwarizmi	7.1	106.4	65	Chappe	-61.2	-91.5	59	Finsen	-42.0	-177.9	72	Izsak	-23.3	117.1	30
Alter	18.7	-107.5	64	Chappell	54.7	-177.0	80	Firsov	4.5	112.2	51	Jackson	22.4	-163.1	71
Amici	-9.9	-172.1	54	Charlier	36.6	-131.5	99	Fischer	8.0	142.4	30	Jarvis	-34.9	-148.9	38
Anders	-41.3	-142.9	40	Chaucer	3.7	-140.0	45	Fitzgerald	27.5	-171.7	110	Jeans	-55.8	91.4	79
Anderson	15.8	171.1	109	Chauvenet	-11.5	137.0	81	Fizeau	-58.6	-133.9	111	Jenner	-42.1	95.9	71
Andersson	-49.7	-95.3	13	Chawla	-42.8	-147.5	15	Fleming	15.0	109.6	106	Joliot	25.8	93.1	164
Andronov	-22.7	146.1	16	Chebyshev	-33.7	-133.1	178	Florensky	25.3	131.5	71	Joule	27.3	-144.2	96
Antoniadi	-69.7	-172.0	143	Chernyshev	47.3	174.2	58	Focas	-33.7	-93.8	22	Jules Verne	-35.0	147.0	143
Anuchin	-49.0	101.3	57	Chrétien	-45.9	162.9	88	Foster	23.7	-141.5	33	Kamerlingh Onnes	15.0	-115.8	66
Apollo	-36.1	-151.8	537	Clark	-38.4	118.9	49	Fowler	42.3	-145.0	146	Karima	-25.9	103.0	3
Appleton	37.2	158.3	63	Coblentz	-37.9	126.1	33	Fox	0.5	98.2	24	Karpinskiy	73.3	166.3	92
Armiński	-16.4	154.2	26	Cockcroft	31.3	-162.6	93	Freundlich	25.0	171.0	85	Karrer	-52.1	-141.8	51
Arrhenius	-55.6	-91.3	40	Compton	55.3	103.8	162	Fridman (Friedmann)	-12.6	-126.0	102	Kasper	8.3	122.1	12
Artamonov	25.5	103.5	60	Comrie	23.3	-112.7	59	Froelich	80.3	-109.7	58	Katchalsky	5.9	116.1	32
Artem'ev	10.8	-144.4	67	Comstock	21.8	-121.5	72	Frost	37.7	-118.4	75	Kearons	-11.4	-112.6	23
Ashbrook	-81.4	-112.5	156	Congreve	-0.2	-167.3	57	Fryxell	-21.3	-101.4	18	Keeler	-10.2	161.9	160
Avicenna	39.7	-97.2	74	Cooper	52.9	175.6	36	Gadomski	36.4	-147.3	65	Kekulé	16.4	-138.1	94
Avogadro	63.1	164.9	139	Cori	-50.6	-151.9	65	Gagarin	-20.2	149.2	265	Kępiński	28.8	126.6	31
Babakin	-20.8	123.3	20	Coriolis	0.1	171.8	78	Galois	-14.2	-151.9	222	Khvol'son	-13.8	111.4	54
Babcock	4.2	93.9	99	Couder	-4.8	-92.4	21	Gamow	65.3	145.3	129	Kibal'chich	3.0	-146.5	92
Backlund	-16.0	103.0	75	Coulomb	54.7	-114.6	89	Ganskiy (Hansky)	-9.7	97.0	43	Kidinnu	35.9	122.9	56
Balandin	-18.9	152.6	12	Cremona	67.5	-90.6	85	Ganswindt	-79.6	110.3	74	Kimura	-57.1	118.4	28
Baldet	-53.3	-151.1	55	Crocco	-47.5	150.2	75	Garavito	-47.5	156.7	74	King	5.0	120.5	76
Barbier	-23.8	157.9	66	Crommelin	-68.1	-146.9	94	Gavrilov	17.4	130.9	60	Kira	-17.6	132.8	3
Barringer	-28.0	-149.7	68	Crookes	-10.3	-164.5	49	Geiger	-14.6	158.5	34	Kirkwood	68.8	-156.1	67
Bawa	-25.3	102.6	1	Ctesibius	0.8	118.7	36	Gerasimovich	-22.9	-122.6	86	Kleymenov	-32.4	-140.2	55
Becquerel	40.7	129.7	65	Curie	-22.9	91.0	151	Gernsback	-36.5	99.7	48	Klute	37.2	-141.3	75
Bečvář	-1.9	125.2	67	Cyrano	-20.5	157.7	80	Ginzel	14.3	97.4	55	Koch	-42.8	150.1	95
Beijerinck	-13.5	151.8	70	D. Brown	-42.0	-147.2	15	Giordano Bruno	35.9	102.8	22	Kohlschütter	14.4	154.0	53
Bel'kovich	61.1	90.2	214	Daedalus	-5.9	179.4	93	Glauber	11.5	142.6	15	Kolhörster	11.2	-114.6	97
Bell	21.8	-96.4	86	D'Alembert	50.8	163.9	248	Glazenap	-1.6	137.6	43	Komarov	24.7	152.5	78
Bellinsgauzen	-60.6	-164.6	63	Danjon	-11.4	124.0	71	Golitsyn	-25.1	-105.0	36	Kondratyuk	-14.9	115.5	108
Belopol'skiy	-17.2	-128.1	59	Dante	25.5	180.0	54	Golovin	39.9	161.1	37	Konoplev	-28.5	-125.5	25
Belyaev	23.3	143.5	54	d'Arsonval	-10.3	124.6	28	Grachev	-3.7	-108.2	35	Konstantinov	19.8	158.4	66
Benedict	4.4	141.5	14	Das	-26.6	-136.8	38	Grave	-17.1	150.3	40	Korolev	-4.0	-157.4	437
Bergman	7.0	137.5	21	Davisson	-37.5	-174.6	87	Green	4.1	132.9	65	Kosberg	-20.2	149.6	15
Bergstrand	-18.8	176.3	43	Dawson	-67.4	-134.7	45	Gregory	2.2	127.2	67	Kostinskiy	14.7	118.8	75
Berkner	25.2	-105.2	86	de Forest	-77.3	-162.1	57	Grigg	12.9	-129.4	36	Kovalevskaya	30.8	-129.6	115
Berlage	-63.2	-162.8	92	de Moraes	49.5	143.2	53	Grissom	-47.0	-147.4	58	Koval'skiy	-21.9	101.0	49
Bhabha	-55.1	-164.5	64	de Roy	-55.3	-99.1	43	Grotrian	-66.5	128.3	37	Kozyrev	-46.8	129.3	65
Bingham	8.1	115.1	33	de Vries	-19.9	-176.7	59	Guillaume	45.4	-173.4	57	Kramarov	-2.3	-98.8	20
Birkeland	-30.2	173.9	82	Debus	-10.5	99.6	20	Gullstrand	45.2	-129.3	43	Kramers	53.6	-127.6	61
Birkhoff	58.7	-146.1	345	Debye	49.6	-176.2	142	Guthnick	-47.7	-93.9	36	Krasovskiy	3.9	-175.5	59
Bi Sheng	78.3	148.4	55	Dellinger	-6.8	140.6	81	Guyot	11.4	117.5	92	Krylov	35.6	-165.8	49
Bjerknes	-38.4	113.0	48	Delporte	-16.0	121.6	45	H. G. Wells	40.7	122.8	114	Kugler	-53.8	103.7	65
Blackett	-37.5	-116.1	141	Denning	-16.4	142.6	44	Hagen	-48.3	135.1	55	Kulik	42.4	-154.5	58
Blanchard	-58.5	-94.4	40	Deutsch	24.1	110.5	66	Hale	-74.2	90.8	83	Kuo Shou Ching	8.4	-133.7	34
Blazhko	31.6	-148.0	54	Dewar	-2.7	165.5	50	Harden	5.5	143.5	15	Kurchatov	38.3	142.1	106
Bobone	26.9	-131.8	31	Diderot	-20.4	121.5	20	Haret	-59.0	-176.5	29	L. Clark	-43.7	-147.7	16
Bok	-20.2	-171.6	45	Dirichlet	11.1	-151.4	47	Harkhebi	39.6	98.3	237	Lacchini	41.7	-107.5	58
Boltzmann	-74.9	-90.7	76	Dobrovol'skiy	-12.8	129.7	38	Harriot	33.1	114.3	56	Lamb	-42.9	100.1	106
Bolyai	-33.6	125.9	135	Doerfel	-69.1	-107.9	68	Hartmann	3.2	135.3	61	Lampland	-31.0	131.0	65
Bondarenko	-17.8	136.3	30	Donner	-31.4	98.0	58	Harvey	19.5	-146.5	60	Landau	41.6	-118.1	214
Borman	-38.8	-147.7	50	Doppler	-12.6	-159.6	110	Hatanaka	29.7	-121.5	26	Lander	-15.3	131.8	40
Bose	-53.5	-170.0	91	Douglass	35.9	-122.4	49	Hayford	12.7	-176.4	27	Lane	-9.5	132.0	55
Bowditch	-25.0	103.1	40	Dreyer	10.0	96.9	61	Healy	32.8	-110.5	38	Langemak	-10.3	118.7	97
Boyle	-53.1	178.1	57	Drude	-38.5	-91.8	24	Heaviside	-10.4	167.1	165	Langevin	44.3	162.7	58
Bragg	42.5	-102.9	84	Dryden	-33.0	-155.2	51	Helberg	22.5	-102.2	62	Langmuir	-35.7	-128.4	91
Brashear	-73.8	-170.7	55	Dufay	5.5	169.5	39	Henderson	4.8	152.1	47	Larmor	32.1	-179.7	97
Bredikhin	17.3	-158.2	59	Dugan	64.2	103.3	50	Hendrix	-46.6	-159.2	18	Laue	28.0	-96.7	87
Bridgman	43.5	137.1	80	Dunér	44.8	179.5	62	Henyey	13.5	-151.6	63	Lauritsen	-27.6	96.1	52
Bronk	26.1	-134.5	64	Dyson	61.3	-121.2	63	Heron (Hero)	0.7	119.8	24	Leavitt	-44.8	-139.3	66
Brouwer	-36.2	-126.0	158	Dziewulski	21.2	98.9	63	Hertz	13.4	104.5	90	Lebedev	-47.3	107.8	102
Brunner	-9.9	90.9	53	Edison	25.0	99.1	62	Hertzsprung	2.6	-129.2	591	Lebedinskiy	8.3	-164.3	62
Buffon	-40.4	-133.4	106	Edith	-25.8	102.3	8	Hess	-54.3	174.6	88	Leeuwenhoek	-29.3	-178.7	125
Buisson	-1.4	112.5	56	Ehrlich	40.9	-172.4	30	Heymans	75.3	-144.1	50	Leibnitz	-38.3	179.2	245
Butlerov	12.5	-108.7	40	Eijkman	-63.1	-141.5	54	Heyrovsky	-39.6	-95.3	16	Lemaître	-61.2	-149.6	91
Buys-Ballot	20.8	174.5	55	Einthoven	-4.9	109.6	69	Hilbert	-17.9	108.2	151	Lents (Lenz)	2.8	-102.1	21
Cabannes	-60.9	-169.6	80	Ellerman	-25.3	-120.1	47	Hippocrates	70.7	-145.9	60	Leonov	19.0	148.2	33
Cailleux	-60.8	153.3	50	Ellison	55.1	-107.5	36	Hirayama	-6.1	93.5	132	Leucippus	29.1	-116.0	56
Cai Lun	80.1	113.8	43	Elvey	8.8	-100.5	74	Hoffmeister	15.2	136.9	45	Leuschner	1.8	-108.8	49
Cajori	-47.4	168.8	70	Emden	63.3	-177.3	111	Hogg	33.6	121.9	38	Levi-Civita	-23.7	143.4	121
Campbell	45.3	151.4	219	Engel'gardt	5.7	-159.0	43	Hohmann	-17.9	-94.1	16	Lewis	-18.5	-113.8	42
Cannizzaro	55.6	-99.6	56	Eötvös	-35.5	133.8	99	Holetschek	-27.6	150.9	38	Ley	42.2	154.9	79
Cantor	38.2	118.6	81	Erro	5.7	98.5	61	Hopmann	-50.8	160.3	88	Lindblad	70.4	-98.8	66
Carnot	52.3	-143.5	126	Esnault-Pelterie	47.7	-141.4	79	Houzeau	-17.1	-123.5	71	Lippmann	-56.0	-114.9	160
Carol	8.5	122.3	8	Espin	28.1	109.1	75	Hume	-4.7	90.4	23	Lipskiy	-2.2	-179.5	80
Carver	-43.0	126.9	59	Evans	-9.5	-133.5	67	Husband	-40.8	-147.9	29	Litke (Lütke)	-16.8	123.1	39
Cassegrain	-52.4	113.5	55	Evdokimov	34.8	-153.0	50	Hutton	37.3	168.7	50	Lobachevskiy	9.9	112.6	84
Chadwick	-52.7	-101.3	30	Evershed	35.7	-159.5	66	Ibn Firnas	6.8	122.3	89	Lodygin	-17.7	-146.8	62
Chaffee	-38.8	-153.9	49	Ewen	7.7	121.4	3	Ibn Yunus	14.1	91.1	58	Lomonosov	27.3	98.0	92
Chalonge	-21.2	-117.3	30	Fabry	42.9	100.7	184								

(Latest list in Ref. No. 7)

Farside

Crater	Lat.	Long.	Dia.	(+ Latitude = North				– Latitude = South		+ Longitude = East		– Longitude = West		Diameter in km)	
Lorentz	32.6	-95.3	312	Paraskevopoulos	50.4	-149.9	94	Shatalov	24.3	141.5	21	von der Pahlen	-24.8	-132.7	56
Love	-6.3	129.0	84	Parenago	25.9	-108.5	93	Shayn	32.6	172.5	93	von Kármán	-44.8	175.9	180
Lovelace	82.3	-106.4	54	Parkhurst	-33.4	103.6	96	Sherrington	-11.1	118.0	18	von Neumann	40.4	153.2	78
Lovell	-36.8	-141.9	34	Parsons	37.3	-171.2	40	Shi Shen	76.0	104.1	43	von Zeipel	42.6	-141.6	83
Lowell	-12.9	-103.1	66	Paschen	-13.5	-139.8	124	Shirakatsi	-12.1	128.6	51	Walker	-26.0	-162.2	32
Lucretius	-8.2	-120.8	63	Pasteur	-11.9	104.6	224	Shternberg (Sternberg)	19.5	-116.3	70	Wan-Hoo	-9.8	-138.8	52
Ludwig	-7.7	97.4	23	Patsaev	-16.7	133.4	55	Shuleykin	-27.1	-92.5	15	Waterman	-25.9	128.0	76
Lundmark	-39.7	152.5	106	Pauli	-44.5	137.5	84	Siedentopf	22.0	135.5	61	Watson	-62.6	-124.5	62
Lyman	-64.8	163.6	84	Pavlov	-28.8	142.5	148	Sierpinski	-27.2	154.5	69	Weber	50.4	-123.4	42
M. Anderson	-41.6	-149.0	17	Pawsey	44.5	145.0	60	Sikorsky	-66.1	103.2	98	Wegener	45.2	-113.3	88
Mach	18.5	-149.3	180	Pease	12.5	-106.1	38	Sisakyan	41.2	109.0	34	Wexler	-69.1	90.2	51
Maksutov	-40.5	-168.7	83	Perel'man	-24.0	106.0	46	Sita	4.6	120.8	2	Weyl	17.5	-120.2	108
Malyy	21.9	105.3	41	Perepelkin	-10.0	129.0	97	Sklodowska	-18.2	95.5	127	White	-44.6	-158.3	39
Mandel'shtam	5.4	162.4	197	Perkin	47.2	-175.9	62	Slipher	49.5	160.1	69	Wiechert	-84.5	165.0	41
Marci	22.6	-167.0	25	Perrine	42.5	-127.8	86	Smith	-31.6	-150.2	34	Wiener	40.8	146.6	120
Marconi	-9.6	145.1	73	Petrie	45.3	108.4	33	Smoluchowski	60.3	-96.8	83	Wilsing	-21.5	-155.2	73
Mariotte	-28.5	-139.1	65	Petropavlovskiy	37.2	-114.8	63	Sniadecki	-22.5	-168.9	43	Winkler	42.2	-179.0	22
Maunder	-14.6	-93.8	55	Petzval	-62.7	-110.4	90	Soddy	0.4	121.8	42	Winlock	35.6	-105.6	64
Maxwell	30.2	98.9	107	Pikel'ner	-47.9	123.3	47	Sommerfeld	65.2	-162.4	169	Woltjer	45.2	-159.6	46
McAdie	2.1	92.1	45	Pirquet	-20.3	139.6	65	Spencer Jones	13.3	165.6	85	Wood	43.0	-120.8	78
McAuliffe	-33.0	-148.9	19	Pizzetti	-34.9	118.8	44	St. John	10.2	150.2	68	Wróblewski	-24.0	152.8	21
McCool	-41.7	-146.3	21	Planck	-57.9	136.8	314	Stark	-25.5	134.6	49	Wyld	-1.4	98.1	93
McKellar	-15.7	-170.8	51	Planté	-10.2	163.3	37	Stearns	34.8	162.6	36	Xenophon	-22.8	122.1	25
McLaughlin	47.1	-92.9	79	Plaskett	82.1	174.3	109	Stebbins	64.8	-141.8	131	Yablochkov	60.9	128.3	99
McMath	17.3	-165.6	86	Plummer	-25.0	-155.0	73	Stefan	46.0	-108.3	125	Yamamoto	58.1	160.9	76
McNair	-35.7	-147.3	29	Poczobutt	57.1	-98.8	195	Stein	7.2	179.0	33	Zanstra	2.9	124.7	42
McNally	22.6	-127.2	47	Pogson	-42.2	110.5	50	Steklov	-36.7	-104.9	36	Zasyadko	3.9	94.2	11
Mechnikov	-11.0	-149.0	60	Poincaré	-56.7	163.6	319	Steno	32.8	161.8	31	Zeeman	-75.2	-133.6	190
Mees	13.6	-96.1	50	Poinsot	79.5	-145.7	68	Sternfeld	-19.6	-141.2	100	Zelinskiy	-28.9	166.8	53
Meggers	24.3	123.0	52	Polzunov	25.3	114.6	67	Stetson	-39.6	-118.3	64	Zernike	18.4	168.2	48
Meitner	-10.5	112.7	87	Popov	17.2	99.7	65	Stoletov	45.1	-155.2	42	Zhang Yuzhe	-69.0	-137.7	37
Melissa	8.1	121.8	18	Poynting	18.1	-133.4	128	Stoney	-55.3	-156.1	45	Zhiritskiy	-24.8	120.3	35
Mendel	-48.8	-109.4	138	Prager	-3.9	130.5	60	Störmer	57.3	146.3	69	Zhukovskiy	7.8	-167.0	81
Mendeleev	5.7	140.9	313	Prandtl	-60.1	141.8	91	Stratton	-5.8	164.6	70	Zsigmondy	59.7	-104.7	65
Merrill	75.2	-116.3	57	Priestley	-57.3	108.4	52	Strömgren	-21.7	-132.4	61	Zwicky	-15.4	168.1	150
Meshcherskiy	12.2	125.5	65	Purkyně	-1.6	94.9	48	Subbotin	-29.2	135.3	67				
Mezentsev	72.1	-128.7	89	Quételet	43.1	-134.9	55	Sumner	37.5	108.7	50				
Michelson	7.2	-120.7	123	Racah	-13.8	-179.8	63	Sundman	10.8	-91.6	40				
Milanković	77.2	168.8	101	Raimond	14.6	-159.3	70	Sverdrup	-88.5	-152.0	35				
Millikan	46.8	121.5	98	Ramon	-41.6	-148.1	17	Swann	52.0	112.7	42				
Mills	8.6	156.0	32	Ramsay	-40.2	144.5	81	Szilard	34.0	105.7	122				
Milne	-31.4	112.2	272	Raspletin	-22.5	151.8	48	Tamm	-4.4	146.4	38				
Mineur	25.0	-161.3	73	Rayet	44.7	114.5	27	Teisserenc	32.2	-135.9	62				
Minkowski	-56.5	-146.0	113	Razumov	39.1	-114.3	70	Ten Bruggencate	-9.5	134.4	59				
Minnaert	-67.8	179.6	125	Recht	9.8	124.0	20	Tereshkova	28.4	144.3	31				
Mitra	18.0	-154.7	92	Resnik	-33.8	-150.1	20	Tesla	38.5	124.7	43				
Möbius	15.8	101.2	50	Ricco	75.6	176.3	65	Thiel	40.7	-134.5	32				
Mohorovičić	-19.0	-165.0	51	Richards	7.7	140.1	16	Thiessen	75.4	-169.0	66				
Moiseev	9.5	103.3	59	Richardson	31.1	100.5	141	Thomson	-32.7	166.2	117				
Moissan	4.8	137.4	21	Riedel	-48.9	-139.6	47	Tikhomirov	25.2	162.0	65				
Montgolfier	47.3	-159.8	88	Rittenhouse	-74.5	106.5	26	Tikhov	62.3	171.7	83				
Moore	37.4	-177.5	54	Ritz	-15.1	92.2	51	Tiling	-53.1	-132.6	38				
Morozov	5.0	127.4	42	Roberts	71.1	-174.5	89	Timiryazev	-5.5	-147.0	53				
Morse	22.1	-175.1	77	Robertson	21.8	-105.2	88	Tiselius	7.0	176.5	53				
Moseley	20.9	-90.1	90	Roche	-42.3	136.5	160	Titius	-26.8	100.7	73				
Moulton	-61.1	97.2	49	Romeo	7.5	122.6	8	Titov	28.6	150.5	31				
Murakami	-23.3	-140.5	45	Röntgen	33.0	-91.4	126	Trumpler	29.3	167.1	77				
Nagaoka	19.4	154.0	46	Rosseland	-41.0	131.0	75	Tsander (Zander)	6.2	-149.3	181				
Nansen	80.9	95.3	104	Rowland	57.4	-162.5	171	Tseraskiy (Ceraski)	-49.0	141.6	56				
Nassau	-24.9	177.4	76	Rozhdestvenskiy	85.2	-155.4	177	Tsinger (Zinger)	56.7	175.6	44				
Necho	-5.0	123.1	30	Rumford	-28.8	-169.8	61	Tsiolkovskiy	-21.2	128.9	185				
Nernst	35.3	-94.8	116	Rutherford	10.7	137.0	13	Tsu Chung-Chi	17.3	145.1	28				
Neujmin	-27.0	125.0	101	Rydberg	-46.5	-96.3	49	Tyndall	-34.9	117.0	18				
Niepce	72.7	-119.1	57	Ryder	-44.5	143.2	17	Valier	6.8	174.5	67				
Nijland	33.0	134.1	35	Rynin	47.0	-103.5	75	Van de Graaff	-27.4	172.2	233				
Nikolaev	35.2	151.3	41	Saenger	4.3	102.4	75	Van den Bergh	31.3	-159.1	42				
Nishina	-44.6	-170.4	65	Šafařík	10.6	176.9	27	van den Bos	-5.3	146.0	22				
Nobel	15.0	-101.3	48	Saha	-1.6	102.7	99	Van der Waals	-43.9	119.9	104				
Nöther	66.6	-113.5	67	Sanford	32.6	-138.9	55	Van Gent	15.4	160.4	43				
Nušl	32.3	167.6	61	Sarton	49.3	-121.1	69	Van Maanen	35.7	128.0	60				
Numerov	-70.7	-160.7	113	Scaliger	-27.1	108.9	84	van Rhijn	52.6	146.4	46				
Nunn	4.6	91.1	19	Schaeberle	-26.2	117.2	62	Van Wijk	-62.8	118.8	32				
Oberth	62.4	155.4	60	Schjellerup	69.7	157.1	62	van't Hoff	62.1	-131.8	92				
Obruchev	-38.9	162.1	71	Schlesinger	47.4	-138.6	97	Vashakidze	43.6	93.3	44				
O'Day	-30.6	157.5	71	Schliemann	-2.1	155.2	80	Vavilov	-0.8	-137.9	98				
Ohm	18.4	-113.5	64	Schneller	41.8	-163.6	54	Vening Meinesz	-0.3	162.6	87				
Olcott	20.6	117.8	81	Schönfeld	44.8	-98.1	25	Ventris	-4.9	158.0	95				
Olivier	59.1	138.5	69	Schrödinger	-75.0	132.4	312	Vernadskiy	23.2	130.5	91				
Omar Khayyam	58.0	-102.1	70	Schuster	4.2	146.5	108	Vertregt	-19.8	171.1	187				
Onizuka	-36.2	-148.9	29	Schwarzschild	70.1	121.2	212	Vesalius	-3.1	114.5	61				
Oppenheimer	-35.2	-166.3	208	Scobee	-31.1	-148.9	40	Vestine	33.9	93.9	96				
Oresme	-42.4	169.2	76	Seares	73.5	145.8	110	Vetchinkin	10.2	131.3	98				
Orlov	-25.7	-175.0	81	Sechenov	-7.1	-142.6	62	Vil'ev	-6.1	144.4	45				
Ostwald	10.4	121.9	104	Segers	47.1	127.7	17	Virtanen	15.5	176.7	44				
Paneth	63.0	-94.8	65	Seidel	-32.8	152.2	62	Viviani	5.2	117.1	26				
Pannekoek	-4.2	140.5	71	Seyfert	29.1	114.6	110	Volkov	-13.6	131.7	40				
Papaleksi	10.2	164.0	97	Shahinaz	7.5	122.4	15	Volterra	56.8	132.2	52				
Paracelsus	-23.0	163.1	83	Sharonov	12.4	173.3	74	von Békésy	51.9	126.8	96				

(Latest list in Ref. No. 7)

+ Latitude = North – Latitude = South + Longitude = East – Longitude = West Diameter (or long-side dimension) in km

Feature	Lat.	Long.	Dia.
Catena			
Catena Abulfeda	-16.9	17.2	219
Catena Artamonov	26.0	105.9	134
Catena Brigitte	18.5	27.5	5
Catena Davy	-11.0	-7	50
Catena Dziewulski	19.0	100	80
Catena Gregory	-0.6	129.9	152
Catena Humboldt	-21.5	84.6	165
Catena Krafft	15.0	-72	60
Catena Kurchatov	37.2	136.3	226
Catena Leuschner	4.7	-110.1	364
Catena Littrow	22.2	29.5	10
Catena Lucretius	-3.4	-126.1	271
Catena Mendeleev	6.3	139.4	188
Catena Michelson	1.4	-113.4	456
Catena Pierre	19.8	-31.8	9
Catena Sumner	37.3	112.3	247
Catena Sylvester	81.4	-86.2	173
Catena Taruntius	3.0	48	100
Catena Timocharis	29.0	-13	50
Catena Yuri	24.4	-30.4	5
Dorsa, Dorsum			
Dorsa Aldrovandi	24.0	28.5	136
Dorsa Andrusov	-1.0	57.0	160
Dorsa Argand	28.1	-40.6	109
Dorsa Barlow	15.0	31.0	120
Dorsa Burnet	28.4	-57.0	194
Dorsa Cato	1.0	47.0	140
Dorsa Dana	3.0	90.0	70
Dorsa Ewing	-10.2	-39.4	141
Dorsa Geikie	-4.6	52.5	228
Dorsa Harker	14.5	64.0	197
Dorsa Lister	20.3	23.8	203
Dorsa Mawson	-7.0	53.0	132
Dorsa Rubey	-10.0	-42.0	100
Dorsa Smirnov	27.3	25.3	156
Dorsa Sorby	19.0	14.0	80
Dorsa Stille	27.0	-19.0	80
Dorsa Tetyaev	19.9	64.2	176
Dorsa Whiston	29.4	-56.4	85
Dorsum Arduino	24.9	-35.8	107
Dorsum Azara	26.7	19.2	105
Dorsum Bucher	31.0	-39.0	90
Dorsum Buckland	20.4	12.8	380
Dorsum Cayeux	1.6	51.2	84
Dorsum Cloos	1.0	91.0	100
Dorsum Cushman	1.0	49.0	80
Dorsum Gast	24.0	9.0	60
Dorsum Grabau	29.4	-15.9	121
Dorsum Guettard	-10.0	-18.0	40
Dorsum Heim	32.0	-29.8	148
Dorsum Higazy	28.0	-17.0	60
Dorsum Nicol	18.0	23.0	50
Dorsum Niggli	29.0	-52.0	50
Dorsum Oppel	18.7	52.6	268
Dorsum Owen	25.0	11.0	50
Dorsum Scilla	32.8	-60.4	108
Dorsum Termier	11.0	58.0	90
Dorsum Thera	24.4	-31.4	7
Dorsum Von Cotta	23.2	11.9	199
Dorsum Zirkel	28.1	-23.5	193
Lacus			
Lacus Aestatis	-15.0	-69.0	90
Lacus Autumni	-9.9	-83.9	183
Lacus Bonitatis	23.2	43.7	92
Lacus Doloris	17.1	9.0	110
Lacus Excellentiae	-35.4	-44.0	184
Lacus Felicitatis	19.0	5.0	90
Lacus Gaudii	16.2	12.6	113
Lacus Hiemalis	15.0	14.0	50
Lacus Lenitatis	14.0	12.0	80
Lacus Luxuriae	19.0	176.0	50
Lacus Mortis	45.0	27.2	151
Lacus Oblivionis	-21.0	-168.0	50
Lacus Odii	19.0	7.0	70
Lacus Perseverantiae	8.0	62.0	70
Lacus Solitudinis	-27.8	104.3	139
Lacus Somniorum	38.0	29.2	384
Lacus Spei	43.0	65.0	80
Lacus Temporis	45.9	58.4	117
Lacus Timoris	-38.8	-27.3	117

Feature	Lat.	Long.	Dia.
Lacus Veris	-16.5	-86.1	396
Mare, Oceanus			
Mare Anguis	22.6	67.7	150
Mare Australe	-38.9	93.0	603
Mare Cognitum	-10.0	-23.1	376
Mare Crisium	17.0	59.1	418
Mare Fecunditatis	-7.8	51.3	909
Mare Frigoris	56.0	1.4	1596
Mare Humboldtianum	56.8	81.5	273
Mare Humorum	-24.4	-38.6	389
Mare Imbrium	32.8	-15.6	1123
Mare Ingenii	-33.7	163.5	318
Mare Insularum	7.5	-30.9	513
Mare Marginis	13.3	86.1	420
Mare Moscoviense	27.3	147.9	277
Mare Nectaris	-15.2	35.5	333
Mare Nubium	-21.3	-16.6	715
Mare Orientale	-19.4	-92.8	327
Mare Serenitatis	28.0	17.5	707
Mare Smythii	1.3	87.5	373
Mare Spumans	1.1	65.1	139
Mare Tranquillitatis	8.5	31.4	873
Mare Undarum	6.8	68.4	243
Mare Vaporum	13.3	3.6	245
Oceanus Procellarum	18.4	-57.4	2568
Mons, Montes			
Mons Agnes	18.6	5.3	1
Mons Ampère	19.0	-4.0	30
Mons André	5.2	120.6	10
Mons Ardeshir	5.0	121.0	8
Mons Argaeus	19.0	29.0	50
Mons Bradley	22.0	1.0	30
Mons Delisle	29.5	-35.8	30
Mons Dieter	5.0	120.2	20
Mons Dilip	5.6	120.8	2
Mons Esam	14.6	35.7	8
Mons Ganau	4.8	120.6	14
Mons Gruithuisen Delta	36.0	-39.5	20
Mons Gruithuisen Gamma	36.6	-40.5	20
Mons Hadley	26.5	4.7	25
Mons Hadley Delta	25.8	3.8	15
Mons Hansteen	-12.1	-50.0	30
Mons Herodotus	27.5	-53.0	5
Mons Huygens	20.0	-2.9	40
Mons La Hire	27.8	-25.5	25
Mons Maraldi	20.3	35.3	15
Mons Moro	-12.0	-19.7	10
Mons Penck	-10.0	21.6	30
Mons Pico	45.7	-8.9	25
Mons Piton	40.6	-1.1	25
Mons Rümker	40.8	-58.1	70
Mons Usov	12.0	63.0	15
Mons Vinogradov	22.4	-32.4	25
Mons Vitruvius	19.4	30.8	15
Mons Wolff	17.0	-6.8	35
Mont Blanc	45.0	1.0	25
Montes Agricola	29.1	-54.2	141
Montes Alpes	46.4	-0.8	281
Montes Apenninus	18.9	-3.7	401
Montes Archimedes	25.3	-4.6	163
Montes Carpatus	14.5	-24.4	361
Montes Caucasus	38.4	10.0	445
Montes Cordillera	-17.5	-81.6	574
Montes Haemus	19.9	9.2	560
Montes Harbinger	27.0	-41.0	90
Montes Jura	47.1	-34.0	422
Montes Pyrenaeus	-15.6	41.2	164
Montes Recti	48.0	-20.0	90
Montes Riphaeus	-7.7	-28.1	189
Montes Rook	-20.6	-82.5	791
Montes Secchi	3.0	43.0	50
Montes Spitzbergen	35.0	-5.0	60
Montes Taurus	28.4	41.1	172
Montes Teneriffe	47.1	-11.8	182
Palus, Planitia			
Palus Epidemiarum	-32.0	-28.2	286
Palus Putredinis	26.5	0.4	161
Palus Somni	14.1	45.0	143
Planitia Descensus	7.1	-64.4	1

Feature	Lat.	Long.	Dia.
Promontorium			
Promontorium Agarum	14.0	66.0	70
Promontorium Agassiz	42.0	1.8	20
Promontorium Archerusia	16.7	22.0	10
Promontorium Deville	43.2	1.0	20
Promontorium Fresnel	29.0	4.7	20
Promontorium Heraclides	40.3	-33.2	50
Promontorium Kelvin	-27.0	-33.0	50
Promontorium Laplace	46.0	-25.8	50
Promontorium Taenarium	-19.0	-8.0	70
Rima, Rimae			
Rima Agatharchides	-20.0	-28.0	50
Rima Agricola	29.0	-53.0	110
Rima Archytas	53.0	3.0	90
Rima Ariadaeus	6.4	14.0	250
Rima Artsimovich	27.0	-39.0	70
Rima Billy	-15.0	-48.0	70
Rima Birt	-21.0	-9.0	50
Rima Bradley	23.8	-1.2	161
Rima Brayley	21.4	-37.5	311
Rima Calippus	37.0	13.0	40
Rima Cardanus	11.4	-71.5	175
Rima Carmen	19.8	29.3	10
Rima Cauchy	10.5	38.0	140
Rima Cleomedes	27.0	57.0	80
Rima Cleopatra	30.0	-53.8	14
Rima Conon	18.6	2.0	30
Rima Dawes	17.5	26.6	15
Rima Delisle	31.0	-32.0	60
Rima Diophantus	29.0	-33.0	150
Rima Draper	18.0	-25.0	160
Rima Euler	21.0	-31.0	90
Rima Flammarion	-2.8	-5.6	80
Rima Furnerius	-35.0	61.0	50
Rima G. Bond	33.3	35.5	168
Rima Galilaei	11.9	-58.5	89
Rima Gärtner	59.0	36.0	30
Rima Gay-Lussac	13.0	-22.0	40
Rima Hadley	25.0	3.0	80
Rima Hansteen	-12.0	-53.0	25
Rima Hesiodus	-30.0	-20.0	256
Rima Hyginus	7.4	7.8	219
Rima Jansen	14.5	29.0	35
Rima Krieger	29.0	-45.6	22
Rima Laplace *	48.0	-26.0	130
Rima Mairan	38.0	-47.0	90
Rima Marcello	18.6	27.7	2
Rima Marius	16.5	-48.9	121
Rima Messier	-1.0	45.0	100
Rima Milichius	8.0	-33.0	100
Rima Newcomb *	29.9	43.8	41
Rima Oppolzer	-1.7	1.0	94
Rima Réaumur	-3.0	3.0	30
Rima Reiko	18.6	27.7	2
Rima Rudolf	19.6	29.6	8
Rima Schröter	1.0	-6.0	40
Rima Sharp	46.7	-50.5	107
Rima Sheepshanks	58.0	24.0	200
Rima Siegfried	-25.9	103.0	14
Rima Suess	6.7	-48.2	165
Rima Sung-Mei	24.6	11.3	4
Rima T. Mayer	13.0	-31.0	50
Rima Vladimir	25.2	-0.7	14
Rima Wan-Yu	20.0	-31.5	12
Rima Widmannstatten *	-6.1	85.5	46
Rima Yangel'	16.7	4.6	30
Rima Zahia	25.0	-29.5	16
Rimae Alphonsus	-14.0	-2.0	80
Rimae Apollonius	5.0	53.0	230
Rimae Archimedes	26.6	-4.1	169
Rimae Aristarchus	26.9	-47.5	121
Rimae Arzachel	-18.0	-2.0	50
Rimae Atlas	47.5	43.6	60
Rimae Bode	10.0	-4.0	70
Rimae Boscovich	9.8	11.1	40
Rimae Bürg	44.5	23.8	147
Rimae Chacornac	29.0	32.0	120
Rimae Daniell	37.0	26.0	200
Rimae Darwin	-19.3	-69.5	143
Rimae de Gasparis	-24.6	-51.1	93
Rimae Doppelmayer	-25.9	-45.1	162
Rimae Focas	-28.0	-98.0	100

Feature	Lat.	Long.	Dia.
Rimae Fresnel	28.0	4.0	90
Rimae Gassendi	-18.0	-40.0	70
Rimae Gerard	46.0	-84.0	100
Rimae Goclenius	-8.0	43.0	240
Rimae Grimaldi	-9.0	-64.0	230
Rimae Gutenberg	-5.0	38.0	330
Rimae Hase	-29.4	62.5	83
Rimae Herigonius	-13.0	-37.0	100
Rimae Hevelius	1.0	-68.0	182
Rimae Hippalus	-25.5	-29.2	191
Rimae Hypatia	-0.4	22.4	206
Rimae Janssen	-45.6	40.0	114
Rimae Kopff	-17.4	-89.6	41
Rimae Littrow	22.1	29.9	115
Rimae Maclear	13.0	20.0	110
Rimae Maestlin	2.0	-40.0	80
Rimae Maupertuis	52.0	-23.0	60
Rimae Menelaus	17.2	17.9	131
Rimae Mersenius	-20.0	-46.5	300
Rimae Opelt	-13.0	-18.0	70
Rimae Palmieri	-28.0	-47.0	150
Rimae Parry	-6.1	-16.8	82
Rimae Petavius	-25.9	58.9	80
Rimae Pettit	-23.0	-92.0	450
Rimae Pitatus	-28.5	-13.8	94
Rimae Plato	52.9	-3.2	87
Rimae Plinius	17.9	23.6	124
Rimae Posidonius	32.0	28.7	70
Rimae Prinz	27.0	-43.0	80
Rimae Ramsden	-33.9	-31.4	108
Rimae Repsold	50.6	-81.7	166
Rimae Riccioli	-2.0	-74.0	400
Rimae Ritter	3.0	18.0	100
Rimae Römer	27.0	35.0	110
Rimae Secchi	1.0	44.0	35
Rimae Sirsalis	-15.7	-61.7	426
Rimae Sosigenes	8.6	18.7	190
Rimae Sulpicius Gallus	21.0	10.0	90
Rimae Taruntius	5.5	46.5	25
Rimae Theaetetus	33.0	6.0	50
Rimae Triesnecker	4.3	4.6	215
Rimae Vasco da Gama	10.0	-82.0	60
Rimae Zupus	-15.0	-53.0	120
Rupes			
Rupes Altai	-24.3	22.6	427
Rupes Boris	30.5	-33.5	4
Rupes Cauchy	9.0	37.0	120
Rupes Kelvin	-27.3	-33.1	78
Rupes Liebig	-25.0	-46.0	180
Rupes Mercator	-31.0	-22.3	93
Rupes Recta	-22.1	-7.8	134
Rupes Toscanelli	27.4	-47.5	70
Sinus			
Sinus Aestuum	10.9	-8.8	290
Sinus Amoris	18.1	39.1	130
Sinus Asperitatis	-3.8	27.4	206
Sinus Concordiae	10.8	43.2	142
Sinus Fidei	18.0	2.0	70
Sinus Honoris	11.7	18.1	109
Sinus Iridum	44.1	-31.5	236
Sinus Lunicus	31.8	-1.4	126
Sinus Medii	2.4	1.7	335
Sinus Roris	54.0	-56.6	202
Sinus Successus	0.9	59.0	132
Vallis			
Vallis Alpes	48.5	3.2	166
Vallis Baade	-45.9	-76.2	203
Vallis Bohr	12.4	-86.6	80
Vallis Bouvard	-38.3	-83.1	284
Vallis Capella	-7.6	34.9	49
Vallis Christel	24.5	11.0	2
Vallis Inghirami	-43.8	-72.2	148
Vallis Krishna	24.5	11.3	3
Vallis Palitzsch	-26.4	64.3	132
Vallis Planck	-58.4	126.1	451
Vallis Rheita	-42.5	51.5	445
Vallis Schrödinger	-67.0	105.0	310
Vallis Schröteri	26.2	-50.8	168
Vallis Snellius	-31.1	56.0	592

* IAU-dropped name

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Lunar Photograph Credits

Label	Credits
CNSA 001	China National Space Administration 國家航天局
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NAIC 001	National Astronomy and Ionosphere Center, USA.
NASA 001 - NASA 029	National Aeronautics and Space Administration, USA.
T001 - T274	Alan Chu, Hong Kong, China.
USGS 001	U. S. Geological Survey / Clementine Mission

Version History

Version	Release Date	Major Changes
1.1	Oct 2003	- First release with 90 photos and illustrations, 62 pages.
2.1	Jan 2005	- Extensive refinement, over 200 images, 184 pages, additions including mosaic images & illustrations on lunar geology.
3.0	Feb 2006	- Map 22 & Map 23 interchanged. - Over 250 original Moon images including mosaics. - Over 900 named surface features, 209 pages.
3.1	Jan 2007	- Renewed crater diameters & coordinates as IAU/USGS publications. - Marked *Krishna*, *Sung-Mei* as IAU-dropped names. - Rechecked Data of Lunar Images & Index. - Added Lunar Spacecraft & Crater List (Nearside + Farside). - Added/renewed 40 images, 225 pages.
3.2	Feb 2008	- Regrouped Map 15, 16, 29 with NP or SP images. - Added Lunar Geologic Timescale, Global Maps & Non-Crater List. - Minor changes in feature descriptions, 231 pages.
3.3	Jan 2009	- Selenographic coordinates with latitude preceding longitude. - Relabeled T112 (Map 2), T105 (Map 6), T114 & T187 (Map 10), T119 (Map 12), T211 (Map 22). - Updated Map 32, Map 33, Farside & Spacecraft pages. - Added geologic text to features of interest, 233 pages.
3.4	Feb 2010	- Rearranged the order of Map 23, 24, 25 as Map 25, 23, 24. - Expanded Map 1 with geologic interpretation. - Added lunar images from DMK31AF camera. - Renewed Farside, Spacecraft & Appendices. Total 246 pages.
3.5	Mar 2011	- Revised Map 1, 4, 6, 8, 9, 11, 14, 27, 28, 29, 30, 31, 33. - Added lunar images from Canon DSLR. - Renewed Farside, Spacecraft & Appendices. Total 257 pages.