WHY HAS MARS UNIQUELY PRESERVED THE RECORD OF ITS EARLY (POSSIBLY HABITABLE) TIMES? J.-P. Bibring[1] and F. Forget[2], [1]IAS, batiment 121, 91405 Orsay Campus, France, bibring@ias.u-psud.fr, [2]LMD, Paris, France.

Introduction: A variety of ancient structures, in heavily cratered terrains, are witnesses of events that took place in the Noachian era, more than 4 billions years ago. The mineralogical History of Mars, determined on the basis of OMEGA/Mars Express hyperspectral data [1], proposed that a large scale aqueous alteration took place prior to the Late Heavy Bombardment (LHB), with thick layers of Mg/Fe smectites the prime mineralogical outcome, eventually followed by transient episodes of further alteration, towards Al-rich phyllosilicates. In the search for sites preserving this earliest record, Marwth Vallis was identified as an optimized site, for having kept the most ancient stratigraphic record, with Al-rich layers on top of Mg/Fe-rich phyllosilicates: it would thus constitute a unique - possibly in the entire solar system –opportunity to decipher the geological, climatic and environmental evolution of Mars, over the first hundreds of millions years that followed its formation [2]. Rather uniquely at Mars, Marwth Vallis constitutes an extended area, hundreds of km large, in contrast with the small size of most spots exhibiting ancient hydrated minerals. This could result from the fact that Marwth Vallis has not been thoroughly remobilized by the impact gardening of the LHB. In this paper, we present the first GCM results of an investigation done to evaluate the possibility that Marwth Vallis could have been protected by km-thick layers of ices during this long-lasting (tens to hundreds millions years) episode.

Early Mars shape model: up to now, no attempts had been made to run Mars global circulation models (GCM) with a simplified surface topography mimicking that expected to precede the LHB: for this study, we set as the only large topographic feature the dichotomy (see figure 1). No basins were included, as they are supposed to have originated later, at < 4.1 By, from impacts related to the LHB. Figure 2 illustrates the latitude/longitude dependence of the boundary layers (black lines), that best fit the present topography of the dichotomy (blue lines). In a further study, the present day 6 km N/S altitude difference will be increased to > 8 km, to account for its plausible value prior to its lava infilling.

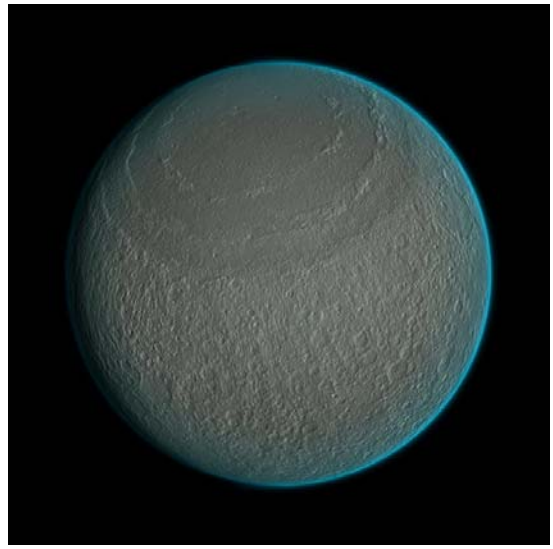

Figure 1: artist view of Mars following the formation of the dichotomy, illustrating to the surface topography considered in the present study.

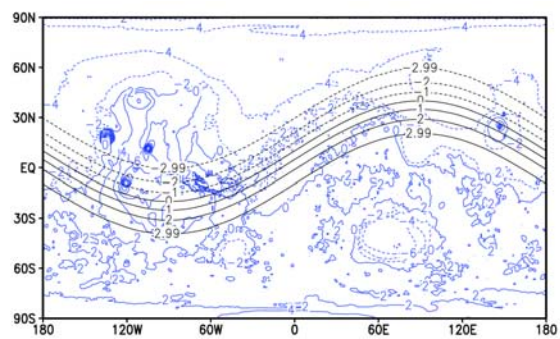

Figure 2: latitude/longitude level lines taken in this study (black contours), as the best topographic fit with the present dichotomy. The present day topography is shown in blue.

The fate of water ice: We performed GCM simulations with this surface configuration, with the goal of identifying the potential sinks of condensed water (ice), at different obliquities. We used a version of the LMD GCM recently adapted to simulate early Mars conditions and which includes a detailed radiative transfer model using revised CO_2 gas collision induced absorption properties, a parameterisation of the CO_2 ice cloud microphysical and radiative properties [3], and a self-consistent representation of the water cycle,

with atmosphere–surface interactions, atmospheric transport, and the radiative effects and H_2O gas and clouds taken into account [4]. In this study, we used the ice equilibration algorithm developed by [4] to predict where the ice tends to accumulate after several hundreds of years.

Figure 3 presents the distribution of water ice at the end of a simulation assuming a mean CO_2 pressure of 0.8 bar, an obliquity of 45° (likely on early Mars), a circular orbit, and a solar luminosity set to 75% of its present value. As one could have expected, water ice condenses primary in the poles, and over the flanks of the dichotomy . A major result is that the slopes over the dichotomy are not ice covered uniformly; preferred spots span over longitudes close to the Marwth Vallis area, as a result of the longitude dependence of the dichotomy itself. The simulation conducted with the 6 km altitude difference shows a maximum of deposition at longitudes slightly higher than those of Marwth Vallis. However, it is expected that when the altitude difference will increase, in order to better simulate the pre lava infilling situation, an even better match with Mawrh Vallis will be met.

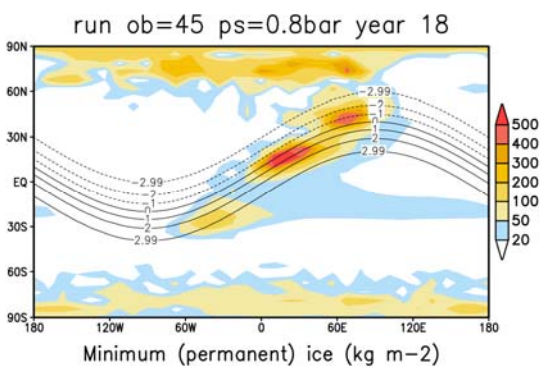

Figure 3: plot illustrating water ice deposition with a 45° obliquity, in two major types of sites: over the polar caps, and along the dichotomy slopes with an increased thickness at longitudes close to Marwth Vallis.

Discussion: It was argued along the past years that Mars unique role in comparative planetology, primarily due to its size, was to have recorded most steps of inner planet evolution, from its formation till its geological death. However, no validated explanation could be presented, as to the reason why it had also preserved terrains modeled prior to the LHB, without having been severely gardened. The present study offers a plausible explanation of Mars unique role, to enable retrieving the conditions that prevailed over the first hundreds of millions years after it formed. The fact that terrains preserving such ancient conditions is fundamental. This early period is the most favorable for Mars to have harbored habitable conditions: Mg/Fe smectite formation occurred at a planetary scale, recording conditions with liquid water playing a major role. If life emerged elsewhere than on Earth, and/or if prebiotic chemistry took place, these terrains are likely the most favorable to have kept the record; moreover, they could be the best representatives of the sites and environmental conditions that occurred on Earth, also prior to the LHB, where and when life might have emerged, on ancient terrestrial long standing bodies of water. The very specific Mars surface topography, which kept the dichotomy as the major relief and obstacle to atmospheric circulation, may have enabled thick layers of ice to protect the underlying stratigraphic and mineralogical record against the LHB gardening. Marwth Vallis truly constitutes a unique site, in the entire solar system, as a unique window to the most ancient, and possibly most fascinating terrains, in which records of life emergence are preserved.

References: [1] Bibring J.-P. et al. (2006) *Science 312*, 400-404. [2] Bibring J.-P. (2011), Overarching questions related to the formation of units at Marwth Vallis, *5th MSL Landing Site Workshop*. [3] Forget F. et al. (2013), *Icarus 222*, 81-99. [4] Wordsworth R. et al. (2013) *Icarus 222*, 1-19.