

This document contains the questions and resources for each point on the *Mars Globe* Interactive.

Point 1: Exobiology

Exobiology experiments (studies designed to detect life in space or on another planet) on the Viking 1 and 2 landers were inconclusive for life on Mars. Does a negative or inconclusive finding regarding life at a particular place on Mars mean Mars is a lifeless planet? Why or why not?

Resources

Exobiology: It's Life...isn't it?

<http://www.nature.com/nature/journal/v430/n6997/full/430288a.html>

Astrobiology at NASA Viking Project

<https://astrobiology.nasa.gov/missions/viking-1-and-2/>

Point 2: Water Ice Frost

The Viking 2 lander detected water ice frost on Mars. What does the presence of water ice frost tell scientists about the presence of water in the atmosphere of Mars today or in the past?

Resources

Frost at Utopia Planitia on Mars

http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/vl2_p21873.html

The Viking 1 and 2 Missions Page from NASA

<http://mars.nasa.gov/programmissions/missions/past/viking/>

National Geographic Society

Encyclopedia Entry – Frost

<http://nationalgeographic.org/encyclopedia/frost/>

NASA Mars Rover Finds Mineral Vein Deposited By Water

<http://mars.nasa.gov/mer/newsroom/pressreleases/20111207a.html>

Point 3: Flood Channel

The Mars Pathfinder spacecraft landed in part of a suggested flood channel known as Ares Vallis. How do the large rocks found at the landing site support the interpretation that Ares Vallis was carved by a flood rather than gently flowing water?

Resources

Mars Pathfinder

<http://mars.nasa.gov/MPF/>

Mars Pathfinder Science Results

<http://mars.nasa.gov/MPF/science/geology.html>

Mars Pathfinder Landing Site

<http://nssdc.gsfc.nasa.gov/planetary/marsland.html>

Point 4: Extremophiles

The Mars Exploration rover Spirit found evidence of hot springs on Mars. What role do hot springs play in supporting extremophiles, microbes adapted to survive in harsh environments, on Earth?

Resources

Mars Rover Investigates Signs of Steamy Martian Past

<http://mars.nasa.gov/mer/newsroom/pressreleases/20071210a.html>

Spirit and Opportunity Highlights

<http://mars.nasa.gov/mer/home/>

National Geographic Society Encyclopedia Entry – Ocean Vents

<http://nationalgeographic.org/encyclopedia/ocean-vent/>

Life in Extreme Heat

<https://www.nps.gov/yell/learn/nature/otherlifeforms.htm>

Microbial Life in Extremely Hot Environments

<http://serc.carleton.edu/microbelife/extreme/extremeheat/index.html>

Point 5: Martian Equator

The Mars rovers Spirit and Opportunity landed near the Martian equator. Why do you think a landing site near the equator would be important for large, solar-powered machinery intended to operate for many months on the surface of the planet?

Resources

Technologies of Broad Benefit: Power

http://mars.nasa.gov/mer/technology/bb_power.html

Spirit and Opportunity Highlights

<http://mars.nasa.gov/mer/home/>

Point 6: Martian Dust

Dust accumulating on solar panels was expected to limit the Mars Exploration Rover Mission to less than a year, but both rovers operated years longer. In fact, Opportunity is still active as of fall 2016. What role do you think Martian winds played in keeping solar-powered Spirit and Opportunity active longer than expected?

Resources

Opportunity: The Amazing Self-Cleaning Mars Rover

<http://www.space.com/25577-mars-rover-opportunity-solar-panels-clean.html>

Spirit and Opportunity Highlights

<http://mars.nasa.gov/mer/home/>

Point 7: Water Detection

In 2008, the Phoenix Mars lander provided the first direct detection of water ice on Mars. Why is the direct detection of water ice important to astronomers?

Resources

NASA Phoenix Mars Lander Confirms Frozen Water

http://www.nasa.gov/mission_pages/phoenix/news/phoenix-20080620.html

Point 8: Link Outcrop

Rounded pebbles in what appears to be an ancient stream were documented near the Curiosity rover site. What does the presence of rounded pebbles suggest about the flow of water in the streambed?

Resources

Pebbly Rocks Testify to Old Streambed on Mars

https://www.nasa.gov/mission_pages/msl/news/msl20130530f.html#.V_eQYZMrI_U

Rock Outcrops on Mars and Earth

http://www.nasa.gov/mission_pages/msl/multimedia/pia16189.html

Curiosity's Landing Site: Gale Crater

<http://mars.nasa.gov/msl/mission/timeline/prelaunch/landingsiteselection/aboutgalecrater/>

Point 9: Valles Marineris

How does the Martian canyon system Valles Marineris compare with Earth's Grand Canyon? How does Valles Marineris compare with the East African rift zone?

Resources

Valles Marineris

<http://mars.jpl.nasa.gov/gallery/atlas/valles-marineris.html>

Grand Canyon: Geographic Formations

<https://www.nps.gov/grca/learn/nature/geologicformations.htm>

The Grand Canyon: How It Formed

<http://unctv.pbslearningmedia.org/resource/ess05.sci.ess.earthsys.canyon/the-grand-canyon-how-it-formed/>

East African Rift System

<https://www.britannica.com/place/East-African-Rift-System>

National Geographic Society Encyclopedia Entry – Rift Valley

<http://nationalgeographic.org/encyclopedia/rift-valley/>

Point 10: Martian North Pole

Layers of ice cover the Martian North Pole. How can layers in ice help us understand changes in climate on Mars or Earth?

Resources

Blockfall on the North Polar Layered Deposits

<http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA18586>

North Polar Layers of Mars

http://www.nasa.gov/multimedia/imagegallery/image_feature_1731.html

Paleoclimatology – The Ice Core Record

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

Point 11: Olympus Mons

Olympus Mons is a Martian volcano about the same width as the state of Arizona and approximately two-and-a-half times taller than Mount Everest. Why might Olympus Mons be so big compared to similar volcanoes on Earth, such as Mauna Kea on the “Big Island” of Hawaii?

Resources

Olympus Mons

<http://mars.jpl.nasa.gov/gallery/atlas/olympus-mons.html>

Olympus Mons – The Caldera in Close – Up

http://m.esa.int/Our_Activities/Space_Science/Mars_Express/Olympus_Mons_-_the_caldera_in_close-up

Point 12: Polar Ice Cap

Both Mars and Earth have permanent polar ice caps. How does the northern polar ice cap of Mars compare with the polar ice caps of Earth?

Resources

Polar Regions

<http://phoenix.lpl.arizona.edu/mars121.php>

Strange Martian Spirals Explained

http://science.nasa.gov/science-news/science-at-nasa/2010/16jun_martianspirals/

NASA Orbiter Penetrates Mysteries of Martian Ice Cap

<http://mars.jpl.nasa.gov/mro/news/index.cfm?FuseAction=ShowNews&NewsID=1001>

All About Sea Ice

<http://nsidc.org/cryosphere/seaice/index.html>

Quick Facts on Ice Sheets

<https://nsidc.org/cryosphere/quickfacts/icesheets.html>

Point 13: South Pole

Unlike the northern polar ice cap, Mars' southern polar ice cap is covered by dry ice (frozen carbon dioxide) year-round. What possible explanations might there be for why the southern polar ice cap stays cold enough for carbon dioxide ice through the summer?

Resources

NASA Radar Finds Ice Age Record in Mars' Polar Cap

<http://www.jpl.nasa.gov/news/news.php?feature=6519>

Mars Polar Lander Science Goals

<https://mars.jpl.nasa.gov/msp98/lander/science.html>

Impacts of a Warming Arctic

http://climate.nasa.gov/resources/education/pbs_modules/lesson2Engage/

Thermodynamics: Albedo

<https://nsidc.org/cryosphere/seaice/processes/albedo.html>

Point 14: Hellas

The Hellas impact basin is a giant impact crater on the surface of Mars. What does the presence of ancient impact basins like Hellas suggest about how much Mars has been resurfaced by geologic processes?

Resources

Lunar Orbiter: Impact Basin Geology

http://www.lpi.usra.edu/lunar/missions/orbiter/lunar_orbiter/impact_basin/

The Moon's Major Impact Basins

<http://www.planetary.org/multimedia/space-images/earth/lunar-impact-basins.html>

Hellas

<https://www.britannica.com/place/Hellas-impact-basin-Mars>

Point 15: Impact Craters

What similarities and differences do you see between the ancient, heavily cratered highlands on Mars and the surface of the Moon?

Resources

Impact Features

http://www.lpi.usra.edu/publications/slidesets/redplanet2/slide_17.html

Why is the Moon so Scarred With Craters?

<http://spaceplace.nasa.gov/craters/en/>

Impact Cratering

http://www.lpi.usra.edu/education/explore/shaping_the_planets/impact_cratering.shtml

Point 16: Ejecta Blanket

An “ejecta blanket” is material forced outside of an impact crater that extends from the rim of the depression. What about the shape of this “ejecta blanket” might indicate that ice or liquid water was present when it formed?

Resources

Rampart Crater

<http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA20261>

Themis: Concentric Rims

<http://redplanet.asu.edu/?p=17014>

National Geographic Society Encyclopedia Entry – Crater

<http://nationalgeographic.org/encyclopedia/crater/>

Point 17: Martian Gullies

Gullies on the sides of canyons and craters are some of the youngest features seen on Mars. What does the evidence suggest for some of the possible ways Mars gullies might have been formed? Do you think all gullies on Mars are formed by one process, or could multiple mechanisms be responsible for these features?

Resources

Light-Toned Gully Materials on Hale Crater Wall

http://www.uahirise.org/PSP_002932_1445

Adding Composition Data About Mars Gullies

<http://www.nasa.gov/image-feature/jpl/pia20763/adding-composition-data-about-mars-gullies>

Will the Real Culprit Behind Mars' Gullies Please Stand Up?

<http://www.astronomy.com/news/2016/08/will-the-real-culprit-behind-mars-gullies-please-stand-up>

How do Gullies Form on Mars?

<https://eos.org/research-spotlights/how-do-gullies-form-on-mars>

Mars Gullies Likely Not Formed by Liquid Water

<http://www.jpl.nasa.gov/news/news.php?feature=6580>

Point 18: Dust Storm

Continent-size and even planet-size dust storms are common on Mars. Why might dust storms on Mars be so much larger than dust storms on our own world?

Resources

The Fact and Fiction of Martian Dust Storms

<http://mars.nasa.gov/news/whatsnew/index.cfm?FuseAction=ShowNews&NewsID=1854>

Martian Dust Storm

http://www.nasa.gov/mission_pages/msl/multimedia/vasavada-4.html

Scientists Track “Perfect Storm” on Mars

<http://hubblesite.org/newscenter/archive/releases/2001/31/text/>

NASA Mars Orbiters Reveal Seasonal Dust Storm Pattern

<http://www.jpl.nasa.gov/news/news.php?release=2016-146>

National Geographic Society Encyclopedia Entry - Dust

<http://nationalgeographic.org/encyclopedia/dust/>

Dust Storm Sweeps from Africa into Atlantic

<http://visibleearth.nasa.gov/view.php?id=53872>

The Dust Bowl

<http://www.pbs.org/kenburns/dustbowl/>

Point 19: Northern Plains

The vast lowland plains of northern Mars are smoother than the heavily cratered highlands of the south. What are some possible explanations for these differences in landscape?

Resources

Fractured Northern Plains, Mars

http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/vo1_035a64.html

Mars Geologic Map of the Northern Plains

<http://astrogeology.usgs.gov/search/map/Mars/Geology/year-2000/Mars-Geologic-Map-of-the-Northern-Plains>

Vastitas Borealis

<https://www.britannica.com/place/Vastitas-Borealis>

Point 20: Glacier

Some scientists suggest that a glacier exists below the Martian surface, where rock and soil insulate it from sunlight. Similar features, called rock glaciers, are present on Earth. Do you think this landform is actually a Martian glacier covered with rock and soil?

Resources

Found it! Ice on Mars

http://science.nasa.gov/science-news/science-at-nasa/2002/28may_marsice/

Glacier?

http://www.uahirise.org/ESP_018857_2225

Glacier Types: Rock

<https://nsidc.org/cryosphere/glaciers/gallery/rock.html>

Point 21: Tharsis Region

How might the giant volcanoes in the Tharsis region of Mars be related to the “Tharsis bulge” in the planet’s crust?

Resources

Tharsis

<http://photojournal.jpl.nasa.gov/catalog/PIA00408>

Olympus Mons

<http://mars.jpl.nasa.gov/gallery/atlas/olympus-mons.html>

Tharsis

<https://www.britannica.com/place/Tharsis>

Point 22: Avalanche

The HiRISE camera on the Mars Reconnaissance Orbiter has captured many avalanches in action. What might be possible causes for an avalanche on Mars?

Resources

Caught in Action: Avalanches on North Polar Scarps

http://www.uahirise.org/PSP_007338_2640

Dynamic Mars

http://www.uahirise.org/ESP_042572_2640

Frost Avalanche on Mars

<http://www.nasa.gov/image-feature/frost-avalanche-on-mars>

National Geographic Society

Encyclopedia Entry – *Avalanche*

<http://nationalgeographic.org/encyclopedia/avalanche/>