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A Field Guide to Jezero Crater, Mars

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ABEONA STANDARD FIELD NOTEBOOK

A Field Guide to Jezero Crater,
MARS

Western Washington University Honors Capstone
a project by Lee Adair
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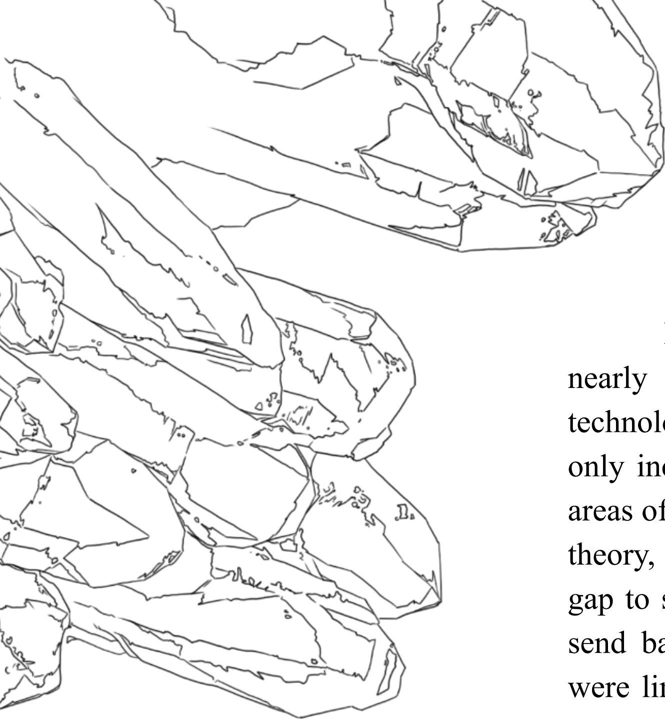
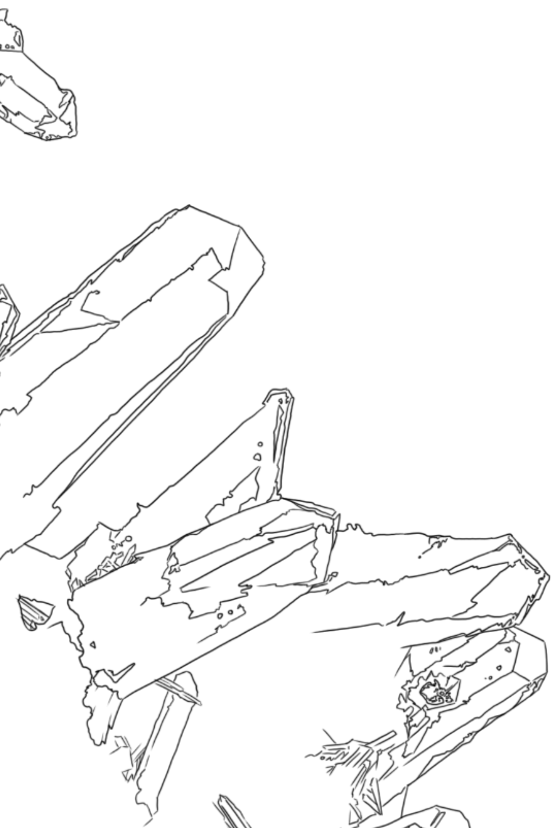


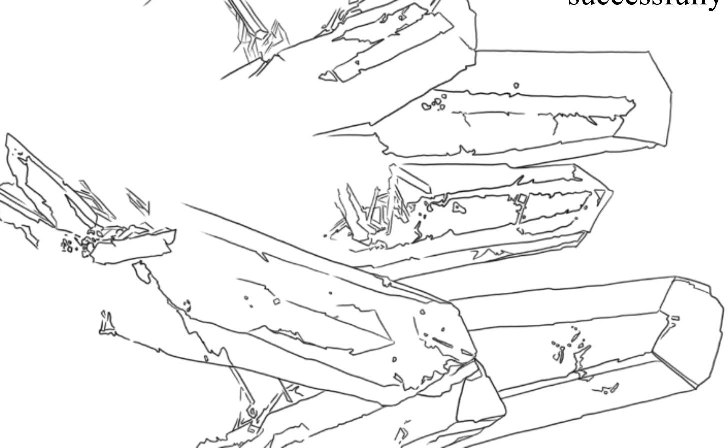
Introduction

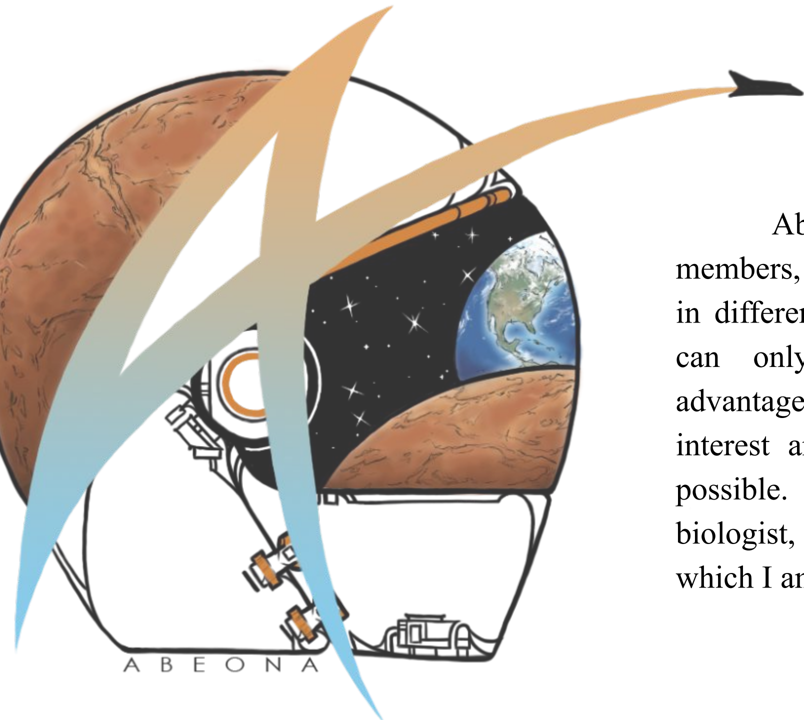
Mars has been a source of fascination since its discovery nearly four centuries ago. With the advent of improved technology, human understanding of the planet and its conditions only increased over time, allowing for further and more specific areas of study. Some questions, however, remained in the realm of theory, due, primarily, to distance. Rovers and orbiters closed this gap to some degree, offering a variety of data collection tools to send back observations from the planet's surface. These rovers were limited in both movement and capacities, running on finite power sources and left to the harsh ground conditions. Their time on the Martian surface set the foundations for the most recent and ambitious undertaking: sending people to live on a ground settlement.



The mission, known as the Abeona Mission, was grounded in the discoveries made by the Perseverance rover over two decades ago. Perseverance was a rover tasked with collecting and examining samples from Jezero Crater in hopes of finding evidence of extinct life in the geological record. Even before the samples made it to earth in 2038, the skeleton of Abeona was in progress, with Jezero as the primary region in which humans would conduct research. The planning was extensive, as a mission with humans would require habitats capable of creating a sustainable oxygen supply, specialized equipment, food and water sources, and considerable training on the part of the crew.

Gradually, thanks in large part to the mapping and traverse of Perseverance, Abeona came into focus: a human-led expedition with a dynamic crew, sharing a primary habitat and collecting subsurface ice as a source of water, using more powerful instruments to refine the data collected from other missions. The crew of the Abeona, after two years of space flight, landed successfully in Jezero in 2045.





Abeona and Crew

Abeona's crew is multifaceted: each of the nine members, including myself, have collaged backgrounds in different sciences. Because the habitat and resources can only support so many individuals, it was advantageous to select people with several areas of interest and experience to cover as many projects as possible. There are two engineers, one chemist, one biologist, one physician, one botanist, two geologists (of which I am one), and one physicist.

sol 5 || The pace of activity in the habitat has made retrospection feel impossible. There is a presentness in this mission I haven't felt in ages. In the month prior to the mission, even in the flight over, the apprehension took up so much of our head space that we weren't exactly 'living in the moment'. Everything was about touching down. Now that we have, now that we have broken ground, every sol is a new sequence of tests and assembly with little downtime between. This is the first time I've felt capable of even examining the last few days, even though the task itself seems exhausting.

Perhaps the most difficult part of this stage of the mission is awaiting the actual field work. Because so much of these first few sols is about getting up and running, I haven't actually gotten to walk around and make observations. I have been able to do some setup outside of the habitat, but I keep spotting samples I'd like to collect, or noting formations that I would want to hike to. Until the crew and the team on earth feels it is safe to do so, I must wait to start any sort of project.

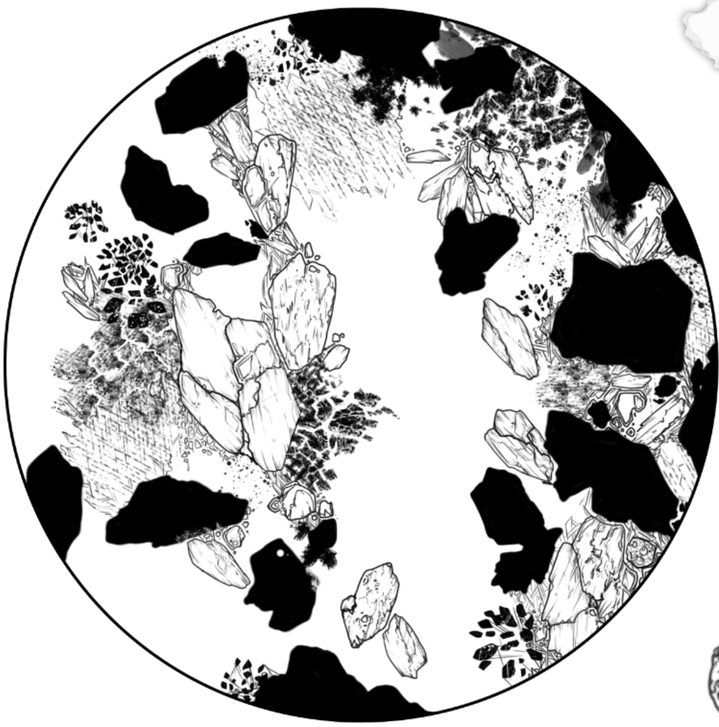
To our credit, nothing has gone incredibly wrong.

Rocks of Jezero

The crater floor in Jezero is **basalt**, an extrusive igneous rock. It forms when mafic magma (magma that is rich in magnesium and iron) is exposed to the surface and cools rapidly, creating fine-grained crystals and occasional vesicles.

Basalt can be chemically weathered by water, creating secondary minerals, like opaline silica and phyllosilicates. Many of these secondary minerals have been found across Mars, indicating that water was once abundant on its surface.

phyllosilicates ("sheet silicates"): a class of minerals defined by the presence and formation of Si2O5.

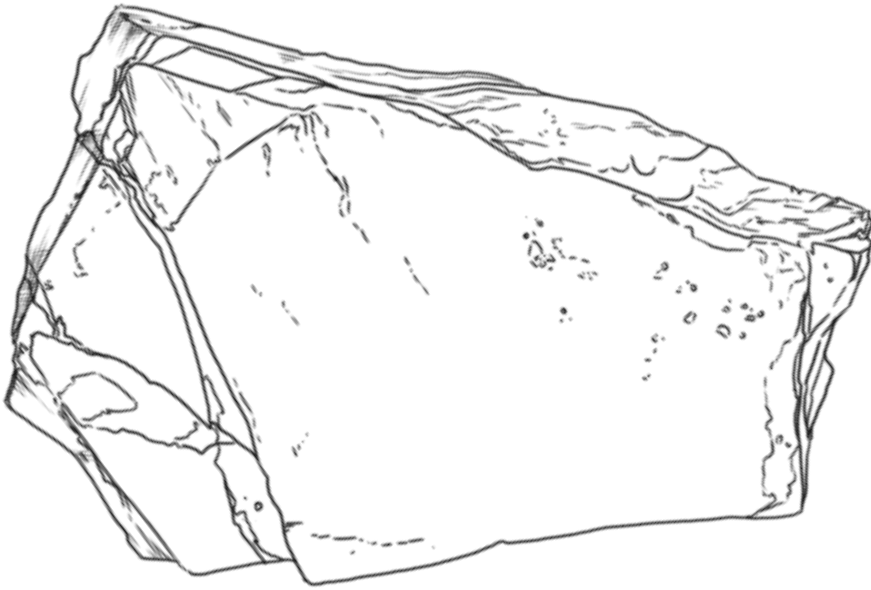


Pictured above are partial sketches of thinly sliced basalt under a microscope. At this scale, one can observe the fine crystals of pyroxene, olivine, and plagioclase feldspar.
To the left is a sketch of vesicular basalt, whose surface has been slightly eroded while the texture below has been preserved.

aeolian: of or relating to the wind.

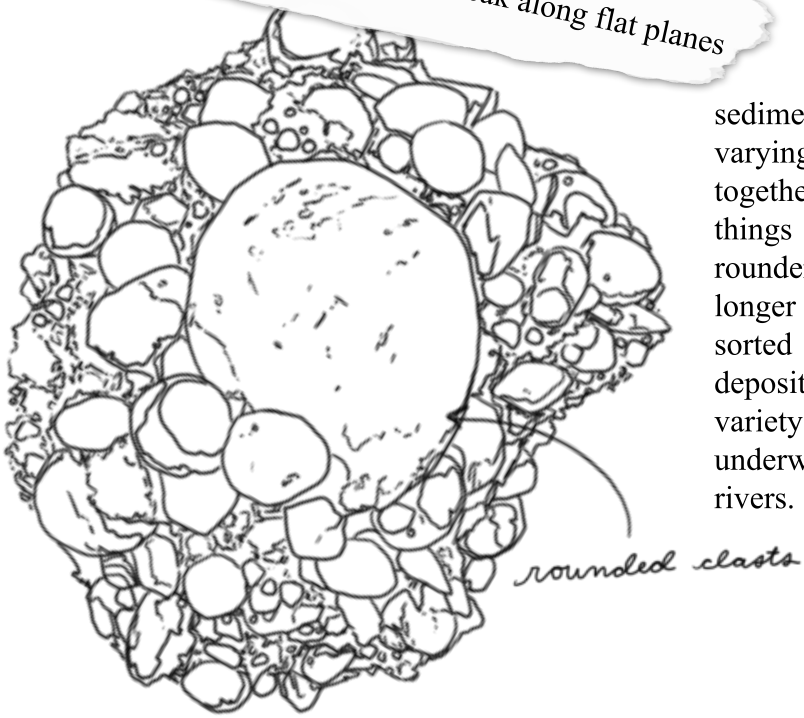
fluvial: of or occurring within a river.

lacustrine: of or relating to lakes.



Many rocks of Jezero are sedimentary, and their actual classification depends on grain size and sorting. One that is present is **shale** or mudstone, a very fine-grained rock with distinct layers. These layers can indicate at what angle they were deposited and whether any sort of deformation or movement has occurred in the stratigraphy of an area.

fissility: the tendency of a rock to break along flat planes



Drawn at left is a **conglomerate**— a sedimentary rock that contains rounded clasts, varying in size from gravel to sand. They are held together by a matrix of smaller sediments. Some things can be inferred from the conglomerate: rounder grains mean they likely have traveled longer distances, and how well the clasts are sorted can determine factors around their deposition. Conglomerates on earth occur in a variety of locations near water, including deep underwater, underneath glaciers, and by/within rivers.

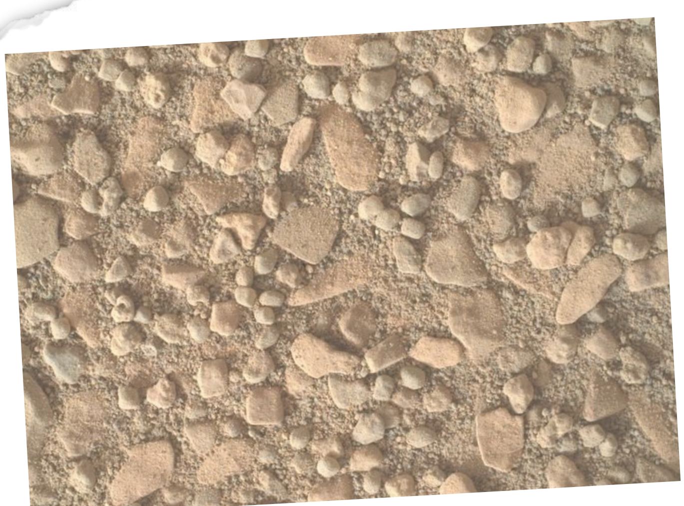
This picture is a conglomerate sample from Gale crater, with clasts around 1 cm in diameter. Gale was also likely the site of a lake and delta system.

Image credit: NASA/ JPL

ventifacts: rocks that have been eroded by grains of sediment or other materials. They are most commonly found in locations where aeolian processes are the dominant erosional force. The forms they take are dependent on a variety of factors, including the type of rock, its original shape, and the direction or strength of wind present.

Aeolian processes actively shape the surface of the crater. Float rocks are subject to the abrasion of wind and dust, sometimes leading to the creation of ventifacts. In some cases, these ventifacts can be used to determine the present and past wind environments in an area.

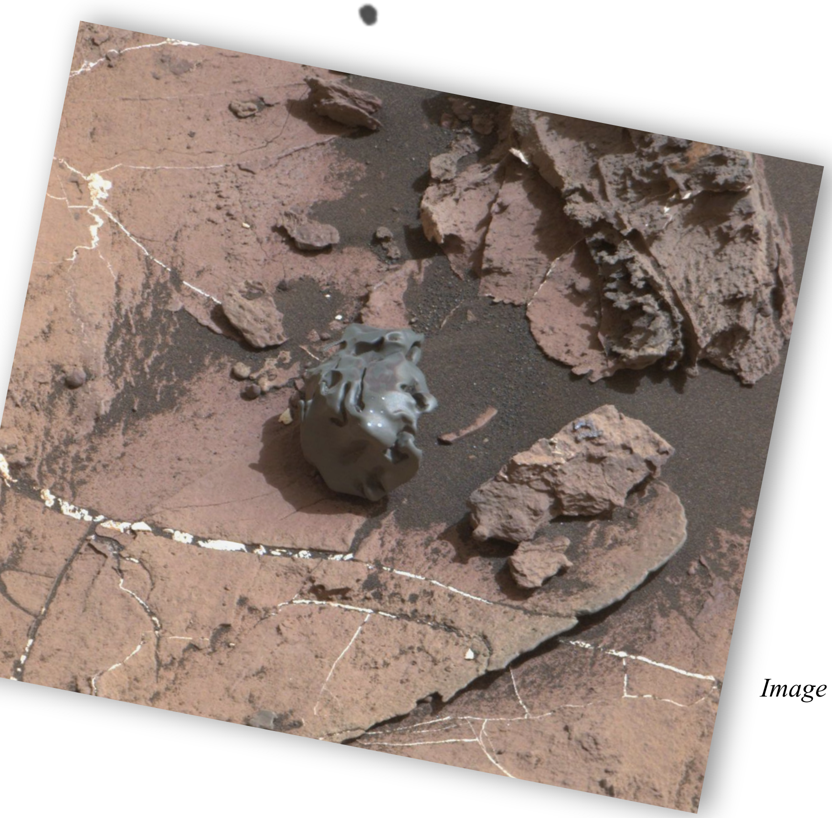
nodules



nodules: a type of concretion of rock or material that is different from the formations it is around, and is generally round in shape.

Image credit: NASA/ JPL

While not as common as other rocks, meteorites can be found scattered about the planet's surface. Because Mars has a much thinner atmosphere, there is a greater chance of meteorites reaching the ground. The meteorites that we have found stick out from the surround rocks for their dark color and unique texture. When looking at them spectrally, they register as being unlike the other float rocks due to their high content of iron and nickel. They are also rather heavy, making them difficult to collect and transport.



Pictured left is a meteorite (named "Egg Rock") found during the Curiosity rover traverse. By using ChemCam, the rover was able to confirm the composition was iron and nickel.

Image credit: NASA/ JPL

Rough Geological Timeline

Based on crater counting methods and principles of stratigraphy, Mars' history can be divided into four epochs.

Pre-Noachian: (4.5-4.1 Gya)

Little remains of this time in Martian history. However, the general consensus around Pre-Noachian Mars is that it endured a lot of impacts. These impacts of asteroids and meteorites likely introduced water vapor, which mixed with gasses from the cooling mantle and formed a relatively thick atmosphere and possible oceans. This is when life could have had the conditions to develop.

Noachian: (4.1-3.7 Gya)

This period is notable for its impacts and volcanic activity. This is around the time the Tharsis bulge, and the volcanoes on it, began to form, and crustal fracturing developed large structures, like Valles Marineris. The volcanic activity introduced new materials into the atmosphere and caused the planet to warm, and also affected the water and the rocks forming at that time. Concurrently, the interior of the planet began to cool, causing the dynamo to cease and weakening the planet's magnetic field.

Hesperian: (3.7-3.0 Gya)

The Hesperian period saw a drastic change in global conditions, with a slowing of geologic activity and an overall dip in global temperature. Water became trapped in ice and would occasionally be released by the heat of impacts, occasionally causing flooding. The remaining volcanic activity introduced sulfur dioxide to water in the atmosphere, which can be found in deposits across the planet's surface.

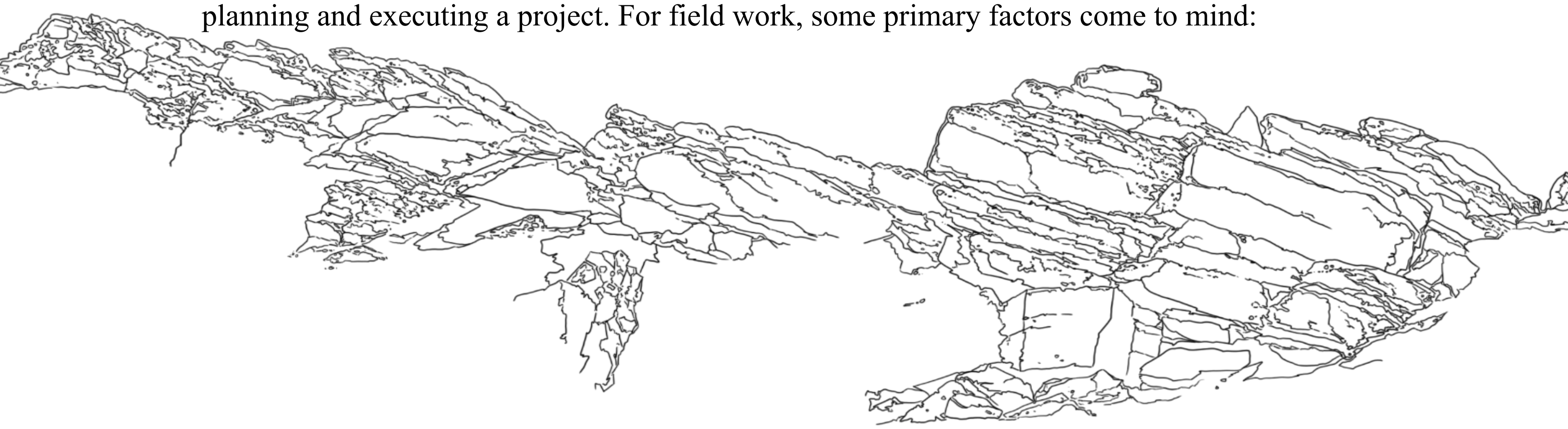
Amazonian: (3.0 Gya to present)

As of now, the planet has lost much of its original atmosphere and the primary geologic agent is wind. Conditions on the planet have been relatively consistently arid and cold. Much of the activity of the previous epochs is undergoing weathering and resurfacing.

delta: a landform and depositional environment that occurs where rivers connect to a larger body of water. These environments have a lot of variation depending on the riverbed's gradient and what process primarily controls their movement. There are three primary types: tide-dominated, river-dominated, and wave-dominated deltas. Rock types present can vary, but sediment sizes can range from clasts to sands and silts.

Notes on the Surface Conditions

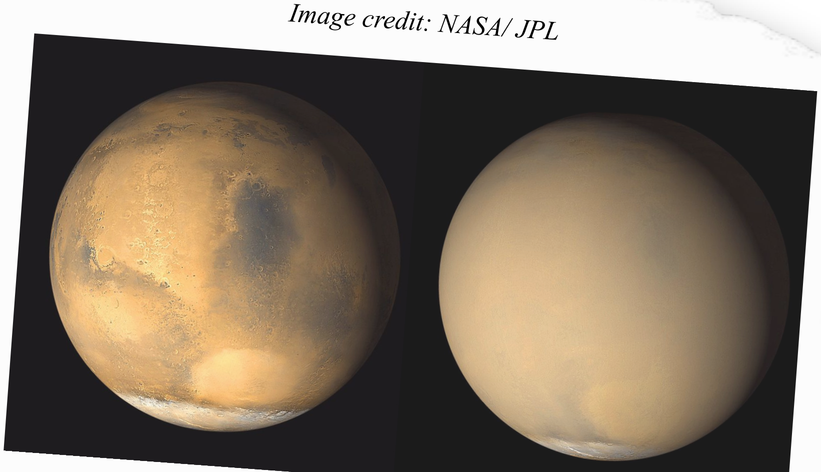
Working on Mars has a multitude of difficulties that need to be accounted for before planning and executing a project. For field work, some primary factors come to mind:



1. The atmosphere on Mars is both different in composition and thinner than that of Earth's. It's primarily composed of CO2, with trace amounts of nitrogen, argon, and oxygen, and retains little heat. Within Jezero crater, temperatures range from around -80℃ at night to above -20℃ during the day. The suits the crew use account for these changes, but can limit mobility a bit.
2. The gravity of Mars is lower than that of earth. Mars is not only smaller, but generally less dense, leading to a gravity of 3.7 m/s2, as compared with the normal 9.8 m/s2. This is compounded by the adjustment from zero-g in orbit and transit to the conditions at the site.
3. Weather and solar activity can limit the amount of time during which samples can be collected. Martian weather is generally less intense than earth's, but high winds can yield destructive and persistent dust storms. As for solar radiation, the planet's lack of magnetosphere or protective atmosphere means a variety of radiation can reach the surface. Again, the suits do protect the wearer, but only to a certain degree. Some conditions outside the habitat require the crew to shelter in place until both us on the ground and the team on earth can confirm our safety.

sol 39 || It's our first dust storm today, and though systems predicted it before it hit the habitat, it's much different experiencing it than I thought it would be. Dust storms are not uncommon on Mars, and some can even be sizable enough to engulf the whole planet. Fortunately, this seems to be an isolated system that will likely dissipate in a sol or two. I am a bit excited to get back out again, as the dust will have accumulated on surfaces and we can do some tests on what blew into the crater.

Image credit: NASA/ JPL



Drill Sites

Perseverance was outfitted with a variety of tools for data collection on the Mars surface. One of its more innovative additions was a drill attached to the rover's robotic arm, which had interchangeable bits that allowed for the collection of rock samples. These samples were then stored and subsequently dropped in certain locations along the traverse. Eventually, these samples were returned to earth for further examination and more detailed testing.

The drill, pictured right, with a rock core before being placed in a sample tube.

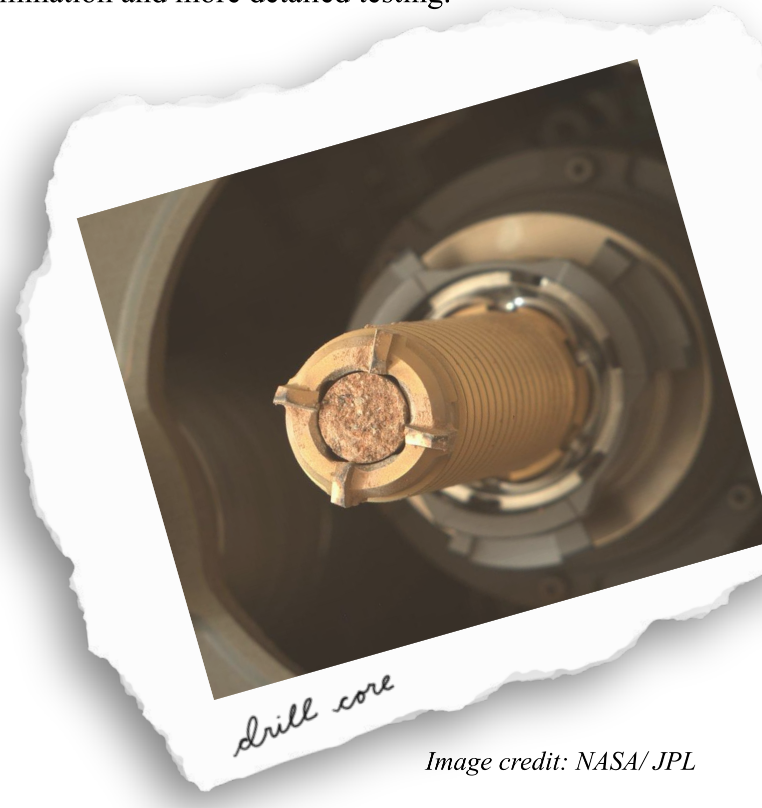
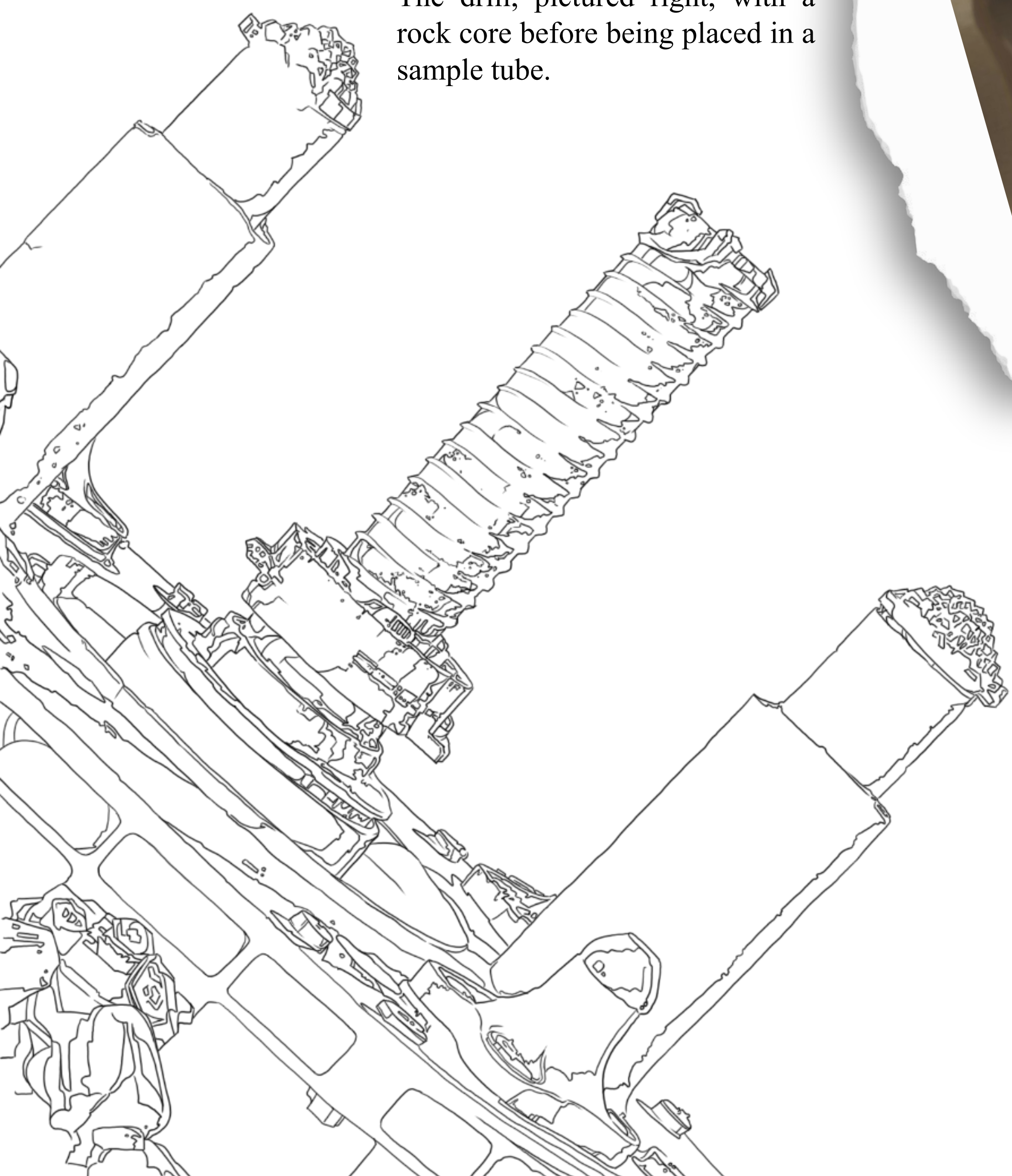
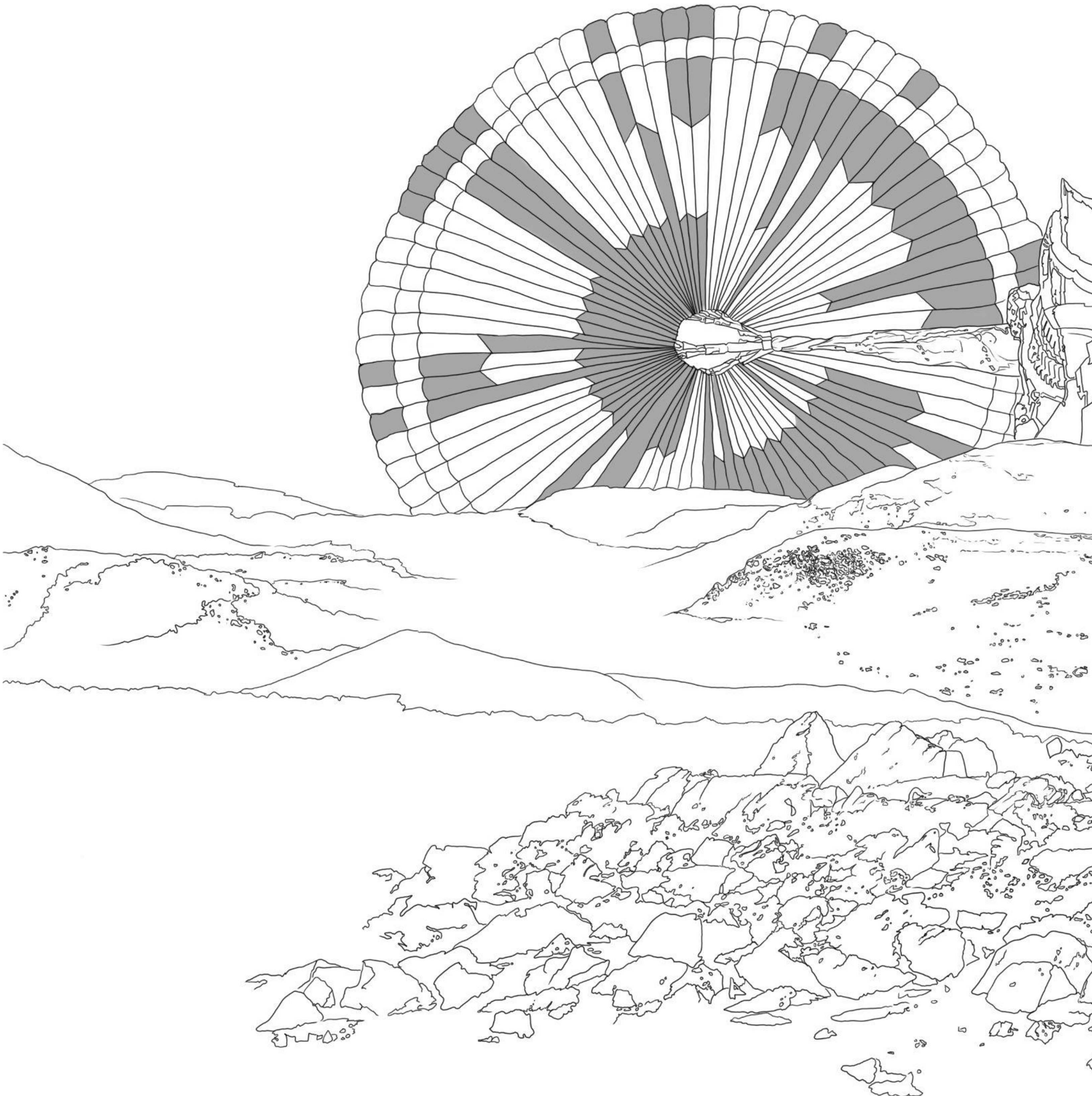


Image credit: NASA/ JPL



sol 52 || I made the trek today to the Perseverance landing site, mostly because I had time to fill. The erosional conditions within the crater meant that few traces were left of its traverse, but I hoped to be able to uncover debris from the gear that landed the rover. There had been orbiter images taken of the remnants nearly two decades prior, in which the heat shield and the parachute could be observed. Most focus remained on the rover rather than what it left behind.



After approximately two kilometers of hiking uphill, I came upon the Octavia E. Butler landing. Initially, it was unclear where everything would be situated, even when using the original orbiter photo for reference. At the time the image was taken, everything was within several hundred meters of each other, but erosional forces could have moved or covered up the parachute, heat shield, and descent stage. Using a northern crater to orient myself, I sought out and found the heat shield and its aeroshell, which was coated in a fine layer of dust. Its edges had fragmented on impact and slowly been consumed by dust, but the center of the heat shield was still in decent condition.

My next find was the descent stage, over 600 meters east. It had suffered a similar amount of damage as the heat shield, resembling a pile of giant snapped matchsticks and foil. I didn't want to disturb the site too much, so I refrained from picking at the rockets and machinery. It seemed a touch charred. I suppose that was expected, given how it crashed down after performing the sky crane maneuver.

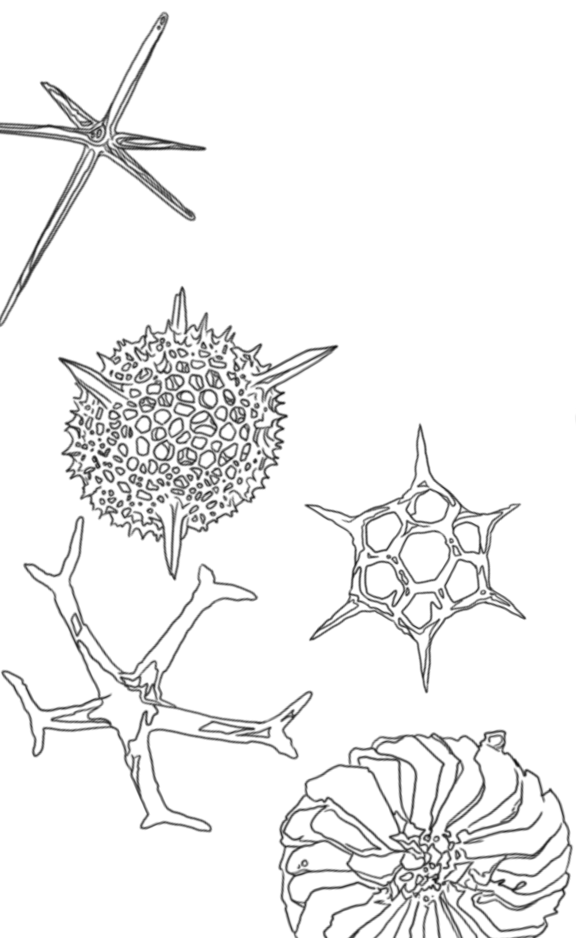
The hardest component to find was the parachute, which had been carried from its original position in the orbiter photograph. After nearly twenty minutes of shuffling through dust, I was able to spot the bright orange patches. It had been partially covered and snagged on a jagged float rock. The material was incredibly tough, hardly taking any damage and mostly plagued by discoloration. Again, I didn't wish to move it or touch it in any significant capacity, but I was reminded of its patched message in binary:

"Dare mighty things". If only they knew.

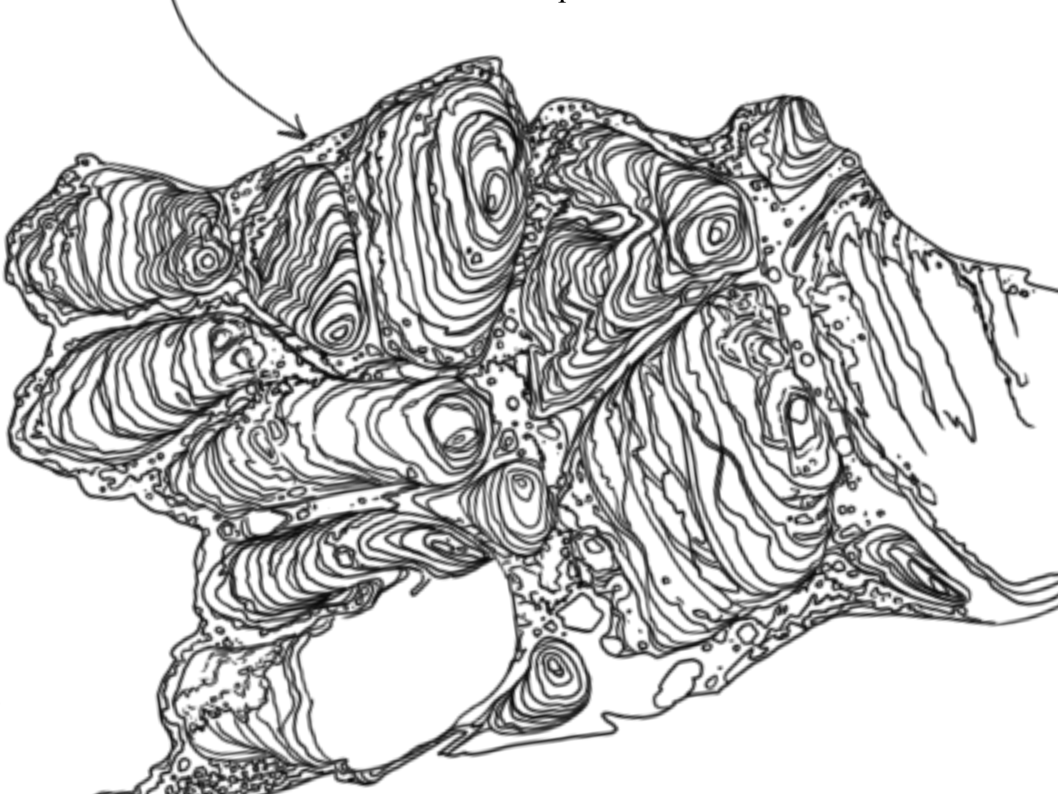
Stromatolites

The primary objective of most recent Mars missions has revolved around finding evidence for past life. Observations of the Martian surface and geology indicates there was once large amounts of water and a more substantive atmosphere, which may have made it habitable enough for life to develop and become preserved in the geological record. It is likely that the rocks containing these organisms, however, have been subject to millions of years of erosion and deposition, making them harder to access and observe simply by using an orbiter or rover. Crewed missions, as well as the samples collected from the Perseverance rover, allow for more specific investigations of what life may have looked like within the waters of Mars.

As it is understood now, there was a window of time within the Pre-Noachian and Noachian period where conditions would be ideal for primitive life to have formed. When examining the sample cores, geologists were looking for some indication of life, likely a layer that was distinct from the sediments above or below it. A possible analog for what scientists were looking for were stromatolites— a rock that forms when bacteria or other small organisms become cemented into 'microbial mats'. The bacteria themselves can adhere to sediments, which can become layered and fossilized over long periods of time. On earth, their presence indicates conditions viable for life, including water. These stromatolite layers can contain microfossils, which are the remains of an organism that are only several millimeters in size.



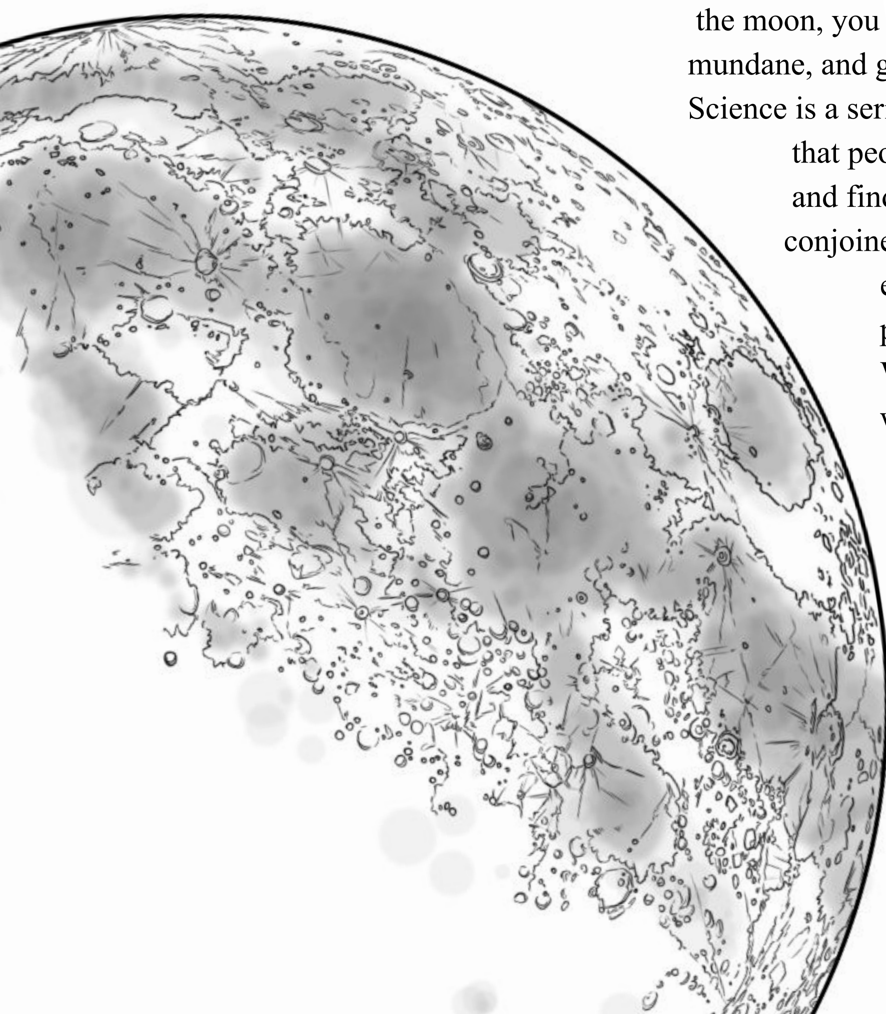
Layers gradually build up as the bacteria gets cemented between sediment. Drawing is based on fossilized sample from earth.



sol 74 || I knew I would miss things about earth. It was inevitable. Prior to leaving, I tried to predict what exactly I would miss, tried to quantify and savor all the moments I wouldn't get on Mars. This activity, however, became a source of distress, not only for me, but for my crew, who I would ask for insights. It became evident that no manner of reorganizing my favorite earth things would actually conclude what I would miss most. It felt like I was mourning every moment as they happened. I also knew it would eventually make leaving impossible, even though the mission was so incredibly exciting.

Little did I know in all of this debate that the thing I would miss the most was the moon. Mars has two, Phobos and Deimos, and they can occasionally be spotted over some hazy horizon. But they are nothing when compared to earth's moon. Phobos and Deimos are a matter of miles across, likely a few captured asteroids left to orbit the planet. Earth's moon, however, is proportionally large when placed next to earth. The giant impact hypothesis explains that a proto-earth collided with a planet-sized object, creating the two bodies we observe today.

Perhaps my favorite aspect of our moon is that you don't need any tools to observe that its surface is varied. So much of ground based astronomy needs higher resolution to make valuable inferences about a planet or moon's history, but the moon has a distinct dichotomy between the lunar highlands and lowlands. Science can frequently move beyond something that is observable or approachable, becoming trapped in a realm of theory and numbers that most people find challenging to decipher. With the moon, you can start simple, with something mundane, and gradually begin to sink into its history. Science is a series of interlocking questions. The issue is that people can enter in at any point in the chain and find themselves stranded between a lot of conjoined concepts, which gradually begins to exclude larger and larger populations of people from learning about science. Whenever I used to be overwhelmed by what I was learning, I would consider the moon. Start small. *Why were there two different colors of rock?* They must be made of different things. *What changed to have two different rocks occur in the same place?* Something must have happened, maybe an impact, that



caused rock with a different composition to flow on top of the other. *How can we know there was an impact?* We can consider how cratered the surface is: the lighter rocks have more craters, the darker rocks are less cratered, so the dark rocks are younger, and must cover over the older surface. A series of easy questions, of basic curiosity, and you're developing a geological record.

That is what is so exciting about being on Mars, a new series of questions that we had to guess from a distance. My favorite piece of Mars media was the assertion that the surface was covered in canals. Given the tools they had at their disposal, a series of complex channels traversed by sentient life wasn't entirely without reason. Not only that, but it was compelling, the possibility of life just an orbit away. With better tools came better observations and the gradual realization that if Mars had life, it likely didn't look like us. I remember this story because I can recognize the lines of questions, the logic, the interlocking to a conclusion, even if the conclusion was wrong.

I wish that for new scientists, for the people who come to this habitat after us and for the people looking up at the sky: to ask questions, to probe in directions we may not have thought possible. Abeona was once a question, something so distant we couldn't make out the details. With time, and a chain of questions that could stretch out to Jupiter, I now find myself on another planet. There is a time for correctness, but there is always time to be curious.

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