Tammy Plotner

ASTRONOMER'S POCKET
FIELD GUIDE

Moonwalk with Your Eyes

A Pocket Field Guide

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Foreword

Fig. 1 Robert Gendler.

We shall never know when this happened, on the shores of what vanished sea. There were no eyes or cameras present to record so obscure, so inconspicuous an event. Now, the Moon calls again – and this time life responds with a roar that shakes Earth and sky.

Arthur C. Clarke

Since the birth of the Moon over four billion years ago, it and the Earth have been locked together in a cosmic embrace separated by some 384,403 km of space (Fig. 1). When it first formed, it rotated much faster on its axis, its tidal bulge leading the way. Because the lunar crust was not liquefied, this bulge could not keep up the frenzied pace and it passed beyond the Earth–Moon line. Thanks to torque of Earth's gravity, the bulge was captured like a wrench tightening a nut, and the Moon has slowed its spin to match its orbital rate – always facing Earth. We call it the "Near Side"… and it is only as far away as your own back yard.

This gravitation coupling affects us deeply. It touches the environment around us as the Earth–Moon system governs the oceans tides and drains kinetic energy and angular momentum from the Earth's rotation. The phase of the Moon, it would seem, also influences the behavior of a number of animals – including humans. Animals are not just responding to the changes in amount of available light, which may make them better predators or able to see each other – but possibly to monthly circadian rhythms in operation – as in humans. It is also possible that we are both responding to gravitational effects by our Earth–Moon system. Just ask any fisherman, and he will tell you it is true… Just as many farmers also use a planting "Moon calendar."

Ancient cultures thought of time as a circle – with no beginning or end (Fig. 2). We had no control over time or nature, and the heavens were a great mystery. The Moon was a supernatural phenomena or perhaps a deity to be worshiped. It was not until around 428 BC that Greek philosopher Anaxagoras put the Earth and Moon into perspective as giant spherical rocks, and that the latter reflected the light of the former. By 1609, Galileo made us realize it was something just a little bit more by revealing a distant world waiting to be explored. Later in the seventeenth century, Giovanni Battista Riccioli and Francesco Maria Grimaldi were charting the Moon's features and less than 200 years later we were standing on the surface.

Here on Earth we can see with our eyes the mute testimony of the Moon's beginnings. Whether it was spun off, blasted away, or formed at the same time as our planet is all irrelevant in the stillness of the night. Even our most distant ancestors saw this exact same Moon. The ancient astronomers saw the dark patches, believed them to be filled with water, and named them "maria" – the Latin word for sea. And indeed they are seas… seas of long healed lava. The "terrae" or "highlands" were believed to be higher… And so they are. Our human curiosity has led us ever deeper into exploration, from casual observation of impact craters to the deepest understanding of the composition of regolith, gravity fields, magnetic fields, surface temperatures, atmosphere, and even the presence of lunar ice.

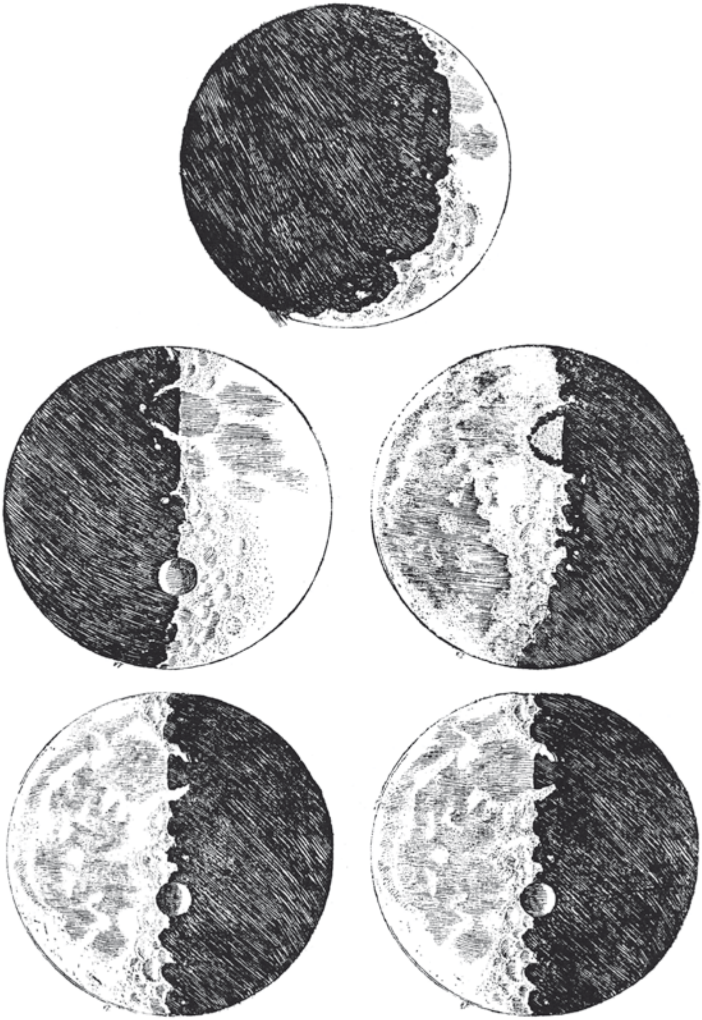

Fig. 2 Galileo's Moon drawing (public domain).

The Moon has inspired poet and philosopher… (Fig. 3). Scientist and explorer. Around it has been built calendars and temples… books and prophecies. Let it inspire you.

Caledonia, OH **Tammy Plotner**

Fig. 3 “Moon Over Tasmania” – Shevill Mathers.

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PART I

NEW MOON

CHAPTER 1

LUNAR DAY ZERO

Meet me by Moonlight alone,
And then I will tell you a tale
Must be told by the Moonlight alone…

Joseph Augustine Wade

We begin our travels together with the New Moon (Fig. 1.1). By astronomical definition, the Moon is now in conjunction with the Sun as seen from Earth. The shadowed portion of the side that always faces us is pointed our way… and we simply cannot see it. It is there – only hidden. The moment of conjunction in ecliptic longitude is unique, occurring at a slightly different

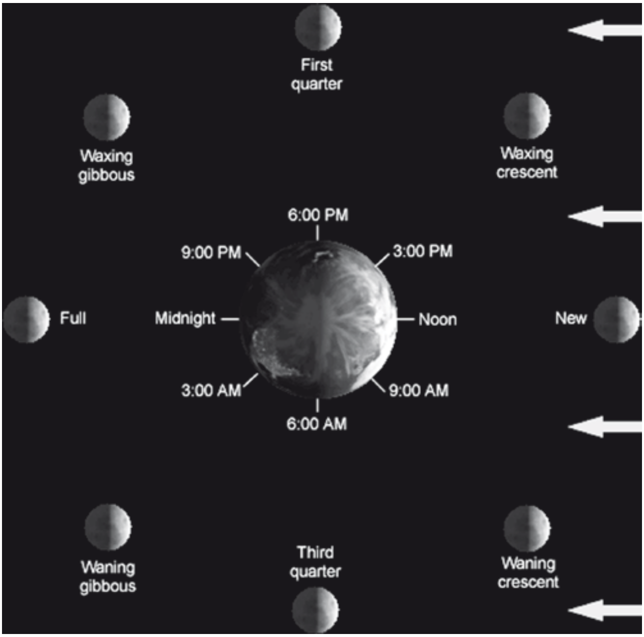

Fig. 1.1 Lunar phase diagram – donated by Minesweeper (Wikipedia).

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time each lunar month and you will find its precise time listed in the tables at the back of this book. We will even learn more about how to deal with these "times" as time goes on! Within a matter of hours our nearest astronomical neighbor will have moved away from the Sun's glare and our "Lunar Days" will begin. Let us take a moment now to prepare ourselves.

Observing the Moon is as easy as using your eyes, binoculars, or a telescope – and each chapter will outline things for you to observe in each category. I would love to be able to give you the answer to the perfect pair of binoculars or the perfect telescope to use for lunar observing – but the fact is, I cannot. Your choice of optics is a matter of individual taste and budget. Even the most humble of binoculars and telescopes will provide an incredible view of the lunar surface over your eyes alone, so let us simply discuss just a bit more about them (Fig. 1.2).

Binoculars are both technical and simple at the same time. They consist of an objective lens (the large lens at the far end of the binocular), the ocular lens (the eyepiece), and a prism (a light reflecting, triangular sectioned block of glass with polished edges). The prism folds the light path and allows the body to be far shorter than a telescope. It also flips the image around so it does not look upside down. The traditional Z-shaped Porro prism design is well suited to astronomy and consists of two joined right-angled prisms, which reflects the light path three times. The sleeker, straight-barreled roof

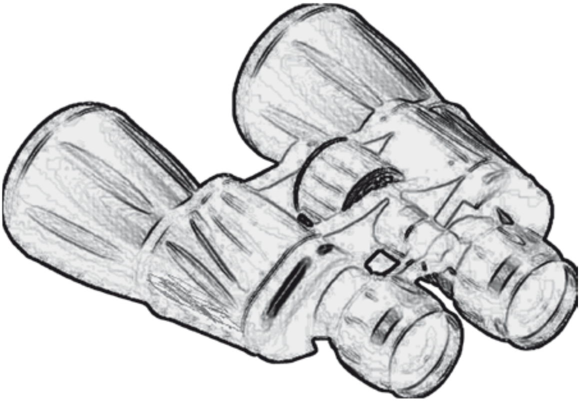

Fig. 1.2 Porro prism binoculars.

prism models are more compact and far more technical. The light path is longer, folding four times, and requires stringent manufacturing quality to equal the performance. These models are better suited to terrestrial subjects and are strongly not recommended for astronomy use. If you are using binoculars for lunar astronomy, go with a Porro prism design.

Every pair of binoculars will have a pair of numbers associated with it: the magnifying power times (×) the objective lens size. For example, a popular ratio is 7×35. For astronomical applications, these two numbers play an important role in determining the exit pupil – the amount of light the human eye can accept (5–7 mm depending on age from older to younger). By dividing the objective lens (or aperture) size by the magnifying power you can determine exit pupil of a pair of binoculars. Like a telescope, the larger the aperture, the more the light gathering power – increasing proportionately in bulk and weight. Stereoscopic views of the night sky through big binoculars are an incredible, dimensional experience and one quite worthy of a mount and tripod! As you journey through the binocular department, go armed with the knowledge of how to choose your binocular's lens size (Fig. 1.3).

Fig. 1.3

Why does the binocular lens size matter? Because binoculars truly are a twin set of refracting telescopes, the size of the objective (or primary) lens is referred to as the aperture. Just as with a telescope, the aperture is the light gathering source and this plays a key role in the applications binoculars are suited for. Theoretically, more aperture means brighter and better resolved images – yet the size and bulk increases proportionately. To be happiest with your choice, you must ask yourself what you will be viewing most often with your new binoculars. Let us take a look at some general uses for astronomy binoculars by their aperture.

Binoculars with a lens size of less that 30 mm, such as 5 × 25 or 5 × 30, are small and very portable. The compact models can fit easily into a pocket or backpack and are very convenient for a quick look at well-lit situations. In this size range, low magnifications are necessary to keep the image bright. Compact models are also great binoculars for very small children. If you are interested in choosing binoculars for a child, any of these models are very acceptable – just keep in mind a few considerations. Children are naturally curious, so limiting them to only small binoculars may take away some of the joy of learning. After all, imagine the thrill of watching a raccoon in its natural habitat at sundown… Or following a comet! Choose binoculars for a child by the size they can handle, whether the model will fold correctly to fit their interpupilary size, and durability. Older children are quite capable of using adult-sized models and are naturals with tripod and monopod arrangements. For less than the price of most toys, you can put a set of quality optics into their hands and open the door to learning. Children as young as 3 or 4 years old can handle 5 × 30 models easily and enjoy wildlife and stargazing both!

Binocular aperture of up to 40 mm is a great mid-range size that can be used by almost everyone for multiple applications. In this range, higher magnification becomes a little more practical. For those who enjoy stargazing, this is an entry level aperture that is very acceptable to study the Moon, and they make wonderful binoculars for older children. Binoculars up to 50–60 mm in lens size are also considered mid-range, but far heavier. Again, increasing the objective lens size means brighter images in low light situations – but these models are a bit more bulky. They are very well suited to lunar astronomy, but the larger models may require a support (tripod, monopod, car window mount) for extended viewing.

Capable of much higher magnification, these larger binocular models will seriously help to pick up small features. The 50-mm size is fantastic for older children who are ready for more expensive optics, but there are drawbacks. The 50–60 mm binoculars are pushing the maximum amount of weight that can be held comfortably by the user without assistance, but do not rule them out. Available in a wide range of magnifications, these models are for serious study and will give crisp, bright images.

Binoculars any larger than 50–60 mm are some serious aperture. These are the perfect size allowing for bright images at high magnification. For astronomy applications, binoculars with equations like 15 × 70 or 20 × 80 are definitely going to open a whole new vista to your observing nights. The wide field of view allows for a panoramic view. If you have never experienced binocular astronomy, you will be thrilled at how easy objects are to locate and the speed and comfort at which you can observe. A whole new experience is waiting for you! (Fig. 1.4)

When choosing binoculars for lunar astronomy, just keep in mind that all binoculars are expressed in two terms – magnifying power × objective lens size. So far we have only looked at the objective lens size. Like a telescope, the larger the aperture, the more the light gathering power – increasing proportionately in bulk and weight. Stereoscopic views of the night sky through big binoculars are an incredible, dimensional experience, but for

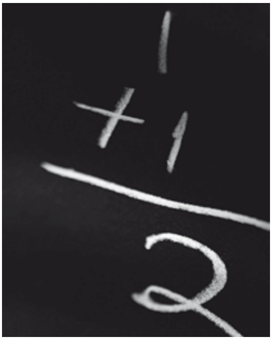

Fig. 1.4

astronomical applications we need these two numbers to play an important role in determining the exit pupil – the amount of light the human eye can accept. By dividing the objective lens (or aperture) size by the magnifying power you can determine exit pupil of a pair of binoculars. Let us take a look at why that is important.

How do binoculars magnify? What is the best magnification to use? What magnifying power do I choose for astronomy? Where do I learn about what magnifying power is best in binoculars? Because binoculars are a set of twin refracting telescopes meant to be used by both eyes simultaneously, we need to understand how our eyes function. All human eyes are unique, so we need to take a few things into consideration when looking at the astronomy binocular magnification equation. By dividing the objective lens (or aperture) size by the magnifying power you can determine exit pupil of a pair of binoculars and match it to your eyes. During the daylight, the human eye has about 2 mm of exit pupil – which makes high magnification practical. In low light or Moongazing, the exit pupil needs to be more around 5 to be usable.

While it would be tempting to use as much magnification as possible, all binoculars (and the human eye) have practical limits. You must consider eye relief – the amount of distance your eye must be away from the secondary lens to achieve focus. Many high "powered" binoculars do not have enough outward travel for eye glass wearers to come to focus without your glasses. Anything less than 9-mm eye relief will make for some very uncomfortable viewing. If you wear eyeglasses to correct astigmatism, you may wish to leave your glasses on while using binoculars, so look for models which carry about 15-mm eye relief.

Now, let us talk about what you see! If you look through binoculars of two widely different magnifying powers at the same object, you will see you have the choice of a small, bright, crisp image or a big, blurry, dimmer image – but why? Binoculars can only gather a fixed amount of light determined by their aperture (lens size). When using high magnification, you are only spreading the same light over a larger area, and even the best binoculars can only deliver a certain amount of detail. Being able to steady the view also plays a critical role. At maximum magnification, any movement will be exaggerated in the viewing field. For example, seeing craters on the Moon is a tremendous experience – if only you could hold the view still long enough to identify which one it is! Magnification also decreases the amount of light that reaches the eye. For these reasons, we must consider the next step – choosing the binocular magnification – carefully.

Binoculars with 7× magnifying power or less, such as 7×35, not only deliver long eye relief, but also allow for variable eye relief that is customizable to the user's own eyes and eyeglasses. Better models have a central focus mechanism with a right eye diopter control to correct for normal right/left eye vision imbalance. This magnification range is great for most astronomy applications. Low power means less "shake" is noticed. Binoculars with 8× or 9× magnification also offer long eye relief and allow comfort for eyeglass wearers as well as those with uncorrected vision. With just a bit more magnification, they compliment astronomy. Binoculars with 10× magnifying power are a category of their own. They are at the edge of multipurpose eye relief, and magnifying power at this level is excellent across all subject matter. However, larger aperture is recommended for locating faint astronomy subjects.

Binoculars with 12–15× magnifying power offer almost telescopic views. In astronomy applications, aperture with high magnification is a must to deliver bright images. Some models are extremely well suited to binocular astronomy with a generous exit pupil and aperture combined. Binoculars with 16× magnification and higher are on the outside edge of high magnification at hand-held capabilities. They are truly designed exclusively as mounted astronomical binoculars. Most have excellent eye relief, but when combined with aperture size, a tripod or monopod is suggested for steady viewing. If you are interested in varying the power, you might want to consider zoom binoculars. These allow for a variety of applications that are not dependent solely on a single feature. Models can range anywhere from as low as 5× magnification up to 30×, but always bear in mind the higher the magnification – the dimmer the image. Large aperture would make for great astronomy applications when a quick, more magnified view is desired without being chained to a tripod.

The next thing to do is take a good look at the binoculars you are about to purchase. Check out the lenses in the light. Do you see blue, green, or red? Almost all binoculars have antireflection coatings on their air-to-glass surfaces, but not all are created equal. Coatings on binocular lenses were meant to assist light transmission of the object you are focusing on and canceling ambient light. Simply "coated" in the description means they probably only have this special assistance on the first and last lens elements – the ones you are looking at. The same can also be said of the term "multicoated"; it is probably just the exterior lens surface, but at least there is more than one layer! "Fully coated" means all the air-to-glass surfaces are coated, which is better…, and "fully multicoated" is best. Keeping stray light from bouncing around and spoiling the light you want to see is very important, but beware of ruby-coated lenses… These were meant for bright daylight applications and will rob astronomical binoculars of the light they seek.

Last, but not least, is a scary word – collimation. Do not be afraid of it. It only means the optics and the mechanics are properly aligned. Most cheap binoculars suffer from poor collimation, but that does not mean you cannot find an inexpensive pair of binoculars that are well collimated. How can you tell? Take a look through them with both eyes. If you cannot focus at long distance, short distance, and a distance in-between, there is something wrong. If you cannot close either eye and come to focus with the other, there is something wrong. Using poorly collimated binoculars for any length of time causes eye strain you would not soon forget.

Now for telescopes!

A simple refractor or refracting telescope is a hollow tube that uses a primary lens at its opening to diffract or change the path of incoming light waves (Fig. 1.5). This primary lens is called the "objective lens" and is used to collect more light than the human eye. When light passes through the objective lens, it is bent – or refracted. Light waves that enter on a parallel path converge or meet together at a focal point. Light waves that enter at an angle converge on the focal plane. It is the combination of both, which forms an image that is further refracted and magnified by a secondary lens called the eyepiece. As with any telescope, the size of the primary or objective light gathering source is the key. The larger the primary, the more light can be gathered revealing ever fainter objects in greater detail. However, since a refractor telescope lens can never be large – why has the design endured? Unlike a reflector telescope, the refractor tube is sealed. Like looking through glass, looking through air also causes a certain amount of diffraction, as well as turbulence and heat wave issues. Because

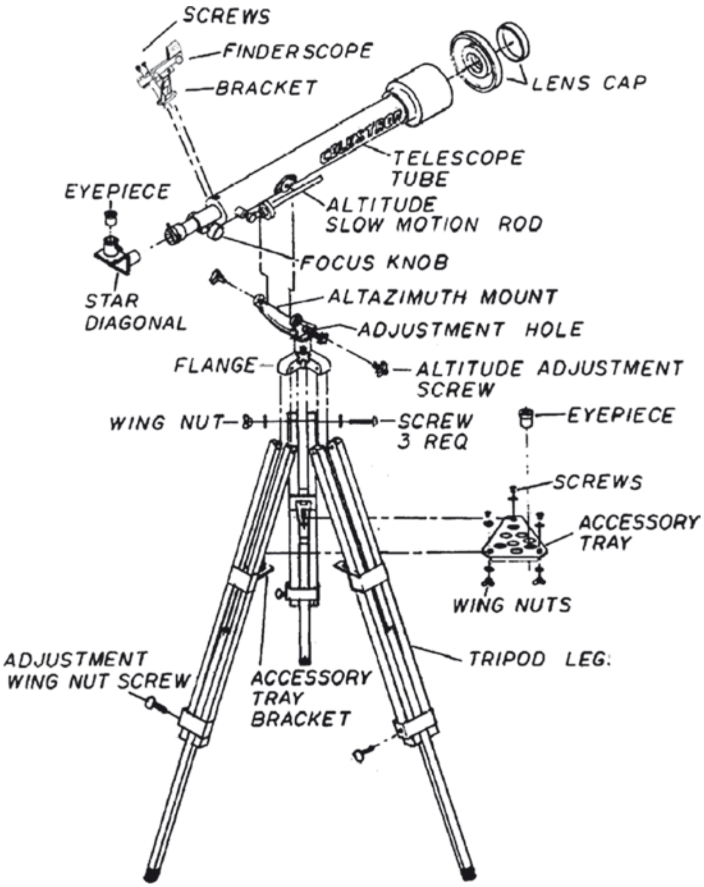

Fig. 1.5 Refractor telescope.

the interior of a refractor is never exposed to the outside air, the view is considered to be far more crisp and steady – making the refractor ideal for studying lunar and planetary details – or resolving close double stars. Since both the primary and secondary light gathering sources are locked into place, this also means the refractor telescope requires less maintenance to keep its optical parts aligned.

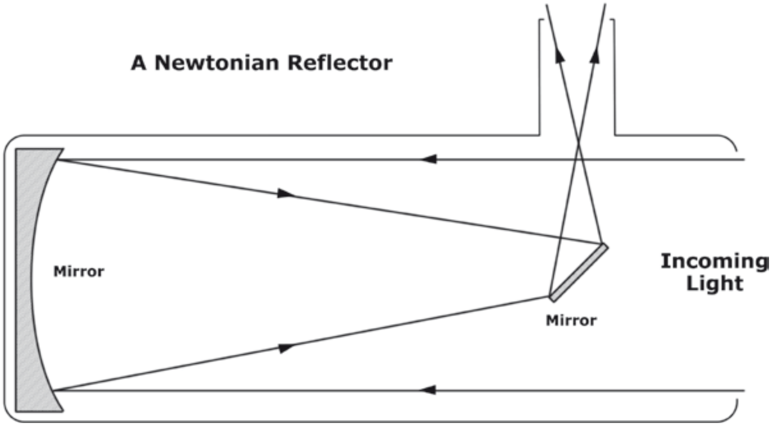

Fig. 1.6 Reflector telescope.

Another consideration on behalf of the refractor telescope is its ability to be used for both terrestrial and celestial applications. Special additions to the viewing end of the telescope called a "star diagonal" will invert the image again so that it is correctly oriented and gives the viewer a more comfortable position when aimed at the zenith. The small size and portability of the refractor also make it an excellent choice for travelers, and modern binoculars are nothing more than a pair of twin refractors!

A reflector or reflecting telescope uses an arrangement of one or more curved mirrors to gather light and return it along an optical path to a point of focus (Fig. 1.6). The most critical element of this type of telescope is the major light gathering source – the primary mirror. Light strikes the parabolic, reflective surface of the primary and returns to a point of focus called the focal plane. Because each spherical or parabolic-shaped primary mirror is slightly different, the distance the light needs to travel to achieve focus is called the focal length. At its focus point, the image (in a simple reflector telescope) is collected on another mirror surface called the secondary. The secondary mirror is then aimed toward the viewer who uses a series of lenses called an eyepiece to magnify the image and send it to the eye.

Since Sir Isaac Newton's day, the reflector telescope has continued to remain popular because it is the least expensive way to gather light over large surfaces. The size of the primary light gathering source is very important, because the more the light that can be collected, the fainter the object of study can be and the better it can be resolved. While the Newtonian design has been adopted for some of the world's largest telescopes, it has undergone many design changes to create hybrids. Why is this important? Because the longer the focal length is (the light path between the primary and final point of focus) the more useful is the magnification that can be applied. This is expressed in a simple term called the focal ratio and will be defined in terms like *f*/4 for a short focal length and *f*/10 for longer length. In order to achieve this long focal length without making the telescope tube longer, a reflector design was introduced called the Cassegrain. Light enters the telescope, is collected on a parabolic primary mirror at the rear, and is reflected to a hyperbolic secondary mirror mounted on a clear glass plate at the front of the scope. From there, the light is reflected and refocused once again back through a hole in the primary mirror where it is then magnified with an eyepiece. This process is what is known as "folding the optical path." The result is a short telescope body that is long on focal length.

Other types of reflector telescopes also used a folded optical path, and their designs make them application specific – such as astrophotography. Reflector telescope hybrids are usually named after their designer, so you will encounter styles such as Schmidt Cassegrain, Dall-Kirkham, Ritchey-Chretien, Dobsonian, Gregorian, Herschelian, Schiefspiegler, and Yolo. Almost all major observatory telescopes in the world, such as Palomar, Mt. Wilson, Lick, and even the Hubble Space telescope are a type of reflector! Before you buy a telescope of any type, remember this simple fact: The larger the light gathering source (aperture), the better the object is resolved and the fainter the object may be. This is why observatories use very large reflector telescopes – to reveal very faint objects in greater detail. Do not forget that even a huge telescope will not make something larger just because the telescope is bigger! For example, the size of Jupiter magnified 50× will be the size of Jupiter magnified 50× in all telescopes…, but a large aperture scope will allow you to see small details on the planet where a smaller aperture telescope cannot. That is resolving power! The smaller the numbers are when it comes to resolving power, the finer the detail. If you choose a reflector

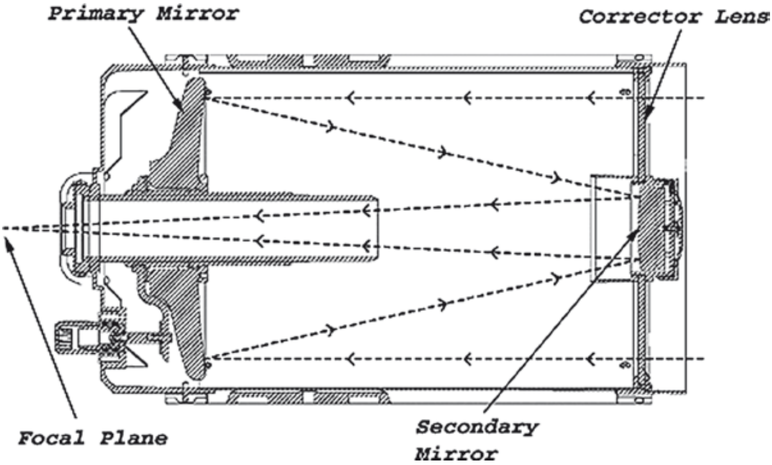

Fig. 1.7 Schmidt-Cassegrain telescope.

telescope for yourself, please remember the more simple Newtonian designs will sometimes need a minor adjustment to the mirror positioning to align everything perfectly for the best possible image. This process is called collimation and is not much different than tuning a guitar. There are even tools to help!

A Schmidt-Cassegrain is a catadioptric telescope; a telescope which utilizes a system of both lenses and mirrors (Fig. 1.7). The most noteworthy design piece is the aspheric corrector plate, which helps to focus the incoming light. The corrector is important because it is used to refocus the fuzzy image created by a spherical lens – a reflection of the light from the mirror where it is not aimed directly at the bottom of the curve in the exact middle. A single aspheric lens can replace an entire complex system of lenses, making for a lighter, more portable telescope. Essentially, the Schmidt-Cassegrain telescope provides an incredibly sharp, clear image – optically perfect – yet is more complex and expensive.

What else might you need? Eyepieces of course (Fig. 1.8). Again, eyepieces are a matter of individual taste and budget. Rather than steer you toward a particular brand, the best thing to do is simply to explain what eyepieces

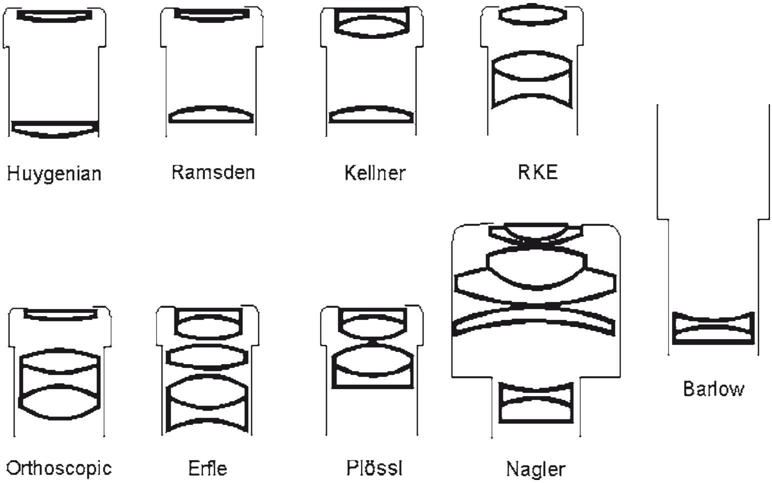

Fig. 1.8 Eyepieces.

are and how they work. They come in an array of sizes, magnification factors, styles, types, and manufacturers… One thing is for certain, no telescope would work without one! The best way to learn about telescope eyepieces is to start with fundamentals. To make any telescope eyepiece work in a telescope, it must first fit the focuser. While there are exotic focuser sizes, the standard sizes for almost all telescope eyepieces are expressed as 0.965″, 1.25″, and 2″. This is a dimension that comes from measuring the diameter of the telescope eyepiece barrel. Let us take a look at each one:

The 0.965″ Telescope Eyepiece: Once upon a time, almost all amateur telescopes came equipped with 0.965″ eyepieces. They were small, inexpensive to produce and very limited. Because of the size, the style was also limited to a few basic designs. While there are a few good quality 0.965″ eyepieces out there, most are of inferior quality, have a very restricted field of view, and should be avoided whenever possible.

The 1.25″ Telescope Eyepiece: By the mid-1980s, the amateur telescope industry was beginning to blossom and so were telescope sales – making the production of larger eyepieces not only more profitable but neces-

sary to keep interest in the hobby. This larger design offered a more comfortable field of view, room for more elements and design improvements, brighter images, and improved contrast. It did not take long before the 1.25″ eyepiece became the industry standard, and virtually every telescope offered today is equipped with a 1.25″ focuser assembly.

The 2″ Telescope Eyepiece: Once considered only the domain of observatory-class and research-grade telescopes, the 2″ eyepiece is now frequently offered as standard equipment with deluxe model telescopes. Capable of delivering brighter, higher contrast images, better eye relief, and a wider field of view, 2″ eyepieces are the premium by which all others are judged. Like the 1.25″, the 2″eyepiece is available in a variety of exotic glasses and designs – each to user-specific applications.

No matter what size telescope focuser you may have, there are adapters available to make any eyepiece work with your focuser and eyepiece. For example, you can adapt a 0.965″ focuser to accept a 1.25″ eyepiece – or adapt a 2″ focuser to accept a 1.25″ eyepiece. However, piling on adapters to make a 0.965″ focuser use a 2″ eyepiece is not helping – nor is restricting a 2″ focuser to use 0.965″ eyepieces. Adapters are simply a nice tool to help you make the most of the telescope eyepieces and equipment that you may have collected over the years. Do not discard an old eyepiece because it seems "out of date" – you may have a hidden gem!

The magnifying power of any eyepiece is a simple equation expressed in millimeters: divide the focal length of the telescope by the focal length of the eyepiece and your answer is the amount of magnification (Fig. 1.9). Long focal length eyepieces such as 32 and 25 mm are of lower magnifica-

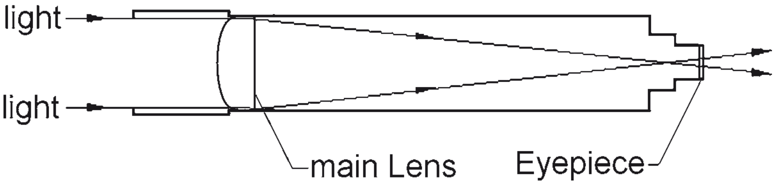

Fig. 1.9

tion, while lower numbers like 10 and 5 mm are magnifying powerhouses. While it would be tempting to use as much magnification as possible, all telescopes (and the human eye) have practical limits. If you look through your telescope with two different focal length eyepieces, you will see you have the choice of a small, bright, crisp image or a big, blurry, dimmer image – but why? A telescope can only gather a fixed amount of light. When using high magnification (lower focal length number) you are only spreading the same light over a larger area. Even the best telescope can only deliver a certain amount of detail, and magnifying beyond a telescope's limits only makes for empty magnification.

So let us talk about magnifying powers! Low magnifications such as 20–50× are ideal for wide-field views under dark skies, while 20–100× are great for helping to locate smaller targets. 75–200× is suitable for the Moon, and more than 200× truly requires atmospherically steady skies to make the additional magnification work for you. While it may seem to confuse the issue, you also need to consider your telescope's *f*-ratio. To make a particular focal length eyepiece work well with your telescope, you will need to determine exit pupil. Before you panic at the thought of more math, exit pupil is merely the focal length of the eyepiece divided by the *f*-ratio. For example, an *f*/5 telescope with a 25-mm eyepiece would deliver 5 mm of exit pupil. Why is this important? At low magnification the exit pupil must be smaller than your eye (5–7 mm) or the extra light is simply lost. For high magnifications, the exit pupil must be between 0.5 and 1.0 mm of exit pupil to avoid empty magnification. Using our *f*/5 example, a 5-mm eyepiece would deliver 1.0 mm of exit pupil and be right at the practical limits of magnification. Remember, telescope eyepieces come from a variety of manufacturers, so we are just talking about general applications.

Over the years, the telescope eyepiece has underwent a lot of design changes! While a good many of these are obsolete, who knows what you may stumble upon in an attic or at a tag sale? Never discard an old eyepiece without consulting with a trusted, experienced astronomer. What appears to be a useless old piece of junk could very well be an historical gem! Now, let us take a look at some designs:

Huygens Telescope Eyepiece: At one time, these were supplied as 0.965″ eyepieces with many amateur telescopes. They were a simple, two-element design that had very short eye relief and a very restricted field of view.

Ramsden Telescope Eyepiece: This is also a two-element design with improved optical quality, but it simply is not up to modern standards. The Ramsden has a small field of view and is best suited for telescopes with *f*-ratios of less than *f*/10.

Kellner Telescope Eyepiece: The Kellner is a three element design that delivers sharp, bright images at low to medium powers and works best in small to medium telescopes; Kellner eyepieces are noted for an apparent field of view of about 40° and good eye relief at low power.

Orthoscopic Telescope Eyepiece: The Orthoscopic eyepiece is a four element design and is still often considered the best all-round eyepiece for planetary, lunar, and solar viewing. It is noted for sharp views, excellent color correction, good contrast, and longer eye relief.

Plossl Telescope Eyepiece: The four-element Plossl design is perhaps the most popular telescope eyepiece design on today's market and an all-around performer. It provides excellent image quality, good eye relief, and an apparent field of view of about 50°. A well-manufactured Plossl will deliver high contrast and pinpoint sharpness out to the edge of the field of view.

Erfle Telescope Eyepiece: The Erfle consist of five or six elements and was created solely for an ultra wide field of view – such as 60°–70°. At low powers it provides impressive deep sky views – huge swatches of sky with contrasty backgrounds and pinpoint stars. Galaxies and nebulae are framed by the fields in which they lay. However, at high magnification the image sharpness can become distorted at the edges of some manufacturer designs in some telescopes without corrective measures.

Now that you know much more about telescope eyepieces, there are a few other terms you just might encounter – such as lanthunum. Lanthunum optical glass offers extra long eye relief and excellent field of view. ED optical glass stands for extra low dispersion, and like lanthanum gives better eye relief and field of view – turning higher power eyepieces into a pleasure instead of a peep-hole. When choosing a telescope eyepiece, be sure to look for multicoatings, internal baffling, and blackening to prevent reflections and internal threading to accept filters. A quality

manufacturer will disclose all the information you need to make a good decision about a telescope eyepiece. While buying an expensive telescope eyepiece will not turn a bad telescope into a good one, a high-quality eyepiece will turn a good telescope into an extraordinary optical experience!

Now that you are armed and ready… Let us go Moon Walk!

CHAPTER 2

LUNAR DAY ONE

As we start our explorations of the lunar surface together, let us start by talking about how this section is divided. Factually, a lunar day is the period of time it takes for the Moon to complete one full rotation on its axis with respect to the Sun. Equivalently, it is the time it takes for the Moon to make one complete orbit around the Earth and come back to the same phase. It is marked from a New Moon to the next New Moon. To find these times and calculate the lunar day, just reference the tables you will find in the back of this book – but first you will need to learn just a little bit more!

Each lunar cycle takes 27 days, 7 h, and 43.2 min, but it just is not quite that easy (Fig. 2.1). Since the Earth and Moon are also orbiting the Sun, our perspective from anywhere here on terra firma is also slightly different. For example, from full Moon to full Moon takes 29 days, 12 h, and 44 min. Thus, our very first lesson on Day 1 is to learn Universal Time – sometimes referred to as UT or GMT (general meridian time). While it may seem a little confusing at first, it would not take long until you understand how to make the calculations for where you live, and by using the table (also included in the back of this book), you will quickly understand what "Day" it is on the Moon! Day One would be 24–36 h from the date and time of New Moon, Day Two would be 48–60 h from the date and time of New Moon, and so on.

Because each observer is positioned in a different area around the planet Earth, not everyone will see the Moon's features alike (Fig. 2.2). For a fellow observing Plato crater at 8:00 p.m. local time in Nottingham, England – an observer in New York, NY would need to be watching at 3:00 p.m. local time to catch the terminator (the line between darkness and shadow) in exactly the same position. That would be quite a feat considering that the Moon might not even be visible at that time! So, if the same New York observer were to view the Moon at 8:00 p.m. at his local time, the terminator will have progressed by 5 h. The Moon will have become "older" and the features will have changed just slightly. By understanding this, you also understand that a feature that is listed on a particular day may or may not be visible depending upon the exact age of the Moon when you observe.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_2,

Fig. 2.1

There may be times when you will need to wait a few hours for something to come into view – or a particular crater will be better the day before or the day following the given day. It is all a matter of time!

Now that we understand time, let us take a look at "how" to observe. Each of the following days is fairly well divided into sections of things that can be seen without any type of visual aid, what can be seen with binoculars, small telescopes, and what needs a larger telescope at high

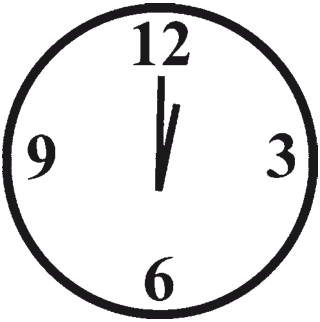

Fig. 2.2

magnification to resolve. No matter where you choose to observe from, comfort and safety are your primary issues. Before you begin seriously using this book, take the time to study the night sky and find a place where you can easily observe the Moon throughout most of its phases. Do not be surprised if you need to drive away from obstructions such as houses or trees to see the Moon's beginning or end. It is very low to the horizon at that time, and very few of us are lucky enough to see it. Do not worry though… Even if you do need to travel a bit away, your eyes and binoculars are usually quite enough to take on all the early challenges!

> I know not that there is anything in nature more soothing to the mind than the contemplation of the moon, sailing, like some planetary bark, amidst a sea of bright azure. The subject is certainly hackneyed; the Moon has been sung by poet and poetaster. Is there any marvel that it should be so?
>
> William Gilmore Simms

Once you have selected your observing area, learn to prepare yourself in advance (Fig. 2.3). Optics such as binoculars, telescopes, and telescope eyepieces need a little time to reach ambient outdoor temperature. Collect other things you might need, such as a red flashlight (to help preserve your night vision), notepad, and writing instrument. Although taking notes and making sketches certainly are not mandatory, these are practices that I highly recommend. Why? As strange as it may sound, the act of making notes will help to reinforce what you are learning – and make those strange names and places stay in your head. After all, if you

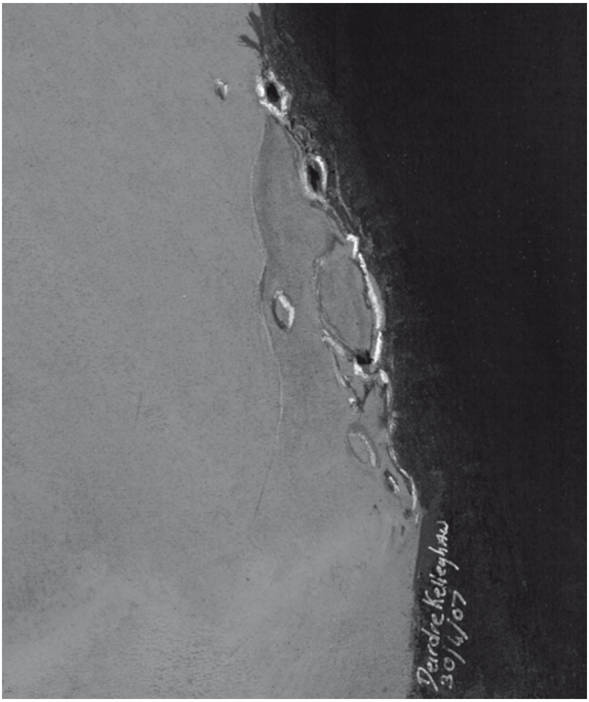

Fig. 2.3 Lunar sketch – Deirdre Kelleghan.

bought this book, that means you admire those who can tell you crater names and places without ever looking at map, and it would not be long until you can do the same! The same holds true of sketching. No one will ever come to "grade" your sketches, and you never need to show them. But, the act of sketching allows you to see much finer details than you will notice by just observing. Even if you only draw a circle with some lines going through it, you will find yourself going back to add more and more details, because you will see more and more to add. Besides, one day when you look back at your notes and sketches, it is great fun to see all that you have accomplished!

Now that you are set up and ready to go, the next thing to know is… Do not rush. The Moon has been up there for thousands of years before you and it will be there thousands of years after. While it would be wonderful to accomplish everything on each day and do it all within one lunar cycle – chances are that will never happen. What happens is that clouds, rain, and snow demand on our time and just life in general! You will get the most pleasure from "Moon Walk with Your Eyes" if you just spend a quiet evening here and there learning. There may be nights when you only identify one or two things we discuss and others when you catch them all! That is the beauty of our ever-changing Moon… There is always something new to learn or see – or a challenge to revisit.

Are you ready? Then let us talk about Day One…

At 24–36 h old, tonight's Moon is going to be a huge challenge to even spot in the twilight sky (Fig. 2.4). To see it, you will need to be well away from any horizon obstructions and begin looking just before the Sun is officially set (check your local sunrise and sunset times). Because the sky will still be very bright, you may need your binoculars to assist you. Look for the most slender crescent that you can imagine, and you will find that the lighted

Fig. 2.4 One day Moon – Peter Lloyd.

side is aimed exactly in the same direction as the setting Sun. This will help us to learn lunar east from lunar west!

Just like on Earth, the lunar terminator always progresses from east to west – no matter how it appears oriented in the sky. Lunar north and south is the same as our cardinal directions, but not quite so easy to distinguish in a telescope. For binoculars and refractor telescopes, the view is oriented correctly, but reflector telescopes produce a mirror image – things are reversed from left to right and upside down. Confusing? Not really. You get used to it very quickly if you just remember that the terminator always moves from east to west and that the north section of the Moon is far more barren than the heavily cratered south section.

If you have checked your Universal Time and the Moon is older than approximately 32 h at your time of observation, you may wish to advance to Day Two and see if you can spot any features!

Then the golden hour
Will tick its last
And the flame will go down in the flower.
A briefer length of Moon
Will mark the sea-line and the yellow dune.
Then we may think of this, yet
There will be something forgotten
And something we should forget.
It will be like all things we know:
A stone will fail; a rose is sure to go.
It will be quiet then and we may stay
Long at the picket gate
But there will be less to say.

Arna Bontemps

CHAPTER 3

LUNAR DAY TWO

We begin with just our eyes tonight as the Moon appears as a very slender crescent that will soon set as the sky darkens (Fig. 3.1). This lunar apparition looks very much like a pair of bright horns bearing a dark disk. Such a Moon may have given rise to the ancient symbol associated with fertility goddesses originating in Egypt and Mesopotamia. Today we see it "as the Old Moon in the New Moon's arms" – brilliantly lit on one side and softly illuminated on the other. No special equipment is needed to see this event, and thanks to Leonardo da Vinci – we can see the ghostly effect on the Moon as quite logical. He was the first to theorize that sunlight was reflecting off the Earth and illuminating the portion of the Moon not lit by the Sun. We more commonly refer to this as "Earthshine" – but no matter how scientific the explanations are for this apparition, it still remains beautiful.

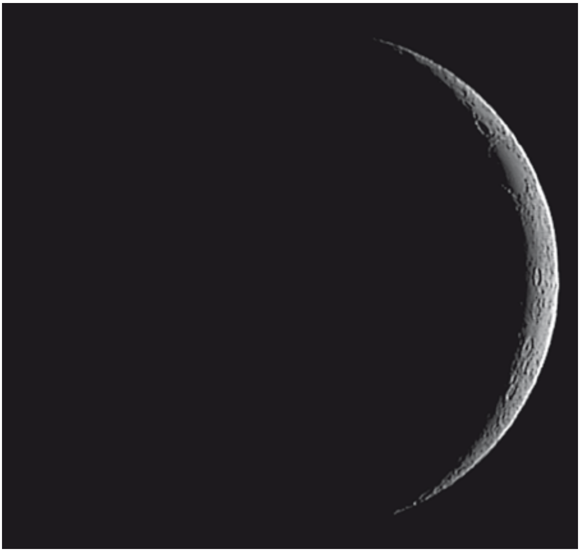

Fig. 3.1 Two day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_3,

> The double Moon, one on the high back drop of the west, one on the curve of the river face,
>
> The sky Moon of fire and the river Moon of water, I am taking these home in a basket, hung on an elbow, such a teeny weeny elbow, in my head.
>
> I saw them last night, a cradle Moon, two horns of a Moon, such an early hopeful Moon, such a child's Moon for all young hearts to make a picture of.
>
> The river—I remember this like a picture—the river was the upper twist of a written question mark.
>
> I know now it takes many many years to write a river, a twist of water asking a question.
>
> And white stars moved when the Moon moved, and one red star kept burning, and the Big Dipper was almost overhead.
>
> Carl Sandburg

Let us begin our series of journeys on the lunar surface designed to acquaint you with specific maria or craters in binoculars and small telescopes. We have learned to tell north from south, and east from west. Now, let us take a closer look…

With binoculars or a small telescope, start by identifying the partially disclosed Mare Crisium just lunar north of center along the terminator (Fig. 3.2). Seen along the curve of the surface, our emerging mare does not look large, but it is actually the size of the state of Washington. Mare Crisium is a unique feature since it is not connected to any other mare. If the lunar terminator has not advanced too far at your viewing time, scan the southeast shoreline of Mare Crisium for Agarum Promontorium – a bright, peninsula-like feature. Look how aggressively it progresses northward across the dark plain before it disappears beneath the once-molten lava. There were times in the past when great lunar observers noted a mist-like appearance in this area. These types of very rare occurrences are called transient lunar phenomenon.

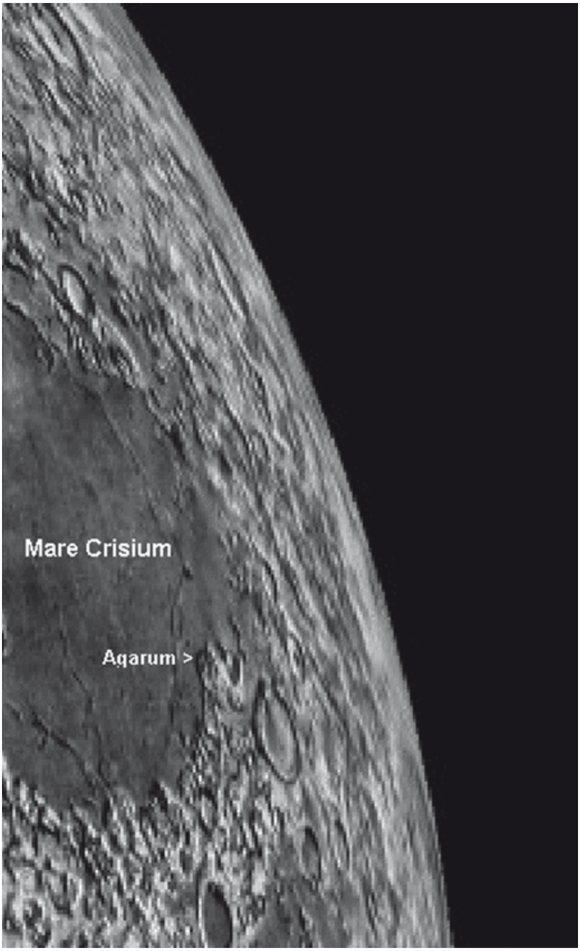

Fig. 3.2 Virtual Moon atlas.

Continuing with binoculars or small telescopes, look almost centrally on the terminator for the very conspicuous crater Langrenus (Fig. 3.3). Depending on your viewing location and time, it may be divided by the terminator, but will be quite recognizable. This wonderful old crater was

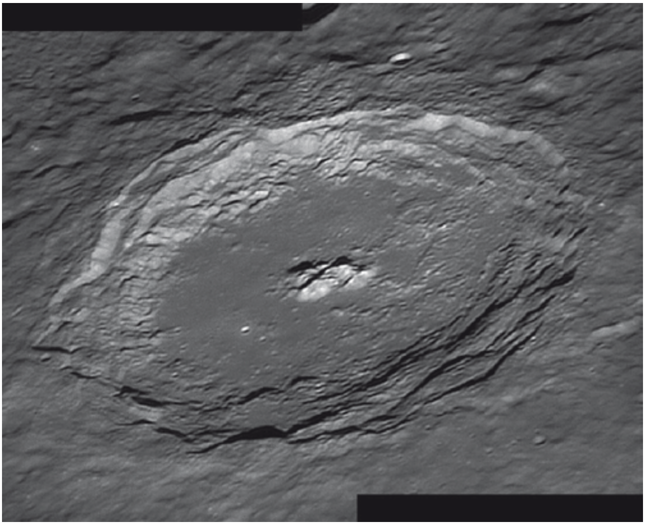

Fig. 3.3 Lagrenus – Damian Peach.

named for Belgian engineer and mathematician Michel Florent van Langren. Better known as Langrenus, the crater floor stretches out over 132 km in diameter with walls rising up to 1,981 m high. The deepest part reaches down 4,937 m below the lunar surface and could swallow Ecuador's Mount Cotacachi whole. Is the Sun rising over its brilliant east wall? If so, look closely and see if you can spot Langrenus' central mountain peak. Rising up 1,950 m, it is as high as the base elevation in Jackson Hole, Wyoming! While that might seem large, it is small for a crater this size and will present a challenge to spot in binoculars.

Have a look at Langrenus in your telescope at high magnification. Formed in the Eratosthenian geological period, it could be anywhere from as much as 3.2 billion to as little as 1.1 billions years old. You will see that its southern border is deformed by its C and E craters and the structure of Crater Lohse further south seems to help support its ancient walls and terraces. Do you notice the floor? The 1,000 m high double mountain peak is very impressive, but look for additional small hills and craterlets. Can you spot the bowl-like formation of 14 km wide crater Acosta intruding on Lagreneus' northern slopes?

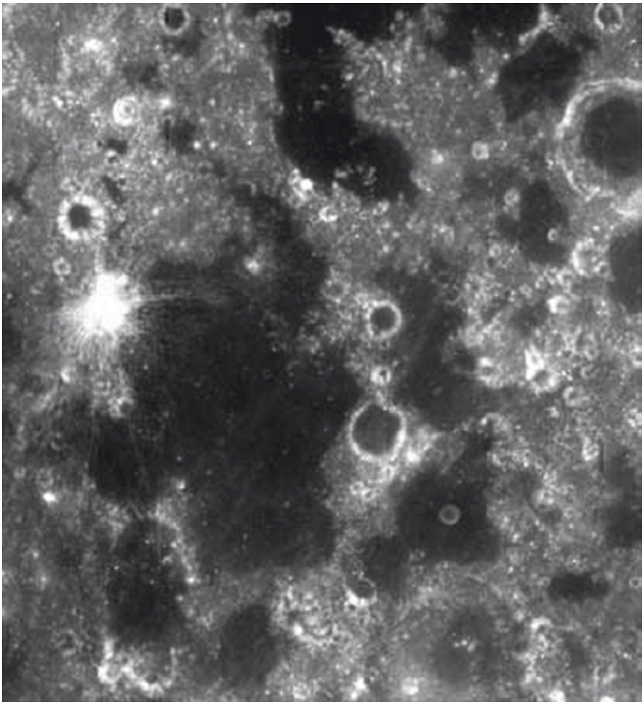

Fig. 3.4 Mare Spumans – Clementine.

As you wander slightly north, you will encounter the beginnings of a dark region about the same size as Langreneus (Fig. 3.4). This is Mare Spumans – the "Foaming Sea." What you are seeing is one of many elevated "lakes" filled with basaltic lava flow from the Upper Imbrian epoch. While it appears rather small in binoculars, it actually stretches for about 206 km in diameter, separated by only a few low foothills from Mare Undarum slightly more north and east. Can you spot small crater Apollonius to the northwest yet? If not, let us continue on to the "Sea of Waves"…

Identical in size to Mare Spumans, Mare Undarum also has a rough diameter of 206 km, but its borders are less specific and its surface a lot less smooth (Fig. 3.5). When Johann Madler was first surveying this area in the early 1800s, he guessed the striations seen in Mare Undarum could

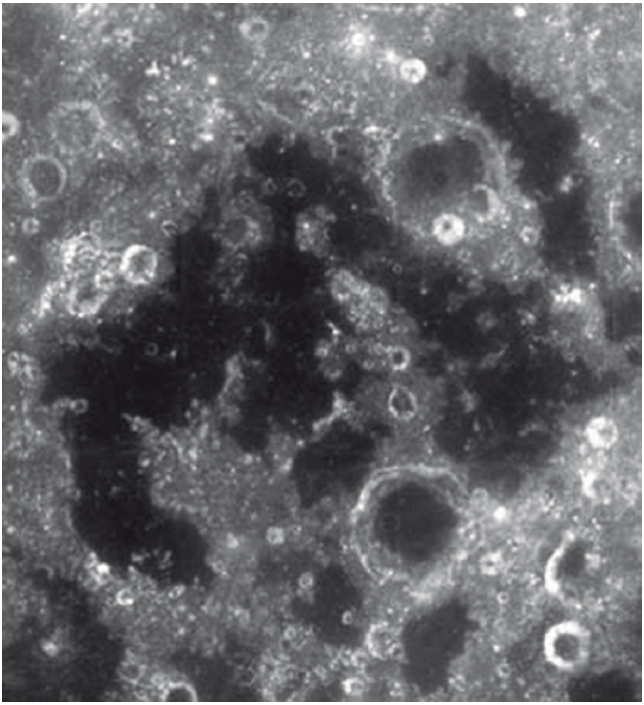

Fig. 3.5 Mare Undarum – Clementine.

have meant that vegetation was present. Considering they were using a primitive 95-mm refractor, I suppose that was not a bad call – but today we know there are at least four volcanic domes situated in Mare Undarum, which display mixing in their soils between the mare ponds and highland materials – a definite reason for changes in albedo. If you are viewing telescopically, can you see small crater Dubyago to the south or the wonderful, flat dark circle of Firmicus to the north?

> … finding that in [the Moon] there is a provision of light and heat; also in appearance, a soil proper for habitat xtremely probable, nay beyond doubt, that there must be inhabitants on the Moon of some kind or other?
>
> Sir William Herschel

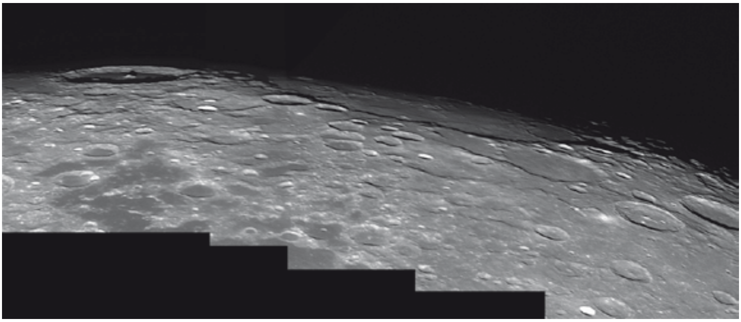

Fig. 3.6 Mare Smythii – Damian Peach.

For challenging larger telescope studies, look to the north where you may see the eastern edge of Mare Crisium just beginning to emerge (Fig. 3.6). The bright point on the shoreline is Promontorium Agarum with shallow crater Condorcet to its east. Look along the shore of the mare for a mountain to the south known as Mons Usov. Just to its north Luna 24 landed and directly to its west are the remains of Luna 15. Can you spot the tiny dark well of crater Fahrenheit nearby? Continue with your telescope north of Mare Crisium for even more challenging features such as northeast limb studies Mare Smythii and Mare Marginis. Between them you will see the long oval crater Neper bordered by Jansky at the very outer edge.

Before we leave for the evening, scan the northeastern lunar limb with binoculars for Mare Humboldtianum, a 650 km wide gray patch that sits squarely in the libration zone (Fig. 3.7). The "Sea of Alexander von Humboldt" is a feature that continues around to the far side of the Moon and can sometimes be hidden from our view, with only about 165 km of it visible from Earth at most. Its basin was formed by an impact during the Nectarian time, but the lava fill came from the Upper Imbrian epoch. There are times when its basin rim lighting will show as a mountain range that can be spotted telescopically. Unofficially the outer ring of mountains is known to lunar observers as the "Andes Mountains" and the inner ring is often called the "Bishop Mountains."

With the Moon quickly setting this evening, let us take a minute or two to learn more about terms you have just seen and will encounter while studying lunar craters. Through years of observing, one thing becomes

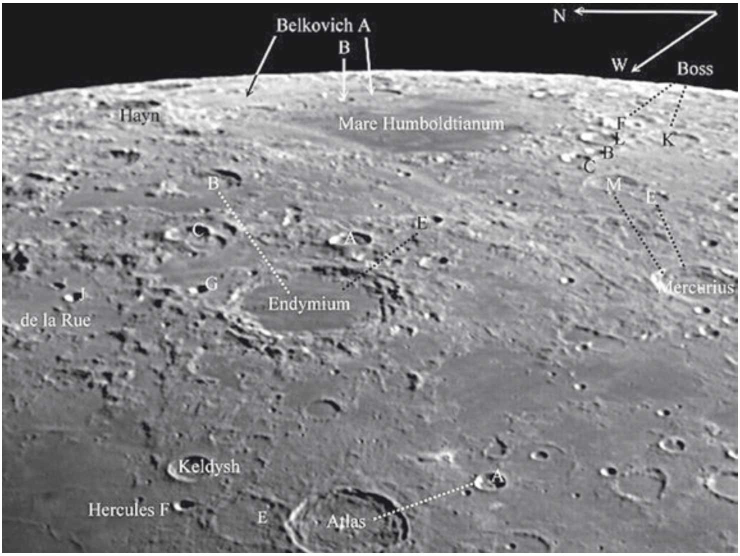

Fig. 3.7 Mare Humboldtianum – Peter Lloyd.

very clear – craters were either created by impacts or by volcanic activity. They spanned a huge variety of depths and sizes, and we desperately needed some type of system to help clarify them. Enter Ralph Baldwin, who created the following classifications:

Class I. **Young craters, from impacts after the formation of the Maria, with the steepest, sharpest walls**

Class II. **Intermediate craters, from before the Maria – with walls showing slight degradation due to subsequent meteoric bombardment and subsidence**

Class III. **Older craters – with outlines considerably more rounded and interrupted by later impacts**

Class IV. **Ancient craters, dating back almost to the Moon's formation – with highly broken and smoothed features**

Class V. **Craters that have been partly obscured by flooding with lava at the time of the formation of the Maria**

Next came Eugene Shoemaker who used geological mapping techniques and divided lunar surface materials into five age systems – four of which are still in use. Our modern classifications are the Pre-Nectarian (4,533 million years – 3,920 million years ago), Nectarian (3,920 million years–3,850 million years ago), Lower Imbrian (3,850 million years – 3,800 million years ago), Upper Imbrium (3,800 million years – 3,200 million years ago), Eratosthenian (3,200 million – 1,100 million years ago), and Copernican (1,100 million years ago to the present day) periods.

Just a few general rules of thumb to keep in mind as you are studying how to quickly identify age structures. For example, the dark mare materials are pretty much Imbrium period, and the easily recognized, light-colored lunar highlands are heavily cratered and belong to the Pre-Imbrian period. Craters found within maria that have lava-flooded floors formed after the Imbrian event, while ones with central peaks belong to the Eratosthenean period. Last, but not least, craters with rugged floors and bright ray systems belong to the Coperrnican time period!

While you would not remember all of this now, there may be lunatic nights when you will want to know more…

CHAPTER 4

LUNAR DAY THREE

Tonight we will return again to the northeast quadrant of the Moon for a closer look at Mare Crisium region (Fig. 4.1). The "Sea of Crises" is not only unique for its lack of connection with any other maria, but it is home to a gravitational anomaly called a mascon. This "mass concentration" might possibly consist of fragments of the asteroid or comet whose impact with the lunar surface created the basin buried beneath the lava flow. The mascon creates an area of high gravity and causes changes in the orbits of lunar probes. This excess gravity has even been known to cause low orbiting lunar satellites to either crash land or be flung out into space! Take a look at Mare Crisium in your telescope and trace the long frozen wave of lava along its west bank known as Dorsum Oppel. Did you catch

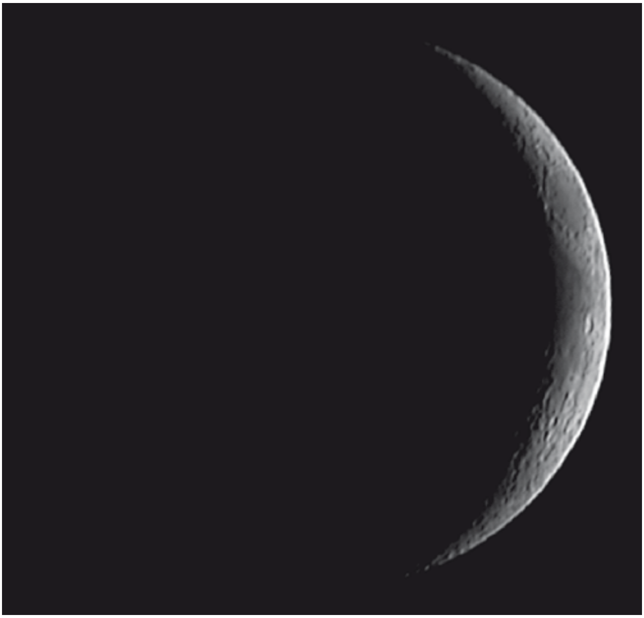

Fig. 4.1 Three day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_4,

the two small punctuations of crater Swift to the north and crater Pierce to its south? When you reach the central point of the western shoreline, look for Promontoriums Olivium and Lavinium. It is easy to catch the sharp, small crater Picard to the east, but did you spot the ruins of crater Yerkes between them? Or, even tinier Curtis east of Picard?

Keep your binoculars handy and look to the area just north of Mare Crisium area to observe spectacular crater Cleomides (Fig. 4.2). This two million year old crater is separated from Crisium by some 60 km of mountainous terrain. Telescopically, Cleomides is a true delight at high magnification. To Cleomides' east, begin by identifying Delmotte, and to the northwest, Debes and Tralles. Turn your telescope toward southern Tralles and power up. Spanning about 44 km in diameter, this three-part crater has many fascinating things to capture your attention. Not only does it share a common wall with Cleomides, but its slopes also support Debes and Debes A to the northwest. Take a close look at its northern crater and you will see another impact, and the south is totally ruined. If viewing conditions are steady, you

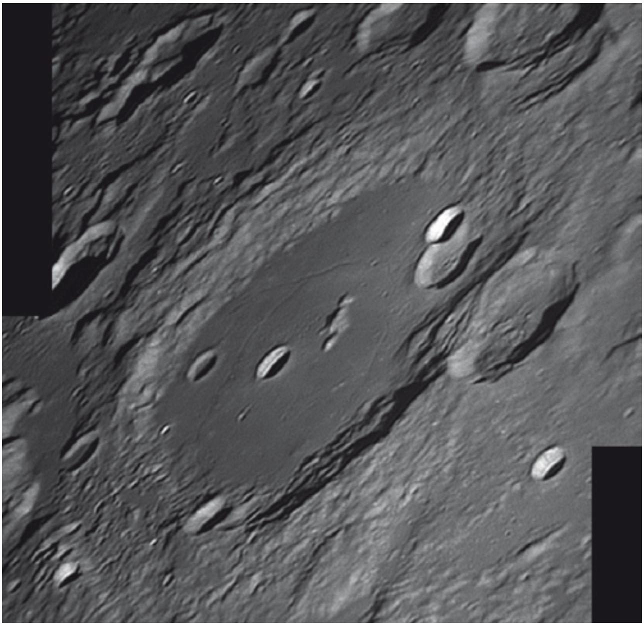

Fig. 4.2 Cleomides – Damian Peach.

will see myriad tiny craterlets situated inside this jumbled, mixed up crater structure that was so fittingly named after Johann G. Tralles – the man discovered how to measure alcohol content in fluids!

There is an inn, a merry old inn
beneath an old grey hill,
And there they brew a beer so brown
That the Man in the Moon himself came down
one night to drink his fill.

J.R.R. Tolkien

Now, let us power up in a telescope and let us take on some challenges. Crater hop north to 60 km wide Burckhardt, which sits on northern rim of Cleomides. It has some very interesting formations, including a central mountain peak, a prominent A crater to the southeast and a sharp F crater to the northeast. Further north you will spy 88 km diameter Geminus. Look at how differently its walls look compared with Burckhardt! Geminus is more terraced in structure – its walls far more steep in appearance. It, too, has a central mountain peak… and many small hills and craterlets on its smooth floor. To the northwest you will spy the ruins of crater Berzelius and further northeast you will see ancient Messala. Spanning about 128 km wide, there is not a lot left of this ruined four billion year old formation. Along its southern edge, you will see where its walls were broken by the impact that caused crater Messala B and the remains of the wall to the northwest where crater Schumacher intrudes. If the lighting is right, you will see that the floor is covered by various waves and flows.

To the northeast you will see a small dark patch known as Lacus Spei – the "Lake of Hope" – a diminutive feature so small that it could be crossed at walking speed in 10 h! (Fig. 4.3). This tiny, 80 km wide patch of lava flow does not have much to distinguish it, except for the small, telescopic well of crater Zeno. To its northwest is Lacus Temporis – the "Lake of Time." How much time would it take to walk across Temporis? Twice as much "Time" as "Hope!" Formed in the Pre-Imbrian period, this 117 km diameter lava flow region also is not anything particularly special… Just another one of those great lunar challenge features that are little known and great collector items!

For binoculars, see if you can spot crater Endymion at the northern cusp (Fig. 4.4). You will see it as a dark, elongated oval. This four billion year old

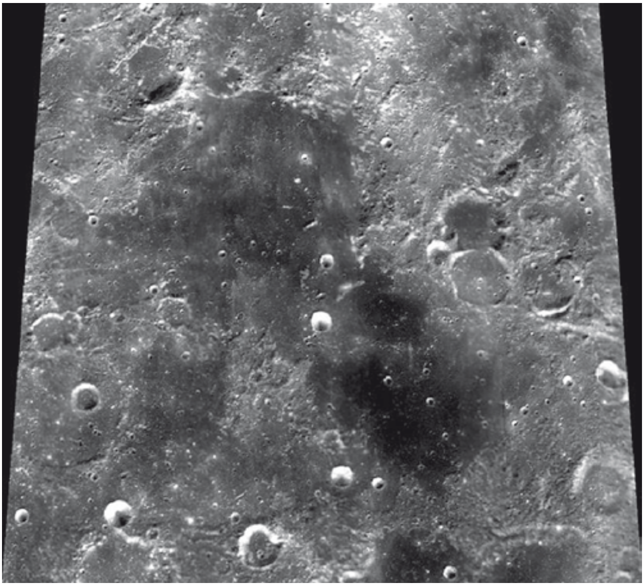

Fig. 4.3 Lacus Temporis – Clementine.

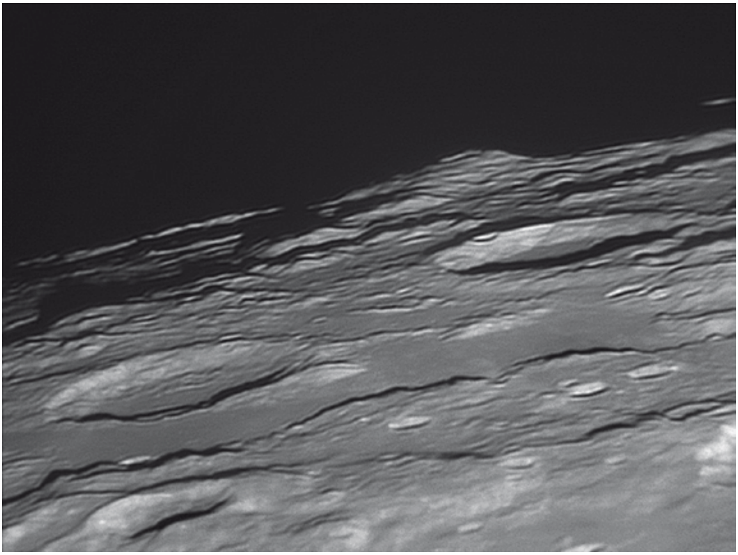

Fig. 4.4 Endymion – Credit: Damian Peach.

crater does not need a telescope, because its dark, lava-covered floor does not display an immense amount of details. Formed in the Pre-Nectarian age, Endymion will occasionally show some nice, bright streaks that originated from Thales crater to the north-northwest – evidence of a nice impact!

Continuing with binoculars and small telescopes, look almost centrally and reidentify Langrenus (Fig. 4.5). Notice how this crater study has changed in just 24 h! For a large telescope challenge near this area, look for a trio of craters that will appear to look like a paw print on the surface just northeast of Langrenus' border. This collection is as follows: Naonobu (north), Atwood (south), and Bilharz (west). Power up and try an even more challenging crater almost on the edge of Langrenus' northern rim. This small pock-mark is known as Acosta. Now continue further south with binoculars

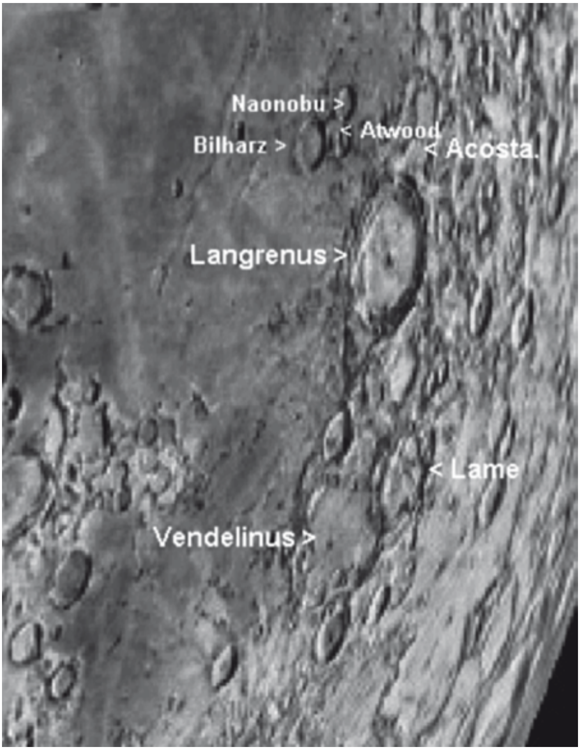

Fig. 4.5 Virtual Moon atlas.

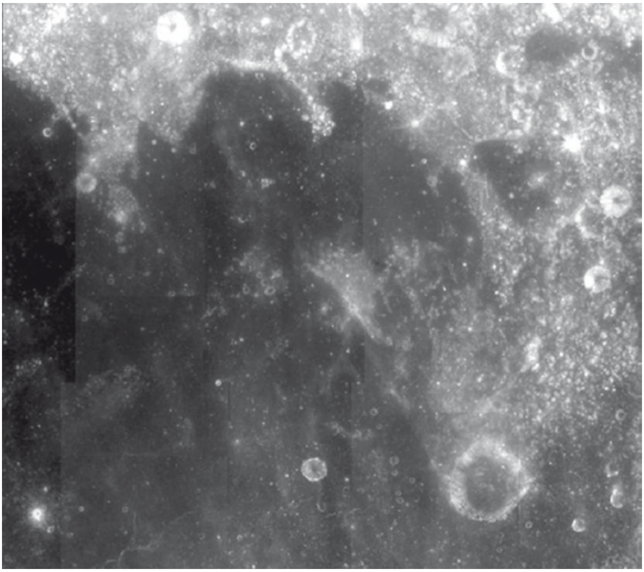

Fig. 4.6 Sinus Successus – Clementine.

of small telescopes for crater Vendelinus. Spanning about 151 km wide and dropping 4,480 m below the lunar surface, Vendelinus displays a partially dark floor with a west wall crest catching the brilliant light of an early sunrise. Notice also that its northeast wall is broken by a younger crater – Lame.

If you are into challenges and curiosities, then look north of in the southern edge of the foothills that surround the Crisium Basin for a very little known feature known as Sinus Successus (Fig. 4.6). Why bother with the "Bay of Success" when no one else does? Because this 104 km wide, C-shaped feature will help to guide you to points of success – the successful lunar landings of the Soviet Luna 16, Luna 18, and Luna 20 probes. Look for the ring of crater Webb between Sinus Successus and Langrenus…

In case you did not know it, Luna 16 was the first robotic probe to land on the Moon and return a soil sample back to Earth (Fig. 4.7). On September 20, 1970, approximately 100 km east of Webb crater, it set itself down and went to work. Panoramic television cameras surveyed the surface – relaying back data. An automatic drill collected a soil

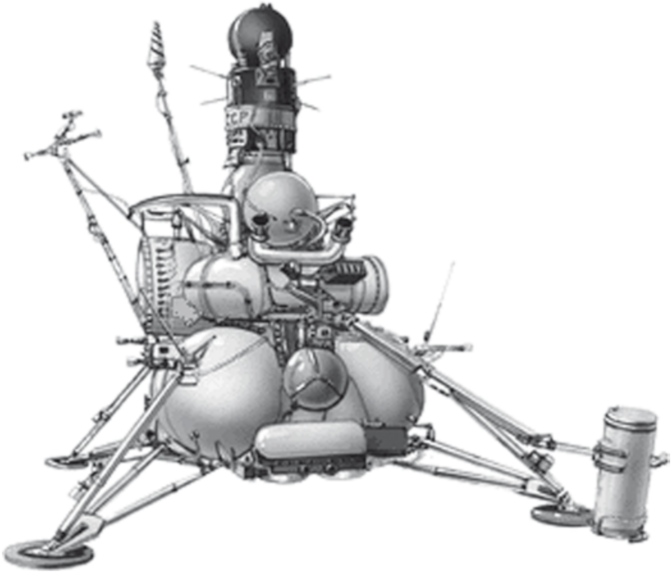

Fig. 4.7 Luna 16 – NASA/Creative Commons.

sample while radiation and temperature were checked. Then a successful lift off and return! On September 7, 1971 Luna 18 entered lunar orbit and successfully completed 85 communications sessions and 54 lunar orbits before it was sent toward the lunar surface in the same area. On September 11, it began its descent, but unfortunately things did not quite work out as well as planned, and it slammed into the mountainous terrain at Sinus Successus. However, not all was lost. Luna 18's continuous-wave radio altimeter still continued to broadcast back the mean density of the lunar topsoil. Luna 20 had much better luck, touching down on February 21, 1972 an unbelievable 1.8 km from the crash site of Luna 18. Its cargo was safely collected and returned to be shared with American and French scientists alike. To me, that makes Sinus Successus a very special place indeed!

If the timing is right, look along the terminator in the southern quadrant for ancient old crater Furnerius (Fig. 4.8). Named for the French Jesuit mathematician George Furner, this crater spans approximately 125 km and is a Lunar Club challenge. Power up and look for two interior craters. The smaller is crater A and it spans a little less than 15 km and drops to a depth of over 1,000 m. The larger crater C is about 20 km in diameter, but

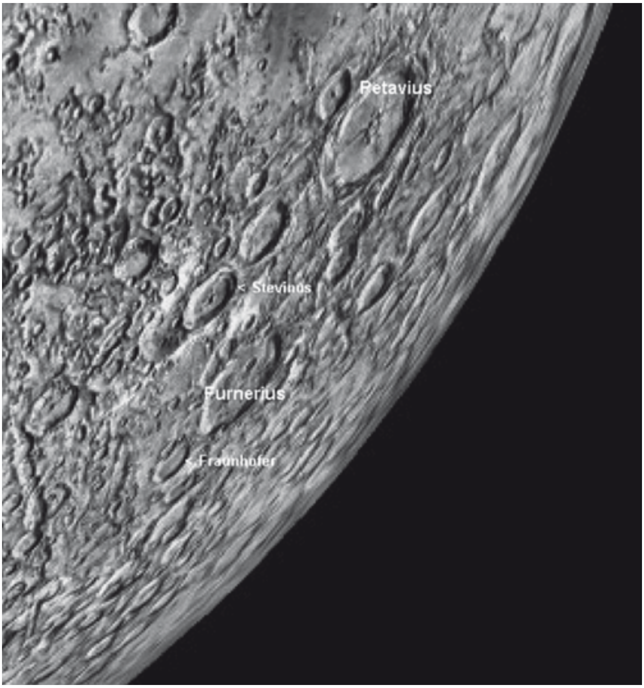

Fig. 4.8 Virtual Moon atlas.

goes far deeper, to more than 1,400 m. That is about as deep as a coral will grow under the Earth's oceans! Although it has no central peak, its walls have been broken numerous times by many smaller impacts. Look at a rather large one just north of central on the crater floor. If skies are stable, power up and search for a rima extending from the northern edge. Shallower and less impressive than other craters, Furnerius will fade to obscurity as the Moon waxes. This flooded old crater has no central peak, but a much younger crater has punched a hole in its lava-filled floor. Look for the long "crack" extending from Furnerius' north shore to crater rim. Perhaps it was caused by the impact? Sharp-eyed observers with good conditions and high power will also spot a multitude of small craters within and along Furnerius' walls. For binocular viewers, try spotting crater Stevinus to the north and Fraunhofer to the south. Keep in mind as you observe that our own Earth has been pum-

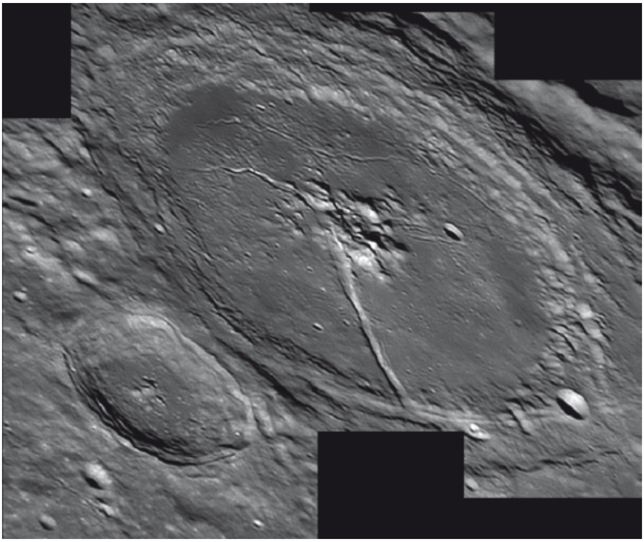

Fig. 4.9 Petavius – Damian Peach.

meled just as badly as its satellite. Can you imagine how differently Furnerius would look if decorated by forests and lakes?

Now our study belongs to a crater named for historian and theologian Denis Pétau – Petavius! (Fig. 4.9). Located almost centrally along the terminator in the southeast quadrant, a lot will depend tonight on your viewing time and the age of the Moon itself. Perhaps when you look, you will see 177 km diameter Petavius cut in half by the terminator. If so, this is a great time to take a high magnification look at the small range of mountain peaks contained in its center, as well as a deep rima that runs for 80 km across its otherwise fairly smooth surface. To the east lies a long furrow in the landscape. This deep runnel is Palitzsch and its Valles. While the primary crater that forms this deep gash is only 41 km wide, the valley itself stretches for 110 km. Look for crater Haas on Petavius' southern edge with Snellius to the southwest and Wrottesley along its northwest wall.

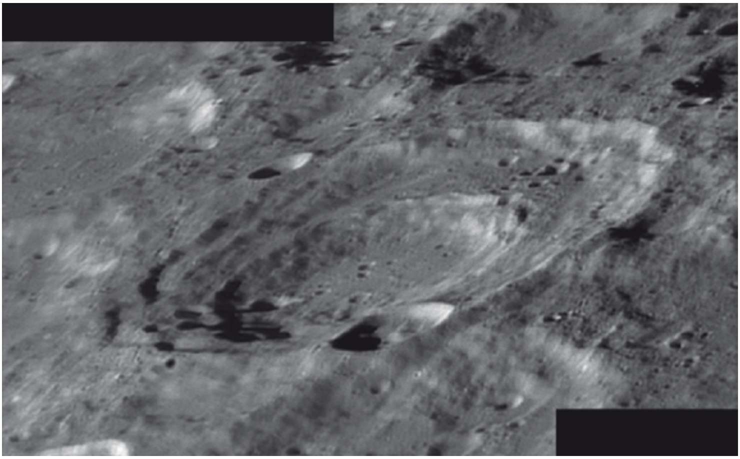

Fig. 4.10 Boussingault – Damian Peach.

For a true telescope challenge, we will have to go out on a limb – the southeastern limb – to have a look at an unusual crater (Fig. 4.10). Named for the French agrochemist and botanist Jean-Baptiste Boussingault, this elliptical-appearing crater actually spans a handsome 71 km. What makes Boussingault so unusual is that it is home to its own large interior crater – A. This double-ring formation gives it a unique stepped, concentric look that is worth your time!

CHAPTER 5

LUNAR DAY FOUR

> *The Moon was but a chin of gold*
> *A night or two ago,*
> *And now she turns her perfect face*
> *Upon the world below…*
>
> Emily Dickinson

We begin our binocular and small telescope explorations tonight by looking near the center of the lunar terminator to identify and take a closer look at Mare Fecunditatis (Fig. 5.1). Its expanse covers 1,463 km in diameter. The combined area of this mare is equal in size to the Great

Fig. 5.1 Four day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_5,

Sandy Desert in Australia – and almost as vacant in interior features. It is home to glasses, pyroxenes, feldspars, oxides, olivines, troilite, and metals in its lunar soil, which is called regolith. Studies show the basaltic flow inside of the Fecunditatis basin perhaps occurred all at once, making its chemical composition different from other maria. The lower titanium content means it is between 3.1 and 3.6 billion years old.

Stretching out across an area about equal in size to the state of California, the Sea of Fertility's western edge is home to features we share terrestrially – grabens (Fig. 5.2). These down-dropped areas of landscape between parallel fault lines occur where the crust is stretched to the breaking point. On Earth,

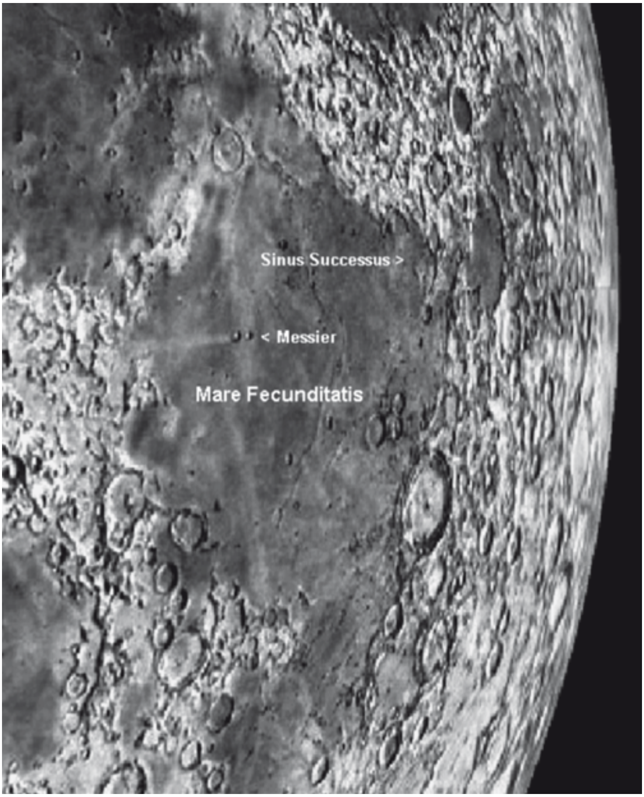

Fig. 5.2 Virtual Moon atlas.

these happen along tectonic plates, but on the Moon they are found around basins. The forces created by lava flow increase the weight inside the basin, causing a tension along the border which eventually fault and cause these areas. Look closely along the western shore of Fecunditatis where you will see many such graben features. They are also bordered by parallel fault lines and are quite similar to such terrestrial features as Death Valley in the western USA.

Now aim toward the earthen shore of Mare Fecunditatus and identify the flat, bright oval of our previous study, Langrenus (Fig. 5.3). This is an opportunity to challenge yourself by identifying two small craters just slightly northwest of the mare's central point – Messier and Messier A – named for the famous French comet hunter – Charles Messier. Scan along the terminator over Mare Fecunditatis about one-third its width from west to east for a pair of emerging bright rings. These twin craters will be difficult in binoculars, but not hard for even a small telescope and intermediate power. The easternmost crater is somewhat oval in shape with dimensions of 9 × 11 km. At high power, Messier A to the west appears to have overlapped a smaller crater during its formation and it is slightly larger at 11 × 13 km. For a challenging telescopic note, you'll find another point of

Fig. 5.3 Messier – Damian Peach.

interest to the northwest. Rima Messier is a long surface crack which runs diagonally across Mare Fecunditatis' northwestern flank and reaches a length of 100 km. Keep the Messiers in mind, for in a few days you will see a pair of "rays" extending out from them.

In binoculars, look for the junction of Mare Fecunditatis and the edge of Mare Tranquillitatis. Here stands ancient Taruntius. Like a "lighthouse" guarding the shores, it stands on a mountainous peninsula overlooking the mare and shooting its brilliant beams across the desolate landscape nearly 175 km. Tonight it appears as a bright ring, but watch in the days ahead as it turns into just another crater. We'll revisit this grand crater again on Lunar Day Seventeen when the shadow play will reveal some very interesting details.

Let's continue our journey further south as we look at a beautiful series of emerging craters – Fabricius, Metius, and the revealed Rheita (Fig. 5.4). Bordered on the south by shallow Jannsen, challenging Fabricius is a 78 km diameter crater highlighted by two small interior mountain ranges.

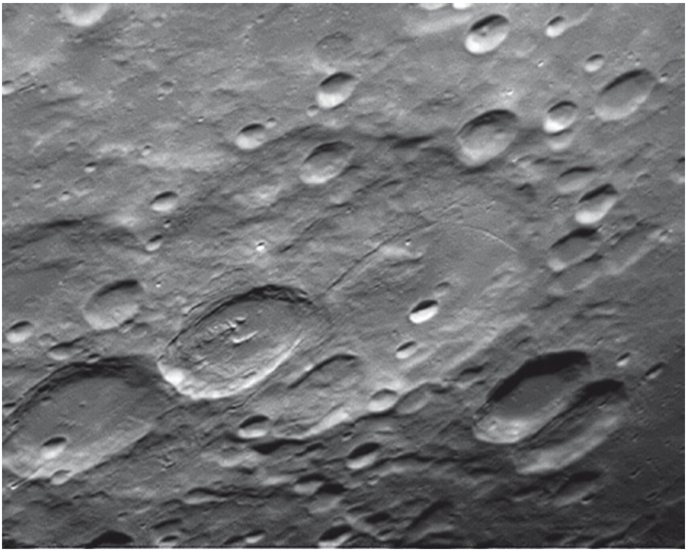

Fig. 5.4 Fabricius/Janssen Area – Dietmar Hager.

To its northeast is Metius, which is slightly larger with a diameter of 88 km. Look carefully at the two. Metius has much steeper walls, while Fabricius shows differing levels and heights. Metius' smooth floor also contains a very prominent B crater on the inside of its southeast crater wall. Further northeast is the telescopic lovely Rheita Valley which stretches almost 500 km and appears more like a series of confluent craters than a fault line. A 70 km diameter crater Rheita is far younger than this formation because it intrudes upon it. Look for a bright point inside the crater which is its central peak.

Just a short distance north of the southern cusp, look for a twin pair of craters on the terminator tonight (Fig. 5.5). These are Steinheil and Watt. The two are nearly identical in size and overlap each other. Steinheil, named for mathematician, physicist, optician, and astronomer Karl August von Steinheil, is just bit deeper and to the north. Watt, named for James Watt, Scottish engineer and first man to patent the use of a telescope for surveying, will show a wee bit more detail on its floor. For a telescopic challenge, remember the distance traveled south from Fabricus to this pair, and extend that distance even further south. Seen on the limb is crater Biela. If conditions are stable, then you might pick up a tiny black point in Beila's west wall – Biela C.

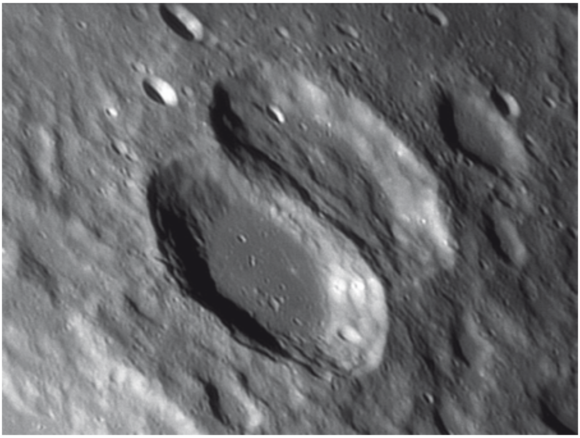

Fig. 5.5 Steinheil and Watt – Damian Peach.

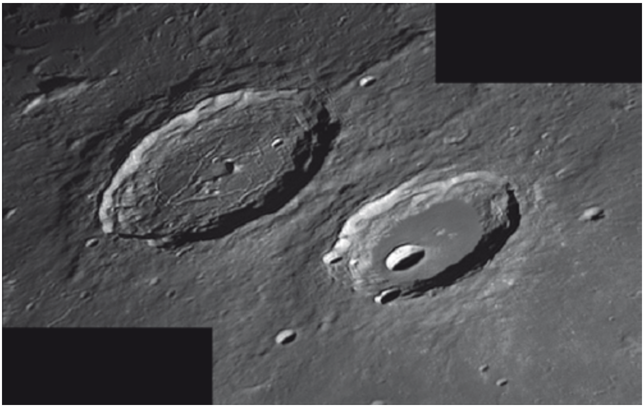

Fig. 5.6 Atlas and Hercules – Damian Peach.

Now, let's go north to Moon walk with two giants – Atlas and Hercules (Fig. 5.6). Located in the northeastern quarter of the lunar surface, this pair of craters is very prominent tonight in either binoculars or telescopes. The smaller, western crater is Hercules – named for the hero of song and legend – and the larger one is Atlas – named for the mythical figure who bore the weight of the world on his shoulders. When Hercules is near the terminator its western bright wall is in strong contrast to an interior so deep that it remains in shadow. Spanning 71 km in diameter and plunging down 3,200 m, Crater Hercules also contains an interior crater revealed as the Sun rises over it in the next 24 h. Far more detail tonight are shown in much older crater Atlas. Spanning 90 km in diameter and more shallow at less than 3,000 m, Atlas contains a small interior peak. Power up in a telescope and see if you can spot a Y-shaped crack along Atlas' floor known as the Rimae Atlas. If timing permits, up the magnification in your telescope and take a closer look at 69 km diameter Hercules for a deep interior crater called G or the tiny E crater which marks the southern crater rim. North of both grand craters is another unusual feature which many observers miss. It is a much more eroded and far older crater which only shows a basic outline and is only known as Atlas E.

If you Moon walk along the terminator to the due west of Atlas and Hercules, you'll see the punctuation of 40 km wide Burg just emerging from the shadows. While it doesn't appear to be a grand crater just yet, it has a redeeming feature: it's deep – real deep. If Burg were filled with water

here on Earth, it would require a deep submergence vehicle like ALVIN to reach its 3,680 m floor! This class II crater stands nearly alone on an expanse of lunarscape known as Lacus Mortis. If the terminator has advanced enough at your time of viewing, you may be able to see this walled-plain's western boundary peeking out of the shadows.

I with borrow'd silver shine,
What you see is none of mine.
First I show you but a quarter,
Like the bow that guards the Tartar:
Then the half, and then the whole,
Ever dancing round the pole.

Jonathan Swift

As your eye moves back south and toward Mare Crisium, you will also see another interesting pair – smaller Cepheus to the northwest and larger Franklin to the southeast (Fig. 5.7). While they aren't particularly impressive

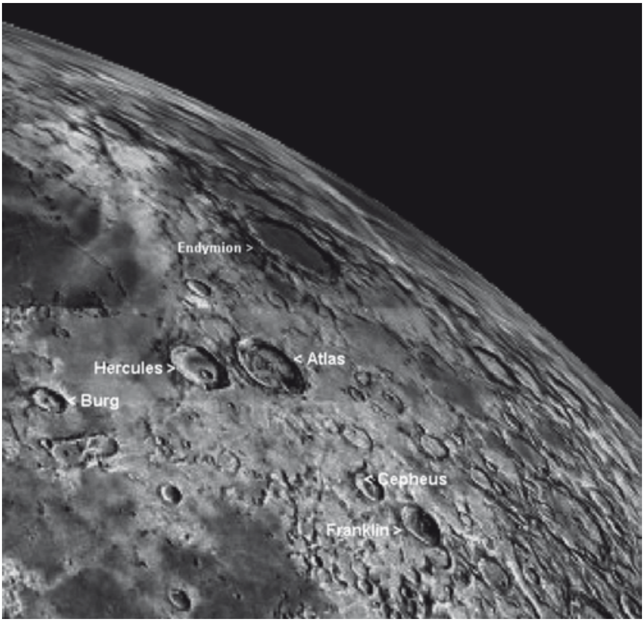

Fig. 5.7 Virtual Moon atlas.

to binoculars, you'll find both of these formations rather exquisite at higher power in a telescope. Cepheus is a very old formation, belonging to the Eratosthenian age and could be upwards to as much as 3 billion years old. Its high terraced walls are impossible to get an accurate height measurement on, but it does average about 41 km wide. Notice how it is overlapped by intervening younger crater, Cepheus A. Franklin is much wider at 58 km in diameter, and its height, too, is incalculable. Why? Because both of these craters never show on the terminator so we are never able to get a shadow/height estimate. Unlike Cepheus, Franklin belongs to the Lower Imbrian period, and its age approaches more closely 4 billion years. As you magnify, you will see a much different structure. It has a flat floor with hills, craterlets, and a central mountain peak. In case you were wondering, Franklin is named after Benjamin Franklin!

Now, let's check out a changeable, sometimes transient, and eventually bright feature on the lunar surface – crater Proclus (Fig. 5.8). At around 28 km in diameter and 2,400 m deep, Proclus will appear almost centrally

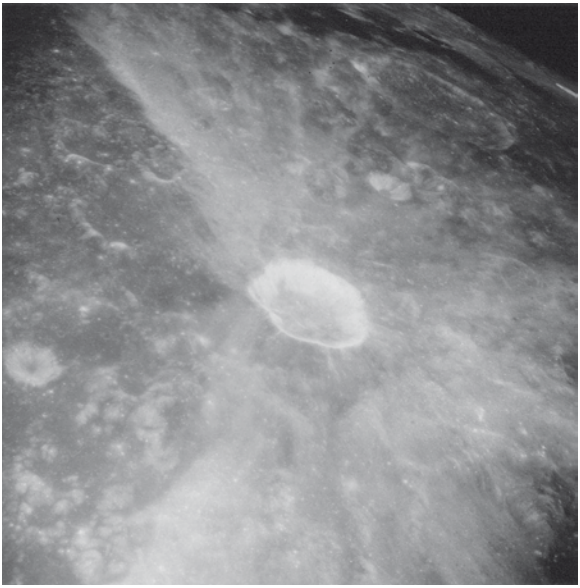

Fig. 5.8 Proclus – Apollo 15 image (NASA).

on the west mountainous border of Mare Crisium. For many viewers tonight, it will seem to be about two-thirds black, but one-third of the exposed crater will be exceptionally brilliant – and with good reason. Proclus has an albedo, or surface reflectivity, of about 16% – an unusually high value for a lunar feature. Watch this area over the next few nights as two rays from the crater will widen and lengthen, extending approximately 322 km to both the north and south. Despite whether you use binoculars or a telescope, Proculus is easily visible! Keep an eye on this crater during all phases of the Moon.

Now let's take a closer look at the area around Proclus – a region of uplands called Palus Somni – the "Marsh of Sleep" (Fig. 5.9). Formed in the Pre-Imbrian period and roughly about 4 billion years old, this 206 km wide expanse appears as a lighter gray region than Mare Crisium's floor, but not as light as the basin rim. It is a system of ridges and uneven terrain, although there are a few regions which are relatively level. In 1907, lunar observer Garrett P. Serviss reported that Palus Somni as having "a color which is unique upon the Moon, a kind of light brown, quite unlike the hue

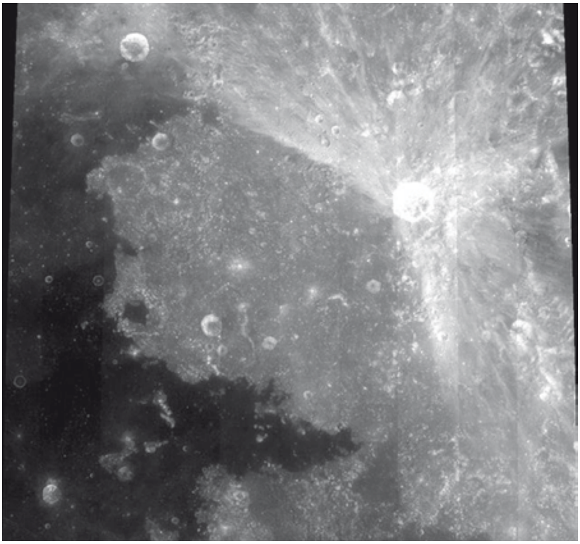

Fig. 5.9 Palus Somni – Clementine.

of any of the other plains or mountain regions"…although today the region just appears to be a slightly younger lava flow. Sharp-eyed observers will note small telescopic craters such as Crile to the east, Franz to the northwest, and the shallow crater Lyell on the western edge. If you follow Palus Somni to its south shore, you'll discover Sinus Concordiae – the "Bay of Harmony." This darker inlet is bordered on the western edge by Rimae Cauchy and to the southeast by indistinguishable craters Watts and Da Vinci. North of Palus Somni is Sinus Amoris – the "Bay of Love." Look for the singular peak of Mons Maraldi along its western shore and the ruins of the Montes Taurus peaks to the north. Is this an area affected by volcanism? You bet. Along the southern edge is Mons Esam, a slightly elevated regions that is home to several small lunar lava domes!

If you continue north of Proculus, you'll spot another dominant crater along Crisium's northwestern edge – Macrobius. This 66 km diameter crater is also well worth a look! Dipping down below the lunar surface about 3,700 m, you'll notice some very steep walls which look almost as if they had been mined… But it was formed by an impact. Can you spot the rebound dome in Macrobius' center? Other impacts have also happened here, too. Put some magnification on it in your telescope and you'll pick up a C crater breaking down the western rim and companion crater Tisserand to the east. Take a look at the gigantic depression to Macrobius' north, too. The area is unnamed, but it does contain a darker region known as Lacus Bonitatis – the "Lake of Goodness."

Are you lost? There's no need to be! Let's take a look at two pictorial maps that will help to guide you along the way. Here's a look at the Mare Fecunditatus region: (1)Taruntius, (2) Secchi, (3) Messier and Messier A, (4) Lubbock, (5) Guttenberg, (6) Montes Pyrenees, (7) Goclenius, (8) Magelhaens, (9) Columbo, (10) Webb, (11) Langrenus, (12) Lohse, (13) Lame, (14) Vendelinus, (15) the Luna 16 landing site (Fig. 5.10).

And here is a closer look at the area around Atlas and Hercules: (1) Mare Humboldtianum, (2) Endymion, (3) Atlas, (4) Hercules, (5) Chevalier, (6) Shuckburgh, (7) Hooke, (8) Cepheus, (9) Franklin, (10) Berzelius, (11) Maury, (12) Lacus Somniorum, (13) Daniel, (14) Grove, (15) Williams, (16) Mason, (17) Plana, (18) Burg, (19) Lacus Mortis, (20) Baily, (21) Atlas E, (22) Keldysh, (23) Mare Frigoris, (24) Democritus, (25) Gartner, (26) Schwabe, (27) Thales, (28) Strabo, (29) de la Rue, (30) Hayn (Fig. 5.11).

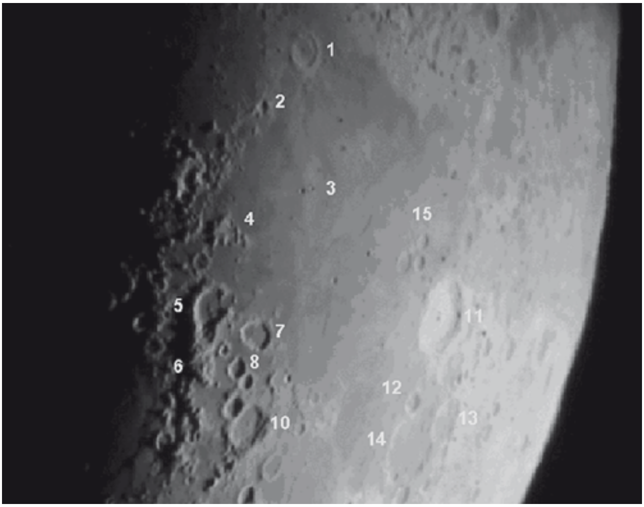

Fig. 5.10 Mare Fecunditatus Region photographic map – image credit – Greg Konkel.

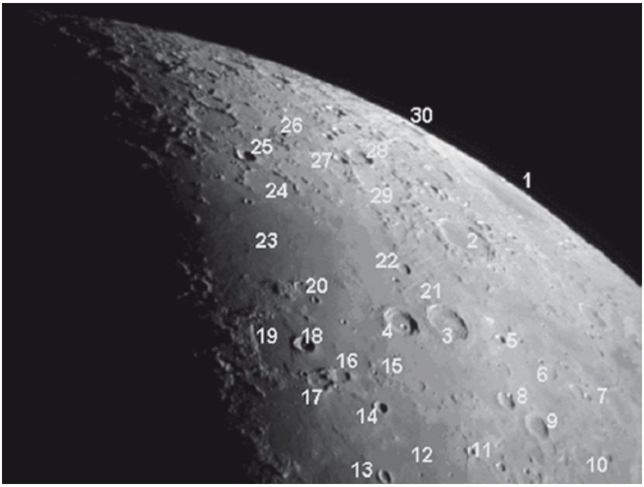

Fig. 5.11 Atlas and Hercules Region photographic map – image credit – Greg Konkel.

CHAPTER 6

LUNAR DAY FIVE

As a pale phantom with a lamp
Ascends some ruined haunted stair,
So glides the Moon along the damp
Mysterious chambers of the air.

Henry Wadsworth Longfellow

On the lunar surface tonight, let us begin with a look at Mare Serenitatus – the "Serene Sea" (Figs. 6.1 and 6.2). On its northeast shore, binoculars will have no trouble spotting the shallow ring of crater Posidonius. Almost flat

Fig. 6.1 Five day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_6,

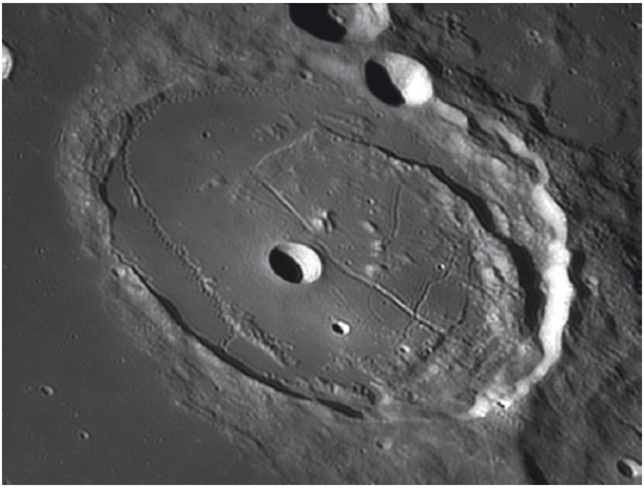

Fig. 6.2 Posidonius – Damian Peach.

from eons of lava flows, this crater shows numerous variations in texture along its floor in small telescopes. This huge, old, mountain-walled plain is considered a class V crater and could be as much as 3 billion years old. Spanning 84 × 98 km, you can plainly see Posidonius is shallow – dropping only 2,590 m below the surface. Tonight it will resemble a bright, elliptical pancake on the surface to smaller optics with its ring structure remaining conspicuous to binoculars throughout all lunar phases. However, a telescope is needed to appreciate the many fine features found on Posidonius' floor. Power up to observe the stepped, stadium-like wall structure and numerous resolvable mountain peaks joining its small, central interior crater. It has its own interior rimae that is especially prominent to the east and a smashing view of trio Posidonius O, I, and B on the north crater rim. Adding crater Chacornac to the southeast makes things even more interesting! Did you spot the small punctuation of Daniell to the north?

Now, look a bit south of and east of Posidonius and almost parallel to the terminator for a curious feature known as the Serpentine Ridge, or more properly as Dorsa Smirnov and the accompanying Dorsa Lister (Fig. 6.3). Can you detect the very tiny crater Very in its center? This thin, white line wanders across the western portion of Mare Serenitatus for a distance of

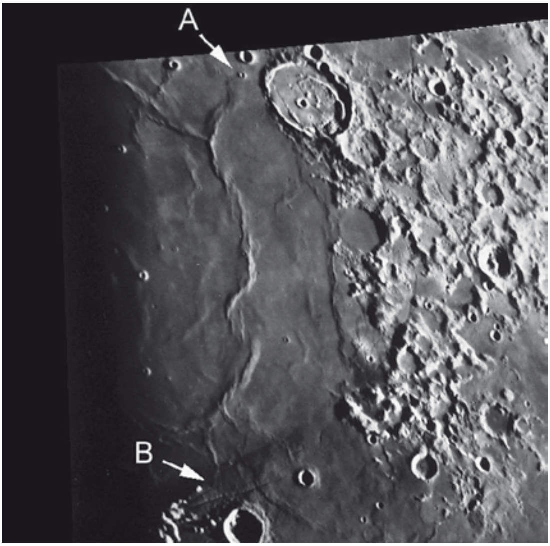

Fig. 6.3 Serpentine Ridge – Consolidated Lunar Atlas.

about 134 km. In some places it rises as high as 305 m above the smooth sands. This lunar "wrinkle" is an amazing 10 km wide! Power up in a telescope. The northern portion of the Serpentine Ridge is Dorsa Smirnov until it branches west and becomes Dorsa Lister. If the shadow play is good at your time, you might be lucky enough to resolve Dorsum Nicol, which connects the two. Only about 51 km long, Dorsum Nichol will appear almost as a circular, crater-like feature – but it is not. As part of the Mare Serenitatis/Mare Tranquilitatis border, it is not much more than a just an area where the two distinct lava flows cooled and contracted, causing the surface to heave up, but you will also find it is connected to the Rima Plinius as well.

It is where these two vast lava plains converge that we will set our sights (Fig. 6.4). Telescopically you will see a bright "peninsula" westward from where the two conjoin which extends toward the east: just off that look for bright and small crater Pliny (Plinius) – a 44 km wide ring with a prominent central peak. It is near this rather inconspicuous feature that the remains of Ranger 6 lie forever preserved. It crashed there on February 2, 1964. Unfortunately, technical errors occurred and Ranger 6 was never able to

Fig. 6.4 Plinius – Apollo 15 (NASA).

transmit lunar pictures. Not so Ranger 8! On a very successful mission to the same relative area, this time we received 7,137 "postcards from the Moon" in the last 23 min before hard landing. On the "softer side," Surveyor 5 safely touched down near this area after 2 days of malfunctions on September 10, 1967. Incredibly enough, the tiny Surveyor 5 endured temperatures of up to 139°C, but was able to spectrographically analyze the area's soil… And by the way, it also managed to televise an incredible 18,006 frames of "home movies" from its distant lunar locale!

South of Pliny are two nice crater challenges to add to your list – the 27 km wide punctuation of Arago and the ghost ring of 77 km wide Lamont to its southwest. While Arago is not so hard to resolve, add as much magnifications as your observing conditions will allow and see if you can conquer the low mounds of Arago Alpha and Arago Beta to the northwest and southwest, respectively. If so, then surely you can see the ruins of Lamont! If you still have trouble making it out, look for a series of rilles which will make it vaguely resemble a "peace sign" traced in the lunar dust.

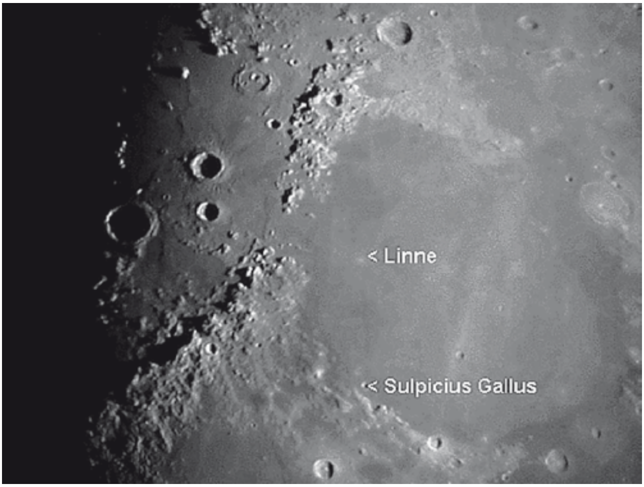

Fig. 6.5 Linne – Greg Konkel.

Now let us pick up a binocular curiosity located on the northeast shore of Mare Serenitatis (Fig. 6.5). Reidentify the bright ring of Posidonius, which contains several equally bright points both around and within it – and look at Mare Crisium and get a feel for its size. A little more than one Crisium's length west of Posidonius you will meet Aristotle and Eudoxus. Drop a similar length south and you will be at the tiny, bright crater Linne on the expanse of Mare Serenitatis. So what is so cool about this little white dot? With only binoculars you are resolving a crater that is 1 mile wide, in a 11 km wide patch of bright ejecta – from close to 400,000 km away! Speaking of ejecta, did you notice how much Proclus has changed tonight? It is now a bright circle and beginning to show bright lunar rays.

Now, let us Moon walk toward the southern quadrant and explore "The Sea of Nectar"…

At around 1,000 m deep, Mare Nectaris covers an area of the Moon equal to that of the Great Sandhills in Saskatchewan, Canada (Fig. 6.6). Like all maria, it is part of a gigantic basin which is filled with lava, and there is evidence of grabens along the western edge of the basin. While Nectaris' basaltic flows appear darker than those in most maria, it is one of the older formations on the Moon, and as the terminator progresses you will be able

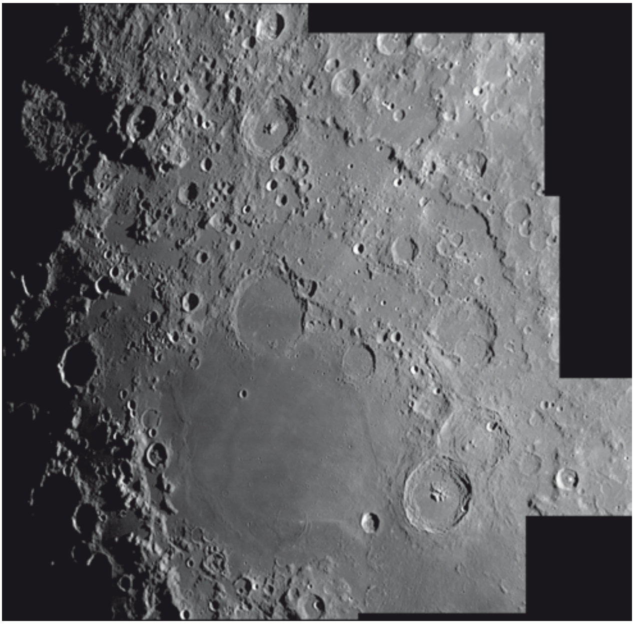

Fig. 6.6 Mare Nectaris – Damian Peach.

to see where ejecta belonging to Tycho crosses its surface. For a real challenge, look for an ancient and ruined crater which lies on the southern shore of Mare Nectaris. To binoculars, Fracastorius will look like a shallow, light colored ring, but a telescope will reveal its northern wall is missing – perhaps melted away by the lava flow which formed the mare. This is all that remains of a once grand crater which was more than 117 km in diameter. The tallest of its eroded walls still stand at an impressive 1,758 m, placing them as high as the base elevation of Mt. Hood, yet in places nothing more than a few ridges and low hills still stand to mark the crater's remains. Power up and look for interior craterlets. Be sure to mark your lunar challenge notes with your observations!

Your next assignment is a very fine old crater on the northwest shore of Mare Nectaris – Theophilus (Fig. 6.7). Slightly south of midpoint on the terminator, this crater contains an unusually large multiple-peaked central mountain which can be spotted in binoculars. Theophilus is an odd crater: it is

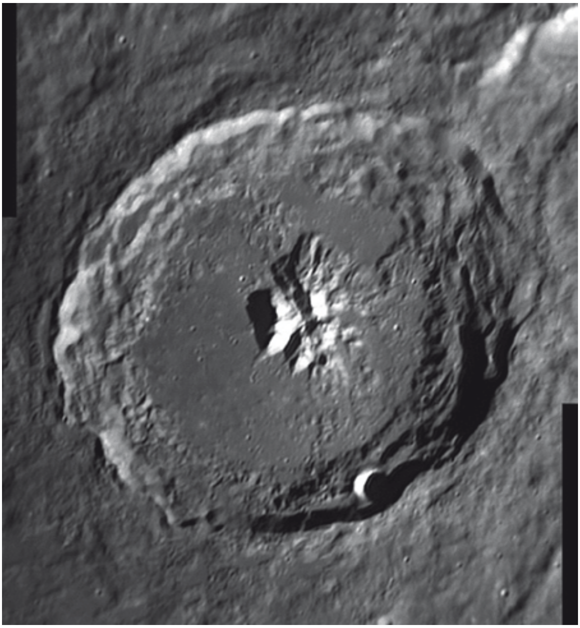

Fig. 6.7 Theophilus – Damian Peach.

shaped like a parabola – with no area on the floor being flat. It stretches across a distance of 100 km and dives down 440 m below the surface. Tonight it will appear dark, shadowed by its massive west wall, but look for sunrise on its 1,400 m summit! Head to the eastern shore of Mare Nectaris to catch an easily noticed broken black line. This is the western flank of the Pyrenees Mountains which stretch close to 350 km north to south. The black line you see is a good example of a lunar scarp, a feature more like a cliff than a true mountain range. This scarp ends to the north in crater Guttenberg. We will take a much closer look at it on Lunar Day Seventeen. Just south of Guttenberg, you will find high contrast crater Santbech.

Are you lost yet? Do not be afraid… Let us try using this map to guide you to these features: (1) Isidorus, (2) Madler, (3) Theophilus, (4) Cyrillus, (5) Catharina, (6) Dorsum Beaumont, (7) Beaumont, (8) Fracastorius, (9) Rupes Altai, (10) Piccolomini, (11) Rosse, (12) Santbech, (13) Pyrenees Mountains, (14) Guttenberg, (15) Capella (Fig. 6.8).

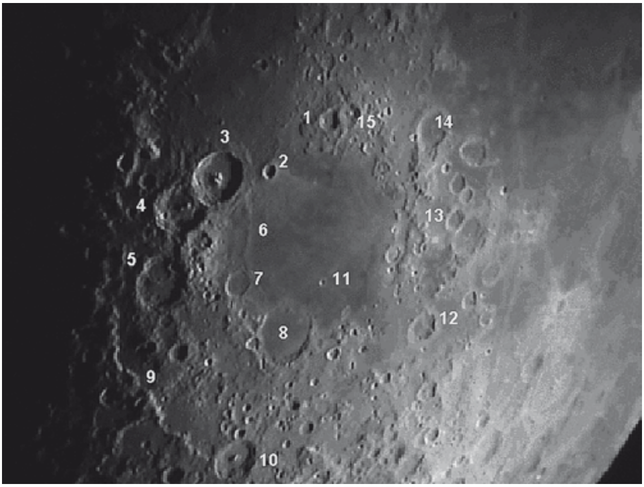

Fig. 6.8 Mare Nectaris photographic map – Greg Konkel.

Now that you are a bit more familiar with the landscape, let us try working on some harder targets (Fig. 6.9). For a telescopic and binocular challenge, Moon walk further south to visit one of the oldest features left on the visible lunar side. Start by reidentifying two prominent craters in the southeast quadrant – Metius and Fabricus. While viewing the area around them, note that Fabricus' walls actually intrude on Metius – pointing to a younger age of formation. Around Fabricus, but not including Metius, is the boundary of a mountain-walled plain extending into the terminator. High magnification will reveal many breaks in its hexagonal walls surrounding a floor marred by many smaller craters and fine fissures. This is Jannsen. Look for three prominent interior craters, as well as an ancient rima falling near the shadow's edge. It may not seem exciting, but remember Jannsen could go back to the time when the Moon first formed – more than 4 billion years ago!

If you are looking for something a bit more off the beaten path, then return to Theophilus (Fig. 6.10). Just outside of its east wall, you will also find a young crater – Madler. As you head east across the northern shore of Mare Nectaris, look carefully for two partial rings. The northernmost is so eroded that it never received a name, while a slight, faint horseshoe marks all that remains of Daguerre. This incredibly ancient crater formed in the Pre-Imbrian period and could possibly exceed 4 billion years old. Named for

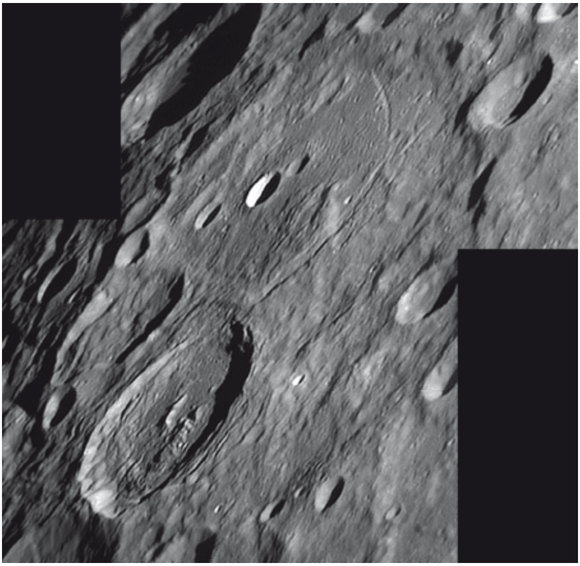

Fig. 6.9 Jannsen – Damian Peach.

Fig. 6.10 Daguerre – Wes Higgins.

the inventor of the diorama, Louis Jacques Mandé Daguerre, you will find nothing of photographic interest in these broken, eroded walls but the sands of time. Its south wall is essentially gone, long ago eaten away by lava flow. If the shadow play is correct, perhaps you will also spy where it once had neighbors to the northwest and southeast.

> There is something haunting in the light of the Moon; it has all the dispassionateness of a disembodied soul, and something of its inconceivable mystery.
>
> Joseph Conrad

Let us Moon walk around the shores of Mare Tranquillitatis and take in a few more sights before we leave for the night (Fig. 6.11). If you begin telescopically in the north just west of Pliny, you will see a small inlet known as Sinus Honoris – the "Bay of Honor." Its northern edge is defined by Rimae Maclear and the bright point leads to crater Maclear to the southwest and slightly larger crater Ross to the northeast. Rima Sosigenes comprises Honoris' western edge terminating in the dark ring of small crater Sosigenes. Continuing south along the Tranquillitatis western bank, you will encounter the fault line of Rima Ariadaeus, ending in small crater Ariadaeus – then the twin rings of the emerging Sabine and Ritter. As we turn toward the

Fig. 6.11 Ritter and Sabine – Damian Peach.

east along the south bank, we are traveling the Rima Hypatia, crowned by tiny crater Molke. Here we drop into Sinus Asperitatis – the “Bay of Roughness.” Toward its center you will see the remains of a once grand nameless crater holding the younger, sharper Torricelli in its center. Congratulations on Lunar Day Five challenges well done!

CHAPTER 7

LUNAR DAY SIX

> *Yes, lovely Moon! if thou so mildly bright*
> *Dost rouse, yet surely in thy own despite,*
> *To fiercer mood the phrenzy-stricken brain,*
> *Let me a compensating faith maintain;*
> *That there's a sensitive, a tender, part*
> *Which thou canst touch in every human heart…*
>
> William Wordsworth

Tonight on the lunar surface, all of Mare Serenitatis and Mare Tranquillitatis will be revealed, and so it is fitting we should take an even closer look at both the "Serene" and "Tranquil" seas (Fig. 7.1). Formed some 38 million

Fig. 7.1 Six day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_7,

years ago, these two areas of the Moon have been home to most of mankind's lunar exploration. Somewhere scattered on the basalt landscape on the western edge of Tranquillitatis, a few remains of the Ranger 6 mission lie tossed about, perhaps forming a small impact crater of their own. Its eyes were open, but blinded by a malfunction…forever seeing nothing. To the southwest edge lie the remnants of the successful Ranger 8 mission which sent back 7,137 glorious images during the last 23 min of its life. Nearby, the intact Surveyor 5 withstood all odds and made space history by managing to perform an alpha particle spectrogram of the soil while withstanding temperatures considerably greater than the boiling point. Not only this, but it also took over 18,000 pictures!

Now let us go to the southwest edge of Tranquillitatis and visit with the Apollo 11 landing area (Fig. 7.2). Although we can never see the "Eagle" telescopically, we can find where it landed. For telescopes and binoculars the landing area will be found near the terminator along the southern edge

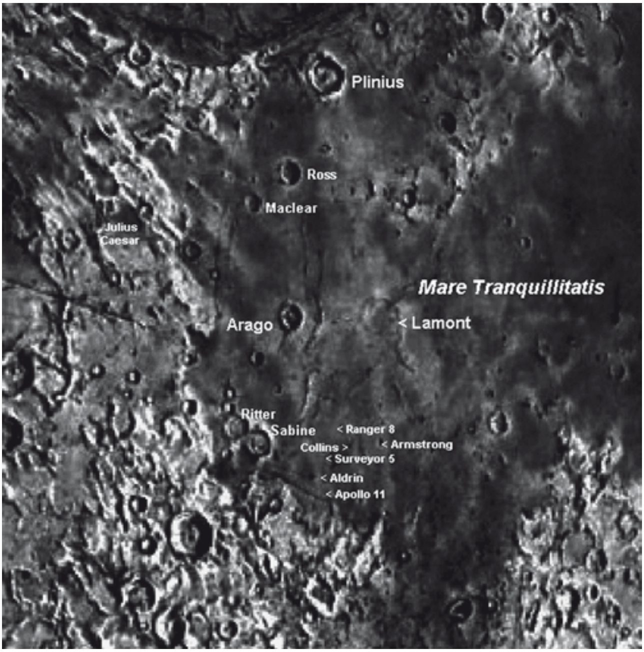

Fig. 7.2 Lunar history – Virtual Moon Atlas.

of Mare Tranquillitatis. No scope? No problem. Find the dark round area on the lunar northeastern limb – Mare Crisium. Then locate the dark area below that – Mare Fecundatatis. Now look mid-way along the terminator for the dark area that is Mare Tranquillitatis. The bright point west where it joins Mare Nectaris further south is the target for the first men on the Moon. We were there! Telescopically, start tracing the western wall of Tranquillitatis and looking for the small circles of craters Sabine and Ritter which are easily revealed tonight. Once located, switch to your highest magnification. Look in the smooth sands to the east to see a parallel line of three tiny craters. From west to east, these are Aldrin, Collins, and Armstrong – the only craters to be named for the living. It is here where Apollo 11 touched down, forever changing our perception of space exploration.

> That's one small step for [a] man, one giant leap for mankind.
>
> Neil Armstrong (July 20, 1969)

When you are ready, let us change our perception of the size of the things we see on the lunar surface by exploring the edges of Mare Serenitatus – a feature that is about the same size as the state of New Mexico (Fig. 7.3). On its southwest border stands the Haemus Mountains, which will continue on beyond the terminator. Look in their midst for the sharp punctuation of

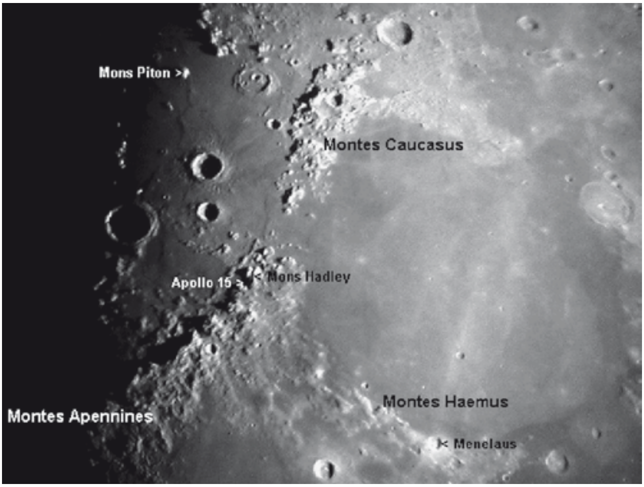

Fig. 7.3 Mountain ranges – Greg Konkel.

Class I Menelaus. This small crater has a brilliant west inner wall and deeply shadowed floor. Like Taruntius, Menelaus is another fine crater to watch for expansive ray systems as the terminator progresses. Although the Montes Haemus look pretty impressive, they are nothing more than foothills compared with the Apennines which have yet to emerge into the sunlight. Look at Serenitatus' northwest edge to view some real mountains! These are the Montes Caucasus, rising up to 5,182 m above the plains. Look closely at the maps and you will find this is also home to the Apollo 11, Apollo 16, and Apollo 17 landers, as well as Luna 21. It is an area that you can deeply appreciate for its historical significance. Like its Earthly counterpart, the Caucasus Mountain Range has peaks that reach upwards of 6 km – summits as high as Mount Elbrus! Nearby and slightly smaller than its terrestrial namesake, the lunar Apennine mountain range extends some 600 km with peaks rising as high as 5 km. Be sure to look for the summit of Mons Hadley, one of the tallest peaks you will see at the northern end of this chain. It rises above the surface to a height of 4.6 km, making that single mountain about the size of asteroid Toutatis.

For those seeking a bit of a telescopic and binocular challenge, look no further than the Valles Alpes (Fig. 7.4). More commonly known as the "Alpine Valley," this deep gash cut across the northern surface will be easily

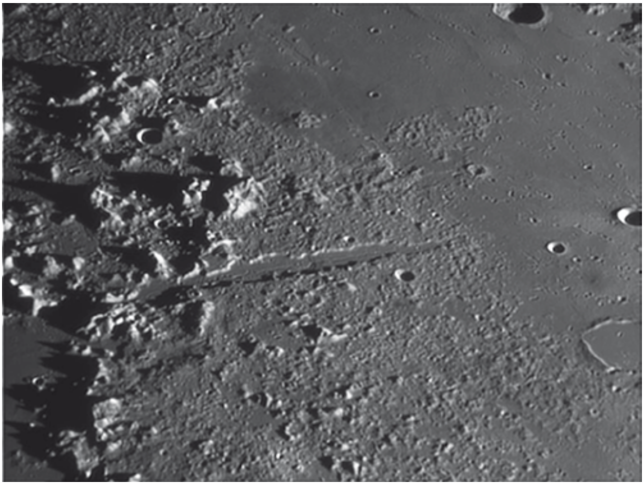

Fig. 7.4 Valles Alpes – Dietmar Hager.

visible and lighting conditions will be just right to notice its 1.6–21 km wide and 177 km long expanse. Using it as your guide, start at the western point and drop south along the Montes Alpes where you will see three bright peaks – Mons Blanc, Promontorium DeVille, and Promontorium Agassiz. Can you see lonely Mons Piton in the gray sands of Mare Imbrium? It stands 2,250 m above the lunar surface – about the average height of the Sierra Madres – but as a single, lonely peak.

Let us take on another telescopic challenge as we look mid-way along the terminator at the west shore of Mare Tranquillitatis for crater Julius Caesar (Fig. 7.5). This is also a ruined crater, but it met its demise not through lava flow – but from a cataclysmic event. The crater is 88 km long and 73 km wide. Although its west wall still stands over 1,200 m high, look carefully at the east and south walls. At one time, something plowed its way across the lunar surface, breaking down Julius Caesar's walls and leaving them to stand no higher than 600 m at the tallest. Do you see Alfraganus on the terminator? Follow the terrain to Theophilus and look west for Ibyn-Rushd with crater Kant to the northwest and the beautiful peak of Mons Penck to its east.

So…Are you ready to do a Moon walk for a challenge crater we have not listed yet? Then look to the northwest shore of Mare Serenitatis for the prominent pair of Aristoteles and Eudoxus – viewable even in small binoculars (Fig. 7.6). Let us take a closer look at larger Aristoteles to the north. As a Class I crater,

Fig. 7.5 Julius Ceasar – Wes Higgins.

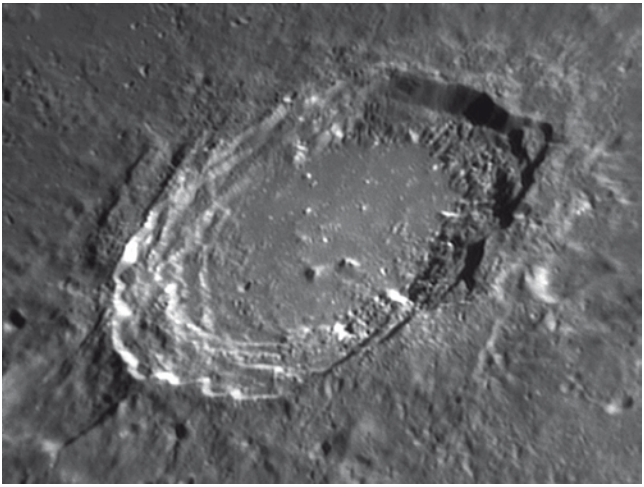

Fig. 7.6 Artistoteles – Damian Peach.

this ancient old beauty has some of the most massive walls of any lunar feature. Named for the great philosopher, it stretches across 87 km of lunar landscape and drops below the average surface level to a depth of 366 m – a distance which is similar to Earth's tallest waterfall, the Silver Cord Cascade. While it has a few scattered interior peaks, the crater floor remains almost unscarred. As a telescopic challenge, be sure to look for a much older crater sitting on Aristoteles' eastern edge. Tiny Mitchell is extremely shallow by comparison and only spans 30 km. Look carefully at this formation, for although Aristoteles overlaps Mitchell, the smaller crater is actually part of the vast system of ridges which supports the larger one.

Depending on where the terminator is located at your viewing time, you may have the opportunity to check a few more off your viewing list (Fig. 7.7). Look for the prominent pair of Aristillus and Autolycus caught just east of the Apennine Mountain range. The larger and northernmost is Aristillus. If the sunlight is high enough, you may be able to see ridges in its thick walls or the Sun rising over its multiple center peaks. Watch in the days ahead as it gains a ray system. To the south is much smaller Autolycus. Its walls are not as impressive, but it, too, will gain a ray system.

If you have not logged the shallow Archimedes, tonight is your chance (Fig. 7.8). Formed in the Upper Imbrian and perhaps a little more than

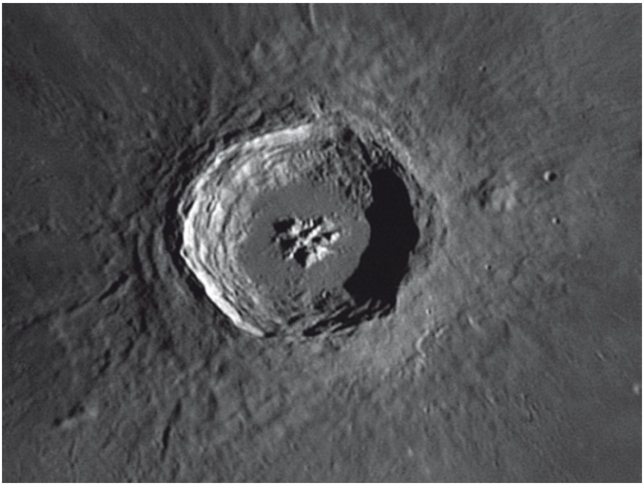

Fig. 7.7 Aristillus – Damian Peach.

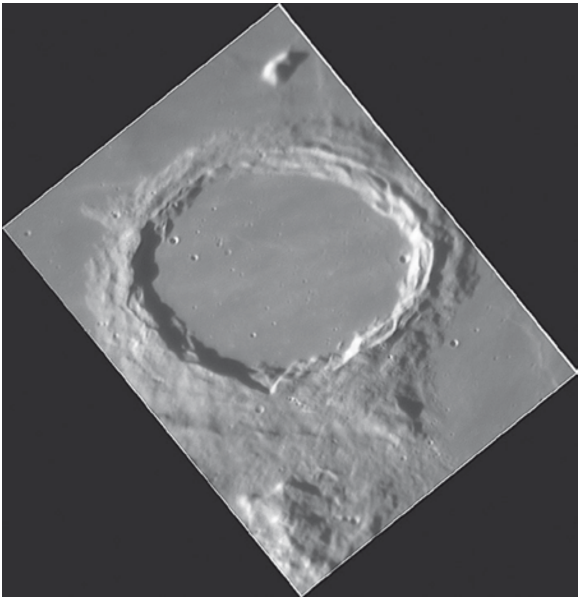

Fig. 7.8 Archimedes – Wes Higgins.

3 billion years old, this landmark feature named for the "man of machines" is definitely an exceptional lunar feature for any optical device. Take a look at its high walls and steep slopes which look almost as if they were built, rather than naturally formed by an impact. Along the south rim you will catch Montes Archimedes – a group of mountains which are situated on a plateau. At widest, the range might reach as much as 140 km but most of the peaks are compressed in an area about 70 km in diameter. Are they impressive? If you were standing at the base they would be. Most of them average about 2 km high, which would be very comparable to the central Himalayas. Can you spot tiny crater Bancroft to Archimedes southwest – or make out any craterlets on its smooth, lava-covered floor?

Take a look to Archimedes northeast (Fig. 7.9). Here you will find another odd feature – Sinus Lunicus – the "Bay of Lunik." How did it come about its strange name? In this case, it is an honor bestowed upon it by the International Astronomical Union in the year 1970 – because right here is where the Luna 2 landed on September 14, 1959. What is so special about

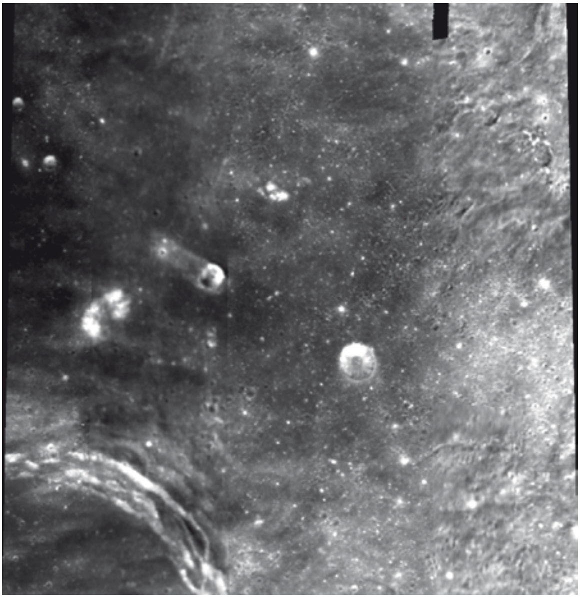

Fig. 7.9 Sinus Lunicus – Clementine.

that? Luna 2 was the very first space probe to make successful contact with another interplanetary body, confirming the Moon had no appreciable magnetic field, and found no evidence of the Moon having radiation belts. It may have impacted arriving at its destination – but it hit its mark! Astronomers in Europe reported seeing the black dot of the crashing probe. The event lasted for nearly 300 s and spread over an area of 40 km.

> …two minutes and 24 seconds after midnight Moscow time on 14 September 1959, the end of the long era when knowledge about the Moon which came from quiet nights at the telescope, was heralded by the crash of the Soviet spacecraft Luna 2.

Don E. Wilhelms

Ready to take a look at some strange formations? Then Moon walk just to the southeast of Archimedes and you will see a dark, piano-shaped area called Paulus Putredinus – the "Marsh of Decay" (Fig. 7.10). Formed in the

Fig. 7.10 Palus Putredinus – Apollo 15 Flyover (NASA).

Imbrian period, this 185 km diameter, very differently colored area is surrounded on all sides by mountain rimae. Lava filled? Darn right. And this lava is different than other areas. According to research, it may contain mafic glass spherules, which could possibly be used to help identify mare basalt vent sources. One of the reasons you will want to power up on this region is Hadley Rille – location of the Apollo 15 mission. It was selected because of the variety of important lunar surface features concentrated in the small area. The Apennine Mountains to the east surround the Imbrium basin and could have contained very old, exposed rocks while the smooth lava flows of Palus Putredinus formed much later. The deep crack of Hadley Rille, sharply etched in the mare surface, is thought to be one of the youngest rilles on the Moon and who knew what wonders they might find there? We will take a closer look at Hadley Rille when it is more fully revealed tomorrow.

> So we come around the corner and looked down at the Moon and here's all these things we've been told about in reality. And they're much better than the photos. And you say 'Wow, look at that stuff. Wow, look at Aristarchus. Look at Humboldt, Copernicus, all that stuff. Wow! It's even better than these guys who had lectured to us and got us stimulated. So it's all back to the guys who teach you.
>
> David R. Scott (Apollo 15)

Our next Moon walk is further south into Mare Vaporum – the "Sea of Vapors" (Fig. 7.11). It is an unusual 236 km wide feature with a basin that originated in the Pre-Imbrian period while the 55,000 km^2 of lunar material surrounding the mare came from the Lower Imbrian epoch and the mare material is from the Eratosthenian epoch. Small wonder appears to have so many variations! The older basin is actually within the Procellarum basin – an area not yet revealed. As a curiosity which should not be lost, to the north, look for a surface formation which was once known as Morotcha. The name no longer exists on modern lunar charts, but why part with tradition? Look for the bright ring of crater Manilius and let us gather in a few more lunar oddities!

If you would like to continue with your "lacus" education, then power up on the region around Manilius for a closer look (Fig. 7.12). North toward the terminator is Lacus Felicitatis (the Lake of Happiness) which stretches some 90 km in diameter. Farther south is 80 km wide Lacus Odii (the Lake of Hatred) – the smallest of this group. Continue southeast for the largest – Lacus Doloris (the Lake of Sorrow), 110 km across at its widest point.

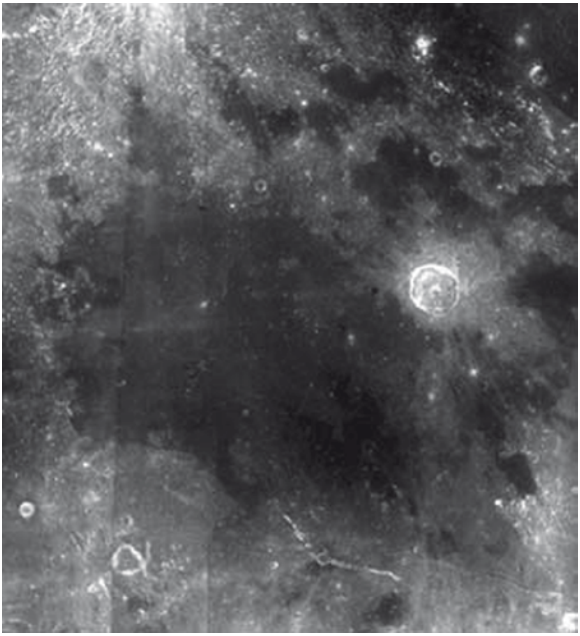

Fig. 7.11 Mare Vaporum – Clementine.

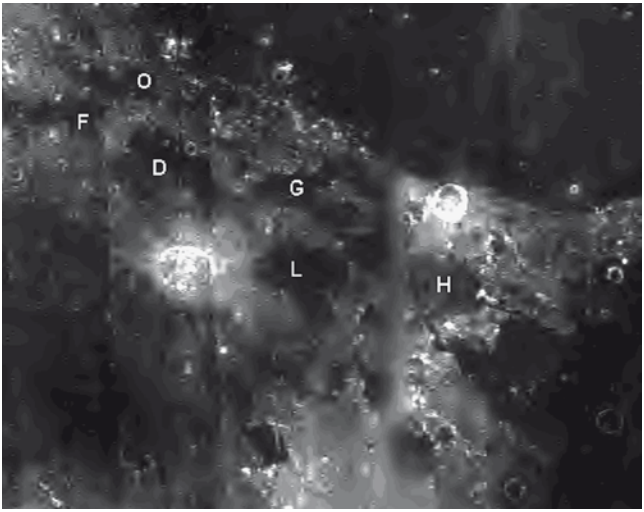

Fig. 7.12 Lunar Great Lakes – Tammy Plotner.

To its east is Lacus Gaudii (the Lake of Joy). Look closely for its upland region untouched by lava flow. Toward the south is Lacus Lenitatis (the Lake of Softness), and further east is Lacus Hiemalis (the Wintry Lake). While these features seem minor compared with others, their combined area rivals that of the American Great Lakes! Perhaps you would like to try your hand at more? Then look just north of landmark crater Posidonis for Lacus Mortis (Lake of Death) and its counterpart Lacus Somniorum (Lake of Dreams). Is there a connection here? You betcha'. These two basin areas filled with basaltic flow which should have joined, but a small mountain range kept them apart.

What is that? You see more? Then mark your notes for what you have accomplished and let us have a look at many other studies in this area you may not have noted yet: (1) Burg, (2) Barrow, (3) Grove, (4) Daniel, (5) Posidonius, (6) Apollo 17 Landing Area, (7) Plinius, (8) Bessel, (9) Menelaus, (10) Manilius, (11) Apennine Mountains, (12) Conon, (13) Palus Putredinus, (14) Mons Hadley, (15) Archimedes, (16) Autolycus, (17) Aristillus, (18) Mons Piton, (19) Cassini, (20) Caucasus Mountains, (21) Calippus, (22) Alexander, (23) Eudoxus, (24) Mare Serenitatis, (25) Linné, (26) Haemus Mountains (Fig. 7.13).

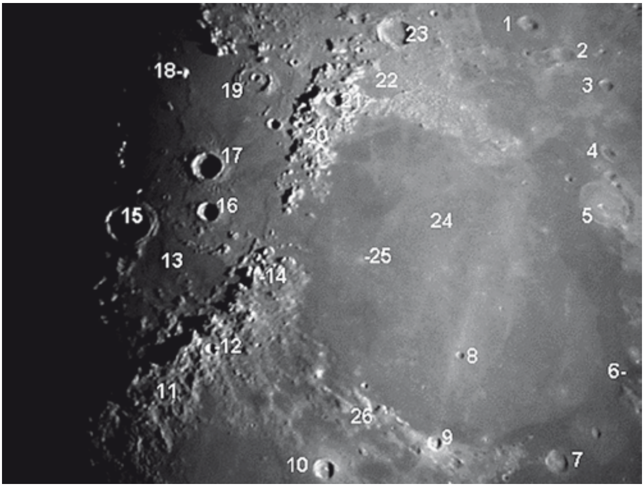

Fig. 7.13 Photographic map – Greg Konkel.

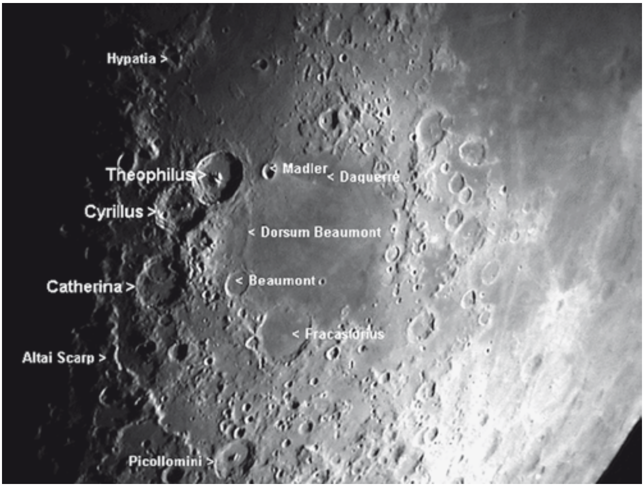

Fig. 7.14 "Theo Trio" – Greg Konkel.

We will continue our lunar explorations as we look for the "three ring circus" of landmark craters – Theophilus, Cyrillus, and Catherina – a challenging crater which spans 114 km and goes below the lunar surface by 4,730 m (Fig. 7.14). Are you ready to discover a very conspicuous lunar feature that was never officially named? Cutting its way across Mare Nectaris from Theophilus to shallow crater Beaumont in the south, you will see a long, thin, bright line. What you are looking at is an example of a lunar dorsum – nothing more than a wrinkle or low ridge. Chances are good that this ridge is just a "wave" in the lava flow that congealed when Mare Nectaris formed. This particular dorsa is quite striking tonight because of low illumination angle. Has it been named? Yes. It is unofficially known as "Dorsum Beaumont," but by whatever name it is called, it remains a distinct feature you will continue to enjoy! Also to the far south along the terminator you will see Mutus, a small crater with black interior and bright, thin west wall crest. Angling further southwest from Mutus, look for a "bite" taken out of the terminator. This is crater Manzinus.

The most outstanding feature tonight on the Moon will be a southern crater near the terminator – Maurolycus (Fig. 7.15). Depending on your viewing time, the terminator may be running through it. These shadows will multiply

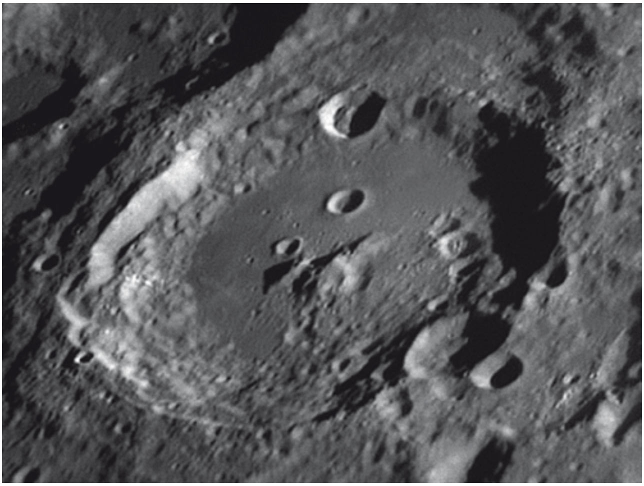

Fig. 7.15 Maurolycus – Damian Peach.

its contrast many times over and display its vivid formations. As true lunar challenge, Maurolycus will definitely catch your eye with its black interior and western crest stretched over the terminator's darkness. Too many southern craters to be sure? Do not worry. Maurolycus dominates them all tonight. Look for its double southern wall and multiple crater strikes along its edges. Maurolycus is found about two Crisium lengths southwest of Theophilus and in tonight's light will appear especially fine. But look just north of Maurolycus to pick out the battered remains of Class III crater Gemma Frisius, another lunar challenge. Spanning 90 km wide and descending 5,213 m below the Moon's surface, you will find its walls broken, yet enough of its northern boundary remains to clearly reveal the impact that created Goodacre. Look for the shadows which blend Goodacre and Gemma Frisius together. We will take a closer look at the "Gem" on Lunar Day Nineteen.

Now we are ready for some serious study (Fig. 7.16). Our first order of business will be to identify crater Curtius. Directly in the center of the Moon is a dark-floored area known as the Sinus Medii – the "Bay in the Middle." South of it will be two conspicuously large craters – Hipparchus to the

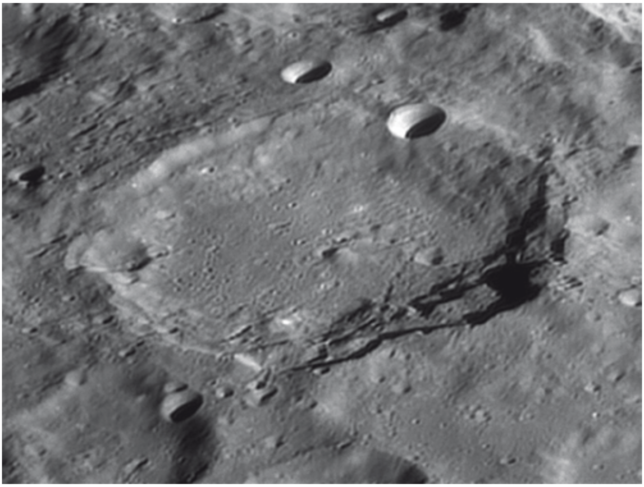

Fig. 7.16 Curtius – Damian Peach.

north and ancient Albategnius to the south. Trace along the terminator toward the south until you have almost reached its point (cusp) and you will see a black oval. This normal looking crater with the brilliant west wall is ancient crater Curtius. Because of its high southern latitude, we shall never see the interior of this crater – and neither has the Sun! It is believed the inner walls are quite steep, and so crater Curtius' interior has never been illuminated since its formation billions of years ago. Because it has remained dark, we can speculate there may be "lunar ice" (water ice possibly mixed with regolith) pocketed inside its many cracks and rilles which date back to the Moon's formation!

Because our Moon has no atmosphere, the entire surface is exposed to the vacuum of space. When sunlit, the surface reaches up to 385K, so any exposed lunar ice would vaporize and be lost because the Moon's gravity could not hold it. The only way for ice to exist would be in a permanently shadowed area. Near Curtius is the Moon's south pole, and imaging from the Clementine spacecraft showed around 15,000 km^2 of area where such conditions could exist. So where did this ice come from? The lunar surface never ceases to be pelted by meteorites – most of which contain water-related ice. As we know,

Fig. 7.17 Agrippa and Godin – Wes Higgins.

many craters were formed by just such impacts. Once hidden from the sunlight, this ice could continue to exist for millions of years.

Now, let us Moon walk to the north of Sinus Medii and have a look at a pair we have not yet encountered on our lunar travels – Agrippa and Godin (Fig. 7.17). The larger of the two, Agrippa, measures around 46 km in diameter and drops to a depth of 3,070 m. To the south is Godin, which is somewhat smaller at 35 km in diameter, but a bit deeper at 3,200 m. Note how Godin's interior slopes toward its central peak.

It is time now to find the lunar crater named for Joseph Fraunhofer – the spectral king (Fig. 7.18). Return again to the now shallow appearing crater Furnerius. Can you spot the ring at its southern edge? This is crater Fraunhofer – a challenge under these lighting conditions. For those wanting to sharpen their observing skills, return to identify Metius, Fabricus, and Janssen to the south. Southwest of this trio you will see a sharply defined small crater known as Vlacq. Power up to resolve its small central mountain peak. Angling off to the west and extending westward is multiple crater Hommel. Look especially for Hommel A and Hommel C which fit nicely and precisely within the borders of the older crater. Note how many

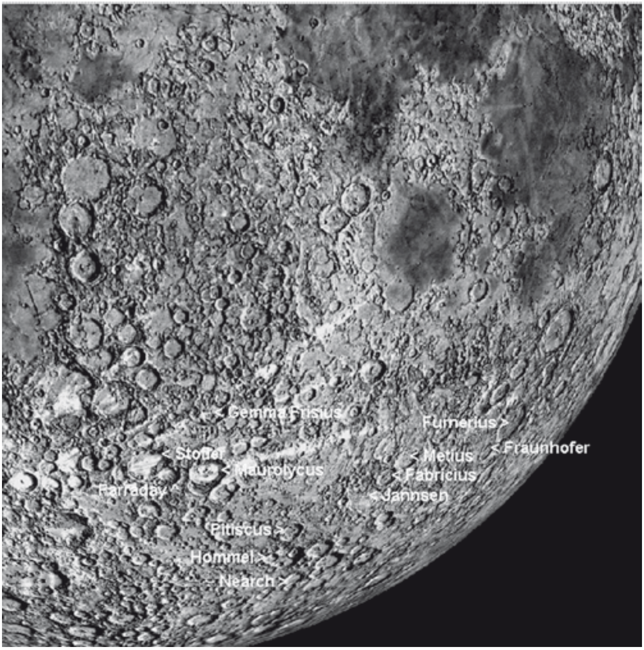

Fig. 7.18 Virtual Moon Atlas.

individual craters make up its borders. Just north of Hommel is Pitiscus and to its south is Nearch.

Let us hope to another challenging feature and a crater which conjoins it – Stofler and Faraday (Fig. 7.19). Located along the terminator, crater Stofler was named for Dutch mathematician and astronomer Johan Stofler. Consuming lunar landscape with an immense diameter of 126 km and dropping 2,760 m below the surface, Stofler is a wonderland of small details in eroded surroundings. Breaking its wall on the north is Fernelius, but sharing the southeast boundary is Faraday. Named for English physicist and chemist Michael Faraday, it is more complex and deeper at 4,090 m, but far smaller at 70 km in diameter. Look for myriad smaller strikes which bind the two together. We will visit this region again. Congratulations of a fine job of observing on Lunar Day Six!

Fig. 7.19 Stofler – Wes Higgins.

PART II

FIRST QUARTER

CHAPTER 8

LUNAR DAY SEVEN

The half Moon shows a face of plaintive sweetness
Ready and poised to wax or wane;
A fire of pale desire in incompleteness,
Tending to pleasure or to pain…

Christina Rossetti

Tonight we will begin our lunar explorations as we look to the far north and explore the "Sea of Cold" – Mare Frigoris (Figs. 8.1 and 8.2). This long, vast lava plain extends 1,126 km across the surface from east to west, yet never ranges more than 72 km from north to south. Look for the unmistakable dark ellipse of landmark crater Plato caught on Frigoris' southern central

Fig. 8.1 Seven day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
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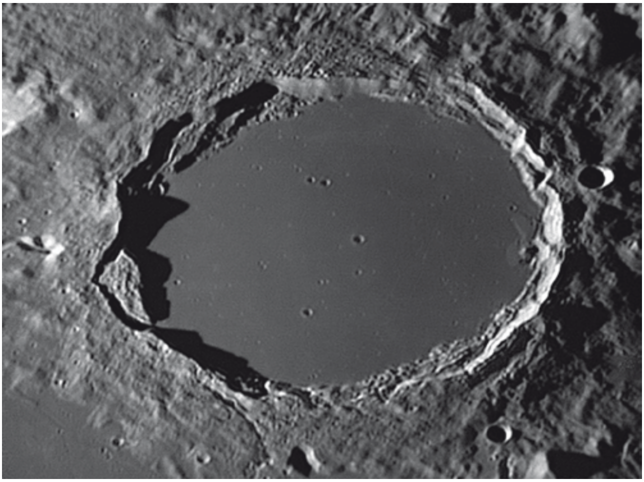

Fig. 8.2 Plato – Damian Peach.

shore. Named after the famous philosopher, this Class V crater spans approximately 101 km but is a shallow 1 km deep. The bright rim of Plato's enclosure is very ragged and can rise as high as 2 km above the surface, casting unusual shadows on the lava covered floor. At around 3 million years old, Plato is more ancient than Mare Imbrium to its south. For 300 years astronomers have been keeping a watchful eye on this crater. Hevelius called it the "Greater Black Lake," because of its low albedo (surface reflectivity). Despite its dark appearance, Plato is well known as a home for lunar transient phenomena such as flashes of light, unusual color patterns, and areas that could be outgassing. Enjoy this lunar feature which will point the way to others in the future! We will be back to look again on Lunar Day Twenty…

If you missed your chance last night to see the incredible Alpine Valley, it is now fully disclosed in the sunlight (Fig. 8.3). Viewable through binoculars as a thin, dark line, telescopic observers at highest powers will enjoy a wealth of details in this area, such as a crack running inside its boundaries. It is a wonderful lunar observing challenge and a guide to our next lunar feature – Cassini and Cassini A. Where the valley joins the lunar Alps, follow the range south into Mare Imbrium. Along the way you will see the protruding bright peaks of Mons Blanc, Promontorium DeVille, and at the very end, Promontorium Agassiz ending in the smooth sands. Southeast of Agassiz

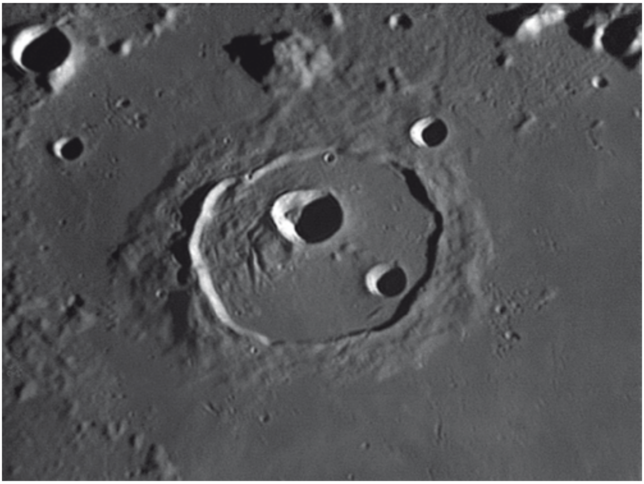

Fig. 8.3 Crater Casinni–Credit: Damien Peach.

you will spot Cassini. The major crater spans 57 km and reaches a floor depth of 1,240 m. The challenge is to also spot the central crater A, which is only 17 km wide, yet drops down another 2,830 m below the surface. This shallow crater holds another challenge within – Cassini A. But, look carefully… Can you spot the B crater on Cassini's inner southwestern rim? Or the very small M crater just outside the northern edge?

For more advanced lunar observers, head a bit further south to the Haemus Mountains to look for the bright punctuation of a small crater on the southwest shore of Mare Serenitatis (Fig. 8.4). Increase your magnification and look for a curious feature with an even more curious name… Rima Sulpicius Gallus. It is nothing more than a lunar wrinkle which accompanies the crater of the same name – a long-gone Roman counselor. Can you trace its 90 km length?

Let us continue our study of the lunar poles by returning to landmark crater Plato (Fig. 8.5). North of it you will note a "double crater." This elongated diamond-shape is Goldschmidt, and the crater which cuts across its western border is Anaxagoras. The lunar north pole is not far from Goldschmidt, and since Anaxagoras is just about 1° outside of the Moon's theoretical "arctic" area, the lunar sunrise will never go high enough to clear the southernmost rim. As proposed with yesterday's study, this "permanent darkness" must mean there is ice! For that very reason, NASA's Lunar Prospector probe

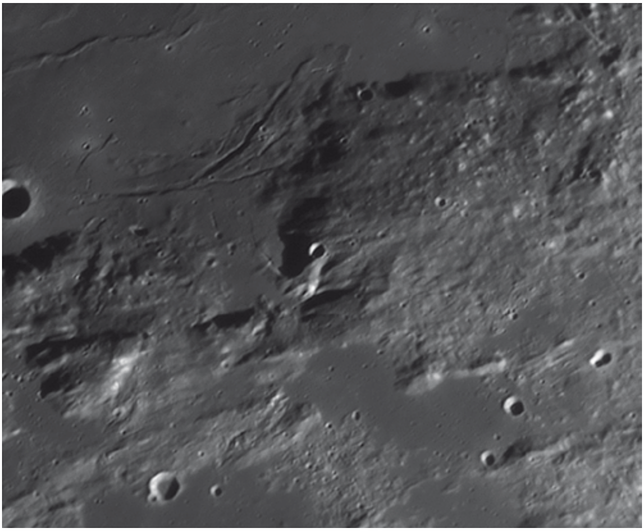

Fig. 8.4 Rima Sulpicius Gallus – Wes Higgins.

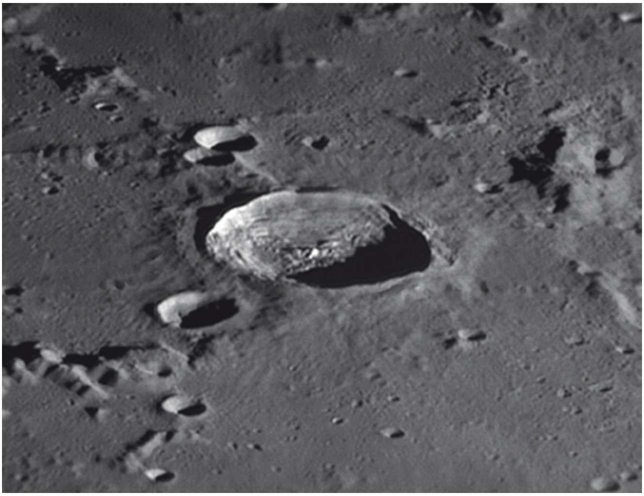

Fig. 8.5 Anaxagoras – Damian Peach.

was sent to explore here. Did it find what it was looking for? Answer – Yes. The probe discovered vast quantities of cometary ice which has hidden inside the crater's depths untouched for millions of years. If this sounds rather boring to you, then realize this type of resource may aid our plans to eventually establish a manned base on the lunar surface.

On March 5, 1998 NASA announced that Lunar Prospector's neutron spectrometer data showed that water-based ice was discovered at both lunar poles (Fig. 8.6). The first results showed the "ice" mixed in with lunar regolith (soil, rocks, and dust), but long-term data confirmed nearly pure pockets hidden beneath about 40 cm of surface material – with the results being strongest in the northern polar region. It is estimated there may be as much as 6 trillion kilograms (6.6 billion tons) of this valuable resource! If this still does not get your motor running, then realize that without it we could never establish a manned lunar base because of the tremendous expense involved in transporting our most basic human need – water. The presence of lunar water could also mean a source of oxygen, another

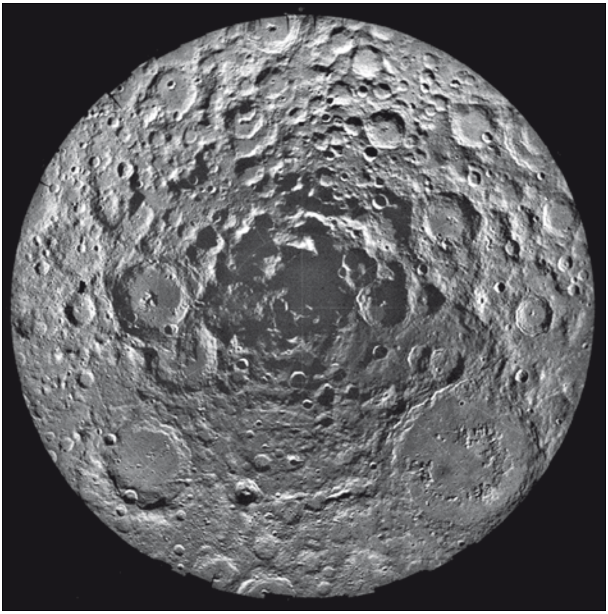

Fig. 8.6 Lunar Prospector Image (NASA).

vital material we need to survive. To return home or voyage onward, these same deposits could provide hydrogen which could be used as rocket fuel. So as you view Anaxagoras tonight, realize you may be viewing one of mankind's future "homes" on a distant world!

Are you ready for a challenge? Then using our past knowledge of Mare Serenitatis, look for the break along its western shoreline dividing the Caucasus and Apennine mountain ranges (Fig. 8.7). Just south of this break is the bright peak of Mons Hadley. Along this ridge line and smooth floor, look for a major fault line known as the Hadley Rille, winding its way across 120 km of lunar surface. In places, the rille spans 1,500 m in width and drops to a depth of 300 m below the surface. Believed to have been formed by volcanic activity some 3.3 billion years ago, we can see the impact the lower lunar gravity has had on this type of formation, since earthly lava channels are usually less than 10 km long and only around 100 m wide.

During the Apollo 15 mission, Hadley Rille was visited at a point where it is only 1.6 km wide – still a considerable distance as seen in comparison to astronaut James Irwin and the lunar rover (Fig. 8.8). Over a period of time, lava may have continued to flow through this area, yet it remains forever

Fig. 8.7 Hadley Rille – Damian Peach.

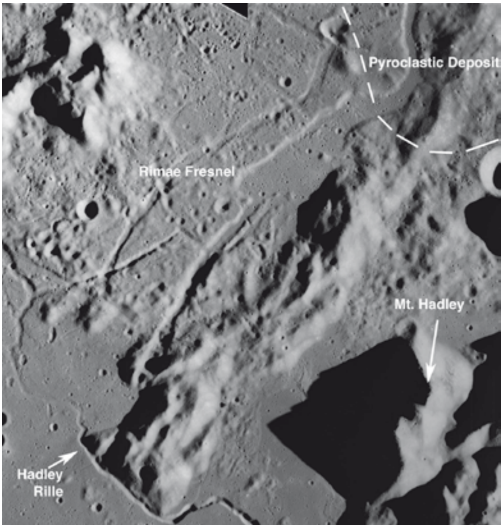

Fig. 8.8 Hadley Rille – NASA/JSC/Arizona (Apollo Image Archive).

buried beneath years of regolith. Hoping for fresh exposures from what are thought to be stratified mare beds along tops of the rille walls, exploration and collection of samples became important in this region. Geologists would then be able to study the origin of lunar sinuous rilles, and determine if they were caused by some sort of fluid flow mechanism-possible volcanic activity.

Now it is time to take a closer look at Sinus Medii – the "Bay in the Middle" of the visible lunar surface (Fig. 8.9). Central on the terminator, and the adopted "center" of the lunar disk, this is the point from which latitude and longitude are measured. This smooth plain may look small, but it covers about as much area as the states of Massachusetts and Connecticut combined. During full daylight, temperatures in Sinus Medii can reach up to 212°! On a curious note, in 1930 Sinus Medii was chosen by Edison Petitt and Seth Nicholson for a surface temperature measurement at full Moon. Experiments of this type were started by Lord Rosse as early as 1868, but on this occasion Petit and Nicholson found the surface to be slightly warmer than boiling water. Around a hundred years after Rosse's attempt, Surveyor 6 successfully landed in Sinus Medii on November 9, 1967, and became the very first probe to "lift off" from the lunar surface.

Fig. 8.9 Sinus Medii Region – Greg Konkel.

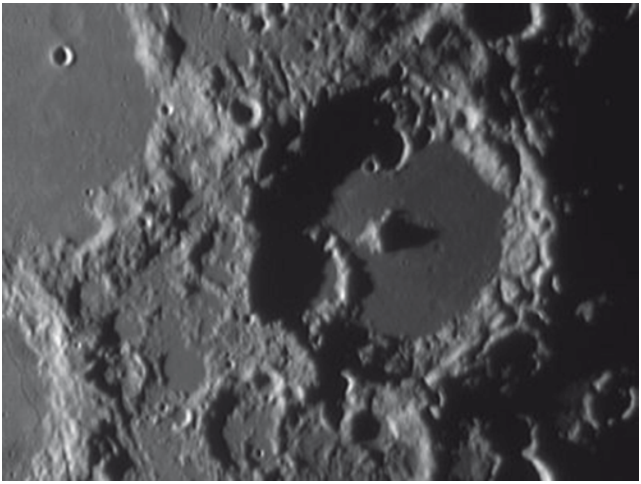

Fig. 8.10 Albategnius – Peter Lloyd.

Now, Moon walk south past Hipparchus for the huge, hexagonal walled plain of Albategnius – one of the most prominent craters around (Fig. 8.10). You will see it is easily visible in binoculars and telescopes. Located about

one-third the way north from the southern pole near the terminator, Albategnius is a very old crater. Stretching 131 km in diameter and 4,390 m deep, look for a brilliant inner west wall and, if the timing is right, a small central peak on its dark floor. Albategnius' walls themselves are marred with many craters, but one of the finest is Klein extending from the southwest to almost touch the central peak. Directly to its lunar east, and about the same distance as Albategnius is wide, look for a trio – small western Andel, larger eastern Descartes, and larger still southern Abulfeda. Power up! Between Andel and Descartes is the small pockmark of Dolland. North of Dolland is a ruined, unnamed crater with a pronounced set of rings on its northwestern shore. On the eastern edge of the relatively smooth floor, the remains of the Apollo 16 mission still shine on.

Partially filled with lava after creation, Albategnius ancient formation later became home to several wall-breech craters, such as Klein, which can be seen telescopically on the southwest wall (Fig. 8.11). Yet, Albategnius holds more than just the distinction of being a prominent crater tonight – it also

Fig. 8.11 Albategnius – Ranger 9 (NASA).

holds a place in history. On May 9, 1962 Louis Smullin and Giorgio Fiocco of the Massachusetts Institute of Technology (MIT) aimed a ruby laser beam toward the Moon's surface and Albategnius became the first lunar feature to reflect laser light from Earth. On March 24, 1965 Ranger 9 took a "snapshot" of Albategnius from an altitude of approximately 2,500 km. Ranger 9 was designed by NASA for one purpose – to achieve lunar impact trajectory and send back high-resolution photographs and video images of the lunar surface. Ranger 9 carried no other science packages. Its destiny was to simply take pictures right up to the moment of impact. They called it…a "hard landing." Power up with a telescope for another challenge. Can you spot the small craters Vogel and Burnham on its southeast edge? Or Ritchey just outside its eastern wall?

Once you have studied Albategnius, hop one crater north to study ancient Hipparchus (Fig. 8.12). It will appear almost like a sideways "figure 8" view in binoculars. This is not truly a crater – but a hexagonal mountain-walled plain. Spanning about 150 km in diameter with walls around 3,320 m high, it is bordered just inside its northern wall by telescopic crater Horrocks. This deep appearing "well" is 30 km in diameter and its rugged interior drops down an additional 2,980 m below the floor. To the south and just outside the edge of the plain is crater Halley. Slightly larger at 36 km in

Fig. 8.12 Hipparchus – Damian Peach.

diameter, this crater named for Sir Edmund Halley is a little shallower at 2,510 m deep – but it has a very smooth floor. To the east you will see a series of three small craters, the largest of which is Hind and shallow crater Saunder is just to its east. Just northwest of Hipparchus' wall are the beginnings of the Sinus Medii area. Look for the deep imprint of Seeliger – named for a Dutch astronomer. Due north of Hipparchus is Rhaeticus, and here is where things really get interesting. If the terminator has progressed far enough, you might spot tiny Blagg and Bruce to its west, the rough location of the Surveyor 4 and Surveyor 6 landing area. Directly north of Rhaeticus will be a long series of surface "cracks" known as rimae. These particular ones are the Rimae Triesnecker and you will see the crater itself just to their west.

Welcome to the Southern Highlands, where things are about to get very confusing (Fig. 8.13). To help guide you along the way, look west for the very prominent descending ring series of shallow landmark craters

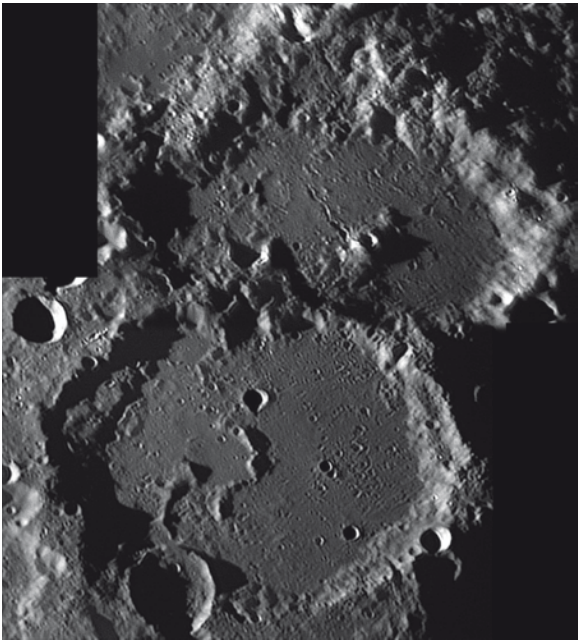

Fig. 8.13 Regiomontanus and Purbach – Damian Peach.

Ptolemaeus, Alphonsus, Arzachel – which appear similar to the Theophilus, Cyrillus, and Catharina trio. Just south of this set of rings is the remains of darker crater Purbach. Named for fifteenth century astronomer Georg von Peuerbach, this highly eroded ring spanning 118 km is nearly obliterated on its western side – yet the eastern walls still stand a respectable 2,980 m high. Power up and take a close look at the W crater in Purbach's center. It, too, has eroded with time. Sharing a common wall, you will find the very unique Regiomontanus to the south. Unlike the ring of Purbach, this one is oblate. With dimensions of 120 × 110 km, Regiomontanus' beauty is in the central peak. Again, use high magnification. On a steady night you will see the A crater sitting atop a nearly 6 km wide base mountain which reaches 1,200 m above the crater floor. Careful examination reveals what appears to be a volcano that has blown its top! Can you trace the lava flow?

Hop one more crater south until we end up at the spectacular crater Walter (Fig. 8.14). Named for Dutch astronomer Bernhard Walter, this 132 × 140 km wide lunar feature offers up amazing details at high power. Take the time to study the differing levels, which drop to a maximum of 4,130 m below

Fig. 8.14 Walter – Wes Higgins.

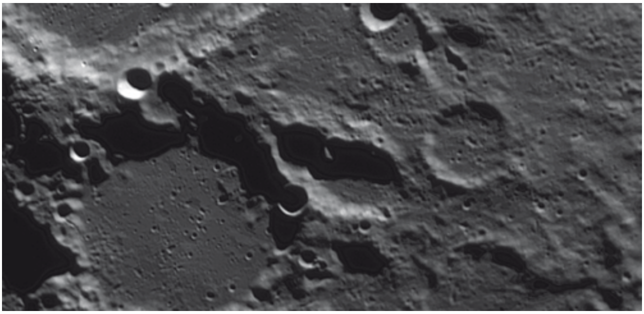

Fig. 8.15 Lacaille – Wes Higgins.

the surface. Multiple interior strikes abound, but the most fascinating of all is the wall crater Nonius. Spanning 70 km, Nonius would also appear to have a double strike of its own – one that is 2,990 m deep!

For a real challenge, see if you can identify crater Lacaille located on the northeast edge of Purbach (Fig. 8.15). This 68 km wide crater is not the most impressive in the area, but it does drop down about 2,775 m below the Moon's surface. This depth is very comparable to that of Hawaii's Haleakala Crater, which reaches down almost an identical distance to the ocean's floor. For the most part, Lacaille's interior is very smooth, with only a few minor craterlets along the northern edge marring the unbroken lava. Look carefully at its eastern wall, where a much newer impact has occurred, and to the south where the crater walls have eroded. Now, let us talk about the man this crater is named for. From 1750 to 1754, Abbé Nicolas du La Caille had the good fortune to study the southern hemisphere's stars from the Cape of Good Hope. He named 14 of the 88 constellations and studied 10,000 stars. He cataloged several nebulous star clusters and even discovered a galaxy! While this might seem pretty simple, think on this… Lacaille did it with a half inch refractor spyglass. Most of our modern finderscopes are bigger!

Now, return again to the descending rings of Ptolemaeus, Alphonsus, and Arzachel (Fig. 8.16). These are landmark craters which will guide you to other telescopic challenges – such as the small well of cratelet Ammonius situated inside the plains of Ptolemaeus' walls and the deep shape of Alpetragius located on the southwestern edge of Alphonsus. While you are

Fig. 8.16 Alpetragius – Damian Peach.

powering up on Alpetragius, look for how steep its inner slopes are and how massive its central peak is! Can you spot the very faded and eroded Alpetragius X to the northwest? How about Alpetragius M and N to the southeast? Alpretragius sprang up in those highland areas with the older craters during the Nectarian period, where its walls in rose in terraces and the central mountain may have played a very important volcanic role in its formation.

> When the Moon is ninety degrees away from the Sun it sees but half the Earth illuminated (the western half). For the other (the eastern half) is enveloped in night. Hence the Moon itself is illuminated less brightly from the Earth, and as a result its secondary light appears fainter to us…
>
> Galileo Galilei (The Starry Messenger)

Are you ready for some even more challenging features? Then let us take a deep breath and go again, because one of the most sought-after and unusual features may (depending on how far the terminator has progressed at your viewing time) may be visible to small telescopes in the southern half of the Moon near the terminator – Rupes Recta (Fig. 8.17). Also known as "The Straight Wall," this 130 km long, 366 m high feature slopes upward

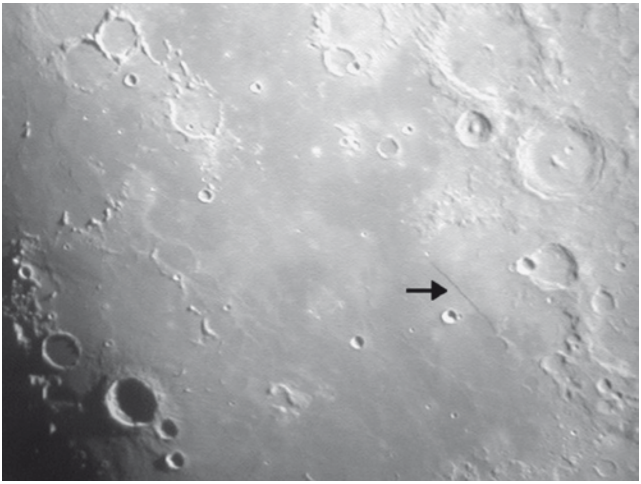

Fig. 8.17 Rupes Recta – Greg Konkel.

with the steepest angle on the lunar surface at 41°. As an observing challenge under these conditions, use triple ring craters Ptolemy, Alphonsus, and Arzachel to help guide you. The "Straight Wall" will appear as a very thin line stretching across the edge of Mare Nubium. Look for bright crater Birt along the west to help spot it.

When you have finished with the Straight Wall, there is a larger telescope challenge that is very fun if the lighting is right (Fig. 8.18). Just head slightly north for Cantena Davy – just west of crater Ptloemaeus. What you are looking for is a series of small strikes which form a Y-like pattern in the walled plain of crater Davy. None of these are large – nor conspicuous. If they were, they would not be a challenge! Ranging from about 1 to 3 km in diameter and beginning about in the area of craterlet Davy C, there are perhaps a dozen of these small impacts which may have all came from the same body striking the Moon along the same trajectory. It is a nice test of both your optics and seeing conditions, so if you do not get it this lunar cycle, try next time! Now, skip across the gray sands of Nubium further west and let us take a look at the crater on the peninsula-like feature Guericke. Named for Dutch physicist Otto von Guericke, this 58 km diameter crater has all but eroded away. Look for a break in its eastern wall and notice how lava flow has eradicated the north.

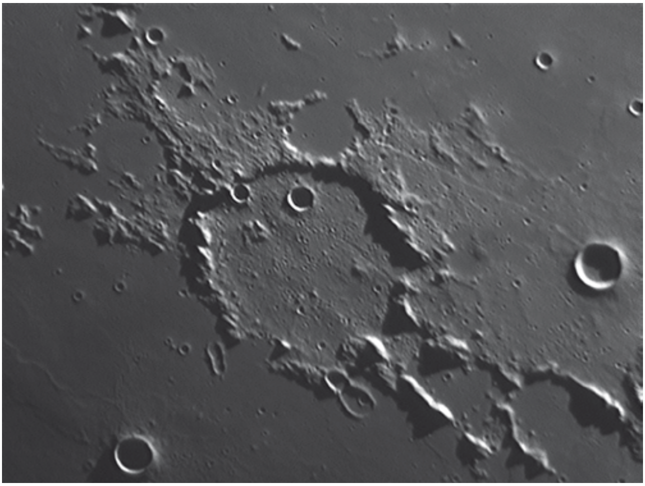

Fig. 8.18 Guericke – Wes Higgins.

When you are done, let us Moon walk east and take a high power look at companion craters and drive the names home again. Starting at the northern point of Rupes Recta, you will find yourself at Promontorium Taenarium. Just to the west of the point is splendid Alpetragius with its huge central peak. To the southeast is Arzachel, which sports a similar size central peak along with rimae and interior craterlets. Southwest is small Thebit with a very formidable puncture on its west wall. If they are not visible tonight – try again tomorrow. Use this photo to help you identify features such as: (1) Sinus Asperitatis, (2) Theophilus, (3) Cyrillus, (4) Catharina, (5) Rupes Altai, (6) Piccolomini, (7) Sacrobosco, (8) Abulfeda, (9) Almanon, (10) Taylor, (11) Abenezra, (12) Apianus, (13) Playfair, (14) Aliacensis, (15) Werner, (16) Blanchinus, (17) Lacaille, (18) Walter, (19) Regiomontanus, (20) Purbach, (21) Thebit, (22) Arzachel, (23) Alphonsus, (24) Ptolemaeus, (25) Albategnius (Fig. 8.19).

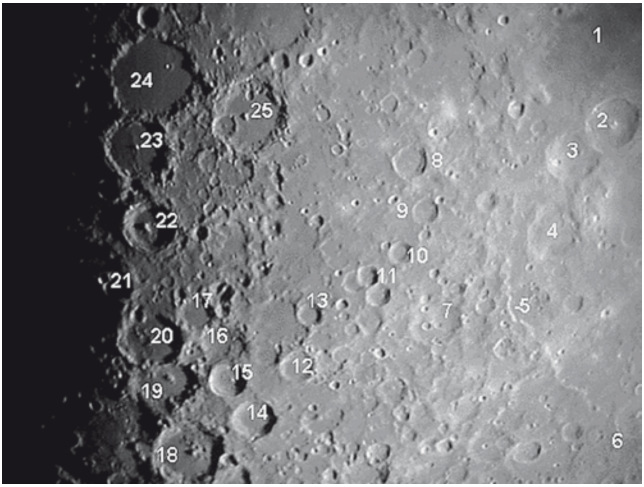

Fig. 8.19 Photographic lunar map – Greg Konkel.

CHAPTER 9

LUNAR DAY EIGHT

I sing to you and the Moon
But only the Moon remembers.
I sang
O reckless free-hearted
free-throated rhythms,
Even the Moon remembers them
And is kind to me…

Carl Sandburg

Let us begin our Moon walk tonight with a deeper look at the "Sea of Rains" (Figs. 9.1 and 9.2). Our mission is to explore the disclosure of Mare Imbrium, home to Apollo 15. Stretching out 1,123 km over the Moon's northwest quadrant, Imbrium was formed around 38 million years ago when a huge object impacted the lunar surface creating a gigantic basin. The basin itself is surrounded by three concentric rings of mountains. The most distant ring reaches a diameter of 1,300 km and involves the Montes Carpatus to the south, the Montes Apenninus southwest, and the Caucasus to the east. The central ring is formed by the Montes Alpes, and the innermost has long been lost except for a few low hills which still show their 600 km diameter pattern through the eons of lava flow. Originally, the impact basin was believed to be as much as 100 km deep. So devastating was the event that a Moon-wide series of fault lines appeared as the massive strike shattered the lunar lithosphere. Imbrium is also home to a huge mascon, and images of the far side show areas opposite the basin where seismic waves traveled through the interior and shaped its landscape. The floor of the basin rebounded from the cataclysm and filled in to a depth of around 12 km. Over time, lava flow and regolith added another 5 km of material, yet evidence remains of the ejecta which was flung more than 800 km away, carving long runnels through the landscape.

Now, Moon walk along the south shore of Mare Imbrium right where the Apennine mountain range meets the terminator (Fig. 9.3). At 58 km in diameter and 3,749 m deep, Eratosthenes is an unmistakable landmark.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
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Fig. 9.1 Eight day Moon – Peter Lloyd.

Fig. 9.2 Mare Imbrium – Greg Konkel.

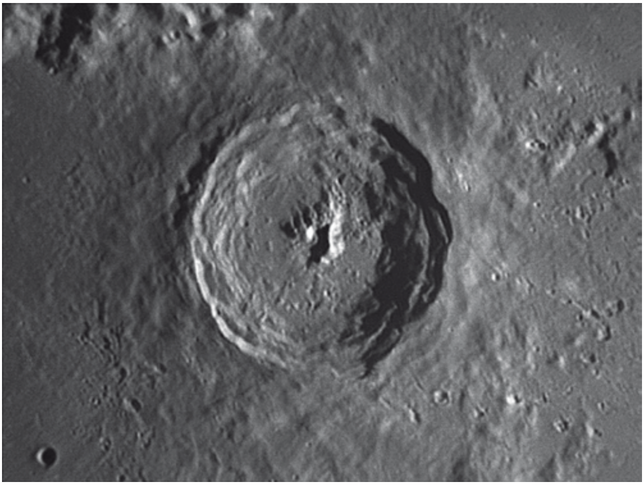


Fig. 9.3 Eratosthenes – Damian Peach.

Named after the ancient Greek mathematician, geographer and astronomer Eratosthenes, this splendid crater will display a bright west wall and a black interior hiding its massive crater capped central mountain – which is every bit as high as Muhabura in Uganda! Extending like a tail, an 80 km mountain ridge angles away to its southwest. As beautiful as Eratosthenes appears tonight, it will fade away to almost total obscurity as the Moon approaches Full. See if you can spot it again in 5 days.

Now let us dance (Fig. 9.4). If you thought Eratosthenes was it, power up and look again. Just at the end of that southwest trail of mountains are the ruins of crater Stadius, which is peppered with small meteor impacts. Do you remember Comet Shoemaker-Levy and Jupiter? Then look to Stadius' northwest where you will see a long line of impact craters that must have occurred at roughly the same time from a series of similar sized meteors. If you look east, you might spot the small impact of Bode. Go south of Stadius and trace the rilles through Mare Insularum to the blank, small ring of Gambart. Just northeast of this crater are two small punctures and the crash site of Surveyor 2.

Surveyor 2 was originally designed to land on the Moon and gather information to determine soil and terrain characteristics for the upcoming

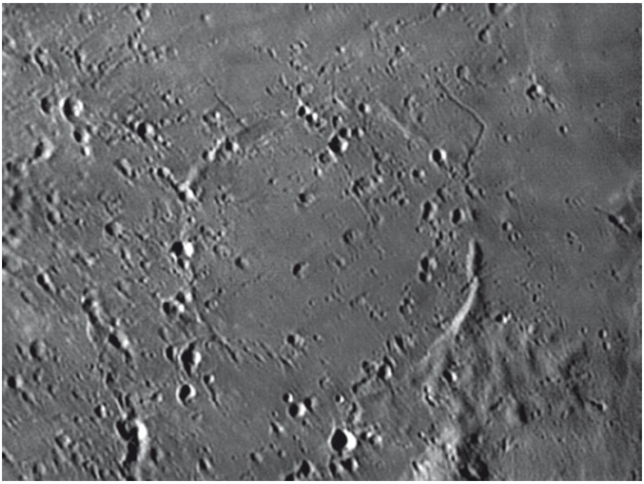


Fig. 9.4 Stadius – Damian Peach.

Apollo missions. Along with that, the mission was designed to test radar reflectivity, temperature, bearing strength and even spacecraft temperatures and how they would affect lunar soil samples. Unfortunately, when Surveyor 2 was only 130 km away from its target, one vernier engine failed to ignite and the planned course correction ended with the 292 kg craft smacking into the surface at 03:18 UTC, September 23, 1966. Another "hard landing"…

Now, let us Moon walk back to landmark crater Plato on the northern shore of Imbrium, where we will look for the disjointed line of (1) Montes Recta – the "Straight Range" (Fig. 9.5). Further east you will find the scattered peaks of (2) the Teneriffe Mountains. It is possible these are the remnants of much taller summits of a once stronger range, but only around 1,890 m of them still survive above the surface. To the southeast, (3) Mons Pico stands like a monument 2,400 m above the gray sands – a height which places it level with Kindersley Summit at Kootenay Park in British Columbia. Further southeast is the peak of (6) Mons Piton – also standing alone in the barren landscape of Imbrium. Perhaps once a member of the (5) Montes Alpes to the east, Piton still towers 2,450 m above the surface with a base 25 km in diameter still remaining in the lava flow. Yet look closely at the lunar Alpes,

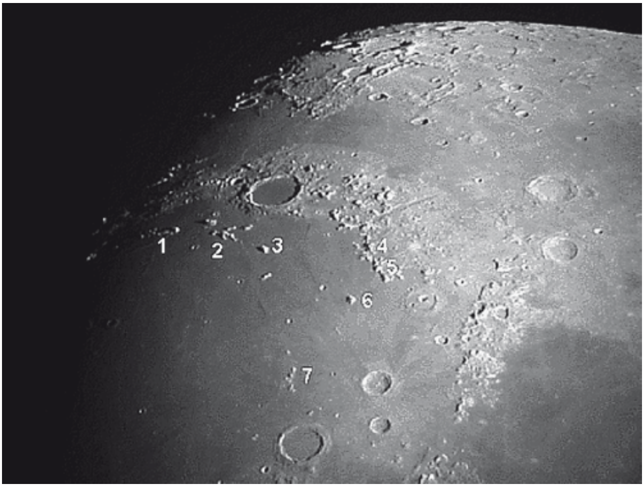


Fig. 9.5 Montes map – Greg Konkel.

for (4) Mons Blanc is 3,600 m high! Just north of shallow Archimedes stand (7) the Montes Spitzbergen whose remaining expanse trails away for 60 km on the southern edge of a rille which begins at the small punctuation of crater Kirch to the north. While they only extend 1,500 m above the surface, which is still comparable with the outer Himalayans!

If you are catching a very spectacular crater nearly central on the terminator and are ready to have a look, then let us wait no longer (Fig. 9.6). While Copernicus is not the oldest, deepest, largest, or brightest crater on the Moon, it certainly is one of the most detailed. Visible in binoculars and spectacular when magnified in a powerful telescope, this youthful crater gives a highly etched appearance. Its location in a fairly smooth plain near the center of the Moon's disk, and its prominent "splash" ray system, all combine to make Copernicus visually stunning in all optics. Spanning 100 km, with 23 km thick walls, the "Mighty One" is most definitely an impact crater that left its impression down to 3,840 m below the surface. Geologist Gene Shoemaker cited many features of Copernicus which mirror our own terrestrial impact features. Many of these Copernican features could have been caused by a large meteoritic body – a body about the size of Comet Halley's nucleus. No matter what optical aid you use, mid-placed Copernicus simply rocks!

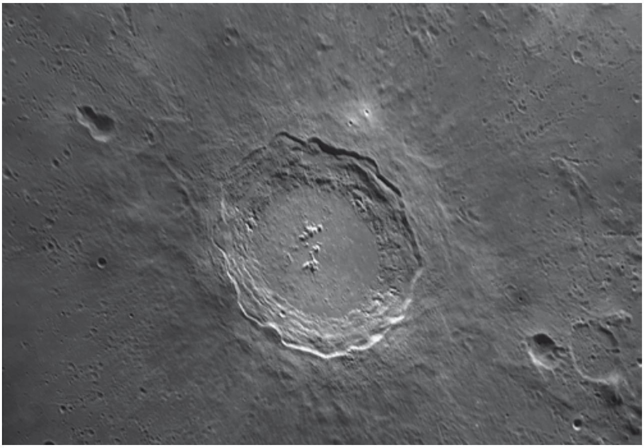


Fig. 9.6 Copernicus – Wes Higgins.

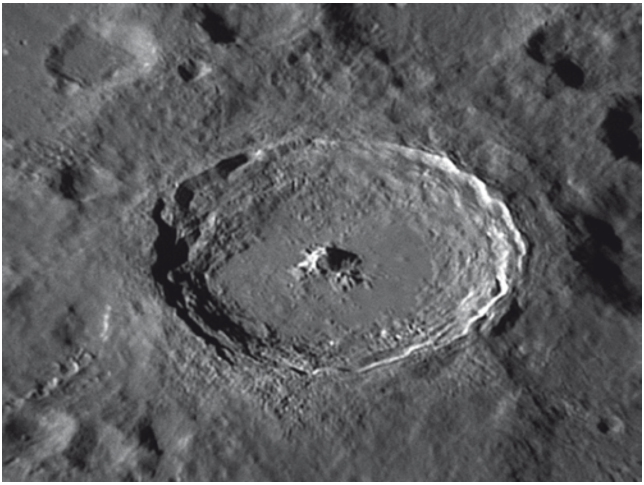


Fig. 9.7 Tycho – Damian Peach.

There is no ducking lunar impacts, though… and it is time to look at the grandest impact of all, Class I crater Tycho (Fig. 9.7). Spanning 90 km wide and descending 4,206 m below lunar surface, Tycho's massive walls are 21 km thick. As one of the youngest craters, Tycho might not look like

much tonight, but it is surely one of the most impressive of all features when the Moon reaches Full. Look around Tycho for six small craters encircling it like an old analog telephone dial. To the southeast, another prominent feature calls attention to itself – Maginus. Power up and look closely at the more than 50 meteoritic impacts that have all but destroyed it. The very largest of the wall craters is on the southwest crest and is named Maginus C. On the outer north wall, look for less conspicuous Proctor. It, too, has been struck many times!

Now, let us do a little "mountain climbing!" Using Copernicus as our guide, to the north and northwest of this ancient crater lie the Carpathian Mountains ringing the southern edge of Mare Imbrium. As you can see, they begin well east of the terminator, but look into the shadow. Extending some 40 km beyond the line of daylight, you will continue to see bright peaks – some of which reach a height of 2,072 m – comparable to a great portion of the Earthly Pyrenees. When the area is fully revealed tomorrow, you will see the Carpathian Mountains disappear into the lava flow that once formed them.

Many lunar features can be spotted in binoculars and are very easy with a telescope at mid-range magnifications. If you are lost, use this photo to help you identify: (1) Eudoxus, (2) Aristotle, (3) Caucasus Mountains, (4) Lunar Alps, (5) Valles Alpes, (6) Aristillus, (7) Autolycus, (8) Archimedes, (9) Mons Piton, (10) Mons Pico, (11) Straight Range, (12) Plato, (13) Mare Frigoris, (14) W. Bond, (15) Barrow, (16) Meton, (17) Cassini, (18) Alexander, (19) Montes Spitzbergen, (20) Mons Blanc (Fig. 9.8).

Let us try looking just south of Sinus Medii and identifying these features: (1) Flammarion, (2) Herschel, (3) Ptolemaeus, (4) Alphonsus, (5) Davy, (6) Alpetragius, (7) Arzachel, (8) Thebit, (9) Purbach, (10) Lacaille, (11) Blanchinus, (12) Delaunay, (13) Faye, (14) Donati, (15) Airy, (16) Argelander, (17) Vogel, (18) Parrot, (19) Klein, (20) Albategnius, (21) Muller, (22) Halley, (23) Horrocks, (24) Hipparchus, (25) Sinus Medii (Fig. 9.9).

It is time to Moon walk south in hopes of catching a very unusual event (Fig. 9.10). On the southern edge of Mare Nubium is the old walled plain Pitatus. Power up. On the western edge you will see smaller and equally old Hesiodus. Almost central along their shared wall there is a break to watch for when the terminator is close. Upon occasion, sunrise on the Moon will

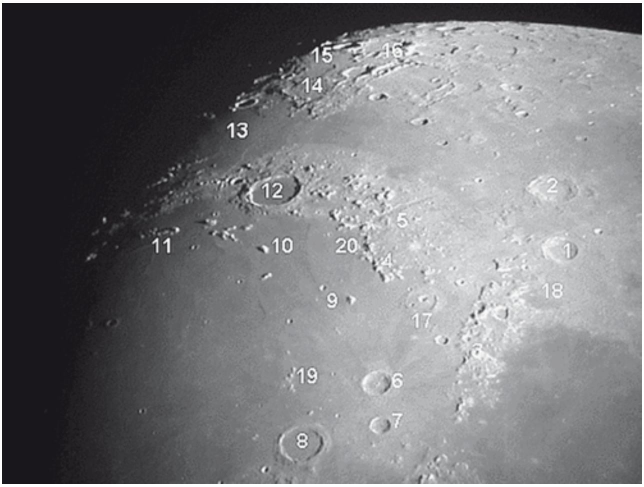


Fig. 9.8 Lunar north photographic map – Greg Konkel.

Fig. 9.9 Lunar highlands photographic map – Greg Konkel.

Fig. 9.10 Hesiodus and Rima – Wes Higgins.

pass through this break creating a beam of light across the crater floor in a beautiful phenomenon known as the "Hesiodus Sunrise Ray." For a very brief moment, a shaft of sunlight will shine through this break and create an experience you will never forget. If the terminator has moved beyond it at your observing time, then look to the south for small Hesiodus A. This is an example of an extremely rare double concentric crater. This formation is caused by one impact followed by another, slightly smaller impact, at exactly the same location.

Although you cannot help but be drawn visually to this next crater, let us start at the southern limb near the terminator and work our way up one last time for the mighty Clavius (Fig. 9.11). As a huge mountain-walled plain, Clavius is rivaled only in sheer size by similarly structured Deslandres and Baily. Rising 1,646 m above the surface, the interior wall slopes gently downward for a distance of almost 24 km and a span of 225 km. Its crater-strewn walls are over 56 km thick. Your first sighting will be the large and shallow dual rings of Casatus with its central crater and Klaproth adjoining it. Further north is Blancanus with its series of very small interior craters, but

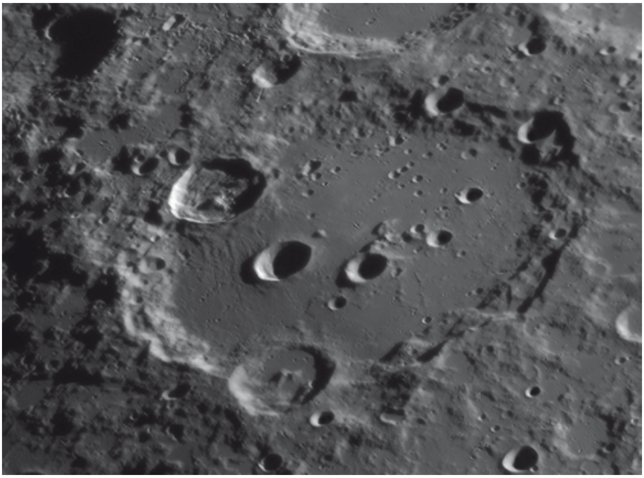


Fig. 9.11 Clavius – Wes Higgins.

wait until you see them all at high magnification when seeing conditions are steady! Caught on the southeast wall is Rutherford with its central peak and crater Porter on the northeast wall. Look between them for the deep depression labeled D. West of D you will also see three outstanding impacts: C, N, and J; while CB resides between D and Porter. The southern and southwest walls are also home to many impact craters, and look carefully at the floor for many, many more. It has been often used as a test of a telescope's resolving power to see just how many more craters you can find inside tremendous old Clavius. Power up and enjoy!

CHAPTER 10

LUNAR DAY NINE

The Moon has a face like the clock in the hall;
She shines on thieves on the garden wall,
On streets and fields and harbour quays,
And birdies asleep in the forks of the trees
The squalling cat and the squeaking mouse,
The howling dog by the door of the house,
The bat that lies in bed at noon,
All love to be out by the light of the Moon.

Robert Louis Stevenson

We start tonight's Moon walk with landmark crater Plato – considered by some observers as the darkest single low-albedo feature on the Moon (Fig. 10.1). Because of its low reflectivity, this crater has the distinction of being one of the only mountain-walled plains that do not "disappear" as the Moon grows full. With Plato in the center of the field note the pyramid-like peak of 2,400 m high Mons Pico due south in northeastern Mare Imbrium. East of Pico is an unnamed dorsum – or lava wave – terminating just above crater Piazzi Smyth to the south. Power up in a telescope and check out the triangular peak near its end.

Now let us go to the lunar surface to have a look through binoculars or telescopes at tremendous impact region located to the lunar west of Plato (Fig. 10.2). Sinus Iridum is one of the most fascinating and calming areas on the Moon. At around 241 km in diameter and ringed by the Jura Mountains, it is known by the quiet name of the "Bay of Rainbows," but was formed by a cataclysm. Astronomers speculate that a minor planet around 200 km in diameter impacted our forming Moon at a glancing angle, and the result of the impact caused "waves" of material to wash up to a "shoreline," forming this delightful C-shaped lunar feature. The impression of looking at an Earthly bay is stunning as the smooth inner sands show soft waves called "rilles," broken only by a few small impact craters. The picture is completed by Promontoriums Heraclides and LaPlace, which tower above the surface, at 1,800 m and 3,000 m, respectively, and appear as distant "lighthouses"

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_10,

Fig. 10.1 Nine day Moon – Peter Lloyd.

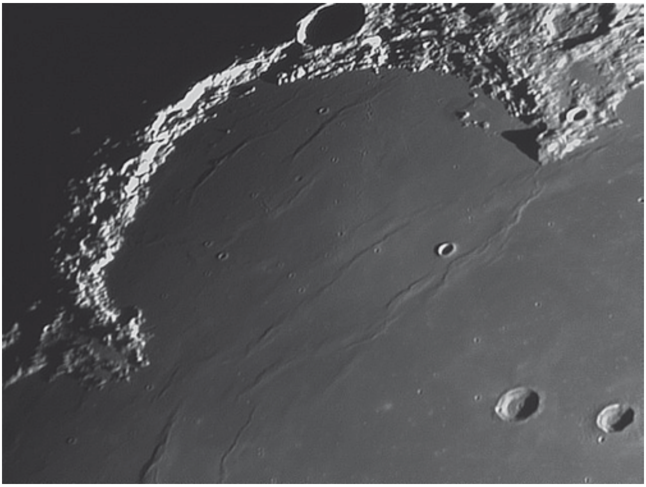


Fig. 10.2 Sinus Iridum – Eric Roel (LPOD).

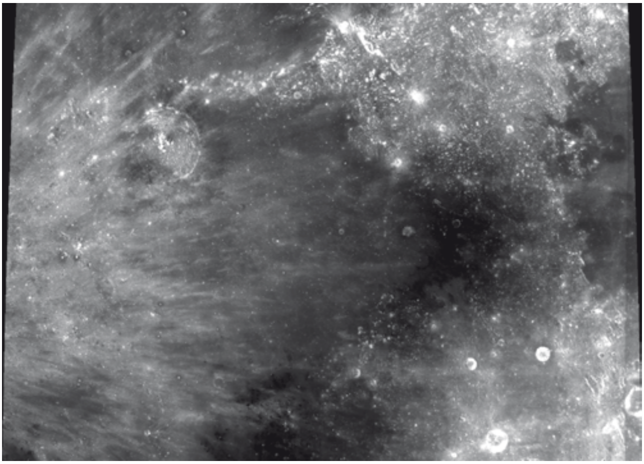


Fig. 10.3 Sinus Aestuum – Clementine.

set on either tip of Sinus Iridum's opening. For a great telescopic challenge, imagine that Sinus Iridum is a mirror focusing light – this will lead your eye to crater Helicon. The slightly smaller crater southeast of Helicon is Leverrier. Be sure to power up to capture the splendid north-south oriented "wave-like" ridge that flows lunar east. Enjoy this serene feature…

Mare Insularum, the "Sea of Islands," will be partially revealed tonight as one of the most prominent of lunar craters – Copernicus – guides the way to the region (Fig. 10.3). While only a small section of this reasonably young mare is now visible southwest of Copernicus, the lighting will be just right to spot its many different colored lava flows. To the northeast is a lunar challenge: Sinus Aestuum – the "Bay of Billows." This mare-like region has an approximate diameter of 290 km, and its total area is about the size of the state of New Hampshire. Containing almost no features, this area is low albedo and provides very little surface reflectivity. Can you see any of Copernicus' splash rays beginning to appear across it yet?

Let us take a look and see; we can identify (1) Mons Wolf, (2) Eratosthenes, (3) Gay-Lussac, (4) Montes Carpatus, (5) Copernicus, (6) Reinhold, (7) Mare Insularum, (8) Gambart, (9) Apollo 14 landing site, (10) Frau Mauro, (11) Bonpland, (12) Parry, (13) Lalande, (14) Ptolemaeus, (15) Herschel, (16) Flammarion, (17) Mosting, (18) Sinus Medii, (19) Triesnecker, (20) Murchison, (21) Pallas, (22) Bode, (23) Ukert, (24) Sinus Aestuum, (25) Stadius.

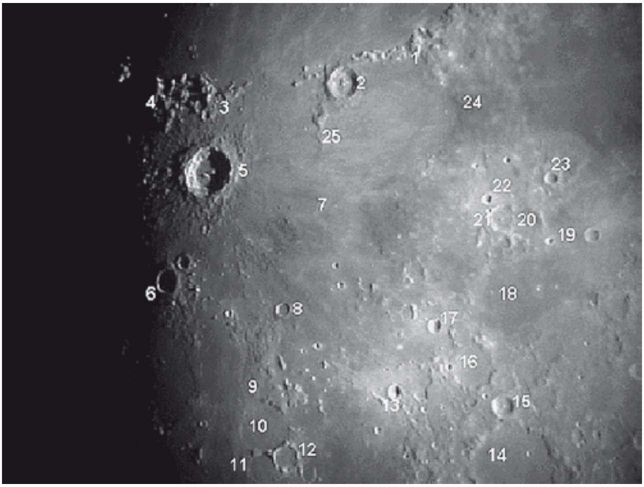


Fig. 10.4 **Lunar photographic map – Greg Konkel.**

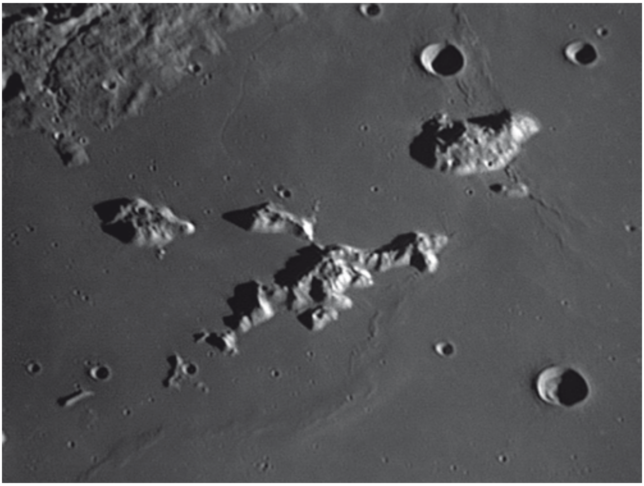


Fig. 10.5 Montes Teneriffe – Damian Peach.

Use landmark crater Copernicus as a guide and look north-northwest to survey the Carpathian Mountains (Figs. 10.4 and 10.5). The Carpathians ring the southern edge of Mare Imbrium beginning well east of the terminator.

But let us look on the dark side. Extending some 40 km beyond into the Moon's own shadow, you can continue to see bright peaks – some reaching 2,000 m high! Tomorrow, when this area is fully revealed, you will see the Carpathians begin to disappear into the lava flow forming them. Continuing northward to Plato – on the northern shore of Mare Imbrium – reidentify the singular peak of Pico. Between Plato and Mons Pico you will find the many scattered peaks of the Teneriffe Mountains. It is possible that these are the remnants of much taller summits of a once precipitous range. Now the peaks rise less than 2,000 m above the surface.

Time to power up! (Fig. 10.6). West of the Teneriffes, and very near the terminator, you will see a narrow line of mountains, very similar in size to the Alpine Valley. This is known as the Straight Range or the Montes Recti. To binoculars or small scopes at low power, this isolated strip of mountains will appear as a white line drawn across the gray mare. It is believed this feature may be all that is left of a crater wall from the Imbrium impact. It runs for a distance of around 90 km and is approximately 15 km wide. Some of its peaks reach as high as 2,072 m! Although this does not sound particularly impressive, that is over twice as tall as the Vosges Mountains in west-central Europe and on the average very comparable to the Appalachian Mountains in the eastern USA.

Fig. 10.6 Montes Recti – Damian Peach.

While you are there, take another look at landmark crater Eratosthenes. Just slightly north of lunar center, this easily spotted feature dangles at the end of the Apennine Mountain range like a yo-yo caught on a string. Its rugged walls and central peaks make for excellent viewing in any lighting condition. If you look closely at the mountains northeast of Eratosthenes, you will see the high peak of Mons Wolff. Named for the Dutch philosopher and mathematician, this outstanding feature reaches 35 km in height.

Return to our landmark Copernicus and travel south along the western shore of Mare Cognitum, the "Sea That Has Become Known" and look along the terminator for the Montes Riphaeus – "The Mountains in the Middle of Nowhere" (Fig. 10.7). But are they really mountains? Let us take a closer look. At the widest, this unusual range spans about 38 km and runs for a distance of around 177 km. Less impressive than most lunar mountain ranges, some peaks reach up to 1,250 m high, making these summits about the same height as our volcano Mount Kilauea. While we are considering volcanic activity, consider that these peaks are all that is left of Mare Cognitum's walls after lava filled it in. At one time this may have been amongst the tallest of lunar features!

Fig. 10.7 Montes Riphaeus – Greg Konkel.

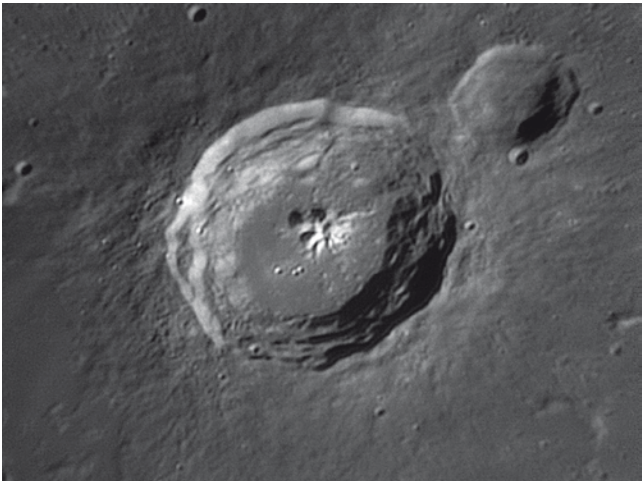


Fig. 10.8 Bullialdus – Damian Peach.

Once you have studied the Montes Riphaeus, you will begin noticing another lunar crater that looks a whole lot like a smaller version of Copernicus – the highly underrated crater Bullialdus (Fig. 10.8). Located close to the center of Mare Nubium, even binoculars can make out Bullialdus when it is near the terminator. If you are telescoping – power up – this one is fun! Very similar to Copernicus, Bullialdus has thick, terraced walls and a central peak. It is a very young crater, perhaps only slightly over a billion years old and formed during the Eratosthenian period. Measuring about 60 km in diameter, you will see its slopes are very steep, indicating an impact and supported by a smashing ray system of ejecta. Can you identify Bullialdus L to the west, Bullialdus E to the southwest, and craters Bullialdus A and B to the south? Look at how the surface of the floor changes between them and how the mountains and summits change as well.

If you examine the area around Bullialdus carefully, you can note that it is a much newer crater than shallow Lubiniezsky to the north, interesting little Koenig to the southwest, and almost nonexistent Kies (a real challenge) to the south (Fig. 10.9). Kies is very important because it is also home to several lava domes. The largest is known as Kies Pi. Both of these are challenge features that you will find on many lunar observing lists.

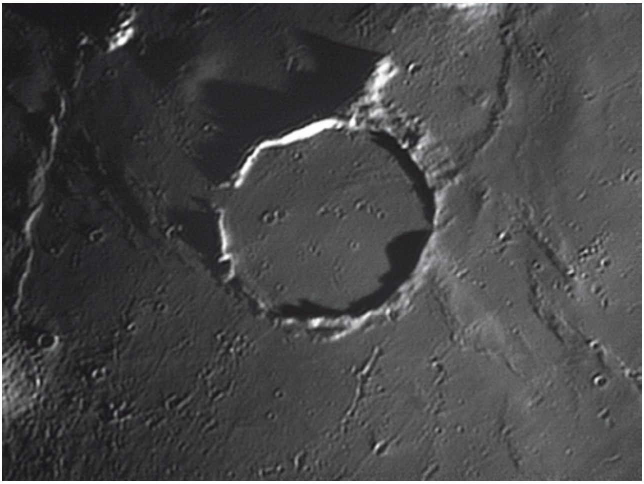


Fig. 10.9 Kies – Damian Peach.

Fig. 10.10 Mercator and Campanus – Damian Peach.

If the terminator has progressed enough at your viewing time, take a challenge and look southwest of striking crater Bullialdus for a pair of similar sized craters on the shore of Mare Nubium – Mercator to the southeast and Campanus to the northwest (Fig. 10.10). Just to their south

Fig. 10.11 Wurzelbauer – Damian Peach.

you will see a triangular dark area that looks like it might be part of Mare Nubium, yet has a few bright points of its own. This is Palus Epidemiarum, a very small plain. Look for the oval of crater Capuanus trapped on its southern edge.

Moon walk further south and slightly east to locate the gray ring Pitatus on the south shore of Mare Nubium and note how the view has changed in just 24 h (Fig. 10.11). Now barely visible, you can see where this once grand crater's walls vary greatly in height. To Pitatus' south are two twin mountain-walled plains. Let us start by looking at Wurzelbauer to the west. Only when it is near the terminator can you truly see where time has distorted and warped this once grand crater. Its slightly younger neighbor – Gauricus, to the east – will show many marks in its walls from smaller meteor strikes at high power.

Can you see two larger craters to the southwest? (Fig. 10.12). The northernmost is Wilhelm, but set your sights toward the southern – Longomontanus. Named for Danish astronomer and assistant to Tycho Brahe, Christian S. Longomontanus, this splendid mountain-walled plain measures about 150 km in diameter, shows a broken border on its north and an off-center mountain peak. Notice how its smooth sands have eroded its edges over time.

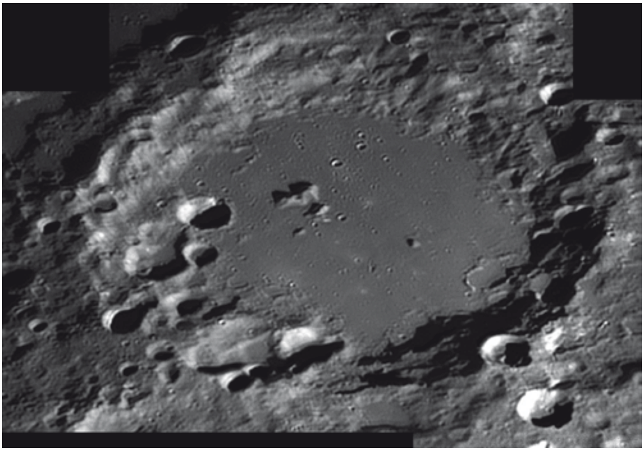


Fig. 10.12 Longomontanus – Damian Peach.

Just outside its eastern wall, look for the remains of a much older crater destroyed when Longomontanus formed. Just to its north are the remains of Montanari and the double strike of crater Brown to the northeast. This splendid binocular and small telescope trophy are often overlooked in favor of its grander neighbors. What a terrific job you have done through Lunar Day Nine!

CHAPTER 11

LUNAR DAY TEN

It was a July midnight; and from out
A full-orbed Moon, that like thine own soul soaring,
Sought a precipitate pathway up through heaven,
There fell a silvery silken veil of light,
With quietude, and sultriness and slumber,
Upon the upturn'd faces of a thousand
Roses that grew in an enchanted garden,
Where no wind dared to stir, unless on tiptoe…

Edgar Allen Poe

Tonight we will begin our Moon walk in the lunar north as we explore another challenging region – Sinus Roris (Fig. 11.1). "The Bay of Dew" is actually a northern extension of the vast region of the Oceanus Procellarum. Covering about 202 km, many lunar maps are not quite true to Sinus Roris' dimensions. Its borders are not exactly clear given the curvature on which we see this feature, but we do know that the eastern edges join Mare Frigoris. This area is much lighter than most features of this type. If you seek answers, then look further north as Roris' high albedo can be attributed to the ejecta from many nearby impacts. It also holds a fanciful place in history, as seen in this excerpt from the science fiction story "Man on the Moon" by Wernher van Braun:

> We can't land where the surface is too rugged, because we need a flat place to set down. Yet the site can't be too flat, either-grain-sized meteors constantly bombard the moon at speeds of several miles a second; we'll have to set up camp in a crevice where we have protection from these bullets. There's one section of the moon that meets all our requirements, and unless something better turns up on closer inspection, that's where we'll land. It's an area called Sinus Roris, or "Dewy Bay," on the northern branch of a plain known as Oceanus Procellarum, or "Stormy Ocean" (so called by early astronomers who thought the moon's plains were great seas). Dr. Fred L. Whipple, chairman of Harvard University's astronomy department, says Sinus Roris is ideal for our purpose – about 1,000 km from the lunar north pole, where the daytime temperature averages a reasonably pleasant 40° and the terrain is flat enough to land on, yet irregular enough to hide in.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_11,

Fig. 11.1 Ten day Moon – Peter Lloyd.

As you stand here on Earth and look for Sinus Roris, do not forget to use your imagination as well (Fig. 11.2). Tonight is a great time to blur your science eyes just a little bit and see if you can spot the combination of light and dark areas, which make the lunar globe look like face…, and behold the "Man In the Moon"!

Now, let us take a real look at where real men have been to the Moon (Fig. 11.3). It is time to investigate Mare Cognitum, "The Sea That Has Become Known." Look for Mare Cognitum south of our landmark crater Copernicus and conjoining the southern shore of Oceanus Procellarum. Also formed by an impact, the remains of the basin ring still exist as the bright semicircle of the Montes Riphaeus, which borders it to the northwest. The very small, bright point of the high albedo crater Euclides will help to guide you along to the right area. Just to its east is the shallow ring Fra Mauro formation, the landing area for Apollo 14. Let us talk about why exploration in this area was so important.

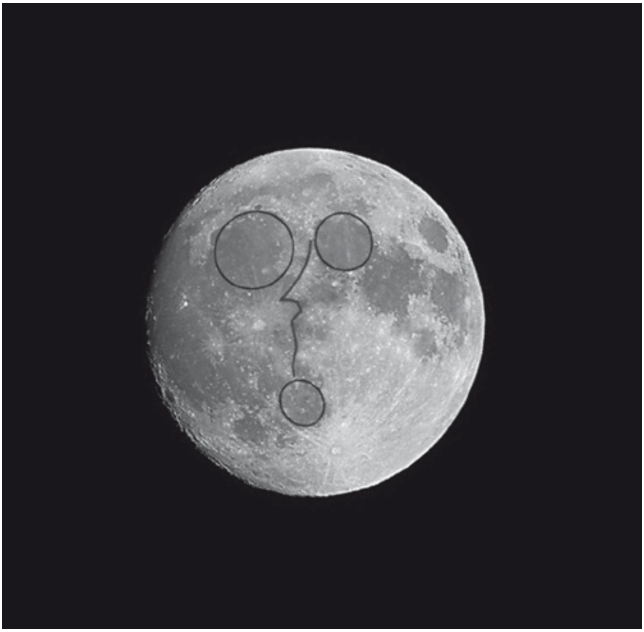


Fig. 11.2 The man in the Moon.

Named for the 80 km diameter Fra Mauro crater, these highlands are hills believed to be the ejecta from the impact that formed Mare Imbrium (Fig. 11.4). This debris may have come from as deep as 161 km below the surface, and so studying this area would help us understand the physical and chemical nature of the area below the lunar crust. The Fra Mauro formation became more interesting to scientists when the Apollo 12 seismometer at Surveyor Crater (177 km to the west) relayed to Earth signals of monthly Moonquakes. These phenomena were believed to have originated in the Fra Mauro crater as the Moon passed through its perigee.

Less than half a century ago, the Apollo 13 crew was on a mission to land in the Fra Mauro highlands (Fig. 11.5). Although a near-disaster kept the crew from completing the mission, Apollo 14 carried out the plan less than a year later. Apollo 14 landed in the hills at the edge of the crater Fra Mauro near a newer impact region called Cone Crater – around 305 m across and

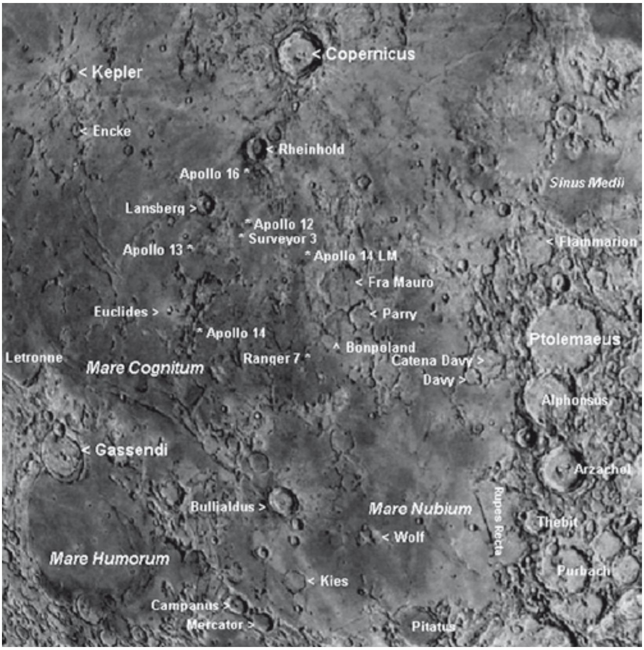


Fig. 11.3 Virtual Moon atlas.

76 m deep. Astronauts Shepard and Mitchell took samples from the crater's outer walls and photographed the interior. Tonight we will be able to see this landing area on the lunar surface. Along the terminator to the south, you will see a dark expanse known as Mare Nubium. On its northern shore and near the terminator's center, you will see an inlet of small shallow craters. The brightest of these small rings is crater Parry with Fra Mauro appearing larger and shallower to its north. Power up in your telescope! Fra Mauro has a long fissure running between its north and south borders. At the northern crater edge you will see the ruins of an ancient impact. Appearing as an X, it definitely marks the spot of the successful Apollo 14 lunar landing.

Now, let us Moon walk west for a look into Mare Humorum – the "Sea of Moisture" – an area about the size of the state of Arkansas. It is believed that a planetoid collision originally formed Mare Humorum. The incredible impact

Fig. 11.4 Fra Mauro – Damian Peach.

crushed the surface layers of the Moon resulting in a concentric "anticline" that can be traced out to twice the size of the original impact area. The floor of this huge crater then filled in with lava and was once thought to have a greenish appearance, but in recent years it has more accurately been described as reddish. That is one mighty big crater – no matter what color it is!

Humorum is home to one of the most graceful and recognizable landmark craters of all – Gassendi (Fig. 11.6). Sitting proudly on the northern shore, Gassendi sports a bright ring and a complex central mountain peak that is well within the range of binoculars. At around 110 km in diameter and 2,010 m deep, this ancient lunar denizen contains a triple mountain peak in its center and is known as one of the most "perfect circles" on the Moon. Telescopic viewers will appreciate Gassendi at high power in order to see

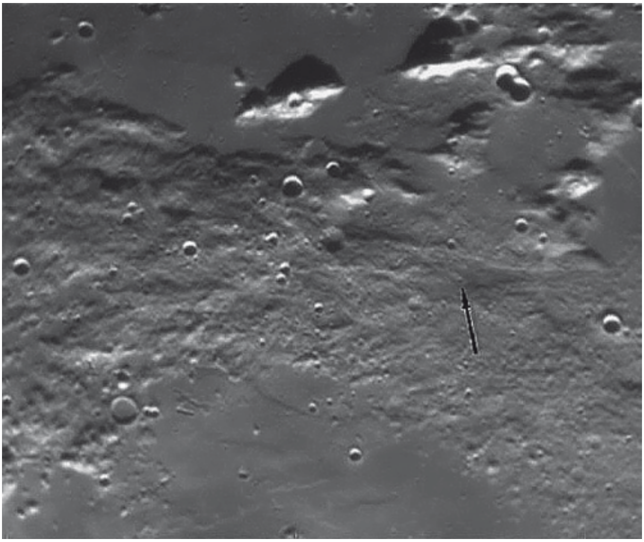


Fig. 11.5 Apollo 14 landing site – Wes Higgins.

how its southern crater edge has been eroded by lava flow. Also of note are the many rilles and ridges that exist inside the crater and the presence of the younger Gassendi A on the north wall.

Let Gassendi be your guide as you Moon walk north to examine the ruins of the crater Letronne (Fig. 11.7). Sitting on a broad peninsula on the south edge of Oceanus Procellarum, this class V crater once spanned 118 km. Thanks to the lava flows that formed Procellarum; virtually the entire northern third of the crater was submerged, leaving the remaining scant walls to rise no more than a 1,000 m above the surface. While this might seem shallow, it is as high as El Capitan in Yosemite.

It is time to head deeper toward the lunar south below Humorum as we take a close look at the dark, heart-shaped region Palus Epidemiarum – the "Marsh of Epidemics" (Fig. 11.8). Caught on its southern edge is the largely eroded Campanus with well-defined Cichus to the east and Ramsden to the west. Power up in your telescope and look carefully at its smooth floors. If conditions are favorable, you will catch Rima Hesiodus cutting across its northern boundary and the crisscross pattern of Rima Ramsden in

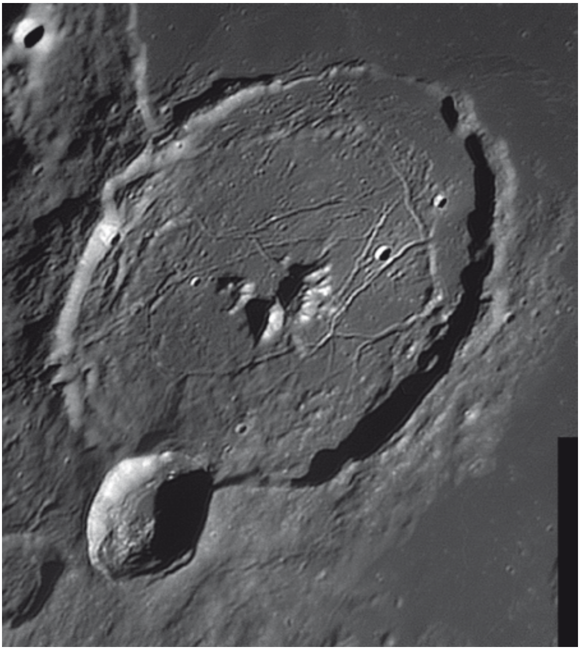


Fig. 11.6 Gassendi – Damian Peach.

the western lobe. Can you make out a tiny, deep puncture mark to the northeast? It might be small, but it has a name – Marth.

Stand down for a while now. Let your eyes relax from looking at the bright lunar surface. When you are ready, it is time to return again and we will set sail on the Oceanus Procellarum… the "Ocean of Storms" (Fig. 11.9).

Encompassing most of the northwest quadrant and stretching across 2,102,000 km^2 of area, it rivals the Bering Sea in sheer size. No wonder it was considered an ocean! Created by lava floods, but never contained within an impact basin, it is similar to Earth's Siberian Traps – great upwellings of lava from our shared primeval history. Formed in the Imbrian geological period, it could be anywhere from three billion to four billion years old. Oceanus Procellarum's name could refer to its vivid volcanic past, but there is a story behind the name "Ocean des Temp Utes"… It originated

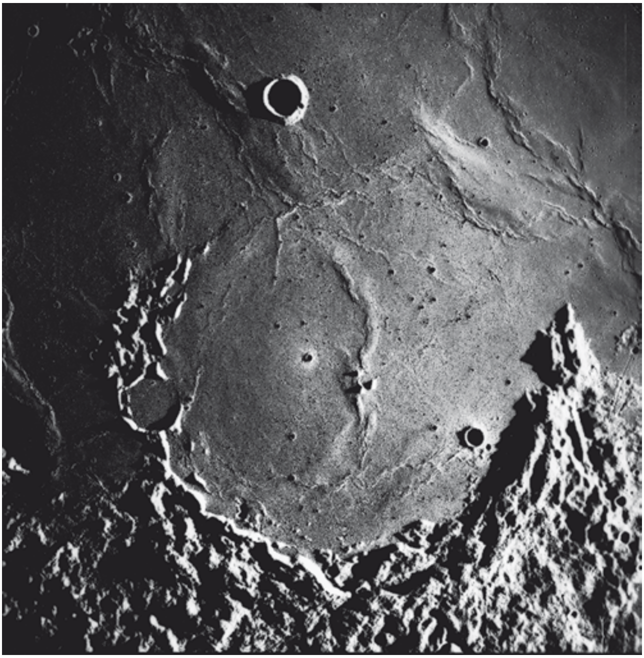


Fig. 11.7 Letronne – Apollo 16 (NASA).

from a myth claiming stormy weather ahead if it was visible during the second quarter. While the Moon does not play a role in our Earthly weather, what could cause such a myth to arise? Factually, if skies are clear enough to see the Ocean of Storms during the night, they will allow heat to escape directly into our upper atmosphere. Rising air can cause clouds to form. Water vapor molecules cool and begin coalescing faster than they can be scattered by thermal energy, condensing and forming clouds where only one of two things can happen. Water molecules will either evaporate, changing back into vapor, or join to grow liquid drops whose critical mass will fall back to Earth as either rain or snow. Tempestuous weather? Perhaps…

When you leave from the landmark port of Gassendi, head north to small crater Gassendi B. As you move across the gray sands, look for a serene wave following the southwestern shore. This is Dorsum Ewing, and you

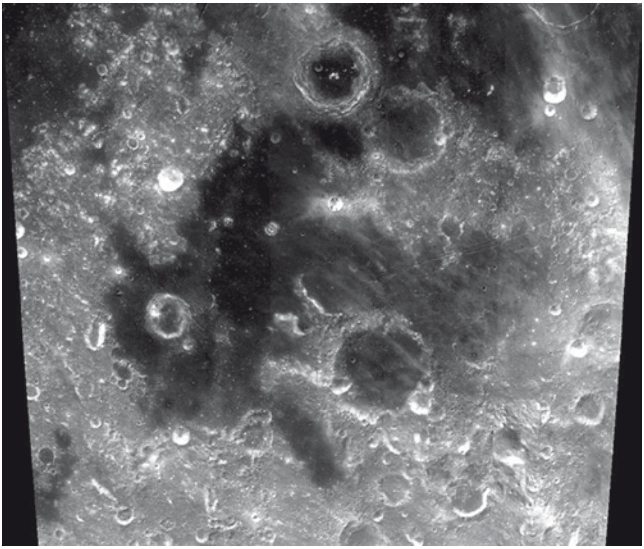


Fig. 11.8 Palus Epidemiarum – Clementine.

will see it trail south into the pockmark of Herigonius east of Gassendi B. East of Herigonius are two additional craters – the northernmost is Norman. Return again to Dorsum Ewing and follow it north where it leads to some low hills and the tiny crater Scheele and more prominent Wichmann even further north. If you look closely at Wichmann you will see it as a small impact on what appears to be the remains of a long-ago flooded, now terribly eroded crater that has no name. Travel northward along the wave of the Dorsa Euclides until you reach the small well of crater of Euler, and just ahead you will see our next port – Kepler. This great landmark crater named for Johannes Kepler spans only 32 km, but drops to a deep 2,750 m below the surface. It is a class I crater that is a geological hotspot! (Fig. 11.10).

As the very first lunar crater to be mapped by the US Geological Survey, the area around Kepler contains many smooth lava domes reaching no more than 30 m above the plains. The crater rim is very bright, consisting mostly of a pale rock called anorthosite. The "lines" extending from Kepler are fragments that were splashed out and flung across the lunar surface when the impact occurred. According to records, in 1963 a glowing red area was

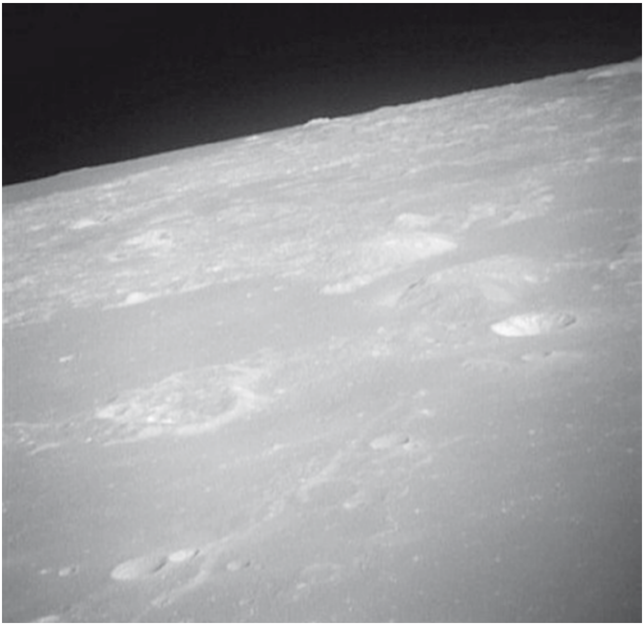


Fig. 11.9 Flying over Oceanus Procellarum – Apollo 15 (NASA).

Fig. 11.10 Kepler – Damian Peach.

spotted near Kepler and extensively photographed. Normally one of the brightest regions of the Moon, the brightness value at the time nearly doubled! Although it was rather exciting, scientists later determined that the phenomenon was caused by high-energy particles from a solar flare reflecting from Kepler's high albedo surface – a sharp contrast from the dark mare composed primarily of dark minerals of low reflectivity (albedo) such as iron and magnesium. The region is also home to features known as "domes" – similar to Earth's shield volcanoes – seen between the crater and the Carpathian Mountains. In the days ahead all details around Kepler will be lost, so take this opportunity to have a good look at one awesome small crater.

When you are ready to sail again, we will cross the western edge of the second largest lunar sea – Mare Imbrium – the "Sea of Rains." As we head northeast we stop to reinforce the landmark of Sinus Iridum and its features. At the eastern opening is Promentorium LaPlace. Little more than 56 km in diameter, it rises above the gray sands some 3,019 m, almost identical in height to Buttermilk Mountain near Aspen. Promontorium Heraclides to the west covers roughly the same area, yet rises to little more than half of LaPlace's height.

Sail around the interior shoreline of the "Bay of Rainbows" and take another look at the Juras Mountains in a higher light. Extending some 422 km around and reaching up to 6,000 m in height, these many peaks are essentially the north wall of the Iridum basin. Does their name sound familiar? It should, because like many lunar features, it has an Earthly counterpart – the Jura Mountains in Switzerland. While the elevations are not quite the same, the formations are rather similar, with both having high vertical walls while decreasing in size laterally. Can you see sunrise lighting certain peaks more brightly than others? Can you spot crater Bianchinni in the center? Or the beginnings of crater Sharp to the northwest?

While we are at Sinus Iridum, we will sail across western expanse of the "Cold Sea," Mare Frigoris, and northeast of the punctuation of Harpalus for a grand old crater – J. Herschel (Fig. 11.11). Although it looks small because it is seen on the curve, this wonderful old-walled plain named for the great observer John Herschel contains some very tiny details. Its southeastern rim forms the edge of Mare Frigoris, and the small (26 km wide) Horrebow dots its southwest edge. The crater walls are so eroded with time that not

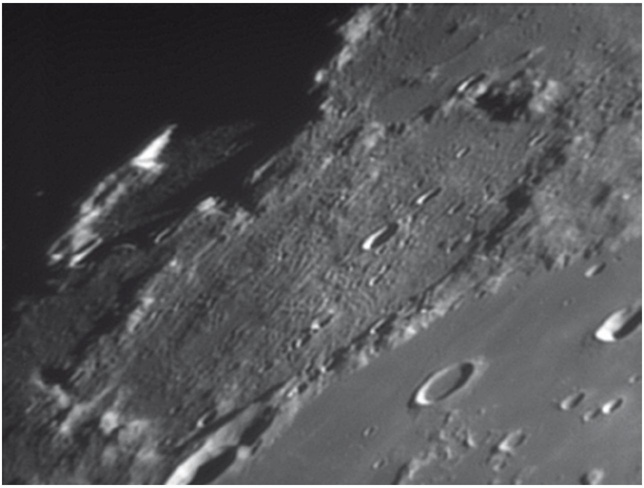


Fig. 11.11 J. Herschel – Damian Peach.

much remains of the original structure. Look for many very small telescopic impact craters that pepper J. Herschel's uneven basin and exterior edges. Power up! If you can spot the small central crater C, you are resolving a feature only 12 km wide from some 385,000 km away! Formed in the Pre-Nectarian period, this walled plain could be as much as four billion years old… Congratulations on a fine job with Lunar Day Ten!

CHAPTER 12

LUNAR DAY ELEVEN

> *The night walked down the sky with the Moon in her hand.*
>
> Frederick L. Knowles

We start our observing evening on the beautiful Moon as we return to landmark crater Gassendi standing at the north edge of Mare Humorum (Figs. 12.1 and 12.2). Closely examine the northwestern rim of the mare for crater Mersenius. It is a typical Nectarian geological formation, spanning

Fig. 12.1 Eleven day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_12,

Fig. 12.2 Mersenius – Damian Peach.

approximately 83 km in diameter in all directions. Power up in a telescope to look for fine features such as steep slopes supporting newer impact crater Mersenius P and tiny interior craterlet chains. Can you spot white formations and crevices along its terraced walls? How about Rimae Mersenius? Further south you will spy tiny Liebig helping to support Mersenius D's older structure, along with its own small set of mountains known as the Rupes Liebig. Continue to follow the edge of Mare Humorum around the wall known as Rimae Doppelmayer until you reach the shallow old crater Doppelmayer. As you can see, the whole floor fractured crater has been filled with lava flow from Mare Humorum's formation, pointing to an age older than Humorum itself. Look for a shallow mountain peak in its center – there is a very good chance that this peak is actually higher than the crater walls. Did this crater begin to upwell as it filled? Or did it experience some volcanic activity of its own? Take a closer look at the floor if the lighting is right to spy a small lava dome and evidence of dark pyroclastic deposits – it is a testament to what once was!

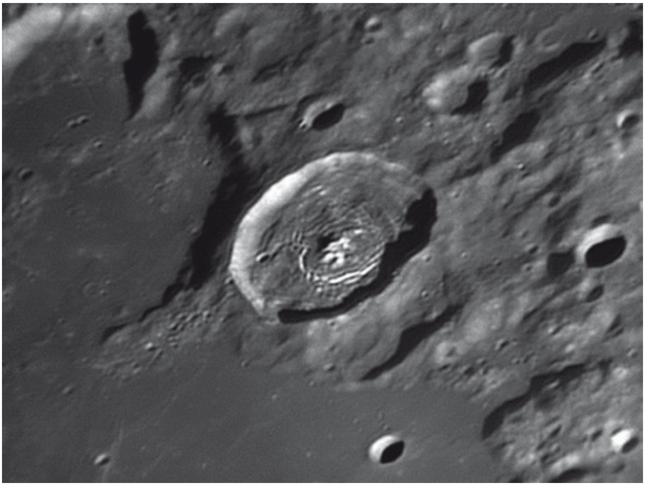


Fig. 12.3 Vitello – Damian Peach.

Continue along the southern shore of Mare Humorum and identify ancient crater Vitello (Fig. 12.3). Notice how this delicate ring resembles earlier study Gassendi on the opposite shore. Its slopes have been crushed by the impact that formed crater Lee to its west. As you begin to circle around Mare Humorum and start northward again, you will be traveling along the Rupes Kelvin – ending in the spearhead formation of Promentorium Kelvin. Here again is another extremely old feature, a triangular mountainous cape born in the Pre-Imbrian period and as much as four billion years old. It could be as long as 66 km and about as wide as 34 km, but its height is impossible to judge.

Take a breath now, and we will look for two more dark patches to guide us on (Fig. 12.4). South of Mare Humorum is darker Paulus Epidemiarum eastward and paler Lacus Excellentiae westward. To their south you will see a complex cojoined series of craters we will take a closer look at – Hainzel and Mee. Hainzel was named for Tycho Brahe's assistant and measures about 70 km in length and sports several various interior wall structures. Power up in a telescope and look. Hainzel's once high walls were obliterated on the north-east by the strike that caused Hainzel C and to the north by the impact that caused the formation of Hainzel A. To its basic south is eroded Mee – named for a Scottish astronomer. While Crater Mee does not appear to be much more than simple scenery, it spans 172 km and is far

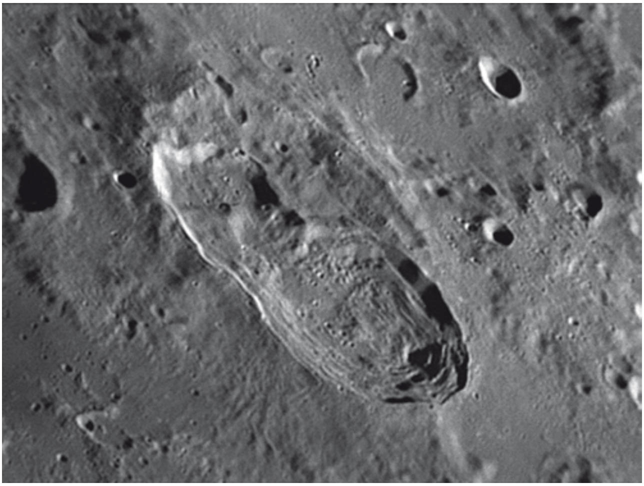


Fig. 12.4 Hainzel – Damian Peach.

older than Hainzel. While you can spot it easily in binoculars, close telescopic inspection shows how the crater is completely deformed by Hainzel. Its once high walls have collapsed to the northwest and its floor is destroyed. Can you spot small impact crater Mee E on the northern edge?

The next crater hop south brings us to one of the most unusually formed craters on the Moon – Schiller (Fig. 12.5). Located near the lunar limb, 184 km wide Schiller appears as a strange gash bordered on the southwest in white and black on the northeast. This oblong depression might be the fusion of two or three craters, yet it shows no evidence of crater walls on its smooth floor. Schiller's formation still remains a mystery. Be sure to look for a slight ridge running along the spine of the crater to the north through the telescope. Larger scopes should resolve this feature into a series of tiny dots.

Now, rest your eyes for a while. We are about to head north…
Return to Oceanus Procellarum and landmark crater Kepler (Fig. 12.6). To the north you will see equally bright Aristarchus – quite probably one of the youngest of the prominent features at around 50 million years old. It is hard to miss the blinding beacon of Aristarchus! Its albedo is double that of other lunar features, and it is so dazzling that it can usually be spotted

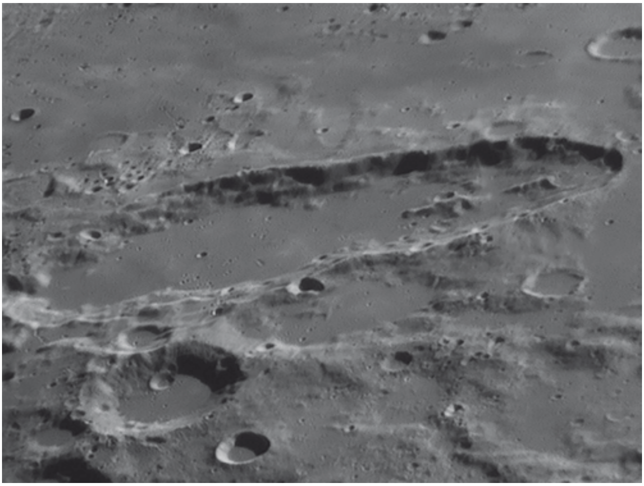


Fig.12.5 Schiller – Wes Higgins.

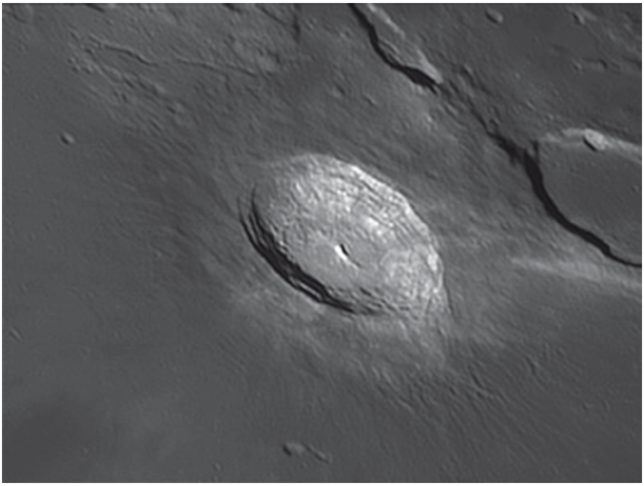


Fig. 12.6 Aristarchus – Damian Peach.

with the unaided eye and quite frequently with binoculars during Earthshine. Power up in the telescope and take a look around the south-eastern edge for the Aristarchus plateau – an elevated area that contains a

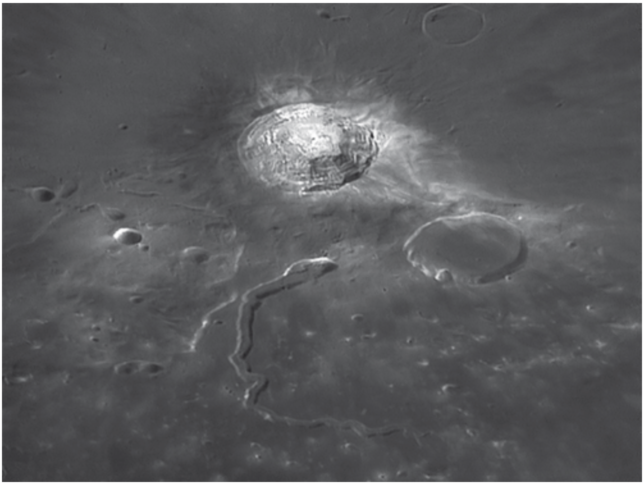


Fig. 12.7 Schroter's Valley – Wes Higgins.

number of volcanic features, such as sinuous rilles. This is also home to other lunar transient phenomena, and even Lunar Prospector measured radon gas emissions from this area. Watch Aristarchus as the Moon grows full, because it will also develop a ray system.

Now, grab your telescope and look west of Aristarchus for less prominent crater Herodotus (Fig. 12.7). Just to the north you will see a fine, white thread-like feature known as Vallis Schroteri – or Schroter's Valley. Winding its way across the Aristarchus plain, this feature is about 160 km long, from 3 to 8 km wide, and about 1 km deep. But, what is it? Schroter's Valley is a prime example of a collapsed lava tube – created when molten rock flowed over the surface. This may have been from a major meteor strike, such as the formation of Aristarchus crater, or early volcanic activity. What is left is a long, narrow cave on the surface, which only shows well when the lighting is correct. Like many sinuous rilles covering the surface, collapse has occurred. If intact tubes can be found on the lunar surface they could conceivably provide shelter for future settlers!

Are you ready for some lunar oddities? (Fig. 12.8). Then be glad you have done your homework, because it is time to return south to lunar landmark crater Kepler. Head due west across Oceanus Procellarum until you encounter the bright ring of crater Reiner. Spanning 30 km, this crater is not anything in

Fig. 12.8 Reiner and Reiner Gamma – Damian Peach.

particular – just shallow-looking walls with a little hummock in the center. But, look further west and a little more north for an anomaly – Reiner Gamma. Well, it is bright. It is slightly eye-shaped. But what exactly is this one? Possessing no real elevation or depth above the lunar surface, Reiner Gamma could very well be an extremely young feature caused by a comet. Only three other such features exist – two on the lunar far side and one on Mercury. They are high albedo surface deposits with magnetic properties. Unlike a lunar ray of material ejected from below the surface, Reiner Gamma can be spotted during the daylight hours – when ray systems disappear. And, unlike other lunar formations, it never casts a shadow.

Reiner Gamma causes a magnetic deviation on a barren world that has no magnetic field. This has many proposed origins, such as solar storms, volcanic gaseous activity, or even seismic waves. But, one of the best explanations for its presence is a cometary strike. It is believed that a split-nucleus comet, or cometary fragments, once impacted the area and the swirl of gases from the high-velocity debris may have somehow changed the regolith. On the other hand, ejecta from an impact could have formed around a magnetic "hot spot," much like a magnet attracts iron filings. No matter which theory is correct, the simple act of viewing Reiner Gamma and realizing that it is different from all other features on the Moon's earthward facing side makes this journey worth the time!

Fig. 12.9 Lunar Rays – Greg Konkel.

Do you like looking at things that are considered dubious? (Fig. 12.9). Then let us take another trip to peek at a ray system whose origins are uncertain. You will find the bright ring of Bessel just slightly south of center in Mare Serenitatis, but the ray system is splashed all over it. Did they come from Menelaus on the mare's edge? Or from as far south as Tycho? Next time the terminator passes over this region, look closely. Do you see the rays now – or just a complicated system of dorsa?

If you would like a real challenge telescopic challenge, look just south of central on Oceanus Procellarum about halfway between Kepler and Gassendi for a large crater that has mostly melted down (Fig. 12.10). This "ghost crater" has no name, but look along its edge for Class I Flamsteed. It is very near here that Surveyor 1 still stands. It made its landing on June 2, 1966 and sent back more than 11,000 pictures of the rock strewn, desert-like floor. This area was one of the first chosen for an Apollo mission landing, but was later scratched for a more central location. Congratulations on all your hard work through Lunar Day Eleven!

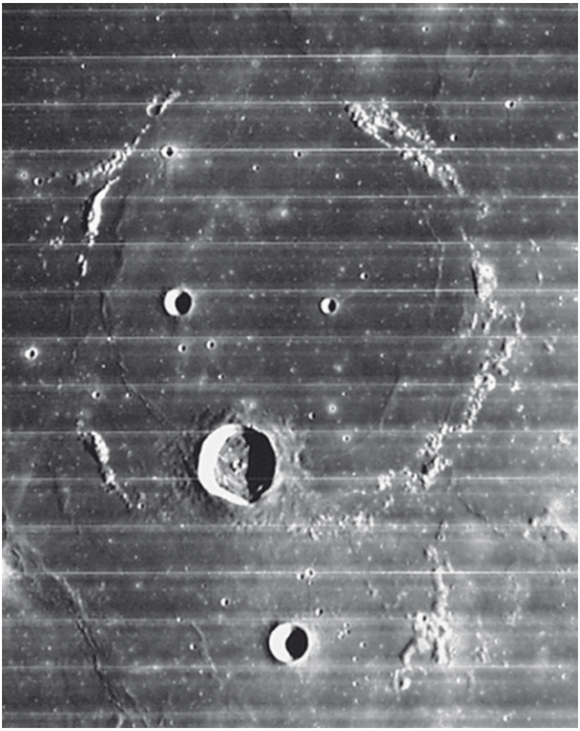


Fig. 12.10 Flamsteed – Lunar Orbiter 4 (NASA).

CHAPTER 13

LUNAR DAY TWELVE

Hey diddle diddle,
The cat and the fiddle,
The cow jumped over the Moon;
The little dog laughed to see such sport,
And the dish ran away with the spoon.

A nursery rhyme from the 1700s

As the Moon nears full, it becomes more and more difficult to study, but there are still some features that we can take a look at (Fig. 13.1). Using a colored filter on Moon filter on your telescope is of great benefit – or even

Fig. 13.1 Twelve day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_13, © Springer Science+Business Media, LLC 2010

wearing sunglasses with your binoculars can be helpful. Before we go to our binoculars or telescopes, just stop and take a look. Do you see the "Cow Jumping over the Moon"? It is strictly a visual phenomenon – a combination of dark maria that looks like the back, forelegs, and hind legs of the shadow of that mythical animal!

Tonight the great Grimaldi, found in the central region of the Moon near the terminator, is the best lunar feature for binoculars (Fig. 13.2). This huge, old basin on the western limb comes from the Pre-Nectarian geological period and is definitely at least four billion years old. Spanning about 216 km in diameter and filled with low albedo lava, Grimaldi – like Plato – is a landmark feature that is easily noticed even without optical aid, but holds wonderful details for study. Using a telescope, take a look at the inner walls of Grimaldi, where you will see that they have been heavily eroded and worn away by impacts and time. All that is left now is a series of low hills and ridges – there are no sharp crater walls to distinguish it. Beyond the basin, an outer wall still remains. If the lighting is right at your time of observation, you will notice that it appears more strong to the north and west, as opposed to the southeast Rimae Grimaldi. Take a close look at the floor region. It is home to a mascon, as well as lunar transient phenomena. Can you spot Lohrmann crater to its north or Riccioli crater to the southeast?

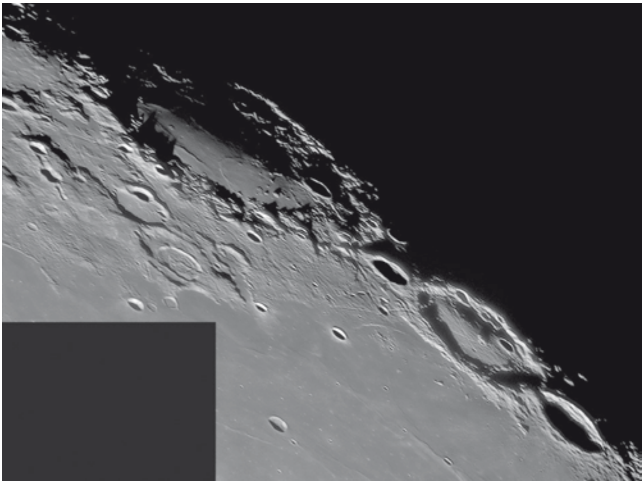


Fig. 13.2 Grimaldi – Bob Pilz.

If you would like to see how well you have mastered your telescopic skills, then let us crater hop (Figs. 13.3 and 13.4). About one Grimaldi length south, you will see a narrow black ellipse with a bright rim. This is Rocca. Go the same distance again (and a bit east) to spot a small, shallow crater with

Fig. 13.3 Hansteen – Damian Peach.

Fig. 13.4 Billy – Damian Peach.

a dark floor. This is Cruger and its lava-filled interior is very similar to another study we will soon locate. Now look between them. Can you see a couple of tiny dark markings? Believe it or not, this is called Mare Aestatis – the "Summer Sea." It is not even large enough to be considered a medium-sized crater, but is a mare! Now, hop east and you will see two craters nearly identical in size and depth. The southern crater is Billy – one of the darkest floored areas on the Moon. Inside Billy's bright rim, you will notice an interior as featureless as a mare. North of Billy is Hansteen, whose interior is much brighter and shows complex details. Comparing the two will show that Billy was once filled with smooth lava, while Hansteen avoided that fate and shows its native scarred interior.

For larger telescopes, let us try a challenging study worthy of your observing skills (Fig. 13.5). Due west of Hansteen you will find a small crater known as Sirsalis near the terminator. It will appear as a small, dark ellipse with a bright west wall along with its twin, Sirsalis B. The feature you will be looking for is the Sirsalis Rille – the longest lunar "wrinkle" presently known. Stretching northeast of Sirsalis and extending 459 km south to the bright rays of Byrgius, this major "crack" in the lunar surface shows several branchings – like a long dry river bed. Geologically forming in the Imbrian period, chances are the Sirsalis Rille is a lunar graben. Thanks to Lunar Orbiter images, the evidence points to shifting tectonic plates as the source of this incredible feature.

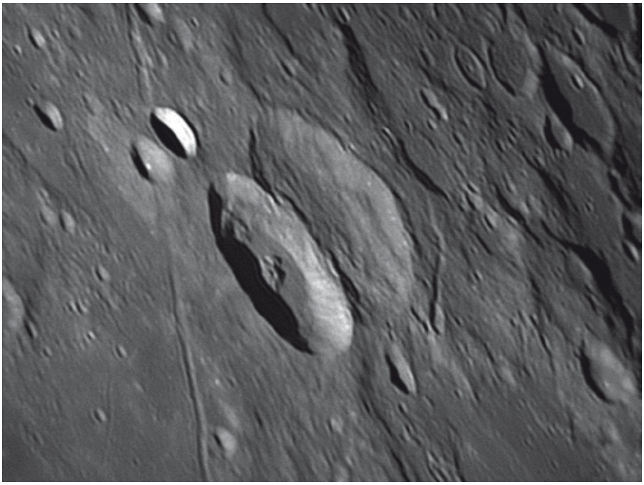


Fig. 13.5 Sirsalis – Damian Peach.

Fig. 13.6 Byrgius (bottom center) – Consolidated Lunar Atlas.

Time to Moon walk along the terminator toward the west and south until you encounter the bright crater Byrgius (Fig. 13.6). Named for Joost Bürgi, who made a sextant for Tycho Brahe, this "seen on the curve" crater is really quite large with a diameter of 85 km. Perhaps its most interesting feature is the high-albedo Byrgius A, which sits along its eastern wall line and produces a wonderfully bright ray system that extends over 400 km across the lunar surface. Once upon a time, Byrgius was thought to have a rimae, too… But it was later found out to be just an extension of the Sirsalis Rille. While Byrgius is noted as a challenge crater in many books, it is also a great crater to help add to your knowledge of selenography!

Continue south near the southern cusp for two outstanding features (Fig. 13.7). The easiest is crater Schickard – a class V mountain-walled plain. Named for Dutch mathematician and astronomer Wilhelm Schickard, this 227 km diameter feature is loaded with subtle interior details and has

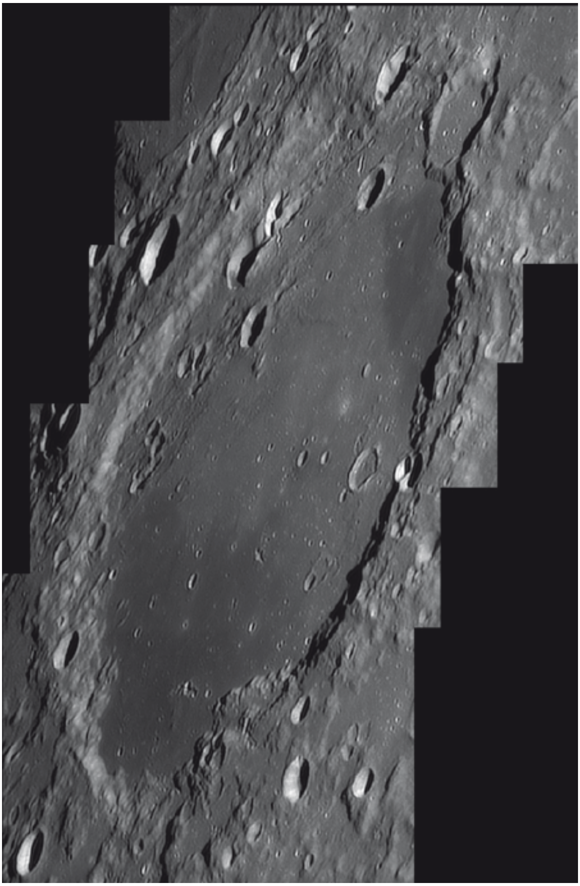


Fig.13.7 Schickard – Damian Peach.

another crater caught on its northern wall, which is named Lehmann. At high power you will see a variegated floor and dark areas near the walls – yet the center is creased by a lighter coloration. It is believed that Schickard was formed by an early impact before Mare Nectaris formed. Its floor may have contained vents that allowed it to fill with lava during the Imbrium period. As it cooled and matured another impact event occurred nearby, which formed the Orientale Basin and splashed material its way. But Schickard was not done evolving yet… Lava continued to flow and left even more dark evidence for us to observe. How do we know this is so?

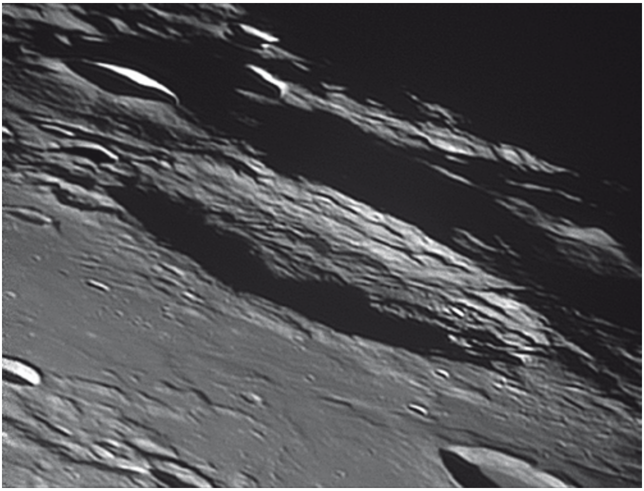


Fig. 13.8 Inghirami – Damian Peach.

If you are able to resolve Schickard's tiny interior impacts, you will see that far fewer of them occur over newer material. Older formations bear the scars of time and impact, while younger features are fresh and unmarked!

Are you ready for another challenge? (Fig. 13.8). If the lighting is right, look west of Schickard for a well-defined black ellipse with a highlighted southwest wall. This is Inghirami, and its northeastern section will be quite dark. This high wall will cast a shadow across the gray crater floor toward the terminator. Inghirami is an isolated circular formation that occurred during the Nectarian geological period and is about 89 km in diameter and approximately 2,774 m deep. How did it form? We are not quite sure, but a close inspection will show a little bit of a central mountainous region against its rather tormented-looking floor. Look for some high walls to the northwest when the shadows are right!

Now, head further south for one of the Moon's most incredible features – Wargentin (Fig. 13.9). Among the many strange things on the lunar surface, Wargentin is unique. Once upon a time, it was a very normal crater and had been so for hundreds of millions of years, and then it happened: either a fissure opened in its interior or the meteoric impact that formed it caused molten lava to begin to rise. Oddly enough, Wargentin's walls did not have large enough breaks to allow the lava to escape, and it continued to fill the crater to the rim.

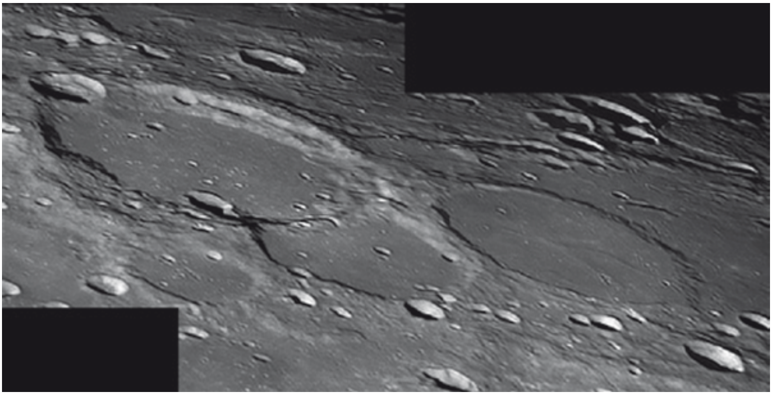


Fig. 13.9 Phocylides, Nasymyth & Wargentin – Damian Peach.

Often referred to as "the Cheese," enjoy Wargentin tonight for its unusual appearance… and be sure to note craters Nasmyth and Phocylides as well!

Rest your eyes for a while, and when you are ready we will return again to our landmark of Grimaldi and begin our journey north…

As you Moon walk north of Grimaldi on a crater hop, the next major feature you will encounter is the walled plain of Hevelius (Fig. 13.10). With a diameter of about 64 miles, this round area does not have a height we can really measure because of its lunar position, but we can see that it does have some relatively steep walls around its edges. Hevelius was formed in the Nectarian geological period, and if you look closely you will see that it has a small central peak, a fine rimae, and many craterlet chains, too. Can you spot large interior Crater Hevelius A with just binoculars? How about companion crater Cavalerius, which is part of its northern border?

Further north you will spy the nice sized ovals of Cardus and Krafft (Fig. 13.11). Nearby and sitting on the lonely gray sands is a very small well of a crater called Galileo. It is a supreme challenge for binoculars to spot, but telescopes of any size at higher magnifications will easily reveal it perched on the terminator in the west-northwest section of the Moon. Set in the smooth sands of Oceanus Procellarum, Galileo is a very tiny, eye-shaped crater with a soft rille accompanying it. Of course, this crater

Fig. 13.10 Hevelius – Damian Peach.

was named for the man who first contemplated the Moon through a telescope. No matter what lunar resource you choose to follow, all agree that giving such an insignificant crater a great name like Galileo is like calling a Harley–Davidson just a motorcycle! For those familiar with some of the outstanding lunar features, read any account of Galileo's life and just look at how many spectacular craters were named for people whose work he supported and endorsed. We cannot change the names of lunar cartography, but we can remember Galileo's many accomplishments, achievements, and trials each time we view this crater.

A hop further north will reveal the prominent small ring of Seleucus and the large, shallow ring of Eddington, but set your sights again on Sinus Roris – the

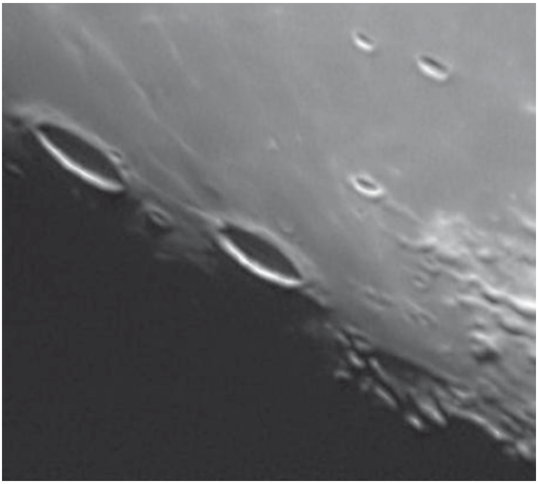


Fig. 13.11 Cardanus and Krafft (Wikipedia).

Fig. 13.12 Location of Sinus Roris (Wikipedia).

"Bay of Dew" (Fig. 13.12). Spanning about 515 km wide, Sinus Roris is an area of lava flow believed to have formed in the Eratosthenian geological period, which connects Mare Frigoris and Oceanus Procellarum. Usually not very well

defined on any lunar chart, you will notice that it appears just slightly brighter to the north than the south – a result of eject deposits from the northern tier craters. Where it begins and ends? Well, that is not well defined either, but just west of the bright, mountainous region that surrounds Sinus Iridum you will spy a small dark patch known as Mons Rumker. Power up.

Mons Rumker is home to a complex of agglomerated lunar domes forming a circular array that is a bit difficult to study during high lighting conditions (Fig. 13.13). This large, elevated mound measures about 66 km in diameter and could contain as many as 30 lunar domes, which are the lunar equivalent of a terrestrial shield volcano. It is here that lava quietly bubbled to the surface, gently cooling, and left us something to marvel at some three billion years later!

> A map of the Moon… should be in every geological lecture room; for no where can we have a more complete or more magnificent illustration of volcanic operations. Our sublimest volcanoes would rank among the smaller lunar eminences; and our Etnas are but spitting furnaces.
>
> James Dwight Dana

Congratulations on studies well done on Lunar Day Twelve!

Fig. 13.13 "Mega Dome" – Wes Higgins.

CHAPTER 14

LUNAR DAY THIRTEEN

> *Thy beauty haunts me heart and soul,*
> *Oh, thou fair Moon, so close and bright;*
> *Thy beauty makes me like the child*
> *That cries aloud to own thy light...*
>
> William Henry Davies

Tonight the Moon will look nearly Full and it is a good time to spot yet another lunar asterism (Fig. 14.1). Since the dawn of mankind, we have been gazing at the Moon and seeing fanciful shapes in large lunar features.

Fig. 14.1 Thirteen day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_14, © Springer Science+Business Media, LLC 2010

Tonight, as the Moon rises, is your chance to catch a lunar challenge – "The Rabbit in the Moon." The Rabbit is a compilation of all the dark maria. The Oceanus Procellarum forms the "ear" while Mare Humorum makes the "nose." The "body" is Mare Imbrium and the "front legs" appear to be Mare Nubium. Mare Serenitatis is the "backside" and the picture is complete where Mare Tranquillitatis and Mare Fecunditatis shape the "hind legs" with Crisium as the "tail." See the Moon with an imaginative mind and new eyes – and find the Rabbit. It's already out of the hat and in the heavens.

Let's launch our telescopic and binocular lunar explorations as we head for the far north for an "on the edge" feature – Pythagoras (Fig. 14.2). Named for the Greek philosopher and mathematician, you will see this smooth, walled plain as a thin, bright ellipse standing out well against the background of northern landmark Sinus Iridum. Pythagoras is one of the deepest craters in the northern quadrant and would be even more spectacular if visible from overhead – rather than at an angle. Look for its tall and prominent central peak caught in its 133 km wide spread.

Return to landmark crater Grimaldi and we'll continue our on journey of lunar evolution as we have a look at another walled plain just to the

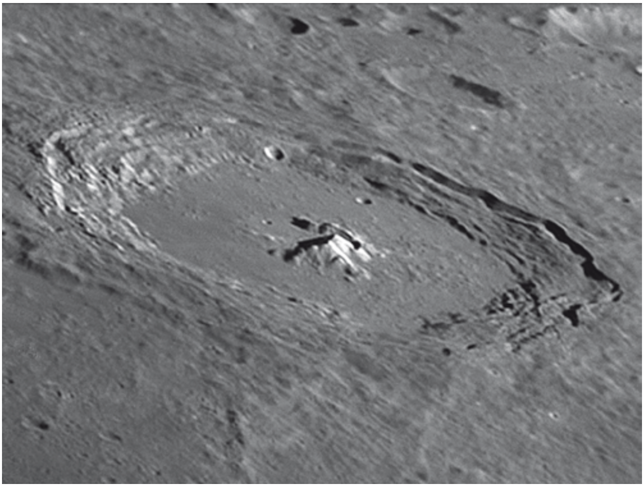


Fig. 14.2 Pythagoras – Damian Peach.

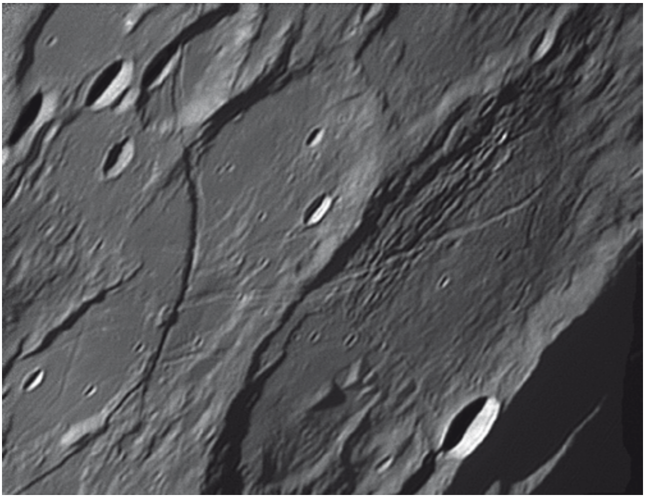


Fig. 14.3 Rimae Darwin – Damian Peach.

south – Darwin (Fig. 14.3). Named for English naturalist Charles Darwin, this equally old feature bears the scars of the impact that created the Orientale Basin. Look carefully at the slopes in the northeast, for this may very well be material that was thrown there and left to slide back down to the crater floor. Spanning around 130 km in diameter, Darwin's actual size is only diminished by the fact that we view it on a curve. Its northern and southern shores have almost completely eroded, yet evidence remains of its eastern margin broken by the Rima Darwin which stretches for 280 km. Was there lava here as well? Yes. Evidence still exists in the form of a dome along Darwin's battered western edge.

If the lighting is right, look at the western edge of Darwin for the Montes Cordillera (Fig. 14.4). This is the external mountainous ring of Mare Orientale, and they could range as long as 877 km in length, 293 km in width, and 5,547 m in height. Many of the summits reach as much as 1,525 m! That's like comparing it to the northeastern fringe of the Qinghai-Tibet Plateau in China. Its main peak, Qilianshan, is 5,547 m above the surface, too!

Let's continue our studies by using a landmark feature we've learned to help guide us to other interesting points on the lunar surface. Even small binoculars will reveal the outstanding presence of crater Tycho with its bright

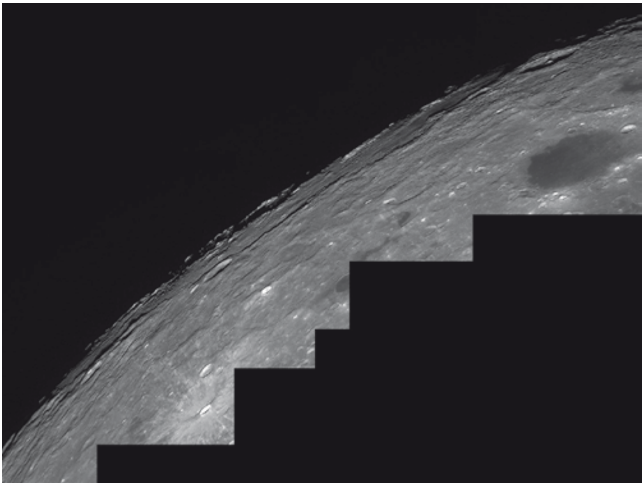


Fig. 14.4 Mare Orientale – Damian Peach.

ejecta pattern splashing across the surface. Look closely at one of the brightest of the rays, for it passes over Mare Nubium – the "Sea of Clouds." This exceptionally dark, irregular plain stretches out over 563 × 64 km and has many areas worth exploring – but power up again on Tycho.

Named for Danish astronomer, Tycho Brahe, this fantastic impact crater is very impressive in even the most modest of optical aids. Spanning 85 km, this lunar feature will be very prominent and unmistakable in the southern hemisphere of the Moon. Tycho's highly conspicuous ray system supports its origin as an impact crater. The rays span hundreds of kilometers across the lunar surface. Tycho is also one of the youngest of the major features at an astounding age of only 50,000,000 years old! On January 9, 1968 Surveyor 7 – the last lunar robot of its kind – landed quietly at lunar sunrise on Tycho's slopes. Because previous Surveyor missions provided the Apollo program with all data necessary for manned missions, Surveyor 7's presence was scientific only. Two weeks later, when the Sun set on the landing site, Surveyor 7 had provided over 21,000 photographs, determined physical and chemical properties associated with the Southern Highland area, and detected laser beams aimed at it from two separate Earth observatories.

Look closely at the bright ray of material thrown across its dark floor from the impact that caused Tycho (Fig. 14.5). It is easy to see that it is laid "over"

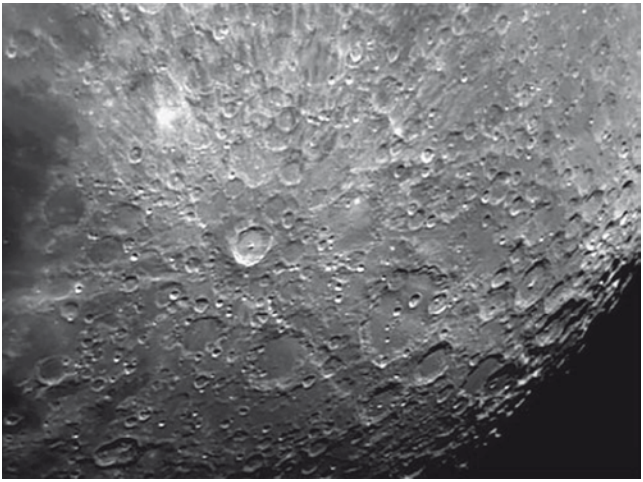


Fig. 14.5 Tycho's rays – Roger Warner.

the surface of the lava flow and this is an important clue to the age of lunar features. One of these rays crosses the Apollo 17 landing site 2,000 km from Tycho itself and may have caused a landslide from the mountains where the astronauts sampled. This suggests that Tycho is about 100 million years old. While this might seem like a great age, the Sea of Clouds could be between 3 and 4 billion years old. Once upon a time, an impact formed its basin as well. Thanks to the Moon's lack of atmosphere, the lava flow quietly filled the basin and left it as we see it tonight.

If we were poised at the edge of space, we would see our Moon is readying itself to pass either just north or just south of the cone of shadow projected by Earth. Take the time to study the limbs of the Moon for the effects of libration. Follow Tycho's bright ray toward the southwest and see if you can spot the Doerfel Mountains as tiny bumps on the limb edge. While they might not appear to be much, they are three times higher than Mount Everest!

The light from a nearly Full Moon can be almost overpowering in a telescope, so try switching to binoculars and see how many features you remember which now appear as bright points. Do you recognize Proclus on the edge of Mare Crisium? How about Furnerius along the southeastern limb? Look at how things can change just by the amount of light reflected from the Sun and congratulate yourself on all your great work through Lunar Day Thirteen!

PART III

FULL MOON

CHAPTER 15

LUNAR DAY FOURTEEN

> *May you have warm words on a cold evening,*
> *a Full Moon on a dark night and a smooth*
> *road all the way to your door.*
>
> Irish blessing

Tonight is Full Moon and it goes by many different names (Fig. 15.1). During the month of January it is called the Full Wolf Moon – its name derived from the North American Indians who would hear the wolves howling in search of food in the cold, snow-covered, and barren landscape.

Fig. 15.1 Fourteen day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_15,

In Europe it was referred to as the Moon After Yule. In February it is the Full Snow Moon, because the northern hemisphere is usually heavy in snow in the upper regions. Native Indian tribes of the north and east most sometimes referred to it as the Full Hunger Moon, as well. In many cultures, March is known as the “Worm Moon.” As ground temperatures begin to warm and produce a thaw in the northern hemisphere, earthworms return and encourage the return of robins. For the Indians of the far north, this was also considered the “Crow Moon.” The return of the black bird signaled the end of winter. Sometimes it has been called the “Crust Moon” because warmer temperatures melt existing snow during the day, leaving it to freeze at night. Perhaps you may have also heard it referred to as the “Sap Moon.” This marks the time of tapping maple trees to make syrup. To early American settlers, it was called the “Lenten Moon” and was considered to be the last full Moon of winter.

How about April? It’s the “Pink Moon.” As strange as the name may sound, it actually comes from the herb known as moss pink – or wild ground phlox. April is the time of blossoming and the “pink” is one of the earliest wide-spread flowers of the spring season. As always, this Moon is known by other names as well, such as the Full Sprouting Grass Moon, the Egg Moon, and coastal tribes referred to it as the Full Fish Moon. Why? Because spring was the season the fish swam upstream to spawn! By May in most areas, flowers are everywhere, so it’s not hard to imagine how this came to be known as the “Full Flower Moon.” Since northern hemisphere Earth is reawakening after the winter season, the agricultural cycle has begun and this is also known as the “Full Corn Planting Moon.” Another name? The “Milk Moon” because of the increased productivity from cows grazing on the rapidly greening pastures. In June it is referred to as the Full Strawberry Moon, but our friends in Europe referred to it as the Rose Moon. The North American version came about because the short season for harvesting strawberries comes each year during the month of June – so the full Moon which occurs during that month was named for this tasty red fruit!

During July, something strange is happening in the woods...deer sprout antlers. Because of this natural phenomenon, July’s Moon is sometimes referred to as the “Buck Moon.” For some of us, however, the month of July also brings fearsome storms and Luna is also referred to as the “Thunder Moon.” In more agricultural regions it’s the “Hay Moon.” Among coast dwellers, it is the “Sturgeon Moon” – a name given by ancient fishermen whose best catches occurred during this month. Elsewhere it has been called the "Red Moon" because hazy-heat rising from the Earth's surface at low angles gives the Moon color as it rises. July's Moon is also the "Grain Moon," or for scholars, the "Green Corn Moon." In August it is known as the "Fruit" or "Barley" Moon, perhaps because it's sometimes slightly colored – or because it's a time when both are crops ripe? In September, many cultures refer to this one in particular as the "Corn Moon" because this time of year most corn crops are ready for harvest.

It is the Harvest Moon! On gilded vanes
And roofs of villages, on woodland crests
And their aerial neighborhoods of nests
Deserted, on the curtained window-panes
Of rooms where children sleep, on country lanes
And harvest-like fields, its mystic splendor rests.
Henry Wadsworth Longfellow

September's Full Moon can sometimes be the "Harvest Moon" but this particularly celebrated Full Moon occurs the closest to Autumnal Equinox. Because the Moon's orbit carries it nearly parallel to the eastern horizon, it will rise at dusk at this time of year for the next several nights in a row. On the average, the Moon rises about 50 min later each night, but at Fall Equinox it's around 20 min later for mid-northern latitudes and even less farther north. Because of this added light, the name "Harvest Moon" came about because it allowed farmers more time to work in the fields.

Often times we perceive the Harvest Moon as being more orange than at any other time of the year. The reason is not only scientific enough – but true! Coloration is caused by the scattering of the light by particles in our atmosphere. When the Moon is low, we get more of that scattering effect and it truly does appear more orange. The very act of harvesting itself produces more dust and often times that coloration will last the whole night through (Fig. 15.2).

Under the Harvest Moon,
When the soft silver
Drips shimmering
Over the garden nights,
Death, the gray mocker,
Comes and whispers to you

Fig. 15.2 "A Sky Gazer's Full Moon" – Robert Gendler.

As a beautiful friend
Who remembers
Under the summer roses
When the flagrant crimson
Lurks in the dusk
Of the wild red leaves,
Love, with little hands,
Comes and touches you
With a thousand memories,
And asks you
Beautiful, unanswerable questions.

Carl Sandburg

October is known as the "Hunter's Moon" or the "Blood Moon," its name came from a time when hunters would stalk the fields by Luna's cold light in search of prey before the winter season began. Pick a place at sunset to watch it rise – a place having a stationary point with which you can gauge

its progress. Make note of the time when the first rim appears and then watch how quickly it gains altitude! How long does it take before it rises above your marker? Native American legend refers to the November Moon as the Full Beaver Moon. Because the northern climate is now getting colder, it became the time to set beaver traps before swamps froze – leaving trappers a supply of warm furs to survive the winter months. Some also believe that the Beaver Moon may have been so named for the beavers themselves, who ready their homes for coming cold. No wonder this is also called the Frosty Moon as well! December is "Full Moon before Yule." Check to see when the Moon is full at Winter Solstice if it happens to be at perigee – its closest point to the Earth. While you might hear a tall tale or two about it being brighter than normal since it is also close to solstice, judge for yourself! Is it truly brighter? Or just an illusion?

And we all know the size is only an "illusion" (Fig. 15.3). No matter what it's called, we can watch Selene rise when it is Full and enjoy the "Moon Illusion." Everyone knows our nearest astronomical neighbor looks larger when it's on the horizon, but did you know this is a psychological phenomenon and not a physical one? Prove it to yourself by looking at the rising Moon upright...it looks larger, doesn't it? Now stand on your head, or find a comfortable way to view it upside down...now how big is it? Try using a small coin held at arm's length, compare it to Luna as it rises, and then again as it seems to "shrink" as it gets higher! You've now qualified for extra credit!

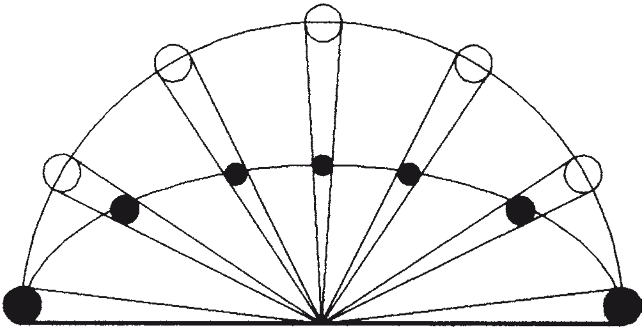


Fig. 15.3 Moon Illusion (NASA).

Fig. 15.4 Full Moon Bright Points (NASA).

Tonight let's have a look at the far away world as we return again with binoculars to identify the maria once again (Fig. 15.4). Take the time to repeat the names to yourself and to study a map. One of the keys to successfully learning to identify craters is by starting with large, easily recognized features. Even though the Moon is very bright when Full, try again using colored or Moon filters with your telescope to have a look at the many surface features which throw amazing patterns across its surface. If you have none, just give a pair of sunglasses a go. Look for things you might not ordinarily notice – such as the huge streak which emanates from crater Menelaus. Look at the pattern projected from Proclus – or the intense mark of little-known Pytheas north of Copernicus. How about the dazzling dot of Aristarchus?! Check how a nothing crater like Censorinus shines on the southeast shore of Tranquillitatis, while Dionysus echoes it on the southwest. Could you believe Manlius just north of central could be such a perfect ring – or that Anaxagoras would look like a northern polar cap? On the eastern limb we see the bright splash ray patterns surrounding ancient Furnerius – yet the rays themselves emanate from the much younger crater Furnerius A. All over the visible side, we see small points light up: a testament to the Moon's violent past written in its scarred lines. Take a look now at the western limb...for the sunrise is about to advance around it.

> The vast loneliness is awe-inspiring and it makes you realize just what you have back there on Earth.
>
> James Lovell (December 24, 1968)

Almost 400 years ago Galileo Galilei changed the face of astronomy when he observed the Moon (Fig. 15.5). Pointing his newly developed telescope at our nearest celestial neighbor, his observation of mountains and craters on the surface opened the world's eyes to what lay just beyond the range of human sight. Galileo said, "It is a beautiful and delightful sight to behold the body of the Moon." Is the Moon truly "Full" tonight, or can you still see a bit of the terminator? Libration could be favorable to study a collection of shallow, dark craters known as Mare Australe – the "Southern Sea." Located on the southeastern limb, this large binocular and telescopic object is well-worth looking for because it's a challenge that isn't always visible. Be sure to look at other libration favorable areas, such as Mare Orientale and Mare Humbudtianum, too.

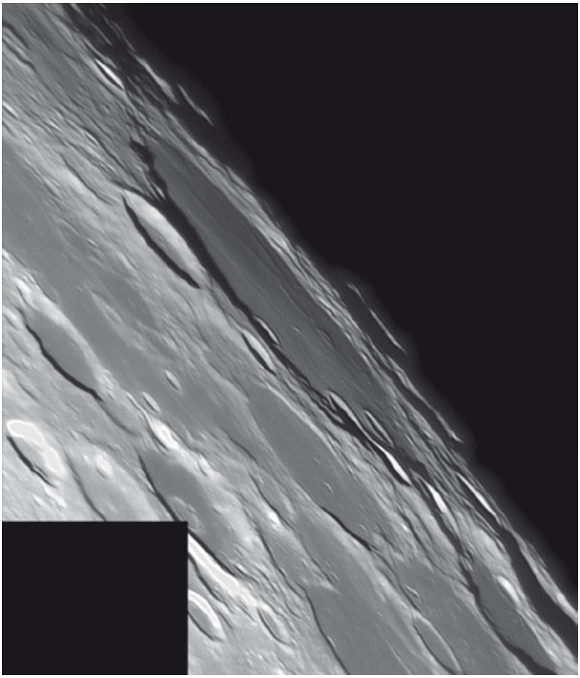


Fig. 15.5 Mare Australe – Damian Peach.

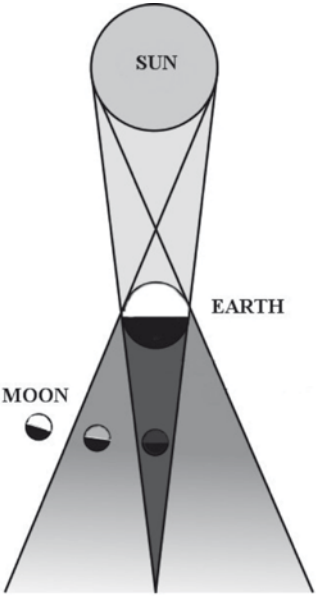
> …I distinguish two parts of it, which I call respectively the brighter and the darker. The brighter seems to surround and pervade the whole hemisphere; but the darker part, like a sort of cloud, discolors the Moon's surface and makes it appear covered with spots. Now these spots, as they are somewhat dark and of considerable size, are plain to everyone and every age has seen them, wherefore I will call them great or ancient spots, to distinguish them from other spots, smaller in size, but so thickly scattered that they sprinkle the whole surface of the Moon, but especially the brighter portion of it. These spots have never been observed by anyone before me; and from my observations of them, often repeated, I have been led to the opinion which I have expressed, namely, that I feel sure that the surface of the Moon is not perfectly smooth, free from inequalities and exactly spherical... but that, on the contrary, it is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere by lofty mountains and deep valleys.

(Describing his pioneering telescope observations
of the Moon made from January 1610)
Galileo Galilei

Of course, Full Moon is the only time an eclipse event happens, too. You'll find they occur around the time of both Spring and Fall Equinox – for good reason. While it might not seem like a big deal, a penumbral eclipse is when our Moon passes into the outer regions of Earth's shadow cone, producing mild shadings. While it's not known to be particularly exciting or even noticeable, some penumbral eclipses are exceptionally deep and edge of the Moon will just graze the inner umbral shadow. As a rule of thumb, remember that the Moon moves about its own diameter each hour, so the very beginning of a penumbral eclipse will be difficult to notice. Slowly and steadily, the coloration will begin to change and even inexperienced eclipse watchers will notice that something is different.

On the other hand, a total lunar eclipse is a wonderful example of the precision of orbital paths (Fig. 15.6). The relationship between the Sun, Earth, and Moon now become apparent as our satellite passes through our cone of shadow, instead of just above or just below. A round body, such as a planet, casts a shadow "cone" through space. When it's at Earth, the cone is widest at 13,000 km in diameter, yet by the time it reaches the Moon it has narrowed to only 9,200 km. Considering the distance to the Moon is 384,401 km, that's

Fig. 15.6 Lunar Eclipse (Wikipedia).



hitting a very narrow corridor in astronomical terms! Regardless of whether or not you can experience the whole event, there is something very wonderful about viewing an eclipse and watching the clockwork movements of orbit. It is both enlightening and spiritual (Fig. 15.7).

> Thy shadow, Earth, from Pole to Central Sea,
> Now steals along upon the Moon's meek shine
> In even monochrome and curving line
> Of imperturbable serenity.
>
> Thomas Hardy

Of course, the Moon will never completely disappear as it passes through the Earth's umbral shadow cone (Fig. 15.8). Thanks to our atmosphere bending the sunlight around us, it scatters the light and refracts the signature red and copper coloration we associate with lunar eclipse. Why? Just the small particles in our air – dust and clouds – the shorter wavelengths of light from the Sun are more likely to be scattered (in this case, red) and that's what we see. Exactly the same reason sunset and sunrise appears to be red! If you'd like to dedicate a portion of your mind to science, then try

Fig. 15.7 Eclipsed Moon – Fred Espenak (NASA).

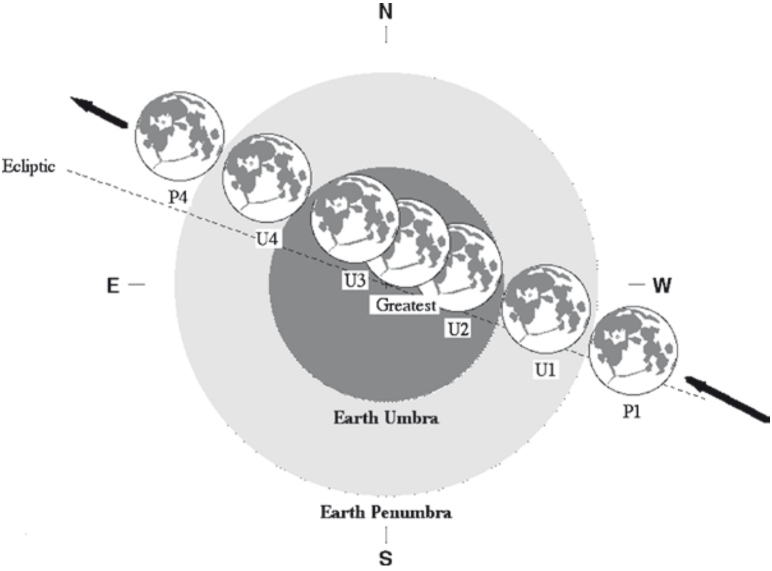


Fig. 15.8 Eclipse – NASA.

judging the eclipse coloration on the Danjon scale. It was devised by Andre Danjon for rating the overall darkness of lunar eclipses:

L = 0: Very dark eclipse. Moon almost invisible, especially at mid-totality.
L = 1: Dark eclipse, gray or brownish in coloration. Details distinguishable only with difficulty.
L = 2: Deep red or rust-colored eclipse. Very dark central shadow, while outer edge of umbra is relatively bright.
L = 3: Brick-red eclipse. Umbral shadow usually has a bright or yellow rim.
L = 4: Very bright copper-red or orange eclipse. Umbral shadow is bluish and has a very bright rim.

Don't forget when you're viewing an eclipse to take along your telescope and binoculars, too! While just watching the eclipse is a grand experience, you will never forget for the rest of your life watching the terminator race across the Moon... covering and unveiling features one at a time. If you have ever seen the shadow of a cloud race across an open field, then you can understand what I am trying to say. Imagine watching a distant mountaintop burst into light just seconds before the sunlight reaches the foothills... Or watching a dark crater well bloom before your eyes. It's magic!

CHAPTER 16

LUNAR DAY FIFTEEN

Art thou pale for weariness
Of climbing heaven and gazing on the Earth,
Wandering companionless
Among the stars that have a different birth,
And ever changing, like a Joyless eye
That finds no object worth its constancy?

Percy Bysshe Shelley

Tonight let's begin our Moon walk adventures by talking about Luna 9, also known as Lunik 9 (Fig. 16.1). In 1966, the unmanned Soviet lunar probe became the first to achieve a soft landing on the Moon's surface and successfully

Fig. 16.1 Fifteen day Moon – Peter Lloyd

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_16,

transmit photographs back to Earth. The lander weighed in at 99 kg, and the four petals, which formed the spacecraft, opened outward. Within 5 min of landing, antennae sprang to life and the television cameras began broadcasting back the first panoramic images of the surface of another world, proving that a landing would not simply sink into the lunar dust. Last contact with the spacecraft occurred just before midnight on February 6, 1966.

Tonight you can view the area of the first successful landing on the Moon by turning your binoculars or telescopes toward the Oceanus Procellarum – the Ocean of Storms (Fig. 16.2). While the area will be brightly lit and it will be difficult to pick out small features, Procellarum is the long, dark expanse that runs from lunar north to south. On its western edge, you can easily identify the dark oval of landmark crater Grimaldi. About one Grimaldi-length northward and on the western shore of Procellarum is where you will find the remains of Luna 9.

Now, let's turn our attention toward the eastern limb and check out the shadow play (Fig. 16.3)! To the north you will see eastern edge where the terminator is now receding. Look for the dark shades of Mare Humboldtianum and the equally dark floor of crater Endymion to its west. Although we've seen it before on Lunar Day Three, sombre Endymion will help guide you to

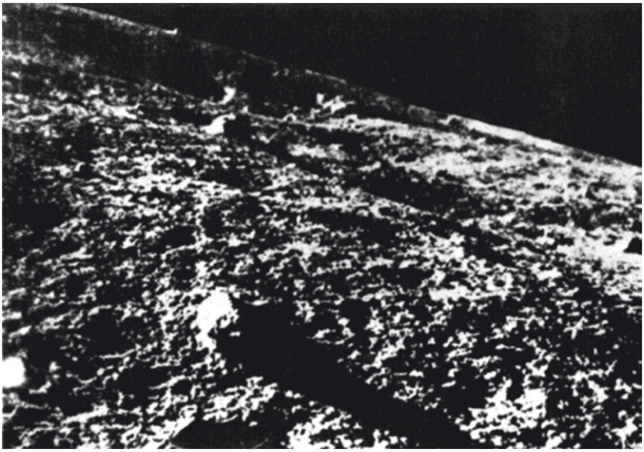


Fig. 16.2 Image from the Luna 9 lander in February, 1966 in the Oceanus Procellarum (NASA).

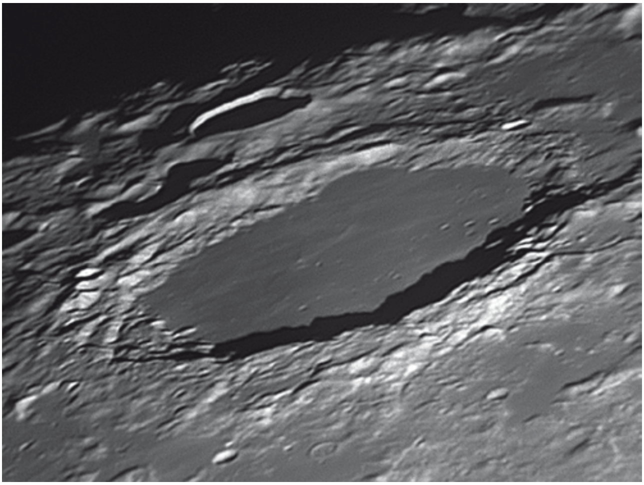


Fig. 16.3 Endymion – Damian Peach.

features you wouldn't normally see during the first few lunar days because of poor position. Look to its north for the walled plain of De La Rue. Formed in the Pre-Nectarian geological area, what remains of this 139 km wide crater is a wasteland. Its floors and walls are totally deranged, barely supporting the rims of larger crater Strabo on its north wall and accompanying crater Thales to Strabo's west. Take a close look at Thales. You can see it is several billion years younger – its impact ejecta spread far and wide. To Endymion's west you can see the tiny 34 km dip of Keldish north of Atlas and Hercules, while Lacus Temporis holds court to the south. If the terminator has not progressed too far at your time, look for tiny crater Mercurius caught on Lacus Temporis eastern shore.

Moon walk south to check out the eastern edge of Mare Crisium in different relief (Fig. 16.4). The bright point on the shoreline is Promontorium Agarum with shallow crater Condorcet to its east. Look along the shore of the mare for a southern mountain known as Mons Usov just west of Condorcet. Just to its north Luna 24 landed. It was the last of the Soviet Luna spacecraft and the third to successfully retrieve and return 170 g of lunar samples to the Earth on August 22, 1976. For over 30 years, Luna 24 held the distinction of being the final spacecraft from any country to have landed on the Moon, only to have that record broken by Chandrayaan-1 in

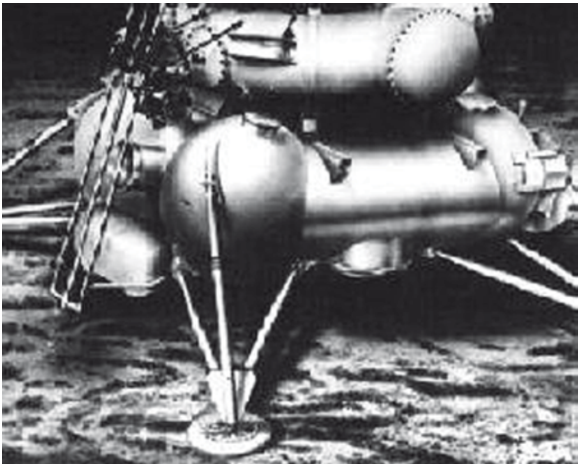


Fig. 16.4 Lunar 24 – NASA.

2008 – but the record still holds for "soft landings"! Luna 24 also held the record as the last spacecraft to return extraterrestrial samples until Stardust returned in 2006. Just south is the final resting place of Luna 23 which touched down on November 6, 1974. While it was intended to take deep core samples and return, the mission partially failed. However, it still successfully transmitted back 3 days worth of data. Directly to its west are the remains of Luna 15. It wasn't quite so lucky, though. . . It smashed into the surface on July 21, 1969. Unfortunate? Not hardly. It began the revolutionary age of creating good relations between the Soviet Space Agency and NASA by sharing flight plans! Can you spot tiny crater Fahrenheit nearby?

On the southern bank of Mare Crisium, you'll see the sinuous twin veins of Dorsum Termier extending northward across the deep gray sands (Fig. 16.5). To its west is the vague shape of Crater Shapley, named for the great Harlow Shapley – discoverer of the pulse nature of the Cepheid variable stars and the distribution of the globular clusters in the halo of the Milky Way. As you continue around the shoreline on the west bank beginning north, you'll encounter the small broken circle of Tebutt and the much more well-defined ring of crater Lick further north. Almost mid-point on the western bank of Mare Crisium is the home of 37 km wide crater Yerkes, highlighted by conspicuous Picard to the east. Follow the wave of Dorsum Oppel and you'll run across both Peirce and Swift as well.

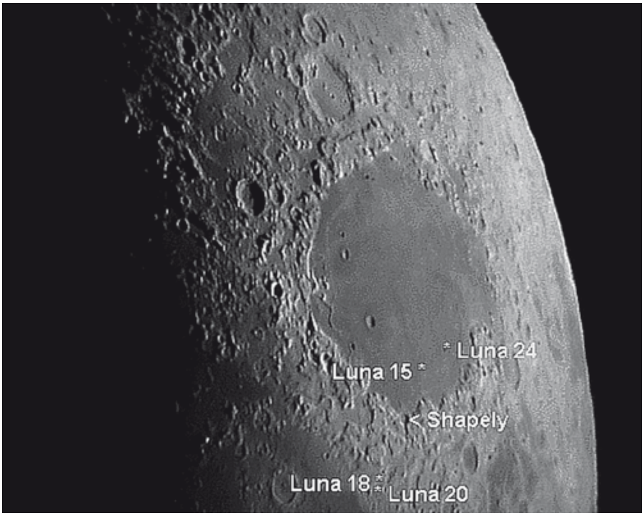


Fig. 16.5 Photographic Crisium map – Greg Konkel.

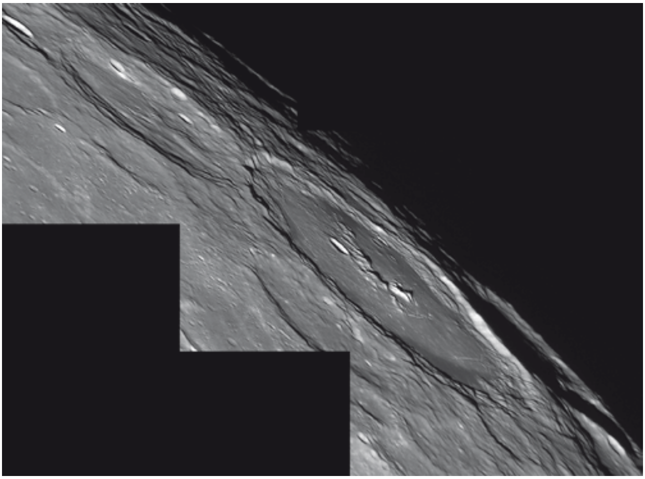


Fig. 16.6 Humboldt – Damian Peach.

Now, let's Moon walk to the edge of the east limb and slightly south of central to identify crater Humboldt (Fig. 16.6). Seen on the curve, this roughly 200 km wide crater holds a wealth of geographical details. Its flat,

cracked floor has central peaks and a small mountain range, as well as radial rille structure. If libration and steadiness of skies are in your favor, power up and look for dark pyroclastic areas and a concentric inner crater. Look for long, shallow Legendre and Phillips on Humboldt's west wall. It's not often you'll have a chance to study this crater, and your best bet is during the waning phase.

If you are unable to identify Humboldt, try using western Petavius as your guide (Fig. 16.7). Although we have studied Petavius on Lunar Day Three, now is your chance once again to see it in a different light and to mark your studies of the Petavius Wall (1). Look for unusual features, such as 57 km diameter Wrottesley on Petavius' northwest wall, or the long runnel of Palitzsch. Look for Snellius (2) to the south and Stevenius (4) showing off its central peak. Can you make out the unusual shadows in crater Hase (3)? Congratulations on making it to Lunar Day Fifteen!

Fig. 16.7 Petavius map – Alan Chu.

CHAPTER 17

LUNAR DAY SIXTEEN

Slowly, silently, now the Moon
Walks the night in her silver shoon;
This way, and that, she peers, and sees
Silver fruit upon silver trees…

Walter de la Mare

As the Moon begins to wane, we see features in a much different light (Figs. 17.1 and 17.2). Tonight let us return to Mare Crisium and power up with the telescope to discover some of the wonderful details that can be seen. Use the map below to help you discover these wonderful features:

Fig. 17.1 Sixteen day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_17,

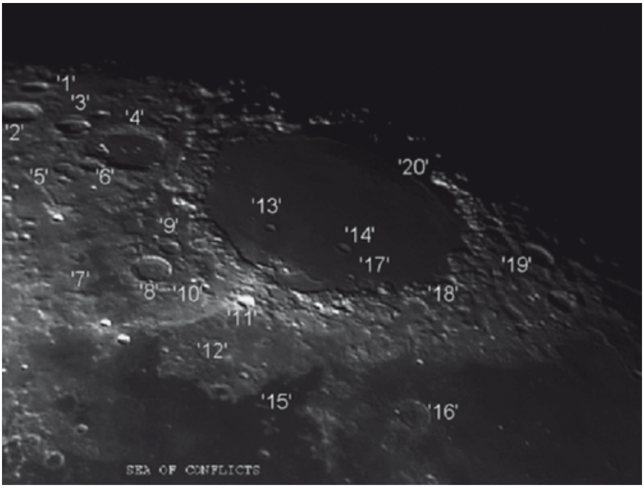


Fig. 17.2 Mare Crisium – Roger Warner.

(1) Bernoulli, (2) Geminus, (3) Burckhardt, (4) Cleomides, (5) Debes, (6) Tralles, (7) Lacus Bonitatis, (8) Macrobius, (9) Tisserand, (10) Fredholm, (11) Proclus, (12) Palus Somni, (13) Swift and Pierce, (14) Picard, (15) Sinus Concordiae, (16) Taruntius, (17) Lick, (18) Shapely, (19) Firmicus, (20) Promontorium Agarum.

Are you ready to explore further? Then relocate shallow crater Cleomides just north of Mare Crisium (Fig. 17.3). With binoculars, or a telescope at low power, follow the rings to the north as you encounter Burckhardt, Geminus, and the faded old Messala. For a telescopic challenge, look for crater Delmotte at the eastern edge of Cleomides' rim. Shift to the northwest for Trailes and Debes on its western edge. Moon walk to the south shore of Crisium and begin by identifying crater Shapley trapped on the edge of the mare's enclosure. To the southeast of Shapley you will see two small gray ovals. The northernmost is 58 km wide crater Firmicus with crater Apollonius to its south.

Now, let us take a look at the two gray regions which lay due east of these craters (Fig. 17.4). The northernmost is Mare Undarum and southern Mare Spumans. We studied them on Lunar Day Four, but look almost between them to the east for broken crater Dubiago. You will find this circular formation is actually a conglomeration of many smaller craters, with only an original wall to the east. On the south shore of Spumans you will find

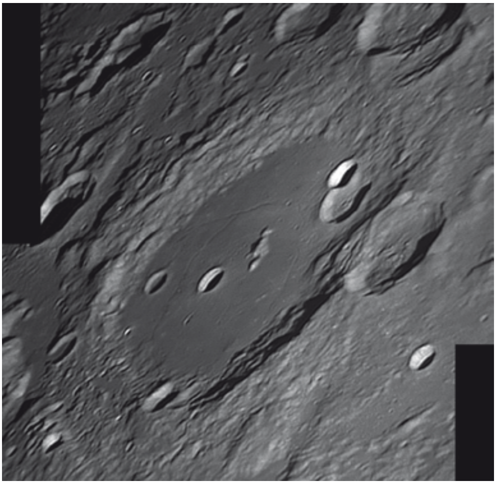


Fig. 17.3 Cleomedes – Damian Peach.

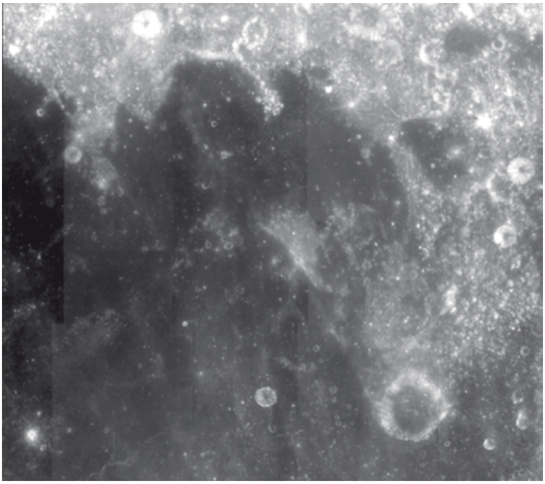


Fig. 17.4 Sinus Successus (Clementine).

another telescopic challenge – Maclaurin. This flat open crater only spans about 51 km in diameter and displays a shallow, central peak. Further south you will see the smooth gray area of Sinus Successus. If you look at

the paler peninsula on Successus' northern shore, you are seeing crater Ameghino and the landing area of the Luna 18 and Luna 20 missions. We have been there, too!

> I'm sure we would not have had men on the Moon if it had not been for Wells and Verne and the people who write about this and made people think about it. I'm rather proud of the fact that I know several astronauts who became astronauts through reading my books.
>
> Arthur C. Clarke

As we move further south, look for the ancient impact craters – and past previous studies – Langrenus and Vendelinus just slightly south of central (Fig. 17.5). Spanning approximately 150 km in diameter and with walls reaching up to 4,400 m in height, lava flow has long ago eradicated any interior features within Vendelinus' structure. Its old walls give mute testimony to later impact events, which you can see when viewing crater Holden on the south shore; much larger Lame on the northeast edge; and sharp Lohse northwest. Note how differently its features look in this light!

For a telescopic challenge, continue south to relocate previous study Petavius on the southern terminator (Fig. 17.6). Just beyond its east wall,

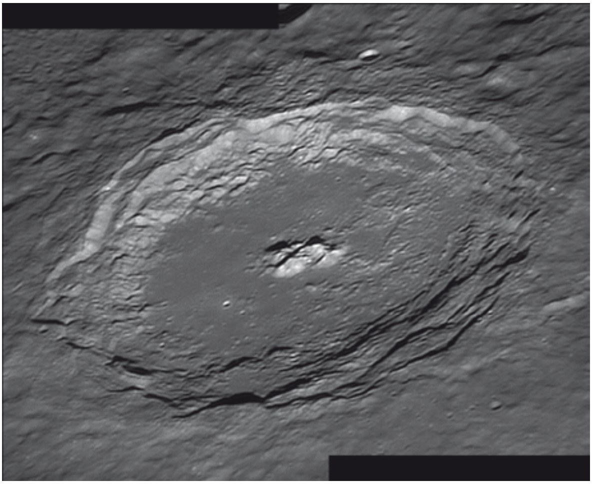


Fig. 17.5 Langrenus – Damian Peach.

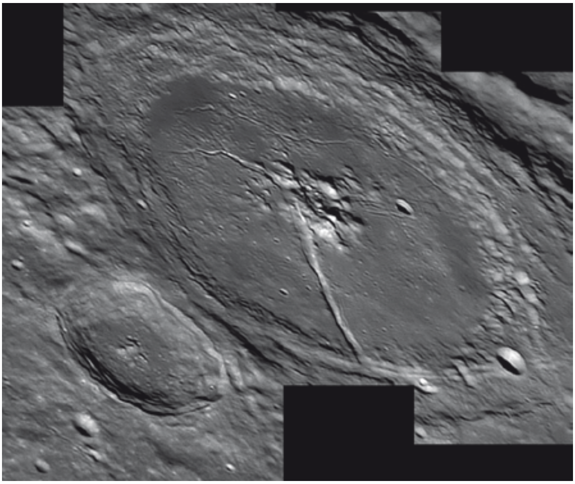


Fig. 17.6 Petavius – Damian Peach.

look for a ridge that extends from north to south separated by darkness from Petavius. This is Palitzsch, a very strange, gorge-like formation that looks as if it was caused by a meteor plowing through the Moon's surface. Palitzsch's true nature was not known until 1954 when Patrick Moore resolved it as a "crater chain" using the 25″ Newall refractor at Cambridge University Observatory. While you are admiring Petavius and its branching rima, keep in mind this 80 km long crack is a buckle in the lava flow across the crater floor. Congratulations on capturing Lunar Day Sixteen!

CHAPTER 18

LUNAR DAY SEVENTEEN

There are nights when the wolves are silent and only the Moon howls.

George Carlin

Tonight, let us first take a quiet journey on the lunar surface as we view an area highlighted by sunset – the Caucasus Mountains (Figs. 18.1 and 18.2). Easily spotted in both binoculars and small telescopes, this range towers some 5,182 m above the surrounding plains – making its peaks as high as Mount Ararat. As the shadows throw the rugged terrain into bold relief, take the time to enjoy watching nightly as the terminator moves along the

Fig. 18.1 Seventeen day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_18,

Fig. 18.2 Montes Caucasus – Greg Konkel.

lunar surface. As time passes you can follow the mountain's shadows shortening and details emerging. It is a very peaceful experience…

As Mare Crisium slowly disappears into the shadows, let us Moon walk to a lunar challenge crater – Macrobius (Fig. 18.3). You will find it just northwest of the Crisium shore. Spanning 64 km in diameter, this Class I impact crater drops to a depth of nearly 3,600 m – about the same as many of our Earthly mines. Its central peak rises back up, and at 1,100 m it may be visible as a small speck inside the crater's interior. Power up and look at how steep its crater slopes are. Can you spot the smaller impact crater Macrobius O to the southeast and conjoining crater Tisserand to the east? Check out how the sunlight highlights the walls. In this particular light you can see how high and terraced they really are! Look for the impact of Macrobius C to the southwest.

Where Mare Fecunditatis and Mare Tranquillitatis meet is young Taruntius (Fig. 18.4). Although we viewed it during a Four Day Moon, let us take a closer look tonight. Formed in the Copernician era and perhaps only about a billion years old, this 58 km wide ring is really eroded considering how young it is compared with other craters. One of the reasons for looking during the waning phase is because you will stand a better chance at spotting

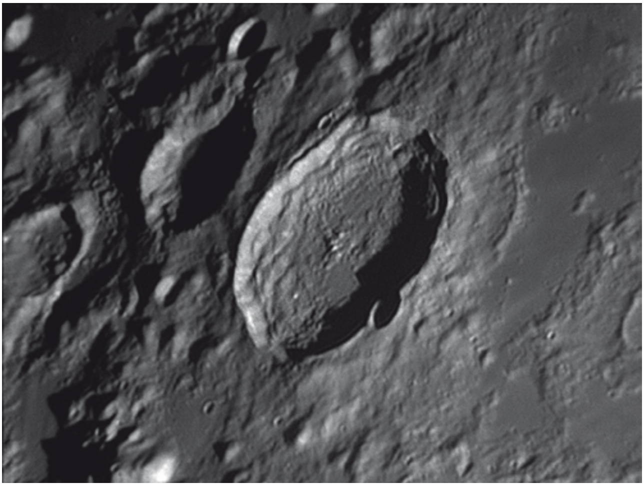


Fig. 18.3 Macrobius – Damian Peach.

Fig. 18.4 Taruntius – Damian Peach.

some of the many "ghost rings" that accompany Taruntius and the unusual amounts of lava floodings to the southwest as well. If the lighting is right, apply high magnification in a telescope, and you will notice that its floor is

Fig. 18.5 Guttenburg and Capella – Wes Higgins.

fractured from an upheaval and the northwest rim has been broken by Cameron crater. Did you notice a slightly darker area around Cameron? Good for you for being observant! Chances are this is a deposit of volcanic ash from a small vent. Can you spot the other just south of the central peak?

Scan Mare Fecunditatis about one-third its width from west to east for another challenge we have studied on Lunar Day Five – but in a different light – the twin Messier craters (Fig. 18.5). Can you spy the long ray of ejecta that points to the west? If so, follow it… Messier's ray will lead you to Rimae Guttenburg, a network of several large parallel rilles that run about 322 km long and are oriented southeast to northwest. Although they will still be slightly overlit at this time, you can still follow them to the more southerly conclusion of crater Guttenburg itself. Guttenburg was formed in the Pre-Imbrian period and could be as much as four billion years old. In binoculars, it has a very irregular shape, but a telescope reveals the true damage. Power up and look for steep slopes supporting Gutenberg A and C to the southwest and what is left of the few high walls crushed by the impact that caused crater Gutenberg E to the east. Its floor is rather flat, but if you look slightly off center and the lighting is right, you will catch some grooves and eroded mountaintops that still give this battered, old crater some character!

Moon walk east for the broken rim of crater Goclenius (Fig. 18.6). Like a shattered life preserver floating on the western shore of Mare Fecunditatis, Goclenius pushes up its own rima ahead of it just like it was riding a wave. Spanning about 56 km in diameter and dropping down about 1,500 m below the surface, look for the peak of Mon Goclenius Epsilon sporting the sunset to the northeast. The difference in shadow play should help you to see just how high the walls are to the north where satellite crater Glocenius B intrudes, along with an unusual groove in the crater interior and an off-center mountain in the floor, too. Awesome job on Lunar Day Seventeen!

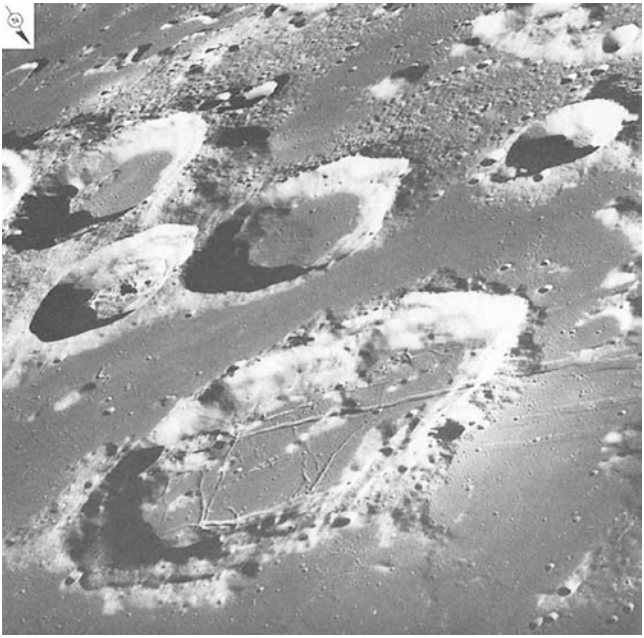


Fig. 18.6 Goclenius – Apollo Image (NASA).

CHAPTER 19

LUNAR DAY EIGHTEEN

> ***That orbed maiden, with white fire laden,***
> ***Whom mortals call the Moon…***
>
> Percy Bysshe Shelley

Tonight the Moon gives a wonderful opportunity to revisit ancient landmark crater Posidonius (Figs. 19.1 and 19.2). Did you notice crater Charconac to Posidonius' southeast? Under this lighting you can see that it is far older than Posidonius itself and its steep slopes are obliterated by Posidonius to

Fig. 19.1 **Eighteen day Moon – Peter Lloyd.**

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_19,

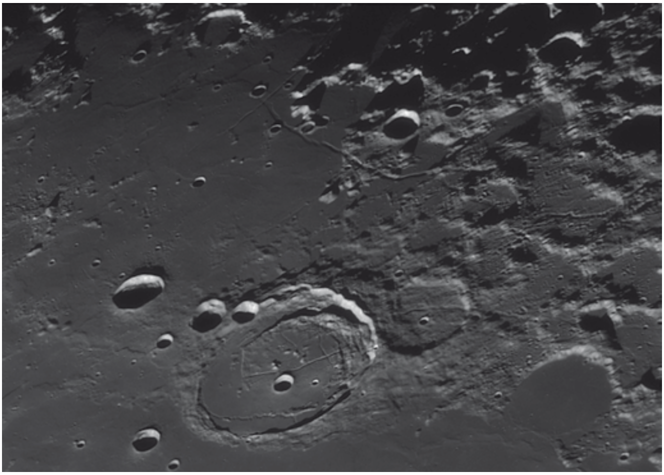


Fig. 19.2 Posidonius Region – Mike Wirths (LPOD).

the northwest. Charonac is just one of those features we do not usually study – although we should. At an estimated 4 billion years old, it sprang to life in the Pre-Imbrian period, and one look at its distressed floor tells of a violent life. Look for craterlet Chacornac A and Rimae Chacornac inside of its 50 km diameter expanse! Now, continue southward from Posidonius and Charconac along the edge of Mare Serenitatis to catch partially open crater Le Monnier. This ruined ring greatly resembles a smaller version of Sinus Iridum, but only measures around 60 km in diameter. Far younger than anything around it, Le Monnier was formed in the Nectarian geological period. What happened to the west wall? Who knows, but what we can see spells of collapse, and the lava of Mare Serenitatis has flowed in. What is so special about Le Monnier? It contains the remains of the Luna 21 mission – forever awaiting salvage in the gray sands along Le Monnier's southern edge. Be sure to look again for Dorsa Smirnov – better known as the "Serpentine Ridge" nearby.

Let us head a little more "off the beaten path" as we look for another challenge crater (Fig. 19.3). To help you along the way, you will first need to identify the three rings of Theophilus, Cyrillus, and Catherina. To the southwest you will see a crater very similar in shape and size.

Fig. 19.3 Sacrobosco – Wes Higgins.

Power up, and let us explore Sacrobosco. Named for the English mathematician "John of Holywood" (Johannes Sacrobuschus), this class III crater spans 98 km and drops down to a floor level of 2,800 m – making those crater walls about as high as the West Ridge of Mt. Everest. On its troubled floor you will see the evidence of three far newer impacts: Crater C to the north which spans 13 km and drops down 2,630 m; Crater A to the west which is 18 km in diameter and 1,830 m deep; and Crater B to the east at 15 km wide and 1,210 m deep. While these strikes are fascinating…look again: Sacrobosco itself is imprinted over the top of a far older crater.

Our last crater for this evening almost triangulates with Catherina and Sacrobosco (Fig. 19.4). You will find it the same distance to the southeast – and with a very prominent central peak. Piccolomini is a 85 km diameter wide, standout lunar feature – mainly because it is a fairly fresh impact crater. Its walls have not yet been destroyed by later impacts and the interior is nicely terraced. Power up and look carefully at the northern interior wall where perhaps a rock slide has slipped toward the crater floor. While the floor itself is fairly featureless, the central peak is awesome. Rising up a minimum of 2 km above the floor, it is even higher than the White Mountains in New Hampshire!

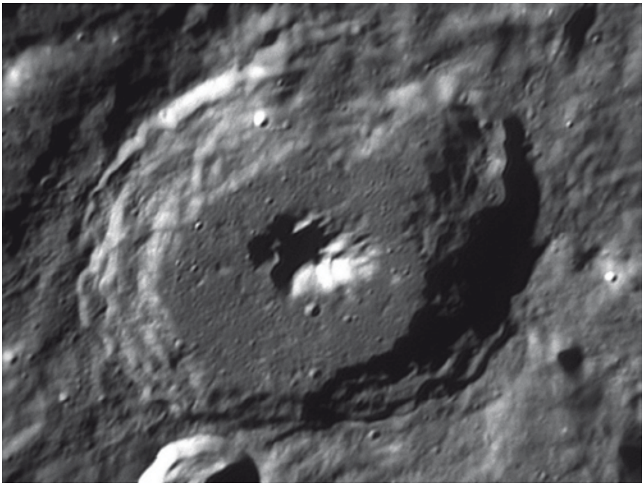


Fig. 19.4 Piccolomini – Damian Peach.

CHAPTER 20

LUNAR DAY NINETEEN

And be their rest unmov'd
By the white Moonlight's dazzling power:
None, but the loving and belov'd,
Should be awake at this sweet hour.

Thomas Moore

As you begin tonight, enjoy sunset over the Caucasus Mountain Range (Figs. 20.1 and 20.2). Can you see the shadow play in the incredible Alpine Valley to the west? Look for a long, narrow scar creasing the foothills between Mare Frigoris and Mare Imbrium. Running a distance of 177 km and ranging between 1.6 and 21 km wide, this gash through the Montes Alpes includes tiny crater Trouvelot to its south. Stable conditions at high power will also reveal a narrow fissure on its floor. Our lunar challenge feature for this evening is prominent enough to be spotted in binoculars, but is well worth the time to power up with the telescope and explore. We glimpsed it first on Lunar Day Seven and we are about to return for some in depth study. Starting with the recognizable slash of the Vallis Alpes, follow the mountain trail south to the double strike of crater Cassini.

Named for Giovanni Cassini, this smashing old Class V crater rises above the lunar topography by 1,067 m, making its shallow walls alone as tall as the Catskill Mountains (Fig. 20.3). It covers about 57 km of lunar landscape in its rough diameter, and the crater floor is 1,240 km below the surface. At one time Cassini may very well have had a central peak, but something obliterated it when Cassini A was formed. This double-stepped feature is 57 km in diameter and drops down an additional 2,830 m. While both Cassini and Cassini A are Lunar Club challenges, look carefully for yet another interior crater. Small crater B is often referred to as the "Washbowl" for its almost perfect concave structure.

Now, Moon walk to where the Caucasus Mountains meet the shore of Mare Frigoris for ancient landmark crater Artistoteles (Fig. 20.4). We have visited this area before on Lunar Day Six, but the scene is much differently highlighted.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_20,

Fig. 20.1 Nineteen day Moon – Peter Lloyd.

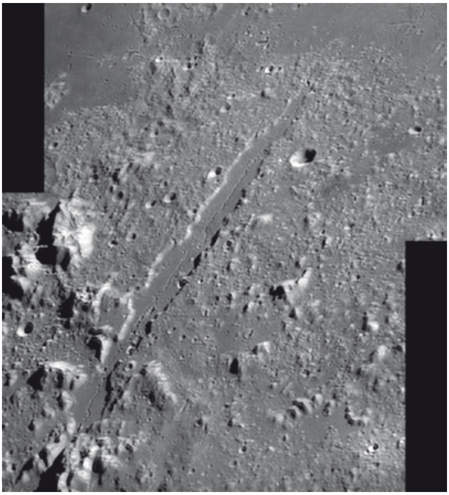


Fig. 20.2 Vallis Alpes – Damian Peach.

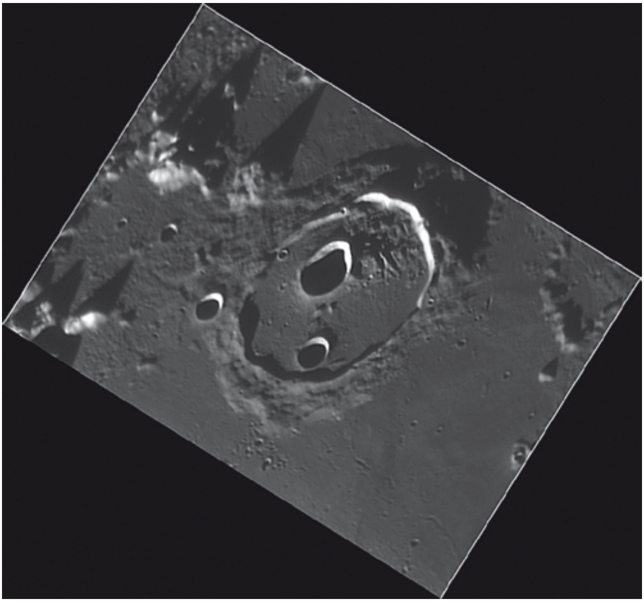


Fig. 20.3 Cassini – Wes Higgins.

Fig. 20.4 Aristoteles and Eudoxus Region – Greg Konkel.

With different relief, we can see companion crater Mitchell's structure far more clearly – and how the landscape upsweeps to meet Aristoteles' eastern wall. Between Aristoteles and southern Eudoxus lay the remains of several other much older, unnamed crater remains. All that is left is nothing more than a few low foothills that give us a clue to their presence. Much younger Eudoxus came about during the Coperican geological time period, making it some 3 billion years younger than its surroundings. Look closely at its 70 km expanse, for in this lighting you will notice it has very steep and battered slopes, held up in part by satellite crater Eudoxus B to the north and Eudoxus G and A to the northeast. Further south you will encounter the remains of crater Alexander – named for "Alexander the Great" – King of Macedonia. There is very little left of royalty here, though, except age. This 85 km wide, triangular-shaped formation is every bit of 4 billion years old and lava flow and erosion has taken its toll.

Let us return to the southern shadows to the area of the now hidden Theophilus, Cyrillus, and Catherina (Fig. 20.5). How can you find it if it is gone? Use the opposite rings of Ptloemaeus, Alphonsus, and Arzachel. Our challenge crater lines up with the centermosts, is due west, and is a prominent ring with a rather ordinary floor… but let us take a look at Abulfeda! We glimpsed it on Lunar Day Seven, and now we are back to explore.

Fig. 20.5 Abulfeda – Wes Higgins.

This charming crater was named for Prince Ismail Abu'l Feda, who was a Syrian geographer and astronomer born in the late thirteenth century. Spanning 62 km, its rocky walls show what once was a great depth, but the crater is now filled-in by lava, and drops to a mere 3,110 m below the surface. While it does not appear very large to the telescope, that is quite big enough to entirely hide Mt. Siple – one of the highest peaks in Antarctica! If conditions are steady, power up and take a look at Abulfeda's smooth-appearing floor. Can you see many smaller strikes? If the lighting is correct, you might even spot one far younger than the others!

Now, let us Moon walk a bit further south for another crater we have studied before – Gemma Frisius (Fig. 20.6). Tonight, we are going to take

Fig. 20.6 Gemma Frisius – Bob Pilz.

a good, close-up look. Formed during the Pre-Imbrian epoch, this battered crater could be well over 4 billion years old. At high magnification you can really begin to assess all the damage this crater formation has undergone in its lifetime, such as the impacts of the G and H craters on the northwest wall – as well as the D crater on the western frontier and the large break of Gemma Frisius A on the southeast corner. Even though its floor remained essentially flat, its mountain peak is not central. Maybe it was shifted when crater Goodacre formed to the northeast?

Let us go for some more challenging features by locating another region which we have visited before on Lunar Day Six – Stofler and Faraday (Fig. 20.7). With different lighting, we now find crater Fernelius a bit more noticeable. Spanning some 66 km wide, this broken circular formation is overlapped by Stofler and was quite probably formed during the Pre-Imbrian geological period. Its satellite A crater resides to the west, but the larger crater you see to the northeast is Kaiser. Look closely and it will appear as if Fernelius' floor elevation appears to be higher than its surroundings. To the west of Furnelius you will spy a small triple ring smash-up which consists of northern Miller, southern Nasireddin, and western Huggins… all part of the tangled mess which helps to support

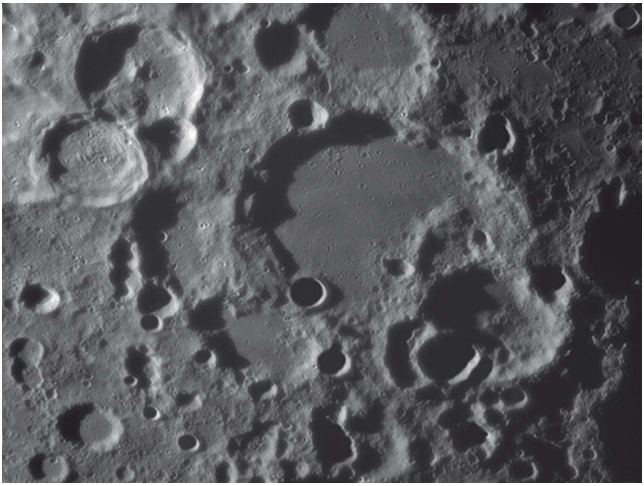


Fig. 20.7 Stofler and Faraday – Bob Pilz (LPOD).

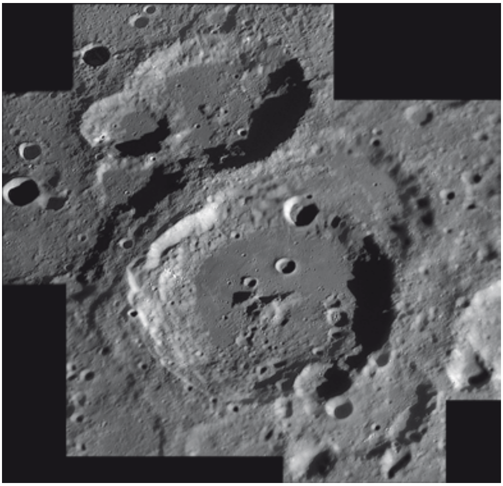


Fig. 20.8 Maurolycus Region – Damian Peach.

the Stofler formation as well. To the south of Stofler and Faraday, you will see evidence of another multiple strike area – a much larger one. This is the conglomeration of Licetus and the four-part Heraclitus. Both formed in the Pre-Imbrian period, and while you will find they share common slopes and walls, there are also several areas where later impacts have crushed and destroyed original structure.

When you are done, journey further south and return to previous study Maurolycus (Fig. 20.8). Look at how differently the light allows us to see it now! Where it once looked like it had a flat floor, we can now see a mesa hiding along the southwest wall. Look at how much high in elevation 56 km wide Buch is to the east… Or just how thick that wall between it and Barocius really is! Maurolycus' multiple structure changes with the lighting, and that is why observing during a different phase can be so rewarding. Features you normally would not notice such as the deformed Clairaut, deep little Breislak, and even steep-sided old Baco now hold their own in a jumbled landscape. Congratulations on all your hard work through Lunar Day Nineteen!

CHAPTER 21

LUNAR DAY TWENTY

Fly not yet; 'tis just the hour
When pleasure, like the midnight flower
That scorns the eye of vulgar light,
Begins to bloom for sons of night,
And maids who love the Moon.
'Twas but to bless these hours of shade
That beauty and the Moon were made;
'Tis then their soft attractions glowing
Set the tides and goblets flowing
Oh ! stay, -oh ! Stay,
Joy so seldom weaves a chain
Like this to-night, that, oh! 'tis pain
To break it's links so soon…

Thomas Moore

And now for late night Moon rise…

In 1961, US President John F. Kennedy launched the country on a journey to the Moon as he made one of his most famous speeches to Congress (Figs. 21.1 and 21.2):

> **I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind or more important for the long-range exploration of space…**

Tonight it is possible to see another landing area – that of Apollo 15 (Fig. 21.3). Locate landmark crater Plato and look due south past the isolated Spitzbergen Mountains to landmark Archimedes. Spend a few moments enjoying Archimedes' well-etched terraced walls and textured bright floor. Then look east; look for the twin punctuations of Aristillus and the more northern Autolycus. South of Aristillus note the heart-shape of

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_21,

Fig. 21.1 Twenty day Moon – Peter Lloyd.

Fig. 21.2 JFK (NASA).

Fig. 21.3 Apollo 15 Landing Area (NASA).

Paulus Putredinus. There you will see Mons Hadley once again – very well highlighted and alone on its northeastern bank. Power up to see the Mons Hadley area includes a cove known as the Hadley Delta, and there on that plain just north of the brilliant mountain peak is where Apollo 15 touched down. Impressive Mons Hadley measures about 24 × 48 km at its base and reaches up an incredible 4,572 m. If this mountain was indeed caused by volcanic activity on the lunar surface, this would make it comparable to some of the very highest volcanically caused peaks on Earth, such as Mount Shasta or Mount Rainer. To its south is the secondary peak Mons Hadley Delta – the home of the Apollo 15 landing site just a breath north of where it extends into the cove created by Palus Putredinus.

Are you ready to explore some more history? Then tonight have a look at the Moon and reidentify Alphonsus – it is the centermost in a line of rings which looks much like the Theophilus, Cyrillus, and Catharina trio (Fig. 21.4). We first spied it on Lunar Day Seven. Alphonsus is a very old, Class V crater which spans 118 km in diameter and drops below the surface by about 2,730 m and contains a small central peak. Partially flooded, Eugene Shoemaker had made of study of this crater's formation and found dark haloes on the floor. Again, this could be attributed to volcanism and Shoemaker believed them to be maar volcanoes, and the halos to be dark ash. Power up and look closely at the central peak, for not only did Ranger

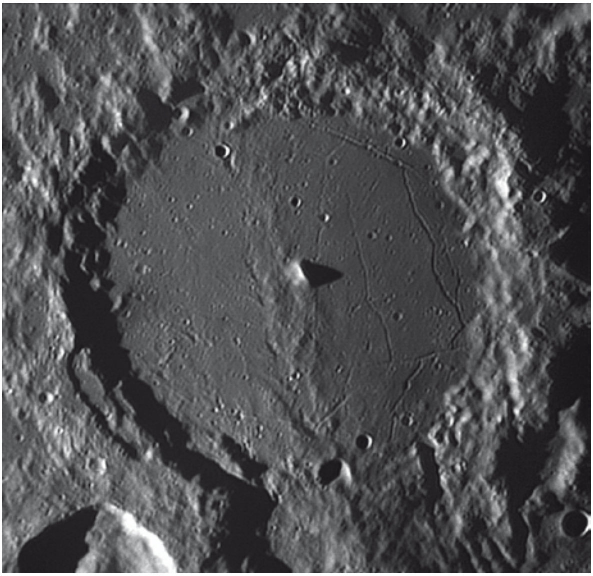


Fig. 21.4 Alphonsus – Damian Peach.

9 hard land just northeast, but this is the only area on the Moon where an astronomer has observed a change and backed up that observation with photographic proof.

On November 2, 1958 Nikolai Kozyrev's long and arduous study of Alphonsus was about to be rewarded (Fig. 21.5). Some 2 years earlier Dinsmore Alter had taken a series of photographs from the Mt. Wilson 60″ reflector that showed hazy patches in this area that could not be accounted for. Night after night, Kozyrev continued to study at the Crimean Observatory – but with no success. During the process of guiding the scope for a spectrogram the unbelievable happened – a cloud of gas containing carbon molecules had been captured! Selected as the last target for the Ranger photographic mission series, Alphonsus delivered 5,814 spectacular high-resolution images of this mysterious region before Ranger 9 splattered nearby. Capture it yourself tonight…

Feeling adventuresome? Then head for the deep south and identify 117 km wide Moretus near the terminator (Fig. 21.6). Easily spotted in

Fig. 21.5 Ranger 9 Alphonsus image (NASA).

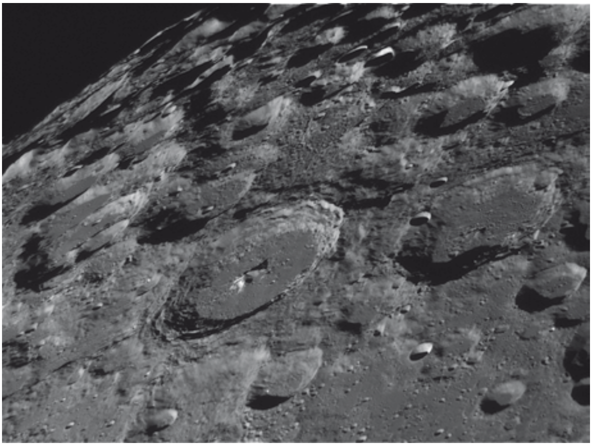


Fig. 21.6 Moretus – Wes Higgins.

binoculars, you will pick up the very noticeable central peak with good reason… At 2,700 m high, it is standing as tall as Mount Paekdu in Korea! Formed in the Eratosthenian geological period, Moretus could have held the expanse of Hadrian's Wall it is so large – yet it barely shows when lighted by sunrise instead of sunset. Awesome job on 20 days of good work!

PART IV

LAST QUARTER

CHAPTER 22

LUNAR DAY TWENTY-ONE

How like a queen comes forth the lonely Moon
From the slow opening curtains of the clouds
Walking in beauty to her midnight throne!

George Croly

Tonight we start with a look at sunset over one of the most often studied and mysterious of all craters – Plato (Figs. 22.1 and 22.2). Located on the northern edge of Mare Imbrium and spanning 95 km in diameter, Class IV Plato is simply a feature that all lunar observers check because of the many reports of unusual happenings. Over the years, mists, flashes of light, areas

Fig. 22.1 Twenty-one day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_22,

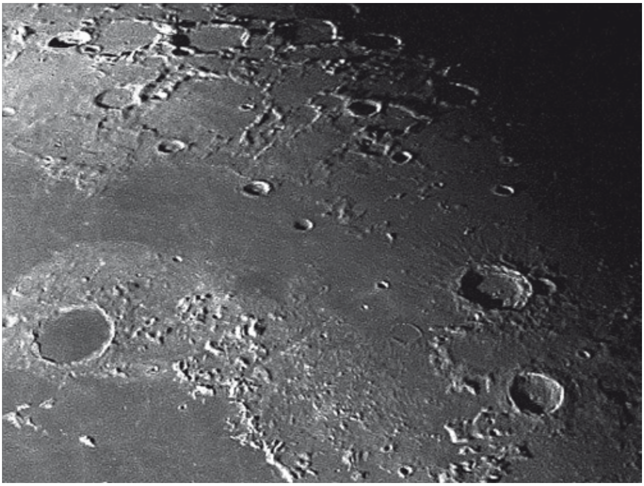


Fig. 22.2 Plato – Shevill Mathers.

of brightness and darkness, and the appearance of small craters have become a part of Plato's lore. On October 9, 1945 an observer sketched and reported "a minute, but brilliant flash of light" inside the western rim. Lunar Orbiter 4 photos later showed where a new impact may have occurred. While Plato's interior craterlets average between less than one and up to slightly more than 2 km in diameter, many times they can be observed – and sometimes they cannot be seen at all under almost identical lighting conditions. No matter how many times you observe this crater, it is ever changing and very worthy of your attention!

Journey southward now, and south of landmark Eratosthenes for an area known as Sinus Aestuum – the "Bay of Billows" (Fig. 22.3). Its very smooth floor is curiously riddled to the north and east by dark stains. At one time Sinus Aestuum may have been completely submerged in basaltic lava across its 290 km expanse. Later the molten rock sank to the Moon's interior before it could do much more than melt away outer layers and older surface features. However, recent studies have shown mixing in the dark mantle terrain, as well as some areas which are spectrally different – dominated by what could be crystallized beads.

While at lower powers Sinus Aestuum seems to have very little to keep your interest, try magnifying and really take a look (Fig. 22.4). Just to the

Fig. 22.3 Sinus Aestuum – Greg Konkel.

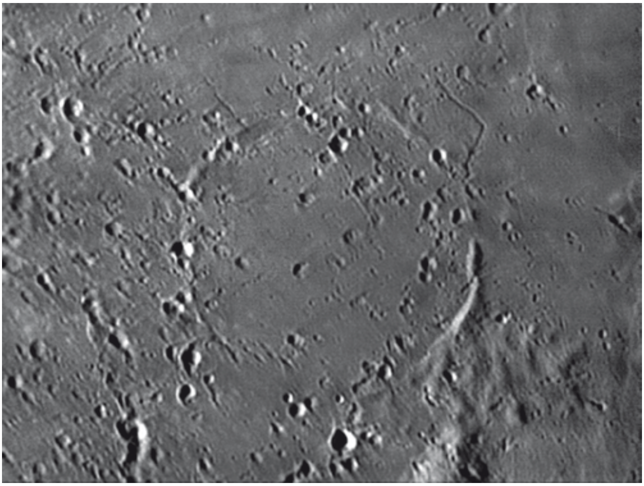


Fig. 22.4 Stadius – Damian Peach.

southwest of Eratosthenes is the wonderful ruins of crater Stadius. This one is a real ghost! Stadius was form in the lower Imbrian period, so it is not really that old, but the lava flow of Mare Insularum has pretty much taken it over. Very little remains that can be measured of its walls, but there

are enough to throw some shadows to the northeast, and you can see the vague outline of companion crater Stadius A to the west. Look for all kinds of little craterlets dotting the floor; especially resolvable is Stadius K to the south and Stadius L, which appears lengthened to the southwest.

While you travel across the plains of Sinus Aestuum, look for the Rimae Bode and an area which may be lighter because it contains a mixing of volcanic glasses and black beads (Fig. 22.5). Crater Bode is nothing more than the tiny dark well along the eastern shore! The long rille in the center has no name, but if the shadows allow you to follow it south, you will end in several lava dome regions that belong to crater Gambart. This is just north of the

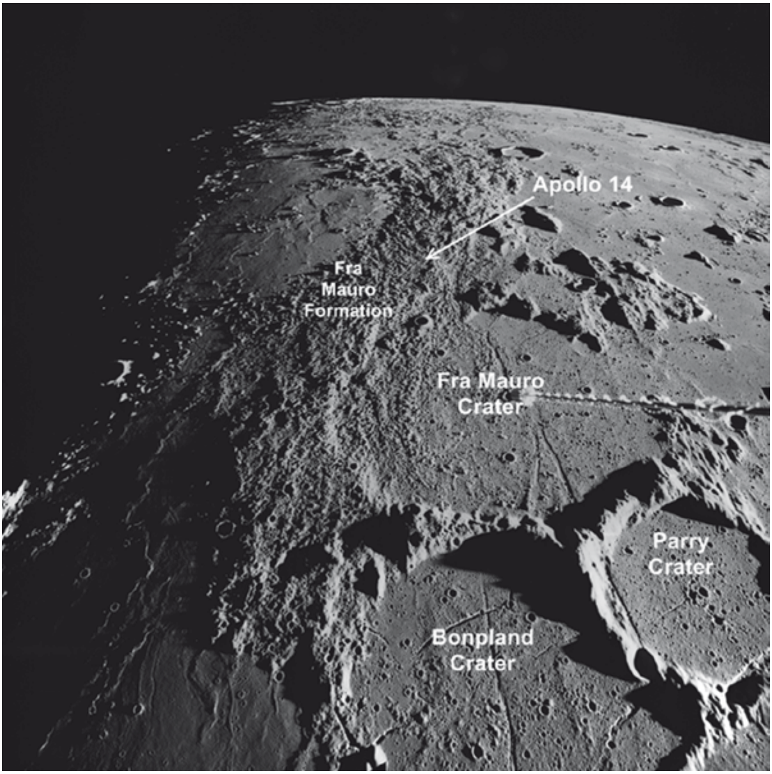


Fig. 22.5 Fra Mauro Region – Apollo Image Archive (NASA/ASU).

Fra Mauro region and also home to the Surveyor 2 landing area. Just a bit more south will bring you to Fra Mauro and – as craters go – 3.9 billion year old Fra Mauro is on the shallow side and spans 95 km. At some 730 m deep, standing at the foot of one of its walls would be like standing at the bottom of the Grand Canyon… Yet, time has so eroded this crater that its west wall is completely missing and its floor is covered with fissures. Even though ruined Fra Mauro seems like a forbidding place to land a manned mission, it remained high on the priority list because it is geologically rich. Ill-fated Apollo 13 was to land in a formation north of the crater which was formed by ejecta belonging to the Imbrium Basin – material which had already been mapped telescopically. By returning samples of this material from deep within the Moon's crust, scientists would have been able to determine the exact time these changes came about. As you view Fra Mauro tonight, picture yourself in a lunar rover traversing this barren landscape and viewing the rocks thrown out from a long-ago impact. How willing would you be to take on the vision of others and travel to another world?

> I don't know if there are men on the Moon, but if there are they must be using the Earth as their lunatic asylum.
>
> George Bernard Shaw

When you are ready, journey along the south shore of Mare Nubium (Fig. 22.6). The thin, light ring you encounter will be past study, Pitatus.

Fig. 22.6 Clavius region – Peter Lloyd.

Further south you will discover two mountain-walled plains whose exposed floors will show bright western and dark eastern walls. These twins are Wurzelbauer to the west and Gauricus to the east. Of course, one of the most impressive of all lunar features is also highlighted to the south – landmark crater Clavius. Within Clavius you will see a near-spiraling curve of progressively smaller craters beginning with Rutherford breaking the southeast wall. Steady seeing and high power will go on to reveal numerous smaller craters populating its broad floor. Be sure to check out crater Porter to the northeast echoing Rutherford. After delighting in Clavius' extraordinary interior detail, use it to locate other interesting features. Between its southwest wall and the terminator lies another major (but smaller) mountain-walled plain known as Blancanus, which may be deeply shadowed. Return to Clavius and head about the crater's width northwest for pentagonal Longomontanus for another look, too! Can you spot on the edge crater Klaproth further south?

Moon walk south of the mighty Clavius to take a closer look at new study, Blancanus (Fig. 22.7). Approximately 109 km in diameter, this crater looks pretty blank compared with its grander neighbor. But, power up to check out its high, terraced walls. Formed by an impact during the Nectarian epoch, you will see steep slopes cut off by shadows to the east where

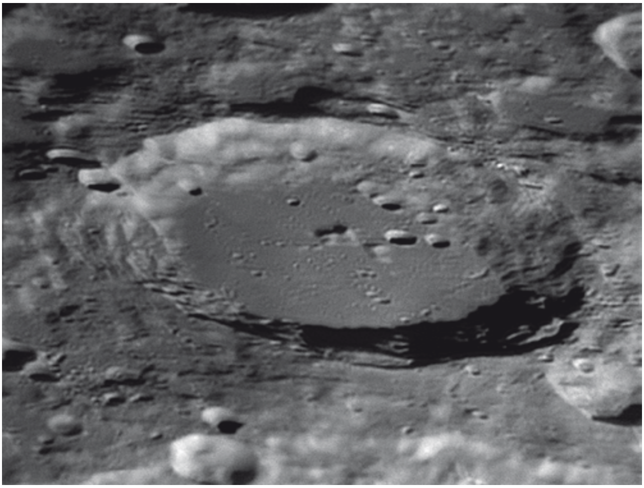


Fig. 22.7 Blancanus – Damian Peach.

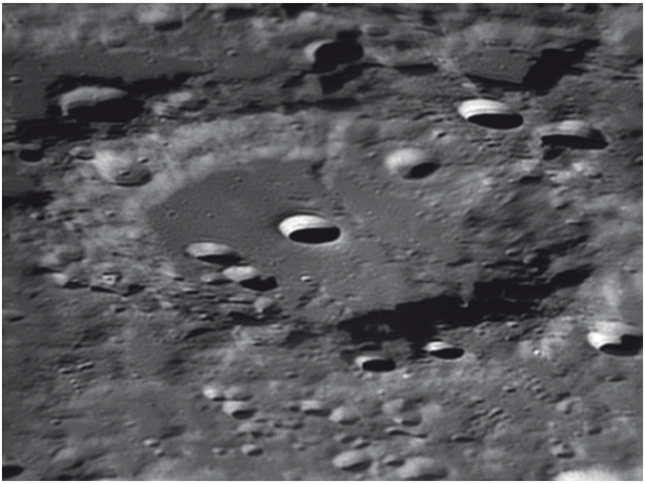


Fig. 22.8 Scheiner – Damian Peach.

Blancanus D intrudes and clever wells of darkness in the southwest where Blancanus C resides. Notice how flat the floor is and see if you can resolve a small group of five craterlets in the southeast or the challenging triple mountain peak.

Another crater overlooked to the west of Clavius is Scheiner (Fig. 22.8). This awesome 114 km wide hole drops a neat 4,000 m below the lunar surface. Formed in the Pre-Nectarian period, you will see it shares a partial wall with Clavius' west slope, but has its own steep formations to the east as evidenced by the shadows. Look for a crested ridge that crosses its flat floor along with interior hills and craters, too. Fantastic job on Lunar Day Twenty-One!

CHAPTER 23

LUNAR DAY TWENTY-TWO

The moving Moon went up the sky.
And nowhere did abide;
Softly she was going up,
And a star or two beside…

Samuel Taylor Coleridge

Tonight let us begin Moon walking by returning to a previous study on Lunar Day Nine – the Riphaeus Mountains (Figs. 23.1 and 23.2). Just southwest of landmark crater Copernicus. Northeast of the range is another smooth floored area on the border of Oceanus Procellarum. It is here that Surveyor 3 landed on April 19, 1967.

Fig. 23.1 Twenty-two day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes*, Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_23,

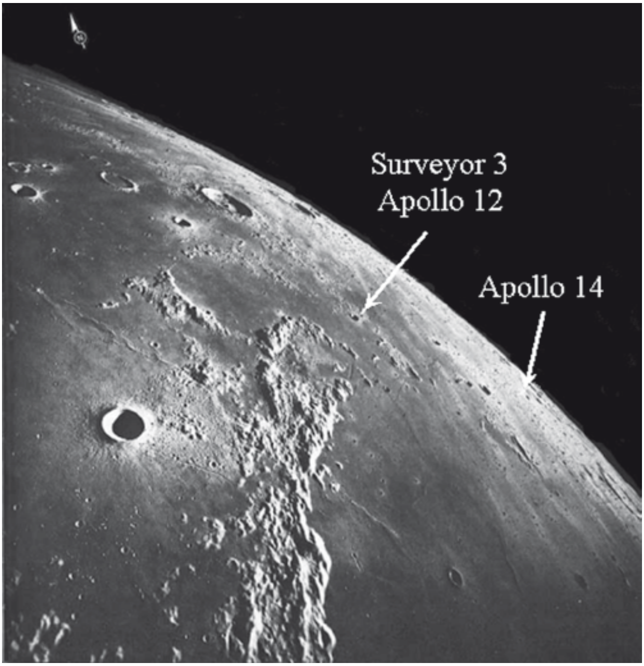


Fig. 23.2 Landing area (NASA).

After bouncing three times, the probe came to rest on a smooth slope in a subtelescopic crater (Fig. 23.3). As its on-board television monitors watched, Surveyor 3 extended its mechanical arm with a "first of its kind" miniature shovel and dug to a depth of 18 inches. The view of subsoil material and its clean-cut lines allowed scientists to conclude that the loose lunar soil could compact. Watching Surveyor 3 pound its shovel against the surface, the resulting tiny "dents" answered the crucial question. The surface of a mare would support the landing of a spacecraft and exploration by astronauts.

Return to Copernicus again, and this time head north for prominent little Class I Pytheas (Fig. 23.4). Like a bright little ring standing alone in the southern half of dark Mare Imbrium, this high contrast feature will catch the eye. Just a bit more to the north is Lambert. Although it is marginally larger, notice how much darker it appears. Lambert stands on a great lunar ridge winding its way up from grand Eratosthenes, 420 km southeast, and

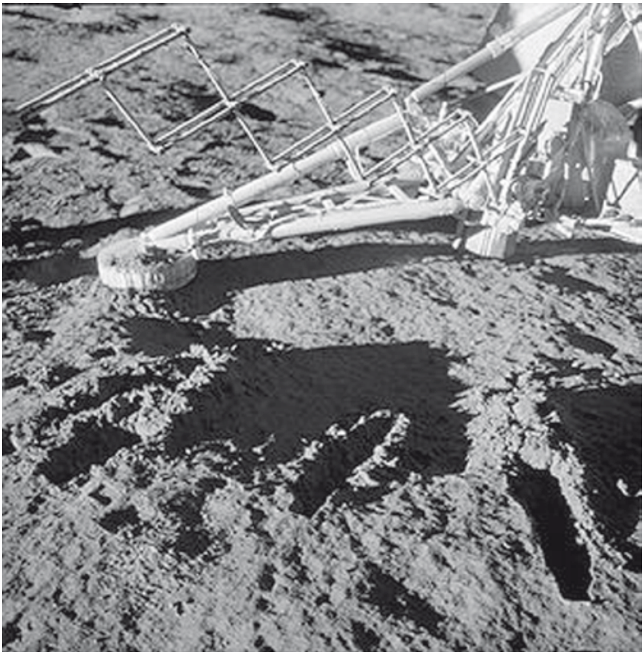


Fig. 23.3 Surveyor 3 deploying shovel (NASA).

Fig. 23.4 Pytheas – Damian Peach.

continues on for another 240 km. As you observe, you may notice the ridge is just slightly lighter than the background. While Lambert is not as grand as its neighbor to the east – Timocharis, you might catch the sunlight reflecting off the hollowed-out remains of its central peak. It is believed that this is a collapsed area of a "rebound dome." A formation created when the crater formed during a particularly nasty impact. Can you see the bright point of crater Euler to the west? Euler is roughly the same size as Lambert and Pytheas – but has a noticeably higher central peak. If the timing is right, you may be able to see the peak of Mons Vinogradov peeking above the terminator to the west.

Now, Moon walk back to Copernicus and put some power its way (Fig. 23.5)! Through steady skies, high magnification easily brings out its central mountain peaks, but look closely at that east wall. Can you resolve the small A crater lodged within it? The shock region around Copernicus' exterior is equally fascinating with its runneled appearance. At the limits of these ramparts, you will see the double impact of tiny crater Fauth to the south, and Gay-Lussac to the north. If conditions are good, you might also spot the Gay-Lussac Rima running diagonally southwest to northeast tangential to Copernicus. About a Copernicus-width southwest look for impressive, but smaller impact crater Reinhold.

Fig. 23.5 Copernicus Crater (Wikipedia).

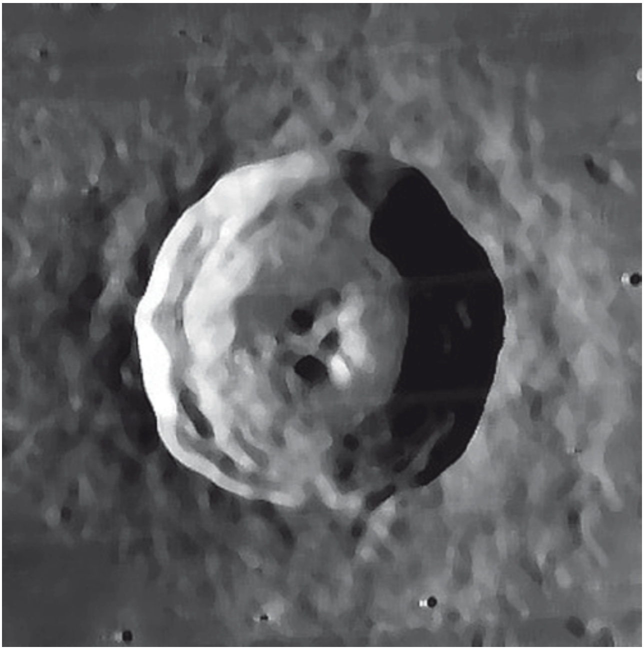


Fig. 23.6 Lansberg – Clementine.

Now let us crater hop… To the southeast of Reinhold, you will spot very similar crater – Lansberg (Fig. 23.6). At this crater's southern boundary will begin a series of low ridges which may be the remains of extinct crater walls. Almost directly in the center of these is the landing area for the Luna 5 mission. If you continue southeast about the same distance into the smooth sands of Mare Insularum, you will be in the landing area for Surveyor 3 and Apollo 12.

When you are done, let us venture toward the south shore of Palus Epidemiarum to have a high power look at crater Capuanus – an area which we first glimpsed on Lunar Day Nine (Fig. 23.7). Named for Italian astronomer Francesco Capuano di Manfredonia, this 60 km wide crater boasts a still-tall southwest wall, but the northeast one was destroyed by lava flow. At its highest, it reaches around 1,900 m above the lunar surface, yet drops to no more than 300 m at the lowest. Look for several strikes along the

Fig. 23.7 Capuanus – Damian Peach.

crater walls as well as more evidence of a strong geological history. To its north, revisit the Hesiodus Rima…a huge fault line extending 300 km across the surface. What a great job you have done through Lunar Day Twenty-two!

CHAPTER 24

LUNAR DAY TWENTY-THREE

What counsel has the hooded Moon
Put in thy heart, my shyly sweet,
Of Love in ancient plenilune.
Glory and stars beneath his feet -- -
A sage that is but kith and kin
With the comedian Capuchin?
Believe me rather that am wise
In disregard of the divine.
A glory kindles in those eyes
Trembles to starlight. Mine, O Mine!
No more be tears in Moon or mist
For thee, sweet sentimentalist.

James Joyce

The slender, silent Moon is once again lit with Earthshine (Fig. 24.1). As we stand here in the moments before dawn, we behold the "New Moon in the Old Moon's Arms." We have almost come full circle, have not we? There is still more to learn…

Before daylight comes, we journey to the lunar surface in search of crater Foucault (Fig. 24.2). To find it, head north to landmark Sinus Iridum and locate the punctuation of crater Bianchini in the center of the ring of Juras Mountains. Just northeast, and near the shore of south-eastern Mare Frigoris, look for a bright little circle – crater Foucault. Physicist Jean Foucault played an instrumental role in the creation of today's parabolic mirrors. His "Foucault knife edge test" made it possible for opticians to test mirror curves for optical excellence during the final phases of shaping before metallization. Thanks to Foucault's insight, we can turn our telescopes on difficult objects such as double stars…or tiny craters!

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_24, © Springer Science+Business Media, LLC 2010

Fig. 24.1 Twenty-three day Moon – Peter Lloyd.

Fig. 24.2 Bianchini – Damian Peach.

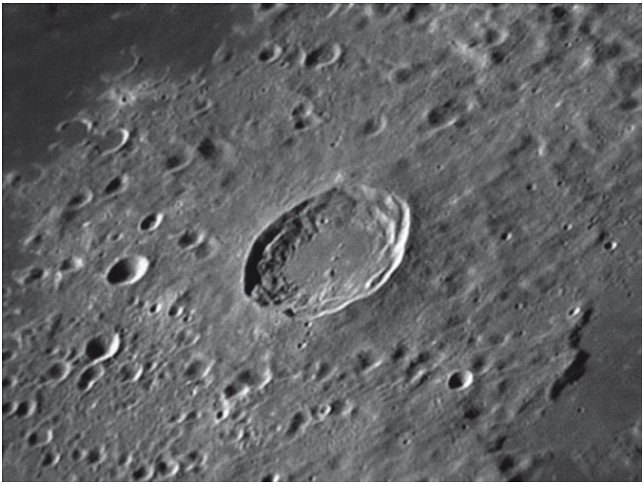


Fig. 24.3 Mairan – Damian Peach.

To the west of Sinus Iridum, you will see another outstanding crater in the highlands – Mairan (Fig. 24.3). This 39 km diameter impact crater has a very dark floor which helps it stand out against the lighter background and the shadows pick up the steep walls. Power up in a telescope and take a look at its slopes where you will discover many little craterlets dotting the terraces and steps. At first glance in binoculars, or a low power, its wide floor might seem rather plain, but if you magnify you will find it also has a mountain peak, craterlets, and hills! Further south is the very narrow sinuous rille known as the Rimae Mairan which extends for about 61 miles and helps to form the shoreline of Sinus Roris.

If you follow it south, it will bring you to Mons Gruithuisen Delta, Mons Gruithuisen Gamma, and crater Gruithuisen – a wonderful series of volcanoes and their namesake (Fig. 24.4). Mons Gruithuisen Gamma is often called the "Topsy Turvy Bathtub." While you might not find these features particularly impressive, consider that we are looking at something only 20 km wide and only 900 m high! Can you resolve the small craterlet at the peak? Just look at all the incredible things you have learned in less than a lunar month.

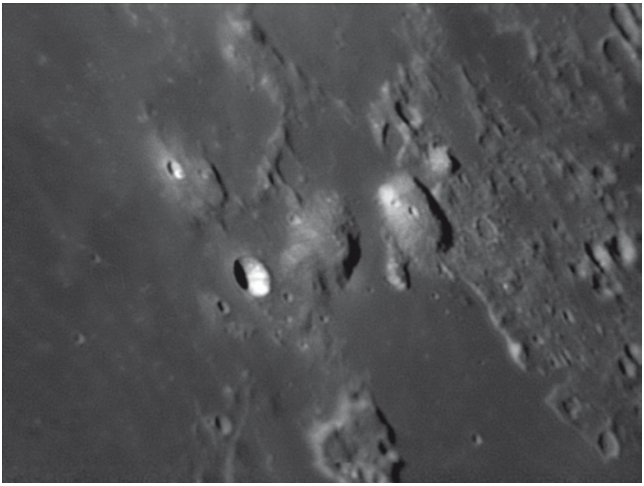


Fig. 24.4 Mons Gruithuisen – Damian Peach.

CHAPTER 25

LUNAR DAY TWENTY-FOUR

Moon, worn thin to the width of a quill,
In the dawn clouds flying,
How good to go, light into light, and still
Giving light, dying.

Sara Teasdale

Tonight we will work in the south and start by identifying the long narrow ellipse of crater Schiller (Figs. 25.1 and 25.2). Moon walk south along the terminator and look for a line of four prominent craters. Their interiors may be black, but the southeast walls will be brilliantly illuminated. The most striking of this quartet is Zucchius and depending on libration may be very

Fig. 25.1 Twenty-four day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes*, Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_25,

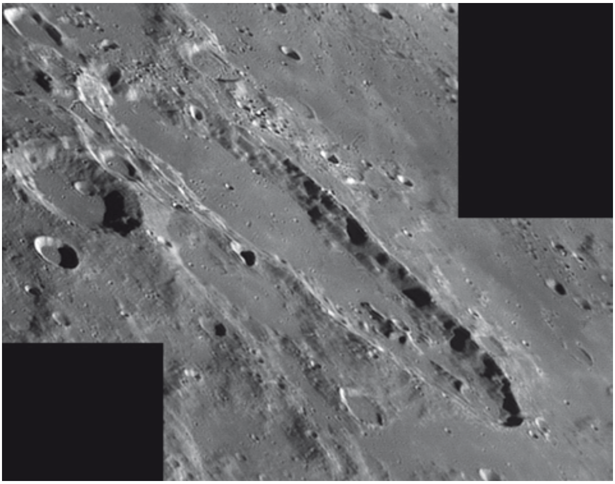


Fig. 25.2 Crater Schiller – Damian Peach.

shadowed. To its east is Bettinus, and at power you will see central peaks in both craters. Further southeast is Kirchner and to its east is the very old Wilson. Just north of Bettinus and – at an angle to Zucchius – you will see a strange, walled, V-shaped area curving back to Schiller. This odd area is one of the Moon's older surface features. An eon or two ago, this was part of a much larger structure which can be traced here and there amidst later forming craters. Since all that is now left is some hills and ridges, no one is certain if the area formed geologically or was caused by an impact.

Now, Moon walk a bit north along the terminator…

In 2006, SMART 1 went into the history books as it impacted the lunar surface in Lacus Excellentiae (Fig. 25.3). Launched on September 27, 2003 by ESA, it entered lunar orbit over a year later on November 13, 2004. After operating 5,000 h through 483 starts and stops, the xenon-ion engines ran out of fuel in September 2005, but not before the mission successfully completed its mapping studies. Although the craft caused a brief flash on the surface as it ended its life, it left an indelible mark on history – one almost as important as that left in 1959 by the first craft to impact the Moon, Luna 2. You will find Lacus Excellentiae and the SMART 1 site just south of Mare Humorum and just north of Schiller. It smashed into the western shore very near a large peak!

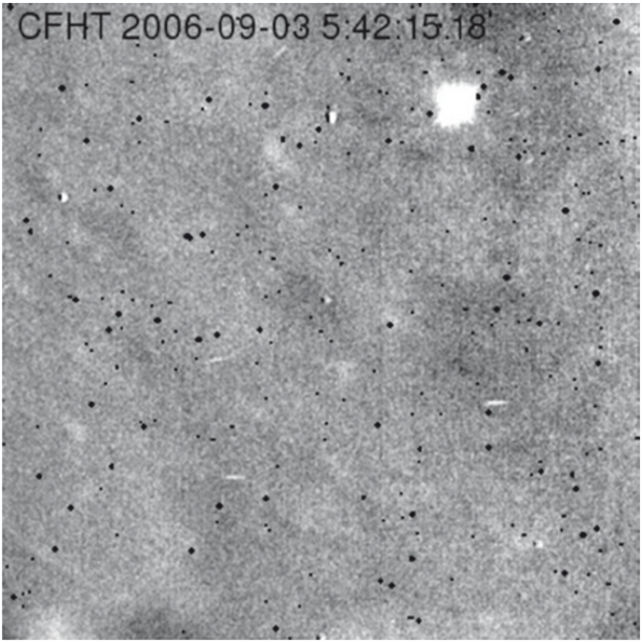


Fig. 25.3 SMART 1 impact flash (NASA).

Continue to Moon walk north along the terminator until you reach the southwest shore of Mare Humorum (Fig. 25.4). Make note of other challenging telescopic features like 90 km wide Vieta and 58 km wide Cavendish. Keep your eyes open for twin craters Henry and Henry Freres (Brothers). Both are identical in size, but nearly a million years separates them in age! Do you remember Byrgius and its bright rays? Take a look now and you can see the A crater from which they emanate much more clearly.

Although we studied Byrgius a bit as the Moon waxed, let us take another look at this marvelous crater (Fig. 25.5). Spanning an impressive 87 km wide Byrgius is usually hidden away by its high albedo intruder on the eastern rim, Byrgius A, and Byrgius D which has crushed its northwest wall. Now that the lighting is different, can you pick out crater Lamarck to the northwest? Parts of the Lamarck crater also overlaid by ejecta from the Mare Orientale basin to the east. The most notable feature in the interior is the tiny, bowl-shaped impact crater Lamarck B and you will notice the remainder of the floor forms a rolling, uneven plain. Congratulations on conquering 24 days of lunar studies!

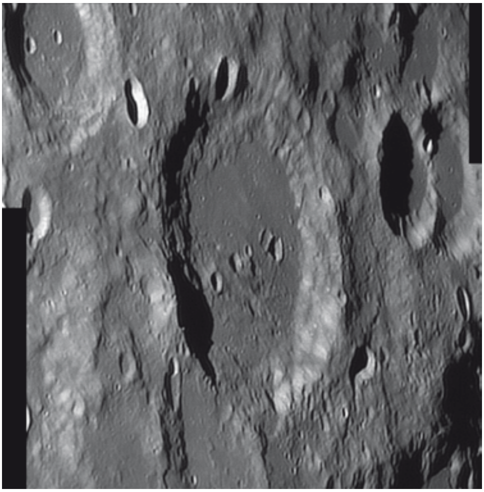


Fig. 25.4 Vieta, Henry and Henry Freres - Damian Peach.

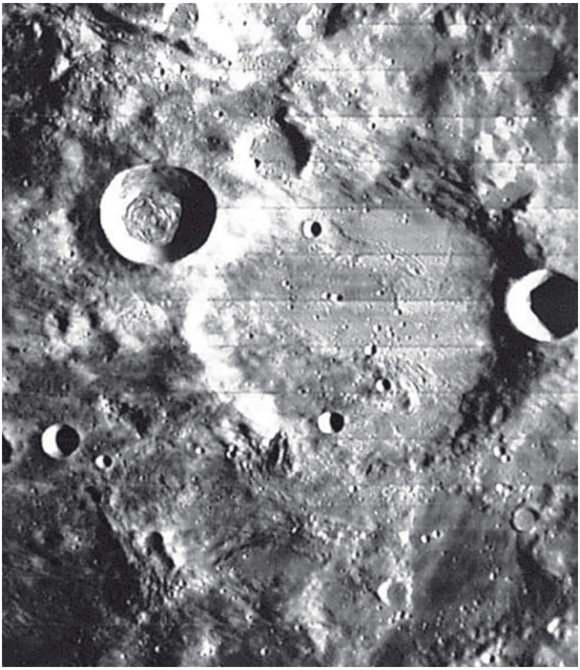


Fig. 25.5 Byrgius – Clemetine.

CHAPTER 26

LUNAR DAY TWENTY-FIVE

> *And the night shall be filled with music,*
> *And the cares that infest the day*
> *Shall fold their tents like the Arabs*
> *And as silently steal away.*
>
> Henry Wadsworth Longfellow

We begin our studies tonight with another Moon walk around landmark crater Grimaldi (Figs. 26.1 and 26.2). Do you remember Sirasilis and its long rimae? Take a look now. Depending on how far the terminator has progressed at your time, you may get a wonderfully highlighted view of the longest rille on the lunar surface. Positioned between Grimaldi and the western bank of

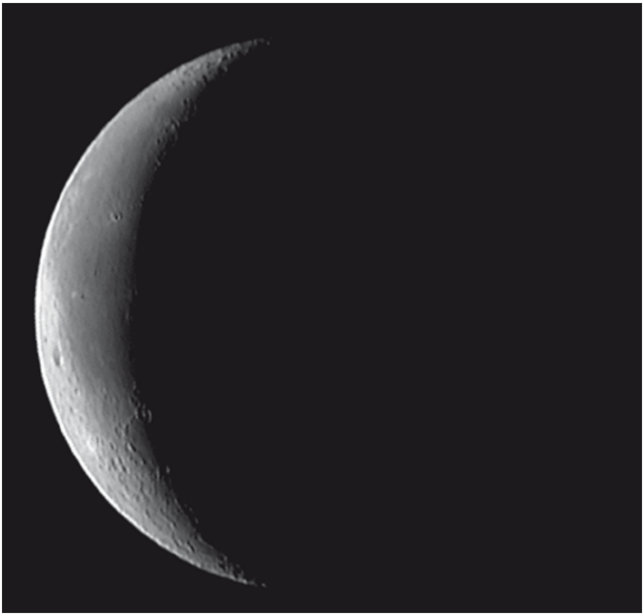


Fig. 26.1 Twenty-five day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes*, Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_26,

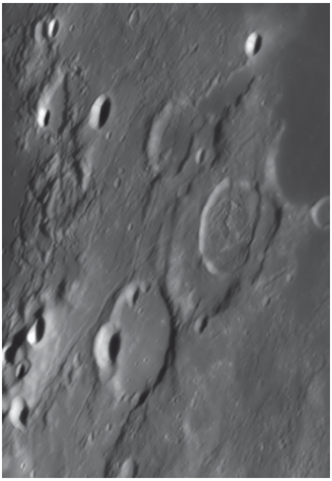


Fig. 26.2 Crater Damoiseau – Wes Higgins.

Oceanus Procellarum, you will find the ruins of crater Damoiseau. Formed in the Upper Imbrian period and spanning a modest 37 km in diameter, this smashed formation is also better viewed during the waning phase when the lighting is far less blinding. It shares part of its structure with Rimae Grimaldi, and you will notice a few areas where Damoiseau's satellite craters have damaged the primary structure's walls. This lighting condition also allows us to see the 150 km walled plain of Riccioli differently, too. Much like Grimaldi, it is a vast, empty expanse filled with lava flow.

Even though the atmosphere will greatly trouble any observations, there is no harm in looking for the punctuations of Cardanus and Krafft – an area also visible on Lunar Day Thirteen (as illustrated here) (Fig. 26.3). Southern Cardanus' circular formation is typical of the Upper Imbrian period and is in excess of three billion years old. Spanning about 51 km in diameter, its high terraced walls reach up about 2,300 m high. Look for shadow play to the south, which will reveal how the lunar surface slopes upward, almost drift-like. If skies are steady, power up and try to resolve the challenging little bright point of Cardanus M along the interior wall. To Cardanus' north is Cantena Krafft, a 61 km long crater chain whose geological timeline origins are unknown. If you follow the series of small impacts on their

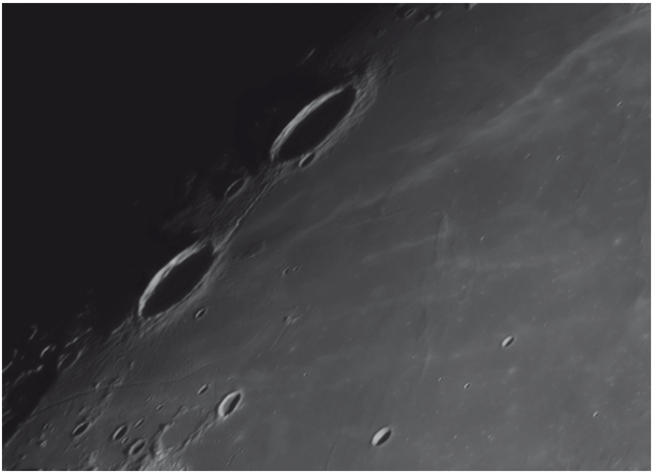


Fig. 26.3 Cardanus and Krafft – Wes Higgins.

trajectory northwards, you will Moon walk right into the southern wall of 53 km wide crater Krafft. Stand on its rimae and look down at the floor 1,250 m below. Krafft was formed at the same time as its southern neighbor, but it has taken a much more recent and violent impact on its eastern wall in the form of Krafft C.

Both Cardanus and Krafft are youngsters compared with the more northern walled plain of Struve. Named for the great Russian astronomer, Friedrich Georg Wilhelm von Struve, this ancient formation is probably in excess of four billion years old. Easily spotted in binoculars, the 175 km wide area has a height that is impossible to calculate because of its angle. If skies are steady, power up in a telescope and look at how the old lava flows have connected it to crater Russell to the north. Like Struve, western Eddington was also formed in the pre-Nectarian geological period and is equally old. What separates this 138 km wide lava plain from its western counterpart? Just a wall… One that we can see, but cannot get an accurate shadow measurement on. We know it is high enough to have kept the two from blending together like the shadowy remains of the craters that border to their south. If libration is favorable, look for challenging 71 km wide Balboa along the limb or 98 km wide Vasco de Gama. Both are "on the edge" features!

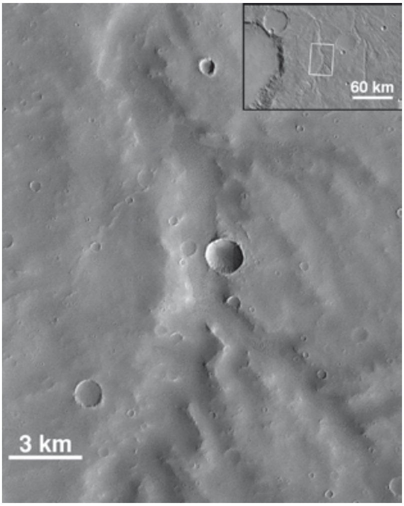


Fig. 26.4 Crater Schiaparelli (NASA).

Moon walk a bit more north across Oceanus Procellarum and you will encounter the 44 km wide well of Seleucus (Fig. 26.4). This little crater sprang into being about the same time as the grand Eratosthenes, and while it does not look impressive from here on Earth, it could easily hide the Nilgiri Hills of India and the tiny peak you see winking from inside could easily represent Ootay. To the west lay the 138 km wide expanse of the walled plain of Eddington… nearly eradicated by the lava flow that formed the vast ocean around it. Can you still see tiny crater Schiaparelli? Giovanni Virginio Schiaparelli was the man who birthed Mars "canals" and first mapped its surface – along with being the first to associate comets with meteoroid streams. Believe it or not, this almost nothing looking crater was the focus for lunar orbiter studies when it came to investigating mare basalts. Why? Because it luckily lay in a region where it has escaped contamination from other formations!

CHAPTER 27

LUNAR DAY TWENTY-SIX

I saw the new Moon late yestreen,
Wi' the auld Moon in her arm:
And if ye gang to sea, maister,
I fear we'll suffer harm.

From the anonymous
Scottish ballad and Sir Patrick Spens.

And now the Moon is nearly gone again – rising just a bit ahead of the Sun (Fig. 27.1).

Fig. 27.1 Twenty-six day Moon – Peter Lloyd.

T. Plotner, *Moonwalk with Your Eyes*, Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_27,

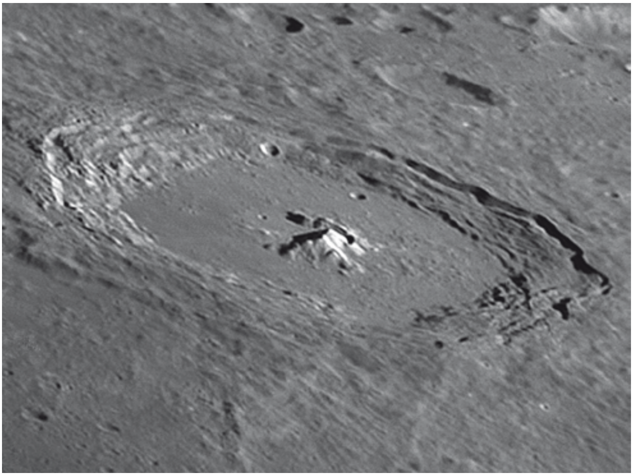


Fig. 27.2 Crater Pythagoras – Damian Peach.

Let us Moon walk to first the northern cusp to take a last look at crater Anaximander, which first became visible on Lunar Day Eleven just north of J. Herschel (Fig. 27.2). Depending on exactly how many hours old the terminator is at your time of viewing, you may be able to catch a glimpse of its 2,800 m high walls and the tremendous impact that collapsed them when crater Carpenter slammed into life shortly after it was born around four billion years ago. If shadow play is right, you may see Anaximander A, which is bordered by two mountains. Look for long shadows along the southwest wall – there is a good reason for them – they rise over 2,900 m above the lunar surface. That is as tall as Mount Francais – the highest peak on the Antartic Peninsula!

As you slide south along the limb edge, you will encounter the long, dark well of Pythagoras. This very young crater occurred some two million years later than it southeast neighbor, Babbage, slamming into the lunar surface and creating a hole 130 km wide and 4,800 m deep. To give you an idea of just how impressive that is, it is even deep than undersea Oahu Honolulu Volcanic Series – part of the volcanic chain that formed the Hawaiian Islands known as the "Deep." Depending on the sunlight angle, you may see that Pythagoras has a lava-flooded floor, which only gives rise to a double central peak and a few low hills and depressions. Even as impressive

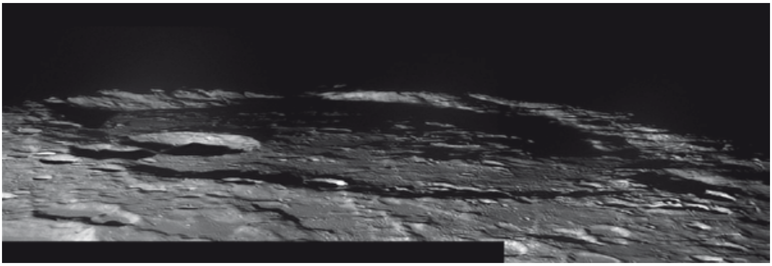


Fig. 27.3 Crater Baily – Damian Peach.

as Pythagoras is, it did very little but blemish 148 km wide Babbage. This walled plain was standing some two million years before and still remains. But, Babbage is not without its battle wounds, either… Look for the awesome impact of C, which left a gaping hole in its western interior! Whatever impact originally caused Babbage happened after what formed Oneopides, though… Because if you look carefully, you will see that Babbage's walls supersede its structure.

Now, let us reverse directions and take a look at the southern cusp (Fig. 27.3). This is your chance to catch a glimpse of the extremely challenging crater Bailey. Seen on the oblique, this 311 km wide walled plain was formed in the Nectarian period close to four billion years ago and it is a total ruin. While it is easily spotted in binoculars, it is not easily identified because it comprises so many overlapping craters caught on a difficult angle. However, Bailey proper is the largest of these crater-like formations and the rest are its satellites. If skies are steady, power up in a telescope to get a good look at this tormented region!

Old features in a new light? (Fig. 27.4). Of course! That is the most wonderful part about Moon walking. Take another look at craters that you viewed on Lunar Day Twelve, such as Schickard, Phoclides, and Wargentin – if they are still there to see. Look at how differently the change in shadow play makes them appear. Although it is more difficult to either get up early or stay up late to observe the Moon at this hour, having less glare helps to reveal craters we normally would not be able to study, like 94 km wide Inghirami. It has its own Vallis system to the northwest and steep, 3,000 m high walls, which would be hidden in nearly Full Moon glare. Can you make

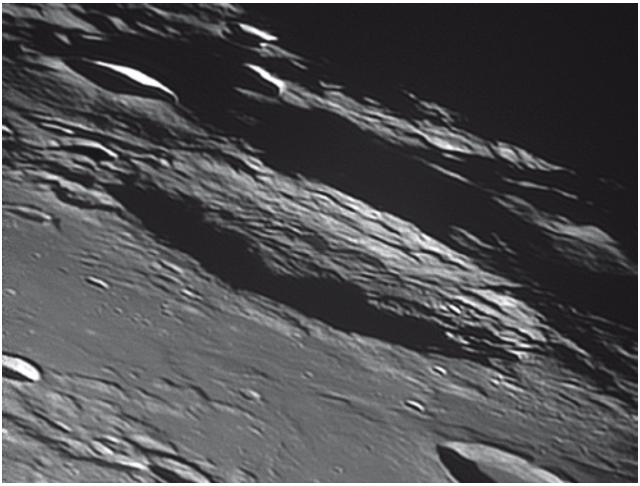


Fig. 27.4 Crater Inghirami – Damian Peach.

out its parallel crest lines or its multiple central peak? You have done a splendid job over the last few weeks and just look at how much you have learned!

> *I like to think that the Moon is there even*
> *if I am not looking at it.*
>
> Albert Einstein

CHAPTER 28

LUNAR DAY TWENTY-SEVEN

> *We are the music makers, and we are the dreamers of the dream.*
> *Wandering by lone sea breakers, and sitting by desolate streams.*
> *World losers and world forsakers, for whom the pale Moon gleams.*
> *Yet we are movers and the shakers of the world forever it seems.*
>
> Arthur William Edgar O'Shaughnessy

If we were only to view the Moon in respect to the stars – the sidereal period – it would take 27 days 7 h 43.2 min for our study to complete an orbit and our time would be drawing to within hours of a close (Fig. 28.1). However, our Earth–Moon system is also orbiting the Sun, and this means it takes just a little while longer for it to return to the exact same phase at which we started from. For all intents and purposes of this book, we have marked our lunar days as the time it takes for the Moon to make one complete orbit around the Earth and come back to the same place. As we have learned though, a lot depends on the time zone in which you live and exactly the point in time marked on our reference charts as to when the Moon officially begins its age. Our time has not ended yet!

In space exploration, a lunar day is the period of time it takes for the Moon to complete one full rotation on its axis with respect to the Sun – essentially the same as our lunar day here on Earth (Fig. 28.2). When we first began reaching out toward the Moon, we saw our own world with new eyes when Bill Anders aimed the 270-mm lens on a Hasselblad camera toward our "pale blue dot" and captured one of the most profound images of all time – Earth seen from another world. It was made into a postage stamp and hailed as the "Greatest Photo of the 20th Century"… But, just as our Moon has not stopped on its inexorable path back toward the Sun – neither did progress.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_28,

Fig. 28.1 Twenty-seven day Moon – Peter Lloyd.

Fig. 28.2 “Earthrise” – Apollo 8 (NASA).

Fig. 28.3 "Earthset" – JAXA.

On October 18, 2007 the Japan Aerospace Exploration Agency (JAXA) and NHK (Japan Broadcasting Corporation) went into space history as the lunar explorer "Kaguya" successfully transmitted the world's first high-definition image of "Earth Set" from lunar orbit (Fig. 28.3). Cruising along at an altitude of about 100 km of our selenographic study, Kaguya (Japanese for "SELENE" – SELenological and ENgineering Explorer) has so far been the largest lunar mission since the Apollo program. At the time of this writing, it was still going strong, gathering information on the Moon's elemental and mineralogical composition, its geography, its surface and subsurface structure, the remnant of its magnetic field, and its gravity field. Scientists are now able to observe plasma, the electromagnetic field, and high-energy particles – paving the way for possible future human exploration and utilization. Each hour that passes gives us a better overall understanding of the Moon's evolution!

Now, let us discuss the synodic period: the time that it takes for the object to reappear at the same point in the sky, relative to the Sun, as observed from Earth. On average, the lunar synodic period is 29 days, 12 h, 44 min, and 3 s long. Precise Fig.s? No. It is only an average because it varies slightly over a period of about a year – the time it takes for our Earth–Moon system to return to the same point in its solar orbit. Thanks to this slightly eccentric orbit, and a little "gravitational pull" from the Sun, the Moon's also experiences periodic variations. We know the Moon is tidally locked to always face toward Earth, but we need to discuss libration!

During our lunar days, the effect of orbit will cause the Moon to rock gently back and forth – like an old-fashioned beam scale reaching the point of

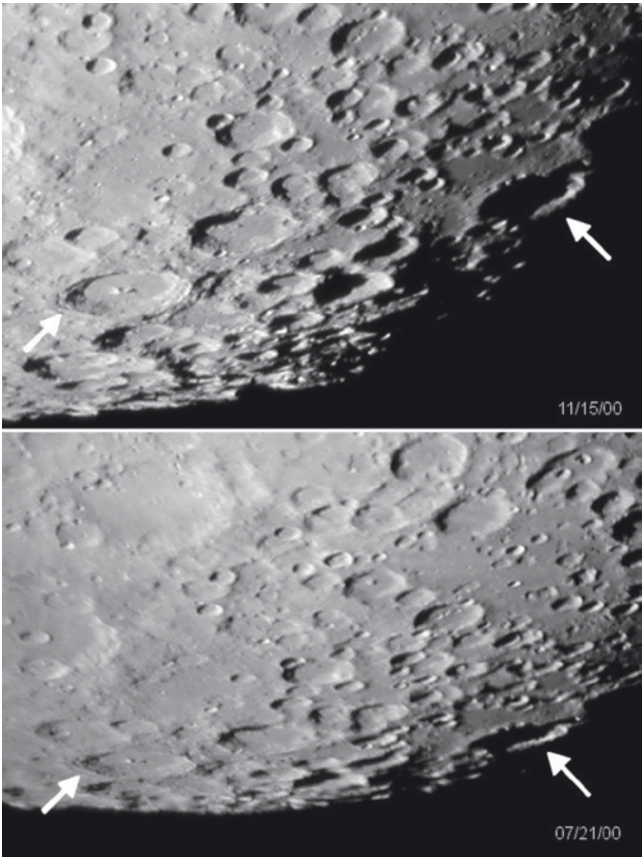


Fig. 28.4 "Libration" – Greg Konkel.

balance (Fig. 28.4). During those times of libration, we can see an extra 9% more of the lunar surface. Perhaps one viewing session will give favorable libration in longitude – a lead or fall-behind resulting from Earth orbit. A few times during the year you may experience libration in latitude, when the Moon's axis of rotation is slightly inclined – much like our seasonal shifts of Earth. And, every single day the Moon is around, we experience diurnal libration – the result of the motion of the observer on Earth as the Earth rotates. Confused? Do not be! Diurnal libration is just as simple as knowing that when the Moon is rising in the east we can see 1° more of

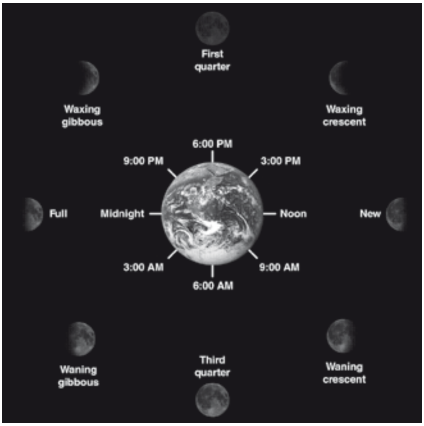


Fig. 28.5 Lunar Phases (Wikipedia).

the Moon's eastern edge and when the Moon is setting in the west we see 1° more of the Moon's western edge. Just how much more can you expect to see during libration period? At maximum during a longitudinal libration: 7°54′ and 6°50′ for latitudinal. Sometimes just that tiny tweak means all the difference between seeing a feature like Mare Humboldt or Mare Orientale – or not seeing them. Galileo noticed… And so will you!

The true challenge of Lunar Day Twenty-Seven is just to see if you can spot the Moon at all (Fig. 28.5). If we could travel into space and see our Earth/Moon system from a distance, we would know it was just about to pass either just above or just below the Sun from Earth's point of view. It is always there… But the light of the Sun blinds us to its presence! Check out your local sunrise time and scan the open horizon before the Sun's first rays light up the landscape. Congratulations on learning so very much through Lunar Day Twenty-Seven!

CHAPTER 29

LUNAR DAY TWENTY-EIGHT

Soon as the evening shades prevail
The Moon takes up the wondrous tale,
And nightly to the listening Earth
Repeats the story of her birth.

Joseph Addison

With only hours – or perhaps minutes – to go before the Moon returns to "New," one of the most supreme challenges you will ever face as a lunar observer will be spotting the ultrathin crescent on this lunar day (Fig. 29.1). It will require an absolutely open horizon and very clear skies. Like the Day One challenge, it is so near to the Sun that your window of opportunity may only list minutes, or you may not have one at all depending on the timing. Scanning the horizon with binoculars can help, but be very careful not to slip across the disc of the rising Sun!

Regardless of whether or not you see this morning's Moon, take stock of all that you have learned in the last lunar month. Remember that these challenges presented here were meant to delight and intrigue you – be it beginner or seasoned sky watcher. You may have a perfect evening when many of the lunar features described here in this book will come very easy to you… while other evenings will be more difficult. Before you become discouraged, remember there is no "time limit" to the Moon! It will wait for you, as it has for thousands of years.

As the Moon's fair image quaketh
In the raging waves of ocean,
Whilst she, in the vault of heaven,
Moves with silent peaceful motion.

Heinrich Heine

When skies are not clear or you simply have time – use it to perfect certain arts to "Moon Watching" that will greatly improve your skills – such as

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_29, © Springer Science+Business Media, LLC 2010

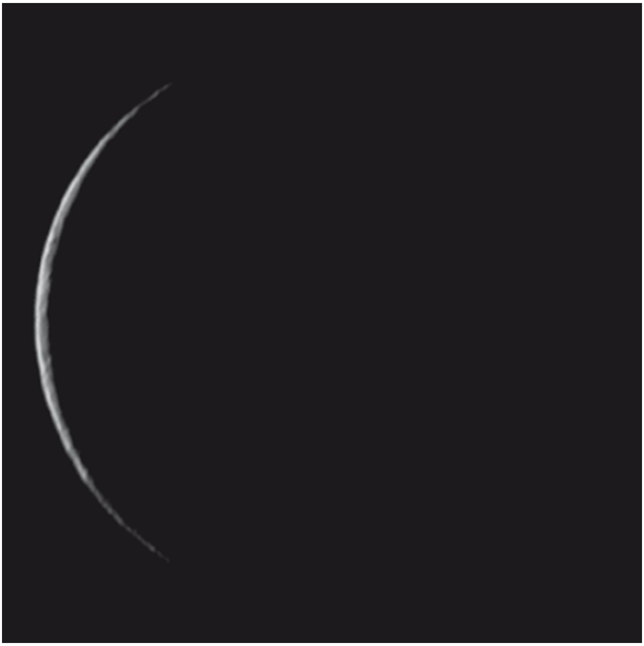


Fig. 29.1 Twenty-eight day Moon – Peter Lloyd.

Fig. 29.2 "Moon Over Timor Rock" – Joe Brimacombe.

sketching or finalizing your notes and observing lists (Fig. 29.2). Use down time to study up! The Internet offers a huge library of lunar data, which was simply unavailable to the lunar observer many years ago. You will

Fig. 29.3 "A Perfect Ending to A Perfect Night" – Joe Brimacombe.

find a great list of recommended links in the index section, which make for perfect reading, along with downloads that will help to aid you in identification, timing, and even predictions of your own.

As you prepare yourself to return again to the beginning, do not forget to gently share your "lunacy" as well. Not all family members, friends or acquaintances can – or will – feel the same about your hobby, but what a wonderful thing if they do! Many times children and teenagers will discuss their problems and life concerns far more readily when they are comfortable "in the dark" with a loved one… and just sharing the peace and pleasure of observing can form lasting ties and bonds (Fig. 29.3).

O! Moon old boughs lisp forth a holier din,
The while they feel thine airy fellowship:
Thou dost bless everywhere with silver lip…

John Keats

Now we have reached the end… Only to return to the beginning!

PART V

TABLES, CHARTS, AND RESOURCES

CHAPTER 30

TIME CONVERSION CHART

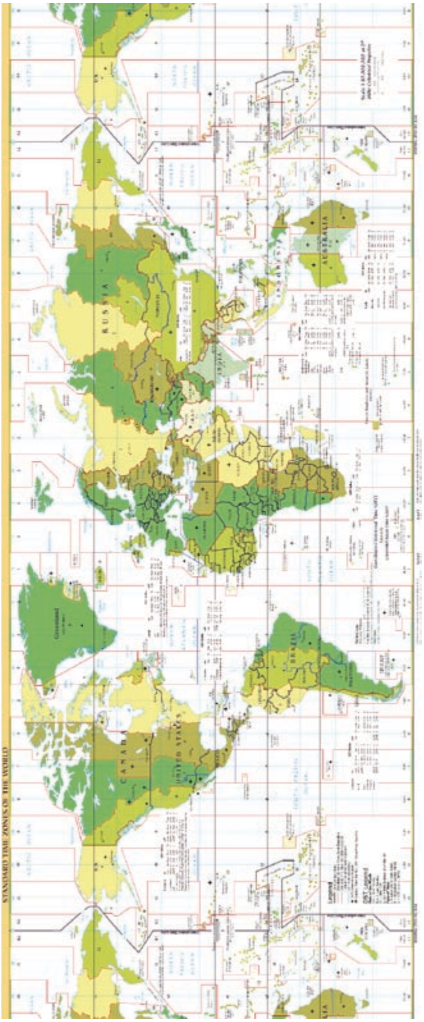
International broadcasting transmissions are directed to different regions all over the world, with different local times. Because of this characteristic, it is not adequate for the stations to announce their transmissions according to the local time in the target areas, because a same program could be directed to large regions with different time zones. Therefore, it was essential for the international broadcasters to adopt a common time reference.

During a long time, the reference adopted was GMT (Greenwich Mean Time). In 1979, the ITU (International Telecommunication Union) had established a new world reference, UTC (Universal Temps Coordonné). Although conceptually the definitions of GMT and UTC differ, in practice both terms are equivalent. Today, almost international broadcasters use UTC time.

In the system of time zones based on the UTC time, the terrestrial surface is divided into 24 different time zones, varying according to the longitude. As a day is divided into 24 h, the difference between two adjacent time zones is of 1 h. The distribution of these time zones in the terrestrial surface is not uniform, because its boundaries vary according to certain criteria, as the national frontiers between countries, as can be seen in the following figure.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_30,

Click over the figure in order to view it more accurately.



The following tables can be used to convert from UTC to local, standard time or summer time (when available). The tables list the main cities from the world; being indicated is the difference between the local time and the UTC time. For example, in the city of Los Angeles the local time is UTC-8, that is, 8 h less than UTC time.

North America	*N*	*S*
Washington, DC	UTC-5	UTC-4
New York	UTC-5	UTC-4
Miami	UTC-5	UTC-4
Dallas	UTC-6	UTC-5
Montreal	UTC-6	UTC-5
Montreal	UTC-6	UTC-5
Denver	UTC-7	UTC-6
Los Angeles	UTC-8	UTC-7
Central America	*N*	*S*
Barbados	UTC-4	UTC-4
Habana	UTC-5	UTC-4
Port-au-Prince	UTC-5	UTC-4
Panama	UTC-5	UTC-5
Mexico	UTC-6	UTC-6
Europe	*N*	*S*
London	UTC	UTC+1
Lisbon	UTC	UTC+1
Dublin	UTC	UTC+1
Madrid	UTC+1	UTC+2
Paris	UTC+1	UTC+2
Rome	UTC+1	UTC+2
Genève	UTC+1	UTC+2
Athens	UTC+1	UTC+2
Amsterdam	UTC+1	UTC+2
Brussels	UTC+1	UTC+2
Berlin	UTC+1	UTC+2
Stockholm	UTC+1	UTC+2
Moscow	UTC+3	UTC+4

(continued)

(continued)

Far East	*N*	*S*
Bangkok	UTC+7	UTC+7
Hanoi	UTC+7	UTC+7
Beijing	UTC+8	UTC+8
Taipei	UTC+8	UTC+8
Hong Kong	UTC+8	UTC+8
Tokyo	UTC+9	UTC+9
Manila	UTC+8	UTC+8
Kuala Lumpur	UTC+8	UTC+8
Seoul	UTC+9	UTC+9
Middle East	*N*	*S*
Beirut	UTC+2	UTC+3
Tel Aviv	UTC+2	UTC+3
Damasco	UTC+2	UTC+3
Riyad	UTC+3	UTC+3
Bagdad	UTC+3	UTC+4
South America	*N*	*S*
Rio de Janeiro	UTC-3	UTC-2
São Paulo	UTC-3	UTC-2
Brasília	UTC-3	UTC-2
Buenos Aires	UTC-3	UTC-3
Montevidéu	UTC-3	UTC-3
Santiago	UTC-4	UTC-3
Caracas	UTC-4	UTC-4
La Paz	UTC-4	UTC-4
Lima	UTC-5	UTC-4
Bogotá	UTC-5	UTC-5
Quito	UTC-5	UTC-5
Africa	*N*	*S*
Accra	UTC	UTC
Dakar	UTC	UTC
Rabat	UTC	UTC
Lagos	UTC+1	UTC+1
Alger	UTC+1	UTC+1
Tripoli	UTC+1	UTC+2
Johanesburg	UTC+1	UTC+2
Lusaka	UTC+2	UTC+2
Cairo	UTC+2	UTC+3

CHAPTER 31

MOON DATES AND TIMES TABLES

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_31,

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

2000 Phases of the Moon

Universal Time

New Moon				**First quarter**				**Full Moon**				**Last quarter**			
	d	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**
Jan	**6**	**18**	**14**	**Jan**	**14**	**13**	**34**	**Jan**	**21**	**4**	**40**	**Jan**	**28**	**7**	**57**
Feb	**5**	**13**	**03**	**Feb**	**12**	**23**	**21**	**Feb**	**19**	**16**	**27**	**Feb**	**27**	**3**	**54**
Mar	**6**	**5**	**17**	**Mar**	**13**	**6**	**59**	**Mar**	**20**	**4**	**44**	**Mar**	**28**	**0**	**21**
Apr	**4**	**18**	**12**	**Apr**	**11**	**13**	**30**	**Apr**	**18**	**17**	**42**	**Apr**	**26**	**19**	**30**
May	**4**	**4**	**12**	**May**	**10**	**20**	**01**	**May**	**18**	**7**	**34**	**May**	**26**	**11**	**55**
Jun	**2**	**12**	**14**	**Jun**	**9**	**3**	**29**	**Jun**	**16**	**22**	**27**	**Jun**	**25**	**1**	**00**
Jul	**1**	**19**	**20**	**Jul**	**8**	**12**	**53**	**Jul**	**16**	**13**	**55**	**Jul**	**24**	**11**	**02**
Jul	**31**	**2**	**25**	**Aug**	**7**	**1**	**02**	**Aug**	**15**	**5**	**13**	**Aug**	**22**	**18**	**51**
Aug	**29**	**10**	**19**	**Sep**	**5**	**16**	**27**	**Sep**	**13**	**19**	**37**	**Sep**	**21**	**1**	**28**
Sep	**27**	**19**	**53**	**Oct**	**5**	**10**	**59**	**Oct**	**13**	**8**	**53**	**Oct**	**20**	**7**	**59**
Oct	**27**	**7**	**58**	**Nov**	**4**	**7**	**27**	**Nov**	**11**	**21**	**15**	**Nov**	**18**	**15**	**24**
Nov	**25**	**23**	**11**	**Dec**	**4**	**3**	**55**	**Dec**	**11**	**9**	**03**	**Dec**	**18**	**0**	**41**
Dec	**25**	**17**	**22**												

2001 Phases of the Moon

Universal Time

	d	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**
				Jan	**2**	**22**	**32**	**Jan**	**9**	**20**	**24**	**Jan**	**16**	**12**	**35**
Jan	**24**	**13**	**07**	**Feb**	**1**	**14**	**03**	**Feb**	**8**	**7**	**12**	**Feb**	**15**	**3**	**24**

Feb	23	8	21	Mar	3	2	03	Mar	9	17	23	Mar	16	20	45
Mar	25	1	21	Apr	1	10	49	Apr	8	3	22	Apr	15	15	31
Apr	23	15	26	Apr	30	17	08	May	7	13	53	May	15	10	11
May	23	2	46	May	29	22	09	Jun	6	1	39	Jun	14	3	28
Jun	21	11	58	Jun	28	3	20	Jul	5	15	04	Jul	13	18	45
Jul	20	19	44	Jul	27	10	08	Aug	4	5	56	Aug	12	7	53
Aug	19	2	55	Aug	25	19	55	Sep	2	21	43	Sep	10	19	00
Sep	17	10	27	Sep	24	9	31	Oct	2	13	49	Oct	10	4	20
Oct	16	19	23	Oct	24	2	58	Nov	1	5	41	Nov	8	12	21
Nov	15	6	40	Nov	22	23	21	Nov	30	20	49	Dec	7	19	52
Dec	14	20	47	Dec	22	20	56	Dec	30	10	41				

2002 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	6	3	55
Jan	13	13	29	Jan	21	17	47	Jan	28	22	50	Feb	4	13	33
Feb	12	7	41	Feb	20	12	02	Feb	27	9	17	Mar	6	1	25
Mar	14	2	03	Mar	22	2	29	Mar	28	18	25	Apr	4	15	29
Apr	12	19	21	Apr	20	12	48	Apr	27	3	00	May	4	7	16
May	12	10	45	May	19	19	42	May	26	11	51	Jun	3	0	05
Jun	10	23	47	Jun	18	0	29	Jun	24	21	42	Jul	2	17	19
Jul	10	10	26	Jul	17	4	47	Jul	24	9	07	Aug	1	10	22

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US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Aug	8	19	15	Aug	15	10	12	Aug	22	22	29	Aug	31	2	31
Sep	7	3	10	Sep	13	18	08	Sep	21	13	59	Sep	29	17	03
Oct	6	11	18	Oct	13	5	33	Oct	21	7	20	Oct	29	5	28
Nov	4	20	34	Nov	11	20	52	Nov	20	1	34	Nov	27	15	46
Dec	4	7	34	Dec	11	15	49	Dec	19	19	10	Dec	27	0	31

2003 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	2	20	23	Jan	10	13	15	Jan	18	10	48	Jan	25	8	33
Feb	1	10	48	Feb	9	11	11	Feb	16	23	51	Feb	23	16	46
Mar	3	2	35	Mar	11	7	15	Mar	18	10	35	Mar	25	1	51
Apr	1	19	19	Apr	9	23	40	Apr	16	19	36	Apr	23	12	18
May	1	12	15	May	9	11	53	May	16	3	36	May	23	0	31
May	31	4	20	Jun	7	20	28	Jun	14	11	16	Jun	21	14	45
Jun	29	18	39	Jul	7	2	32	Jul	13	19	21	Jul	21	7	01
Jul	29	6	53	Aug	5	7	28	Aug	12	4	48	Aug	20	0	48
Aug	27	17	26	Sep	3	12	34	Sep	10	16	36	Sep	18	19	03
Sep	26	3	09	Oct	2	19	09	Oct	10	7	27	Oct	18	12	31
Oct	25	12	50	Nov	1	4	25	Nov	9	1	13	Nov	17	4	15
Nov	23	22	59	Nov	30	17	16	Dec	8	20	37	Dec	16	17	42
Dec	23	9	43	Dec	30	10	03								

2004 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
								Jan	7	15	40	Jan	15	4	46
Jan	21	21	05	Jan	29	6	03	Feb	6	8	47	Feb	13	13	40
Feb	20	9	18	Feb	28	3	24	Mar	6	23	14	Mar	13	21	01
Mar	20	22	41	Mar	28	23	48	Apr	5	11	03	Apr	12	3	46
Apr	19	13	21	Apr	27	17	32	May	4	20	33	May	11	11	04
May	19	4	52	May	27	7	57	Jun	3	4	20	Jun	9	20	02
Jun	17	20	27	Jun	25	19	08	Jul	2	11	09	Jul	9	7	34
Jul	17	11	24	Jul	25	3	37	Jul	31	18	05	Aug	7	22	01
Aug	16	1	24	Aug	23	10	12	Aug	30	2	22	Sep	6	15	11
Sep	14	14	29	Sep	21	15	54	Sep	28	13	09	Oct	6	10	12
Oct	14	2	48	Oct	20	21	59	Oct	28	3	07	Nov	5	5	53
Nov	12	14	27	Nov	19	5	50	Nov	26	20	07	Dec	5	0	53
Dec	12	1	29	Dec	18	16	40	Dec	26	15	06				

2005 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	3	17	46
Jan	10	12	03	Jan	17	6	57	Jan	25	10	32	Feb	2	7	27
Feb	8	22	28	Feb	16	0	16	Feb	24	4	54	Mar	3	17	36

(continued)

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Mar	10	9	10	Mar	17	19	19	Mar	25	20	58	Apr	2	0	50
Apr	8	20	32	Apr	16	14	37	Apr	24	10	06	May	1	6	24
May	8	8	45	May	16	8	57	May	23	20	18	May	30	11	47
Jun	6	21	55	Jun	15	1	22	Jun	22	4	14	Jun	28	18	23
Jul	6	12	02	Jul	14	15	20	Jul	21	11	00	Jul	28	3	20
Aug	5	3	05	Aug	13	2	39	Aug	19	17	53	Aug	26	15	18
Sep	3	18	45	Sep	11	11	37	Sep	18	2	01	Sep	25	6	41
Oct	3	10	28	Oct	10	19	01	Oct	17	12	14	Oct	25	1	17
Nov	2	1	25	Nov	9	1	57	Nov	16	0	58	Nov	23	22	11
Dec	1	15	01	Dec	8	9	36	Dec	15	16	16	Dec	23	19	36
Dec	31	3	12												

2006 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	6	18	56	Jan	14	9	48	Jan	22	15	14
Jan	29	14	15	Feb	5	6	29	Feb	13	4	44	Feb	21	7	17
Feb	28	0	31	Mar	6	20	16	Mar	14	23	35	Mar	22	19	10
Mar	29	10	15	Apr	5	12	01	Apr	13	16	40	Apr	21	3	28
Apr	27	19	44	May	5	5	13	May	13	6	51	May	20	9	21
May	27	5	26	Jun	3	23	06	Jun	11	18	03	Jun	18	14	08
Jun	25	16	05	Jul	3	16	37	Jul	11	3	02	Jul	17	19	13
Jul	25	4	31	Aug	2	8	46	Aug	9	10	54	Aug	16	1	51

Aug	23	19	10	Aug	31	22	56	Sep	7	18	42	Sep	14	11	15
Sep	22	11	45	Sep	30	11	04	Oct	7	3	13	Oct	14	0	26
Oct	22	5	14	Oct	29	21	25	Nov	5	12	58	Nov	12	17	45
Nov	20	22	18	Nov	28	6	29	Dec	5	0	25	Dec	12	14	32
Dec	20	14	01	Dec	27	14	48								

2007 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
								Jan	3	13	57	Jan	11	12	45
Jan	19	4	01	Jan	25	23	01	Feb	2	5	45	Feb	10	9	51
Feb	17	16	14	Feb	24	7	56	Mar	3	23	17	Mar	12	3	54
Mar	19	2	43	Mar	25	18	16	Apr	2	17	15	Apr	10	18	04
Apr	17	11	36	Apr	24	6	35	May	2	10	09	May	10	4	27
May	16	19	27	May	23	21	02	Jun	1	1	04	Jun	8	11	43
Jun	15	3	13	Jun	22	13	15	Jun	30	13	49	Jul	7	16	54
Jul	14	12	04	Jul	22	6	29	Jul	30	0	48	Aug	5	21	20
Aug	12	23	02	Aug	20	23	54	Aug	28	10	35	Sep	4	2	32
Sep	11	12	44	Sep	19	16	48	Sep	26	19	45	Oct	3	10	06
Oct	11	5	01	Oct	19	8	33	Oct	26	4	52	Nov	1	21	18
Nov	9	23	03	Nov	17	22	33	Nov	24	14	30	Dec	1	12	44
Dec	9	17	40	Dec	17	10	17	Dec	24	1	16	Dec	31	7	51

(continued)

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

2008 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	8	11	37	**Jan**	15	19	46	**Jan**	22	13	35	**Jan**	30	5	03
Feb	7	3	44	**Feb**	14	3	33	**Feb**	21	3	30	**Feb**	29	2	18
Mar	7	17	14	**Mar**	14	10	46	**Mar**	21	18	40	**Mar**	29	21	47
Apr	6	3	55	**Apr**	12	18	32	**Apr**	20	10	25	**Apr**	28	14	12
May	5	12	18	**May**	12	3	47	**May**	20	2	11	**May**	28	2	57
Jun	3	19	23	**Jun**	10	15	04	**Jun**	18	17	30	**Jun**	26	12	10
Jul	3	2	19	**Jul**	10	4	35	**Jul**	18	7	59	**Jul**	25	18	42
Aug	1	10	13	**Aug**	8	20	20	**Aug**	16	21	16	**Aug**	23	23	50
Aug	30	19	58	**Sep**	7	14	04	**Sep**	15	9	13	**Sep**	22	5	04
Sep	29	8	12	**Oct**	7	9	04	**Oct**	14	20	02	**Oct**	21	11	55
Oct	28	23	14	**Nov**	6	4	03	**Nov**	13	6	17	**Nov**	19	21	31
Nov	27	16	55	**Dec**	5	21	26	**Dec**	12	16	37	**Dec**	19	10	29
Dec	27	12	22												

2009 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	4	11	56	**Jan**	11	3	27	**Jan**	18	2	46
Jan	26	7	55	**Feb**	2	23	13	**Feb**	9	14	49	**Feb**	16	21	37

Feb	25	1	35	Mar	4	7	46	Mar	11	2	38	Mar	18	17	47
Mar	26	16	06	Apr	2	14	34	Apr	9	14	56	Apr	17	13	36
Apr	25	3	23	May	1	20	44	May	9	4	01	May	17	7	26
May	24	12	11	May	31	3	22	Jun	7	18	12	Jun	15	22	15
Jun	22	19	35	Jun	29	11	28	Jul	7	9	21	Jul	15	9	53
Jul	22	2	35	Jul	28	22	00	Aug	6	0	55	Aug	13	18	55
Aug	20	10	02	Aug	27	11	42	Sep	4	16	03	Sep	12	2	16
Sep	18	18	44	Sep	26	4	50	Oct	4	6	10	Oct	11	8	56
Oct	18	5	33	Oct	26	0	42	Nov	2	19	14	Nov	9	15	56
Nov	16	19	14	Nov	24	21	39	Dec	2	7	30	Dec	9	0	13
Dec	16	12	02	Dec	24	17	36	Dec	31	19	13				

2010 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	7	10	39
Jan	15	7	11	Jan	23	10	53	Jan	30	6	18	Feb	5	23	48
Feb	14	2	51	Feb	22	0	42	Feb	28	16	38	Mar	7	15	42
Mar	15	21	01	Mar	23	11	00	Mar	30	2	25	Apr	6	9	37
Apr	14	12	29	Apr	21	18	20	Apr	28	12	18	May	6	4	15
May	14	1	04	May	20	23	43	May	27	23	07	Jun	4	22	13
Jun	12	11	15	Jun	19	4	29	Jun	26	11	30	Jul	4	14	35
Jul	11	19	40	Jul	18	10	10	Jul	26	1	36	Aug	3	4	59

(continued)

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Aug	10	3	08	Aug	16	18	14	Aug	24	17	05	Sep	1	17	22
Sep	8	10	30	Sep	15	5	50	Sep	23	9	17	Oct	1	3	52
Oct	7	18	44	Oct	14	21	27	Oct	23	1	36	Oct	30	12	46
Nov	6	4	52	Nov	13	16	39	Nov	21	17	27	Nov	28	20	36
Dec	5	17	36	Dec	13	13	59	Dec	21	8	13	Dec	28	4	18

2011 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	4	9	03	Jan	12	11	31	Jan	19	21	21	Jan	26	12	57
Feb	3	2	31	Feb	11	7	18	Feb	18	8	36	Feb	24	23	26
Mar	4	20	46	Mar	12	23	45	Mar	19	18	10	Mar	26	12	07
Apr	3	14	32	Apr	11	12	05	Apr	18	2	44	Apr	25	2	47
May	3	6	51	May	10	20	33	May	17	11	09	May	24	18	52
Jun	1	21	03	Jun	9	2	11	Jun	15	20	14	Jun	23	11	48
Jul	1	8	54	Jul	8	6	29	Jul	15	6	40	Jul	23	5	02
Jul	30	18	40	Aug	6	11	08	Aug	13	18	57	Aug	21	21	54
Aug	29	3	04	Sep	4	17	39	Sep	12	9	27	Sep	20	13	39
Sep	27	11	09	Oct	4	3	15	Oct	12	2	06	Oct	20	3	30
Oct	26	19	56	Nov	2	16	38	Nov	10	20	16	Nov	18	15	09
Nov	25	6	10	Dec	2	9	52	Dec	10	14	36	Dec	18	0	48
Dec	24	18	06												

2012 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	1	6	15	Jan	9	7	30	Jan	16	9	08
Jan	23	7	39	Jan	31	4	10	Feb	7	21	54	Feb	14	17	04
Feb	21	22	35	Mar	1	1	21	Mar	8	9	39	Mar	15	1	25
Mar	22	14	37	Mar	30	19	41	Apr	6	19	19	Apr	13	10	50
Apr	21	7	18	Apr	29	9	57	May	6	3	35	May	12	21	47
May	20	23	47	May	28	20	16	Jun	4	11	12	Jun	11	10	41
Jun	19	15	02	Jun	27	3	30	Jul	3	18	52	Jul	11	1	48
Jul	19	4	24	Jul	26	8	56	Aug	2	3	27	Aug	9	18	55
Aug	17	15	54	Aug	24	13	54	Aug	31	13	58	Sep	8	13	15
Sep	16	2	11	Sep	22	19	41	Sep	30	3	19	Oct	8	7	33
Oct	15	12	02	Oct	22	3	32	Oct	29	19	49	Nov	7	0	36
Nov	13	22	08	Nov	20	14	31	Nov	28	14	46	Dec	6	15	31
Dec	13	8	42	Dec	20	5	19	Dec	28	10	21				

2013 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	5	3	58
Jan	11	19	44	Jan	18	23	45	Jan	27	4	38	Feb	3	13	56

(continued)

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Feb	**10**	**7**	**20**	**Feb**	**17**	**20**	**31**	**Feb**	**25**	**20**	**26**	**Mar**	**4**	**21**	**53**
Mar	**11**	**19**	**51**	**Mar**	**19**	**17**	**27**	**Mar**	**27**	**9**	**27**	**Apr**	**3**	**4**	**36**
Apr	**10**	**9**	**35**	**Apr**	**18**	**12**	**31**	**Apr**	**25**	**19**	**57**	**May**	**2**	**11**	**14**
May	**10**	**0**	**28**	**May**	**18**	**4**	**34**	**May**	**25**	**4**	**25**	**May**	**31**	**18**	**58**
Jun	**8**	**15**	**56**	**Jun**	**16**	**17**	**24**	**Jun**	**23**	**11**	**32**	**Jun**	**30**	**4**	**53**
Jul	**8**	**7**	**14**	**Jul**	**16**	**3**	**18**	**Jul**	**22**	**18**	**15**	**Jul**	**29**	**17**	**43**
Aug	**6**	**21**	**51**	**Aug**	**14**	**10**	**56**	**Aug**	**21**	**1**	**45**	**Aug**	**28**	**9**	**35**
Sep	**5**	**11**	**36**	**Sep**	**12**	**17**	**08**	**Sep**	**19**	**11**	**13**	**Sep**	**27**	**3**	**55**
Oct	**5**	**0**	**34**	**Oct**	**11**	**23**	**02**	**Oct**	**18**	**23**	**38**	**Oct**	**26**	**23**	**40**
Nov	**3**	**12**	**50**	**Nov**	**10**	**5**	**57**	**Nov**	**17**	**15**	**16**	**Nov**	**25**	**19**	**28**
Dec	**3**	**0**	**22**	**Dec**	**9**	**15**	**12**	**Dec**	**17**	**9**	**28**	**Dec**	**25**	**13**	**48**

2014 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	**1**	**11**	**14**	**Jan**	**8**	**3**	**39**	**Jan**	**16**	**4**	**52**	**Jan**	**24**	**5**	**20**
Jan	**30**	**21**	**38**	**Feb**	**6**	**19**	**22**	**Feb**	**14**	**23**	**53**	**Feb**	**22**	**17**	**15**
Mar	**1**	**8**	**00**	**Mar**	**8**	**13**	**27**	**Mar**	**16**	**17**	**08**	**Mar**	**24**	**1**	**46**
Mar	**30**	**18**	**45**	**Apr**	**7**	**8**	**31**	**Apr**	**15**	**7**	**42**	**Apr**	**22**	**7**	**52**
Apr	**29**	**6**	**14**	**May**	**7**	**3**	**15**	**May**	**14**	**19**	**16**	**May**	**21**	**12**	**59**
May	**28**	**18**	**40**	**Jun**	**5**	**20**	**39**	**Jun**	**13**	**4**	**11**	**Jun**	**19**	**18**	**39**
Jun	**27**	**8**	**08**	**Jul**	**5**	**11**	**59**	**Jul**	**12**	**11**	**25**	**Jul**	**19**	**2**	**08**

Jul	26	22	42	Aug	4	0	50	Aug	10	18	09	Aug	17	12	26
Aug	25	14	13	Sep	2	11	11	Sep	9	1	38	Sep	16	2	05
Sep	24	6	14	Oct	1	19	32	Oct	8	10	51	Oct	15	19	12
Oct	23	21	57	Oct	31	2	48	Nov	6	22	23	Nov	14	15	15
Nov	22	12	32	Nov	29	10	06	Dec	6	12	27	Dec	14	12	51
Dec	22	1	36	Dec	28	18	31								

2015 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
								Jan	5	4	53	Jan	13	9	46
Jan	20	13	14	Jan	27	4	48	Feb	3	23	09	Feb	12	3	50
Feb	18	23	47	Feb	25	17	14	Mar	5	18	05	Mar	13	17	48
Mar	20	9	36	Mar	27	7	43	Apr	4	12	05	Apr	12	3	44
Apr	18	18	57	Apr	25	23	55	May	4	3	42	May	11	10	36
May	18	4	13	May	25	17	19	Jun	2	16	19	Jun	9	15	42
Jun	16	14	05	Jun	24	11	02	Jul	2	2	20	Jul	8	20	24
Jul	16	1	24	Jul	24	4	04	Jul	31	10	43	Aug	7	2	03
Aug	14	14	53	Aug	22	19	31	Aug	29	18	35	Sep	5	9	54
Sep	13	6	41	Sep	21	8	59	Sep	28	2	50	Oct	4	21	06
Oct	13	0	06	Oct	20	20	31	Oct	27	12	05	Nov	3	12	24

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US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Nov	**11**	**17**	**47**	**Nov**	**19**	**6**	**27**	**Nov**	**25**	**22**	**44**	**Dec**	**3**	**7**	**40**
Dec	**11**	**10**	**29**	**Dec**	**18**	**15**	**14**	**Dec**	**25**	**11**	**11**				

2016 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	**2**	**5**	**30**
Jan	**10**	**1**	**30**	**Jan**	**16**	**23**	**26**	**Jan**	**24**	**1**	**46**	**Feb**	**1**	**3**	**28**
Feb	**8**	**14**	**39**	**Feb**	**15**	**7**	**46**	**Feb**	**22**	**18**	**20**	**Mar**	**1**	**23**	**11**
Mar	**9**	**1**	**54**	**Mar**	**15**	**17**	**03**	**Mar**	**23**	**12**	**01**	**Mar**	**31**	**15**	**17**
Apr	**7**	**11**	**24**	**Apr**	**14**	**3**	**59**	**Apr**	**22**	**5**	**24**	**Apr**	**30**	**3**	**29**
May	**6**	**19**	**29**	**May**	**13**	**17**	**02**	**May**	**21**	**21**	**14**	**May**	**29**	**12**	**12**
Jun	**5**	**2**	**59**	**Jun**	**12**	**8**	**10**	**Jun**	**20**	**11**	**02**	**Jun**	**27**	**18**	**19**
Jul	**4**	**11**	**01**	**Jul**	**12**	**0**	**52**	**Jul**	**19**	**22**	**56**	**Jul**	**26**	**23**	**00**
Aug	**2**	**20**	**44**	**Aug**	**10**	**18**	**21**	**Aug**	**18**	**9**	**26**	**Aug**	**25**	**3**	**41**
Sep	**1**	**9**	**03**	**Sep**	**9**	**11**	**49**	**Sep**	**16**	**19**	**05**	**Sep**	**23**	**9**	**56**
Oct	**1**	**0**	**11**	**Oct**	**9**	**4**	**33**	**Oct**	**16**	**4**	**23**	**Oct**	**22**	**19**	**14**
Oct	**30**	**17**	**38**	**Nov**	**7**	**19**	**51**	**Nov**	**14**	**13**	**52**	**Nov**	**21**	**8**	**33**
Nov	**29**	**12**	**18**	**Dec**	**7**	**9**	**03**	**Dec**	**14**	**0**	**05**	**Dec**	**21**	**1**	**56**
Dec	**29**	**6**	**53**												

2017 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	5	19	47	Jan	12	11	34	Jan	19	22	13
Jan	28	0	07	Feb	4	4	19	Feb	11	0	33	Feb	18	19	33
Feb	26	14	58	Mar	5	11	32	Mar	12	14	54	Mar	20	15	58
Mar	28	2	57	Apr	3	18	39	Apr	11	6	08	Apr	19	9	57
Apr	26	12	16	May	3	2	47	May	10	21	42	May	19	0	33
May	25	19	44	Jun	1	12	42	Jun	9	13	10	Jun	17	11	33
Jun	24	2	31	Jul	1	0	51	Jul	9	4	06	Jul	16	19	26
Jul	23	9	45	Jul	30	15	23	Aug	7	18	11	Aug	15	1	15
Aug	21	18	30	Aug	29	8	13	Sep	6	7	03	Sep	13	6	25
Sep	20	5	30	Sep	28	2	53	Oct	5	18	40	Oct	12	12	25
Oct	19	19	12	Oct	27	22	22	Nov	4	5	23	Nov	10	20	36
Nov	18	11	42	Nov	26	17	03	Dec	3	15	47	Dec	10	7	51
Dec	18	6	30	Dec	26	9	20								

2018 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
								Jan	2	2	24	Jan	8	22	25
Jan	17	2	17	Jan	24	22	20	Jan	31	13	27	Feb	7	15	54
Feb	15	21	05	Feb	23	8	09	Mar	2	0	51	Mar	9	11	20

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US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Mar	17	13	11	Mar	24	15	35	Mar	31	12	37	Apr	8	7	17
Apr	16	1	57	Apr	22	21	45	Apr	30	0	58	May	8	2	09
May	15	11	48	May	22	3	49	May	29	14	19	Jun	6	18	32
Jun	13	19	43	Jun	20	10	51	Jun	28	4	53	Jul	6	7	51
Jul	13	2	48	Jul	19	19	52	Jul	27	20	20	Aug	4	18	18
Aug	11	9	58	Aug	18	7	48	Aug	26	11	56	Sep	3	2	37
Sep	9	18	01	Sep	16	23	15	Sep	25	2	52	Oct	2	9	45
Oct	9	3	47	Oct	16	18	02	Oct	24	16	45	Oct	31	16	40
Nov	7	16	02	Nov	15	14	54	Nov	23	5	39	Nov	30	0	19
Dec	7	7	20	Dec	15	11	49	Dec	22	17	48	Dec	29	9	34

2019 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	6	1	28	Jan	14	6	45	Jan	21	5	16	Jan	27	21	10
Feb	4	21	03	Feb	12	22	26	Feb	19	15	53	Feb	26	11	28
Mar	6	16	04	Mar	14	10	27	Mar	21	1	43	Mar	28	4	10
Apr	5	8	50	Apr	12	19	06	Apr	19	11	12	Apr	26	22	18
May	4	22	45	May	12	1	12	May	18	21	11	May	26	16	33
Jun	3	10	02	Jun	10	5	59	Jun	17	8	31	Jun	25	9	46
Jul	2	19	16	Jul	9	10	55	Jul	16	21	38	Jul	25	1	18
Aug	1	3	12	Aug	7	17	31	Aug	15	12	29	Aug	23	14	56

Aug	30	10	37	Sep	6	3	10	Sep	14	4	33	Sep	22	2	41
Sep	28	18	26	Oct	5	16	47	Oct	13	21	08	Oct	21	12	39
Oct	28	3	38	Nov	4	10	23	Nov	12	13	34	Nov	19	21	11
Nov	26	15	05	Dec	4	6	58	Dec	12	5	12	Dec	19	4	57
Dec	26	5	13												

2020 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	3	4	45	Jan	10	19	21	Jan	17	12	58
Jan	24	21	42	Feb	2	1	42	Feb	9	7	33	Feb	15	22	17
Feb	23	15	32	Mar	2	19	57	Mar	9	17	48	Mar	16	9	34
Mar	24	9	28	Apr	1	10	21	Apr	8	2	35	Apr	14	22	56
Apr	23	2	26	Apr	30	20	38	May	7	10	45	May	14	14	03
May	22	17	39	May	30	3	30	Jun	5	19	12	Jun	13	6	24
Jun	21	6	41	Jun	28	8	16	Jul	5	4	44	Jul	12	23	29
Jul	20	17	33	Jul	27	12	32	Aug	3	15	59	Aug	11	16	45
Aug	19	2	42	Aug	25	17	58	Sep	2	5	22	Sep	10	9	26
Sep	17	11	00	Sep	24	1	55	Oct	1	21	05	Oct	10	0	39
Oct	16	19	31	Oct	23	13	23	Oct	31	14	49	Nov	8	13	46
Nov	15	5	07	Nov	22	4	45	Nov	30	9	30	Dec	8	0	36
Dec	14	16	16	Dec	21	23	41	Dec	30	3	28				

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US Naval Observatory – Astronomical Applications Department: Phases of the Moon

2021 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
												Jan	**6**	**9**	**37**
Jan	**13**	**5**	**00**	**Jan**	**20**	**21**	**01**	**Jan**	**28**	**19**	**16**	**Feb**	**4**	**17**	**37**
Feb	**11**	**19**	**06**	**Feb**	**19**	**18**	**47**	**Feb**	**27**	**8**	**17**	**Mar**	**6**	**1**	**30**
Mar	**13**	**10**	**21**	**Mar**	**21**	**14**	**40**	**Mar**	**28**	**18**	**48**	**Apr**	**4**	**10**	**02**
Apr	**12**	**2**	**31**	**Apr**	**20**	**6**	**59**	**Apr**	**27**	**3**	**31**	**May**	**3**	**19**	**50**
May	**11**	**19**	**00**	**May**	**19**	**19**	**13**	**May**	**26**	**11**	**14**	**Jun**	**2**	**7**	**24**
Jun	**10**	**10**	**53**	**Jun**	**18**	**3**	**54**	**Jun**	**24**	**18**	**40**	**Jul**	**1**	**21**	**11**
Jul	**10**	**1**	**16**	**Jul**	**17**	**10**	**11**	**Jul**	**24**	**2**	**37**	**Jul**	**31**	**13**	**16**
Aug	**8**	**13**	**50**	**Aug**	**15**	**15**	**19**	**Aug**	**22**	**12**	**02**	**Aug**	**30**	**7**	**13**
Sep	**7**	**0**	**52**	**Sep**	**13**	**20**	**39**	**Sep**	**20**	**23**	**55**	**Sep**	**29**	**1**	**57**
Oct	**6**	**11**	**05**	**Oct**	**13**	**3**	**25**	**Oct**	**20**	**14**	**57**	**Oct**	**28**	**20**	**05**
Nov	**4**	**21**	**14**	**Nov**	**11**	**12**	**46**	**Nov**	**19**	**8**	**57**	**Nov**	**27**	**12**	**28**
Dec	**4**	**7**	**43**	**Dec**	**11**	**1**	**35**	**Dec**	**19**	**4**	**35**	**Dec**	**27**	**2**	**24**

2022 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
Jan	**2**	**18**	**33**	**Jan**	**9**	**18**	**11**	**Jan**	**17**	**23**	**48**	**Jan**	**25**	**13**	**41**
Feb	**1**	**5**	**46**	**Feb**	**8**	**13**	**50**	**Feb**	**16**	**16**	**56**	**Feb**	**23**	**22**	**32**

Mar	2	17	35	Mar	10	10	45	Mar	18	7	17	Mar	25	5	37
Apr	1	6	24	Apr	9	6	48	Apr	16	18	55	Apr	23	11	56
Apr	30	20	28	May	9	0	21	May	16	4	14	May	22	18	43
May	30	11	30	Jun	7	14	48	Jun	14	11	52	Jun	21	3	11
Jun	29	2	52	Jul	7	2	14	Jul	13	18	38	Jul	20	14	18
Jul	28	17	55	Aug	5	11	06	Aug	12	1	36	Aug	19	4	36
Aug	27	8	17	Sep	3	18	08	Sep	10	9	59	Sep	17	21	52
Sep	25	21	54	Oct	3	0	14	Oct	9	20	55	Oct	17	17	15
Oct	25	10	49	Nov	1	6	37	Nov	8	11	02	Nov	16	13	27
Nov	23	22	57	Nov	30	14	36	Dec	8	4	08	Dec	16	8	56
Dec	23	10	17	Dec	30	1	20								

2023 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
								Jan	6	23	08	Jan	15	2	10
Jan	21	20	53	Jan	28	15	19	Feb	5	18	28	Feb	13	16	01
Feb	20	7	06	Feb	27	8	05	Mar	7	12	40	Mar	15	2	08
Mar	21	17	23	Mar	29	2	32	Apr	6	4	34	Apr	13	9	11
Apr	20	4	12	Apr	27	21	20	May	5	17	34	May	12	14	28
May	19	15	53	May	27	15	22	Jun	4	3	42	Jun	10	19	31
Jun	18	4	37	Jun	26	7	50	Jul	3	11	39	Jul	10	1	48
Jul	17	18	32	Jul	25	22	07	Aug	1	18	32	Aug	8	10	28
Aug	16	9	38	Aug	24	9	57	Aug	31	1	35	Sep	6	22	21

(continued)

US Naval Observatory – Astronomical Applications Department: Phases of the Moon

Sep	**15**	**1**	**40**	**Sep**	**22**	**19**	**32**	**Sep**	**29**	**9**	**57**	**Oct**	**6**	**13**	**48**
Oct	**14**	**17**	**55**	**Oct**	**22**	**3**	**29**	**Oct**	**28**	**20**	**24**	**Nov**	**5**	**8**	**37**
Nov	**13**	**9**	**27**	**Nov**	**20**	**10**	**50**	**Nov**	**27**	**9**	**16**	**Dec**	**5**	**5**	**49**
Dec	**12**	**23**	**32**	**Dec**	**19**	**18**	**39**	**Dec**	**27**	**0**	**33**				

2024 Phases of the Moon

Universal Time

	d	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**		**d**	**h**	**m**
												Jan	**4**	**3**	**30**
Jan	**11**	**11**	**57**	**Jan**	**18**	**3**	**52**	**Jan**	**25**	**17**	**54**	**Feb**	**2**	**23**	**18**
Feb	**9**	**22**	**59**	**Feb**	**16**	**15**	**01**	**Feb**	**24**	**12**	**30**	**Mar**	**3**	**15**	**23**
Mar	**10**	**9**	**00**	**Mar**	**17**	**4**	**11**	**Mar**	**25**	**7**	**00**	**Apr**	**2**	**3**	**15**
Apr	**8**	**18**	**21**	**Apr**	**15**	**19**	**13**	**Apr**	**23**	**23**	**49**	**May**	**1**	**11**	**27**
May	**8**	**3**	**22**	**May**	**15**	**11**	**48**	**May**	**23**	**13**	**53**	**May**	**30**	**17**	**13**
Jun	**6**	**12**	**38**	**Jun**	**14**	**5**	**18**	**Jun**	**22**	**1**	**08**	**Jun**	**28**	**21**	**53**
Jul	**5**	**22**	**57**	**Jul**	**13**	**22**	**49**	**Jul**	**21**	**10**	**17**	**Jul**	**28**	**2**	**51**
Aug	**4**	**11**	**13**	**Aug**	**12**	**15**	**19**	**Aug**	**19**	**18**	**26**	**Aug**	**26**	**9**	**26**
Sep	**3**	**1**	**55**	**Sep**	**11**	**6**	**05**	**Sep**	**18**	**2**	**34**	**Sep**	**24**	**18**	**50**
Oct	**2**	**18**	**49**	**Oct**	**10**	**18**	**55**	**Oct**	**17**	**11**	**26**	**Oct**	**24**	**8**	**03**
Nov	**1**	**12**	**47**	**Nov**	**9**	**5**	**55**	**Nov**	**15**	**21**	**28**	**Nov**	**23**	**1**	**28**
Dec	**1**	**6**	**21**	**Dec**	**8**	**15**	**26**	**Dec**	**15**	**9**	**02**	**Dec**	**22**	**22**	**18**
Dec	**30**	**22**	**27**												

2025 Phases of the Moon

Universal Time

	d	h	m		d	h	m		d	h	m		d	h	m
				Jan	6	23	56	Jan	13	22	27	Jan	21	20	31
Jan	29	12	36	Feb	5	8	02	Feb	12	13	53	Feb	20	17	32
Feb	28	0	45	Mar	6	16	31	Mar	14	6	54	Mar	22	11	29
Mar	29	10	58	Apr	5	2	15	Apr	13	0	22	Apr	21	1	35
Apr	27	19	31	May	4	13	52	May	12	16	56	May	20	11	59
May	27	3	02	Jun	3	3	41	Jun	11	7	44	Jun	18	19	19
Jun	25	10	31	Jul	2	19	30	Jul	10	20	37	Jul	18	0	37
Jul	24	19	11	Aug	1	12	41	Aug	9	7	55	Aug	16	5	12
Aug	23	6	06	Aug	31	6	25	Sep	7	18	09	Sep	14	10	33
Sep	21	19	54	Sep	29	23	54	Oct	7	3	47	Oct	13	18	13
Oct	21	12	25	Oct	29	16	21	Nov	5	13	19	Nov	12	5	28
Nov	20	6	47	Nov	28	6	59	Dec	4	23	14	Dec	11	20	52
Dec	20	1	43	Dec	27	19	10								

CHAPTER 32

LUNAR ECLIPSES: 2011–2020

A concise summary of all lunar eclipses from 2011 through 2020 is presented in the following table. The **Eclipse Type** (Penumbral, Partial, or Total) is given followed by the number of the **Saros** series. Eclipses belonging to a given Saros series recur every 18 years 11 days. The **Umbral Magnitude**[1] (fourth column) gives the fraction of the Moon's diameter immersed in Earth's umbral shadow at the instant of greatest eclipse. The **Eclipse Duration**[2] gives the length of the partial eclipse. If the eclipse is total, then the duration of the total phase is also listed in **bold**. Finally, the **Geographic Region of Eclipse Visibility**[3] provides a brief description of the region where each eclipse will be seen.

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[1] **Umbral magnitude** is the fraction of the Moon's diameter obscured by Earth's Umbra. For penumbral eclipses, the umbral magnitude is always less than 0. For partial eclipses, the umbral magnitude is always greater than 0 and less than 1. For total eclipses, the umbral magnitude is always greater than or equal to 1.

[2] **Eclipse duration** is the duration of a partial eclipse. If the eclipse is total, the duration of totality is given in **bold**.

[3] **Geographic region of eclipse visibility** is the portion of Earth's surface where a lunar eclipse can be seen.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_32,

Lunar Eclipses: 2011–2020

Date	Eclipse type	Saros	Umbral magnitude	Eclipse duration	Geographic region of eclipse visibility
2011 Jun 15	Total	130	1.705	03 h 40 m **01 h 41 m**	S. America, Europe, Africa, Asia, Aus.
2011 Dec 10	Total	135	1.110	03 h 33 m **00 h 52 m**	Europe, e Africa, Asia, Aus, Pacific, N.A.
2012 Jun 04	Partial	140	0.376	02 h 08 m	Asia, Aus, Pacific, Americas
2012 Nov 28	Penumbral	145	−0.184	–	Europe, e Africa, Asia, Aus, Pacific, N.A.
2013 Apr 25	Partial	112	0.020	00 h 32 m	Europe, Africa, Asia, Aus.
2013 May 25	Penumbral	150	−0.928	–	Americas, Africa
2013 Oct 18	Penumbral	117	−0.266	–	Americas, Europe, Africa, Asia
2014 Apr 15	Total	122	1.296	03 h 35 m **01 h 19 m**	Aus, Pacific, Americas
2014 Oct 08	Total	127	1.172	03 h 20 m **01 h 00 m**	Asia, Aus., Pacific, Americas
2015 Apr 04	Total	132	1.006	03 h 30 m **00 h 12 m**	Asia, Aus., Pacific, Americas
2015 Sep 28	Total	137	1.282	03 h 21 m **01 h 13 m**	e Pacific, Americas, Europe, Africa, w Asia
2016 Mar 23	Penumbral	142	−0.307	–	Asia, Aus., Pacific, w Americas
2016 Aug 18	Penumbral	109	−0.992	–	Aus., Pacific, Americas
2016 Sep 16	Penumbral	147	−0.058	–	Europe, Africa, Asia, Aus., w Pacific
2017 Feb 11	Penumbral	114	−0.031	–	Americas, Europe, Africa, Asia
2017 Aug 07	Partial	119	0.252	01 h 57 m	Europe, Africa, Asia, Aus.
2018 Jan 31	Total	124	1.321	03 h 23 m **01 h 17 m**	Asia, Aus., Pacific, w N. America
2018 Jul 27	Total	129	1.614	03 h 55 m **01 h 44 m**	S. America, Europe, Africa, Asia, Aus.
2019 Jan 21	Total	134	1.201	03 h 17 m **01 h 03 m**	c Pacific, Americas, Europe, Africa
2019 Jul 16	Partial	139	0.657	02 h 59 m	S. America, Europe, Africa, Asia, Aus.
2020 Jan 10	Penumbral	144	−0.111	–	Europe, Africa, Asia, Aus.
2020 Jun 05	Penumbral	111	−0.399	–	Europe, Africa, Asia, Aus.
2020 Jul 05	Penumbral	149	−0.639	–	Americas, sw Europe, Africa
2020 Nov 30	Penumbral	116	−0.258	–	Asia, Aus., Pacific, Americas

Geographic abbreviations (used above): *n* north, *s* south, *e* east, *w* west, *c* central.

All eclipse calculations are by Fred Espenak, and he assumes full responsibility for their accuracy. Some of the information presented on this Web site is based on data originally published in *Fifty Year Canon of Lunar Eclipses: 1986–2035.*

Permission is freely granted to reproduce this data when accompanied by an acknowledgment: "Eclipse Predictions by Fred Espenak, NASA's GSFC."

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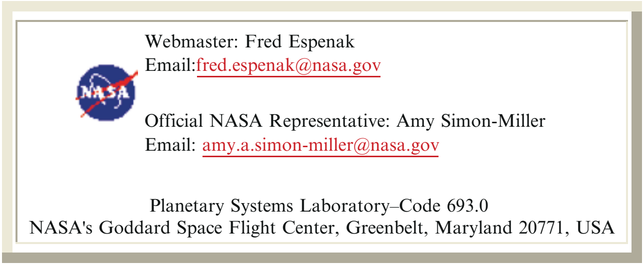

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NASA's Goddard Space Flight Center, Greenbelt, Maryland 20771, USA

CHAPTER 33

LUNAR ECLIPSES: 2021–2030

A concise summary of all lunar eclipses from 2021 through 2030 is presented in the following table. The **Eclipse Type** (Penumbral, Partial, or Total) is given followed by the number of the **Saros** series. Eclipses belonging to a given Saros series recur every 18 years 11 days. The **Umbral Magnitude**[1] (fourth column) gives the fraction of the Moon's diameter immersed in Earth's umbral shadow at the instant of greatest eclipse. The **Eclipse Duration**[2] gives the length of the partial eclipse. If the eclipse is total, then the duration of the total phase is also listed in **bold.** Finally, the **Geographic Region of Eclipse Visibility**[3] provides a brief description of the region where each eclipse will be seen.

All eclipse calculations are by Fred Espenak, and he assumes full responsibility for their accuracy. Some of the information presented on this Web site is based on data originally published in *Fifty Year Canon of Lunar Eclipses: 1986–2035*.

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[1] **Umbral magnitude** is the fraction of the Moon's diameter obscured by Earth's Umbra. For penumbral eclipses, the umbral magnitude is always less than 0. For partial eclipses, the umbral magnitude is always greater than 0 and less than 1. For total eclipses, the umbral magnitude is always greater than or equal to 1.

[2] **Eclipse duration** is the duration of a partial eclipse. If the eclipse is total, the duration of totality is given in **bold.**

[3] **Geographic region of eclipse visibility** is the portion of Earth's surface where a lunar eclipse can be seen.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_33,

Lunar Eclipses: 2021–2030

Date	Eclipse type	Saros	Umbral magnitude	Eclipse duration	Geographic region of eclipse visibility
2021 May 26	Total	121	1.016	03 h 08 m **00 h 19 m**	e Asia, Australia, Pacific, Americas
2021 Nov 19	Partial	126	0.978	03 h 29 m	Americas, n Europe, e Asia, Australia, Pacific
2022 May 16	Total	131	1.419	03 h 28 m **01 h 26 m**	Americas, Europe, Africa
2022 Nov 08	Total	136	1.364	03 h 40 m **01 h 26 m**	Asia, Australia, Pacific, Americas
2023 May 05	Penumbral	141	–0.041	–	Africa, Asia, Australia
2023 Oct 28	Partial	146	0.128	01 h 19 m	e Americas, Europe, Africa, Asia, Australia
2024 Mar 25	Penumbral	113	–0.127	–	Americas
2024 Sep 18	Partial	118	0.090	01 h 05 m	Americas, Europe, Africa
2025 Mar 14	Total	123	1.183	03 h 39 m **01 h 06 m**	Pacific, Americas, w Europe, w Africa
2025 Sep 07	Total	128	1.367	03 h 30 m **01 h 23 m**	Europe, Africa, Asia, Australia
2026 Mar 03	Total	133	1.155	03 h 28 m **00 h 59 m**	e Asia, Australia, Pacific, Americas
2026 Aug 28	Partial	138	0.935	03 h 19 m	e Pacific, America, Europe, Africa
2027 Feb 20	Penumbral	143	–0.052	–	Americas, Europe, Africa, Asia
2027 Jul 18	Penumbral	110	–1.063	–	e Africa, Asia, Australia, Pacific
2027 Aug 17	Penumbral	148	–0.521	–	Pacific, Americas
2028 Jan 12	Partial	115	0.072	00 h 59 m	Americas, Europe, Africa
2028 Jul 06	Partial	120	0.394	02 h 23 m	Europe, Africa, Asia, Australia
2028 Dec 31	Total	125	1.252	03 h 30 m **01 h 12 m**	Europe, Africa, Asia, Aust, Pacific
2029 Jun 26	Total	130	1.849	03 h 40 m **01 h 43 m**	Americas, Europe, Africa, Mid East
2029 Dec 20	Total	135	1.121	03 h 34 m **00 h 55 m**	Americas, Europe, Africa, Asia
2030 Jun 15	Partial	140	0.508	02 h 25 m	Europe, Africa, Asia, Australia
2030 Dec 09	Penumbral	145	–0.159	–	Americas, Europe, Africa, Asia

Geographic abbreviations (used above): *n* north, *s* south, *e* east, *w* west, *c* central.

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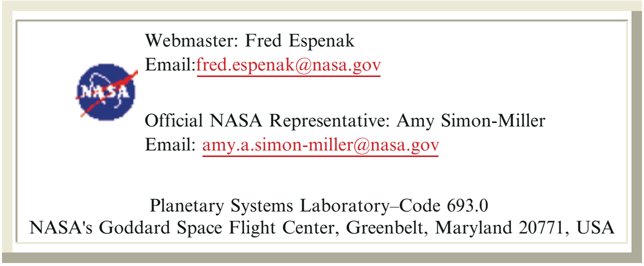

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NASA's Goddard Space Flight Center, Greenbelt, Maryland 20771, USA

CHAPTER 34

LUNAR ECLIPSES: 2031–2040

A concise summary of all lunar eclipses from 2031 through 2040 is presented in the following table. The **Eclipse Type** (Penumbral, Partial, or Total) is given followed by the number of the **Saros** series. Eclipses belonging to a given Saros series recur every 18 years 11 days. The **Umbral Magnitude**[1] (fourth column) gives the fraction of the Moon's diameter immersed in Earth's umbral shadow at the instant of greatest eclipse. The **Eclipse Duration**[2] gives the length of the partial eclipse. If the eclipse is total, then the duration of the total phase is also listed in **bold**. Finally, the **Geographic Region of Eclipse Visibility**[3] provides a brief description of the region where each eclipse will be seen.

---

[1] **Umbral magnitude** is the fraction of the Moon's diameter obscured by Earth's Umbra. For penumbral eclipses, the umbral magnitude is always less than 0. For partial eclipses, the umbral magnitude is always greater than 0 and less than 1. For total eclipses, the umbral magnitude is always greater than or equal to 1.

[2] **Eclipse duration** is the duration of a partial eclipse. If the eclipse is total, the duration of totality is given in **bold**.

[3] **Geographic region of eclipse visibility** is the portion of Earth's surface where a lunar eclipse can be seen.

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_34,

Lunar Eclipses: 2031–2040

Date	Eclipse type	Saros	Umbral magnitude	Eclipse duration	Geographic region of eclipse visibility
2031 May 07	Penumbral	112	–0.085	–	Americas, Europe, Africa
2031 Jun 05	Penumbral	150	–0.814	–	East Indies, Australia, Pacific
2031 Oct 30	Penumbral	117	–0.315	–	Americas
2032 Apr 25	Total	122	1.196	03 h 32 m **01 h 07 m**	e Africa, Asia, Australia, Pacific
2032 Oct 18	Total	127	1.109	03 h 17 m **00 h 49 m**	Africa, Europe, Asia, Australia
2033 Apr 14	Total	132	1.099	03 h 36 m **00 h 50 m**	Europe, Africa, Asia, Australia
2033 Oct 08	Total	137	1.355	03 h 23 m **01 h 20 m**	Asia, Australia, Pacific, Americas
2034 Apr 03	Penumbral	142	–0.223	–	Europe, Africa, Asia, Australia
2034 Sep 28	Partial	147	0.020	00 h 31 m	Americas, Europe, Africa
2035 Feb 22	Penumbral	114	–0.049	–	e Asia, Pacific, Americas
2035 Aug 19	Partial	119	0.109	01 h 19 m	Americas, Europe, Africa, Mid East
2036 Feb 11	Total	124	1.305	03 h 23 m **01 h 15 m**	Americas, Europe, Africa,, Asia, w Australia
2036 Aug 07	Total	129	1.460	03 h 52 m **01 h 36 m**	Americas, Europe, Africa, w Asia
2037 Jan 31	Total	134	1.213	03 h 18 m **01 h 05 m**	e Europe, e Africa, Asia, Australia, Pacific, N.A.
2037 Jul 27	Partial	139	0.814	03 h 13 m	Americas, Europe, Africa
2038 Jan 21	Penumbral	144	–0.109	–	Americas, Europe, Africa
2038 Jun 17	Penumbral	111	–0.521	–	e N. America, C. & S. America, Africa, w Europe
2038 Jul 16	Penumbral	149	–0.490	–	Australia, e Asia, Pacific, w Americas
2038 Dec 11	Penumbral	116	–0.285	–	Europe, Africa, Asia, Australia
2039 Jun 06	Partial	121	0.891	03 h 00 m	Europe, Africa, Asia, Australia
2039 Nov 30	Partial	126	0.947	03 h 27 m	Europe, Africa, Asia, Australia, Pacific
2040 May 26	Total	131	1.540	03 h 31 m **01 h 33 m**	e Asia, Australia, Pacific, w Americas
2040 Nov 18	Total	136	1.402	03 h 41 m **01 h 29 m**	e Americas, Europe, Africa, Asia, Australia

Geographic abbreviations (used above): *n* north, *s* south, *e* east, *w* west, *c* central.

All eclipse calculations are by Fred Espenak, and he assumes full responsibility for their accuracy. Some of the information presented on this Web site is based on data originally published in *Fifty Year Canon of Lunar Eclipses: 1986–2035*.

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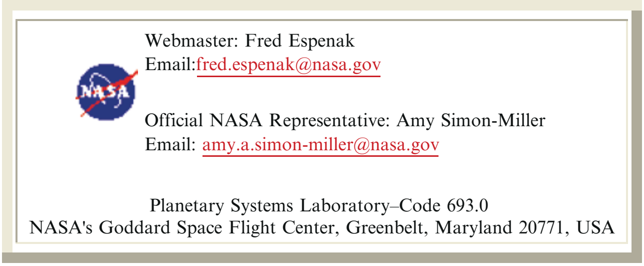

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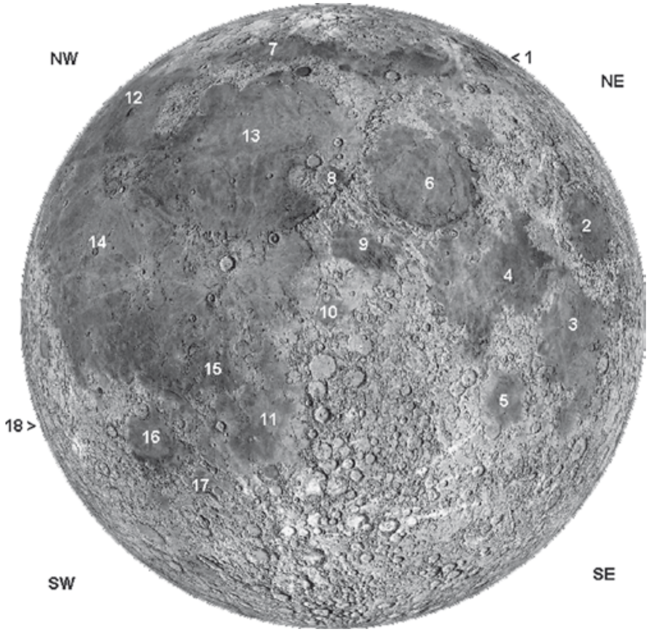
CHAPTER 35

MARIA CHART

1. **MARE HUMBOLDTIANUM**
2. **MARE CRISIUM**
3. **MARE FECUNDITATIS**
4. **MARE TRANQUILLITATIS**
5. **MARE NECTARIS**
6. **MARE SERENITATIS**
7. **MARE FRIGORIS**
8. **PALUS PUTREDINIS**
9. **MARE VAPORUM**
10. **SINUS MEDII**
11. **MARE NUBIUM**
12. **SINUS RORIS**
13. **MARE IMBRIUM**
14. **OCEANUS PROCELLARUM**
15. **MARE COGNITUM**
16. **MARE HUMORUM**
17. **PALUS EPIDEMIARUM**
18. **MARE ORIENTALE**

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_35,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CHAPTER 36

LANDMARK FEATURES CHART

1. **CLEOMEDES**
2. **LANGRENUS**
3. **PETAVIUS**
4. **ATLAS**
5. **HERCULES**
6. **PROCLUS**
7. **PLINIUS**
8. **THEOPHILUS**
9. **CYRILLUS**
10. **FRACASTORIUS**
11. **PICCOLOMINI**
12. **MAUROLYCUS**
13. **STOFLER**
14. **WALTER**
15. **PURBACH**
16. **ALPHONSUS**
17. **PTOLEMAEUS**
18. **ALBATEGNIUS**
19. **HIPPARCHUS**
20. **MONTES APENNINES**
21. **MONTES HAEMUS**
22. **MONTES CAUCASUS**
23. **VALLIS ALPES**
24. **EUDOXUS**
25. **ARISTOTELES**
26. **PLATO**
27. **J HERSCHEL**
28. **SINUS IRIDUM**
29. **MONS RUMKER**
30. **VALLIS SCHROTER**
31. **ARISTARCHUS**
32. **ARISTILLUS**

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_36,

33. ARCHIMEDES
34. ERATOSTHENES
35. COPERNICUS
36. BULLIALDUS
37. RUPES RECTA
38. PITATUS
39. LONGOMONTANUS
40. SCHILLER
41. SCHICKARD
42. GASSENDI
43. BILLY
44. GRIMALDI
45. KEPLER
46. REINER
47. FRA MAURO
48. GALILEO
49. MONTES RIPHAEUS
50. MONTES RECTI


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39>
40>

CHAPTER 37

RECOMMENDED WEB SITES AND DOWNLOADS

Lunar Photo of the Day – http://www.lpod.wikispaces.com

The Lunar Republic – http://www.lunarrepublic.com

Inconstant Moon – http://www.inconstantmoon.com

Consolidated Lunar Atlas – http://www.lpi.usra.edu

Clementine Lunar Browser – http://www.cmf.nrl.navy.mil/clementine/

The International Occultation Timing Association – http://www.lunar-occultations.com

Lunarpedia – http://www.lunarpedia.org

The Lunar and Planetary Institute – http://www.lpi.usra.edu/expmoon/

Association of Lunar and Planetary Observers – http://www.alpo-astronomy.org/

Lunar Transient Phenomena Research – http://www.ltpresearch.org

Google Moon – http://www.google.com/moon/

Virtual Moon Atlas – http://www.ap-i.net/avl/en/start

T. Plotner, *Moonwalk with Your Eyes*, Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_37,

CHAPTER 38

CHALLENGE LISTS AND OBSERVING

One of the most highly respected lunar observing lists of all times belongs to the Astronomical League. Those who are members, either by belonging to a membership involved astronomy club or a member-at-large, can earn certification of achievements and a recognition pin for completion of their studies. Even if you are not a member, the list is still open to the public to use and gratefully acknowledged in this book.

Lunar Club Program

Naked eye objects

Instruments used ________________

OBJECT	FEATURE	DATE	TIME
[ ] (Within 72 h of new)	Old Moon in New Moon's Arms	________	________
[ ] (Within 72 h of new)	New Moon in Old Moon's Arms	________	________
[ ] (Within 40 h of new)	Crescent Moon, Waxing	________	________
[ ] (Within 48 h of new)	Crescent Moon, Waning	________	________
[ ]	Man in the Moon	________	________
[ ]	Woman in the Moon	________	________
[ ]	Rabbit in the Moon	________	________
[ ]	Cow Jumping Over the Moon	________	________
Maria			
[ ]	Crisium	________	________
[ ]	Fecunditatis	________	________
[ ]	Serenitatis	________	________
[ ]	Tranquillitatis	________	________
[ ]	Nectaris	________	________
[ ]	Imbrium	________	________
[ ]	Frigoris	________	________
[ ]	Nubium	________	________
[ ]	Humorum	________	________
[ ]	Oceanus Procellarum	________	________

(continued)

T. Plotner, *Moonwalk with Your Eyes,* Astronomer's Pocket Field Guide,
DOI 10.1007/978-1-4419-0646-5_38, © Springer Science+Business Media, LLC 2010

Lunar Club Program (continued)

Binocular objects

Instruments used ________________________

OBJECT	FEATURE	DATE	TIME
[ ]	**Lunar Rays**	________	________
[ ]	**Sinus Iridum**	________	________
[ ]	**Sinus Medii**	________	________
[ ]	**Sinus Roris**	________	________
[ ]	**Palus Somnii**	________	________
[ ]	**Palus Epidemiarum**	________	________
[ ]	**Mare Vaporum**	________	________
Craters			
[ ] ~4 days old	**Langrenus**	________	________
[ ]	**Vendelinus**	________	________
[ ]	**Petavius**	________	________
[ ]	**Cleomedes**	________	________
[ ]	**Atlas**	________	________
[ ]	**Hercules**	________	________
[ ]	**Endymion**	________	________
[ ]	**Macrobius**	________	________
[ ] ~7 days old	**Piccolomini**	________	________
[ ]	**Theophilus**	________	________
[ ]	**Cyrillus**	________	________
[ ]	**Catharina**	________	________
[ ]	**Posidonius**	________	________
[ ]	**Fracastorius**	________	________
[ ]	**Aristoteles**	________	________
[ ]	**Eudoxus**	________	________
[ ]	**Cassini**	________	________
[ ]	**Hiparchus**	________	________
[ ]	**Albategnius**	________	________
[ ]	**Aristillus**	________	________
[ ]	**Autolycus**	________	________
[ ]	**Maurolycus**	________	________
[ ] ~10 days old	**Plato**	________	________
[ ]	**Archimedes**	________	________
[ ]	**Ptolemaeus**	________	________
[ ]	**Alphonsus**	________	________

(continued)

Lunar Club Program (continued)

[ ]	**Arzachel**	________	________
[ ]	**Walter**	________	________
[ ]	**Maginus**	________	________
[ ]	**Tycho**	________	________
[ ]	**Clavius**	________	________
[ ]	**Eratosthenes**	________	________
[ ]	**Longomontanus**	________	________
[ ]	**Copernicus**	________	________
[ ]	**Bullialdus**	________	________
[ ]	**Aristarchus**	________	________
[ ]	**Gassendi**	________	________
[ ] ~14 days old	**Kepler**	________	________
[ ]	**Grimaldi**	________	________

Telescopic objects

Instruments used ____________________

OBJECT	FEATURE	DATE	TIME
[ ]	**Sinus Aestuum**	________	________
[ ]	**Lacus Mortis**	________	________
[ ]	**Palus Putredinis**	________	________
[ ]	**Promontorium Laplace**	________	________
[ ]	**Promontorium Heraclides**	________	________
[ ]	**Promontorium Agarum**	________	________
[ ]	**Montes Alpes**	________	________
[ ]	**Montes Apenninus**	________	________
[ ]	**Mons Hadley**		
[ ]	**Mons Piton**	________	________
[ ]	**Mons Pico**	________	________
[ ]	**Rupes Altai**		
[ ]	**Rima Hyginus**		
[ ]	**Vallis Schroteri**		
[ ]	**Vallis Alpes**		
[ ]	**Rupes Recta (straight wall)**	________	________
Craters			
[ ]~4 days old	**Picard**	________	________
[ ]	**Fumerius**	________	________
[ ]	**Petavius Wall**	________	________
[ ]	**Messier/Messier A**	________	________

(continued)

Lunar Club Program (continued)

[ ]	Proclus	________	________
[ ]	Fabricius	________	________
[ ] ~7 days old	Plinius	________	________
[ ]	Mitchell	________	________
[ ]	Cassini A	________	________
[ ]	Manilius	________	________
[ ]	Gemma Frisius	________	________
[ ] ~10 days old	Davy	________	________
[ ]	Pitatus	________	________
[ ]	Billy	________	________
[ ]	Fra Mauro	________	________
[ ]	Clavius craterlets	________	________
[ ]	Hippalus	________	________
[ ]	Herschel, J.	________	________
[ ] ~14 days old	Schickard	________	________
[ ]	Reiner Gamma	________	________

Optional Activities

Naked eye

1. Estimate first quarter phase within 8 h.
2. Estimate third quarter phase within 8 h.
3. Estimate full moon within 36 h.
4. Plot moon's position against the stars for 3 consecutive days.
5. Compare the size of the full moon on the horizon with the full moon on the meridian using a dime held at arm's length.
6. Find the thinnest phase by which you can read newsprint.

Binocular

1. Sketch libration – use Mare Crisium or Grimaldi for examples.
2. Sketch a lunar map – use any scale for binoculars only.

Telescopic

1. Plot the moon's hourly motion against the stars for 2 h or more.
2. Measure the height of a lunar mountain – need to calculate the sun's elevation at the mountain and estimate the shadow length – try Mt. Piton.

L_II_Targets

Task or target #	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
Create a sketch/map of the visible lunar surface			
1	Observe a Full Moon and sketch a large-scale (prominent features) map depicting the nearside; disk of visible surface should be drawn at least 5 inches in diameter. Sketch itself should be created only by observing the Moon, but maps or guidebooks may be used when labeling sketched features. Label all Maria, prominent craters, and major rays by the crater name they originated from. (Counts as 3 observations (OBSV): #1, #2, & #3)	L-1	
2		L-1	
3		L-1	
Observe these targets; provide brief descriptions			
4	Alpetragius		55
5	Arago		35
6	Arago Alpha & Arago Beta	L-32	35
7	Aristarchus Plateau	L-18	18
8	Baco	L-55	74
9	Bailly	L-37	71
10	Beer, Beer Catena, & Feuillée		21
11	Bullialdus, Bullialdus A, & Bullialdus B		53
12	Cassini, Cassini A, & Cassini B		12
13	Cauchy, Cauchy Omega, & Cauchy Tau	L-48	36

(continued)

L_II_Targets (continued)

Task or target #	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
14	Censorinus		47
15	Crüger		50
16	Dorsae Lister & Smirnov (A.K.A. Serpentine Ridge)	L-33	24
17	Grimaldi Basin outer and inner rings	L-36	39, etc.
18	Hainzel, Hainzel A, & Hainzel C		63
19	Hercules, Hercules G, Hercules E		14
20	Hesiodus A	L-81	54, 64
21	Hortensius dome field	L-65	30
22	Julius Caesar		34
23	Kies		53
24	Kies Pi	L-60	53
25	Lacus Mortis		14
26	Linne		23
27	Lamont	L-53	35
28	Mairan		9
29	Mare Australe	L-56	76
30	Mare Cognitum		42, etc.
31	Mare Humboltianum basin	L-70	7, etc.
32	Mare Insularum & Sinus Aestuum		32, etc.
33	Mare Marginis		27, 38

34	Mare Smythii		38, 49
35	Mare Spumans		38
36	Mare Undarum		38
37	Marius Hills	L-42	29
38	Mersenius	L-44	51
39	Milichius Pi		30
40	Mons Gruithuisen Gamma & Mons Gruithuisen Delta	L-49	9
41	Mons Rümker (A.K.A. Rümker Hills)	L-65	8
42	Montes Agricola		18
43	Montes Cordillera		39, 50
44	Montes Foucault (The mountains just west and north of Foucault Crater)		2
45	Montes Rook		50
46	Montes Recti, Teneriffe, & Spitzbergen		11, etc.
47	Mösting A	L-61	43
48	Promontorium Archerusia		24
49	Regiomontanus & Regiomontanus A	L-46	55
50	Rabbi Levi		67
51	Rima Aridaeus	L-29	34
52	Rima Cauchy	L-48	36
53	Rima Hadley	L-66	22
54	Rima Hesiodus		63, etc.
55	Rimae Hippalus	L-54	52, 53

(continued)

L_II_Targets (continued)

Task or target #	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
56	Rimae Janssen	L-40	67
57	Rimae Triesnecker	L-35	33
58	Ritter & Sabine	L-38	35
59	Sacrobosco		56
60	Schiller, Segner, Zucchius region	L-59	71
61	Sinus Amoris		25
62	Sinus Asperitatis		46, 47
63	Sinus Concordiae		37
64	Sinus Lunicus		12
65	Stadius & Stadius Catenae		32
66	Taruntius	L-31	37
67	Timocharis		21
68	Vallis Rheita	L-58	68
69	Wargentin	L-43	70
70	Wolf		54
Sketch these targets			
71	Any polar crater (above 80 N latitude or below 80 S latitude)		
72	Clavius & its internal craterlets (counts as 2 OBSV: #72 & #73)	L-9	72
73	Clavius & its internal craterlets	L-9	72
74	Davy Y	L-51	43

75	**Delaunay**		**55**
76	**Mare Crisium**	**L-10**	**26, etc.**
77	**Messier, Messier A, & rays**		**48**
78	**Montes Jura (counts as 2 OBSV: #78 & #79)**		**10**
79	**Montes Jura**		**10**
80	**Müller and craterlet chains**		**44**
81	**Thebit, Thebit A, & Thebit L**		**55**
82	**Vallis Alpes**		**4**
83	**Sketch or image "earthshine" on lunar surface. Identify any major features visible on the shadowed portion of the lunar surface**	**L-2**	
84 **85**	**Create sketches or images of limb feature(s) that depict libration effect. (counts as 2 OBSV: #84 & #85)**		
86	**Sketch or image a close conjunction of Moon and bright star or planet**		
Observe and create multiple sketches (or images) of same targets			
87	**Byrgius A near lunar sunrise (or sunset)**		**50**
88	**Byrgius A near lunar midday**		**50**
89	**Proclus near lunar midday**	**L-12**	**26**
90	**Proclus near lunar sunset**	**L-12**	**26**
91	**Rupes Recta near lunar sunrise**	**L-15**	**54**
92	**Rupes Recta near lunar sunset**	**L-15**	**54**
93	**Tycho near lunar sunrise (or sunset)**	**L-6**	**64**
94	**Tycho near lunar midday**	**L-6**	**64**

(continued)

L_II_Targets (continued)

Task or target #	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
Miscellaneous observations			
95	Observe Statio Tranquillitatis region (AKA "Tranquility Base"). In addition to describing the lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		35
96	Observe another Luna, Lunakhod, or Apollo mission site – in addition to describing lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		
97	Observe another Luna, Lunakhod, or Apollo mission site – in addition to describing lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		
98	Observe occultation (ingress, egress, or graze) of a bright star, planet or planetary moon. Include exact time of event. (count as 1 OBSV; if both ingress behind & egress from behind Moon are logged, count as 2 OBSV)		
99 100	Observe a lunar eclipse; description and/or labeled sketches/images must as a minimum describe entry and event maximum (counts as 2 OBSV: #99 & #100)		

OPTIONAL TARGETS: may substitute for required tasks/targets

OPT-A	**Create a series of sketches or images that show daily phase/position change; 3 or more days/nights at approximately same hour (sub for 2 OBSV)**
OPT-B	**Create two or more sketches or images, taken 1 month or more apart, that show change in Moon's path w/ respect to landmark(s) on the local horizon. Images should be taken with same equipment and at same magnification (sub for 2 OBSV)**
OPT-C	**Create two or more images that depict the change in apparent diameter of the Moon at/near apogee and perigee. Each image should be taken with same equipment and at same magnification (sub for 1 OBSV)**
OPT-D	**Observe a solar eclipse (sub for 1 OBSV; if sketches/images are included and depict entry and event maximum, sub for 2 OBSV)**
OPT-E	**Observe a lowland area with one or more colored filters, and compare the similarities/differences to the unfiltered view (sub for 1 OBSV)**
OPT-F	**Create a series of images at 1-h intervals that show the terminator passing over a prominent feature (sub for 2 OBSV)**

The Lunar Club – Tasks & Targets

Task/ target	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
Create a sketch/map of the visible lunar surface			
1	Observe a Full Moon and sketch a large-scale (prominent features) Map depicting the nearside; disk of visible surface should be drawn at least 5-inches in diameter. Sketch itself should be created only by	L-1	
2	• Observing the Moon, but maps or guidebooks may be used when labeling sketched features • Label all Maria, prominent craters, and labeling sketched features	L-1	
3	• Label all Maria, prominent craters, and major rays by the crater name they originated from. (Counts as 3 observations (OBSV): #1, #2, & #3)	L-1	
Observe these targets; provide brief descriptions			
4	Alpetragius		55
5	Arago		35
6	Arago Alpha & Arago Beta	L-32	35
7	Aristarchus Plateau	L-18	18
8	Baco	L-55	74
9	Bailly	L-37	71
10	Beer, Beer Catena, & Feuillée		21
11	Bullialdus, Bullialdus A, & Bullialdus B		53
12	Cassini, Cassini A, & Cassini B		12
13	Cauchy, Cauchy Omega, & Cauchy Tau	L-48	36

14	Censorinus		47
15	Crüger		50
16	Dorsae Lister & Smirnov (A.K.A. Serpentine Ridge)	L-33	24
17	Grimaldi Basin outer and inner rings	L-36	39, etc.
18	Hainzel, Hainzel A, & Hainzel C		63
19	Hercules, Hercules G, Hercules E		14
20	Hesiodus A	L-81	54, 64
21	Hortensius dome field	L-65	30
22	Julius Caesar		34
23	Kies		53
24	Kies Pi	L-60	53
25	Lacus Mortis		14
26	Linne		23
27	Lamont	L-53	35
28	Mairan		9
29	Mare Australe	L-56	76
30	Mare Cognitum		42, etc.
31	Mare Humboltianum basin	L-70	7, etc.
32	Mare Insularum & Sinus Aestuum		32, etc.
33	Mare Marginis		27, 38
34	Mare Smythii		38, 49
35	Mare Spumans		38

(continued)

The Lunar Club – Tasks & Targets (continued)

Task/ target	Task description or target name	Wood’s LUNAR 100 Catalog	Rükl Atlas (chart)
36	Mare Undarum		38
37	Marius Hills	L-42	29
38	Mersenius	L-44	51
39	Milichius Pi		30
40	Mons Gruithuisen Gamma & Mons Gruithuisen Delta	L-49	9
41	Mons Rümker (A.K.A. Rümker Hills)	L-65	8
42	Montes Agricola		18
43	Montes Cordillera		39, 50
44	Montes Foucault (The mountains just west and north of Foucault Crater)		2
45	Montes Rook		50
46	Montes Recti, Teneriffe, & Spitzbergen		11, etc.
47	Mösting A	L-61	43
48	Promontorium Archerusia		24
49	Regiomontanus & Regiomontanus A	L-46	55
50	Rabbi Levi		67
51	Rima Aridaeus	L-29	34
52	Rima Cauchy	L-48	36
53	Rima Hadley	L-66	22
54	Rima Hesiodus		63, etc.
55	Rimae Hippalus	L-54	52, 53

56	Rimae Janssen	L-40	67
57	Rimae Triesnecker	L-35	33
58	Ritter & Sabine	L-38	35
59	Sacrobosco		56
60	Schiller, Segner, Zucchius region	L-59	71
61	Sinus Amoris		25
62	Sinus Asperitatis		46, 47
63	Sinus Concordiae		37
64	Sinus Lunicus		12
65	Stadius & Stadius Catenae		32
66	Taruntius	L-31	37
67	Timocharis		21
68	Vallis Rheita	L-58	68
69	Wargentin	L-43	70
70	Wolf		54
Sketch these targets			
71	Any polar crater (above 80 N latitude or below 80 S latitude)		
72	Clavius & its internal craterlets (counts as 2 OBSV: #72 & #73)	L-9	72
73	Clavius & its internal craterlets	L-9	72
74	Davy Y	L-51	43
75	Delaunay		55
76	Mare Crisium	L-10	26, etc.

(continued)

The Lunar Club – Tasks & Targets (continued)

Task/ target	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
77	Messier, Messier A, & rays		48
78	Montes Jura (counts as 2 OBSV: #78 & #79)		10
79	Montes Jura		10
80	Müller and craterlet chains		44
81	Thebit, Thebit A, & Thebit L		55
82	Vallis Alpes		4
83	Sketch or image "earthshine" on lunar surface. Identify any major features visible on the shadowed portion of the lunar surface	L-2	
84	Create sketches or images of limb feature(s) that depict libration effect. (Counts as 2 OBSV: #84 & #85)		
85	Create sketches or images of limb feature(s) that depict libration effect. (Counts as 2 OBSV: #84 & #85)		
86	Sketch or image a close conjunction of Moon and bright star or planet		
Observe and create multiple sketches (or images) of same targets			
87	Byrgius A near lunar sunrise (or sunset)		50
88	Byrgius A near lunar midday		50
89	Proclus near lunar midday	L-12	26
90	Proclus near lunar sunset	L-12	26
91	Rupes Recta near lunar sunrise	L-15	54

92	Rupes Recta near lunar sunset	L-15	54
93	Tycho near lunar sunrise (or sunset)	L-6	64
94	Tycho near lunar midday	L-6	64
Miscellaneous observations			
95	Observe Statio Tranquillitatis region (AKA "Tranquility Base"). In addition to describing the lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		35
96	Observe another Luna, Lunakhod, or Apollo mission site – in addition to describing lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		
97	Observe another Luna, Lunakhod, or Apollo mission site – in addition to describing lunar surface, observing notes should include mission name, date(s) of exploration, and a brief description of significance		
98	Observe occultation (ingress, egress, or graze) of a bright star, planet, or planetary moon. Include exact time of event. (count as 1 OBSV; if both ingress behind & egress from behind Moon are logged, count as 2 OBSV)		
99	Observe a lunar eclipse; description and/or labeled sketches/images		
100	Must as a minimum describe entry and event maximum (counts as 2 OBSV: #99 & #100)		

(continued)

The Lunar Club – Tasks & Targets (continued)

Task/target	Task description or target name	Wood's LUNAR 100 Catalog	Rükl Atlas (chart)
OPTIONAL TARGETS: may substitute for required tasks/targets			
OPT-A	**Create a series of sketches or images that show daily phase/position change; 3 or more days/nights at approximately same hour (sub for 2 OBSV)**		
OPT-B	**Create two or more sketches or images, taken 1 month or more apart that show change in Moon's path w/ respect to landmark(s) on the local horizon. Images should be taken with same equipment and at same magnification (sub for 2 OBSV)**		
OPT-C	**Create two or more images that depict the change in apparent diameter of the Moon at/near apogee and perigee. Each image should be taken with same equipment and at same magnification (sub for 1 OBSV)**		
OPT-D	**Observe a solar eclipse (sub for 1 OBSV; if sketches/images are included and depict entry and event maximum, sub for 2 OBSV)**		
OPT-E	**Observe a lowland area with one or more colored filters, and compare the similarities/differences to the unfiltered view (sub for 1 OBSV)**		
OPT-F	**Create a series of images at 1-h intervals that show the terminator passing over a prominent feature (sub for 2 OBSV)**		

Another wonderful lunar observing club activity that has been a favorite of almost everyone around the world over the years has been from the good folks at Sky & Telescope Magazine. The “Lunar 100” represents some of the finest the Moon has to offer and we thank the publishers for sharing the list with so many of us over the years.

The Lunar 100

#	Feature	Significance	Lat.°	Lon.°	Diameter (km)	Date observed	Telescope	Eyepiece/ mag.
1	Moon	Large satellite	–	–	3,476			
2	Earthshine	Twice reflected sunlight	–	–	–			
3	Mare/highland dichotomy	Two materials with distinct compositions	–	–	–			
4	Apennines	Imbrium basin rim	18.9 N	3.7 W	400			
5	Copernicus	Archetypal large complex crater	9.7 N	20.1 W	93			
6	Tycho	Large rayed crater with impact melts	43.4 S	11.1 W	102			
7	Altai Scrap	Nectaris basin rim	24.3 S	22.6 E	425			
8	Theophilus, Cyrillus, Catharina	Crater sequence illustrating stages of degradation	13.2 S	24.0 E	110			
9	Clavius	Lacks basin features in spite of its size	58.8 S	14.1 W	245			

(continued)

The Lunar 100 (continued)

#	Feature	Significance	Lat.°	Lon.°	Diameter (km)	Date observed	Telescope	Eyepiece/ mag.
10	Mare Crisium	Mare contained in large circular basin	18.0 N	59.0 E	540			
11	Aristarchus	Very bright crater with dark bands on its walls	23.7 N	47.4 W	40			
12	Proclus	Oblique-impact rays	16.1 N	46.8 E	28			
13	Gassendi	Floor-fractured crater	17.6 S	40.1 W	101			
14	Sinus Iridum	Very large crater with missing rim	45.0 N	32.0 W	260			
15	Straight Wall (Rupes Recta)	Best example of a lunar fault	21.8 S	7.8 W	130			
16	Petavius	Crater with domed and fractured floor	25.1 S	60.4 E	188			
17	Schroter's Valley	Giant sinuous rille	26.2 N	50.8 W	168			
18	Mare Serenitatis dark edges	Distinct mare areas with different compositions	17.8 N	23.0 E	–			
19	Alpine Valley	Lunar graben	49.0 N	3.0 E	165			
20	Posidinius	Floor-fractured crater	31.8 N	29.9 E	95			
21	Fracastorius	Crater with subsided and fractured floor	21.5 S	33.2 E	112			

22	Aristarchus Plateau	Mysterious uplifted region mantled with pyroclastics	26.0 N	51.0 W	150
23	Pico	Isolated Imbrium basin-ring fragment	45.7 N	8.9 W	25
24	Hyginus Rille	Rille containing rimless collapse pits	7.4 N	7.8 N	220
25	Messier & Messier A	Oblique ricochet-impact pair	1.9 S	47.6 E	11
26	Mare Frigoris	Arcuate mare of uncertain origin	56.0 N	1.4 E	1,600
27	Archimedes	Large crater lacking central peak	29.7 N	4.0 W	83
28	Hipparchus	Subject of first drawing of a single crater	5.5 S	4.8 E	150
29	Aridaeus Rille	Long, linear graben	6.4 N	14.0 E	250
30	Schiller	Possible oblique impact	51.9 S	39.0 W	180
31	Taruntius	Young floor-fractured crater	5.6 N	46.5 E	56
32	Argao Alpha & Beta	Volcanic domes	6.2 N	21.4 E	26
33	Serpentine Ridge	Basin inner-ring segment	27.3 N	25.3 E	155
34	Lacus Mortis	Strange crater with rille and ridge	45.0 N	27.2 E	162
35	Triesnecker Rilles	Rille family	4.3 N	4.6 E	215
36	Grimaldi basin	Small two-ring basin	5.5 S	68.3 W	410

(continued)

The Lunar 100 (continued)

#	Feature	Significance	Lat.°	Lon.°	Diameter (km)	Date observed	Telescope	Eyepiece/ mag.
37	Bailly	Barely discernible basin	66.5 S	69.1 W	303			
38	Sabine & Ritter	Possible twin impacts	1.7 N	19.7 E	30			
39	Schickard	Crater floor with Orientale basin ejecta stripe	44.3 S	55.3 W	206			
40	Janssen Rille	Rare example of a highland rille	45.4 S	39.3 E	199			
41	Bessel ray	Ray of uncertain origin near Bessel	21.8 N	17.9 E	–			
42	Marius Hills	Complex of volcanic domes and hills	12.5 N	54.0 W	125			
43	Wargentin	Crater filled to the rim with lava or ejecta	49.6 S	60.2 W	84			
44	Mersinius	Domed floor cut by secondary craters	21.5 S	49.2 W	84			
45	Maurolycus	Region of saturation cratering	42.0 S	14.0 E	114			
46	Regiomontanus central peak	Possible volcanic peak	28.0 S	0.6 W	108			
47	Alphonsus dark spots	Dark-halo eruptions on crater floor	13.7 S	3.2 W	119			
48	Cauchy region	Fault, rilles and domes	10.5 N	38.0 E	130			

49	Gruithuisen Delta & Gamma	Volcanic domes formed with viscous lavas	36.3 N	40.0 W	20
50	Cayley Plains	Light, smooth plains of uncertain origin	4.0 N	15.1 E	14
51	Davy crater chain	Result of comet-fragment impacts	11.1 S	6.6 W	34
52	Cruger	Possible volcanic caldera	16.7 S	66.8 W	45
53	Lamont	Possible buried basin	4.4 N	23.7 E	106
54	Hippalus Rilles	Rilles concentric to Humorum basin	24.5 S	29.0 W	240
55	Baco	Unusually smooth crater floor and surrounding plains	51.0 S	19.1 E	69
56	Mare Australe	Partially flooded ancient basin	49.8 S	84.5 E	132
57	Reiner Gamma	Conspicuous swirl and magnetic anomaly	7.7 N	59.2 W	70
58	Rheita Valley	Basin secondary-crater chain	72.5 S	51.5 E	68
59	Schiller-Zucchius basin	Badly degraded overlooked basin	56.0 S	45.0 W	335
60	Kies Pi	Volcanic dome	26.9 S	24.2 W	45
61	Mosting A	Simple crater close to middle of lunar near side	3.2 S	5.2 W	13
62	Rumker Hills	Large volcanic dome	40.8 N	58.1 W	70

(continued)

The Lunar 100 (continued)

#	Feature	Significance	Lat.°	Lon.°	Diameter (km)	Date observed	Telescope	Eyepiece/ mag.
63	Imbrium sculpture	Basin ejecta	11.0 N	12.0 E	–			
64	Descartes	Apollo 16 landing site; highland volcanism?	11.7 S	15.7 E	–			
65	Hortensius domes	Dome field north of Hortensius	7.6 N	27.9 W	10			
66	Hadley Rille	Lava channel near Apollo 15 landing site	25.0 N	3.0 E	–			
67	Fra Mauro formation	Apollo 14 landing site on Imbrium ejecta	3.6 S	17.5 W	–			
68	Flamsteed P	Proposed young volcanic crater & Surveyor 1 landing site	3.0 S	44.0 W	–			
69	Copernicus secondary craters	Rays and craterlets near Pytheas	19.6 N	19.1 W	4			
70	Humboldtianum basin	Multi-ring impact basin	57.0 N	80.0 E	650			
71	Sulpicius Gallus dark mantle	Ash eruptions northwest of crater	19.6 N	11.6 E	12			
72	Atlas dark-halo craters	Explosive volcanic pits on floor of Atlas	46.7 N	44.4 E	87			

73	Smythii basin	Difficult-to-observe basin scarp and mare	2.0 S	87.0 E	740
74	Copernicus H	Dark-halo impact crater	6.9 N	18.3 W	5
75	Ptolemaeus B	Saucerlike depression on the floor of Ptolemaeus	8.0 S	0.8 W	164
76	W. Bond	Large crater degraded by Imbrium ejecta	65.3 N	3.7 E	158
77	Sirsalis Rille	Procellarum basin radial rilles	15.7 S	61.7 W	425
78	Lambert R	Buried "ghost" crater	23.8 N	20.6 W	54
79	Sinus Aestuum	Eastern dark-mantle volcanic deposit	12.0 N	3.5 W	90
80	Orientale basin	Youngest large impact basin	19.0 S	95.0 W	930
81	Hesiodus A	Concentric crater	30.1 S	17.0 W	15
82	Linne	Small crater once thought to have disappeared	27.7 N	11.8 E	2.4
83	Plato craterlets	Crater pits at limits of detection	51.6 N	9.4 W	109
84	Pitatus	Crater with concentric rilles	29.8 S	13.5 W	97
85	Langrenus rays	Aged ray system	8.9 S	60.9 E	132
86	Prinz Rilles	Rille system near the crater Prinz	27.0 N	43.0 W	46

(continued)

The Lunar 100 (continued)

#	Feature	Significance	Lat.°	Lon.°	Diameter (km)	Date observed	Telescope	Eyepiece/ mag.
87	Humboldt	Crater with central peaks and dark spots	27.0 S	80.9 E	189			
88	Peary	Difficult-to-observe polar crater	88.6 N	95.3 E	104			
89	Valentine dome	Volcanic dome	30.5 N	10.1 E	30			
90	Armstrong, Aldrin, Collins	Small craters near the Apollo 11 landing site	1.3 N	23.7 E	3			
91	De Gasparis Rilles	Area with many rilles	25.9 S	50.7 W	30			
92	Gylden Valley	Part of the Imbrium radial sculpture	5.1 S	0.7 E	47			
93	Dionysius rays	Unusual and rare dark rays	2.8 N	17.3 E	18			
94	Drygalski	Large South Pole-region crater	79.3 S	84.9 W	149			
95	Procellarum basin	Moon's biggest basin?	23.0 N	15.0 W	3,200			
96	Leibnitz Mountains	Rim of South Pole-Aitken basin	85.0 S	30.0 E	–			
97	Inghirami Valley	Orientale basin ejecta	44.0 S	73.0 W	140			
98	Imbrium lava flows	Mare lava-flow boundaries	32.8 N	22.0 W	–			
99	Ina caldera	D-shaped young volcanic cladera	18.6 N	5.3 E	3			
100	Mare Marginis swirls	Possible magnetic-field deposits	18.5 N	88.0 E	–			

The Lunar 100 is an excellent lunar observing list created by Charles A. Wood, and first published in an article entitled “Introducing the Lunar 100” (Sky & Telescope, April 2004). The Lunar 100 is the property of Charles A. Wood and Sky Publishing Corporation

This guidebook is provided to assist an observer in completing the Lunar 100 by providing an observation checklist and a list of the features sorted by best viewing opportunity

Lunar 100 – Day by Day

Day 2	
2	Earthshine
10	Mare Crisium
16	Petavius
56	Mare Australe
70	Humboltianum Basin (Mare Humboltianum)
73	Mare Smythii
85	Langrenus rays
87	Humboldt
100	Mare Marginis swirls
Day 3	
58	Rheita Valley (Vallis Rheita)
Day 4	
12	Proclus
25	Messier & Messier A
31	Taruntius
40	Janssen Rille (Rima Janssen)
48	Cauchy region
72	Atlas dark halo craters
Day 5	
7	Altai Scarp (Rupes Altai)
8	Theophilus, Cyrillus, Catherina
8	Mare Serenitatus dark edges
20	Posidonius
21	Fracastorius
26	Mare Frigoris
32	Arago Alpha & Beta
33	Serpentine Ridge (Dorsa Smirnov)

(continued)

Lunar 100 – Day by Day (continued)

34	Lacus Mortis
38	Ritter & Sabine
53	Lamont
55	Baco
90	Armstrong, Aldrin, Collins
Day 6	
24	Hyginus Rille (Rima Hyginus)
28	Hipparchus
29	Ariadaeus Rille (Rima Ariadaeus)
35	Triesnecker Rille (Rimae Triesnecker)
41	Bessel ray
45	Maurolycus
50	Cayley Plains
63	Imbrium sculpture
64	Descarte
71	Sulpicus Gallus
82	Linne
89	Valentine dome
93	Dionysius rays
Day 7	
4	Apennines (Montes Apenninus)
19	Alpine Valley (Vallis Alpes)
27	Archimedes
46	Regiomontanus central peak
66	Hadley Rille (Rima Hadley)
75	Ptolemaeus B
76	W. Bond
88	Peary
92	Gylden Valley
Day 8	
15	Straight Wall (Rupes Recta)
47	Alphonsus
51	Davy crater chain
61	Mosting A
79	Sinus Aestuum
83	Plato craterlets
96	Leibnitz Mountains
99	Ina caldera

(continued)

Lunar 100 – Day by Day (continued)

Day 9	
5	Copernicus
6	Tycho
9	Clavius
14	Sinus Iridum
60	Kies Pi
65	Hortensius dome
67	Fra Mauro formation
69	Copernicus secondary craters
74	Copernicus H
78	Lambert R
81	Hesiodus A
84	Pitatus
94	Drygalski
Day 10	
13	Gassendi
30	Schiller
49	Griuthuisen Delta & Gamma
54	Hippalus Rilles (Rimae Hippalus)
59	Schiller-Zucchius basin
68	Flamsteed P
98	Imbrium lava flows
Day 11	
11	Aristarchus
17	Schroter's Valley
22	Aristarchus Plateau
39	Schickard
42	Marius Hills
44	Mersenius
57	Reiner Gamma
86	Prinz Rilles (Rimae Prinz)
91	De Gasparis Rilles (Rimae De Gasparis)
Day 12	
37	Bailly
43	Wargentin
62	Rumker Hills (Mons Rumker)
77	Sirsalis Rille (Rima sirsalis)

(continued)

Lunar 100 – Day by Day (continued)

Day 13	
36	Grimaldi basin
52	Cruger
80	Orientale Basin (Mare Orientale)
97	Inghirami Valley (Vallis Inghirami)
Day 14	
1	Moon
3	Mare/highland dichotamy
95	Procellarum Basin
Days 15–17	
10	Mare Crisium
12	Proclus
16	Petavius
25	Messier & Messier A
31	Taruntius
40	Janssen Rille (Rima Janssen)
56	Mare Australe
58	Rheita Valley (Vallis Rheita)
70	Humboldtianum basin
72	Atlas dark-halo crater
73	Smythii basin (Mare Smythii)
85	Langrenus rays
87	Humbolt
100	Mare Marginis swirls
Days 18–20	
7	Altai Scarp (Rupes Altai)
8	Theophilus, Cyrillus, & Catharina
18	Mare Serenitatus dark edges
20	Posidonius
21	Fracastorius
29	Ariadeus Rille (Rima Ariadeus)
32	Arago Alpha & Beta
33	Serpentine Ridge (Dorsa Smirnov)
34	Lacus Mortis
38	Sabine & Ritter
41	Bessel ray
45	Maurolycus
48	Cauchy region

(continued)

Lunar 100 – Day by Day (continued)

50	Cayley plains
53	Lamont
55	Baco
63	Imbrium sculpture
64	Descarte
71	Sulpicius Gallus dark mantle
82	Linne
89	Valentine dome
90	Armstrong, Aldrin, Collins
93	Dionysius rays
Days 21–22	
4	Apennines (Montes Apenninus)
5	Copernicus
6	Tycho
9	Clavius
15	Straight Wall (Rupes Recta)
19	Alpine Valley (Vallis Alpes)
23	Pico
24	Hyginus Rille (Rima Hyginus)
26	Mare Frigoris
27	Archimedes
28	Hipparchus
35	Triesnecker Rilles (Rimae Triesnecker)
46	Regiomontanus central peak
47	Alphonsus dark spots
51	Davy crater chain
61	Mosting A
66	Hadley Rille (Rima Hadley)
67	Fra Mauro formation
69	Copernicus secondary crater
74	Copernicus H
75	Ptolemaeus B
76	W. Bond
78	Lambert R
79	Sinus Aestuum
81	Hesiodus A
83	Plato craterlets
84	Pitatus

(continued)

Lunar 100 – Day by Day (continued)

88	Peary
92	Gylden Valley
94	Drygalski
96	Leibnitz Mountains
99	Ino Caldera
Days 23–25	
13	Gassendi
14	Sinus Iridum
30	Schiller
49	Gruithuisen Delta & Gamma
54	Hippalus Rille (Rima Hippalus)
59	Schiller-Zucchias basin
60	Kies Pi
65	Hortensius domes
68	Flammsteed P
98	Imbrium lava flows
Days 26–28	
11	Aristarchus
17	Schroter's Valley
22	Aristarchus Plateau
36	Grimaldi
37	Bailly
39	Schickard
42	Marius Hills
43	Wargentin
44	Mersenius
52	Cruger
57	Reiner Gamma
62	Rumker Hills (Mons Rumker)
77	Sirsalis Rille (Rima Sirsalis)
80	Orientale basin
86	Prinz Rilles (Rimae Prinz)
91	De Gasparis Rilles (Rimae De Gasparis)
97	Inghirami Valley (Vallis Inghirami)

Lunar Terminology

Are there still a few words associated with the Moon that you do not understand yet? Here is a simple glossary to help you along…

Albedo – The amount of reflectiveness of a certain surface feature
Anorthosite – Granular igneous rock usually of soda-lime feldspar
Apogee – The point of the Moon's orbit furthest from Earth – 406,700 km
Basin – A large impact crater, with a diameter in excess of 100 km
Breccia – Coarse, preexisting rock and angular fragments
Caldera – Volcano summit depression formed by explosion or collapse
Catena – Crater chain
Cavus – Groups of hollows or irregular depressions
Craters – Indentations that are bowl or saucer shaped in configuration; a depression with steep slopes on the surface; formed by impact or geologic activity
Diurnal – A daily cycle
Dorsum – ridge
Ejecta – Impact crater material that is thrown clear of the source and covers the surface at least one crater diameter; streamers of material originating from a impact area
Gibbous – Phase where more than half, but less than all, the Moon is illuminated
Highlands – Densely cratered and higher elevated areas of the lunar surface
Lacus – Small plain
Lava – Volcanic rock present in mare areas; basalt flow
Mare – The low surface reflectivity area filled with lava that covers the floors of older basins
Mascon – Concentrations of mass on the lunar surface
Mensa – Flat-topped ridges with cliff-like edges
Mons – Mountain
New – Phase during which the Moon is entirely in shadow
Oceanus – A single, large dark area
Palus – A small plain

Patera – A disfigured crater; complex with irregular edges
Perigee – Point of lunar orbit closest to Earth – 356,400 km
Planitia – A low plain
Planum – A high plain
Promontorium – A high point of land.
Ray – A bright streamer of ejecta associated with an impact crater
Regio – Large, reflective area; containing different colorations than surrounding regions
Regolith – Lunar surface material; dust and rocky debris
Rille – Ditch or crack-like feature; may be straight or sinuous
Rima – Fissure
Rupes – Scarp or high cliff
Scarp – Sudden change in topography due to tectonic shifts, previous volcanic events, impact-related related activity or simple erosion
Selenography – Scientific study of the history of the Moon
Sinus – A small plain
Sulcus – Subparallel furrows and ridges
Terminator – Line separating night from day
Tessera – Overlapping layers of terrain
Undae – Dunes
Vallis – Valley
Waning – Lunar period during which illumination decreases
Waxing – Lunar period during which illumination increases

Acknowledgements

Joseph Brimacombe

Dr. Joe R. Brimacombe is the Clinical Associate Professor, Department of Anaesthesia, Cairns Base Hospital, University of Queensland and James Cook University, Cairns, Australia. Aside from his duties he is a tireless astrophotographer, producing some of the finest southern sky images available today and constantly available for imaging requests and projects.
http://www.southerngalactic.com

Clementine

During its 2-month orbit of the Moon in 1994, Clementine captured 1.8 million images of the Moon's surface. The Naval Research Laboratory provides the Clementine Lunar Image Browser as a courtesy to scientific researchers, as well as the general public.
http://www.cmf.nrl.navy.mil/clementine/clib/

Robert Gendler

Robert is a Connecticut physician who began with binocular astronomy and pursued his dream of deep sky imaging. Inspired by the great professional astrophotographer David Malin and by the early black and white images taken with the 200″ at Mt Palomar, we have watched over the years as his images evolved from extraordinary photos of deep space objects to true works of art. It is a blend of science and soul, which very few can match… And you will find Mr. Gendler's work gracing countless books, magazines and periodicals. In his own words, "I took this wonderful opportunity and haven't looked back. Although this is a wonderful hobby, it is physically and

mentally demanding. Equipment is expensive and experience comes only at the expense of sleep and comfort. It requires a substantial commitment but pays back in huge rewards. I can tell you it has enriched my life. I enthusiastically recommend it to anyone with an interest in the areas of astronomy, imaging, or computer science as astroimaging is a marriage of these disciplines. Just a word of caution; after your first successful image be prepared to be hooked for life!"
http://www.robgendlerastropics.com

Dietmar Hager

Born in 1969, Dietmar was raised in the city of Linz, Austria. He attended medical school in Vienna and became an orthopaedic trauma surgeon specializing in hands and microsurgery. He co-founded the microsurgical research and training center (http://www.maz.at), offering international microsurgery courses to attendants from all over the world. Dietmar discovered his passion for astronomy as a child when his father brought him to a local astronomy club at age 15 and encouraged him to join. He was smitten at his first view through a beautiful old 5″ *f*/15 Zeiss refractor. He knew at that moment that one day he would build his own observatory. His dream came true… And his outstanding astronomical imaging is a testament to his skills!
http://www.stargazer-observatory.com

Wes Higgins

Wes' interest in space and astronomy started when he was in the second grade and watching the first US manned space shot on television. He continued to follow with great interest the NASA space programs all the way through the Apollo moon landings. While growing up, he yearned for a telescope, but the thought lay dormant through college, marriage and starting his own business. Eight years ago his dream came true and as he says, "I am sure that for the rest of my life I will be out observing and imaging every chance I get."
higginsandsons.com/astro/

Deirdre Kelleghan

Deirdre is an amateur astronomer and an artist who lives in Dublin, Ireland. As a tireless public outreach worker, she enjoys writing articles on the wonders of astronomy and space, and her work has been published in Irish, English and American astronomical magazines. You will find her at the Irish Astronomical Society plus Dublin Sidewalk Astronomers, The Saturn Observation Campaign, the Irish Federation of Astronomical Societies, the South Dublin Astronomical Society, The Astronomical League, and The Sidewalk Astronomers… not to mention at the eyepiece with a sketch pad every clear night!
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Greg Konkel

Greg has many interests and two of those that occupy a great deal of his time are astronomy and photography. Having recently made the transition from film to digital cameras, he has enthused about the potential of this new technology and has focused his attention lately on integrating these two interests. The purpose of his Web site is twofold… to, hopefully, make a contribution regarding the technical issues surrounding digital astrophotography and to share some of the best images he has acquired – both astronomical and general photographic.
http://www.nwgis.com/greg

Peter Lloyd

Peter is a retired Systems Engineer, but originally qualified as a Chemist. His first "proper job" was for a small research institute where has was a part inventor of a novel optical system that became the heart of a revolutionary new analyser for the clinical laboratory. Deciding to move into developing chemistry, he spent his time devising algorithms and driving a part of the software effort and generally liaising between the engineers and the chemists. Peter eventually withdrew from the chemistry business to engage full time in software writing, analyzer projects and moved to California to engage in the Delphi programming language. From there?

San Diego and DNA studies, then back to the UK until retirement. Peter has been fascinated by Astronomy (particularly the Solar System) ever since he was a small boy and was given his first telescope – an antique brass 3.5-in. refractor. He used it to view the Moon, Jupiter and Saturn and used to take pictures of the Sun from his bedroom window by putting a mirror under the eyepiece and projecting an image onto the ceiling and laying a camera on its back and photographing the ceiling. Before his return to the UK, his interest in astronomy returned and he purchased a 10″ and digital SLR camera to which we owe this awesome images!
http://www.madpc.co.uk/~peterl/Home.html

Shevill Mathers

Shevill Mathers has been a keen amateur astronomer/telescope and camera builder since the early 60s, with a special interest in astrophotography. A member of the BAA, London (Lunar Section), his photographic expertise was greatly encouraged by Patrick Moore, with whom he has maintained a lasting friendship. He was elected a Fellow of the Royal Astronomical Society in 1969. Examples of his fine photography can be seen in books by Patrick Moore as well as numerous astronomical publications. During the early 70s in Tasmania he produced a "Photographic Star Atlas of the Southern Skies." Shevill joined the AST in 1968 and became its tenth president and again in 2000. He also took on the role of Editor of the Bulletin and was responsible for its new design and format until 2005. He has been involved (as an amateur) with the University of Tasmania's Mt Canopus observatory complex since early 1968. In the late 80s he began developing video systems for telescope use, and since 2000 he has employed his special video camera systems on the Mt Canopus 16″ as well as his own telescopes to great advantage on public open days/nights. In 2000, Shevill became a contributing editor to SKY & SPACE magazine with his regular "Moonlighting" column, and in 2005 he became an Associate Editor of the "New" SKY & SPACE Magazine, Australia's Premier magazine for southern observers. His regular column is now augmented by a wide range of articles including ATM articles, Astro News items and Activities from Tasmania as well as reviewing a wide range of astronomical equipment. At the 21st NACAA held in Tasmania, Shevill presented papers/workshops and extensive equipment displays related to video applications in astronomy, with deep sky imaging, solar and All Sky (day and night), in real time, the main features of his work at his Southern Cross Observatory. In 2005, after 5 years as AST President & Editor, Shevill stepped down to be able to spend more time writing and developing various projects, both work related and related to astronomical imaging/technology and telescope building. His final task as president was to initiate the weekly "Hands-On" Observing nights at Mt Canopus, which is proving to be a great success.

Damian Peach

One of Damian's greatest inspirations was reading, and soon after binoculars and telescopes followed. Thanks to BBC's "Sky a Night" hosted by the legendary Patrick Moore, his boundless enthusiasm (as with so many) captivated Damian's growing fascination with the night sky and lead him deeper into the journey. In 1992 he joined the Boston Astronomical Society of Lincolnshire and further inspired went on to even bigger and better things – an observing epiphany on July 23, 1997. Now destined to capture his vision on film, Damian persevered to become the outstanding lunar and planetary artist he is today. He has served as an Assistant Director of the BAA Jupiter and Saturn section, as well as the Assistant Coordinator of the ALPO Jupiter section. Damian has appeared many times on the BBC Sky at Night program with Sir Patrick Moore and live on the BBC All Night Star Party. You will find him imaging Mars live for the program from the observatories in the Canary Islands and authoring or co-authoring numerous articles and papers for all major amateur astronomy publications and some professional science publications. He has contributed to countless magazines and books, won the Association of Lunar and Planetary Observers (ALPO) Walter Haas Award and the British Astronomical Association (BAA) Merlin Medal again for outstanding contributions to planetary astronomy. Through it all, Damian has remained very down-to-earth and continues to share his love and his beautiful photography with those who ask. Says he: "I've been fortunate to observe from some of the world's finest sites over the last several years which has been a real thrill – as well as meeting many great people along the way. I want to say a big thank you to Sir Patrick Moore and his utterly remarkable level of observational work, to Paul Money for his enthusiasm which inspired me as a teenage observer, and to Don Parker, Antonio Cidadao and Thierry Legault for their wise advice and guidance when I first began imaging."
http://www.damianpeach.com

Robert Pilz

Bob graduated from the University of Illinois in 1968, with a B.S. in Astronomy, but got sidetracked for the next 30+ years with a career in computers. After retiring, he finally has ample time to devote to his passion for high-resolution lunar imaging, where he uses an 8″ reflector from a backyard observatory in western North Carolina. Catch more of his great lunar images with his contributions to L.P.O.D. and on his Web site!
http://www.pbase.com/bob_p

Tammy Plotner

Tammy owes a deep debt of gratitude to her family and friends for encouraging her along her sometimes strange and unusual paths she chooses. In her life she has been a success at a great many things, firmly believing that you can do anything you set your mind to. Retiring several years ago, she turned astronomy into a full time vocation, devoting her time to public outreach education and astronomy writing. You will find her work spread far and wide across the Internet, and two of her most special loves are the contributions she makes to Oceanside Photo and Telescope (http://www.optcorp.com) and Universe Today (http://www.universetoday.com). She serves as President of Warren Rupp Observatory and Executive Secretary of the Astronomical League and is involved in many astronomical organizations and endeavors such as the Astronomical Society of the Pacific, NASA Night Sky Network, NASA SpacePlace, Lunar Transient Phenomenon, IOTA, AAVSO and more. She has won numerous observing awards and recognitions, including the Great Lakes Achievement Award and R.G. Wright Service Award. Does she write astronomy books? Yes. You are holding it in your hands. This one and many others!

Virtual Moon Atlas

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Virtual Moon Atlas. Christian Legrand and Patrick Chevalley have dedicated their talents to the awareness of public astronomy, and the authors make this free for amateur astronomers, lunar observers and students who wish to practice selenography. They hope to promote Moon observation and knowledge because our satellite will become one of the next human spatial exploration step. Donations are always welcome to help support this worthy cause!
http://www.ap-i.net/avl/en/start

Roger Warner

Roger Warner lives in the UK within a town called Basildon, located in the county of Essex. Both father and grandfather, his interest in astronomy began 7 years ago, but the last 2 years have been dedicated to learning the art of imaging. The Moon and planets were his beginnings – taken with a low cost camera, which is still used to this day. The Moon became Roger's huge challenge – waiting for the moment of good seeing and grabbing those hidden secrets within. He began to get in close to capture those jaw dropping pictures of the Moons craters, valleys and mountains. With the introduction of a modified webcam, he soon moved on to deep sky – learning the process all over again. His greatest wish is that the images he has produced will inspire others "to progress as well in this wonderful hobby."
http://www.lupas.pwp.blueyonder.co.uk/rwnewastro/lunar.htm

Special thanks to…

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> Every one is a Moon, and has a dark side which he never shows to anybody.
>
> **Mark Twain**

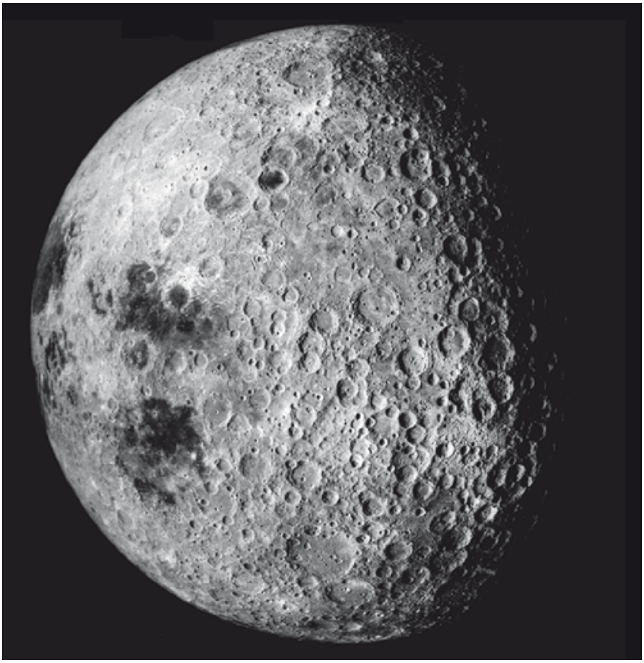

Fig. 1 Lunar Farside – Apollo 16 (NASA).

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