

Europa (moon of Jupiter)

Discovered by: Galileo Galilei, 1610
Distance from the Sun: 780,000,000 km
Distance from Jupiter: 671,000 km
Radius: 1570 km
Mass: 4.8×10^{22} kg
Density: 3010 kg/m³
Surface Composition: Water Ice
Major atmospheric constituent: Oxygen

Europa is the smallest of Jupiter's four planet-sized moons, yet it is only slightly smaller than Earth's Moon. Europa is somewhat similar in bulk composition to the other terrestrial planets (primarily composed of silicate rock). Recent data from Galileo indicate that Europa has a layered internal structure perhaps with a small metallic core. However, Europa's surface is not at all like anything in the inner solar system. Its surface is exceedingly smooth with few features more than a few hundred meters high.

There are very few craters on Europa; only three craters larger than 5 km in diameter have been found. From the observations of water ice absorption bands, and due to the near absence of impact craters we have inferred that the surface is ice rich and also very young and active, perhaps only 30 million years old. The precise age of Europa's surface is unknown. Voyager mapped only a fraction of the surface at high resolution. The images of Europa's surface strongly resemble images of sea ice on Earth. Scientists have postulated that a water-ice shell covers Europa and is more than 150 kilometers thick. It is possible that beneath Europa's surface ice there is a layer of liquid water, perhaps as much as 50 km deep, kept liquid by tidally generated heat due to the pull of Jupiter and its other moons. If so, it would be the only place known in the solar system besides Earth where liquid water exists in significant quantities.

Europa's most striking surface features are the series of dark streaks or cracks that crisscross the entire globe. The larger of these streaks or cracks are roughly 20 km across with diffuse outer edges and a central band of lighter material. These features indicate that the surface ice sheets of Europa are tectonically active. The latest theory for their origin is that they are produced by a series of volcanic eruptions or geysers. It is believed that these cracks are locations of eruptive sites from which liquid water has intermittently flowed out onto the surface and then frozen and thus erased the traces of impact craters. The Jupiter moon called Io has highly active volcanic systems that are driven by the pull of Jupiter. Similarly, although much less intense, heating may exist in the subsurface of Europa, accounting for the resurfacing processes on the planetary surface.

One of the most compelling insights to emerge from 15 years of research on submarine volcanic-hydrothermal systems on Earth is the idea that volcanoes in the presence of liquid water can sustain. Whether or not life can originate in these hydrothermal systems is controversial, but the evidence is unequivocal regarding the linkages between volcanic processes as we know them and abundant carbon-based life forms on and below the seafloor in the vicinity of active spreading centers.

Recent observations with the Hubble Space Telescope reveal that Europa has a very thin atmosphere (1×10^{-11} bar) composed primarily of oxygen. Of the 61 moons in the solar system only four others (Io, Ganymede, Titan and Triton) are known to have atmospheres. Unlike the oxygen in Earth's atmosphere, Europa's is almost certainly not of biogenic origin. It is most likely generated by sunlight and the subsequent splitting of water into hydrogen and oxygen. The hydrogen escapes leaving the oxygen.

Io (moon of Jupiter)

Discovered by: Galileo Galilei, 1610
Distance from the Sun: 780,000,000 km
Distance from Jupiter: 422,000 km
Radius: 1815 km (Earth's moon: 1740 km)
Mass: 9×10^{22} kg
Density: 3550 kg/m^3
Major atmospheric constituent: Sulfur dioxide
Surface constituents: sulfur, silicon, sodium

Looking like a giant pizza covered with melted cheese and splotches of tomato and ripe olives, Io is the most volcanically active body in the solar system. Volcanic plumes rise 300 kilometers (190 miles) above the surface.

The energy for all this activity derives from the gravitational forces between Io, Europa, Ganymede and Jupiter. These gravitational forces cause Io's surface to bulge up and down (or in and out) by as much as 100 meters (330 feet)! This tidal pumping generates a tremendous amount of heat within Io, keeping much of its subsurface crust in liquid form. Thus, the surface of Io is constantly renewing itself, filling in any impact craters with molten lava lakes and spreading smooth new floodplains of liquid rock.

In contrast to most of the moons in the outer solar system, Io is thought to be somewhat similar in bulk composition to the terrestrial planets, primarily composed of molten silicate rock. Recent data from Galileo indicates that Io has a core of iron (perhaps mixed with iron sulfide) with a radius of at least 900 km.

The material erupting from Io's vents appears to be some form of sulfur or sulfur dioxide. The volcanic eruptions change rapidly. In just four months between the arrivals of Voyager 1 and Voyager 2 some of them stopped and others started up. The deposits surrounding the vents also changed visibly.

Io has an amazing variety of terrains: calderas up to several kilometers deep, lakes of molten sulfur, mountains which are apparently NOT volcanoes extensive flows hundreds of kilometers long of some low viscosity fluid (perhaps some form of sulfur), and volcanic vents. Sulfur and its compounds take on a wide range of colors which are responsible for Io's diverse appearance.

Analysis of the Voyager images led scientists to believe that the lava flows on Io's surface were composed mostly of various compounds of molten sulfur. However, subsequent ground-based infrared studies indicate that they are too hot for liquid sulfur. One current idea is that Io's lavas are molten silicate rock. Recent HST observations indicate that the material may be rich in sodium. Or there may be a variety of different materials in different locations.

Some of the hottest spots on Io may reach temperatures as high as 2000 K (1723 °C) though the average is much lower, about 130 K (-143 °C). The hot spots are the principal mechanism by which Io loses its heat.

Unlike the other Galilean satellites, Io has little or no water. This is probably because Jupiter was hot enough early in the evolution of the solar system to drive off the volatile elements in the vicinity of Io. Sulfur dioxide is the primary constituent of a thin atmosphere on Io.

Mars

Distance from the Sun: 227,900,000 km

Radius: 3,397 km

Mass: 6.42×10^{26} kg

Density: 3940 kg/m³

Mean Temperature at Solid Surface: 186 to 268 K (-86°C to -5 °C)

Major Atmospheric Constituents: carbon dioxide, nitrogen, and argon

Mars has inspired our imagination over the centuries, and has been the focus of intense scientific interest for many years. Mars has shown itself to be the most Earth-like of all the planets; as it has polar ice caps that grow and recede with the change of seasons, and markings that appear to be similar to water channels on Earth.

Mars is a small rocky planet that has experienced volcanic eruptions, numerous impact events, and displays many atmospheric changes. Areas of layered soils near the Martian poles suggest that the planet's climate has changed more than once, perhaps caused by a regular change in the planet's orbit. Martian tectonics--the formation and change of a planet's crust--differs from Earth's. Where Earth tectonics involve sliding plates that grind against each other or spread apart in the seafloors, Martian tectonics seem to be vertical, with hot lava pushing upwards through the crust to the surface. Periodically, great dust storms occur that engulf the entire planet. The effects of the storms are dramatic, including dunes, wind streaks, and wind-carved features.

One of the early mysteries pondered by scientists was why Mars does not have oceans like Earth. Mars has an atmosphere that is now too thin and its temperature too cold to allow liquid water. Mars certainly had surface water and groundwater once. This liquid water shaped the valley networks in the highlands and the huge flood channels that cut from the highlands to the northern lowlands. Scientists are not certain of exactly how much water was present. Estimates range from the equivalent of an ocean 10 meters deep covering the entire surface to the equivalent of a layer kilometers deep. However much water there was, it is not now on the surface, except for a bit in the polar ice caps. One question that has been raised is where did the water go? It could be underground in pools of groundwater, either small or huge depending on how much water Mars started with. Or it could have escaped to space and been lost completely (the hydrogen from water can escape easily through Mars's low gravity and small magnetic field).

We don't know if there is or was life on Mars. There are currently no clear signs of any life on the inhospitable surface of Mars. We do know however that the climate of Mars was once quite different than today. We could image the past where Mars had a thicker atmosphere, flowing water, volcanoes, lava flows, open lakes, and perhaps even an ocean. These conditions could have supported life similar to that which develops in hot springs here on Earth.

In a recent study Scientists found a huge deposit of the mineral hematite. This discovery has led to speculation that there was water on Mars long enough for life to form. At a recent meeting of the American Geophysical Union, Arizona State University Prof. Phil Christensen suggested that the hematite deposit "is really the first evidence we have that hot water was around long enough for a geological period of time so that potentially life could have had an opportunity to form." Hematite is an iron oxide mineral that forms by a variety of ways that often involve water. The coarse-grained hematite spotted on Mars also occurs on Earth around volcanic regions such as Yellowstone National Park. It is evidence that a large-scale hydrothermal system may have operated beneath the Martian surface, said the scientists working on the Mars Global Surveyor Mission. "If you want to find out about possible life on Mars, the deposit is a good place to start," Christensen said. "You've got water, you've got heat, and you've got energy."

Titan (moon of Saturn)

Discovered by: Christiaan Huygens, 1655

Distance from Saturn: 1,220,000 km

Radius: 2,580 km

Mass: 1.35×10^{23} kg

Mean density: 1880 kg/m³

Mean temperature at solid surface: 94 K (-178°C)

Atmospheric pressure: 1.5 bars

Major atmospheric constituents: nitrogen, methane

Saturn's moon Titan was long thought to be the largest satellite in the solar system, however, recent observations have shown that Titan has a very thick, opaque atmosphere which hides its solid surface. Due to this extensive atmosphere the surface of Titan cannot be seen at all with visible light however some surface details are visible in the infrared.

Titan's atmosphere has a surface pressure that is more than 1.5 bar (50% higher than Earth's). It is composed primarily of molecular nitrogen (as is Earth's) with no more than 6% argon and a few percent methane. Interestingly, there are also trace amounts of at least a dozen other organic compounds (i.e. ethane, hydrogen cyanide, carbon dioxide) and water. The organics are formed as methane, which dominates Titan's upper atmosphere, and is destroyed by sunlight.

There are probably two layers of clouds at about 200 and 300 km above the surface. Complex chemicals in small quantities are responsible for the orange color as seen from space.

Observations have revealed that Titan is about half water ice and half rocky material. It is probably differentiated into several layers with a 3400 km rocky center surrounded by several layers composed of different crystal forms of ice. There is some speculation that its interior may still be hot. At the surface, Titan's temperature is about 94 K (-178°C). At this temperature water ice does not sublime and thus there is little water vapor in the atmosphere.

It seems likely that the ethane clouds would produce a rain of liquid ethane onto the surface perhaps producing an "ocean" of ethane (or an ethane/methane mixture) up to 1000 meters deep. Recent ground-based radar observations have cast this into doubt, however.

Recent observations with the HST show remarkable near infrared views of Titan's surface. Voyager's camera couldn't see through Titan's atmosphere but in the near infrared the haze becomes more transparent, and HST's pictures suggest that a huge bright "continent" exists on the hemisphere of Titan that faces forward in its orbit. These Hubble results don't prove that liquid "seas" exist, however; only that Titan has large bright and dark regions on its surface. The landing site for the Huygens probe has been chosen in part by examining these images. It will be just "offshore" of the largest "continent" at 18.1 degrees North, 208.7 degrees longitude.

Triton (moon of the planet Neptune)

Distance from Neptune: 354,760 km

Radius: 1352 km

Mass: 2.140×10^{22} kg

Density: 2066 kg/m³

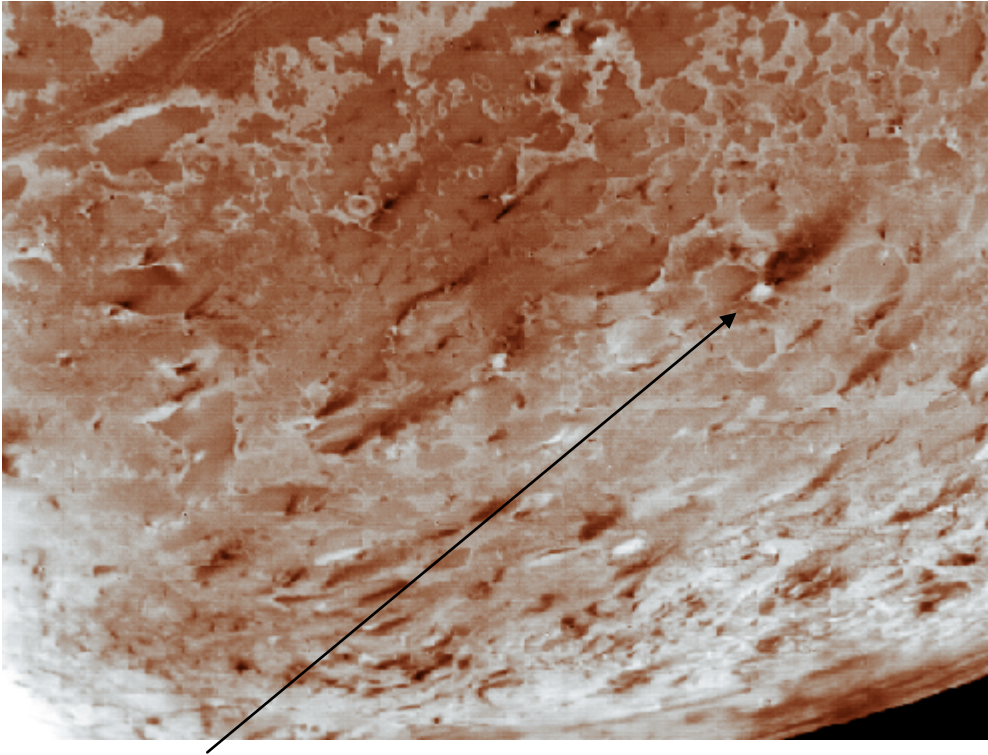
Mean temperature at solid surface: 38 K (- 235 oC)

Triton is the largest moon of Neptune, with a diameter of 2,700 kilometers (1,680 miles). It was discovered by William Lassell, a British astronomer, in 1846 scarcely a month after Neptune was discovered. Triton is colder than any other measured object in the Solar System with a surface temperature of -235° C. It has an extremely thin atmosphere. The atmospheric pressure at Triton's surface is about 14 microbars, 1/70,000th the surface pressure on Earth. It is speculated that nitrogen ice particles might form thin clouds a few kilometers above the surface.

Triton is the only large satellite in the solar system to circle a planet in a retrograde direction -- in a direction opposite to the rotation of the planet. Triton contains more rock in its interior than the icy satellites of Saturn and Uranus. Its relatively high density and retrograde orbit have led some scientists to suggest that Triton may have been captured by Neptune as it traveled through space several billion years ago. If that is the case, tidal heating could have melted Triton in its originally eccentric orbit, and the satellite might even have been liquid for as long as one billion years after its capture by Neptune. Triton is scarred by enormous cracks. Voyager 2 images showed active geyser-like eruptions spewing nitrogen gas and dark dust particles several kilometers into the atmosphere.

Triton is one of only three objects in the Solar System known to have a nitrogen-dominated atmosphere (the others are Earth and Saturn's giant moon, Titan). Triton has the coldest surface known anywhere in the Solar System (38 K); it is so cold that most of Triton's nitrogen is condensed as frost, making it the only satellite in the Solar System known to have a surface made mainly of nitrogen ice. The pinkish deposits that cover a vast portion of the south polar cap is believed to contain methane ice, which would have reacted under sunlight to form pink or red compounds. The dark streaks overlying this pink ice are believed to be an icy and perhaps carbonaceous dust deposited from huge geyser-like plumes, some of which were found to be active during the Voyager 2 flyby. There is a bluish-green band that extends all the way around Triton near the equator; and may consist of relatively fresh nitrogen frost deposits.

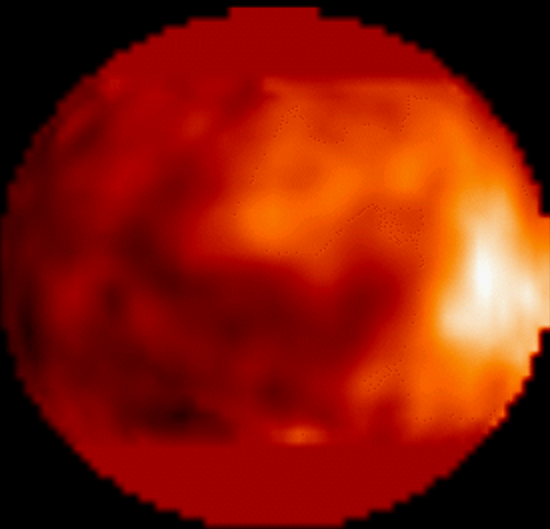
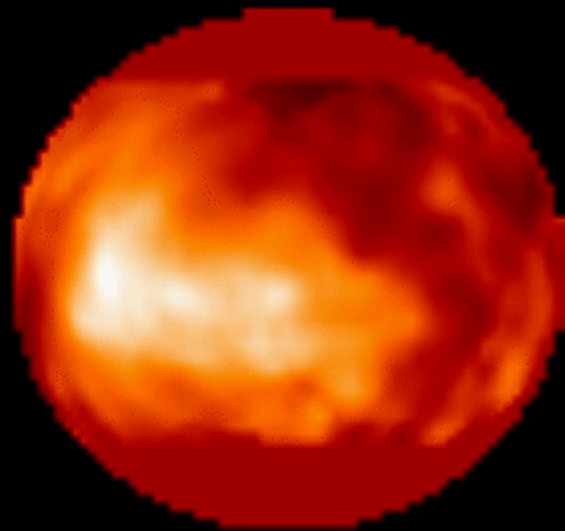
- A. Clearly we do not have all the information that we need to fully understand the environment of the planet/moon you are considering. What question would you want to answer about this environment if you could send a single lander or orbiter to the planet or moon and perform just one test? Explain your reasoning.
- B. Could any of the bacteria that we have talked about potentially survive on the moon or planet that you have read about? If so, state the type of bacteria that could survive and how you think it would 'make a living'(photosynthesis, chemosynthesis). If not, explain why none of these bacteria could survive.
- C. What changes in the atmosphere or surface would most strongly increase the chance for life to exist on the planet or moon that your read about?
- D. Design a hypothetical life form that could live in the environment that you read about. Describe how you think it might "make a living".
- E. Recently many Jupiter-sized planets have been discovered orbiting other stars within the galaxy. Some of these planets are close enough to their companion stars that the planet's average temperature could be high enough for the presents of liquid water. However, since these planets are gas giants it is unlikely that life would have developed on these planets? Why then are these discoveries so important to our search for life?



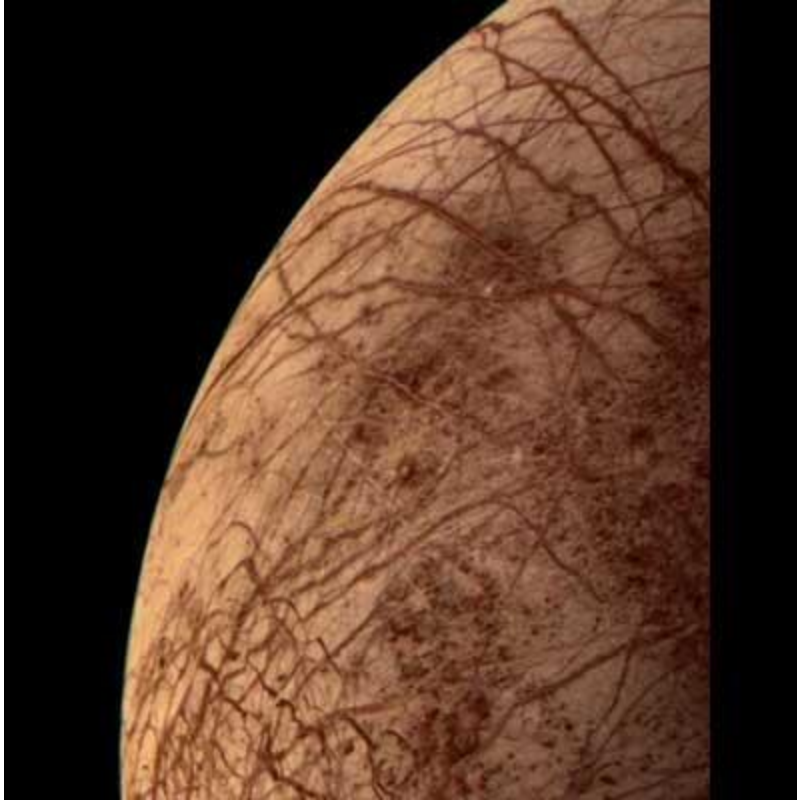
Black “smudges” are outgassing volcanoes

Surface of Titan

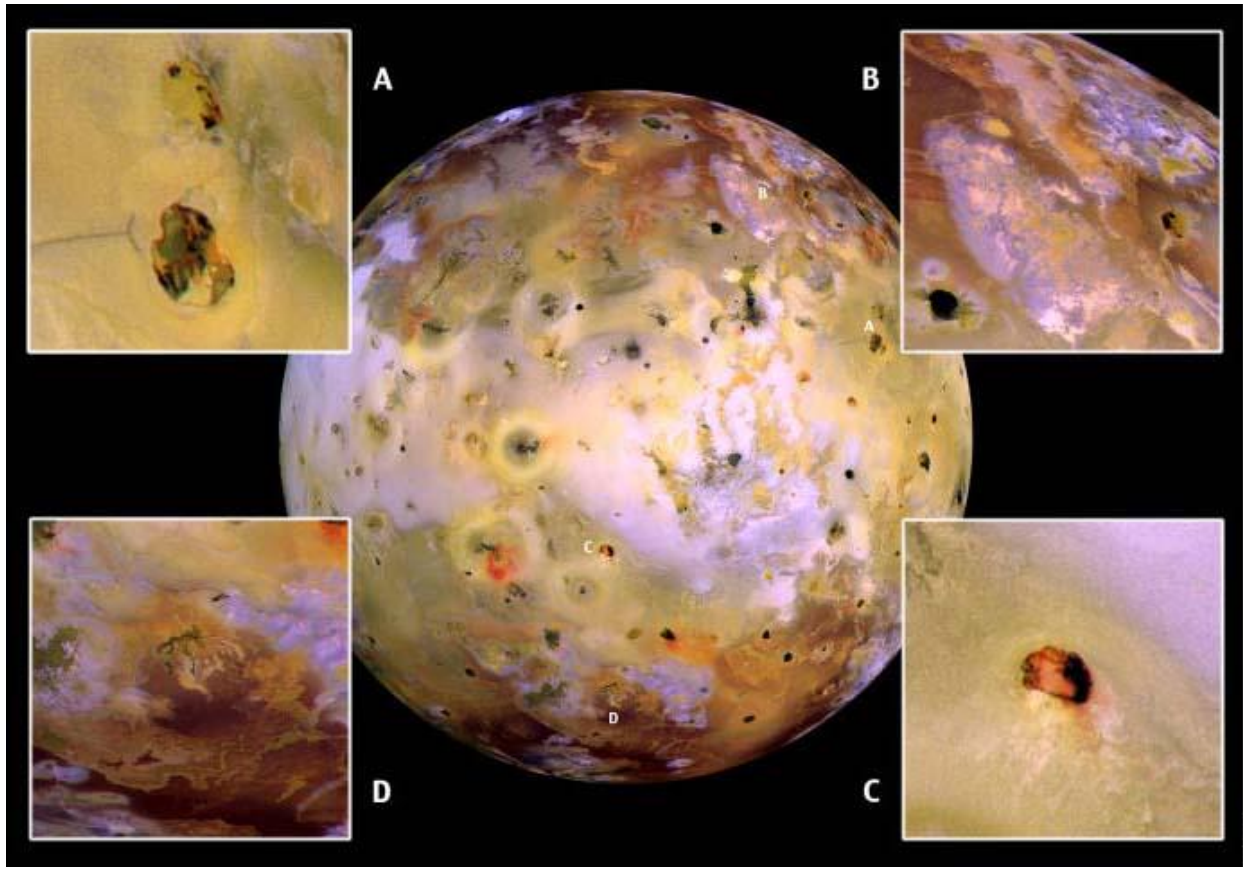
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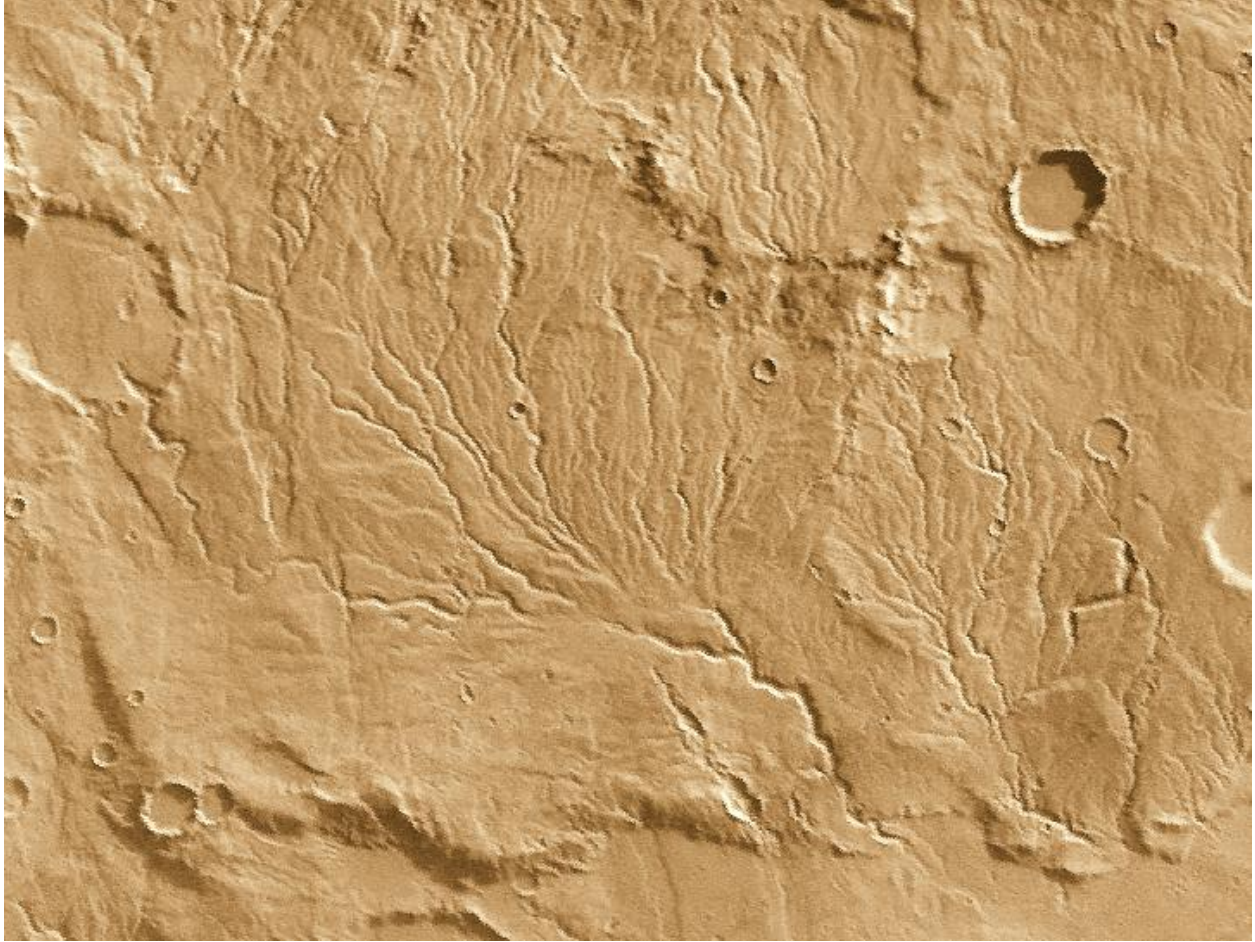
Surface of Titan in Infrared



Lines are fissures in icy crust



Insets are close-ups of volcanoes.



Dried up riverbed on Mars surface