http://www.raclub.org/

The StarGazer

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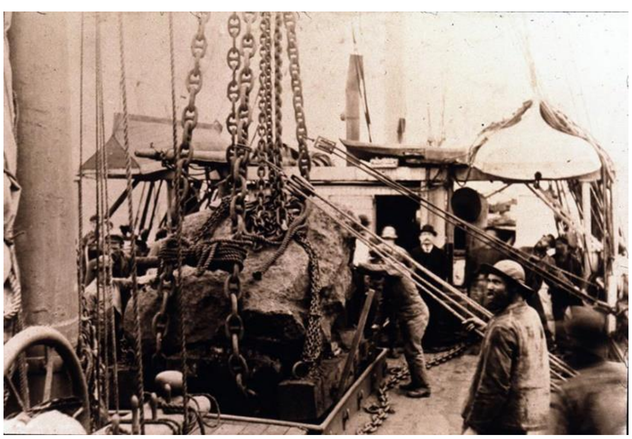
Finding Gladys: The Campbell County Meteorite That Wasn't

By Scott Busby

Over the last century, many publications have recounted amazing stories of individuals finding meteorites or tales of intrepid adventurers tracking down a witnessed fall. One of those stories—little known by the public—is about Ellis Hughes,[1] who in 1902 Oregon, found the great Willamette iron[2] on his neighbor's property and in the next year, used a makeshift wagon to secretly haul its 15.5-tons of iron three-quarters of a mile from his neighbor's property to his own. After Hughes was accused of theft, he lost possession of it to the property owner—Oregon Iron and Steel—which through the courts, reclaimed its rightful ownership of the largest meteorite ever found in North America.

Willamette Meteorite[3]

You may have also read the historical account of Admiral Robert E. Peary's 1895 travels to Greenland and his discovery of the great Cape York irons.[4] Some 60 tons of the Cape York fall took place inland about 10,000 years earlier, and the movement of the ice sheet deposited the massive meteorites, where they were found on the Greenland coast by Peary. With help from the native Innuits, he hauled several tons of meteorites and equipment perilously across frozen Artic ice to a waiting ship that would take his famous finds to their new home in the United States. The largest of the Cape York meteorites is "Ahnighito," weighing in at a phenomenal 34 tons. It is now on permanent display at the American Museum of Natural History in New York City.



Ahnighito being placed in the hold of Peary's ship.[5]

There are also many historical accounts of Daniel Moreau Barringer and the famous Arizona Meteor crater.[6] Barringer was so convinced that the main body of the meteorite lay buried beneath the center of the mile-wide crater near Winslow, Arizona, that he staked a claim to the crater and organized his newly formed mining company to excavate the iron from it. By 1908, nearly 30 holes had been drilled on the floor of Meteor Crater. Barringer had spent nearly $1 million of his own money trying to mine the meteoric iron, only to discover that iron probably vaporized when this uninvited space invader struck the ground at nearly 29,000 mph some 50,000 years ago.

There is also the fantastical history of the illustrious life of the original Meteor Man and famous meteorite hunter Harvey H. Nininger,[8] who traveled the world searching for and finding tons of meteorites. His journey began in McPherson, Kansas, in November 1923, when he witnessed an immense fireball in the sky above him. Although he never found remnants of that November 9 fireball, the experience started Nininger on an incredible journey of discovery of meteorites and meteorite entrepreneurial enterprise. In his old age, Harvey Nininger could look back with satisfaction. By 1959, he had found about half of all the meteorites located in the United States during the preceding 40 years, including many new to science.[9] He has been recognized as one of the leading pioneers in ***(Continued on page 4)***

How to Join RAClub

RAClub, located in the Fredericksburg, Virginia, area, is dedicated to the advancement of public interest in, and knowledge of, the science of astronomy. Members share a common interest in astronomy and related fields as well as a love of observing the night sky.

Membership is open to anyone interested in astronomy, regardless of his/her level of knowledge. Owning a telescope is not a requirement. All you need is a desire to expand your knowledge of astronomy. RAClub members are primarily from the Fredericksburg area, including, but not limited to, the City of Fredericksburg and the counties of Stafford, Spotsylvania, King George, and Orange. We also have several members who live outside Virginia and have joined to have the opportunity to use the Mark Slade Remote Observatory (MSRO)—one of the benefits of joining the club.

The RAClub offers you a great opportunity to learn more about the stars, get advice on equipment purchases, and participate in community events. We meet once a month and hold regular **star parties** each month on the Saturday closest to the new Moon. Our website, www.raclub.org is the best source of information on our events.

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Website: www.raclub.org
Groups.io: Members-only group. When you join RAC, you will receive an invitation to join from the RAC President.

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Options for Dues Payment

RAClub annual membership is $20 per family. Student membership is $7.50. You can now pay your dues in two ways. (For reference, the RAC membership year is January–December. If you join anytime in the last quarter, your membership covers the upcoming year. Astro League dues run July to June.

- **By Mail:** Make out a check to RAC Treasurer and send it to Matthew Scott, RAC Treasurer, PO Box 752, Fredericksburg, VA, 22404-0752. Both new and renewing members should also print out the membership application here, fill it out, and return it with their payment to keep our records up to date.
- ***By PayPal***: You can also pay your dues online. Simply go here, scroll down, and select the appropriate membership type from the dropdown box and click *Pay Now*. You do not need to complete an application because the notification the club receives of your payment will contain all the additional info needed. NOTE: If you pay using PayPal, your actual charge (including the PayPal usage fee) will be: Single/Family $20.91, Student $8.03, Single/Family & AL $28.63, Student & AL $15.76, AL Only $8.03.

Upcoming Events*

Our public events are cancelled until further notice. However, to attend a *club* meeting via Zoom, email president@raclub.org for an invitation.

Star Party, Caledon State Park	February 6
Star Party, Caledon State Park	March 13**
Star Party, Caledon State Park	April 10

Recent Events Completed

Star Party, Caledon State Park	November 14, 2020
Star Party, Caledon State Park	January 9, 2021

*Owing to varied and changing restrictions, please check the website raclub.org for updates.
**Messier Marathon

President's Corner

Dear Members,

Some members have not yet accepted their invitation to join RAC's eMail list. If you are one of those members, you are missing out on timely information concerning star parties, meetings, events, and RAC business. If you have not already done so, please accept the invitation I sent you to join RAC's Groups.io eMail list.

Owing to government restrictions, RAC will be conducting its business meetings via Zoom Video Conferencing for the foreseeable future. I send Zoom meeting invitations to all RAC members via BCC eMail. Non-members may also participate by sending me a request at president@raclub.org.

May God bless you with transparent skies and excellent seeing.

Glenn Faini
President

Did You Know? by Scott Busby

In 1851, Lewis Swift, doyen (the most respected or prominent person in a particular field) of American cometary discovery and an expert visual observer of nebulae, was a country storekeeper at Hunt's Corner, New York, where he purchased from a peddler a copy of the *Works* of Thomas Dick.[1] The book had an electrifying effect on him and inspired him to acquire a small telescope. In 1860, he got his hands on a much better one, a fine 4.5-inch Fitz refractor, with which in July 1862 he picked up a comet in the constellation Camelopardalis. Because he did not, at the time, have any better source of astronomical information than the local newspapers, he at first assumed that he was only seeing another comet that had been reported 2 weeks earlier by Julius Schmidt at Athens. In fact, Schmidt's comet was nowhere near Camelopardalis (it was far to the south in Virgo), and when three nights later Horace P. Tuttle of Harvard independently picked up the new comet—at once recognizing that it was new—Swift announced his earlier sighting to claim a share of the credit for his first cometary discovery. Comet Swift-Tuttle (1862 III) proved to be a splendid object, and it acquired special significance when the Italian astronomer Giovanni Schiaparelli recognized that its orbit was virtually identical to that followed by the debris causing the Perseid meteor shower each August, thereby forging, for the first time, a link between comets and meteors. (The comet's period is now known to be 134 years. It was recovered at its first return since the Civil War in September 1992 by a Japanese amateur astronomer, Tsuruhiko Kiuchi; it is not due back again until 2126.)

[1]Reverend **Thomas Dick** (24 November 1774–29 July 1857), was a British church minister, science teacher, and writer, known for his works on astronomy and practical philosophy, combining science and Christianity, and arguing for a harmony between the two.

Source: *The Immortal Fire Within, Life and Work of Edward Emerson Barnard*, William Sheehan, Cambridge University Press, 1995

Finding Gladys: The Campbell County Meteorite That Wasn't *(from page 1)*

meteoric discovery and research and an authority on meteorites and their types and classifications, including some 1,200 pounds of the rare and beautiful stony-iron pallasites that came from Eliza Kimberly's field near Brenham, Kansas—known as the Kansas Meteorite Farm.

Fast-forward to last year. A gentleman by the name of Kevin Ryan Shorter of Rustburg, Virginia, joined the list of notable people who had found meteorites. On Thursday, July 16, 2020, Ryan was visiting his mom at her home near the town of Gladys, in Campbell County, Virginia. He went there to visit her, not only to say "Hi" and have a good meal but also because he usually stores his work tools and equipment there for his many projects, including maintaining a fleet of six vehicles.

At about 5:15 that afternoon, Ryan decided to take a look at his mom's lawnmower that had stopped working. He found it where she had left it near her garden in the front yard. While tending to the mower, Ryan spotted a small stone—seemingly out of place—among the weeds and grass close to the garden. Out of habit, most folks tend to chuck such errant rocks out of the lawnmower's path. No one wants to risk a dinged blade or popping the dog or anyone else with a mower-flung projectile. Ryan reached for the partially buried stone, snatched it up, and before his muscles tightened like Patrick Corbin in the windup at the mound at Nationals Park, his brain kicked in and he balked. "Wait a sec!" he thought. "This stone feels so much heavier than a similar stone this size." Ryan immediately took the stone inside, washed it off, and inspected it more closely. He was convinced that it had to be a meteorite!

There have been 13 meteorite discoveries in Virginia. The latest was a witnessed fall in Lorton, Virginia, in January 2010.[10] The 308-gram Lorton meteorite, as it is now known, came plummeting to Earth, blasting through the roof of examination room No. 2 in the Williamsburg Square Family Practice. Doctors Marc Gallini and Frank Ciampi, who owned the practice, promptly contacted the Smithsonian Museum of Natural History, which offered them a thank-you reward of $5,000 if they donated it to the museum. Unfortunately, the doctors were only tenants at Williamsburg Square. Upon hearing the news about the meteorite's discovery, the rental property owners of the property came forward and claimed it as rightfully theirs. There was possible legal precedent for this type of thing dating all the way back to Ellis Hughes and the Willamette. Ultimately, the court decided that the Lorton meteorite rightfully belonged to the doctors because it had fallen directly out of the sky, which made it akin to lost or abandoned property. In such cases, rights rest with the finder unless there is a "true owner." "Because a meteorite, unlike a dropped piece of jewelry or wallet, has no 'true owner,' rights rest with the finder, or in this case, the tenant."[11] The doctors donated the meteorite to the Smithsonian as planned, receiving $10,000, which they donated to Doctors Without Borders.

The first recorded meteorite in Virginia fell June 4, 1828, about 9 a.m. It is called the Richmond Meteorite of Chesterfield County. It was followed by the Botetourt Meteorite, Botetourt County, discovered in 1850; the Poplar Hill (Cranberry Plains) Meteorite, Giles County, 1852; Staunton, Augusta County Meteorite, 1871; Indian Valley Meteorite, Floyd County, 1887; Hopper Meteorite, Henry County, 1890; Norfolk Meteorite, former Norfolk County, 1906; Sharps Meteorite, Richmond County, 1921; the Dungannon Meteorite, Scott County, 1923; Forksville Meteorite, Mecklenburg County, 1924; and finally, the Keen Mountain Meteorite, Buchanan County, 1950.[12]

Meteorite Specimen—Gladys. Photo: Ryan Shorter, 2020

Initially, Ryan didn't know how he was going share his find with the world or whether he wanted to. "The first thing to do is validate its origin." he thought. "To determine, without doubt, that the rock is what I think it is—a meteorite." Ryan remembered reading an article by David Abbou published in the Fredericksburg *Freelance Star* about meteors and meteorites. He emailed David with pictures of his find on August 26, 2020. Subsequently, David replied with a CC to Myron Wasiuta, Mark Slade Remote Observatory (www.MSROScience.org), former President of the Rappahannock Astronomy Club (RAC,) and who is very knowledgeable in "all things astronomy." Myron suggested Ryan contact me because I was known in our astronomy club as a meteorite collector.

When someone tells you they've found a meteorite, naturally you're a little skeptical. Especially in Virginia of all places. Most people are, as

Ryan found out when he showed some friends what he had found. There is actually less than 1% chance even if you're pretty good at identifying by appearance, that your specimen is a meteorite. In fact, without testing, it's virtually impossible to be sure. When Ryan contacted me, he attached some images of his find. I was pretty surprised looking at the images he sent and thought there was a pretty good chance it was actually a meteorite after all, but I needed a closer look.

As most people in the RAC know, I am a runner. In February 2020, I had signed up to compete in a 10K race to be held in Lynchburg, Virginia, in August. I had already planned to make it a weekender with my wife Debbie. We would stay at a hotel in old town Lynchburg and take in the sights after my run Saturday the 29th. Unfortunately, I was notified by the race sponsors that in-person racing was canceled owing to COVID-19. Because I had already made a reservation to stay at the Craddock Terry Hotel in Lynchburg, Debbie and I decided to go ahead with our weekend plans; I would run the race virtually on my own. With the trip to Lynchburg assured, I emailed Ryan, who lived in nearby Rustburg. Gladys, where his mom lived and where he found the object, was also not far from Lynchburg. We agreed to meet Saturday morning so I could get an in-person look at his potential meteorite find. I brought some samples from my own meteorite collection to compare and to show Ryan what authentic meteorites looked and felt like. It would be a teaching experience at the very least.

After a short analysis of Ryan's meteorite prospect, I concluded that this could very well be a meteorite, especially after comparing it with some similar size and weight meteorites I brought with me. It had all the general characteristics of an iron oxyhedrite[13] or hexahedrite[14] that survived atmospheric entry, impact into sandy loam soil, and exposure to the elements for an extended period of time. Its surface seemed to have been little effected from long-term environmental erosion, indicating it had been buried and protected by surrounding soil. Alternatively, the minimal erosion could be because it was a recent fall.

The specimen was very dense and heavy for its size and was easily attracted to a magnet but was not independently magnetic. It sported a glossy black appearance with rust apparent in surface grooves and cracks (potential impact shock fractures). Most edges were blunt or somewhat rounded, with the exception of one sharply cleaved side. The surface displayed evidence of a fusion crust from 1 to 3 mm thick, and flowlines were evident in one quadrant. There was at least one approximation of a regmaglypt (thumbprint) and evidence that the sample might have broken off of a larger body.

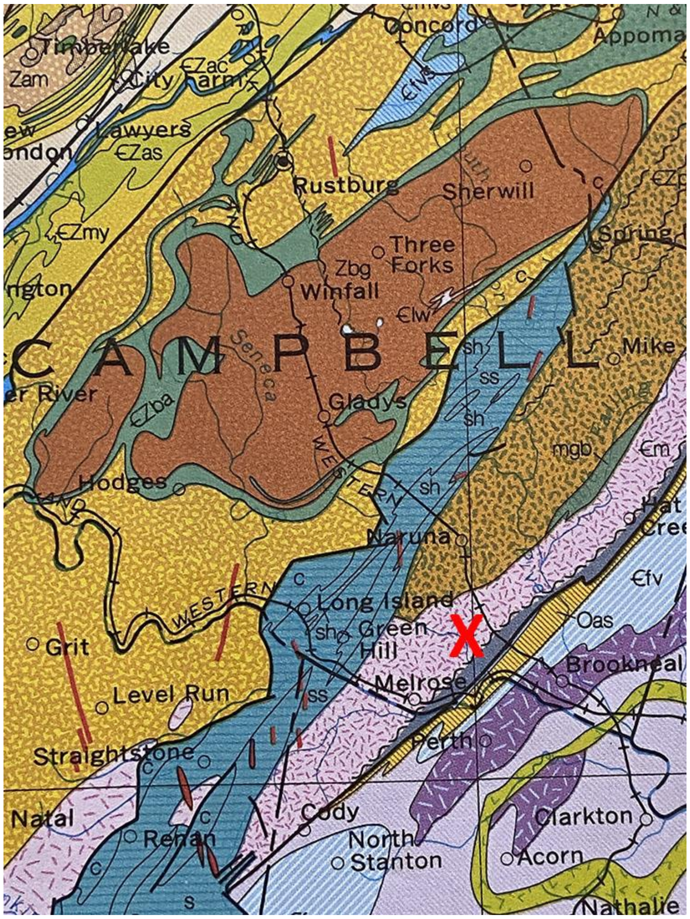
Ryan knew from some of his reading that it was important to cut a window into the meteorite to identify certain characteristics. Using a rotary grinder with a cutoff wheel, he was able to dislodge three small pieces while exposing the interior of the specimen. Those little pieces would become significant in aiding positive identification. In the main mass, the window that exposed underlying material presented a homogenous silvery metallic, fine-grained appearance with no inclusions. At this point in my analysis, I was at least 80 percent sure that Ryan's find was indeed a meteorite. Nevertheless, further tests were surely needed.

Before coming to Lynchburg, I had asked Ryan for details associated with his find. Specifically, what was the exact location—as well as he could remember—where the specimen was found and when? I had done a little research and planned on eliminating all possibilities before giving serious consideration to professional lab analysis. I was also anxious to keep the find a secret to prevent premature release of information to the public that might prompt potential meteorite hunters to descend on Ryan's mother's property. This is always good practice because you wouldn't want to be called out for pushing a fake meteorite story that turned out to be wrong and that resulted in havoc and embarrassment for all concerned.

My assumption now was that Ryan's find *was* a meteorite and adhering to the normal naming convention, Ryan and I decided to name the specimen the Campbell County meteorite or Gladys for short. Most all meteorites are named by the discoverer and usually indicate the location of the fall or find. This find was near the town of Gladys, Virginia, in Campbell County.

Before I left Lynchburg, I recommended that Ryan send the three small fragments to Dr. Syed "Noor" Qadri, a material scientist who had become aware of the possible meteorite find because he was copied on an early flurry of emails about the possible meteorite between Myron Wasiuta and the Northern Virginia Astronomy Club. Noor, as he likes to be called, had offered to do a gratis analysis on the sample and would publish a report on the findings. In email conversation with Noor, he informed Ryan and me that he would analyze the sample using non-invasive techniques (raman spectroscopy),[15] after which he would attempt X-ray diffraction and SEM-EDS analysis[16].

As it turned out, Noor's Gladys analysis was delayed owing to the onset of the COVID-19 pandemic. In fact, by December, there had been no word from Noor. I suggested to Ryan that Noor's analysis might not be forthcoming, and he should send me the sample so I could do my own analysis based on some new knowledge I had. Ryan agreed and promptly sent me the main mass.



DMME Map Area showing approximate location of Gladys finding

I was excited and intrigued on examining Gladys for myself, I decided to approach the analysis as scientifically as possible. I ordered a mineral examination kit and some scales. I crashed on techniques used to analyze minerals, especially meteorites. I also amassed a small book collection on the subject. I ordered a Virginia Soils composition map from the Virginia Department of Mines, Minerals, and Energy (DMME) and set to work trying to validate Gladys. The DMME map displayed the soil and rock composition of the entire state with color codes and symbols. A reference key accompanied the map and interpreted each of the symbols. Each colored area had its own associated symbol. I would use the map to identify composition of the area surrounding where Gladys was found. My intent was to eliminate any iron ore mines or outcroppings of oxides such as hematite or magnetite that could have migrated to the Gladys location. These minerals are frequently confused as meteorites and more often are meteor wrongs.

I approximated the location where Gladys was found by correlating between Google Maps, Apple Maps, and the DMME map (red X). On the DMME map, the X lies within a light purple area (code Ꞓm) known as Melrose granite. I won't get into the characterization of Ꞓm, but the mineralogy = quartz + plagioclase + potassium feldspar + biotite + muscovite + chlorite + epidote + titanite + garnet + magnetite-ilmenite + calcite + zircon (Gates 1981). The operative mineral is, of course, magnetite. The Melrose has been dated at 515 Ma (515 million years ago).

The grey strip to the SE of the X is a shear zone (code my = mylonite) associated with tectonic activity. Most mapped belts of mylonite represent fault zones with multiple movement histories. The mottled orange area directly to the north of the X and oriented SW to NE is code ꞒZpm a metagraywacke, quartzose schist, and melange. Minerology = Quartz + albite + epidote + chlorite + muscovite + magnetite and other assemblages. Again, we find magnetite. Finally, the blue striped area stretching from the SW to the NE from Rehan to Spring is mostly sandstone, shale, siltstone with conglomerated, mixed clasts (apparent alluvium).

I received Gladys through the mail on December 11 and began preliminary analysis. The following data are the result of preliminary analysis:

Weight:	175.74g, (6.199oz) (878.75ct)
Length:	59.76mm (2.352756in)
Width:	49.23mm (1.938189in)
Thickness:	29.47mm (1.160236in)

I examined the sample with a 10X magnifier loupe for any obvious clues that would discount it being a meteorite. There were no vesicles that would indicate volcanism. Rust was evident in some areas, and the cracks seem to be filled with dirt. There was a distinct appearance of a fusion crust and flow lines located in a concave portion of the sample.

I conducted a density test on Gladys using a displacement method, including a comparison of the similar size Sikote-Alin meteorite[17] (SAm) and Canyon Diablo meteorite[18] (CDm) I had in my collection.

Gladys	SAm	CDm
440-400ml = 40	235-200ml = 35	580-500ml = 80
v = 40	v = 35	v = 80
w = 175.74/40	w = 128.43g/35	w = 561.320g/80
d = 4.3935g/cm^3	d = 3.66g/cm^3	d = 7.0165g/cm^3

v = volume w = weight d = density (g/cm^3)

Using a bench grinder, I carefully ground the small area of Gladys that was roughly removed by Ryan using a hand grinder cutoff wheel, so it was totally flat. This small window better showed a distinct silvery metallic appearance. Later on, if opportunity presented itself, I would etch this area with nitric acid to see if a Widmanstatten pattern would show up. This would be a positive indication that Glady was a meteorite because the Widmanstatten pattern would undoubtedly show the Ni minerals kamacite and taenite.

I also took a series of photos of Gladys in a lightbox with a 1-cm cube for scale. I used an Apple iPhone 11 as the camera. Twelve photos were taken at an image size of 3024 x 4032px (34.9 mb). Adobe Photoshop CC 2020 was used with the levels function set at 1.60.

I conducted a streak test on Gladys. Streak color was dark grey to black. This strongly indicates magnetite. A reddish-brown streak could indicate hematite. An actual meteorite is not supposed to leave a determinative streak. Incidentally, two of my Canyon Diablo meteorites left a reddish-brown streak when tested. Now, I have to wonder about their authenticity. Nevertheless, a streak test is non-diagnostic and there are many meteorites that leave streaks.

I measured the specific gravity of Gladys, Sam, and CDm. I took three readings: 35.88, 35.83, and 35.88 (Gladys only), added the values, and divided by three for an average of 35.8633 g.

Gladys	w = 175.74g/35.8633g sg = 4.900274
SAm	w = 128.43g/16.7553g sg = 7.665037
CDm	w = 561.32g/81.8666g sg = 6.85657

w = weight g = grams sg = specific gravity

Findings:

Actual iron meteorites should have a density between 7-8 g/cm^3. They should also have a specific gravity between 7.3 and 7.8. Iron meteorites should also have at least 6 to 16% Ni content.

Sample	Weight	Density	Specific Gravity	Streak	Magnetic	Fusion Crust
Gladys	175.74g	4.3935g/cm^3	4.900274	Dark grey/black	Yes	Yes
SAm	128.43g	3.66g/cm^3	7.665037	None	Yes	No
CDm	561.32g	7.0165g/cm^3	6.85657	Red/brown	Yes	No
Baseline	n/a	7–8 g/cm^3	7.3–7.8	None/slight	Yes	Yes/No

The table shows that my preliminary analysis was not determinative. Even though I was careful in my measurements, there could still be errors. I suppose the last thing to do would be to test for Ni content. There are means to do this, but at that moment, those means were beyond my capability. I acquired some nitric acid and was prepared to etch the window of Gladys. Should a Widmanstatten pattern emerge after etching, that would be definitive enough to declare Gladys a meteorite.

While performing my analysis, I sent off an email to Noor to inquire the status of his analysis of the fragments taken from Gladys. As luck would have it, he responded with the following statement, “Despite my high hopes, the analyses showed no presence of Ni or any other indications that this sample could be a meteorite. After a thorough examination, the sample given was found to be composed of iron oxide (Fe_3O_4) magnetite,[1] which is often confused with meteorites. A magnetite ore of the size that Mr. Shorter found is still rare to find and worthy of investigation. Don’t hesitate to contact me if you have any questions.”

As a follow-up, the DMME soil/rock composition map of Virginia shows a common definitive quantity of magnetite throughout the area where Gladys was found. At first, I thought the specimen was deposited near Gladys by glacial movement during the ice age. However, my research showed that glaciers or ice sheets never reached beyond southern Pennsylvania. That leaves tectonic activity and subsequent alluvial deposits from erosion as the only possible explanation as to how the Gladys sample arrived where it did on Ryan Shorter's mother's property.

In conclusion, the main mass of the specimen was subsequently donated to me by Ryan Shorter as a thank you for believing in him and helping him through the testing of Gladys. The so-called "Campbell County meteorite"—Not! is now a part of my meteorite collection as a demonstration specimen of how easily one can be fooled by Mother Nature. I will use it as a teaching tool. Ryan has also asked me to convey his sincere thanks for the help and optimism received from David Abbou, whose "Meteors and Meteorites" article set him on the path of inquiry. Ryan also thanks Dr. Myron Wasiuta, Director of MSRO, for referring follow-up analysis to me, Scott Busby, at Belmont Observatory. A special thank-you goes to Dr. Syed Noor Qadri for his expertise to definitively identify Gladys.

References:

1. *The Fallen Sky*, chap 1.2, "Ellis Hughes's 15-Ton Caper," Christopher Cokinos, 2009, The Penguin Group
2. https://en.wikipedia.org/wiki/Willamette_Meteorite
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6. *The Fallen Sky*, Book V, "Mr. Barringer's Big Idea," Christopher Cokinos, 2009, The Penguin Group
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8. *The Fallen Sky*, Chapter VI.1, "Epiphany of Euclid Street," pages 180–201, Christopher Cokinos, 2009, The Penguin Group
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10. https://www.washingtonpost.com/wpdyn/content/article/2010/01/28/AR2010012804235.html
11. "Who Owns this Meteorite?" by Ami Dodson, https://www.wm.edu/research/news/social-sciences/who-own-this-meteorite5698.php September 28, 2011, William and Mary University
12. *Virginia Minerals*, 1974, Vol. 20, No. 3, Meteorites of Virginia, F.B. Hoffer, Division of Mineral Resources Quarterly
13. 6 to 16 percent Nickel (Ni). Irons (Siderites)—composed almost wholly of the iron-nickel minerals kamacite and taenite; may also contain the minerals plessite, troilite, schreibersite, cohenite, chromite, and graphite.
14. < 6 percent Ni and consists of kamacite only.
15. Raman spectroscopy is a spectroscopic technique commonly used in chemistry to provide a structural fingerprint by which molecules can be identified. Wikipedia
16. Scanning Electron Microscopy/Energy Dispersive Spectroscopy. https://www.intertek.com/automotive/materials-components/sem-eds/
17. https://en.wikipedia.org/wiki/Sikhote-Alin_meteorite
18. https://en.wikipedia.org/wiki/Canyon_Diablo_(meteorite)
19. https://en.wikipedia.org/wiki/Magnetite

Helicopters on Mars?

By Linda Billard

Artist's rendition of NASA's Ingenuity Mars Helicopter standing on the Mars surface as NASA's Perseverance rover (partially visible on the left) rolls away. Credits: NASA/JPL-Caltech

NASA's latest Mars rover, Perseverance, is due to land on the Red Planet February 18, 2021. It is the most sophisticated rover NASA has ever sent there. Its mission is to collect carefully selected rock and sediment samples for return to Earth, search for signs of ancient microbial life, characterize the planet's geology and climate, and pave the way for human exploration beyond the Moon.

However, this article isn't about Perseverance. Rather it's about one of several cutting-edge technologies that Perseverance is ferrying to the surface of Mars—a helicopter named Ingenuity. It will be the first aircraft to attempt powered, controlled flight on another planet.

Ingenuity weighs about 4 pounds on Earth and has a fuselage about the size of a tissue box. Six years ago, it was, if you will, just a flight of fancy. Although engineers at NASA's Jet Propulsion Laboratory knew it was theoretically possible to fly in Mars' thin atmosphere, they weren't sure they could build a vehicle powerful enough to fly, communicate, and survive autonomously with the extreme restrictions on its mass.

Earthbound tests proved it could fly in a Mars-like environment. Now the team is preparing to test Ingenuity in the actual environment of Mars.

"Our Mars Helicopter team has been doing things that have never been done before—that no one at the outset could be sure could even be done," said MiMi Aung, the Ingenuity project manager at JPL. "We faced many challenges along the way that could have stopped us in our tracks. We are thrilled that we are now so close to demonstrating—on Mars—what Ingenuity can really do."

The helicopter doesn't carry science instruments and isn't part of Perseverance's science mission. Its objective is to demonstrate rotorcraft flight in Mars' extremely thin atmosphere—about 1 percent of the density of the Earth's atmosphere.

Because the Mars atmosphere is so thin, Ingenuity is very light, with much larger rotor blades that spin much faster than those for a helicopter of Ingenuity's mass on Earth. The blades of a typical Earth-bound helicopter spin at 450 to 500 revolutions per minute. The Mars-copter blades are designed to spin up to 40 times a *second*. Mars is also very cold, with nights as cold as minus 130 degrees Fahrenheit (minus 90 degrees Celsius) at Jezero Crater, the landing site. Tests on Earth at the predicted temperatures indicate Ingenuity's parts should work as designed, but the real test will be on Mars.

Ingenuity will attempt up to five test flights within a 30-Martian-day (31-Earth-day) demonstration window. Once a suitable deployment site is found for the helicopter, Perserverance's Mars Helicopter Delivery System will shed the landing cover, rotate the helicopter to a legs-down configuration, and gently drop Ingenuity on the surface in the first few months after landing. Throughout the helicopter's commissioning and flight testing, the rover will assist with the communications to and from Earth.

The inherent delays in communicating with spacecraft across interplanetary distances mean that Ingenuity's flight controllers at JPL won't be able to control the helicopter with a joystick. In fact, they won't even be able to look at engineering data or images from each flight until well after the flight takes place. Consequently, Ingenuity is designed to make some of its own decisions based on parameters set by its engineers. For example, the helicopter has a programmable thermostat to help keep the aircraft warm on Mars. During flight, Ingenuity will also be able to analyze sensor data and images of the terrain to ensure it stays on its assigned flight path.

Ingenuity is intended to demonstrate technologies and first-of-its-kind operations to fly in the Martian atmosphere. If successful, it could enable use of other advanced robotic flying vehicles as part of future robotic and human missions to Mars. Possible uses of a future helicopter on Mars include providing a unique viewpoint not provided by current orbiters high overhead or by rovers and landers on the ground; high-definition images and reconnaissance for robots or humans; and access to terrain that is difficult for rovers to reach. A future helicopter could even help carry light but vital payloads from one site to another.

For an entertaining view of the little helicopter that could, watch this YouTube video.

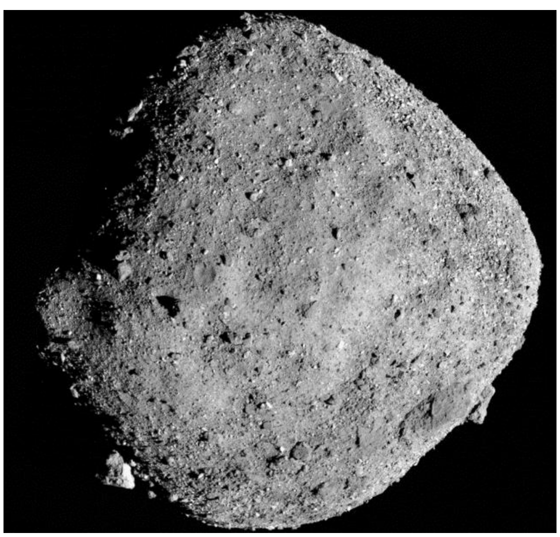
OSIRIS-REx—Voyage to a VERY Small Planet

By Linda Billard

Recently I attended (via Zoom) an excellent presentation by Dr. Dolores Hill, Senior Research Specialist in the Planetary Materials Research Group of the Lunar and Planetary Observatory at the University of Arizona. The presentation was hosted by the Richmond Astronomical Society. Hill is a member of the Education and Public Outreach Team for the NASA's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) asteroid sample return mission to Potentially Hazardous Asteroid (PHA) (101955) 1999 RQ36. She is also an OSIRIS-REx Ambassador, assists science team members, and is co-lead with Carl Hergenrother, for Target Asteroids!, a new citizen science project and Target NEOs!, a new Astronomical League observing program.

Artist's Depiction of OSIRIS-REx Spacecraft. Credit: NASA

Stimulated by her presentation, I decided to read more about OSIRIS-REx and the specific mission Dr. Hill discussed. OSIRIS-Rex's current mission is to recover material from PHA (101955) 1999 RQ36, otherwise known as asteroid Bennu. Although it was discovered in 1999, the asteroid was not named until 2012. The name *Bennu* was selected from more than 8,000 student entries worldwide in a "Name That Asteroid!" contest run by the University of Arizona, The Planetary Society, and the LINEAR Project. The name Bennu references the Egyptian mythological bird Bennu. Features on the asteroid were subsequently named for birds.



Mosaic image of Bennu composed of 12 PolyCam images collected December 2, 2018 by OSIRIS-REx from a range of 15 miles. Credits: NASA/Goddard/ University of Arizona

Bennu was selected for the OSIRIS-Rex mission from more half a million known asteroids. The primary requirement was close proximity to Earth and an orbit with low eccentricity, low inclination, and an orbital radius of 0.8–1.6 au, all intended to make it easier to land on the target asteroid. In addition, the candidate asteroid had to have regolith (i.e., loose rock and dust atop a layer of bedrock) on its surface. This requires a diameter greater than 200 m, because smaller asteroids spin too fast to retain small-sized surface material. Finally, the candidate list shrank further because scientists wanted an asteroid likely to have pristine carbon material from the early solar system, possibly including volatile molecules and organic compounds. Only five asteroids fit these criteria. Bennu was chosen, in part because of its potentially hazardous orbit that could result in a collision with Earth in the 22nd century.

OSIRIS-Rex was launched from Cape Canaveral in 2016, arriving at Bennu in December 2018. It first orbited the asteroid, mapping the surface in detail, seeking potential sample collection sites. Analysis results also allowed scientists to calculate the asteroid's mass and its distribution.

In June 2019, the spacecraft captured an image from a distance of just 2,000 ft above the surface. These high-resolution data revealed that the surface was much rougher than originally thought—based on Earth-based observations—with more than 200 boulders larger than 10 m. On December 12, 2019, a target site for sample collection was announced. Named Nightingale, the area was near Bennu's north pole and inside a small crater within a larger crater.

In October 2020, OSIRIS-REx successfully touched down on the surface of Bennu. Two days later, NASA's OSIRIS-REx mission team received images that confirmed the spacecraft had collected more than enough material to meet one of its main mission requirements—acquiring at least 2 ounces (60 grams) of the asteroid's surface material.

The OSIRIS-REx team will now focus on preparing the spacecraft for the next phase of the mission—Earth Return Cruise. The departure window opens in March 2021 for the spacecraft to begin its voyage home, and the spacecraft is targeting delivery to Earth on September 24, 2023.

Focus On: The Lunar 100—Features 21 through 30

By Jerry Hubbell

(Note from the author: A version of this article was published in the September 2020 ALPO The Lunar Observer *as the Focus On bi-monthly article. Part of my role as the Assistant Coordinator (Lunar Topographical Studies) is to write articles periodically on research done by ALPO contributors. To see full-size versions of the photos in this article, go to http://www.alpo-astronomy.org/gallery3/index.php/Lunar/The-Lunar-Observer/2020/tlo202005. To see the latest issue of The Lunar Observer, go to http://www.alpo-astronomy.org/gallery3/index.php/Lunar/The-Lunar-Observer/2020/tlo202007)*

This is the third of 10 articles in a new series on Chuck Wood's Lunar 100 list. Chuck, the founder of the Lunar Photo of the Day (LPOD), first discussed this list of lunar features in a *Sky & Telescope* article published in 2004 and later published on the *Sky & Telescope* website. This series will run until January 2022. Along the way, I may also insert a few articles on other topics, so the last article may appear as late as the end of 2022. Chuck wanted this list of lunar features (L1 to L100) to be the lunar equivalent of the well-known list of Messier objects, giving lunar observers a way to progress in their study of the Moon and become lifelong observers. The list contains all the diverse features of the Moon, including mare, craters, rilles, mountains, and volcanic domes, It begins with the naked eye view of the full disk of the Moon and progresses to more difficult-to-observe features.

These articles are meant to be the basis for a lunar visual observing program but are not limited to that purpose. They can be the basis for starting your own image-based study of the Moon, which will allow you to use the Lunar Terminator Visualization Tool (LTVT), a sophisticated software program used to do topographical measurements of the lunar surface. These articles introduce and show each of the Lunar 100 features as observed and submitted by ALPO members through narrative descriptions, drawings, and images. Although you can use your naked eye and binoculars to start observing objects L1–L20, seeing objects L21–L80 requires use of a 3-inch (76-mm) telescope. Features at the end of the list (L81–L100) require a 6- to 8-inch (152- to 203-mm) telescope. The best views of many of the different features may be at different phases of the Moon.

One of the best ways to help you learn the features of the Moon is by sketching the lunar surface. Springer Books publishes an excellent book, released in 2012, called *Sketching the Moon* (Handy, et al.). There are also other resources on the Internet to help you get started observing and sketching the Moon, including the ALPO's excellent *Handbook of the ALPO Training Program.*

This article covers features 21 through 30 on Chuck's list and shown in Table 1.

Designation	Feature Name	Description/Significance
L21	Fracastorius	Crater with subsided & fractured floor
L22	Aristarchus Plateau	Mysterious uplifted region mantled with pyroclastics
L23	Mons Pico	Isolated Imbrium basin-ring fragment
L24	Hyginus Rille	Rille containing rimless collapse pits
L25	Messier & Messier A	Oblique ricochet-impact pair
L26	Mare Frigoris	Arcuate mare of uncertain origin
L27	Archimedes	Large crater lacking central peak

Designation	Feature Name	Description/Significance
L28	Hipparchus	First drawing of a single crater
L29	Ariadaeus Rille	Long, linear graben
L30	Schiller	Possible oblique impact

Table 1. The Third Set of 10 Lunar 100 Features

Feature 21—Fracastorius

Figure 1. Fracastorius, Sergio Babino SAO-LIADA, Montevideo, Uruguay, 14 March 2020, 0459 UT, Colongitude 146.8°, 203-mm SCT, ZWO 174mm CMOS camera. North/Right, East/Up.

Feature 22—Aristarchus Plateau

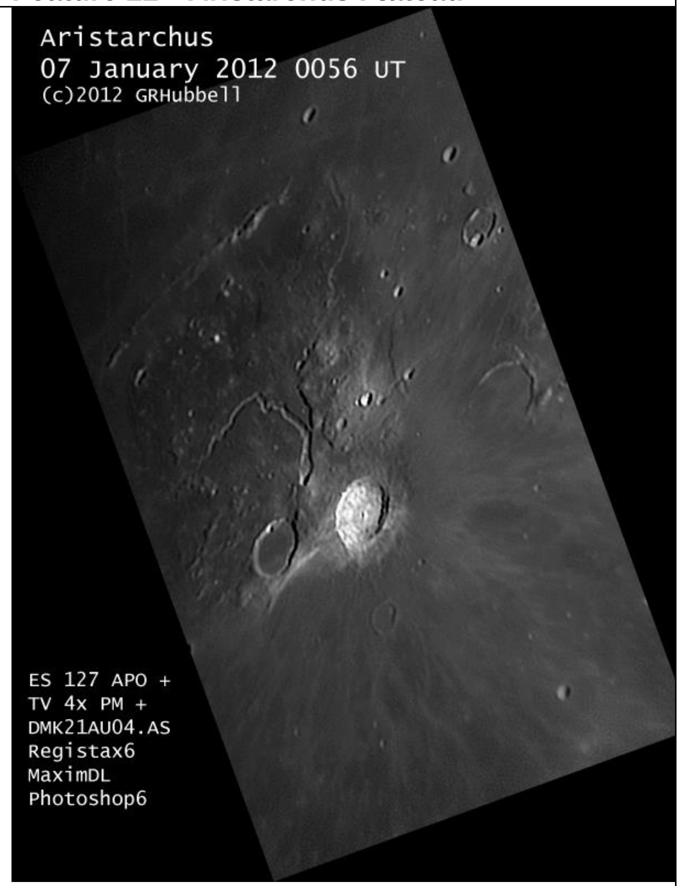


Figure 2. Aristarchus Plateau, Jerry Hubbell, Locust Grove, VA USA, 07 January 2012, 0056 UT, Colongitude 356.2°, 127-mm APO Refractor + 4x PowerMate, DMK21AU04.AS video camera. North/Up, East/Right.

Feature 23—Mons Pico

Figure 3. Mons Pico, Francisco Alsina Cardinalli SLA-LIADA, Oro Verde, Argentina, 20 August 2018, 2334 UT, 200-mm refractor, QHY5-II camera. Colongitude 26.2°, North/Up, East/Right.

Feature 24—Hyginus Rille

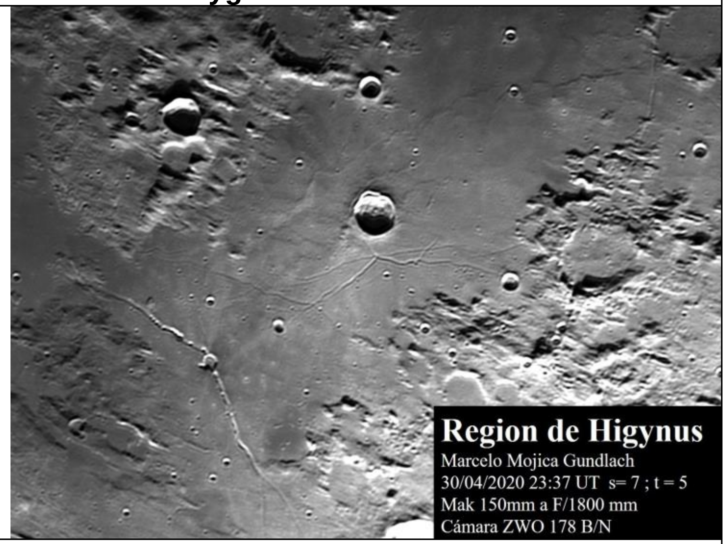


Figure 4. Hyginus Rille, Marcelo Mojica Gundlach LIADA, Cochabamba, Bolivia, 30 April 2020, 2337 UT, Colongitude 9.4°, 152-mm Maksutov, ZWO ASI 178 Camera, Seeing:7/10, Transparency:5/6, North/Up, East/Right.

Feature 25—Messier & Messier A

Figure 5. Messier & Messier A, Desiré Godoy (SLA-LIADA, Oro Verde, Argentina, 08 November 2019 0120 UT, Colongitude 40.7°. 200-mm Newtonian, QHY5-LII-M camera, North/Up, East/Right.

Feature 26—Mare Frigoris

Figure 6. Mare Frigoris, Alberto Anunziato SLA-LIADA, Oro Verde, Argentina, 10 September 2016 2312 UT. Colongitude 22.9°, 279-mm f/10 Celestron Edge HD SCT, QHY5-II camera, North/Up, East/Right.

Feature 27—Archimedes	Feature 28—Hipparchus

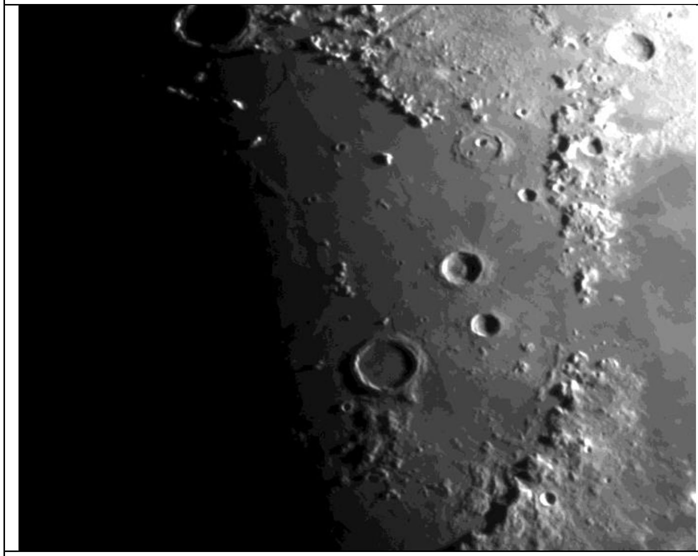
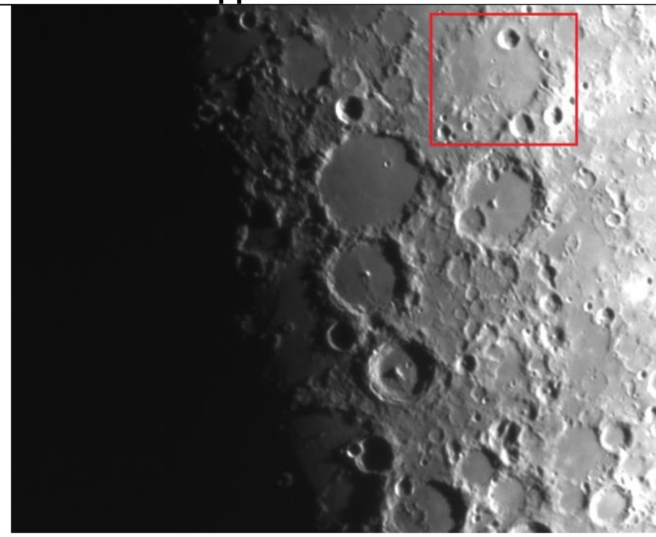

	

Figure 7. Archimedes, Jerry Hubbell, Locust Grove, VA, 20 March 2011 0237 UT, Colongitude 94.8°, 120-mm f/7.5 refractor, ATIK 314e CCD camera. Seeing 7/10, Transparency 5/6, North/Up, East/Right.	Figure 8. Hipparchus (highlighted), Jerry Hubbell, Locust Grove, VA, USA, 13 March 2011, 0217 UT, Colongitude 9.3°, 120-mm f/7.5 refractor, ATIK 314e CCD camera, North/Up, East/Right.

Feature 29—Ariadaeus Rille	Feature 30—Schiller

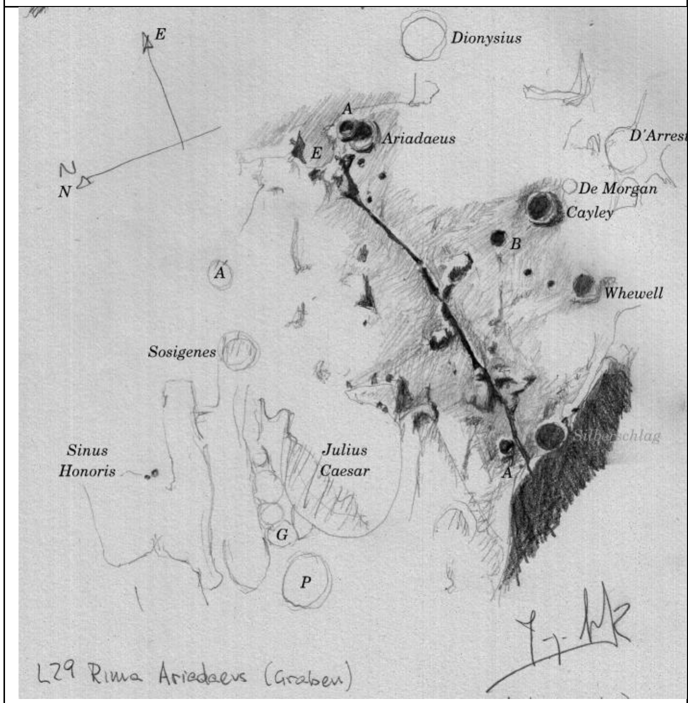
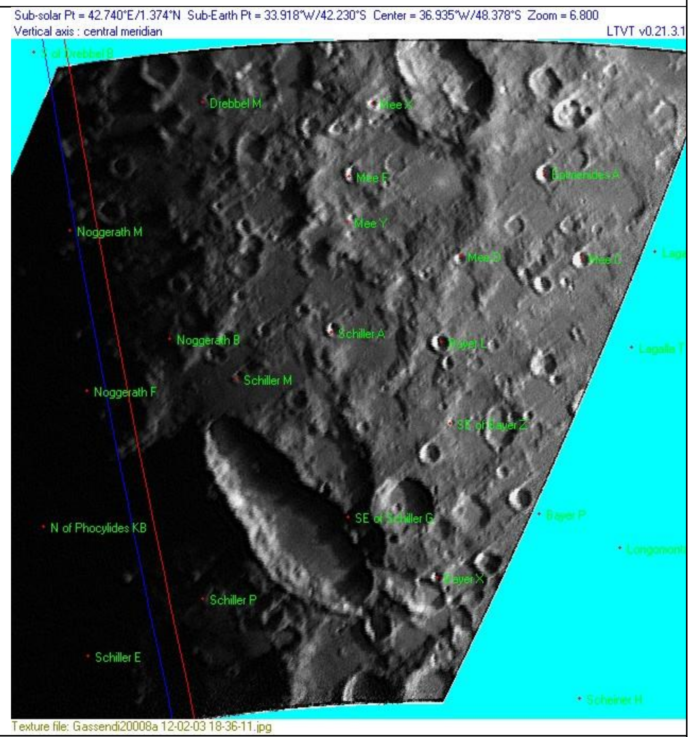

	

Figure 9. Rima Ariadaeus, Jorge Arranz, Lunar Group of the Madrid Astronomical Association (AAM), Madrid, Spain, 30 May 2020, 2110 UT, Colongitude 14.5°, 250-mm f/5 Dobsonian, 8mm eyepiece + 2x Barlow 312x, Seeing 6/10, Graphite bars and pencil on white paper, North/Left, East/Up.	Figure 10. Schiller, LTVT Aerial View, Jerry Hubbell, Locust Grove, VA USA, 03 February 2012, 2336 UT, Colongitude 4.7.5°, 10-inch (254 mm) f/10 Meade SCT, TIS DMK21AU04.AS CCD camera, Seeing 8/10, Transparency 3/5, North/Up, East/Right.

Jorge relates the following about his sketch of Feature 29 (Figure 9), Rima Ariadaeus:

> The drawing was intended to render the Cayley Plains (L50) and part of the Imbrium Sculpture over Julius Caesar (L63), but some trees in the way had it abruptly finished. So, they are just outlined. Please realize that it was done from an urban front yard and with a street-lamp over the telescope!

As always, we had a good response to our request for images and drawings for the third set of 10 features of the Lunar 100 (L21–L30). I am grateful for all the submissions we received. We had a total of 71 images and drawings submitted to the TLO from more than 15 astronomers. Many of the images came from Alberto Anunziato's groups, SAO-SLA and LIADA. Previously, he prefaced the images he sent on behalf of his group this way:

"LUNAR 100 PROGRAM Sociedad Astronómica Octante-Sociedad Lunar Argentina

When we found out that the next objectives of the Focus On Section would be the features listed in the Charles Wood's famous Lunar 100, the members from Sociedad Lunar Argentina (SLA) and Sociedad Astronómica Octante (SAO) of the República Oriental del Uruguay, we considered interesting to join the initiative of "The Lunar Observer" (TLO) and therefore we launched our Lunar 100 Program, under the auspices of the Lunar Section of the Liga Iberoamericana de Astronomía (LIADA). The objective is twofold. We will report the images submitted to the program to "The Lunar Observer". And we will also publish them in all the media of SLA, SAO and LIADA. We think it is a great opportunity to stimulate amateur lunar observation and if the call is successful, we can dream of some final joint publication."

We look forward to future drawings and images submitted by ALPO, SLA, SAO, and LIADA members and others from all across the world. Please share with us any images you have in your image catalog, we hope to see everyone participate in these Focus On articles.

COMPUTER PROGRAMS

Virtual Moon Atlas, https://sourceforge.net/projects/virtualmoon/
Lunar Terminator Visualization Tool (LTVT), http://www.alpoastronomy.org/lunarupload/LTVT/ltvt_20180429-HTML.zip

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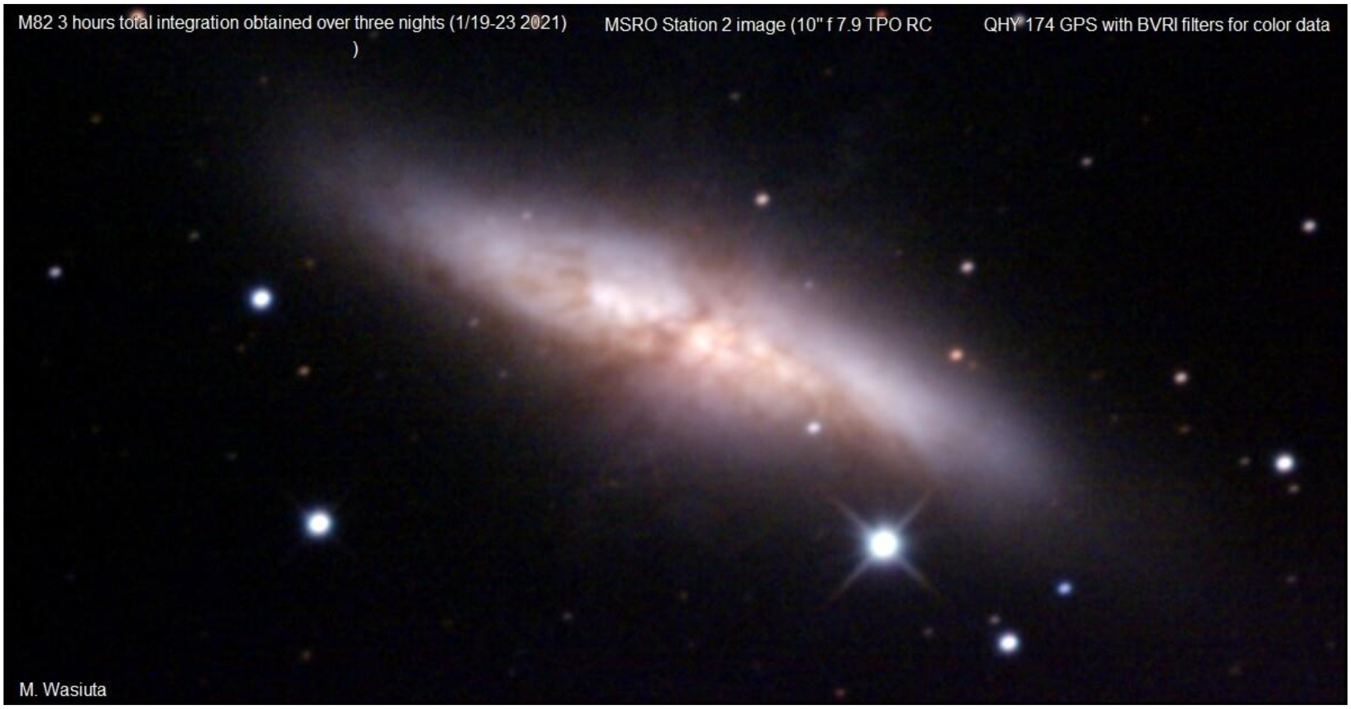
Image of the Quarter



Cigar Galaxy (M82) by Myron Wasiuta

German astronomer Johann Elert Bode discovered M82 and its neighbor M81 (aka Bode's Galaxy) in 1774. Located 12 million light-years from Earth in the constellation Ursa Major, M82 has an apparent magnitude of 8.4. Although it is visible as a patch of light with binoculars in the same field of view as M81, larger telescopes are needed to resolve the galaxy's core. This galaxy's starburst action is thought to have been triggered by interactions with M81.

Myron says: "This image represents my best effort to date on this object—about 3 hours of integration using a 10-inch TPO RC and QHY 174 GPS and BVRI filters contributing the color data to a LRGB stack. I fought moonlight and clouds over the three nights needed to obtain the data and used digital development and gamma scaling to pretty harshly process the image to bring out the faint detail—hence the noticeable graininess. Definitely would benefit from much more exposure. I used 60-second unguided subframes throughout the observation. The telescope is mounted on a CGE Pro mount."