Mars, the Rovers and Perseverance – A Geologist's View

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February 2021 was a great month for those who love Mars and the exploration of the red planet. Within a 10-day period three different probes arrived on or around Mars. United Arab Emirates' Hope Mission was the first one to arrive, entering the Martian orbit on February 9th. One day later, on February 10^{th,} the Chinese Tianwen-1 Mission arrived in orbit. Finally, on February 18^{th,} the American Mars 2020 Mission delivered the rover Perseverance to the surface of Mars.

Perseverance is the most sophisticated autonomous robotic vehicle to land on the red planet (Figure 1). The rover is powered by a Radioisotope Thermoelectric Generator, a fancy way of saying it uses a miniaturized nuclear power plant to generate electricity.

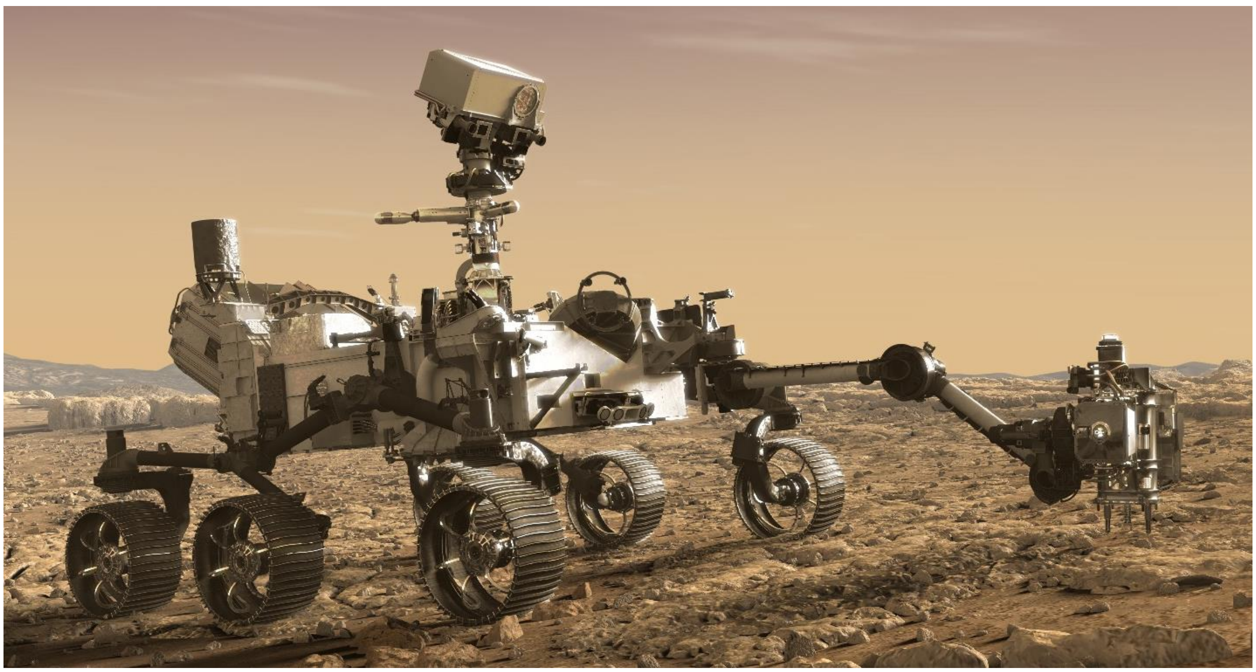

Figure 1: Artist's impression of NASA's Mars rover Perseverance. (NASA Media Advisory M20-085)

Some of the other equipment carried on Perseverance includes:

- An assembly of 23 cameras: 9 engineering, 7 science, and 7 entry, decent and landing cameras.
- A Robotic arm with drilling equipment for core sampling, and x-ray and ultraviolet spectrometers.
- Sensors to analyze environmental factors such as temperature, pressure, wind speed, humidity, etc.
- A special unit to test the extraction of oxygen from the Martian atmosphere.
- Ground penetrating radar to image and analyze the Martian subsurface. This will provide geologists and geophysicists with insights into the geologic history of the Jezero Carter.

- SHERLOC and WHATSON, in combination, these two tools will search the rocks for evidence of past life on Mars.
- Ingenuity, a helicopter which will be used for test flights in the Martian atmosphere and to scout the terrain for Perseverance.

To fully appreciate the mission of Perseverance an understanding of previous rover missions is a must. Every rover that has landed on Mars is more than just a simple remote-controlled drone. Signals from earth and return signals from Mars can take anywhere from 3 to 20 minutes (depending on the distance between the two planets). It is therefore essential that the rovers can act autonomously, that is they must be able to receive and execute complex instructions while adjusting to changing circumstances. In this regard, every rover that has been sent to Mars is effectively an autonomous robot.

Sojourner was the first rover sent to Mars. It landed on Mars on July 4th, 1997. The rover weighed 25 lbs., stood a foot high, and a little over 2 feet long. It landed on Mars using a system of parachutes, heat shields, rockets and finally a cocoon of airbags to cushion its fall. Sojourner traveled 300 ft over a period of 3 months, analyzing multiple rocks and sending back hundreds of photos. Its' chief accomplishment was proof of concept: we could send an autonomous robotic rover to Mars and get data back.

Built upon the success of Sojourner, the Spirit and Opportunity rovers were sent to Mars, with Spirit arriving on January 4th and Opportunity arriving on January 25th of 2004. Both rovers landed using an airbag system similar to Sojourner. Spirit landed in Gusev Crater. Over the next 7 years it traversed 7.7 km finishing its mission on a plateau dubbed Home Plate.

Opportunity landed in the Meridiani Planum, on the other side of the planet or about 9,600 km from Spirit. The landing site was selected for the potential presence of hematite, an iron oxide that on Earth is deposited in water. Opportunity found the suspected hematite in abundance in the form of small round balls, known by geologist as concretions. Those working on the Opportunity project nicknamed these hematite concretions "blue berries" (Figure 2).


Figure 2: Photograph from Opportunity of hematite concretions called "blue berries". Image courtesy of NASA/JPL-Caltech/Cornell

Opportunity operated for 14 years traveling over 45 km, completing its mission at the edge of Endeavour Crater. Along its way it passed Victoria Crater, where it captured amazing photographs of the craters rim (figure 3). The edges of the crater are carpeted with the small round blue berries. The cliffs are composed of hematite-stained sandstones showing a variety of different types of bedding indicative of both eolian and fluvial deposition. Eolian refers to deposition by wind, commonly associated with deserts and sand dunes. Fluvial refers to sediments deposited by rivers. These fluvial deposits provided yet more evidence that water once flowed across the surface of Mars.

Curiosity was next, launching in November of 2011 and landing in August of 2012. Much larger than its predecessors, about the size of a Mini Cooper, it used a radioisotope thermoelectric generator as a power source and a sky crane system for landing. It set down in the Gale Crater where satellite data suggested the crater was once filled with water. Curiosity is still operating today.

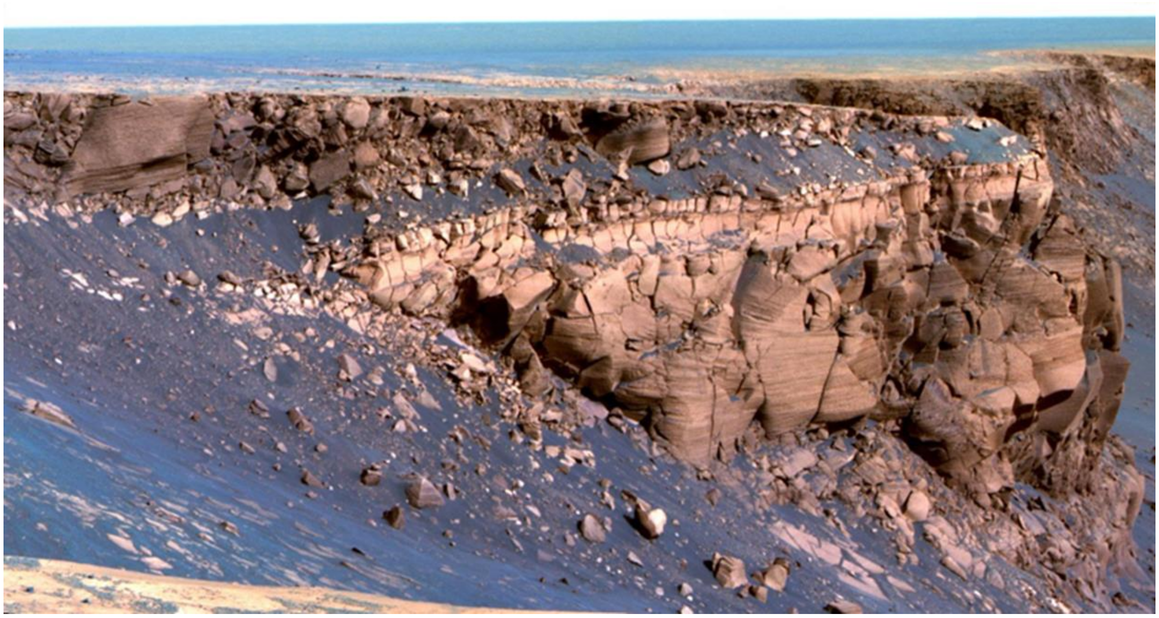

Figure 3: NASA/JPL image PIA 182746: Opportunity at Cape St. Vincent, Victoria Crater with exposed aeolian and fluvial sediments and a grey carpet of hematite blueberries

Perseverance continues and expands upon the Curiosity mission, to search for ancient life and prepare for human settlement. Perseverance landed in the Jezero Crater, where satellite data show an ancient delta (figure 4). The crater formed some 3.9 billion years ago when a meteor crashed into Mars creating a hole in the ground some 45 km in diameter. Contemporaneous with the creation of Jezero Crater, and many other craters on Mars, volcanic eruptions expelled vast quantities of water vapor and other gases into the atmosphere. The water vapor condensed as rain, forming rivers and filling craters. Jezero was one such crater that was filled with water and became a lake.

Figure 4 is a color enhanced satellite image of the west side of the Jezero Crater and the Perseverance landing site. Some of the more significant topographic and sedimentological features include the crater rim which runs from North to South, and a meandering river that cuts through the crater wall running generally from West to East. The river carried with it large amounts of sediment that formed a large delta within the crater.

Geologists studying the satellite data have also identified ancient shorelines around Jezero Crater and rock outcrops around the delta that look like carbonate deposits on Earth. On Earth, ancient deltas, shorelines and carbonate rocks are all features that are associated with abundant fossil evidence of life. Geologist are hoping that these features on Mars will also have evidence of life.

The plan is for Perseverance to go from its landing site shown by the red dot with the number 1 and follow a path that is approximated by the white dashed line. Its first stop will be at the base of the delta (red dot 2) where it will drill a set of core samples. Next it will move to the top of the delta (red dot 3) where it will drill additional core samples. The geologic record on Earth indicates that the top and base of deltas are sites where evidence of life is often preserved, and if there was life on Mars, there is a good chance that it will be found somewhere on the delta.

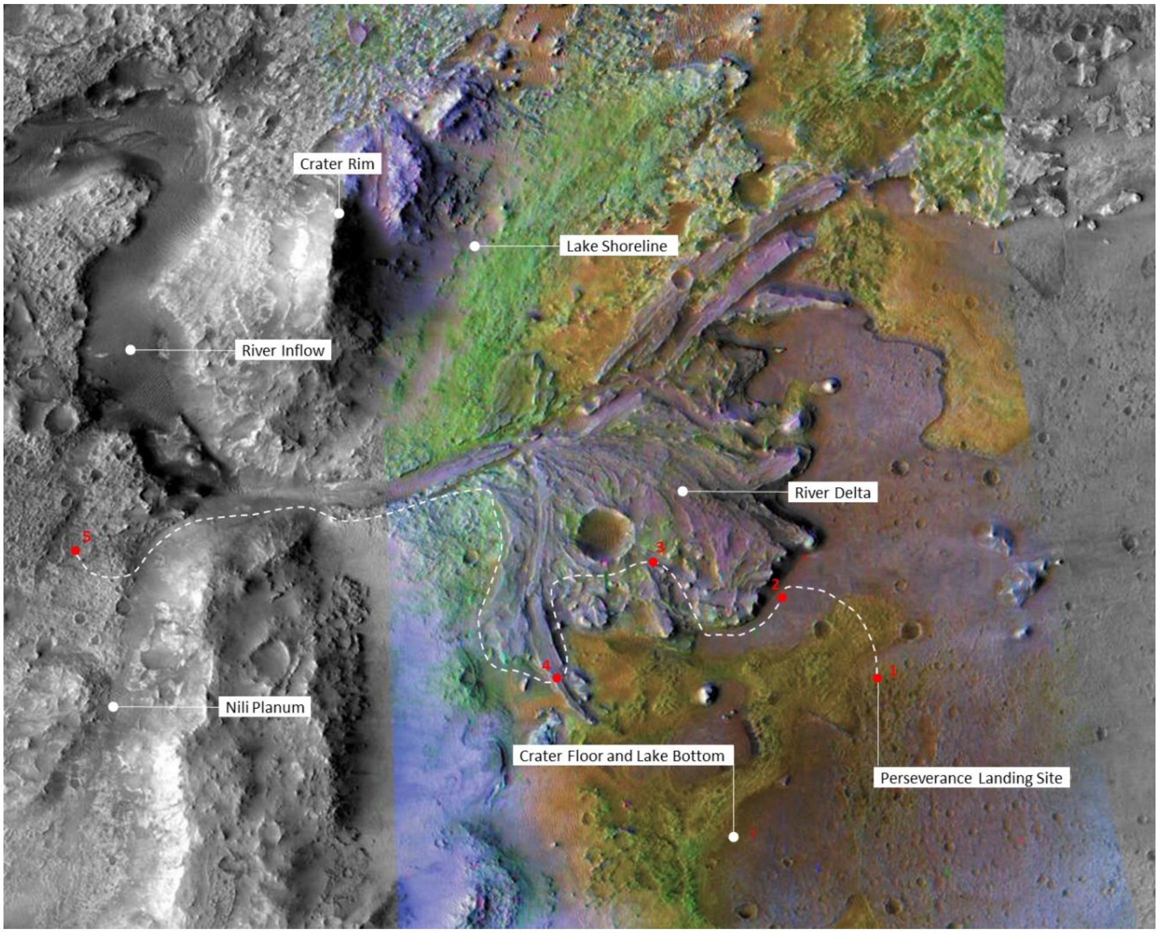

Figure 4: Color enhanced image of the Jezero Crater showing an ancient rover, delta and other physiographic features commonly found on Earth. (Modified from: NASA Announces Landing Site for Mars 2020 Rover, NASA Release 18-103, Credits: NASA/JPL/JHUAPL/MSSS/Brown University)

From the delta, Perseverance will move toward the edge of the crater where rock outcrops appear similar to carbonate deposits on Earth (red dot 4). This will be the next core collection site for Perseverance. Carbonates on Earth are almost always formed from the accumulated remains of carbonate secreting organisms. If these outcrops on Mars are in fact carbonates, it may also provide proof of ancient Martian life.

The presence of ancient life on Mars has direct implications for human settlements on our red neighbor. Permanent settlement will require energy sources. Obvious sources are wind and solar. However, the thin Martian atmosphere, as well as the increased distance of Mars from the sun may reduce the effectiveness of these sources. Oil and gas accumulations on earth come from decomposition of ancient life and other biologic processes. If life existed on Mars in the past, then it is also possible that there are subsurface oil and gas accumulations on Mars. This would provide an additional source of energy on the planet that could sustain human life and fuel growth and development.

After Perseverance has successfully drilled and collected rock samples from the delta and carbonate rocks, it will follow the river up the sides of the crater. At the crest of the crater, the rover will deposit the rock cores on the Nili Planum (red dot 5) for collection by a subsequent Martian mission at a later date.

Whether on Earth or Mars the science of geology and discipline of geophysics are universal. Physical processes that create topography and landforms, rivers, deltas, lakes and even life are the same. The application of geologic principles and geophysical tools have and will continue to play a major role in our understanding to Mars, our search for life, and our preparations for human settlement.

The landing of Perseverance is just the beginning of the adventure. Equipped with 16 scientific and engineering cameras, as well as a multitude of on-board laboratories, geologists, geophysicists and other scientists are looking forward with anticipation to a continuous stream of new data and new discoveries. You can watch the progress of Perseverance at:

https://mars.nasa.gov/mars2020/mission/where-is-the-rover/