MARS EVOLUTION AND HABITABILITY: THE EVOLUTION OF PARADIGMS. J-P. Bibring, J. Carter and F. Poulet, IAS, Bâtiment 121, 91405 Orsay Campus, France, bibring@ias.u-psud.fr.

Introduction: Following the identification of hematite by TES on board the NASA MGS mission [1] as first witness of ancient chemical aqueous alteration at Mars, the discovery of aqueously formed minerals by OMEGA/Mars Express (MEx) [2,3] further refined by CRISM/MRO [4] and that of sulfates by Opportunity [5], have triggered a profound revisiting of Mars History based on mineralogy [6]. An ancient era during which liquid water was likely stable at the surface or within its sub-surface was exhibited, within sites having preserved these records, identified, characterized and located. Noticeably, they were spread over the ancient cratered terrains, rather than within the reddish areas once considered having been oxidized by liquid water. A critical paradigm was being challenged.

The potential for Mars to have hosted habitable conditions was reactivated in a profoundly revisited frame; the possibility to search for witnesses through in-depth *in situ* characterization drove the objectives of the Mars missions launched afterwards. These missions, together with the still operating MEx and MRO, have drastically enlarged the scope of the alteration history of Mars: a wide diversity of altered phases has been identified, translating the evolution of Mars environment along the first billion years. A number of key steps have been identified, among which a global climatic change, with the associated escape of most greenhouse gases, and transients aqueous episodes of various levels, accounting for some of the diversity of altered minerals identified.

With Mars evolution profoundly revisited, fundamental paradigms are being challenged, which a special emphasis on those related to the question of the "emergence" of life on Earth, at Mars and beyond; with a direct outcome on an even more critical one: at what scale, in time and space, is Earth unique ?

Genericities and contingencies: The search for records of Mars habitability translates the long standing belief that life emergence is a generic step in cosmic evolution, provided a number of conditions are met, with the presence of long standing bodies of liquid water a prerequisite. The discovery, primarily through that of phyllosilicates, that ancient Mars environment might have harbored liquid water has thus be seminal. However, a key outcome of the solar system exploration is the degree of diversity which characterizes the solar system bodies, as does the identification and characterization of exoplanets and stellar systems, both wholly unexpectedly. The deciphering of the complex sequence of processes that has driven their evolution advocates for a totally distinct view, emphasizing the key role of contingency to account for the diversity revealed.

As examples, the very specific migration of Jupiter and Saturn, while the protoplanetary disk was still present, is now viewed as having played a major role in shaping the distinct planet evolutionary pathways, as did the subsequent giant impacts, each with its specific parameters. Beyond the formation of the Moon with its major effects on Earth climate evolution, the Moon forming impact influenced a number of other key effects, including the formation of oceans, and the degree of hydration of the outer layers which in turn shaped the very specific plate tectonics. Planet migration and giant impacts are thus exemplary of generic processes, operating at a large scale in space, but with highly specific – contingent – forms which may well constitute the actual drivers of the diversity of evolution.

Similarly, multiple contingencies paved the chemical evolution of C-rich compounds which ended up in "living species", from the collapse of the dense protosolar cloud, the collisional and turbulent building of cometary-like bodies irradiated by the young Sun, the potential immersion of some of them in terrestrial water, at specific temperature, pH, content in cations and other catalyzers, which define the Earth early habitability; beyond the sole presence of water.

Until recently, all these steps were viewed as generic, essentially similar from one site to the next, accounting for the "plurality of worlds" which dominated one's vision of cosmic evolution over centuries. With contingency now taking over genericity, these paradigms are presently being violently shacked, with an urgent need for observational validation; Mars exploration is central, and the upcoming missions at its epicenter.

New addresses: **from global processes to local habitats:** To which extent can the processes that led to "enabling long lasting standing bodies" of water with specific properties, on Earth in its ancient past, thus further hosting the chemical evolution towards living structures, have taken place at Mars? On Earth, the specific Moon-forming giant impact is likely to have played a key role in the formation of stable oceans. In contradiction to the "last veneer" input of volatiles, it seems, most water and organics were likely brought within the inner solar system during the turbulent early dynamics, from comet-like and/or asteroid-like bodies, during the proto-planet accretion. The subsequent giant impact, given its properties (relative mass ratio, geometry, etc…) triggered a global magma ocean, the cooling of which would have raised water in part to the surface, where the thermodynamic conditions, shaped by the impact, favored the stability of liquid water. Under such scenario, the initial organics trapped in the bulk were in part transformed and diffused as atmospheric CO_2. At Mars, both surface and global properties favor a scenario in which the largest impact, given its contingent properties, would have driven distinct effects - notwithstanding other contingent events. In such a scenario, the moons which potentially formed would be much less massive, with no obliquity stabilization effects. The impact triggered magma ocean would be limited to the outer layers, and the rise of both water and CO_2 much reduced: most of the initial inputs would still be stored deep inside Mars, and never show-up at the surface. This could account for both a limited and highly specific water history and a tenuous CO_2 atmosphere.

However, the discovery of pervasive Martian Fe/Mg phyllosilicates which formed at a planetary scale, over tens to hundreds meter in depth, advocates for ancient surface or subsurface standing water; it may have been seeded as on Earth with similar contingently-formed organics from exogenous input. Was Mars environment, along its ancient past, at least locally in time/space, sufficiently similar to the Earth habitable one to enable the chemical evolution of these exogenous organics towards enabling structures similar to those which initiated the terrestrial living tree?

New paradigms, new missions: The vast onset of data acquired now, both remotely and *in situ*, offers to scrutinize and constrain the evolution of Mars environment over its first billion years, with a special focus on the potential for Mars to have harbored “habitable” conditions at given steps.

Specifically, the huge diversity of altered minerals identified at Mars surface, in hundreds of thousands spots [7], when placed within their geomorphological context, translates the time-evolution of Mars History, so as to challenge the potential coupling of increased diversity and enhanced habitability.

We shall present, review and discuss most of the findings of relevance, as a contribution of the upcoming Mars missions: NASA/Mars 2020, ESA/ExoMars, China/HX1, JAXA/MMX, MSR and followers...

Specific outcomes will be to identify favored evolutionary steps with respect to Mars having harbored habitable environments, and to specify types of bio-relics potentially preserved and detectable.

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