WAS LIFE DISCONTINUOUS ON MARS ? GEOLOGY AND EXOBIOLOGY ARGUMENTS, **N.A CABROL, C.P. MCKAY, and E.A.GRIN,** ***NASA Ames Research Center, Space Science Division, Moffet Field, CA 94035-1000***

Water is defined as a key-element for the inception of Life. Considering that the pre-biotic environments of the Earth and Mars were probably sufficiently similar **[1]**, the fluctuant parameter for the apparition and development of Life appears to be the duration of a favorable environment **[2]**.
Considering the various studies in biology and ecosystems, its seems that numerous microbiota can develop in extreme or reduce environments on Earth, as for examples the endolithes of the Antarctica Dry Valleys **[3]**, bacteria in evaporites **[4]** - in halite and gypsum cristals - , development of microorganisms in smectites clays **[5]**, and the wide proliferation of microbial populations in thermal springs environments **[6]**.
All these environments existed once on Mars, at various epochs, and perhaps still today for some of them. The aim of our study is to show that Life could have been developed on Mars, not only at the Noachian period nearly at the same time that it appeared on the Earth, but probably during the following geological periods until Amazonian. Our model is based on ecosystem environments, and different fields of arguments :

Geomorphic evidences : aqueous sedimentary basins and waterlain sediments **[7,8,9]** ; formation of clays materials **[10]** ; formation of fluvial valleys close to volcanic edifices suggesting hydrothermal processes and thermal springs, even recently **[11]** ;
Dynamics and evolution of martian atmosphere and climate. The cases for a Mars Wet and Warm, Wet and Cold, Dry and Cold were envisioned with implications on ecosystem-types developments ;
Correlation of geomorphic evidences and dynamical models to establish the variations of the locations of the ecosystems and their related biota at various epochs, and their present conditions.

In one hand, geomorphic evidences suggested that paleolakes, depressions, and topographic lows could have been the receptacles for large amount of water and sediments which provided to those sites the best and various potential niches during ancient times **[9]**. In another hand, thermal springs of the equator provided the younger potential oases, geologically very close to us. These two types of sites are probably the best candidates for future exploration of Mars. One of the main arguments for the waterlain sediments is that they are obvious at the valley mouths and that the erosion of cemented material will provide unique occasion to have an in situ stratigraphy. In addition, we know from Earth that miroorganism activity -such as stromatolite-type- could be identified even after 3.5 billion years. This type of site can give the theoritical opportunity to find transitional ecosystems and various species related to times and climates and/or local condition modifications, which could provide a beside way to learn about fluctuations on Mars through geological epochs. Concerning the thermal springs, they are known to be spectroscopically identificable from space by their chemical composition. In addition, fossiles of terrestrial thermal spring bacteria communities were identified as old as 0.3 Gy, datation which could be compared to the oldest possible relative datation for the latest activity for Tharsis.

Considering our current knowledge of the planet History, Mars could have develop potential exobiology niches at various epochs, until close to the present. One more argument is that we know from Earth that water and volcano vicinities are the best niches for Life. Whatever were the fluctuations of the martian climates and atmosphere dynamics, we have geomorphic evidences that water and heat -heat meaning here internal heat from hot spots and volcanoes- were always linked on Mars : during Noachian, water flood on craterized uplands and the main volcanic activity was on the craterized uplands ; during Hesperian and Amazonian, volcanism was concentrated on the equator with Tharsis and Elysium, and the hydrology was centered on these regions giving chance for Life to develop.

Meanwhile there are arguments for development of oases even in the last 500 millions years on Mars, we know that conditions are currently unsuitable for life at the surface of Mars. That is why, the tentative modeles are orientated towards a subsurface Life development. This type of potential Life and ecosystem-related is generally assumed to be close to endolithes analogs **[3]**.

It is important to consider that none of the previously quoted presumed ecosystems could have evolved in time and resist to climatic/dynamic variations and to destruction by erosion/resurfacing in the same way. From this constatation, we established a classification of sites and types which appeared necessary in the perspective of future Exobiology investigations of the planet Mars, considering three types :

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1- PPL type : Potential Past Life, but ecosystems destroyed. Such type is not suitable for investigation and remain a theroritical potentiality. One example of PPL could be thermal spring oases on the craterized uplands during Noachian, which traces could have been erased by erosion or resurfacing through geological times.
2- PPF type : defined as Potential Preserved Fossiles in situ, suitable for exobiology investigations. This type is the main target for a first generation of exobiology experimentation in current knowledge. The PPF type is related, as examples, to fossiles such as bacteria communities in amazonian thermal springs, and stromatolites in waterlain sediments of Noachian/Hesperian transitional period.
3- PCE type : Potential Current Ecosystems, mainly related to the subsurface ecosystem model, also suitable for exobiology in first generation exploration but considering but could require more data, and a new remote sensing of Mars, with more resolution, such as the one provided by Mars Global Surveyor.

We summarized the ecosystems and related data in the following table :

Table : Typology of potential Life types

Site	Location	Ages	Biota >	Current conditions
1- Lakes	Eq/mid lat*	N*	Stromatolites	PPF
2- Evaporites	Eq/mid lat	H	Bacteria	PPL
3- Valley wall and floors	Eq/mid lat	H	Endolithes	PPF
4- Thermal sp.	HCU	N	Bacteria com.	PPL
	Tharsis/Elysium	H	Bacteria com.	PPL/PPF ?
	Tharsis/Elyisium	A	Bacteria com.	PPF
5- Clays	need water	N	Bacteria com.	PPL
	need water	H	Bacteria com.	PPL
6- Wet envir.[t]	high lat.	A	endolithes	PPF/PCE ?
	Solis Lacus [12]	A	endolithes	PPF/PCE

* **Keys of symbols :** Eq= equator ; mid.lat= mid. latitudes ; N, H, A= Noachian, Hesperian, Amazonian ; HCU= Heavily craterized uplands ;

> Assumed martian analogs to quoted biota

As a conclusion our model shows that Mars could have experienced different biogeneses independantly, with different ecosystems. They could have several starting points and extinctions at same epochs in various sites, at different epochs at same or different sites, and these different biogeneses are well sustained by geologic and dynamics evidences. In addition, we can say that we have currently an amount of informations from various disciplines such as geology, geomorphology, exobiology. microbiology, radar, which allow us to envisione that Life once appeared on Mars and could be still present. This probability is no negligible but new data are now necessary for further steps, and the next one is an exobiology mission in situ.

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