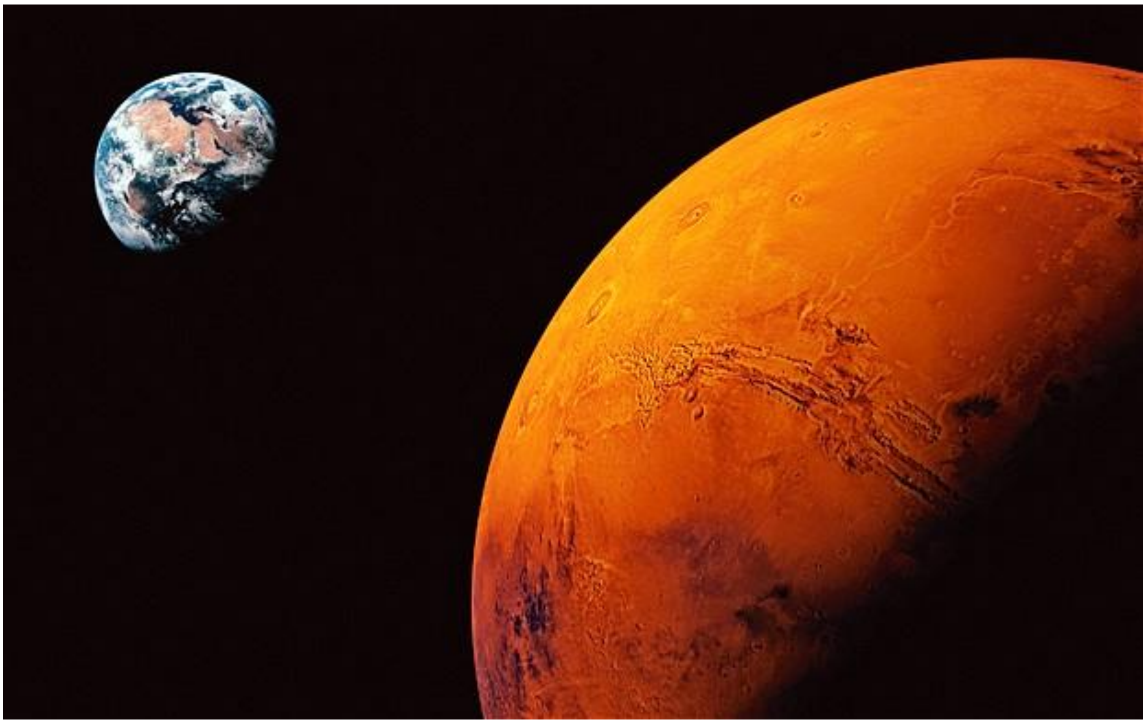
WHERE ON EARTH IS MARS?



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AIM OF THE PROJECT

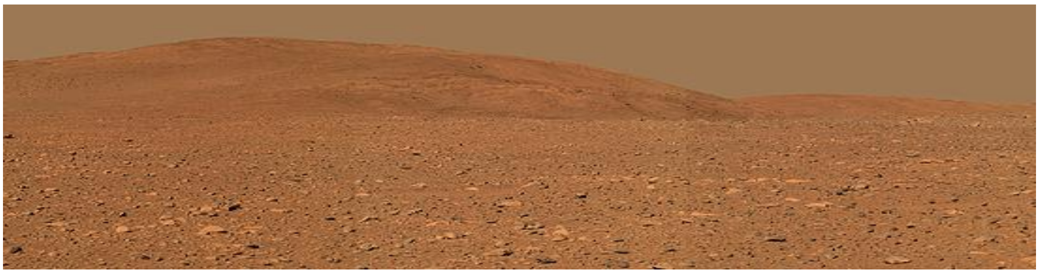
While studying the origins of life on Earth students find it difficult to picture how our planet and the life that it supports have been changing through time. There are some places on Earth called space analogs that present extreme environments, similar to those that occurred on our planet millions of years ago, when life first appeared. Studying some of these analogs helps students to understand the conditions that living organisms first inhabited. In doing so, helps them comprehend the possibilities of life outside our own planet.

INTRODUCTION

During the last decades, scientists have searched for signs of life in other planets. Mars has centered most of the investigations due to its position on the solar system, very close to us, and its similarities to Earth.

Mars and Earth were formed in a very similar way. In fact, Mars may be, in some ways, similar to ancient Earth, and this is very interesting to scientists. Searching for life on Mars is a driving force behind our fascination and dedication to exploring the red planet. But in the meantime, scientists are busy at work studying features of Mars—on Earth. There are places on our planet that can serve as test beds for how to conduct scientific investigations on Mars. These analogs share certain characteristics similar to environments on Mars. Studying aspects of Mars using Earth is much safer, more accessible, and less expensive. The knowledge and expertise gathered from these analog studies are an important and necessary step towards our future exploration of Mars.

The majority of these analogs are considered extreme environments—places too harsh for humans and most other organisms, but where certain creatures like microbes thrive. Extreme environments include such exciting places as volcanoes, deep underground, hydrothermal sea vents, glaciers, and the bottoms of permanently ice-covered Antarctic lakes. As scientists learn more about how these microbes survive, they can use that knowledge to focus their search for life on Mars.



MARS SPACE MISSIONS

Our exploration of Mars has slowly resulted in an accumulation of important scientific discoveries. As a result, we've begun to find some answers to questions about water and life on Mars, with each mission bringing us one step closer to the reality of sending humans to Mars.

NASA Mariners: 1962-1973

Although the initial Mariner missions failed, missions 4 through 10 provided several groundbreaking firsts in space exploration. Launched in 1964, Mariner 4 provided the first close-up images of a planet other than Earth, and its cratered surface. Mariners 6 and 7 effectively disproved the existence of artificial canals on the surface. Experiments detected atmospheric constituents, temperature and surface pressure data.Mariner 9 dramatically altered what we knew about Mars, providing images that showed incredible surface variations, including ancient river beds - feasible evidence of historic water.

Russian Probes: 1969-1973

These Russian probes were the first human artifacts to land on the Red Planet. Mars 5 sent back images of the Martian terrain and information on the temperature, altitude, ozone layer, magnetic field and ionosphere.

NASA Viking Orbiter/Landers: 1975-1982

Launched separately in 1975, Viking 1 and 2 went into Mars orbit in 1976, first imaging the entire surface for viable landing sites.

NASA Mars Global Surveyor: 1996-present

The Mars Global Surveyor mapped the topography of the Martian surface, providing high resolution images and vast amounts of data on gravity, weather, climate, atmosphere and the magnetic field. Its detailed photos of topographical features such as gullies suggested the presence of frozen water.

NASA Mars Pathfinder: 1996-1998

The Pathfinder lander released the first Mars rover, the Sojourner, to explore the Martian surface and provide data on the feasibility of low-cost landings. This mission proved the viability of a number of new technologies, including airbag landings.

NASA Mars Odyssey

Originally planned as an orbiter/lander, the Mars Odyssey was launched as an orbiter-only mission in 2001 to analyze Martian mineral, climate and geological data and study radiation hazards.

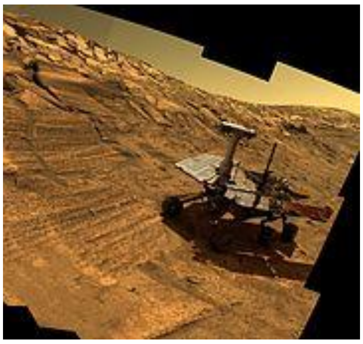
European Space Agency Mars Express

The Mars Express Orbiter, launched in 2003 to obtain high resolution imagery for geological analysis and conduct mineralogical and atmospheric mapping, has discovered the presence of hydrated sulphates, silicates and rock-forming minerals on Mars. In addition to detecting methane in the atmosphere, suggesting volcanic or hydrothermal activity or perhaps even the presence of subsurface microorganisms, it discovered buried impact craters and confirmed the presence of underground water-ice.

NASA Mars Exploration Rovers (MER)

Spirit and Opportunity, the two Mars Exploration rovers launched in 2003 have analyzed Martian rocks and soil in the search for geological clues and measurable data about water on Mars, as well as information about future landing sites. Equipped with advanced instrumentation, including cameras for panoramic photos, navigation and hazard-avoidance, as well as X-ray spectometers, the rovers have provided evidence of historic water, including rock stratification and the distribution of chlorine and bromine along what must have been a former salty sea.

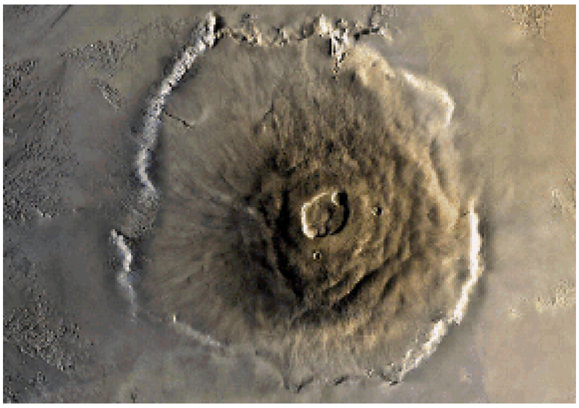
Curiosity Rover (Simulated view)



Opportunity rover (Simulated view)

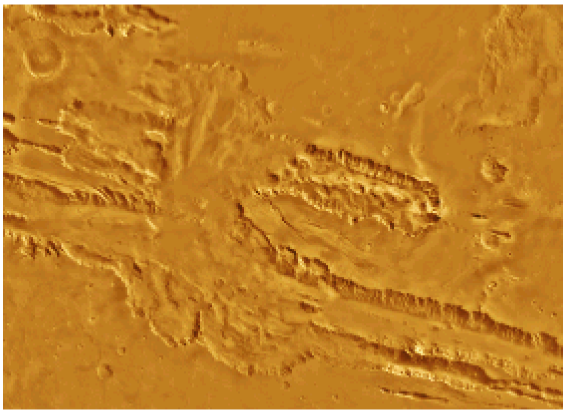
MARS KNOWLEDGE

Mars has many interesting geological features on its surface many of which now are visible from the Hubble Space Telescope.



Enormous Shield Volcanoes: Olympus Mons is 600 km across its base and about 25 km above the surrounding plain.

Wind Erosion: The atmosphere supports high velocity seasonal winds that are correlated with solar heating of the surface.



Large Canyon Systems: The Martian surface has some large canyon systems. The largest is Valles Marineris, which extends for about 5000 km.

Absence of Plate Tectonics: There is no evidence on Mars for large-scale plate tectonics as we find on Earth.

Polar Caps: These polar caps appear to be partially composed of frozen carbon dioxide ("dry ice") and partially composed of frozen water.

Running Water Erosion: There are channels on Mars as much as 1500 km long and 200 km wide that appear to have been cut by running water.

Wherever we find water on Earth, we find life. Could the same be true for Mars? Understanding water on Mars is vital to assess the planet's potential for harboring life and for providing usable resources for future human exploration. It has been proved that once liquid water run over the surface of Mars. Data from the Mars Exploration Rovers and orbiters, such as Mars Odyssey and Mars Global Surveyor, have confirmed evidence of liquid water in Mars' past. Geologic evidence of past water includes enormous outflow channels carved by floods; ancient river valley networks, deltas, and lakebeds; and the detection of rocks and minerals on the surface that could only have formed in liquid water.

Numerous geomorphic features suggest the presence of ground ice (permafrost) and the movement of ice in glaciers, both in the recent past and present. Gullies and slope lineae along cliffs and crater walls suggest that flowing water continues to shape the surface of Mars, although to a far lesser degree than in the ancient past.

Gullies on Mars

Although the surface of Mars was periodically wet and could have been hospitable to microbial life billions of years ago, today the environment on the surface of Mars is harsh and hostile, probably presenting an insurmountable obstacle for living

organisms. Average temperature is -63 degrees centigrades. In addition, Mars lacks a thick atmosphere (only about 0,6% the air pressure on Earth), ozone layer and magnetic field, allowing solar and cosmic radiation to strike the surface unimpeded. The damaging effects of ionizing radiation on cellular structure is another one of the prime limiting factors on the survival of life on the surface. Therefore, the best potential locations for discovering life on Mars may be in subsurface environments.
For this reason, 'Follow the Water' was the science theme of NASA's Mars Exploration Program (MEP) in the first decade of the 21st century. Discoveries by the 2001 Mars Odyssey, Mars Exploration Rovers (MERs), Mars Reconnaissance Orbiter (MRO), and Mars Phoenix Lander have been instrumental in answering key questions about water's abundance and distribution on Mars. The ESA's Mars Express orbiter has also provided essential data in this quest. The Mars Odyssey, Mars Express, MER *Opportunity* rover, MRO, and Mars Science Lander *Curiosity* rover are still sending back data from Mars, and discoveries continue to be made.

MARS ANALOGS

Terrestrial Analogue Sites (also called "Space Analogues") are places on Earth with assumed past or present geological, environmental or biological conditions of a celestial body such as the Moon or Mars. Analogue sites are used in the frame of space exploration to either study geological or biological processes observed on other planets, or to prepare astronauts for surface extra-vehicular activity.

Antarctica, Lassen Volcanic National Park and the Peruvian desserts are but a few of the many places scientists are researching to help practice missions for robotic and human explorers to Mars. For instance, the permanent snow packs found in Lassen Volcanic National Park are, in some ways, akin to permanent snow packs and gullies found in Martian craters and at the poles.
By studying the dynamics of snow packs on Earth, scientists can improve the models they have created to predict and analyze snow packs on Mars. Additionally, snow algae living in the Earthly snow may give hints about how to identify life in Martian snow.

There are two space analogs in Spain: Rio Tinto and Tenerife.

Rio Tinto is a is a river in southwestern Spain. The color of its waters is due to the natural presence of dissolved ion compounds. The river area has a history of mining activity primarily for copper but also for iron and manganese since the Tartessans and the Iberians started mining in 3000 BC. The mining continued until the second part of the 15th century. In the 19th century the mining restarted on a large scale by companies from the United Kingdom and ended in 1986.

Rio Tinto (Huelva)

It is now an expedition target for the Mars Analog Research and Technology Experiment (MARTE). MARTE is drilling for core samples and testing satellite links from Rio Tinto in preparation for remote robotics that may one day survey Mars.

Tenerife has a great value as a Moon and Mars analog, specially due to its lava tubes and volcanic caves around the Mount Teide and Las Cañadas. Teide National Park is a useful volcanic reference point for studies related to Mars because of the similarities in their environmental conditions and geological formations. In 2010 a research team tested the Raman instrument in anticipation of its use in the 2016–2018 ESA-NASA ExoMars expedition. In June 2011 a team of researchers from the UK visited the park to test a method for looking for life on Mars and to search for suitable places to test robotic vehicles. Lava tubes and volcanic caves are a potential habitat for Martian life and a target for astrobiological studies. Evidence for the existence of Martian caves such as long lava channels and lines of pits have been identified from orbiting space craft and epithermal neutron maps indicate the presence of water a few metres below the surface which would be accessible to cave life. Inside the caves, any life will have access to water and would be sheltered from the harsh surface conditions of UV radiation and low humidity as well as from the prevailing weather conditions.

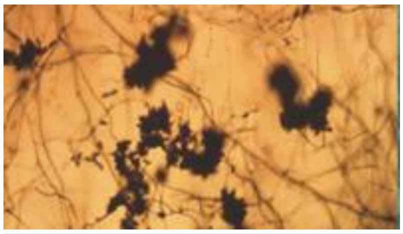
Las Cañadas del Teide (Tenerife)

RIO TINTO

Originating in the Sierra de Huelva mountains of Andalusia, in the town of Nerva, Spain's "red river" runs through the southwestern region of the country. The Rio Tinto is an acidic and heavy metal-rich river. The water is rusty red from the presence of dissolved iron, and has a very high acidity (pH = 2).

Most organisms cannot survive in the Rio Tinto, its waters too toxic for growth. However, Rio Tinto waters are the perfect environment for some extremophile microorganisms. Astrobiologists have collected about 1,300 different organisms, including archaea, yeast, fungi, and protists. The most abundant biomass in the river seems to be algae. Blooms of algae often coat the surface of the water, turning the red water green and producing bubbles of oxygen. it is strange how eukaryotic organisms like algae are able perform in such harsh conditions of acidity and heavy metal concentrations.

Water sample from the river in which different eukaryotic cells (Heliozoa, diatoms, dinoflagelates) and prokaryotes (much more smaller) can be seen.
Credit: Dr. Ricardo Amils Pibernat



Acidophilic demateaceus fungi (black fungi) from Rio Tinto.
Credit: Dr. Ricardo Amils Pibernat

The red color and the acidity of the water are due to a natural abundance of sulfide. Bacteria living in the river turn this sulfide into sulfuric acid, giving the river its low pH. Other bacteria oxidize the iron, giving the river its signature red color. Although both sulfur and iron naturally oxidize (or 'rust') when exposed to air, the bacteria act as catalysts, speeding up the reactions considerably. It is not precisely known how bacteria oxidize the ferrous iron. Scientists believe the process relies on both chemical and biological forces working together.

In addition, scientists say evidence suggests the chemistry of the Rio Tinto and its biology may be a result of an underground, biologically-based, chemical reactor fueled by organisms that do not need oxygen gas to survive. MARTE scientists propose that such a system may exist in the subsurface of the Rio Tinto area. If found, this type of life would represent an entirely new subsurface life system.

Searching for life in the subsurface of another planet will not only require drilling, but sample extraction and handling, as well as new technologies to identify biomarker compounds and search for living organisms.

NASA and the Centro de Astrobiología in Spain are currently working on project by which   the subsurface of the river will be drilled. The drill and the robotic system will bring cores of underground rock, up to 150 meters deep, to the surface. There, a suite of remotely operated science instruments that simulate a Mars mission payload will analyze samples and search for signs of life or biomarkers. The Signs of Life Detector (SOLID) instrument, developed at the, will search for life in the samples using new technology derived from molecular biology. This instrument can detect not just whole organisms, but macromolecules or other life byproducts.

The Mars rover *Opportunity* has revealed clues not only of Mars' wetter past, but also the chemistry of its surface waters. The presence of the mineral jarosite, a hydrous iron sulfate known to only precipitate out of acidic water, shows that Mars was indeed wet and acidic – contrasting with Earth's near neutral surface waters. Jarosite actively forms on the modern Earth, though not just anywhere. Only acidic waters, such as Rio Tinto's, allow this mineral to form. The abundance of jarosite, as well as other acid-specific minerals, at Rio Tinto shows that its geochemical conditions must be similar to those that produced the Martian environments NASA's rovers are currently investigating.

Extremophile aerobic bacteria in the water of Rio Tinto provide conditions similar to those found in other areas in the solar system. Jupiter's moon Europa, for example, is thought to have an acidic, salty ocean under its outer layer of ice. Life in the Rio Tinto - the bacteria feed on iron and sulfide minerals in the river's subsurface rocks - make the likelihood of life on Europa all the more possible. Thus, the Tinto River could represent a unique biological setting also to investigate the possibility of sulfur-based life on Europa.

The astrobiological investigation of Rio Tinto is preparing future astronauts and scientists for upcoming missions to Mars –both robotic and manned. By characterizing the properties and geochemical influence of Rio Tinto's extreme microorganisms, signs of life will be much more easily recognized on Mars, and will help scientists isolate specific environments to investigate.

CONCLUTIONS

After reseaching about the characteristics that Earth and Mars share we cannot but ask ourselves a few questions:

- Can live exist only based on carbon?
- If Rio Tinto serves as a Martian environmental analog, does that mean the kind of life it contains was once supported on Mars?
- Is there a possibility that Mars may have had,and might still have, life?

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