MEMO: MARS ESCAPE AND MAGNETIC ORBITER. F. Leblanc [1], B. Langlais[2], Chassefière E.[1], C. Sotin[2], Barabash S.[3], Dehant V.[4], Dougherty M.[5], Lammer H.[6], Mandea M.[7], and S. Vennerstrom[8], [1]Service d'Aéronomie du CNRS/IPSL, Université Pierre et Marie Curie, Paris, France, [2]Laboratoire de Planétologie et de Géodynamique, Université de Nantes, Nantes, France, [3]Swedish Institute of Space Physics, Kiruna, Sweden, [4]Royal Observatory of Belgium, Brussels, Belgique, [5]Space and Atmospheric Physics, Imperial College, London, UK, [6]Space Research Institute, Austrian Academy of Sciences, Graz, Austria, [7]GeoForschungsZentrum Potsdam, Potsdam, Germany, [8]Danish National Space Center, Department of Solar System Physics, Copenhagen, Denmark.

Introduction: There are several reasons to believe that Mars could have become an Earth like planet rather than the present dry and cold planet. In particular, many elements suggest the presence of liquid water at the Martian surface during a relatively short period at an early stage of its history. Since liquid water may have been the birthplace for life on Earth, the fate of Martian water is one of the major keys and yet unanswered question to be solved.

Mars' chronology has been recently updated thanks to the IR measurements by Omega on board Mars Express [1]. The identification of phyllosilicates in the oldest terrain and of hydrated sulphate deposits lead these authors to suggest a Martian history in three main era, one wet phase at the very beginning of Mars during which most of the atmosphere has been lost either by hydrodynamic escape or following large meteoritic impacts, a second volcanically active period during which a small few hundred millibars of acidic atmosphere formed and a third period almost completely dry which lasts up to present time (see Figure 1) and leads to the formation of the anhydrous ferric oxides which cover the present Martian surface.

Atmospheric escape: During these two last periods, atmospheric escape to space was possible following different mechanisms and favored by the lack of magnetic shielding. This scenario highlights the importance of the global change, which occurs during the formation of Tharsis. It suggests also that the present atmosphere is either the residual of the atmosphere which formed at that time or the residual of a period of strong outgassing which occurred few tens of million years ago or the product of the present equilibrium between present outgassing and loss to space. On the other hand, the compared analysis of volatile inventories of the Earth, Venus and Mars strongly suggests that CO_2 and N_2 mostly escaped to space. Inventories of Venus and Earth are indeed similar (taking into account the CO_2 contained in carbonates on Earth), and Mars presents the same CO_2/N_2 ratio (≈50). But the absolute amounts of the two gases, normalized to the total mass of the planet, are depleted on Mars by a factor 3000 with respect to Earth and Venus. The natural outcome of the similarity of the CO_2/N_2 ratio on the three planets and of the strong depletion of these species on Mars is that escape to space is the most likely candidate for explaining the gradual dissipation of the Martian atmosphere [2]. If this conclusion were correct, it would also imply that the Martian present atmosphere might have reached equilibrium between escape and outgassing.

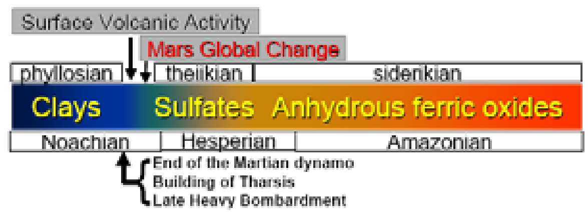

Figure 1 – Global evolution and main events of the Martian chronology. The horizontal axis is for the time up to present (from the beginning of Mars' history around 4.7 Gy ago). The timing of the end of the dynamo is 4.1±0.2 Gy.

Past escape and dynamo history: Any consideration of a past atmospheric escape is limited by our present ignorance of the exact timing of the onset and the end of the dynamo. Indeed the present uncertainty of this timing [3] has strong impact on the total amount of Martian atmosphere that could have escaped during Mars' history [2]. Mars Global Surveyor (1996-2006) detected magnetic field anomalies that are not homogeneously distributed over the entire surface of Mars [3]. At 400 km altitude, the radial field ranges between +/- 250 nT (Fig. 2), which is one to three orders of magnitude larger that what is commonly measured on the Earth (as far as the lithospheric field is concerned). Most of the anomalies are located South of the crustal dichotomy, a limit separating the northern and smoothed lowlands from the southern and very cratered highlands. The largest volcanic edifices (Tharsis, Elysium, Olympus) as well as the largest impact basins (Hellas, Argyre, Isidis) are devoid of significant magnetic anomalies at satellite altitude. The magnetic signature of the Martian lithosphere is very likely due to an ancient earth-like dynamic magnetic field. It occurred in the early stages of Mars, probably during the first 0.5 Gy, between the accretion of Mars and the formation of the Hellas, Argyre, and Isidis impacts. However, the precise timing of the dynamo remains imprecise, as it depends of our ability to correctly study the correlation between large (>100 km) impact craters and their magnetic signature. Current models are not accurate enough to study such correlations.

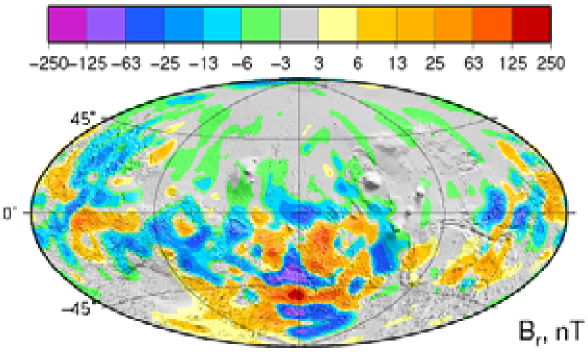

Figure 2 – Radial magnetic field predicted at a constant altitude of 400 km form an equivalent source dipole model [4].

In addition, ion and neutral escapes are highly dependent on the EUV flux as underlined for the ion escape in the previous section. Actually, this conclusion is essential since the past EUV flux is thought to have been up to 10 times larger, 4.1 Gy ago, [4] whereas the solar wind flux may have been up to 100 times larger 4.1 Gy ago [5]. Neutral escape induced by sputtering is thought to have been dominant in the past [2]. But there is considerable uncertainties and controversy on the relative importance historically of any of these losses [6]. Based on present knowledge of escape processes on Mars, there appears to be a large disparity between the escape rates of O and C [7]. If, as seems likely, a predominantly CO_2 atmosphere appeared within the first few hundreds Myr after the formation of the planet and during short episodes [8], Mars should have lost several tens meters of water over geologic time [9].

A new orbiter: Mars Escape and Magnetic Orbiter (MEMO) is a low periapsis orbiter of Mars devoted to the measurement of present escape and the characterization of the fossil magnetic field of Mars. The use of a low periapsis altitude orbit (120-150 km) is required to detect and quantify all populations of atoms and molecules involved in escape. It is also required to measure the magnetic field of Mars with an unprecedented spatial resolution that would allow getting a more precise timing of the dynamo and its disappearance.

Achieving a full characterization of atmospheric escape, and extrapolating it back to the past requires:

(i) to measure escape fluxes of neutral and ion species, and characterize the dynamics and chemistry of the regions of the atmosphere where escape occurs (thermosphere, ionosphere, exosphere), as well as their responses to solar activity, and

(ii) to characterize the lateral variations of the magnetic field of lithospheric origin, and by extension, the timing of the Martian dynamo. Of particular interest is the extinction of the dynamo that is thought to have enhanced the atmospheric escape processes still operating today.

The proposed low-periapsis orbiter will consist of the following elements:

An "Escape Package" to characterize by both in-situ and remote measurements the thermosphere, ionosphere, exosphere and solar wind interaction regions (from one hundred to several thousand km), including thermal, suprathermal and energetic particles.

A "Magnetic Field Package", to characterize the magnetization of the lithosphere, and in particular the contrasts between magnetized and demagnetized areas, which cannot be accomplished with the present MGS coverage. This package will also serve for the characterization of escape processes.

A "Preparing to Aero-assistance Package", to measure atmospheric and meteorological parameters (density, temperature, wind) in the aerocapture region (which extends down to about 40 km altitude), to allow physical 3-D fields of parameters from the middle atmosphere up to the high thermosphere to be built.

A mission like MEMO would ideally complete the present European program for the exploration of Mars by contributing to our understanding of what has made the Earth suitable for life and not Mars.

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