GEOG30790 Planetary Geomorphology
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Presence of water on Mars and glacial geomorphology in the northern polar layered deposits and in Hellas Planitia.

Mars may not have had the harsh conditions that are hostile to the life they are today. Such as lake beds, river channel networks, and deltas are clues to early mar that was warmer and filled with liquid wetter. This indicates that the planet once must have had an atmosphere that is dense enough to trap the heat from the sun to create enough atmospheric pressure to keep liquid water stable on its surface. Today mars do not have active plate tectonics to recycle sediments and it also does not have a magnetic field to protect it from the solar wind and it has less gravity to hold its atmosphere (O'Brien, Morbidelli and Levison, 2006). All these factors may have caused Mars to lose its atmosphere and let to become an extremely frozen desert. Today mars are known as a red planet as almost all its surfaces are a reddish color. However, two locations distinctly stand out from this typical surface the northern and southern polar ice caps. Again similar to Earth.

In this journal article, I will investigate overall water conditions and contains on mars. And then I will look into polar caps focusing on mainly the north polar ice cap. Then I will observe how the north polar ice layers are formed. Then will move down to the equatorial region at Hellas crater to look into more ice related land formations.

Comparison between Mars and Earth

Component	Mars	Earth
Size (km)	6779 diameter	12742 diameter
Equatorial radius (km)	3397	6378
Average distance from Sun (km)	2.27×10^8	1.50×10^8
Orbital period (length of year, Earth days)	687	365
Rotation period (length of day, hours:min)	24:37	23:56
Axial tilt	25.19°	23.44°
Average surface temperature (°C)	−63	14

Mass	6.4×10^{23} kg	5.9×10^{24} kg
Volume	1.6×10^{11}km^3	1.08×10^{12} km^2
Mean density	3.7 m/s^2	5.5 g/cm^3
Escape Velocity	5.02 km/s	11.186 km/s
Atmospheric composition	carbon dioxide 95% nitrogen 2.6% argon 1.9% oxygen 0.16% carbon monoxide 0.06%	carbon dioxide 0.04% nitrogen 78% argon 0.9% oxygen 21%
Temperature mean	-60º	20ºC

Mars has diverse surface characteristics and most are similar to Earth's. Landform features on mars such as vast river channel networks, gullies, valley systems, canyon systems, deltas, lakes with inlets and outlets, and rocks provide enough evidence that mars had once abundance of water coverage on its surface. (Lewis and Aharonson, 2006). However, at present days mars is an extremely cold, dusty, and deserted planet. Its temperature can range from 20ºC on summer days at the equator to -125ºC on winter at its poles. The average temperature of mars is -60ºC whereas, the earth has 14ºC.

Two obvious factors can contribute to making mars' condition so cold. One is that Mars is 229 million kilometers away from the Sun whereas, Earth is only 150 kilometers. Since mars is a half time further away than the Earth, this great distance from the Sun makes mars a lot colder. The other factor is that Mars has a very thin atmosphere has less than one percent of the earth's atmosphere. Mars has a thin atmosphere due to its low gravity, which has only one-third of the earth's gravity. Gravity is an essential element of any planet because it holds down the atmosphere. Atmosphere matter because it acts like a blanket that keeps thermal heat in (O'Brien, Morbidelli, and Levison, 2006). Therefore, even though on a summer day the temperatures are quite warm on Mars, liquid water is not stable due to its low atmospheric pressures.

Today, much evidence that shows mars had an abundance of liquid in the past. However, it has been discovered that water is still present on mars across all surfaces but it is in the form of ice. The map below shows the indication of water ice presence on mars at the present day at different volumes across the planet.

Figure 1: hydrogen contentment on the surface of Mars this reflect the presence of water on mars

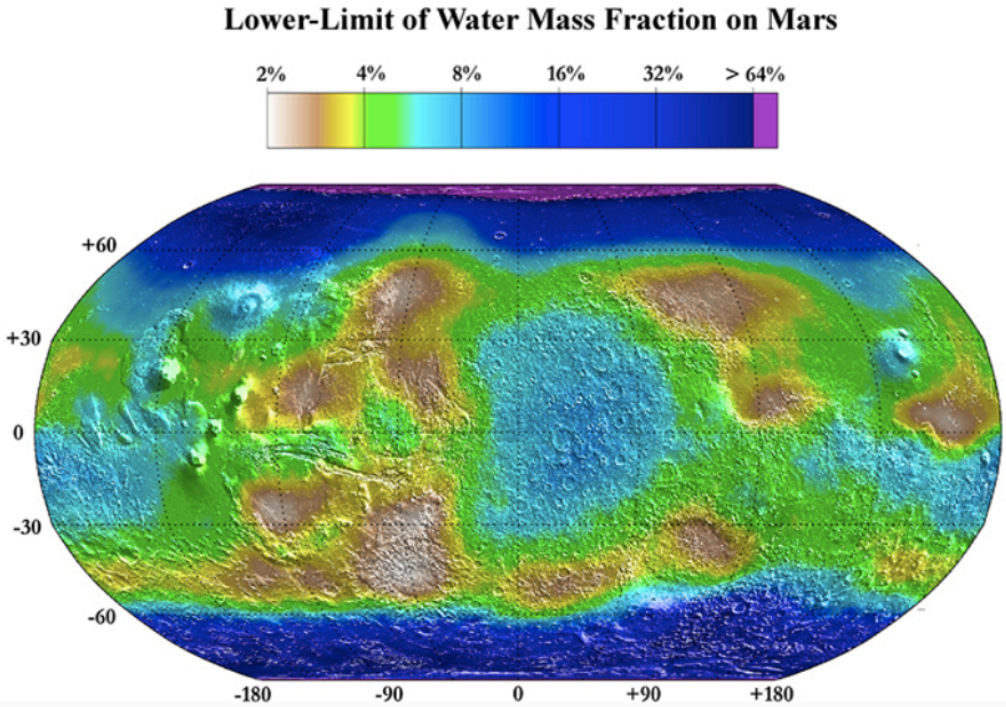
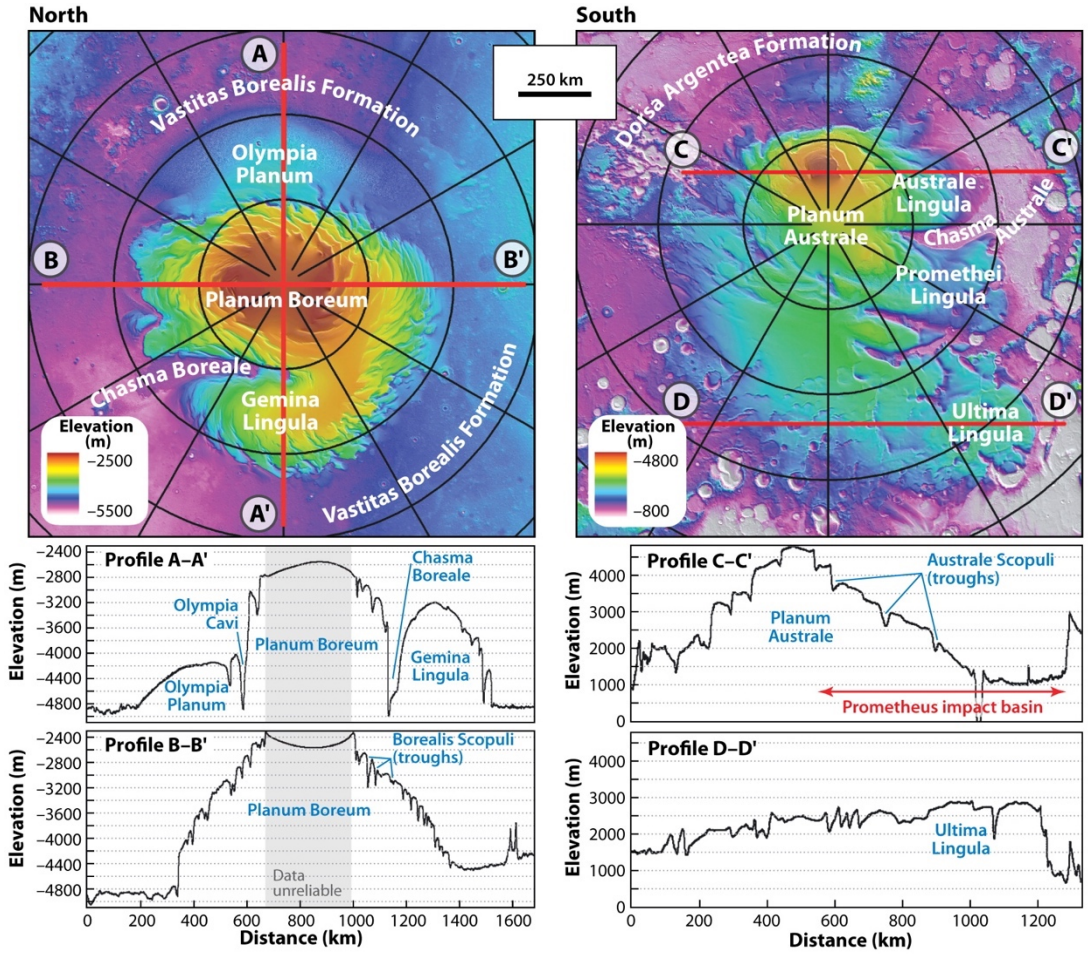


Figure 1: *This map is the result of the Mars Odyssey Gamma Ray Spectroscope (GRS) investigations of the Martian surface and is based on the observation of hydrogen content on the surface. Image credit: NASA/JPL/Los Alamos National Laboratory.*

This is a map of Mars. It is color-coded from white, through browns, green, light-blue, dark-blue, and purple. The colors are overlaid onto a topographic map of Mars. The purple represents the highest amounts of water content and the white is the lowest water content on the Martian surface. The Mars Odyssey Gamma-Ray Spectroscopy (GRS), which is has detected the neutrons that are emitted from the surface of Mars and is explained as being the function of the presence of hydrozoan on the surface. It is presumed that hydrozoan being a very light element, is unlikely to be on its own even in the molecular form at the surface level. Or it would easily skip to space. So the presence of hydrozoan on the surface can generate epithermal and which can generate epithermal neutrons is like to be water. Where the hydrozoan is bound up with oxygen to form heavier water molecules. That makes the hydrozoan stable on the planet and possibly the cold condition of Mars would add more stability because the water is in the state of frozen within the regolith on the upper surfaces of the planet (Orosei *et al*., 2018).

The map shows that there is water presence across the surface of Mars. The dark blue and purple colors represent denser water content the lighter blue, green, brown, to white colors represent the decreasing presence of water content. The water content is very high at both poles north and south. Above and below 60º latitude in both hemispheres, the water content is very dense up to 50% in weight shown in dark-blue color. At the north polar ice cap, it is extremely high greater than 64% showing the area in purple color at the very top. In the lighter blue areas in the mid-latitude in the equatorial regions, the amount of water content is about 8%. At the very low altitudes in the mid regions, water content is only up to 2% to 4%.

Figure 2: Topographic variation and cross sectional profile of Martian polar ice caps.



Byrne S. 2009.
Annu. Rev. Earth Planet. Sci. 37:535–60
Source: (Byrne, 2009)

Figure 2: Regional MOLA topographic maps; north on the left and south on the right at the same scale. Red lines indicate the locations of topographic profiles. The grey shading in the

north polar profile indicates the region for which topographic data are unreliable. These maps are taken from (Byrne, 2009) showing topographic variation and cross-section profile of Martian polar ice caps. The northern polar ice deposits region is called Planum Boreum and the southern Planum Australe. These ice caps are known as layered deposits. The north layered deposits (NPLD) and south layered deposits polar (SPLD) are both dome-shaped. On average the northern cap rises about 2 km above the local plains surrounding it. It is about 1,100 km in diameter. The Southern cap is much smaller only 420 km in diameter and has a thickness of around 3 km.

Figures 3 and 4: below are the images of the north ice cap on the (left) and the south ice cap on the (right). Many used to think that the polar ice was dominated by CO2 ice given that mars' atmosphere contains 95% CO2 but it is now known that these caps are dominated by water ice with a significant proportion of CO2.

Figure 3: North Pole Ice Layered

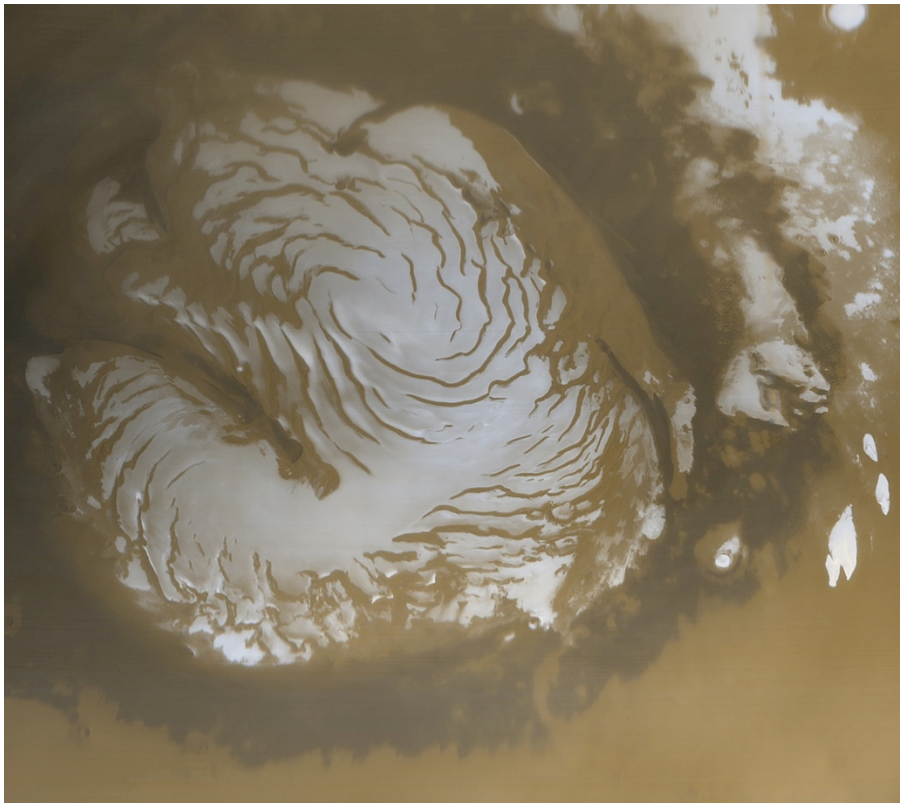


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Figure 3: This is a picture of ice layered cap at the north pole of Mars, acquired by the Mars Global Surveyor (MGS) on March 13, 1999. The light-toned surfaces are the water ice. The dark materials that surround the ice cap are mainly sand basaltic dust and dunes that are formed

and shaped by the wind. This ice cap on the north pole is about 1,100 kilometers across from left to right. The ice is carbon dioxide ice.

Figure 4: South Pole Ice Layered

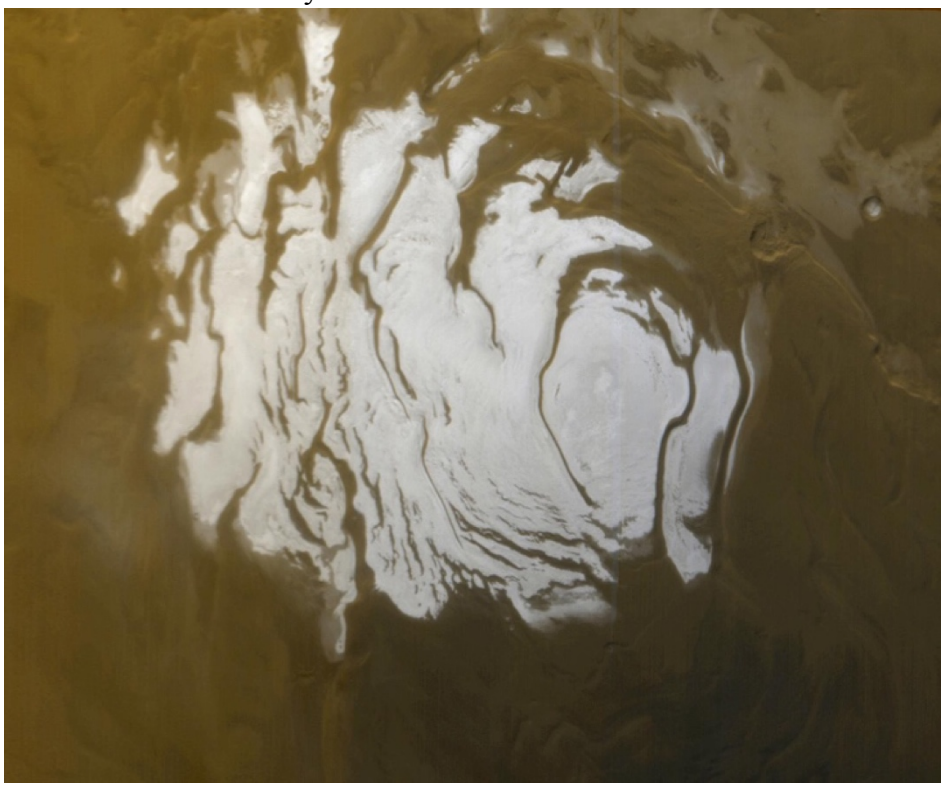

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Figure 4: This is an image of south polar cap of Mars taken by the Mars Global Surveyor (MGS) on April 17, 2000. This ice cap is about 420 km across from left to right. The south pole ice cap has higher albedo.

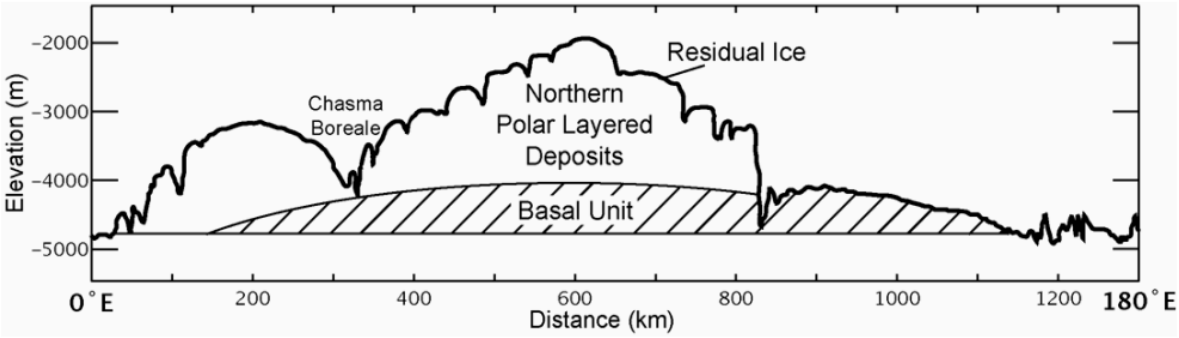
The total volume of ice combining two polar ice caps of Mars is similar to Greenland on Earth (Byrne, 2009). It is imaginable that these ice caps would spread out like glaciers on earth over a long period of time, however, the fact that the condition on mars is extremely cold makes the ice a lot more rigid therefore it acts much more like a stone than a glacier. Ice on earth is the warmer type of ice, it is hardly below the freezing point of 0°C at sea level. In the Antarctic pole, the temperature of ice varies. The base of the ice is significantly warmer than its top. At about 4 km down below in the Antarctic ice base, the ice temperature is about - 3°C, whereas at the top of the glaciers it can be about - 40ºC and -70°C. So mars have an extremely low temperature compared to Earth (Gardner *et al*., 2011). Mars' annual mean temperature is - 60ºC

whereas, Earth's is 20ºC. So Mars requires special conditions if the current solid-phase ice is to thaw or melted into the liquid phase.

The North Pole and also the south pole to a lesser extent also have spiral troughs. Some spirals at the north pole ices cap are up to several hundred meters deep (Phillips et al 2008). The spiral hurricanes here on earth.

The Marian polar caps are a record of processes on multiple spatial and temporal scales. These processes are shown with a cross-section visualization graph below. The graph is taken from the paper about the surface texture of Mars' north polar deposit by Sarah M. Milkovich and James W. Head (Milkovich and Head, 2006).

Figure 5: Cross Section Ice Deposit Stratigraphy of the North Polar Ice Cap.



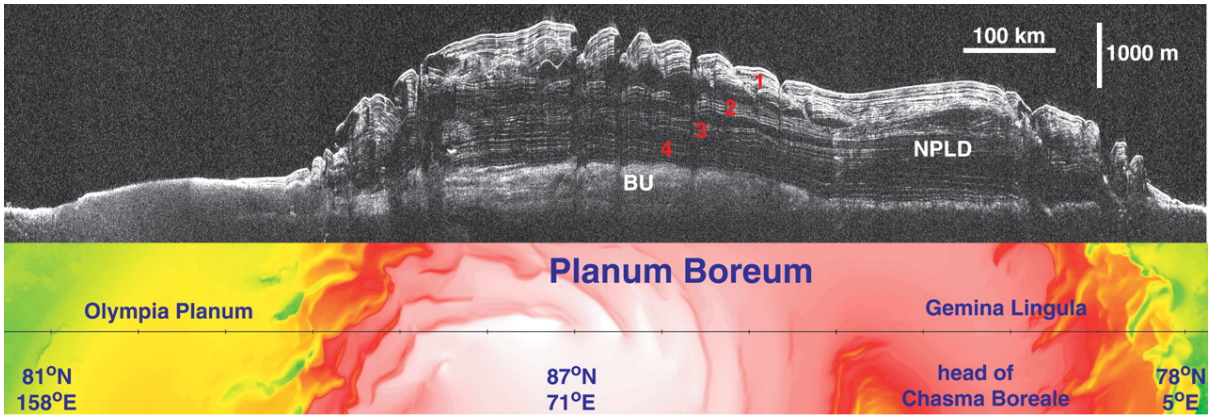
Source: (Milkovich and Head, 2006).

The cross-section graph of the Martian north pole ice cap shows that there are three distinct layers with the ice dome. The residual ice top, the northern polar layered deposits underneath the residual ice layered than the basal unit as the base. However, the topmost layer of ice at the surface level on the floor is thought to be a seasonal ice cap. It means that it would get deposited and sublimed away on a seasonal basis. It means that in the wither it gets deposited and in summer sublimed into the Mars' atmosphere. Underneath the topmost surface, is residual ice which persists from year to year. In the north residual ice is a meter thick water ice. It appears to have a quite young surface age on the order of thousands of years. Underneath the is the residual ice deposits the polar layered deposits known as Northern Polar Layered Deposits (NPPLD), which is a big bulk of the polar caps. In the north pole, the (NPLD) tends to be some kilometers thick. These deposits are made up of thousands of small-scale layers. In the north, these polar layered deposits are expected to be about 4 to 5 million years old. Underneath the

(NPLD) is a basal unit. The underlying and surrounding terrain which the oldest among those upper units (Milkovich and Head, 2006).

The internal stratigraphy of the (NPLD) is translated into a vertical resolution showing subsurface profiles down to about 15 meters by cross-sectionally scanning by the Shallow Rader (RHARAD) shown below-called radar gram.

Figure 6: internal stratigraphy of the (NPLD) by (RHARAD)



Source: (Phillips et al., 2008)

(Top) Radargram from SHARAD orbit 5192 (Bottom) Ground track of orbit 5192 shown on a digital elevation model (DEM) derived from Mars Orbiter Laser Altimeter (MOLA) data.

Figure 6 shows a radar gram of a SHARAD traversing across Planum Boreum from the outlying plateau of Olympia Planum near 14ºE to Gemina Lingula near 5ºE. In this map, the differences between the layers are reflected in the radar reflection system. According to (Phillips, et al 2008) that these reflections are associated with the boundaries between different fractions of ice, dust, and sand. This map shows that the oldest unit the basal unit's thickness in the (NPLD) stratigraphy varies according to the variation of elevation across the Planum Boreum (Phillips *et al.*, 2008).

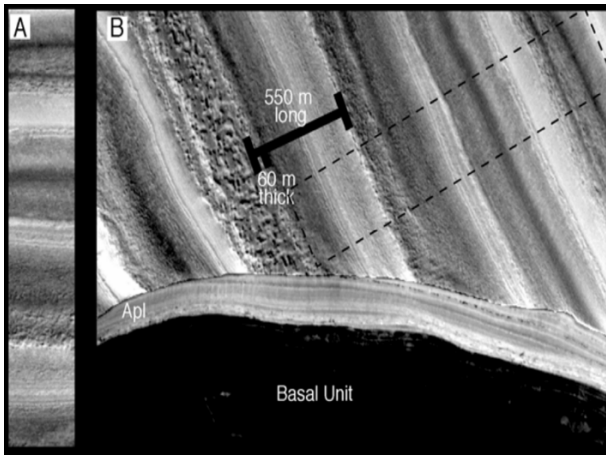
Layered surface features in the north polar ice cap region.

A lot of the North Pole Layer Deposits (NPLD) are exposed on slopes. The slope is called troughs. There is no single type of layer in a terrestrial ice sheet. Various factors influence the layering process such as an annual snow accumulation, melting and refreezing or sublimation

events, and deposition of dust and volcanic ash all contribute to layering. Average trough slopes are understood to be less than 8º. The images below show morphologies of layerings and

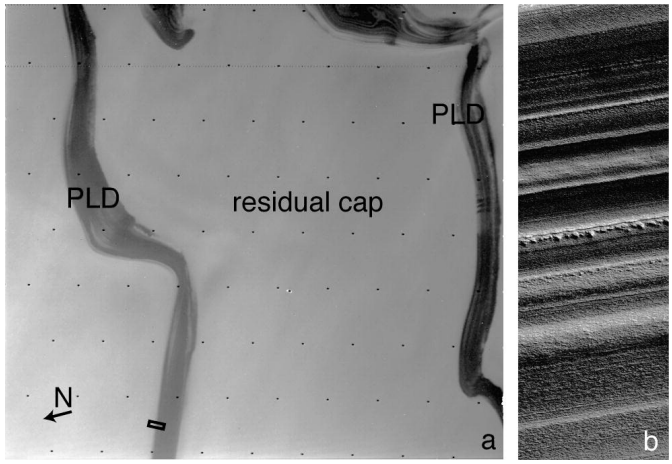
Patterns that are exposed on slopes on the NPLD. These images are taken from (Milkovich and Head 2006) and (Fishbaugh *et al.*, 2010)..

Figure 7 and 8 : The morphology of layering on the North Pole Layers Deposits NPLD exposed on gentle slopping troughs



(Milkovich and Head, 2006)

The effect of slope on layer exposure. A) Subframe of MOC image E02/01209. B) Larger subframe of MOC image E02/01209. The scale bar shows the horizontal distance along the surface between a pair of layers exposed on the trough wall on the left and the true thickness of the same layers as exposed on the cliff wall in the middle. The dark unit on the bottom right is the basal unit underlying the NPLD (Milkovich and Head, 2006)



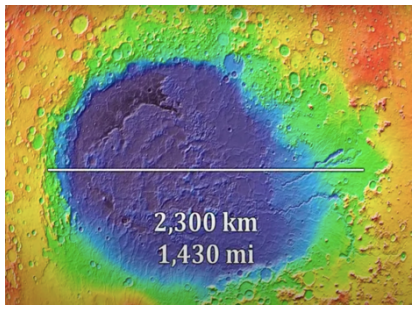
(Fishbaugh et al., 2010)

The feature a) on the left is a Viking image 062B32. Image width = 68 km is a surface view of residual cap and polar layered deposits. The residual cap is the surface polar ice cap. The light and dark are layering are slopes or troughs in the NPLD at different scales. The Small, black box shows location of Mars Orbiter Camera MOC image shown in 1b. b) Portion of MOC image M00/02072, showing NPLD layers Image width = 0.83 km. Illumination is from the upper right (Fishbaugh *et al*. 2010).

Glacial and Periglacial Geomorphological characteristics in mid-latitude Hellas Planitia

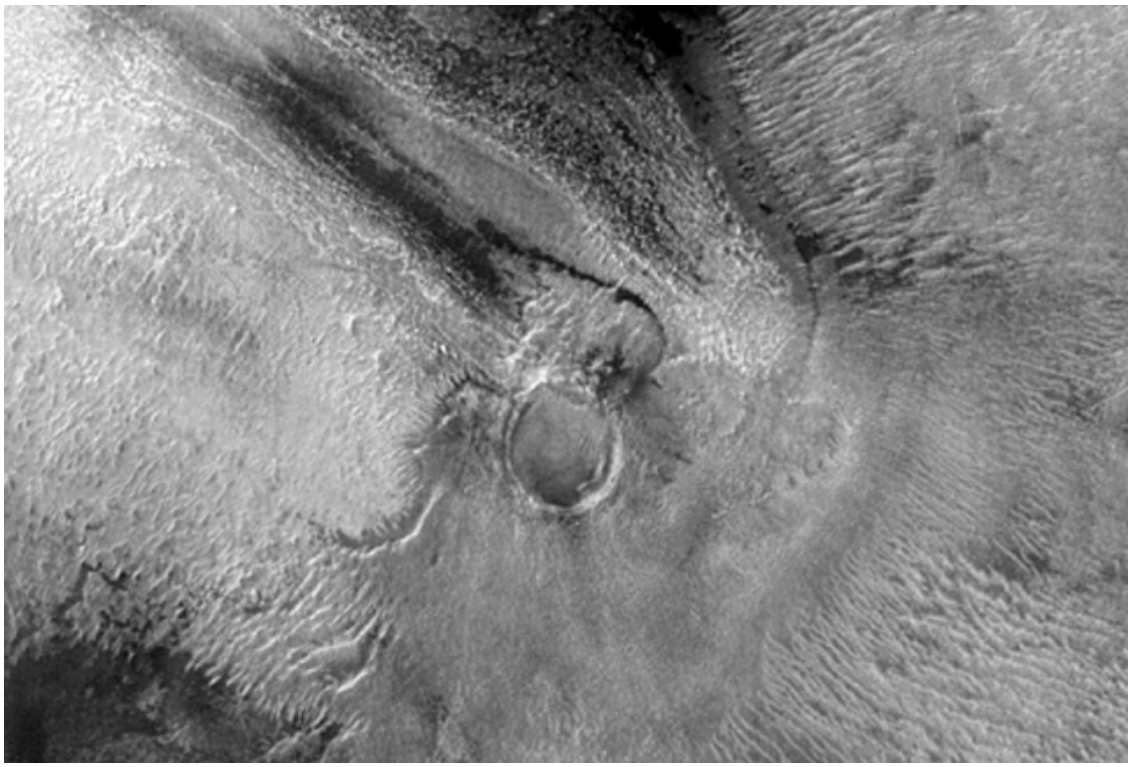
Figure 1 above showed that hydrogen abundances inferred from gamma-ray, high-energy neutron, and neutron spectrometer data show that the northern uppermost surface contains large amounts of water ice poleward of latitudes 60°, which can exceed 50% by mass. And it also showed that water ice on Mars is also present in the equatorial region at and across the planet's surfaces at various levels. Now I am going to move down from the north pole to Hellas crater, which lies in the equatorial region to look into some glacial or periglacial characteristics.

Hellas Planitia



Hellas Planitia is the second largest crater after Utopia Planitia and is considered to be a crater on Mars. The Hellas crater is about 2,300 km in diameter, which is a bit more than halfway through the mainland of the United States and has about 45% of the land area of the US. It is about 7 km deep and is located at the equator more to the southern region of Mars. Figure 1 above shows that in the area of Hellas Planitia water contends around 8% of its mass. So mars are globally covered with some sort of ice with in its regolith.

Figure 9: A tongue-shaped glacier valley in the Hellas Crater



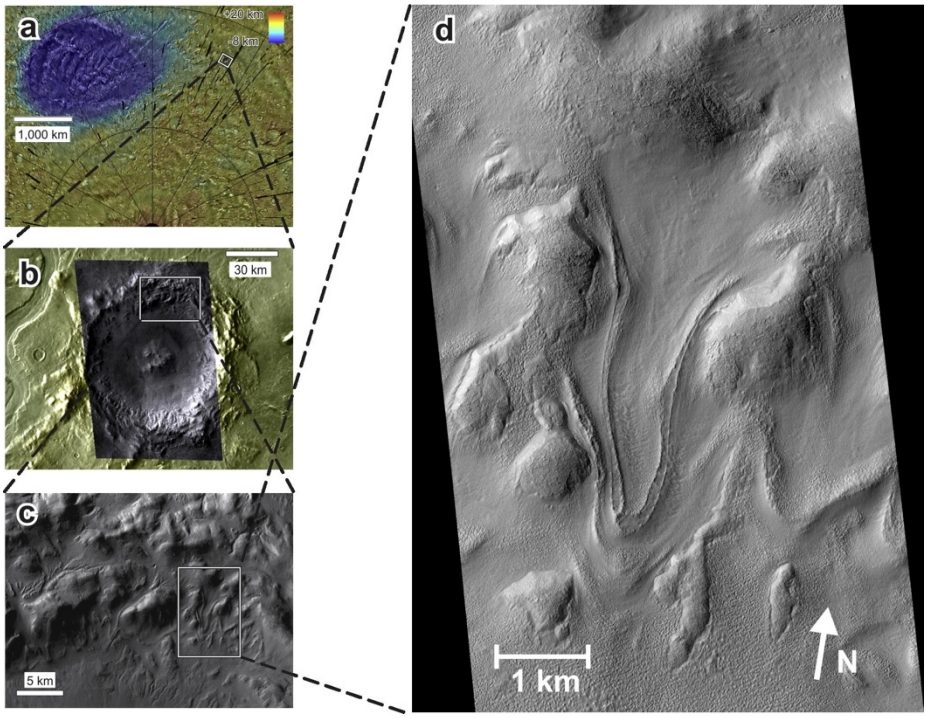
HiRISE Image, ESP_072765_1380

This is a HiRISE image that shows a tongue-shaped flow in a Valley in Hellas crater at Latitude -41º and longitude 76ºE. This is a lineated valley-filled type of glacier. This is can be an analog of glacier-like flow (GLF) in mid-latitudes on Mars.

Mars is now thought to be globally covered by ice in some sort of permafrost or segregated pure ice below its surface. Compare to Earth Mars' equatorial region is also extremely colder mean of -50º. These icy-soil deposits influence the formation of Martian landforms in the same way as they do on Earth but slower. Therefore, in addition to the polar ice caps, Mars also has many landforms that are similar to glacial landforms on Earth. The tongue-shaved valley filled also a product of glacier-like phenomena. These types of valleys form gradually through the accumulations of talus and finer debris derived from avalanches and rockfalls that bounce, roll, or slide to the downslope margins of perennial snow and firn banks (Hubbard *et al.*, 2011). The fink bank is a line across the glacier, from edge to edge, that marks the transition between exposed glacier ice below and the snow-covered surface of a glacier.

The location and expansion of this glacier-like formation (GLF) tongue-shaped landform in Hellas crater is investigated by (Hubbard, et al 2011).

Figure 10 : Glacier-Like Formation (GLF)



Source: (Hubbard et al., 2011)

(a) Location of the host crater to the east of the Hellas basin illustrated as a MOLA elevation transparency superimposed on a Themis daytime IR mosaic. (b) View of the host crater illustrated as a Context (CTX) image mosaic overlaid on an expansion of (a). (c) Expanded CTX view of the inner northern rim of the host crater wall, illustrating the presence of at least nine GLFs in this vicinity. (d) The GLF investigated herein, is illustrated as a section of HiRISE image PSP_002320_1415. The scene is illuminated from the west with the Sun ~23° above the horizon (Hubbard *et al*., 2011).

Conclusion

Mars is very cold, frozen, dusty, and serest today but its landscapes and topographic features indicate that it was once dominated by liquid water like earth today. Mars Odyssey Gamma-Ray Spectroscopy (GRS) data showed that water on Mars is present today all across surfaces in the form of water ice but most are cocked up at its polar ice caps. The polar ice caps are known as polar layer deposits. According to the cross-section profile data of the north polar ice cap from SHARAD, there are three distinct layers of ice deposits. the basal unit is the oldest than the north polar layer deposits and then residual ice youngest. However, there is seasonal ice deposition and sublimation activities take place over the residual ice, which considered to be the youngest. The layered deposit morphologies are exposed on slopes that can be detected without penetrating the surface of the ice. These layers can reflect the period of mars' recent history. In the equatorial region ice-related land formation in Hellas cater also is investigated. The tongue-shaped land formation is believed to have formed through the process of glaciation. Overall I have looked into water conditions and water contains on mars. It is found to be that water played a huge role in shaping the Martian landscape not only in the past but also in the present.

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