Features

posted June 14, 2001

Outflow Channels May Make a Case for a Bygone Ocean on Mars

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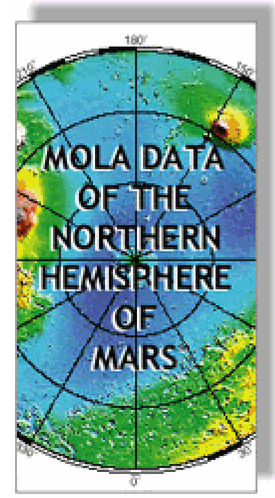


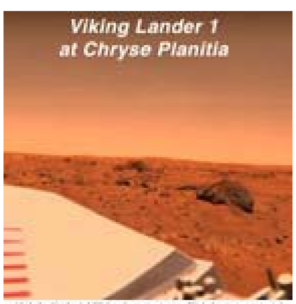
(From Smith *et al.*, 1999, *Science*, v. 284, p. 1500.)

High-resolution elevation data from the Mars Orbiter Laser Altimeter (MOLA) onboard the Mars Global Surveyor (MGS) spacecraft have been analyzed recently in Chryse Planitia to test the hypothesis that large outflow channels emptied into an ocean in this region of Mars. Researchers Mihail (Misha) Ivanov (Vernadsky Institute of Geochemistry and Analytical Chemistry) and James Head (Brown University) collected quantitative MOLA information on channel patterns, continuity, and elevations where those patterns change or disappear into the northern lowlands. Their recently published report describes how the channels end, or become more subtle, at elevations very close to a previously mapped geologic contact interpreted by some to represent a shoreline of an ancient ocean. Ivanov and Head hypothesize that the change in channel topography is consistent with flow of water from a river into a submarine environment with possible deposition of sediments by density currents deep into the North Polar basin.

Reference:

Ivanov, M. A. and J. W. Head, III (2001) Chryse Planitia, Mars: Topographic configuration, outflow channel continuity and sequence, and tests for hypothesized ancient bodies of water using Mars Orbiter Laser Altimeter (MOLA) data, *Journal of Geophysical Research,* vol. 106, p. 3275-3295.

Chryse Planitia



(NASA/JPL image PIA00572)

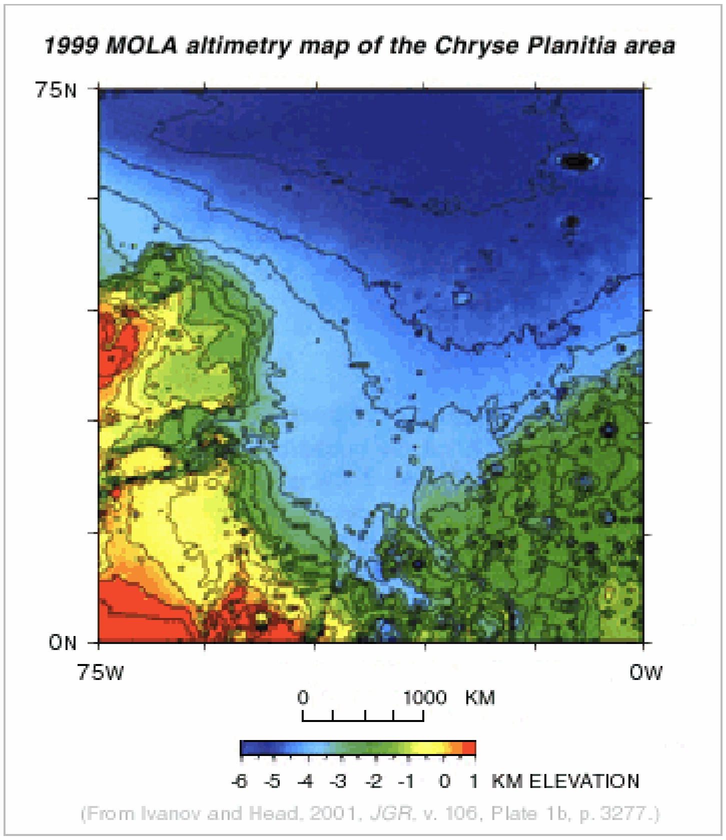
Chryse Planitia, chosen in the mid-1970s for the landing site of Viking 1, is a relatively flat, low, broad plain just north of the Martian equator. Because many of the largest Martian outflow channels converge here, Chryse Planitia is an ideal setting to study channel patterns and depositional environments. More importantly, researchers have noticed that the distinctive textures and teardrop-shaped islands inside the channels change and disappear near the margins of Chryse Planitia. These changes have led some people to hypothesize that debris-laden rivers may have emptied their loads into a lake at Chryse Planitia or into an ocean that occupied the northern lowlands. The actual timing of this bygone ocean is unknown, but may be Hesperian to Early Amazonian.

What the MOLA Data Reveal

Ivanov and Head cite five main lines of evidence from MOLA data that support the hypothesis that large outflow channels emptied into an existing standing body of water in the northern lowlands of Mars in Hesperian-Early Amazonian times.

- Chryse Planitia is not a locally closed basin but instead opens into the North Polar basin.

  MOLA data show that Chryse Planitia is not a closed basin, as thought previously, but rather a low area with a gentle regional slope to the north-northeast. [See areas colored blue in the map below.] If Chryse Planitia were a closed depression, then we'd expect water and sediments to be confined inside. The absence of a topographic low within Chryse Planitia, and lack of a barrier between the channel mouths and the northern lowlands, suggests that channels emptied and spread out beyond Chryse into the North Polar basin.

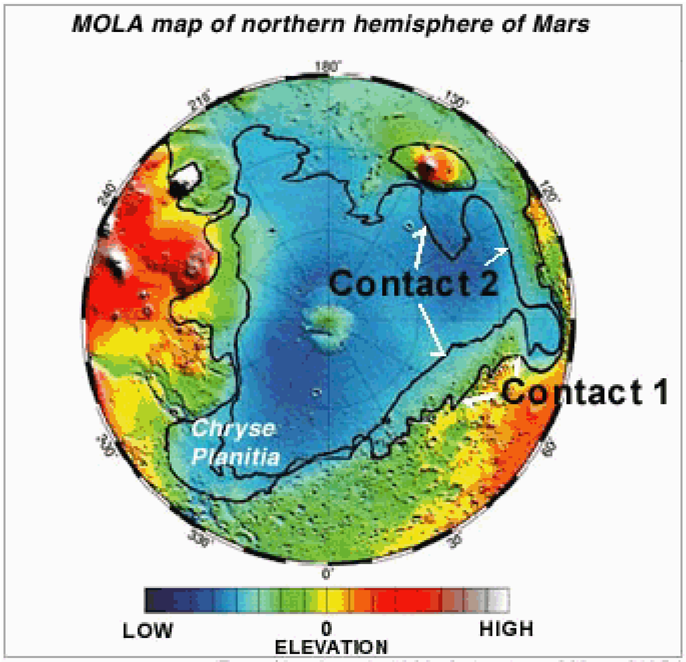


- The distinctive patterns of the six largest channels end at relatively the same elevation even though the channels are of different ages and are separated by hundreds of kilometers over a total lateral distance of more than 2500 kilometers.

  The six major outflow channels studied by Ivanov and Head were Kasei, Maja, Simud, Tiu, Ares, and Mawrth Valles. They determined the elevation of the most distal part of each channel at its contact with adjacent plains deposits and found the elevations to be quite close, all occurring within a range of 284 meters. (In contrast, the entire northern lowlands, from the edge of the cratered terrain to the bottom of the North Polar basin, has an elevation range of more than 3000 meters.) One explanation for this similarity in elevation where each channel ends (approximately -3742 meters, with a standard deviation of 153 meters) is that it represents a base level or shoreline where the channels joined a large body of water. It might be where rivers met the ocean.

- The Hesperian-aged channels end at elevations close to a previously mapped geologic contact interpreted as a shoreline of an ancient ocean.

  In 1989, Timothy Parker and colleagues at the Jet Propulsion Lab mapped boundary contacts between landforms in the northern lowland plains. They outlined two contacts that are generally parallel to the southern boundary of the northern lowlands, and interpreted them as two separate highstands of a now vanished ocean. The MOLA map shown below is centered on the north pole and shows topography of the northern hemisphere of Mars. Low elevations are shown in shades of blue while the black lines indicate positions of contact 1 and contact 2. Contact 2 has a range in elevation of 4700 meters with a mean elevation of -3760 meters. The dramatic variations in elevations could be due to geologic activity (for example, surface uplift or tilting, subsidence, erosion, sedimentation, lava flooding, etc.) that may have occurred after the shoreline formed. Contact 1 has a mean elevation of -1680 meters, and its elevation varies by almost 11 kilometers. Ivanov and Head report that the mean elevation of the termini of Chryse channels (-3742 meters) is within 18 meters of the mean elevation of Contact 2.

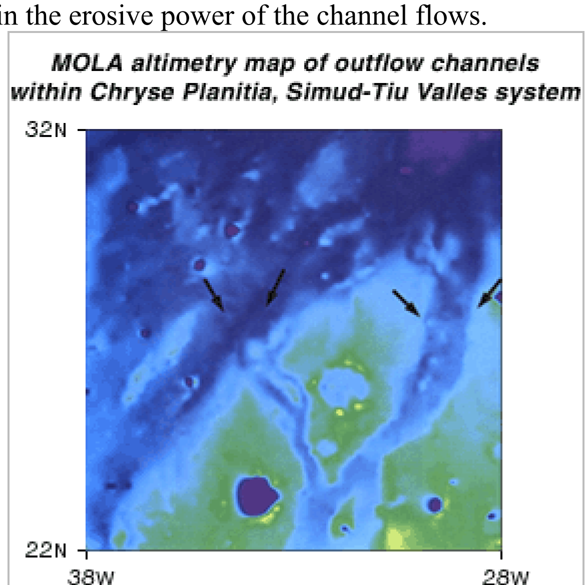


(From Head *et al.*, 1999, *Science*, v. 286, p. 2135.)

Mars has no actual sea level. The elevation designated as zero, therefore, is defined by the mean Martian radius, 3,382.9 kilometers, and the average atmospheric pressure of 6.1 millibars (6.1 thousandths of the Earth's atmosphere). If you were standing on the martian surface and the center of the planet were 3,382.9 kilometers beneath your feet, then you would be standing at 0 kilometers elevation, shown on this MOLA map in yellow.

- Some of the channels continue out of Chryse Planitia for hundreds of kilometers into the North Polar basin, but their patterns are subdued and very different once past their recognized termini.

  Subtle elongated depressions in the MOLA data continue along the trend of the mapped channels beyond the channel termini as shown in the MOLA map below. Black arrows indicate where the channels (Simud on the left and Tiu on the right) lose their distinct patterns. Ivanov and Head consider the loss of distinctive channel patterns as corresponding to a reduction in the erosive power of the channel flows.



(From Ivanov and Head, 2001, *JGR*, v. 106, Plate5b, p.3290.)

- The distinctive change in channel pattern is consistent with rapid loss of energy as when a river discharges into a shallow submarine environment.

  Ivanov and Head report that the lateral extent of the subdued channels compares favorably with environments on Earth where rivers enter marine environments, moving from subaerial (more erosional) to submarine (more depositional) settings and distributing sediment widely downslope as density currents.

Relationship of the Chryse Channels with the Hypothesized Ocean

Try to picture the floods. The crashing, tumultuous torrents were large and dirty, carrying rocks, ice, and sediments through the channels. Debris-laden floodwaters scoured the landscape, cutting through the underlying rock, and when they spread out, where did the floodwaters go? Did the water merely sink underground? Did it fill the North Polar basin to make an ocean? Did it enter an existing ocean? We can only guess what happened.

We need more information on the actual volumes of water and sediments involved in the floods and the timing of the floods. Ivanov and Head refer to different estimates of channel volumes (from Michael Carr, Victor Baker and others) to try to give us a better picture. Carr's estimate of the water volume of a single large flood in a Martian outflow channel is 300,000 km^3. This is enough water to flood the entire North American continent by 30 meters! It would take at least 46 of these floods to fill the Martian northern lowlands to the level of Contact 2. Other estimates suggest that each channel may have filled the North Polar basin in separate events, requiring significant water loss between floods and refilling to essentially the same level. Ivanov and Head favor the hypothesis that the channels flowed into a preexisting standing body of water whose margins were already near the level of Contact 2 and cite the striking similarity of elevations where the channels end and the proximity of these elevations to the mapped Contact 2.

Mars Ocean Still Being Debated

Whether or not Mars had large bodies of standing water remains an unanswered question and not all investigators support the notion of a vast northern ocean. Photogeologic mapping of the proposed shorelines by Michael Malin and Kenneth Edgett in 1999 using high resolution images of Mars taken with the Mars Orbiter Camera (MOC) showed no features they would attribute to the action of water in a coastal environment. Other researchers contend that ridge networks in the northern lowlands are indicative of tectonic processes related to the Tharsis volcanoes. Tectonic features in this area of Mars, however, are not inconsistent with the possible presence of an ocean. Earth's ocean basins are prime examples of tectonic features.

Confirming the presence of large bodies of standing water in Martian history will require a multifaceted approach. We'll need laser altimiters (MOLA) for topographic data, cameras for photogeologic mapping, infrared spectrometers (such as onboard 2001 Mars Odyssey) for mapping the distribution of minerals on the surface, gamma ray spectrometers (also on Odyssey) for mapping the surface distribution and abundance of chemical elements, as well as mineral and chemical studies of meteorites and rocks returned from Mars (to check for the presence of salts, for example.) If there were standing bodies of water on Mars billions of years ago they may have influenced the planet's atmosphere and climate, geology, environmental chemistry, and ultimately its capacity to support the emergence of life. These are the reasons why scientists, including Ivanov and Head, seek evidence of ancient oceans on Mars. The search may quench our collective thirst for knowledge about the Red Planet.

Additional Resources

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Mars Exobiology Strategy

Mars Global Surveyor

2001 Mars Odyssey

MOLA Science Investigation.

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