## September's

# Total Lunar Eclipse

Alan MacRobert

### The whole western world can see the eclipse of September 27–28.

**The current** "tetrad" of four total eclipses of the Moon a half-year apart will end with a bang on Sunday evening, September 27th, for the Americas. Unlike last April's eclipse, which may not even have been precisely total (see the July issue, page 12), this one will carry the Moon through the umbra of Earth's shadow for a nice long hour and 12 minutes. Europe and Africa will see the eclipse happen on the local morning of the 28th.

Observers in eastern North America can watch every stage of the eclipse from beginning to end (weather permitting!), during convenient hours of late twilight or darkness with the Moon generally high in the sky.

Viewers in much of the American West will find the first partial stage of the eclipse already in progress when the Moon rises (due east) around the time of sunset. But even on the West Coast, the Moon will lift above the eastern horizon before totality begins. The map on the facing page, and the diagram and timetable on page 28, tell what to expect at your location and when.

This eclipse is unusual in one particular way. It's the *biggest* eclipsed Moon you'll ever see! The year's closest lunar perigee occurs just 59 minutes before mid-eclipse. The Moon (in Pisces) will appear 13% larger in diameter than it did when eclipsed last April 4th.

The events that happen to a shadowed Moon are more complex and interesting than many people realize. This eclipse, with its wide visibility, convenient evening schedule, and record size, is going to get a lot of publicity. So keep the following description handy for when family and friends ask you for the lowdown.

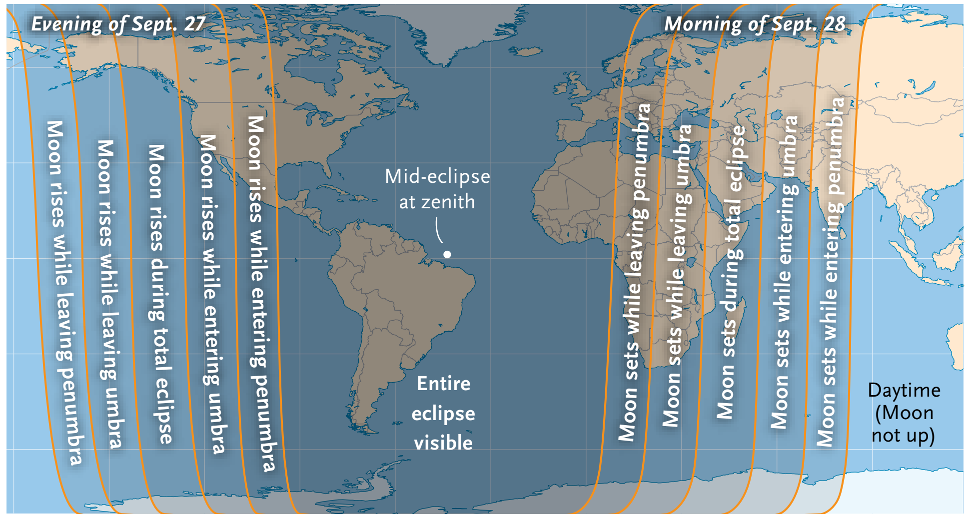
**LASER MOONSHOT** During the total lunar eclipse of April 15, 2014, laser rangers at New Mexico's Apache Point Observatory shot powerful pulses at the Apollo 15 landing site through a 2.5-meter (100-inch) telescope. The Apollo astronauts left small corner reflectors on the Moon's surface. Astronomers can time a reflected photon's round trip well enough now to track the Moon's position and orbital motion to millimeter accuracy. In this way they can watch vast amounts of subtle physics at work, including the most precise tests of general relativity that are currently possible. Sunlight interferes with the measurements when the Moon is full, but not when the full Moon is eclipsed.

DAN LONG / APACHE POINT OBSERVATORY

### Stages of the Eclipse

A total lunar eclipse has five stages, with different things to watch for at each.

The first *penumbral* stage begins when the Moon's leading edge enters the pale outer fringe of Earth's shadow: the penumbra. But the shading is so weak that you won't see anything of the penumbra until the Moon is about halfway across it. During this eclipse, watch for a slight darkening to become apparent on the Moon's celestial northeast side: its left side as seen from North




**TWO ECLIPSES AGO** *Above:* Before dawn on October 8, 2014, Jeff McGrath shot the cirrus-hazed Moon through a 160-mm *f*/8 refractor at Stansbury Park Observatory Complex in Utah.

**WIDE VIEW THIS TIME** *Left:* For your location, check whether the Moon will rise (or set) during some stage of the eclipse. An eclipsed Moon is always full, so the Sun sets (or rises) at almost the same time on the opposite horizon. This means that a lunar-eclipse moonrise or moonset always happens in a very bright sky!


**CRATER TIMING GUIDE** Craters and spots that stand out well during a lunar eclipse are identified here. Approximate times when the umbra's edge will cross them are listed at right.

America, its upper left side as seen from Europe.

The penumbra is the region where an astronaut standing on the Moon would see Earth covering only part of the Sun's face. The penumbral shading becomes stronger as the Moon moves deeper in.

The second stage is *partial eclipse*. This begins much more dramatically when the Moon's leading edge enters the umbra: Earth's inner shadow where the Sun is completely hidden. With a telescope, you can watch the edge of the umbra slowly engulfing one lunar feature after another (see the Crater Timings box on the facing page), as the entire sky begins to grow darker.

The partial phase will last just over an hour. As its end approaches, only a final bright sliver remains outside the umbra. By this time the rest should already be showing a dim, foreboding reddish glow.

The third stage is *total eclipse,* beginning when the last rim of the Moon slips into the umbra. But the Moon won't black out: it's sure to glow some shade of intense orange or red. This red light is sunlight that has skimmed and bent through Earth's atmosphere, all around the edge of our globe, on its way to the Moon. In other words, it's light from all the sunrises and sunsets that ring our world at any given moment. An astronaut standing on the Moon would see the dark Earth thinly rimmed with brilliant orange from the Sun hidden behind it — brilliant enough to illuminate the lunar landscape around him an eerie red.

This umbral light can change a lot from one eclipse to the next. Two main factors affect its brightness and color. The first is simply how deeply the Moon goes into the umbra while passing through; the center of the umbra is much darker than its edges. At mid-eclipse this time, the Moon's south-southeastern edge will be only a quarter of a lunar diameter inside the umbra, so expect that side to be distinctly brighter than the rest.

The other factor is the state of Earth's atmosphere along the sunrise-sunset line. If the air is very clear, the eclipse is bright. But if a major volcanic eruption has recently polluted the stratosphere with thin global haze, a lunar eclipse will be dark red, ashen gray, or occasionally almost black.

In addition, *blue* light is refracted through Earth's clear, ozone-tinted upper atmosphere above the thicker layers that produce the red sunrise-sunset colors. This ozone-blue light colors the Moon a bit near the umbra's edge. The result can be a subtle mix of changing blue, gray, purple, and even green.

Time-lapse videos may show large "flying shadows" in the umbra, caused by changing cloud-shadowing effects around the sunrise-sunset line as Earth turns and the Moon moves.

And then, as the Moon continues eastward along its orbit, events replay in reverse order. The Moon's edge re-emerges into sunlight, ending totality and beginning stage four: a partial eclipse again.

When all of the Moon escapes the umbra, only the last, penumbral shading is left for stage five. By about 30 or 40 minutes later, nothing unusual remains.

We'll have more than two years' wait until the next total eclipse of the Moon, on January 31, 2018. And that will be visible only from the Eastern Hemisphere and the western side of North America.

The previous tetrad of lunar eclipses happened in 2003–04. The next begins on April 25, 2032.

## Uranus Again

During the eclipse of October 8, 2014, eleven days short of a year before this one, the Moon was only about 1° from 6th-magnitude Uranus. This time Uranus is about 15° to the Moon's east. But take a look during a quiet few minutes if the Moon is high in a dark sky at your location while the eclipse is still total. Use the finder charts on page 49. Uranus is 15 times larger than the Moon but, on this night, it's 8,000 times farther away. It will be magnitude 5.7. In the darkness of the total lunar eclipse, can you glimpse Uranus naked-eye? ✦

*Although* S&T *senior editor* ***Alan MacRobert*** *sees Earth totally eclipsing the Sun every clear evening from his house, he really wants to see it happening from Mare Crisium.*

## Crater Timing Predictions

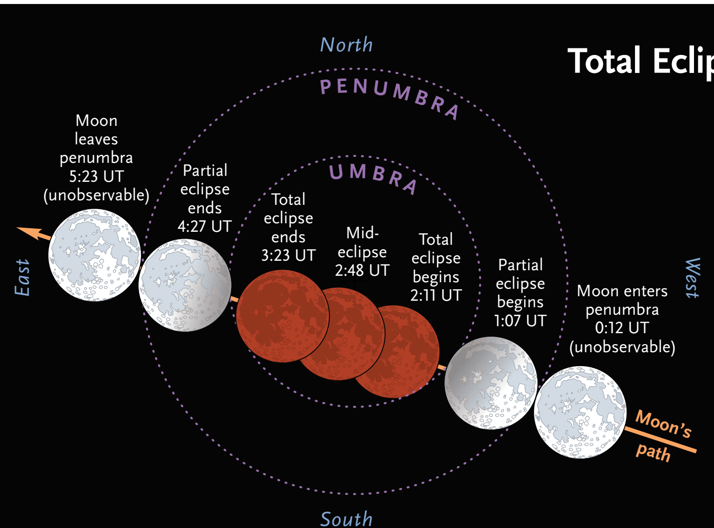
**ENTRANCES**

| Feature | UT |
|---|---|
| Grimaldi | 1:11 |
| Aristarchus | 1:15 |
| Billy | 1:18 |
| Kepler | 1:18 |
| Pytheas | 1:25 |
| Copernicus | 1:26 |
| Timocharis | 1:28 |
| Plato | 1:30 |
| Campanus | 1:31 |
| Aristoteles | 1:38 |
| Eudoxus | 1:39 |
| Manilius | 1:39 |
| Menelaus | 1:42 |
| Tycho | 1:43 |
| Dionysius | 1:45 |
| Plinius | 1:46 |
| Censorinus | 1:53 |
| Proclus | 1:55 |
| Taruntius | 1:57 |
| Goclenius | 2:00 |
| Langrenus | 2:05 |

**EXITS**

| Feature | UT |
|---|---|
| Grimaldi | 3:31 |
| Billy | 3:33 |
| Campanus | 3:37 |
| Tycho | 3:38 |
| Kepler | 3:43 |
| Aristarchus | 3:45 |
| Copernicus | 3:51 |
| Pytheas | 3:53 |
| Timocharis | 3:58 |
| Plato | 4:04 |
| Manilius | 4:05 |
| Dionysius | 4:06 |
| Menelaus | 4:08 |
| Censorinus | 4:11 |
| Plinius | 4:11 |
| Eudoxus | 4:11 |
| Aristoteles | 4:12 |
| Goclenius | 4:12 |
| Langrenus | 4:16 |
| Taruntius | 4:18 |
| Proclus | 4:20 |

## Total Eclipse of the Moon, Night of September 27–28, 2015




S&T: LEAH TISCIONE

| Eclipse event | EDT | CDT | MDT | PDT |
|---|---|---|---|---|
| Penumbra first visible? | 8:40 p.m. | 7:40 p.m. | — | — |
| Partial eclipse begins | 9:07 p.m. | 8:07 p.m. | 7:07 p.m. | — |
| Total eclipse begins | 10:11 p.m. | 9:11 p.m. | 8:11 p.m. | 7:11 p.m. |
| Mid-eclipse | 10:48 p.m. | 9:48 p.m. | 8:48 p.m. | 7:48 p.m. |
| Total eclipse ends | 11:23 p.m. | 10:23 p.m. | 9:23 p.m. | 8:23 p.m. |
| Partial eclipse ends | 12:27 a.m. | 11:27 p.m. | 10:27 p.m. | 9:27 p.m. |
| Penumbra last visible? | 12:55 a.m. | 11:55 p.m. | 10:55 p.m. | 9:55 p.m. |

## Crater Timings Sought!

**The size of Earth's umbra** varies slightly from one eclipse to the next for reasons that are still unknown. For 170 years, careful observers have timed when the edge of the umbra crosses lunar markings during eclipses. In the June issue (page 28) Roger Sinnott told of the massive analysis that he and his colleagues did of the 26,658 timings that are on record since 1842. And he called for readers to make timings during this upcoming eclipse, especially because it offers a very similar repeat of the much-timed eclipse of September 27, 1996.

All you will need is a small telescope (use fairly high power), a timepiece that reads to the second, and a notepad and pencil.

Check in advance that your watch or device is accurately set to the second (for instance, at time.gov/widget). The idea is to time when the umbra's edge — defined as *where the shadow changes brightness most abruptly* — crosses a feature's center. Record the time to at least the nearest 5 seconds.

The photo at the top of the facing page labels some standard timing targets. The table above gives many rough predictions, so you don't get caught flat-footed. It's fine to skip some.

Please report your timings to Roger Sinnott at rsinnott@post.harvard.edu. We'll publish results in a future issue. You can become a part of lunar history.

# Telescopic Moon Map

The Moon shows fantastic detail in even the smallest telescope. And light pollution doesn't affect it a bit. In city or country, the Moon will be an intimate part of your astronomy life. Use this map — with the help of the previous four-page article — to explore our closest neighbor world.

## Lunar Features

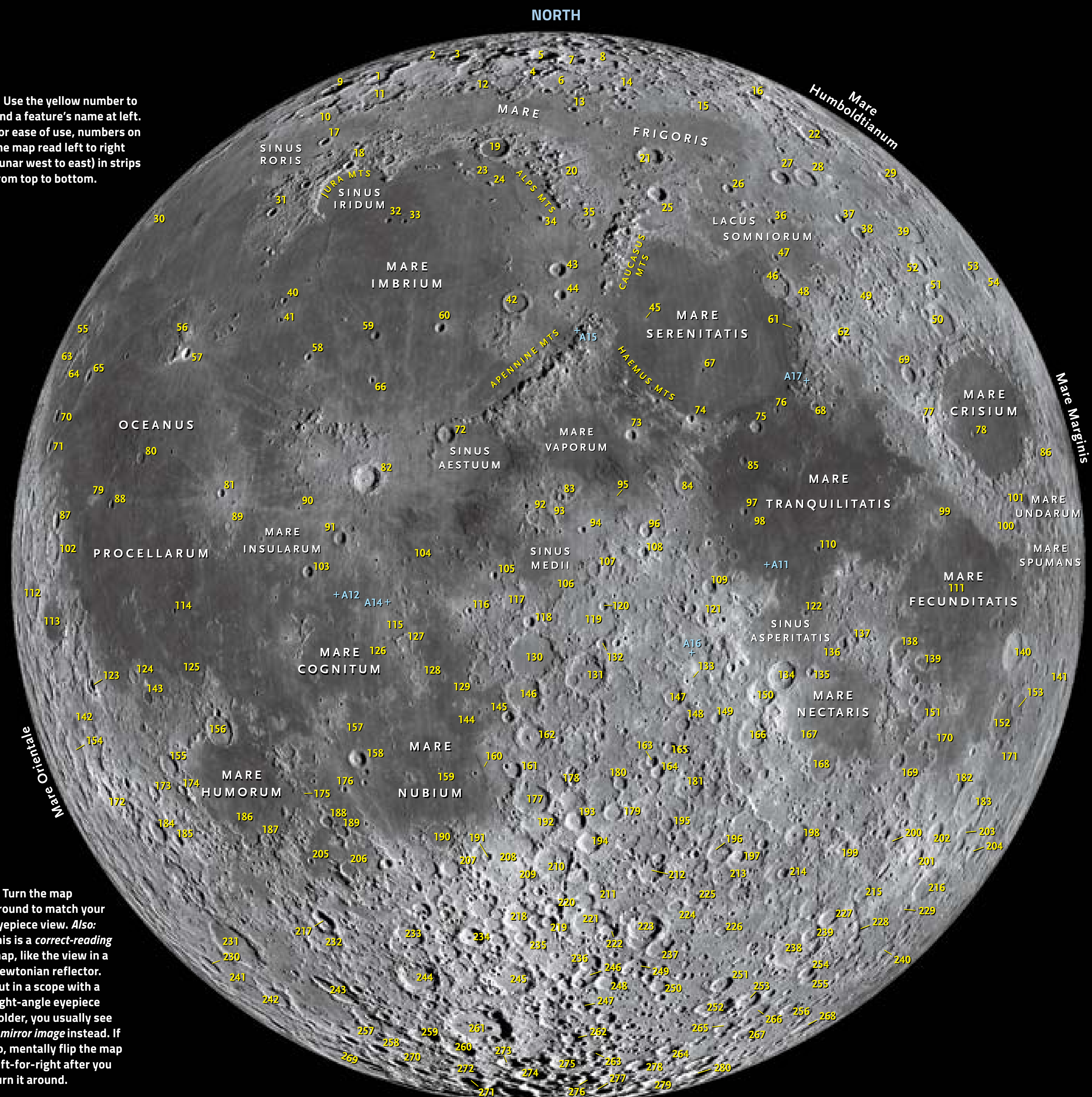
**Crater Names**

1 Anaximander
2 Anaximenes
3 Philolaus
4 Epigenes
5 Goldschmidt
6 W. Bond
7 Barrow
8 Meton
9 Pythagoras
10 South
11 J. Herschel
12 Fontenelle
13 Archytas
14 C. Mayer
15 Gärtner
16 Strabo
17 Harpalus
18 Bianchini
19 Plato
20 Alpine Valley
21 Aristoteles
22 Endymion
23 Teneriffe Mountains
24 Mt. Pico
25 Eudoxus
26 Bürg
27 Hercules
28 Atlas
29 Mercurius
30 von Braun
31 Mairan
32 Helicon
33 Le Verrier
34 Mt. Piton
35 Cassini
36 Grove
37 Cepheus
38 Franklin
39 Messala
40 Delisle
41 Diophantus
42 Archimedes
43 Aristillus
44 Autolycus
45 Linné
46 Posidonius
47 Daniell
48 Chacornac
49 Taurus Mountains
50 Cleomedes
51 Burckhardt
52 Geminus
53 Berosus
54 Hahn
55 Russell
56 Schröter's Valley
57 Aristarchus
58 Euler
59 Lambert
60 Timocharis
61 Le Monnier
62 Römer
63 Struve
64 Eddington
65 Seleucus
66 Pytheas
67 Bessel
68 Vitruvius
69 Macrobius
70 Krafft
71 Cardanus
72 Eratosthenes
73 Manilius
74 Menelaus
75 Plinius
76 Dawes
77 Proclus
78 Picard
79 Reiner Gamma
80 Marius
81 Kepler
82 Copernicus
83 Ukert
84 Julius Caesar
85 Ross
86 Condorcet
87 Cavalerius
88 Reiner
89 Encke
90 Hortensius
91 Reinhold
92 Pallas
93 Murchison
94 Triesnecker
95 Rima Hyginus
96 Agrippa
97 Arago
98 Lamont
99 Taruntius
100 Apollonius
101 Firmicus
102 Hevelius
103 Lansberg
104 Gambart
105 Mösting
106 Réaumur
107 Rhaeticus
108 Godin
109 Delambre
110 Maskelyne
111 Messier
112 Riccioli
113 Grimaldi
114 Flamsteed
115 Fra Mauro
116 Lalande
117 Flammarion
118 Herschel
119 Hipparchus
120 Horrocks
121 Taylor
122 Torricelli
123 Sirsalis
124 Hansteen
125 Letronne
126 Bonpland
127 Parry
128 Guericke
129 Davy
130 Ptolemaeus
131 Albategnius
132 Halley
133 Descartes
134 Theophilus
135 Mädler
136 Isidorus
137 Capella
138 Gutenberg
139 Goclenius
140 Langrenus
141 La Pérouse
142 Crüger
143 Billy
144 Lassell
145 Alpetragius
146 Alphonsus
147 Abulfeda
148 Almanon
149 Tacitus
150 Cyrillus
151 Colombo
152 Vendelinus
153 Lamé
154 Darwin
155 Mersenius
156 Gassendi
157 Lubiniezky
158 Bullialdus
159 Nicollet
160 Straight Wall
161 Thebit
162 Arzachel
163 Abenezra
164 Azophi
165 Geber
166 Catharina
167 Beaumont
168 Fracastorius
169 Santbech
170 Cook
171 Holden
172 Byrgius
173 Cavendish
174 Liebig
175 Hippalus
176 König
177 Purbach
178 La Caille
179 Apianus
180 Playfair
181 Sacrobosco
182 Wrottesley
183 Petavius
184 Vieta
185 Fourier
186 Doppelmayer
187 Vitello
188 Campanus
189 Mercator
190 Pitatus
191 Hell
192 Regiomontanus
193 Werner
194 Aliacensis
195 Pontanus
196 Zagut
197 Lindenau
198 Piccolomini
199 Neander
200 Reichenbach
201 Stevinus
202 Snellius
203 Hase
204 Adams
205 Ramsden
206 Capuanus
207 Gauricus
208 Deslandres
209 Lexell
210 Walter
211 Kaiser
212 Gemma Frisius
213 Rabbi Levi
214 Stiborius
215 Rheita
216 Furnerius
217 Hainzel
218 Orontius
219 Nasireddin
220 Miller
221 Stöfler
222 Faraday
223 Maurolycus
224 Buch
225 Büsching
226 Nicolai
227 Metius
228 Young
229 Fraunhofer
230 Inghirami
231 Schickard
232 Mee
233 Wilhelm
234 Tycho
235 Saussure
236 Licetus
237 Barocius
238 Janssen
239 Fabricius
240 Vega
241 Wargentin
242 Phocylides
243 Schiller
244 Longomontanus
245 Maginus
246 Heraclitus
247 Lilius
248 Cuvier
249 Clairaut
250 Baco
251 Pitiscus
252 Hommel
253 Vlacq
254 Steinheil
255 Watt
256 Biela
257 Zucchius
258 Bettinus
259 Scheiner
260 Blancanus
261 Clavius
262 Zach
263 Pentland
264 Mutus
265 Nearch
266 Rosenberger
267 Hagecius
268 Pontécoulant
269 Bailly
270 Kircher
271 Casatus
272 Klaproth
273 Gruemberger
274 Moretus
275 Curtius
276 Simpelius
277 Schomberger
278 Manzinus
279 Boguslawsky
280 Boussingault

**Apollo Landing Sites**

A11 Apollo 11
A12 Apollo 12
A14 Apollo 14
A15 Apollo 15
A16 Apollo 16
A17 Apollo 17

■ Use the yellow number to find a feature's name at left. For ease of use, numbers on the map read left to right (lunar west to east) in strips from top to bottom.




■ Turn the map around to match your eyepiece view. *Also:* this is a *correct-reading* map, like the view in a Newtonian reflector. But in a scope with a right-angle eyepiece holder, you usually see a *mirror image* instead. If so, mentally flip the map left-for-right after you turn it around.