

## A COLD AND WET MARS

Alberto G. Fairén<sup>1</sup>, Alfonso F. Davila<sup>1</sup>, Luis G. Duport<sup>2</sup>, Esther R. Uceda<sup>1</sup>, Darlene S. Lim<sup>1</sup>, Ricardo Amils<sup>3,4</sup>, and Chris McKay<sup>1</sup>

<sup>1</sup>NASA Ames Research Center, Space Science and Astrobiology Division, 94035 Moffett Field, CA, USA. (afairen@arc.nasa.gov). <sup>2</sup>Dpto. de Geociencias Marinas. Universidad de Vigo. Lagoas Marcosende 36200 Vigo, Spain. <sup>3</sup>Centro de Biología Molecular, Universidad Autónoma de Madrid, 28049-Cantoblanco, Madrid, Spain. <sup>4</sup>Centro de Astrobiología (CSIC-INTA). 28850-Torrejón de Ardoz, Madrid. Spain.

### Introduction

Water on Mars has been explained by invoking controversial and mutually exclusive solutions based on warming the atmosphere with greenhouse gases (the “hot and wet” Mars [1]) or on local thermal energy sources (the “cold and dry” Mars [2]). Both have critical limitations and none has been definitively accepted as a compelling explanation for the presence of liquid water on Mars. In the recent years, several studies have indicated that weathering fluids loaded with high abundances of diverse salts can remain in liquid state for temperatures well below 273 K [3]. Here we consider the hypothesis that cold, hypersaline and acidic liquid solutions have been stable on the surface of Mars under a mean temperature of roughly 250 K and for relatively extended periods of time, completing a hydrogeological cycle in a water-enriched but cold planet.

### Thermodynamic analysis of the Martian weathering fluids

To analyze the evolution of residual liquid water between 280K and 240K, we examined equilibrium models of freezing and evaporation/sublimation processes of a liquid solution. Two different scenarios were modeled, one where freezing dominates over evaporation/sublimation and vice-versa (see figure 1). A fraction of the initial water reservoir remains in liquid state for temperatures as low as 240 K in both scenarios, but when the evaporation/sublimation process is more effective than freezing alone, the available quantity of free liquid water is higher in the range of 260 to 245 K. The lowering of the freezing point is therefore a function of the rate of evaporation/sublimation versus freezing, which in turn determine the ionic activity of the solution. A very fast evaporation (or sublimation) increases more effectively the ionic activity of the solution, and consequently the freezing point reaches lower values. When this happens, a sequence of phase transitions is observed, depending on the saturation equilibrium of the different components in the solution. Some phases, such as gypsum, become unstable at temperatures <260 K, when the

sulfate concentration is very low or due to pH variations, while other phases such as jarosite are favored at those temperatures. This can be used to put constraints on the temperature at which the deposits in Meridiani formed. At temperatures below 250 K, less than half of the initial liquid water has been lost through evaporation/sublimation or entrapment in the crystal structure of the precipitated hydrated salts. However residual water remains in liquid state at these temperatures, supporting the idea of super-cooled water solutions forming valleys and seas on the surface of Mars.

### Conclusions

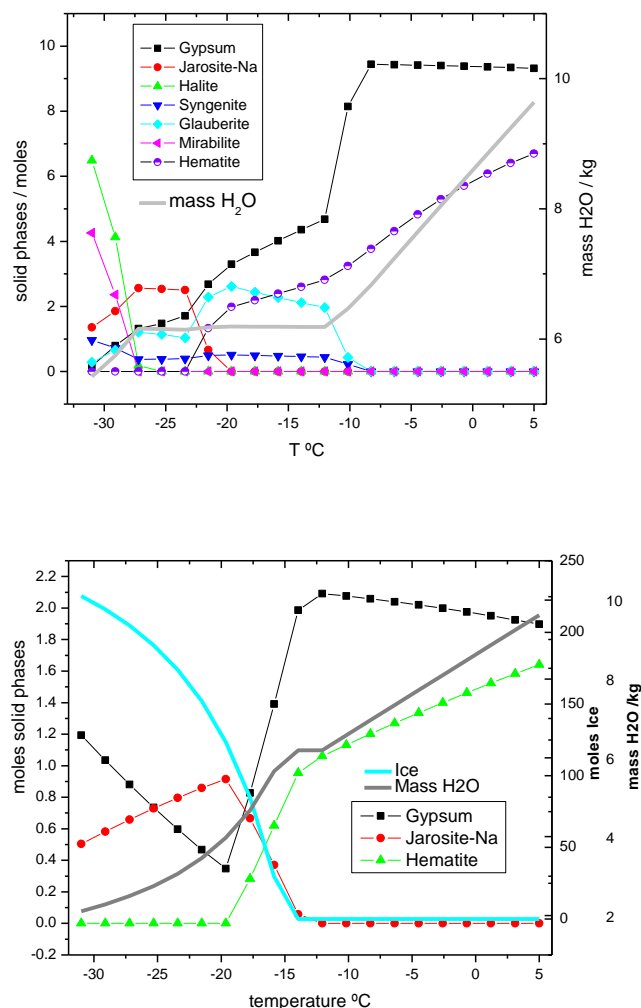
This model can reconcile accumulating evidence for long lasting liquid water on the surface of Mars in the form of oceans or seas, valleys, channels, gullies, deltas, layered outcrops and aqueous-derived mineralogies [4], concurrently with widespread glacier formation [5] and existing climatic models which predict serious obstacles to warm Martian climate [6]. This cold hydrological cycle would have been active only in episodes of dense atmosphere, as having a minimum water vapor partial pressure is essential for water to flow, and local high temperatures (over 250 K) are required to trigger evaporation and snowfall. During episodes with a thin atmosphere and lower temperatures (under 250 K), only transient liquid water can potentially exist on most of the Martian surface. Assuming that surface temperatures have always been maintained below 273 K, Mars can be considered a “cold and wet” planet for its entire geological history.

### References:

- [1] Pollack, J. B., et al. (1987), *Icarus*, 71, 203-224.
- [2] Gaidos, E., and G. Marion (2003), *J. Geophys. Res.*, 108, doi:10.1029/2002JE002000.
- [3] Clark, B. C. (1979), *J. Mol. Evol.*, 14, 13–31.
- [4] Malin M. C., and K. S. Edgett (2003), *Science*, 302, 1931-1934.
- [5] Head, J. W., et al. (2004), *Geophys. Res. Lett.*, 31, doi:10.1029/2004GL020294.
- [6] Colaprete, A., and O. B. Toon (2003), *J. Geophys. Res.*, 108, 5025, doi:10.1029/2002JE001967.
- [7] Fairén *et al.* (2007), The case for a cold and wet Mars. In *Planet Mars Research Focus*. NOVA Publishers, ISBN 978-1-60021-826-2.

**Figure 1:**

Residual water mass in function of temperature in a model of evaporation/sublimation and freezing, followed by continuing freezing down to 240 K. The full suite of iron minerals and salts listed in Table 1 for model simulations at pH = 2.0 and with an assumed initial water mass of 10 kg., resulted in the precipitation of ferric iron as a mixture of jarosite and hematite at very low temperatures. Two different situations of precipitation vs dissolution of salts in combinations of evaporation/sublimation and freezing are presented: in the upper graphic evaporation/sublimation is more effective than freezing, and in the lower graphic is the opposite. The concrete sequence of precipitation and evaporation is very sensitive to the initial concentration in the solution and CO<sub>2</sub> fugacity (assumed here to be 2 bars), but the general trends are similar in a wide range of initial conditions. It is important to note the opposite behavior for the different evaporitic phases (mainly gypsum vs jarosite) and the influence of these behaviors in the modification of the available liquid water mass. Also, these models are kinetic only for the freezing process, as the freezing and evaporation velocities vary, and so the models show different saturation combinations for the different salts through the freezing process.

**Table 1:**

Const.	(soil/rock)
SiO <sub>2</sub> (aq)	(Weight %) 44.7
S	(Weight %) 14.6
Fe <sup>3+</sup>	(Weight %) 19.2
Al <sup>3+</sup>	(Weight %) 9.1
Mg <sup>2+</sup>	(Weight %) 8.1
Ca <sup>2+</sup>	(Weight %) 6.6
Na <sup>2+</sup>	(Weight %) 3.2
Cl <sup>-</sup>	(Weight %) 0.46
K <sup>+</sup>	(Weight %) 0.39
Mn	(Weight %) 0.33
Zn	(ppm) 309.62
Br	(ppm) 112.0
Ni	(ppm) 349.7

Averaged values of soil end member components after recent Martian missions, see [7].