Your guide to THE MOON

Astronomy magazine

by Robert Burnham

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618128

THE CRESCENT MOON

South is up to match the view in a telescope, and east lies to the left.

If you look into the western sky a few evenings after New Moon, you'll spot a bright crescent glowing in the twilight. The Moon is nearly everyone's first sight with a telescope, and there's no better time to start watching it than early in the lunar cycle, which begins every month when the Moon passes between the Earth and Sun.

Each evening thereafter, as the Moon makes its orbit around Earth, the part of it that's lit by the Sun grows larger. If you look closely at the crescent Moon, you can see the unlit part of it glows with a ghostly, soft radiance. This is "the old Moon in the New Moon's arms," and the light comes from sunlight reflecting off the land, clouds, and oceans of Earth. Just as we experience moonlight, the Moon experiences earthlight. (Earthlight is much brighter, however.)

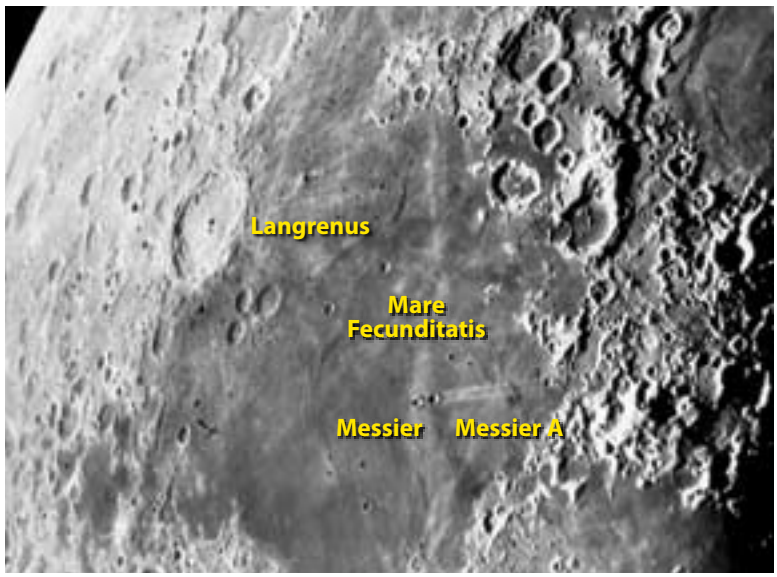
At this point in the lunar cycle, the illuminated portion of the Moon is fairly small. Nonetheless, two lunar "seas" are visible: Mare Crisium and Mare Fecunditatis. Both are flat expanses of dark lava whose appearance led early telescopic observers into thinking they were actual seabeds. That's why the features were named using the Latin word for sea: mare (pronounced MAH-ray; the plural is maria, MAH-ree-uh). The Moon's lava flows are often hundreds of millions of years younger than the basins that contain them. The basins resulted from impacts by large asteroids, and the mare lavas flowed out later like soup to fill the bowl.

Virtually every lunar crater was produced by the impact of a meteorite, some gigantic. Away from the smooth, dark maria, the lunar surface looks heavily cratered and generally light in tone thanks to the minerals it contains.

On the Moon, as with most solar system bodies, the older a surface is, the more craters it bears. (This rule of thumb showed scientists, even before they had lunar samples to date, that the relatively uncratered maria were much younger.) A glance at two different areas will tell you their relative ages.

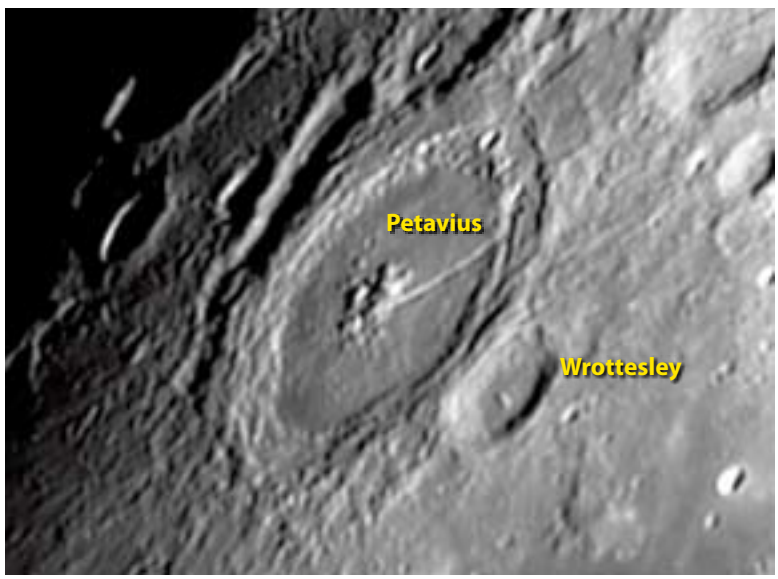
The youngest lunar craters are usually small because the biggest pieces of debris in the solar system collided with planets and moons first. Many young craters are surrounded by streaky rays that mark where jets of shattered rock flew from the impact. Full Moon, however, is the best time to go ray-hunting, so we'll come back to it a little more than a week from now.

COVER PHOTO BY FRANK BARRETT



CONSOLIDATED LUNAR ATLAS/LPL/U. ARIZONA

"COMET TAILS" EXTENDING from Messier and Messier A resulted from a nearly horizontal impact by a meteorite traveling westward. The big crater Langrenus (82 miles across) is rich in telescopic features to explore at medium and high magnification: wall terraces, central peaks, and rays.

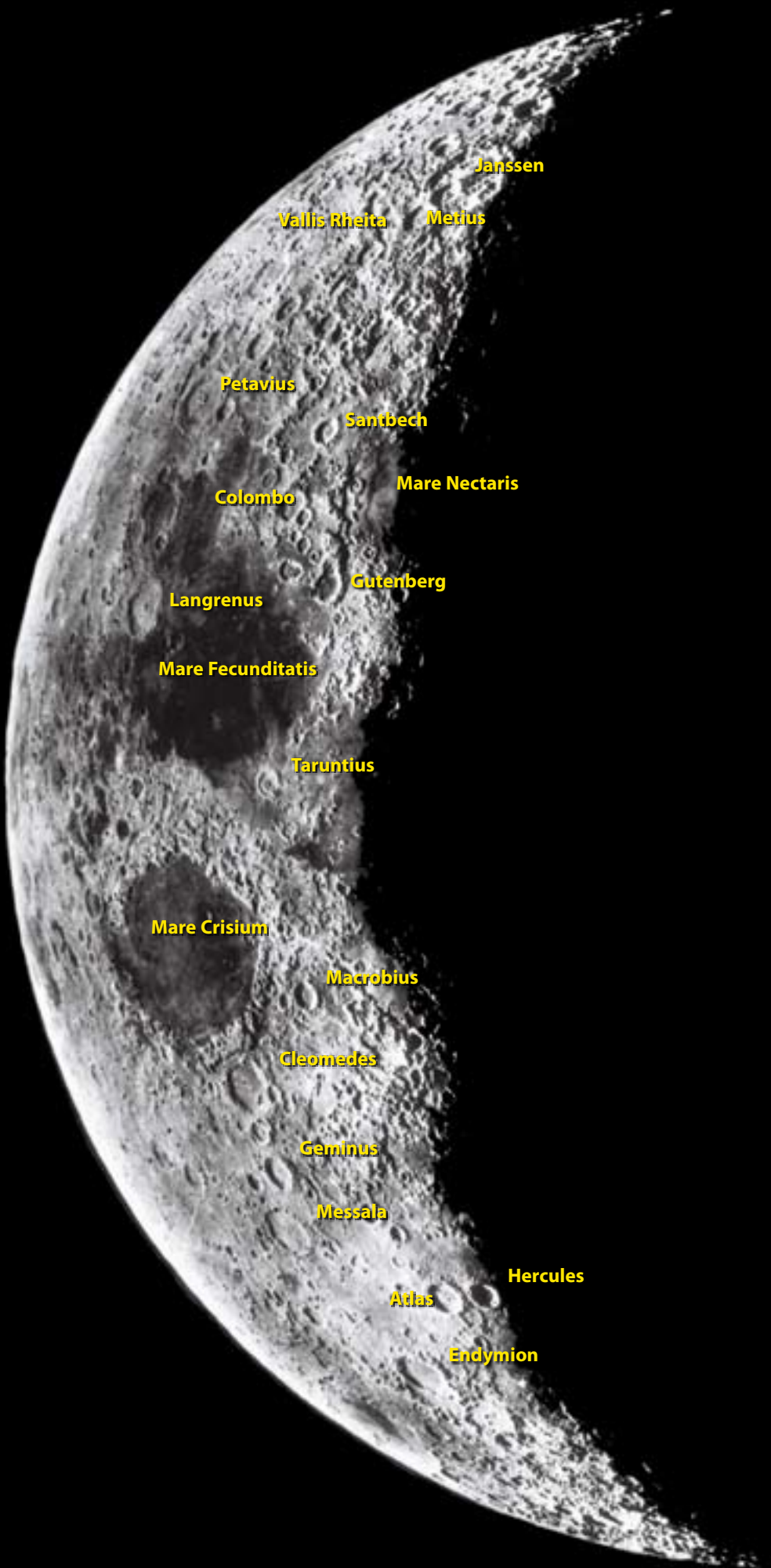


DAMIAN PEACH

ALWAYS SEEN AT AN ANGLE, the 110-mile-wide crater Petavius would be spectacular if it lay closer to the center of the Moon. The shallow floor is typical for large craters, as are the multiple central peaks. One rille (groove) is obvious, but shallower ones cross the floor also; look for them when the atmosphere is steady and sunlight falls grazingly on the lunar surface.

MOONWATCHER'S TIP

Place your telescope outside half an hour before you want to start viewing. It needs time to cool down so your views will not be distorted by warm air currents inside the tube.



LICK OBSERVATORY

FIRST QUARTER MOON

South is up to match the view in a telescope, and east lies to the left.

First Quarter Moon gets its name from the fact that the Moon has now completed the first quarter of its monthly orbit of Earth. It's a great time to explore the Moon's eastern hemisphere, which contains the sites of the first and last manned lunar landings. They occurred in southern Mare Tranquillitatis and near the southeastern shore of Mare Serenitatis, respectively. (No, your telescope can't show the landers — unfortunately, they're too small to see, even using the Hubble Space Telescope.)

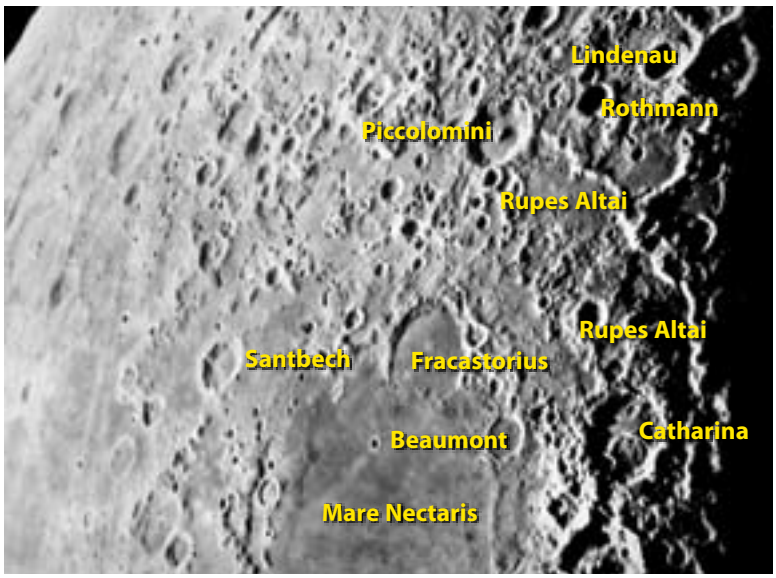
Many sights lie within the grasp of a backyard telescope, however. Compare the big circular maria, such as Serenitatis, Nectaris, Crisium, and Fecunditatis, each of which fills an ancient impact basin. The Nectaris basin is the oldest, with an age of 3.92 billion years.

Nectaris also shows the basin structure clearly, with two rocky rings visible, mainly on the west. The innermost and deepest ring forms the mare shoreline, while the other is the Rupes Altai, a concentric scarp (cliff) facing east into the basin. The crater Fracastorius offers a fascinating glimpse into a slice of lunar time — the impact that made it came after the basin impact but before the mare flooding began. Note how its northern wall has been melted by the mare lava. The rugged highlands the Altai scarp snakes through include the oldest surfaces on the Moon.

The landscape here is, as geologists say, saturated with craters — any new impact would destroy, on average, one older crater.

Looking toward more recent times, check out the brilliant, fresh rays around Proclus, with their "dead zone" on the crater's southwestern side. Lunar geologists think this indicates the impacting body was traveling northeast when it struck.

In Mare Vaporum lie linear features trending northwest-southeast. The troughs, which are collapsed pieces of crust flanked by faults, are called rilles. They reflect the influence of a huge impact that created the Imbrium basin. This feature, still in shadow tonight, will become visible during the next few evenings as the Sun rises over it.



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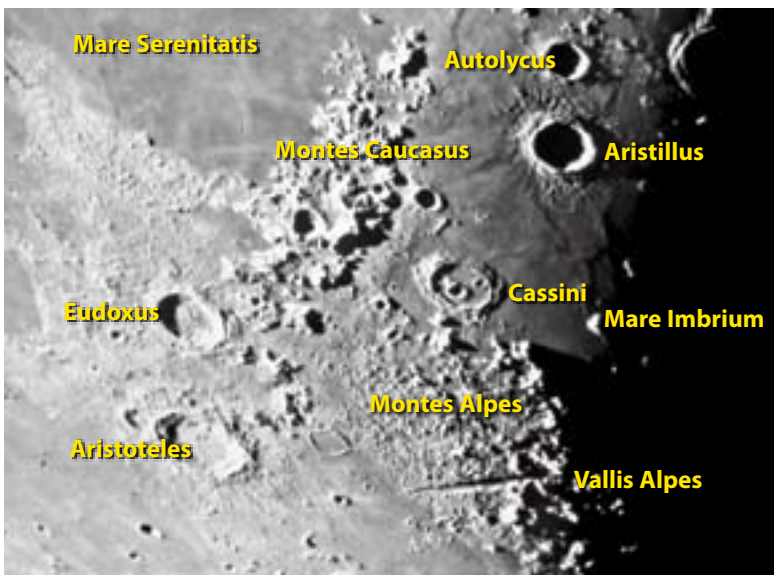
FLOODED FRACASTORIUS tells a tale of mare lava flows. They breached the northern wall of this 78-mile-wide crater and flowed inside, burying all details on its floor. Circling the western part of the large Nectaris impact basin, the cliffs of the Altai scarp (Rupes Altai) catch the morning Sun in this view taken shortly before First Quarter.



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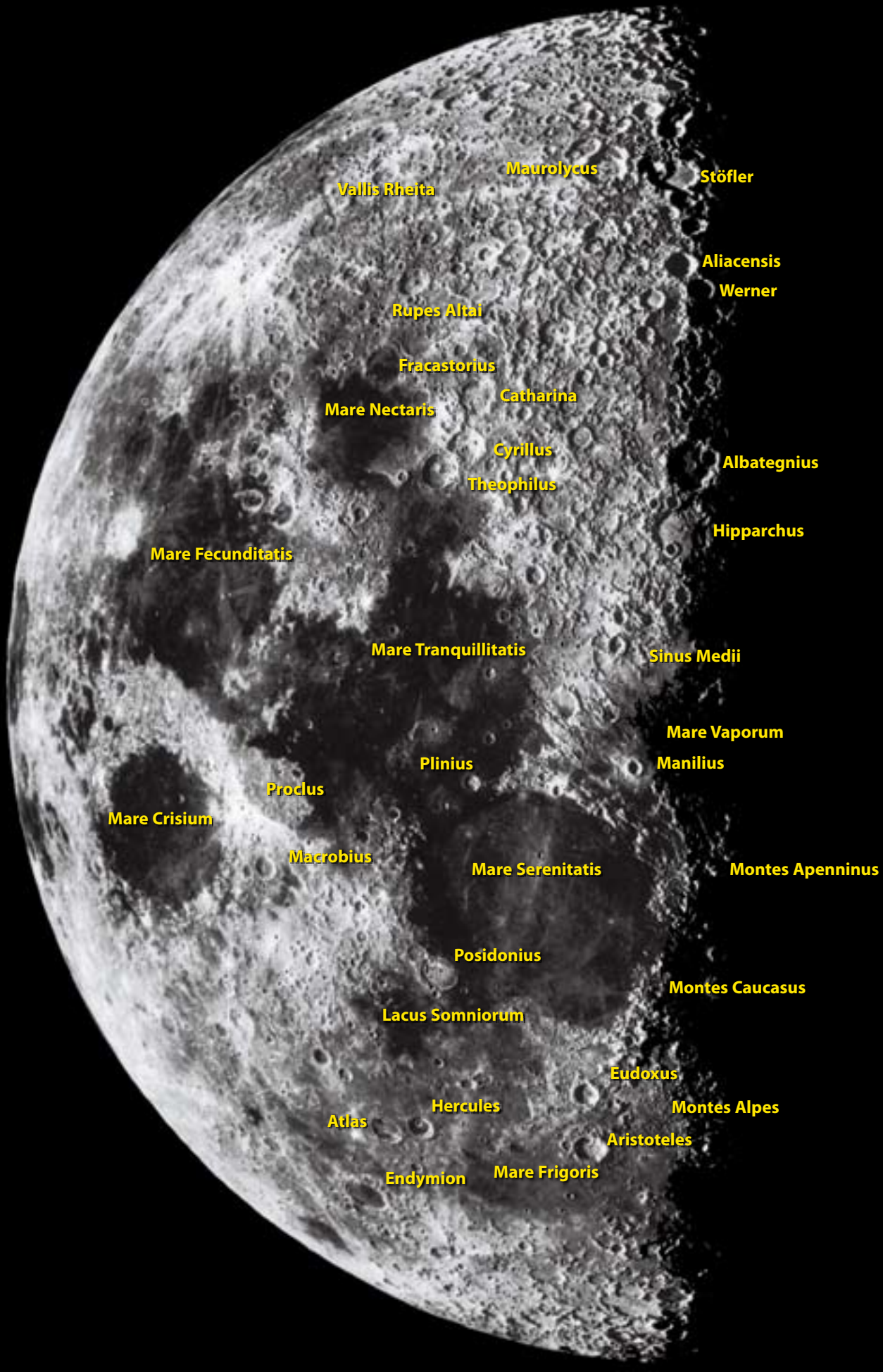
IMPACT-BASIN RIMS MEET in the Montes Caucasus, with Serenitatis (the older basin) lying to the east and Imbrium (younger) to the west. The 80-mile-long Vallis Alpes cuts through the mountain range and has a thin rille down the middle of its floor, but the rille is notoriously hard to spot.

MOONWATCHER'S TIP

If you get a kick out of exploring the Moon with your telescope, you can bet others will, too, especially kids. The next time the Moon hangs in the evening sky, invite a friend (of any age) to take a look.



LICK OBSERVATORY

THE WAXING GIBBOUS MOON

South is up to match the view in a telescope, and east lies to the left.

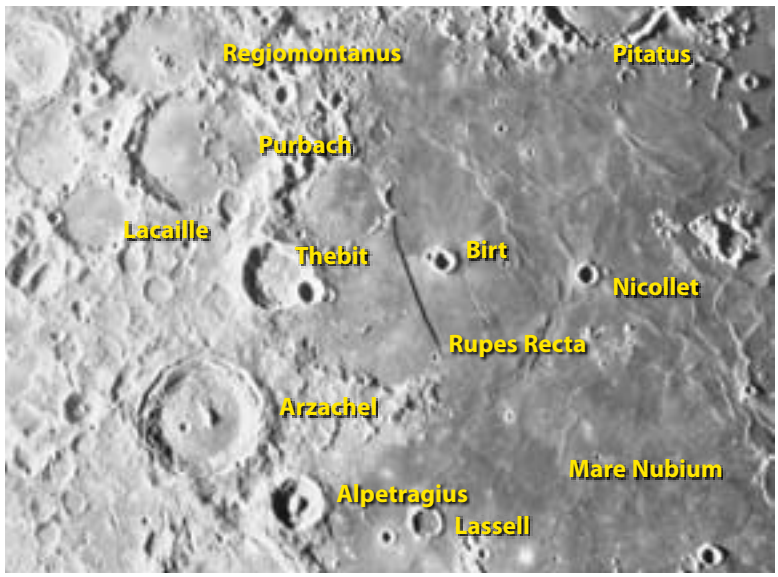
By the time the Moon is 9 or 10 days old, it's a stunning sight in any telescope. Features toward the eastern limb are becoming washed out as the Sun climbs high over them and its light flattens the terrain. But in compensation, the sunrise line (called the terminator) is revealing a wealth of sights across the western hemisphere as it moves imperceptibly onward.

Prime among these are Mare Imbrium and the features that surround it. The Montes Apenninus and the Montes Alpes form part of the rim of the Imbrium impact basin. This impact, 3.85 billion years ago, blasted a saucer-shaped basin and shot debris over most of the Moon's earthside hemisphere. Hundreds of millions of years later, lava filled the basin (and the giant crater Sinus Iridum). You can trace gouges in the Apennines and beyond from this event. The Vallis Alpes, a trough bordered by faults, is another product of the impact.

Farther afield, scan your telescope across Copernicus, a crater that many observers count as the Moon's most magnificent. A light-gray splash pattern of rays surrounds it, testimony to its relatively young age, about 800 million years, according to lunar scientists. Continuing south, explore a trio of craters along the east shore of Mare Nubium. North to south, they are Ptolemaeus, Alphonsus, and Arzachel. Ptolemaeus is extremely shallow, but at sunrise and sunset, it reveals many broad depressions in its otherwise flat floor. Alphonsus contains small, dark splotches that are the sites of true volcanic eruptions. Arzachel resembles a miniature Copernicus.

Southwest from Arzachel lies a dark, straight line on Mare Nubium that runs roughly north-south. This is Rupes Recta, the Straight Wall, a fault scarp whose edge faces west. It appears as a dark line during lunar morning (before Full Moon), but a bright line on lunar afternoons (after Full Moon).

South of Mare Nubium lie the heavily cratered highlands. Two craters stand out particularly. Tycho is smaller than Copernicus, but it has a ray pattern that extends over the entire Earth-facing side of the Moon. Some rays are visible tonight, but they really stand out at Full Moon. South from Tycho lies Clavius, a huge crater that would be much better known if it lay nearer the center of the Moon. Note the curious chain of craters that arcs across its convex floor.



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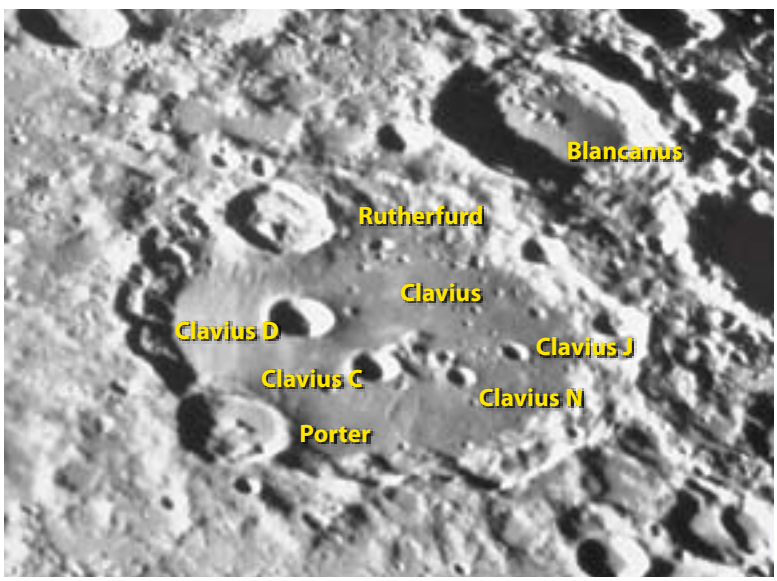
THE BLACK LINE of the Moon's Straight Wall, Rupes Recta, marks a geological fault. While the 70-mile-long feature isn't perfectly straight, it does look eerie the first time you spot it. Its total height is less than 1,000 feet, however, and despite its stark appearance, the slope is a gentle 10° or less.



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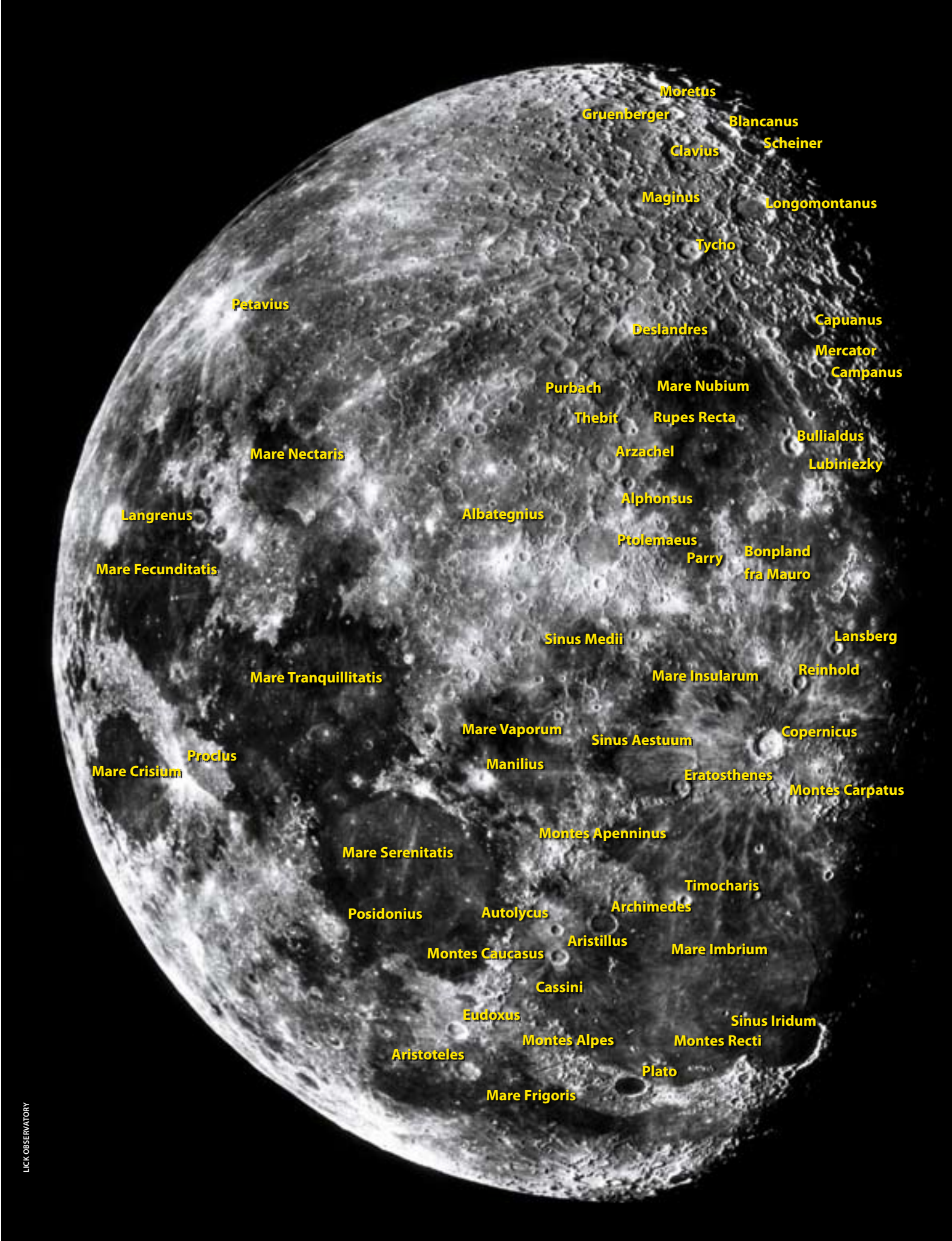
HIDDEN IN THE HIGHLANDS south of Tycho, the 140-mile-wide crater Clavius is almost lost in the tangled scene. Low sunlight reveals it has a convex floor.

MOONWATCHER'S TIP

Earth's atmosphere is seldom steady enough to allow highest magnifications. Start with the lowest power eyepiece, and increase the magnification until the image quality starts to degrade.



LICK OBSERVATORY

THE FULL MOON

South is up to match the view in a telescope, and east lies to the left.

Many beginning lunar observers ask if Full Moon is the best time to explore the Moon. The answer depends on what you're looking for. If you want to see craters and mountains, then the answer is no. Such features have most of their details washed out by the "noon-day" Sun, which pours down on the lunar terrain, hiding the shadows that bring out the features.

But if you want to explore rays and lava flows, Full Moon is the best time of all. (If glare's a problem, see the Moonwatcher's Tip below.)

The Full Moon's most prominent feature is the globe-spanning network of rays coming from the crater Tycho. This crater lies in the southern highlands and is a little smaller than the famous Copernicus. Tycho is young in lunar terms, being only 108 million years old, according to samples of its ejecta collected by astronauts.

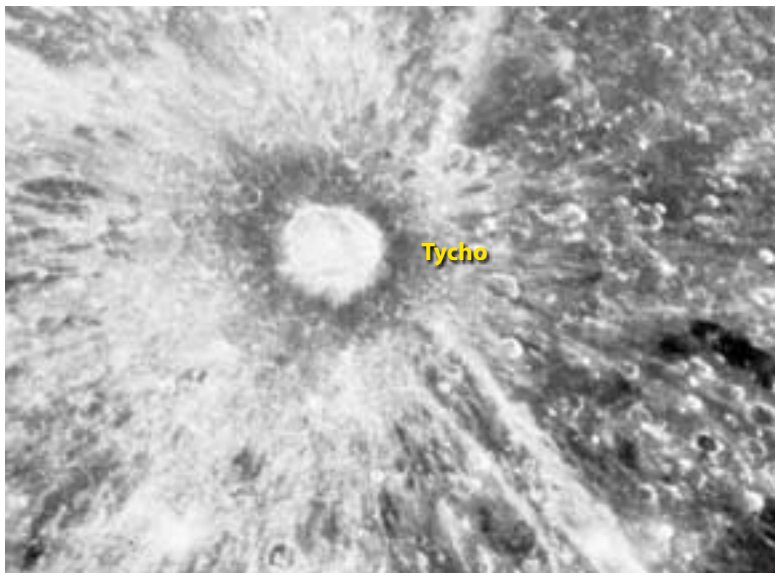
Several of its rays head generally southward and continue onto the Moon's farside. Another shoots off to the northwest, where it passes near another rayed crater, Kepler. The longest Tycho ray, however, is the one going northeast. It travels all the way to Mare Serenitatis, and perhaps beyond. This ray is called the Bessel ray, after the small crater it crosses on Mare Serenitatis.

Surrounding Tycho itself is a dark ring. Studies of this feature from lunar orbit and one unmanned spacecraft that landed on the crater rim indicate the dark material is glassy impact-melted rock. It originated in the explosion that created the crater when a meteorite fell.

The Moon's second most-known ray pattern belongs to Copernicus. This crater (age: 800 million years) is much older than Tycho, and its rays have faded somewhat. Scientists think rays disappear in about a billion years, as the shattered and pulverized rock in the ray darkens with prolonged exposure to sunlight and as debris from other impacts mixes with it.

West of Copernicus, the crater Kepler has a ray pattern proportionally less extensive due to Kepler's smaller size. Interestingly, the nearby crater Aristarchus appears bright inside and looks fresh, but has only a weak ray pattern. Nearby is the famous Vallis Schröteri, or Schröter's Valley, a lava channel.

Full Moon is also a good time for picking out lava flows by observing tint differences. Spend some time gazing at the various tints you see in the maria, especially the two zones in Mare Serenitatis and the various flows in Imbrium and Nubium, and across Oceanus Procellarum.



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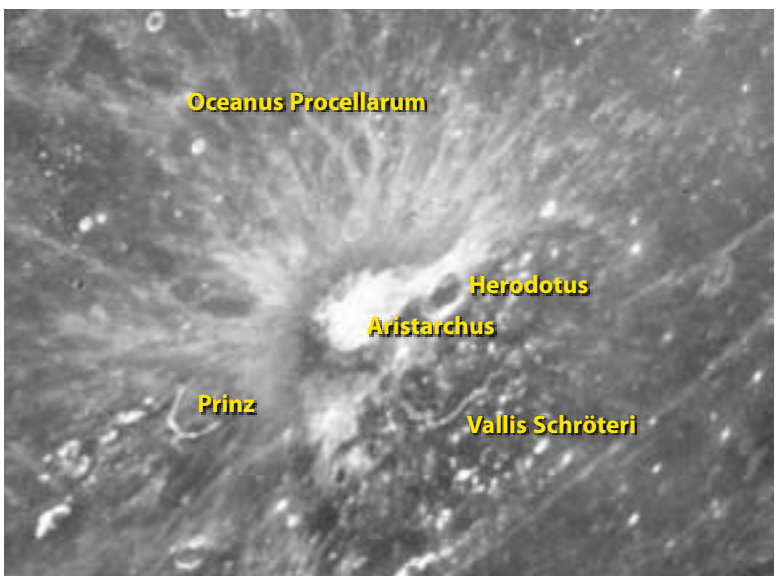
RING AROUND THE CRATER? The dark collar that surrounds Tycho is a deposit of glassy material melted in the impact that created the 53-mile-wide crater. The material fell close to the crater when it was thrown nearly straight up by the force of the impact blast, which occurred about 108 million years ago.



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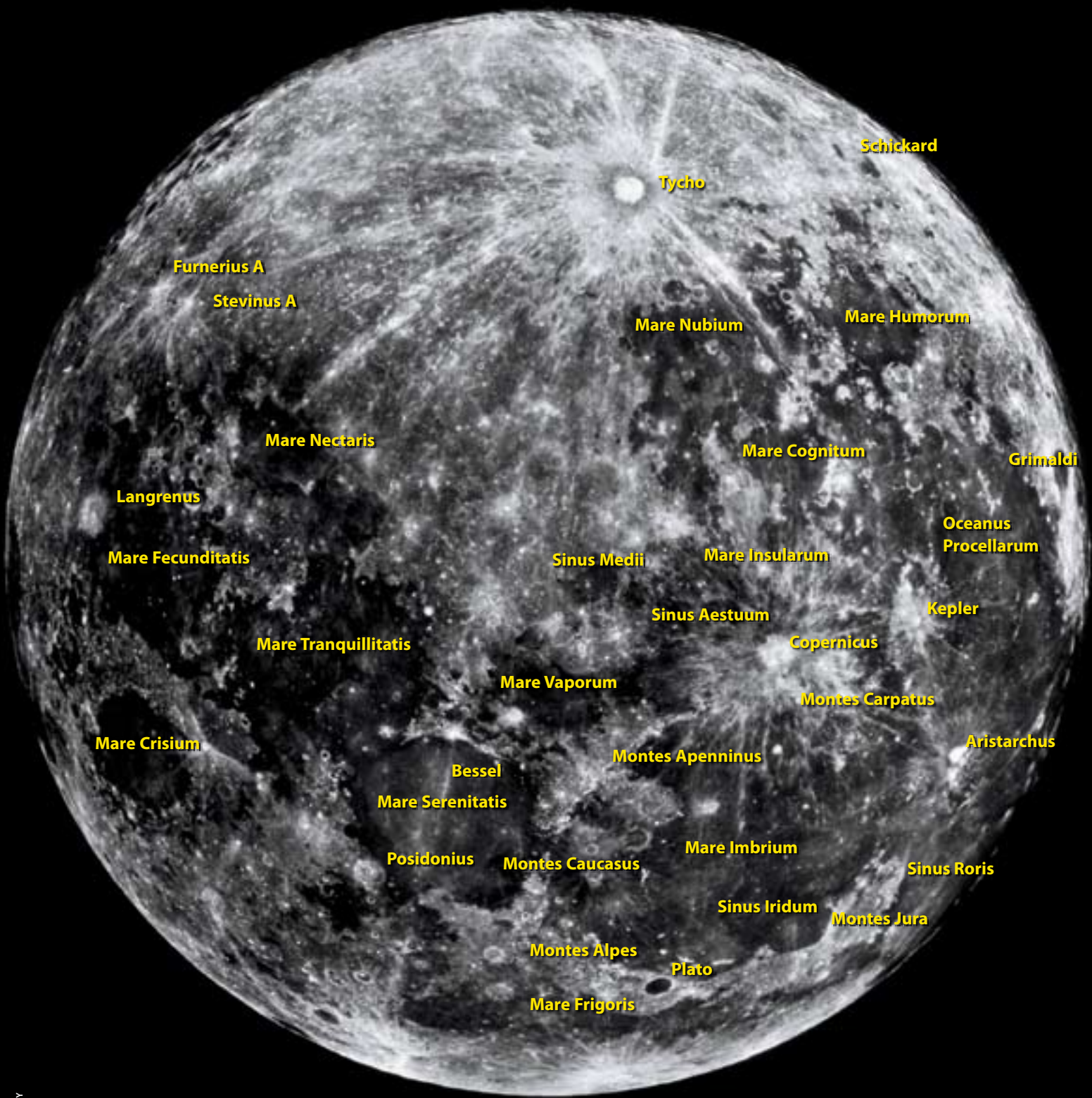
ARISTARCHUS APPEARS BRIGHT — so bright that famed 18th-century astronomer Sir William Herschel thought the crater was a volcano actually erupting! The region around Aristarchus has seen much volcanic activity, and Vallis Schröteri is a channel carved by a lava flow — but the 25-mile-wide crater was made by a meteorite impact.

MOONWATCHER'S TIP

This observer's trick definitely looks weird, but it works. If the Full Moon is too bright to view comfortably, put on sunglasses or hold one of its lenses over the telescope eyepiece. Another technique is to use higher power to reduce the amount of Moon in the field of view.



LICK OBSERVATORY

THE WANING GIBBOUS MOON

South is up to match the view in a telescope, and east lies to the left.

After Full Moon, the bright rays fade, and landscapes once again take on relief that vanished when the Sun was high. As the sunset line hides the eastern maria, it brings out features in the southern highlands that have been hard to see for the last week.

The Rupes Altai stands out now as a dark line wrapping around Mare Nectaris. The low angle of sunlight beautifully reveals the trio of Theophilus, Cyrillus, and Catharina, with terraces inside their walls, central peaks (on Theophilus and Cyrillus), and countless details on their outside walls. Note the progression in age: Catharina — the oldest of the three — is overlaid in part by Cyrillus' debris, and Theophilus' wall breaks into that of Cyrillus.

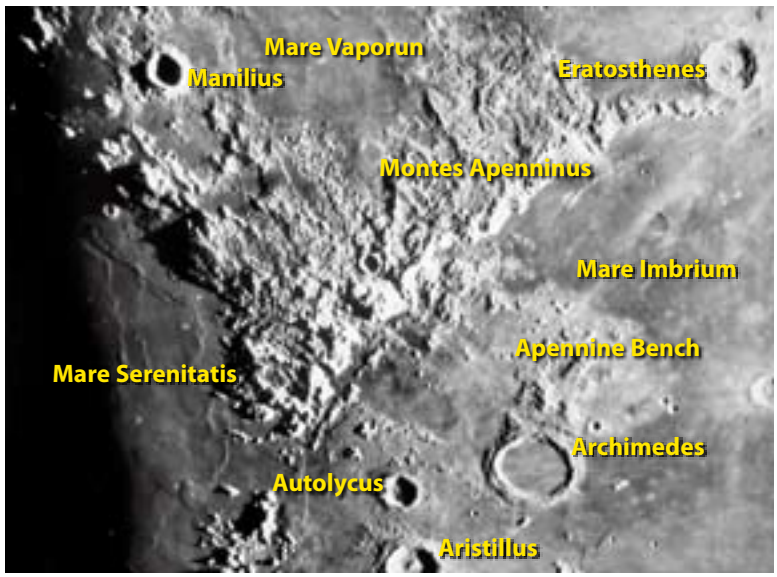
Late lunar afternoon brings out the valleys and sculpture around Mare Vaporum. Grooves visible telescopically with medium magnification (around 100x) are associated with the gigantic impact that created the Imbrium basin. Flying debris carved valleys that run radial to Imbrium, while seismic shaking tore the rocks. These effects are especially visible in the Montes Apenninus.

On Oceanus Procellarum lies Aristarchus. This fresh impact crater lacks a splash of rays, but it appears very bright. Use high power to explore the crater and its surroundings. Note the sinuous rille, Vallis Schröteri, that winds to the north and west (see photos on pages 8 and 12).

Then, take a look along the Moon's western limb. Dark patches of mare show where basaltic lava crept up through the rocks and flooded smaller regions, often just a crater's floor, such as in Grimaldi. Schickard, too, shows traces of mare. Immediately to its east lies a patch of highlands looking a little darker than most. Lunar geologists call this "cryptomare" and describe it as the ghostly trace of ancient lava flows covered by later debris. In the case of Schickard, the covering material comes from an impact basin — Orientale — lying over the western limb and mostly invisible from Earth.

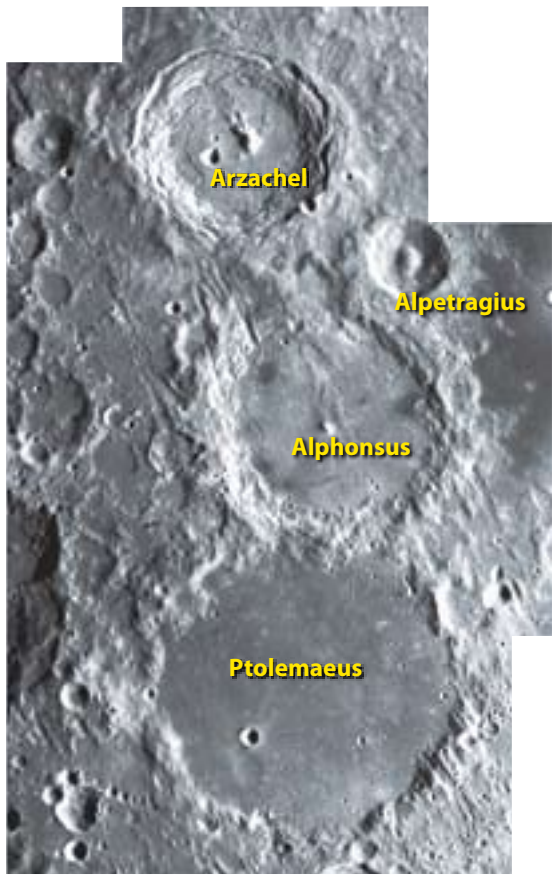
MOONWATCHER'S TIP

After Full Moon, the line of lunar sunset marches slowly across the craters and seas. (At the equator, it's moving about as fast as you could walk.) Look closely at your favorite sights, and notice how they look different when lit from the west.



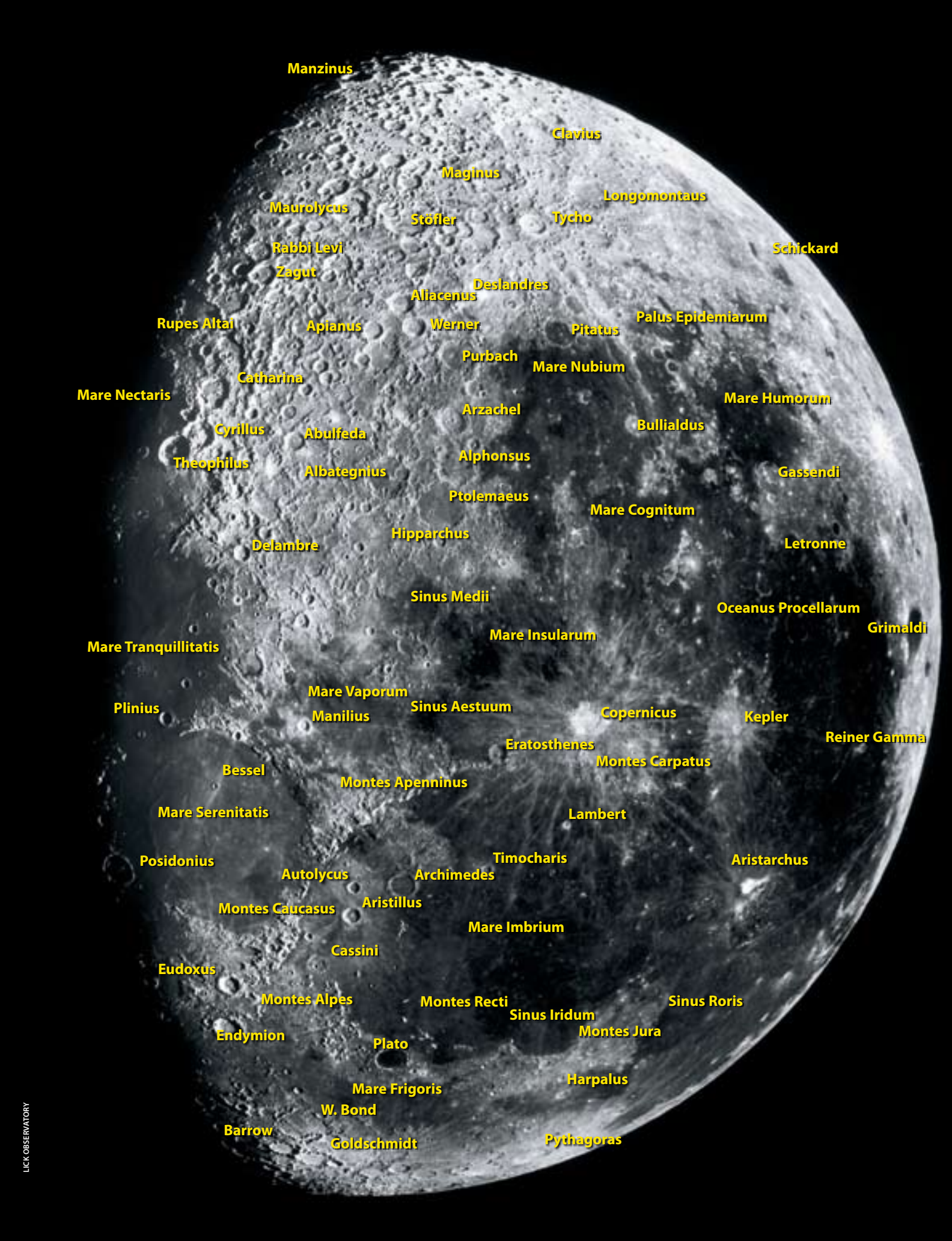
CONSOLIDATED LUNAR ATLAS/LPL/U. ARIZONA

THE APENNINES FORM the southeast rim of the Imbrium impact basin. A meteorite falling between the basin impact and the mare flooding created Archimedes, a well-defined crater 52 miles across. The Apennine Bench is a portion of Imbrium basin floor unflooded by lava.



RALF VANDEBERGH

DARK SPLOTCHES in Alphonsus show where volcanic eruptions burst through the crater floor, scattering dark cinders. Ptolemaeus shows little detail most times — but catch it near the lunar terminator at sunrise or sunset, when you can spot a few large, soft dimple-craters.



LICK OBSERVATORY

LAST QUARTER MOON

South is up to match the view in a telescope, and east lies to the left.

When Last Quarter phase rolls around, the Moon is beginning the last fourth of its monthly circuit, hence the name. Most people don't notice a Last Quarter Moon unless they get up early and catch it standing above the southern horizon at daybreak.

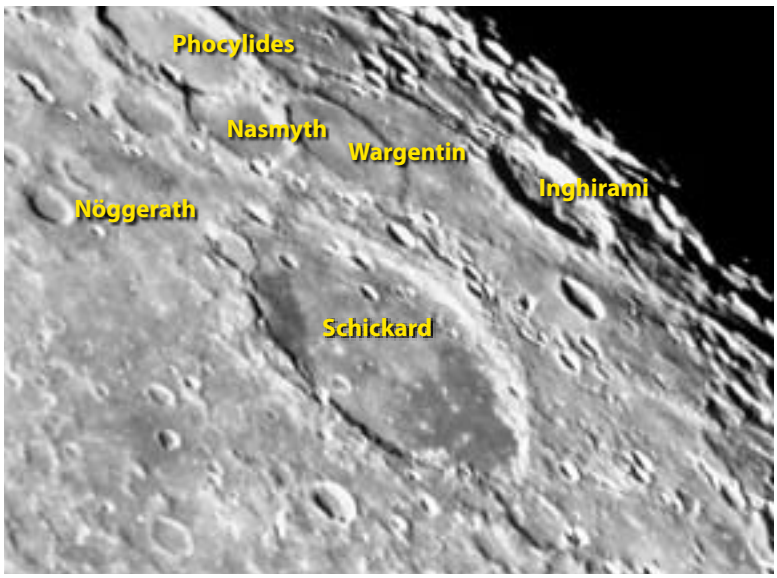
Last Quarter is the perfect time to explore those features in the southern highlands that appeared too washed out earlier in the cycle. Tycho's rays have all but disappeared, but the crater itself displays features such as terraces, multiple central peaks, and a smooth floor of impact-melted rock. Its giant neighbor Clavius is also seen to good advantage around now, with slanting sunlight revealing details in its walls and floor.

Farther north, the Straight Wall (Rupes Recta) now scribes a bright line across part of Mare Nubium as its west-facing slope catches the afternoon Sun. Nearby, the big craters of the highlands — Arzachel, Alphonsus, Ptolemaeus — show off their differences in floor details, wall terraces, and central peaks (buried in the case of Ptolemaeus).

West of Mare Nubium lies Mare Humorum, another circular mare nestled inside an impact basin. Paralleling the example of Mare Nectaris and Fracastorius, the 68-mile-wide crater Gassendi sits on Humorum's inner ring, with one wall dissolved by the mare lavas. If the atmosphere above your observing site is steady, use high power and go hunting for rilles that lace across the crater's floor.

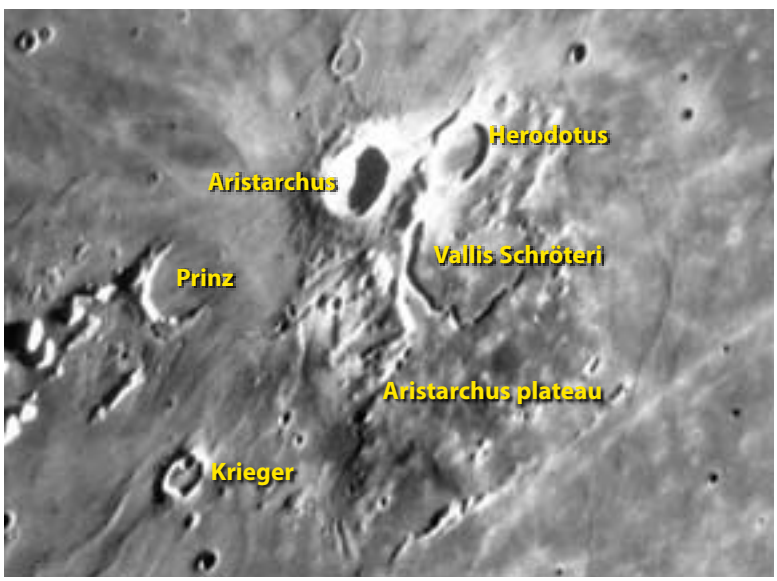
Copernicus, as ever, makes a splendid sight. It's fascinating to watch sunlight play on this crater over the 2-week-long lunar day. An evening or two after First Quarter, you see a thin ring of bright light as the crater rim's highest peaks catch the first rays of Sun. Then, dawn creeps into Copernicus, revealing terraces, a flat floor, and the central peaks. At Full Moon, Copernicus' rays show best. As the Sun descends from lunar noon, shadows re-emerge, and crater details become visible again.

Toward lunar sunset, the shadows grow and merge, hiding the Moon's awesome starkness. Then, one fine, crisp evening, you'll look up to see a young Moon low in the west, and the eternal story will begin anew.



CONSOLIDATED LUNAR ATLAS/LPL/U. ARIZONA

LAVA DARKENS the entire floor of Schickard (140 miles across), but the center is covered by debris ejected from the Orientale impact basin. Wargentin is a crater that was entirely filled with lava or impact-melted rock.



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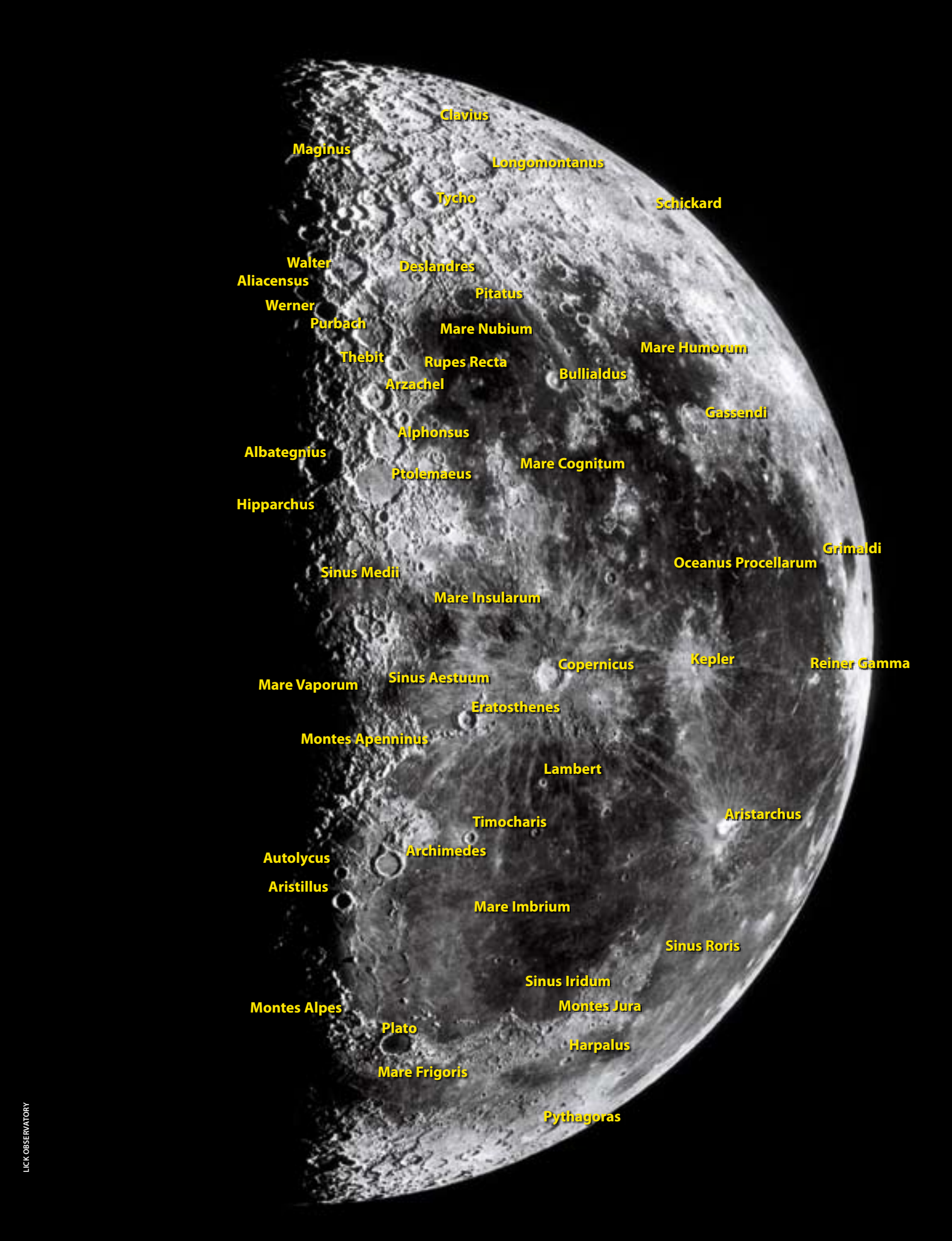
LOW SUN ANGLES reveal details inside Aristarchus (25 miles across) and in its surroundings. (Compare this with the Full Moon view on page 8.) The crater sits at the southern edge of a plateau likely raised by the impact that created the Imbrium basin. The plateau is mantled by volcanic ash that perhaps erupted when Schröter's Valley was carved by lava flows.

MOONWATCHER'S TIP

The Last Quarter Moon always makes a beautiful sight in the predawn sky. Why not set your alarm clock early and catch the Moon before anyone else? You'll also be seeing it when the air is (usually) at its most tranquil and undistorting, so your views should be especially sharp and clear.



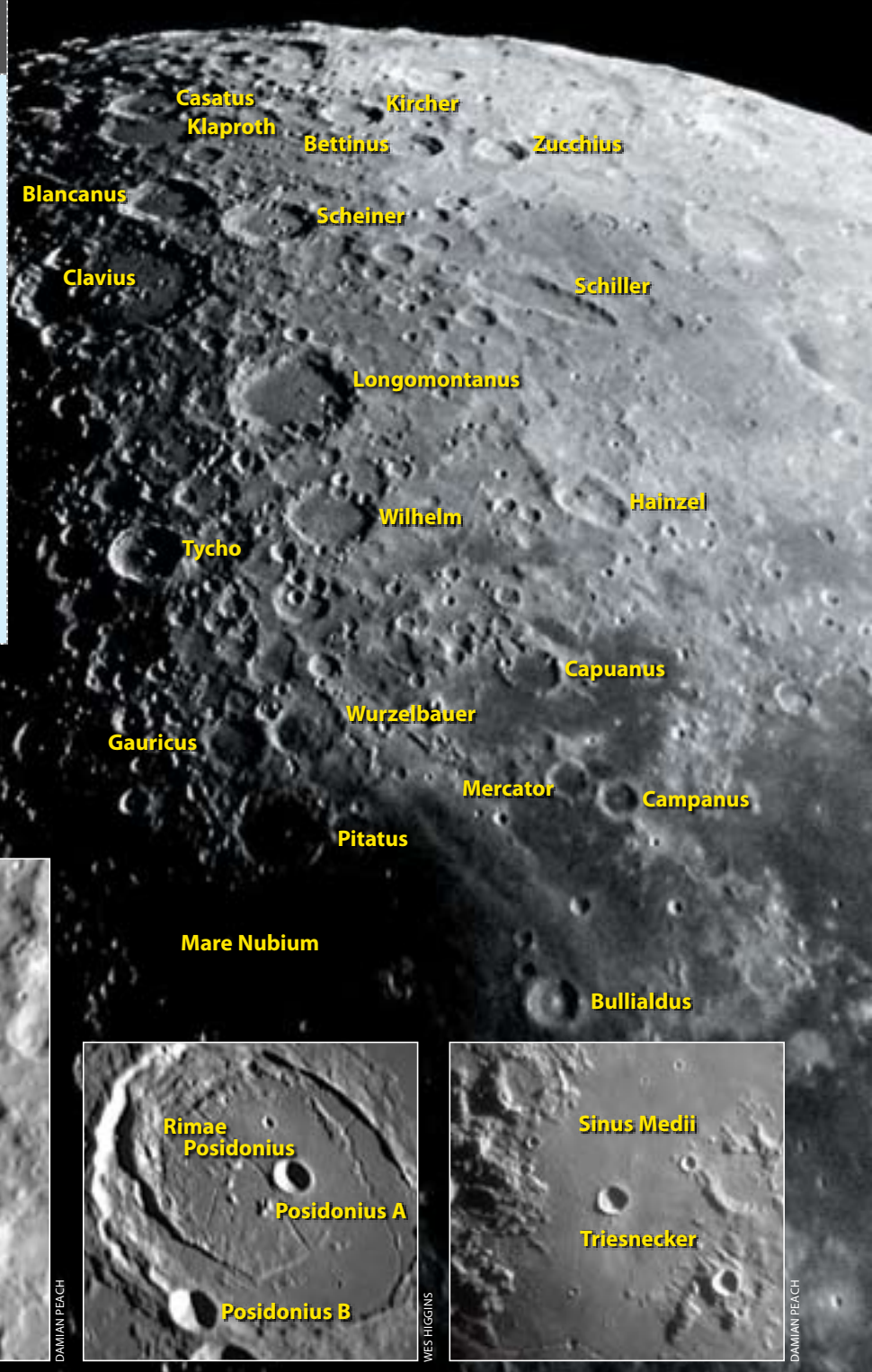
LICK OBSERVATORY

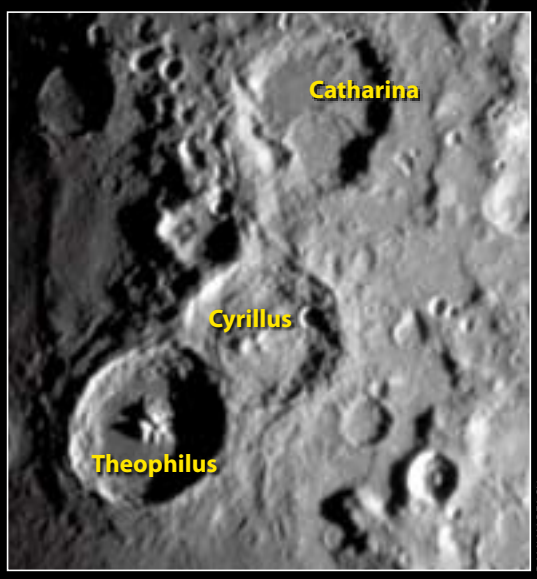
LUNAR GALLERY

PARTIAL AND TOTAL LUNAR ECLIPSES 2008–2013

DATE	TYPE	BEST SEEN FROM:
2008 Feb. 21	Total	c Pacific, Americas, Europe, Africa
2008 Aug. 16	Partial	S. America, Europe, Africa, Asia, Aus.
2009 Dec. 31	Partial	Europe, Africa, Asia, Aus.
2010 June 26	Partial	e Asia, Aus., Pacific, w Americas
2010 Dec. 21	Total	e Asia, Aus., Pacific, Americas, Europe
2011 June 15	Total	S. America, Europe, Africa, Asia, Aus.
2011 Dec. 10	Total	Europe, Asia, Aus., Pacific, w N. America
2012 June 4	Partial	e Asia, Aus., Pacific, Americas
2013 April 25	Partial	Europe, Africa, Asia, Aus.

THE MOON'S SOUTHERN LIMB displays a rugged profile born through countless impacts of meteorites and asteroids. It's easy to get lost among all the craters, but this view offers you a glimpse of what a Moon-bound astronaut might see on the approach trajectory. RALF VANDEBERGH





DAMIAN PEACH

RELATIVE AGES SHOW CLEARLY in this trio of same-size craters adjacent to Mare Nectaris. Theophilus (62 miles in diameter) is youngest, as shown by its wall jutting into that of Cyrillus next door, and Catharina is the most battered, eroded, and oldest.

WES HIGGINS

ON THE SHORE OF MARE SERENITATIS, Posidonius (59 miles across) shows off a lava-flooded floor, rilles (officially called rimae), and several craterlets.

DAMIAN PEACH

IN THE CENTER OF THE MOON, the crater Triesnecker (16 miles across) stands beside a network of fine rilles. Use medium to high magnification on a night when the atmosphere is settled and quiet.

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