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The paleo-ocean of Mars

John E. Brandenburg

Morningstar Applied Physics LLC

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***Corresponding author's Name & Add.**

John E. Brandenburg
Morningstar Applied Physics LLC

Abstract

The Mars ocean hypothesis[1] proposed that the Northern Plains of Mars, approximately one third of Mars surface, was once covered by an ocean of liquid water. Given that the Northern Plains of Mars are the youngest portion of Mars surface- as evidenced by their sparse cratering relative to most of the planet's surface- the Mars paleo-ocean appears to have endured for most of Mars geologic history in either liquid or solid form.[2][3][4] The paleo-ocean, named the "Malacandrian Ocean"[4] or "Oceanus Borealis,"[3] would have filled the Vastitas Borealis basin in the northern hemisphere of Mars, an area which lies 4–5 km (2.5–3 miles) below the mean planetary elevation. This would have begunat a time period of approximately 4.0 billion years ago. Evidence for this ocean includes geographic changes in the terrain smoothness at a common elevation, geomorphology that resembles ancient shorelines, and the chemical properties of the Martian soil and atmosphere in the Northern Plains region. Mars would have required a denser atmosphere and warmer climate to allow a liquid ocean to remain at the surface[5].

Keywords

Mars ocean, Paleo-ocean, Biology, Shorelines, Water, Climate history.

HISTORY OF THE PALEO-OCEAN CONCEPT

The Mars Ocean Hypothesis was first presented at the July 1986 MECA meeting in Washington DC by John Brandenburg[1] and was an outgrowth of a paper presented at the 1984 Case For Mars II conference in 1984, concerning an investigation of Cydonia, where evidence for a Mars paleo-ocean was also discussed[6]. While the Brandenburg paper proposed a paleo-ocean filling the entire northern plains of Mars, a paper on smaller seas and lakes on ancient Mars was also presented at the same MECA conference by Timothy Parker[7]. The concept of a Martian polar ocean was discussed in the book Life on Mars[8] by David Chandler.

The hypothesis of a large paleo-ocean in the Northern Plains of Mars was made based on observations that the Northern plains of Mars form a large low elevation basin, into which many outflow channels emptied, then contemporary estimates of Mars past water inventory which were approximately enough to form a 400meter deep planetary wide layer, and evidence from apparent water channels that past Mars conditions would allow liquid water on it surface. Since then the Mars Ocean Hypothesis has been the subject of many investigations and has become generally accepted as part of ancient Mars environment.

The concept of extinct oceans in the modern era Mars dates back to the speculations of Percival Lowell in *Mars as the Abode of Life*[9] and was thus engrained in the popular concept of Mars from the beginning of the 20th century. An extinct Martian ocean was further memorialized in Edgar Rice Burroughs John Carter of Mars series of novels and thus became part of a cultural expectation concerning Mars.

OBSERVATIONAL DATA

Support for the Mars ocean hypothesis comes mostly from images from Mars orbiters but also from the Viking and Mars Polar lander soil analyses. Imagery gathered by the Viking orbiters in 1976, revealed possible paleo-ocean shorelines near the pole, Arabia and Deuteronilus regions, these paleo-shorelines are at approximately the 6mB (milliBar) elevation line, the elevation on Mars where liquid water can begin to ex-

ist, and are thousands of kilometers long[10]. Networks of dried channels that merge into larger channels suggest erosion by liquid water, and resemble ancient riverbeds on Earth. Large channels, 25 km wide and several hundred meters deep, seem to have brought water from underground aquifers in the Southern uplands into the Northern plains[11]. Much of the northern hemisphere of Mars is located at a significantly lower elevation than the rest of the planet, this is known as the Martian Dichotomy, and these northern plains have amuch lower in relief than other parts of Mars. This data suggests that water on Mars started out uniformly distributed but eventually drained globally to form an ocean on the lowest elevations, that is, on the Northern Plains.

The Mars Orbiter Laser Altimeter (MOLA),accurately determined in 1999 the relative elevations of all parts of Mars and found that the basin for water flow towards the ocean on Mars would cover three-quarters of the planet[12]. The distribution of crater types below 2400 m elevation in the, probable ocean basin, the Vastitas Borealis plain, was studied in 2005 and was found to be consistent with strong erosion caused by direct vaporization of solid ice. Based on these studies the ancient ocean would have covered approximately ¼ of the planet to a depth of 2 kilometers[13]. The paleo-ocean, here named the Malacandrian Ocean, is seen below on a map of Mars elevations. Elevations below the 6mBarr line, the proposed shoreline of the ocean, are colored blue.

A geophysical model proposed in 2007 by Taylor Perron and Michael Manga found that, after compensations for polar wander caused by mass redistributions from volcanism, the Martian paleo-shorelines first proposed in 1987[1] are consistent with the elevation shifts produced by the volcanism[14]. The model shows the variation of the Martian shorelines "can be explained by the movement of Mars' spin axis".

Delta-like structures have been observed where apparent water channels met the paleo-ocean shoreline. Mars Imagery revealed that seventeen of them are found at the altitude of a proposed shoreline for a Martian ocean[15]. This is consistent if the deltas were all next to a large body of water[16]. Such deltas are consistent with a long-lived liquid ocean, lasting millions of years.

Data from MARSIS, a radar on board the Mars Express orbiter, supports the hypothesis of an extinct

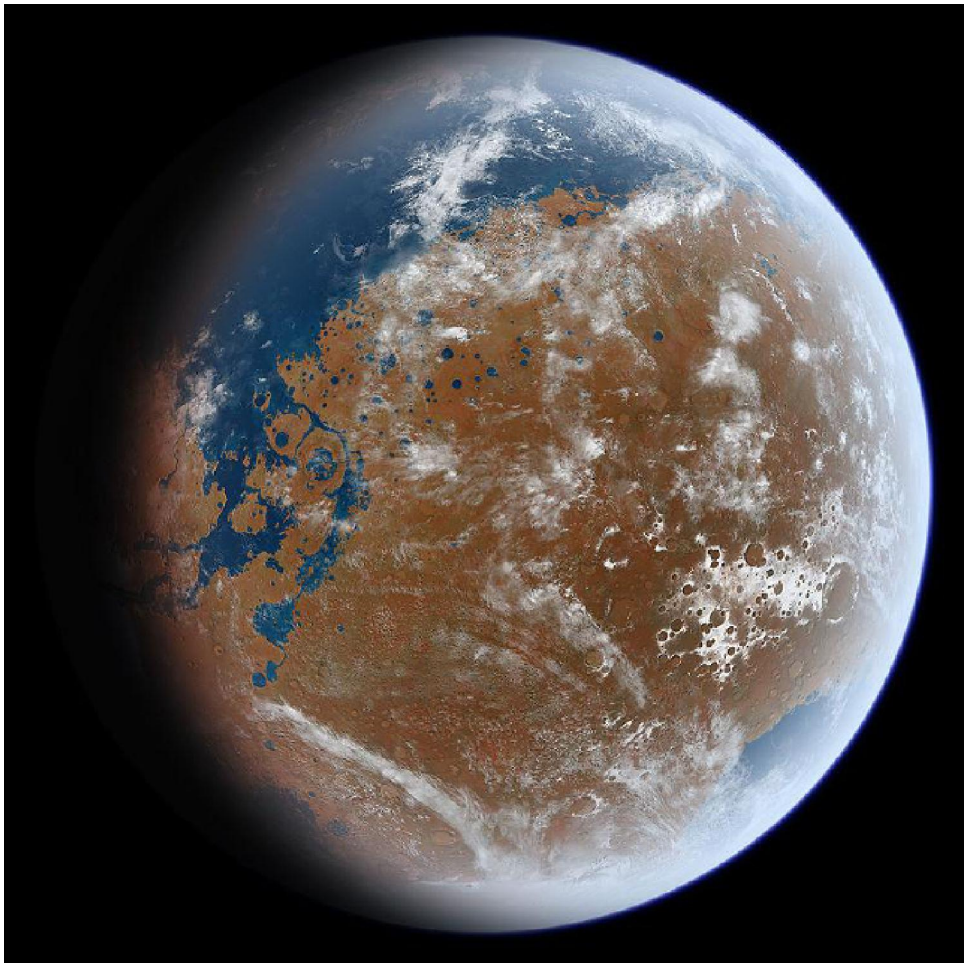

Figure 1 : Mars with its ancient ocean (Ittiz)

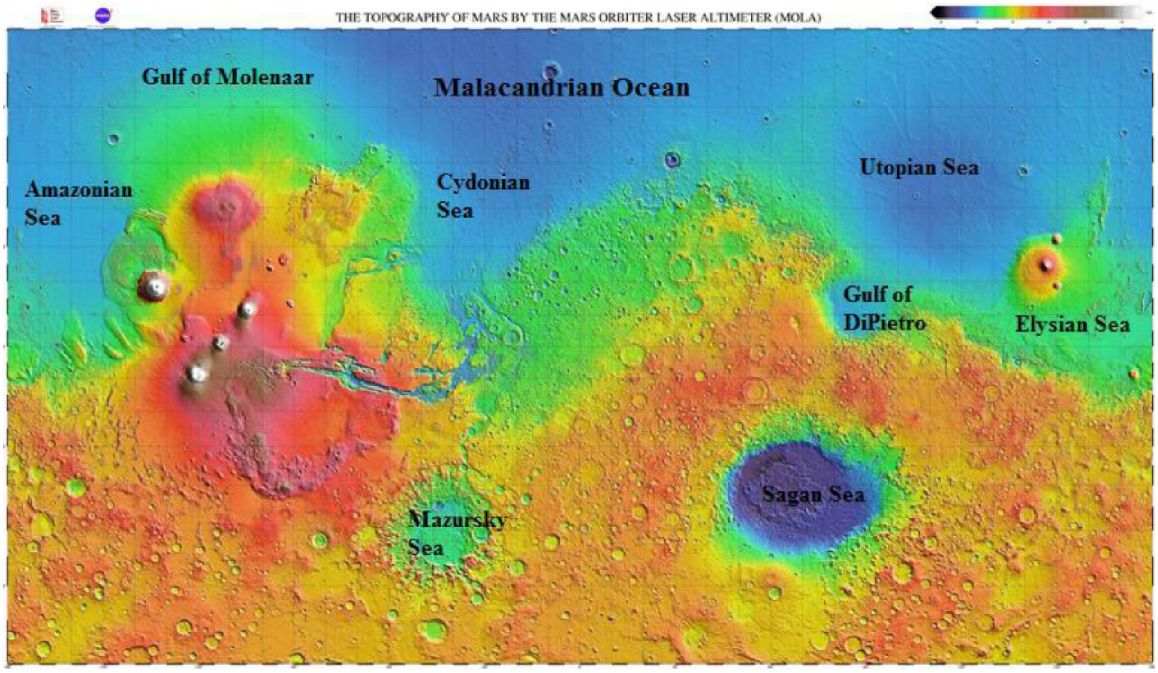

Figure 2 : A Mars topographical map based on MOLA data showing the possible extent of the paleo-ocean in blue proposed names from th author are shown

large, northern ocean. The instrument found a dielectric constant of the surface that is similar to with low-density sedimentary deposits, large deposits of ground-ice, or a combination of the two. The measurements were completely distinct from that of a lava-rich surface[17].

lava-The Viking and Mars Phoenix Polar landers landed on what would have been the bed of the Mars paleo-ocean and found salty, oceanic clays with strongly similar composition despite being widely separated on the planet[18]. The Phoenix Polar lander also found frozen water at shallow depths below the surface[19].

IMPORTANCE TO MARS PAST CLIMATE AND BIOLOGY

The fact that an ocean sat in the north of Mars means that the conditions on Mars had to have been Earth-like in the past. The liquid state of water is one of the most demanding in terms of conditions of pressure and temperature. The presence of liquid oceans on Earth, defines terrestrial conditions of temperature and atmospheric pressure. A liquid water environment is thought essential for biology "as-we-know-it" and thus an ocean on Mars in the past makes life on Mars in the past much more probable. The presence of a liquid ocean also requires an Earth-like hydro-cycle with evaporation, rain and snow around the periphery of a paleo-ocean.

Atmospheric pressure on the present day Martian surface exceeds that of the triple point of water(6.11mBar) only in the lowest elevations, generally in the old ocean basin. At higher elevations water can exist only in solid or vapor form (assuming pure water). Mean temperatures at the surface of Mars are currently less than 210 K(thefreezing point of water is 273 K), much less than what is needed to allow liquid water. However, early in its history Mars may have had more Earth-like conditions that allowed liquid water at the surface.

Early Mars appears to have had a carbon dioxide atmosphere similar in pressure to present-day Earth (1000 hPa)[20]. Despite a weak early Sun, the greenhouse effect from a thick carbon dioxide atmosphere, if bolstered with small amounts of methane[21] or insulating effects of carbon dioxide ice clouds,[22] would have been sufficient to warm the mean surface temperature to a value above the freezing point of water.

A 2009 study of Mars channels found a much higher density of stream channels on Mars surface than previously recognized. The density of channels near the paleo-ocean basin arecomparable to what is found on Earth[23]. The huge number of valley networks is strongly consistent with abundant rain on Mars in the past and thus an Earth-like hydro-cycle. So evidence of not only a Venusian-type planetary greenhouse is seen, but that it raised temperatures enough to have a robust hydro-cycle. Globally, the distribution of the Martian precipitationvalleys is consistent with a large northern ocean since the valleys are concentrated in the north and become less numerous and more shallow as one proceeds south[24][25].

Figure 3 : A possible delta structure on the old ocean shoreline found in the chryse region

The presence of a liquid ocean and hydro-cycle isthus consistent with planetary greenhouse of Carbon dioxide at approximately one atmosphere with perhaps additional gases such as methane. Such a dense atmosphere of carbon dioxide, in the presence of abundant liquid water, could have been reduced by formation of carbonates through weathering[26], however an acidic ocean would have prevented carbonate formation. Mars soil analysis from the landers is consistent with such an acidic ocean[27].

The ocean was believed to have been the original incubator of life on Earth, so the presence of an ocean on Mars is a powerful argument that life had begun on Mars. The watery environment supports and protects life from ultraviolet light and provides a bath of minerals for growth. If Mars had an ocean, then living things probably dwelt in it. The question would be not whether life had begun on Mars, but how long the ocean, and the life in it, had endured.

The presence of an ocean on the Northern plains of Mars, which are the youngest non-volatile surfaces on Mars, indicates, with the presence of many water channels on the ancient highlands of Mars, that liquid water may have been part of the Mars environment from its beginnings until recently in the planet's geologic history. This picture is radically at odds with present concepts of Mars as only having liquid surface water for a brief period after its formation. Thus, confirmation of a Northern Polar ocean may profoundly change the main- stream view of Mars geologic and biologic history.

FATE OF THE OCEAN

Given the evidence of a vastpaleo-ocean on Mars, the fate of the ocean requires mechanisms for its disappearance before the present era. As the Martian climate cooled, the surface of the ocean would have frozen. One hypothesis states that part of the ocean remains in a frozen state buried beneath a thin layer of rock, debris, and dust on the flat northern plains near the northern polar cap[28]. The water could have also sunk into a subsurface cryosphere[2] or been lost to the atmosphere (by sublimation) and eventually lost

to space throughultraviolet photolysis or atmospheric sputtering[29][30].

REFERENCES

[1] Brandenburg, E.John; "The Paleo-ocean of Mars", MECA symposium on Mars: Evolution of its climate and atmosphere, Lunar and Planetary Institute, retrieved 19 February 2014, 20–22 (**1987**).

[2] S.M.Clifford, T.J.Parker; The evolution of the martian hydrosphere: Implications for the fate of a primordial ocean and the current state of the Northern plains, Icarus 154, 40-79 (**2001**).

[3] V.R.Baker, R.G.Strom, V.C.Gulick, J.S.Kargel, G.Komatsu, V.S.Kale; Ancient oceans, ice sheets and the hydrological cycle on Mars, Nature, **352**, 589-594 (**1991**).

[4] The real Mars, by michael hanlon, Carroll & Graf (October 20), 62-71 (**2004**).

[5] Head, W.James et al. ; "Large standing bodies of water in the past history of Mars: Further tests for their presence using MOLA data", AGU Spring Meeting, (**1999**).

[6] The face on Mars, RandolfoPozos, North Atlantic Books, Berkeley California, (**1985**).

[7] Parker, Timothy et al.; "Geomorphic evidence for ancient seas on Mars" MECA symposium LPI Tech.Report, **97**, 87-01 (**1986**).

[8] Life on Mars, David chandler, Clark Irwin and Co. Ltd. Toronto Canada, (**1979**).

[9] Lowell percival, Mars as the abode of life, Mac Millian Press New York, 112 (**1908**).

[10] "Mars probably once had a huge ocean", University of california - berkeley (Science Daily), 13 June, (**2007**).

[11] Read, L.Peter, S.R.Lewis; "The martian climate revisited: Atmosphere and environment of a desert planet", Praxis, Chichester, UK, (**2004**).

[12] D.Smith et al.; Science: 284.1495, (**1999**).

[13] J.M.Boyce, P.Mouginis, H.Garbeil; "Ancient oceans in the northern lowlands of Mars: Evidence from impact crater depth/diameter relationships", Journal of geophysical research (American Geophysical Union) Bibcode:2005JGRE..11003008B. doi:10.1029/2004JE002328. Retrieved 2 October 2010, **110** (**E03008**), 15 (**2005**).

[14] J.Perron, Taylor, X.Jerry; Mitrovica, michael manga, Isamu matsuyama and mark A. Richards (14 June), (**2007**).

[15] G.DiAchille, B.Hynek; Ancient ocean on Mars supported by global distribution of deltas and valleys.nat, Geosci, doi:10.1038/ngeo891, **3**, 459-463 (**2010**),.

[16] DiBiasse, A.Limaye, J.Scheingross, W.Fischer, M.Lamb; Deltic deposits at aeolis dorsa: Sedimentary evidence for a standing body of water on the northern plains of Mars, Journal of Geophysical Research Planets, **118**, 1285-1302 (**2013**).

[17] J.Mouginot, A.Pommerol, P.Beck, W.Kofman, S.Clifford; Dielectric map of the Martian northern hemisphere and the nature of plain filling materials, Geophysical Research Letters, doi:10.1029/2011GL050286, **39**, L02202 (**2012**).

[18] P.Toulmin et al.; Geochemical and mineralogical interpretation of the Viking inorganic chemical results, J.Geophysical Res., **84**, 4625-4634 (**1977**).

[19] S.P.Kounaves, M.H.Hecht, J.Kapit, K.Gospodinova, L.P.DeFlores, R.C.Quinn, W.V.Boynton, B.C.Clark, D.C.Catling, P.Hredzak, D.W.Ming, Q.Moore, J.Shusterman, S.Stroble, S.J.West, S.M.M.Young; Wet chemistry experiments on the 2007 Phoenix Mars Lander Mission: Data Analysis and Results, J.Geophys.Res.: **115**, E00E10 (**2010**).

[20] Carr, H.Michael; Retention of an atmosphere on early Mars, Journal of Geophysical Research, **104**, 21897-21909 (**1999**).

[21] Squyres, W.Steven, James F.Kasting; Early Mars: How warm and how wet?, Science, **265**, 744-749 (**1994**).

[22] F.Forget, R.T.Pierrehumbert; Warming early Mars with carbon dioxide clouds that scatter infrared radiation, Science, **278**, 1273-1276 (**1997**).

[23] "New Map bolsters case for ancient ocean on Mars", Space.com. 23 November, (**2009**).

[24] G.DiAchille, B.Hynek; Ancient ocean on Mars supported by global distribution of deltas and valleys, nat.Geosci., doi:10.1038/ngeo891, **3**, 459-463 (**2010**).

[25] DiBiasse, A.Limaye, J.Scheingross, W.Fischer, M.Lamb; Deltic deposits at aeolis dorsa: Sedimentary evidence for a standing body of water on the northern plains of Mars, Journal of Geophysical Research Planets, **118**, 1285-1302 (**2013**).

[26] A.G.Fairen, D.Fernadez-Remolar, J.M.Dohm, V.R.Baker, R.Amils; Inhibition of carbonate synthesis in acidic oceans on early Mars, Nature, **431**, 423-426 (**2004**).

[27] Greenwood, P.James, Ruth E.Blake; Evidence for an acidic ocean on Mars from phosphorus geochemistry of Martian soils and rocks, Geology, **34**, 953-956 (**2006**).

[28] P.Janhunen; Are the northern plains of Mars a frozen ocean?, Journal of Geophysical Research, **107**, 5103 (**2002**).

[29] Kerr, A.Richard; Is Mars looking drier and drier for longer and longer?, Science, **317**, 1673 (**2007**).

[30] M.H.Carr, J.W.Head; Oceans on Mars: An assessment of the observational evidence and possible fate, Journal of Geophysical Research, **108**, (**2002**).