EVALUATION OF EXTRATERRESTRIAL LIFE ORIGIN BASED ON EXTREME ENVIRONMENTS EVIDENCE

Miguel Fernández Martín

UAB Universitat Autònoma de Barcelona

Genetics Bachelor's degree 2020/2021

INTRODUCTION

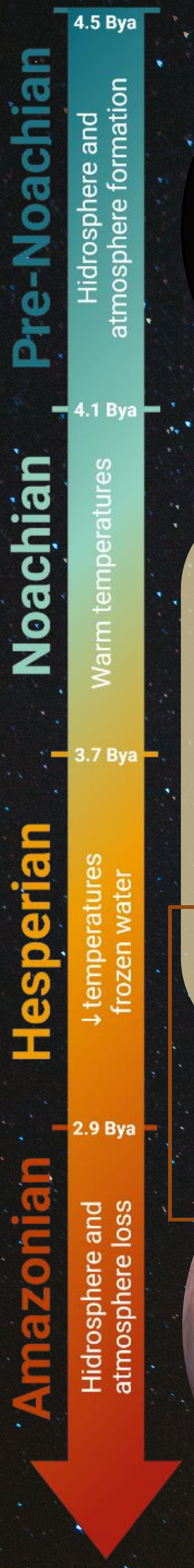
Life arose on Earth between 4.6 and 3.5 billion years ago (oldest fossil record) [1], when the planet displayed massive, tempered (-2-50ºC) water bodies, with pH values relatively neutral (6-7), as well as mainland territory (0-50ºC) [2]. Several celestial bodies show similar characteristics, however, Mars accessibility encourages research to focus on its study. Since 1960, different space agencies have devoted missions to investigate Mars' conditions and potential habitability. These missions concluded that, in the past, 20% of the Red Planet was covered in water, essential for life to originate, at a life-permissive temperature [3]. Upcoming missions are aimed to evaluate the presence of **biosignatures** that reveal ancient biological activity. The study of **extreme environments** on Earth allows international agencies to choose an adequate location for current (e.g., *Perseverance Rover*) and future (e.g., *Rosalind Rover*) missions in their endeavour to find life on Mars.

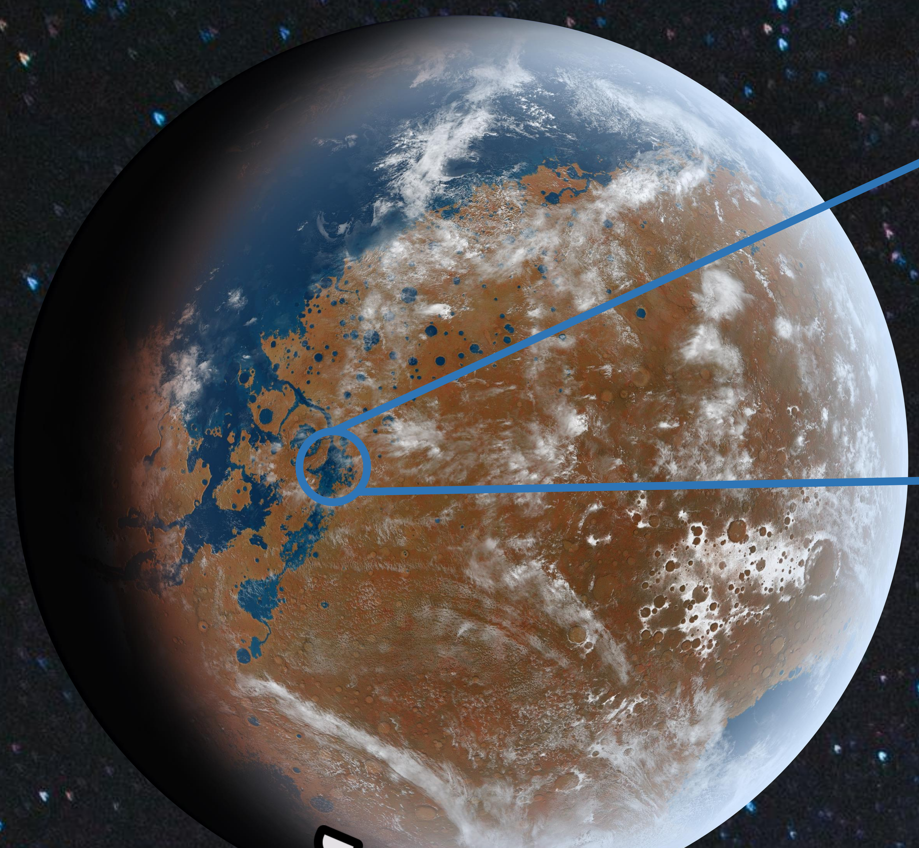
MATERIAL & METHODS

Resources: NASA, ESA, CAB, LCOGT, Space.com, Marspedia.org
Search engines: NCBI, PubMed, GoogleScholar
Keywords: Mars, Earth, Biosignature, Extremophiles, Analogue
Logical operators: AND, OR, NOT

OBJECTIVES

1) To assess the possibility of **extraterrestrial life existence** from the study of terrestrial **analogue environments**.
2) To evaluate how the finding of life would illuminate the question about its **origin on Earth.**





ACIDIC IRON-RICH WATER BODIES

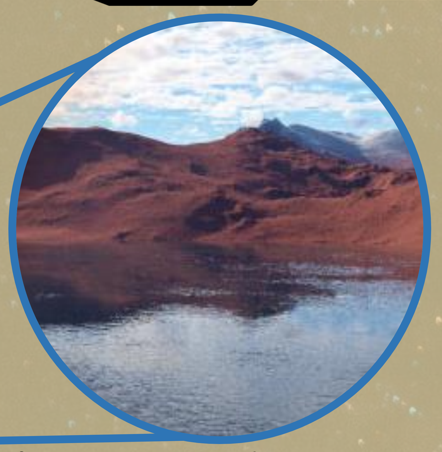


Figure 1. Artist's impression of Noachian's Martian surface at *Sinus Meridiani.* Credit: NASA's Goddard Space Flight Center.

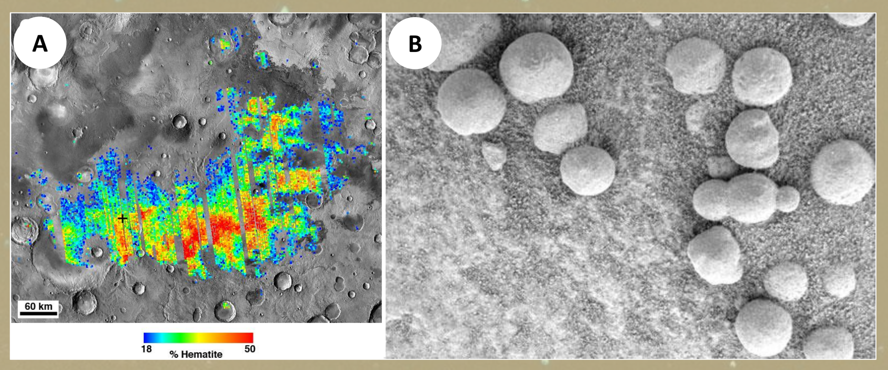


Figure 2. Martian hematite. (A) *Sinus Meridiani* hematite deposits captured by TES. (B) Sphere-like grains or "blueberries" composed of dark grey hematite in *Sinus Meridiani* [4].

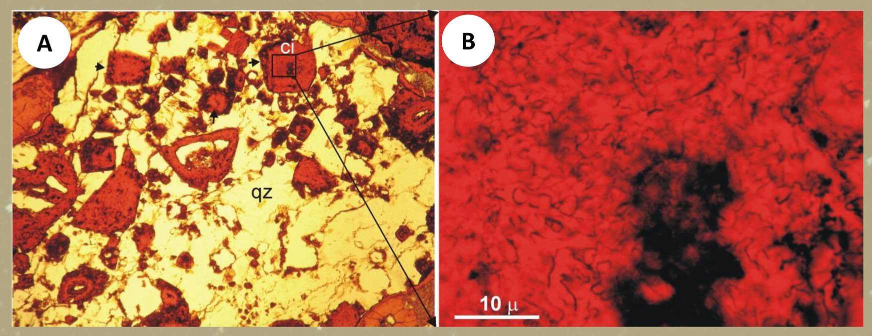


Figure 3. (A) Cuboidal structures filled by iron oxides retrieved from Rio Tinto Basin. (B) High magnification view of a cuboidal feature in (A), showing a high density of microbial filaments fossilized within a translucent iron oxide matrix [5].

Hematite (Fe_2O_3) formations in the Rio Tinto Basin preserve fossilized textures that indicate the presence of past organisms that enabled the deposition in the first place (Figure 3). Hematite deposits in Mars (Figure 2) seem to have been formed similarly to those on Earth, suggesting a shared biogenic origin and an akin form of indirect preservation.

Figure 4. Acidic iron-rich water in Rio Tinto, Spain. Note the red coluor due to the iron oxide high content. Credit: CAB-INTA

SUBSURFACE

Biological alteration produces conspicuous micron-scale granular and tubular textures in basaltic materials (Figure 6), such as those found in Mars' subsurface [6].

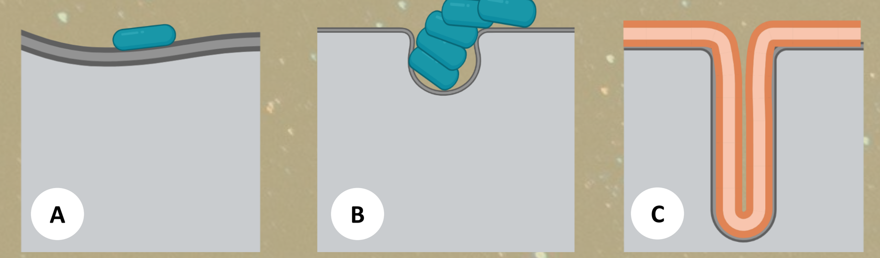


Figure 5. Basalt biological alteration. (A) Colonization of volcanic glass by a microbial cell (e.g., *N. friedmannii*). (B) Glass dissolution and formation of a cavity. (C) Preserved microtubule formation by Fe_2O_3 coating.

Figure 6. Tortuous tubes emanating from a crack in western Atlantic crust [6].

Figure 7. Subsurface terrestrial habitats as analogues for Martian subsurface. (A) Llullaillaco volcano (Atacama, Chile). (B) McMurdo Dry Valleys (Antarctica). Credit: National Science Foundation

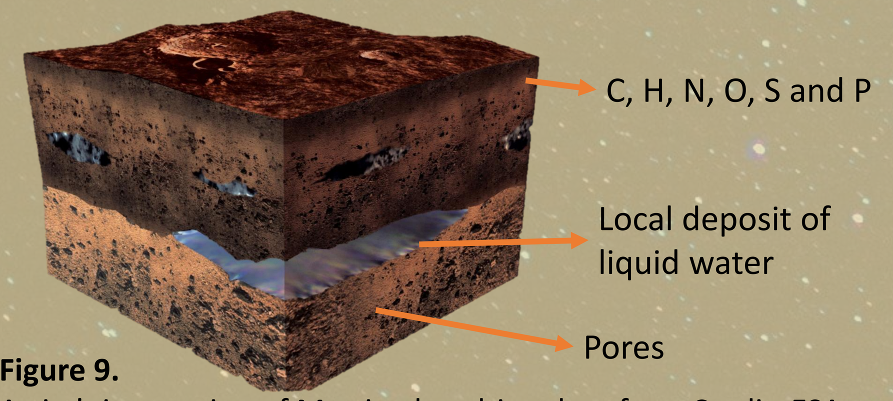


Figure 9.
Artist's impression of Martian basaltic subsurface. Credit: ESA

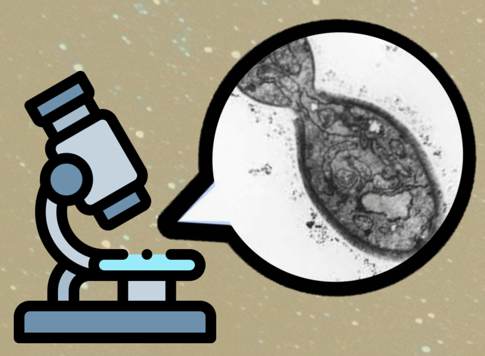
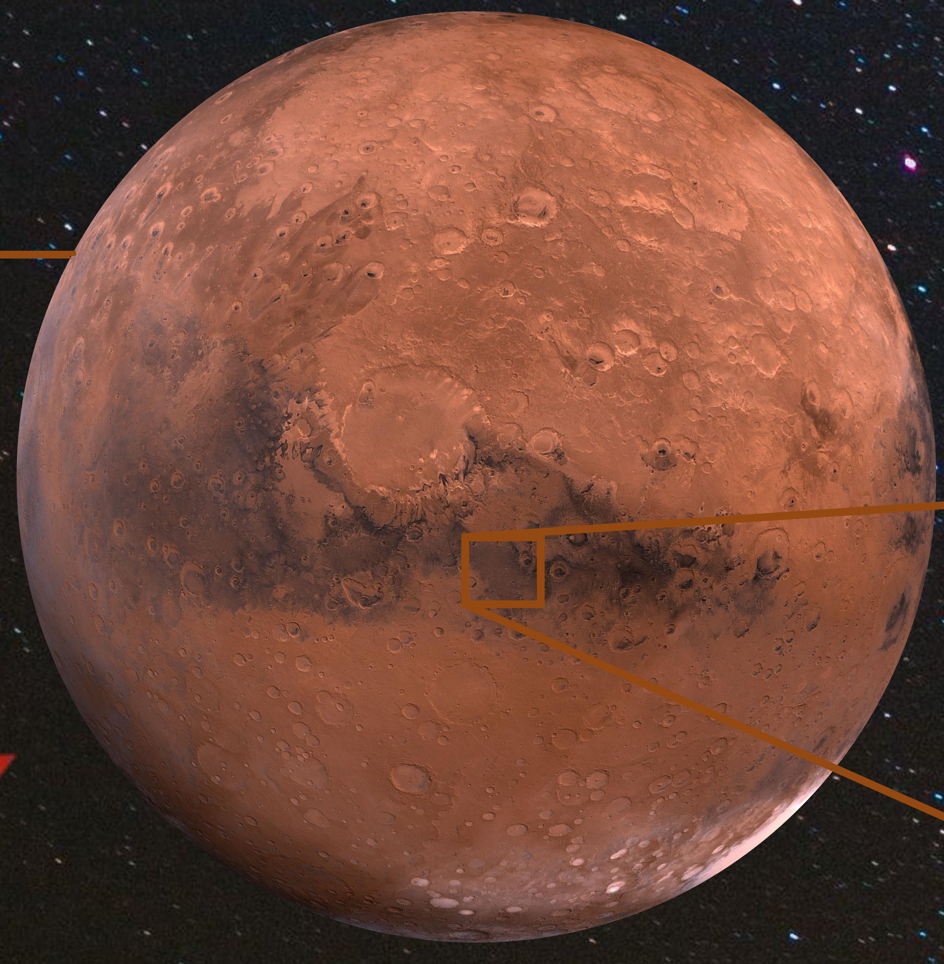


Figure 8. *Naganishia* (*Cryptococcus*) *friedmannii,* isolated from Atacama and Antarctica's basaltic subsurfaces. Credit: Vishniac, H., 1985.

FUMAROLIC ENVIRONMENTS

Table 1. Microorganisms isolated from Martian analogue environments on Earth.

Fillum	Class	Phylotype	
Verrucomicrobia	Spartobacteria	FJ59261 (Atacama)	96% sequence identity
		KJ6223648/3 (Mt. Erebus)	
		JN615785 (Azores)	
Chloroflexi	Ktedonobacteria		



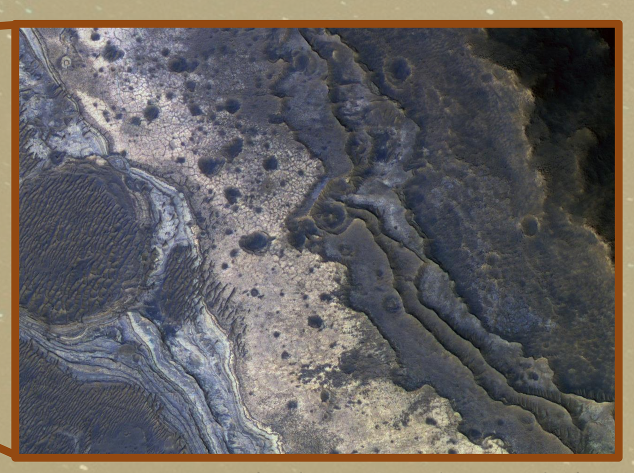


Figure 10. Opal deposits detected by NASA's Mars Reconnaissance in the *Valles Marineris* canyon system. Credit: NASA

Microorganisms isolated from Earth's environments play an important role in opal's biogenesis, suggesting a potential biological origin for Martian opal formations [7].

Figure 11. Terrestrial environments as Martian analogues due to their volcanic activity, oligotrophic soil, extreme temperatures, high UV radiation and low atmospheric pressure and water availability. (A) Llullaillaco volcano (Atacama, Chile). (B) Terceira volcano (Azores, Portugal). (C) Warren Cave (Mt. Erebus, Antarctica). Credit: National Science Foundation & National Geographic.

Figure 12. **Martian timeline.**

CONCLUSION

There might not be living organisms on Mars currently, however, their past existence might have left some detectable hints, changing our perspective on the origin of life concerning its probability. Even if nothing is found, Mars would be the perfect model to understand why life hadn't appeared despite conditions being favorable.

REFERENCES

[1] Wacey, D. *et al*. (2011). Microfossils of sulphur-metabolizing cells in 3.4-billion-year-old rocks of Western Australia. *Nat. Geosci.,* 4, 698-702. doi: 10.1038/ngeo1238
[2] Krissansen-Totton, J *et al*. (2018). Constraining the climate and ocean pH of the early Earth with a geological carbon cycle model. *PNAS,* 115, 4105-4110. doi: 10.1073/pnas.1721296115
[3] Forget, F. (2009). The present and past climates of planet Mars. *EPJ Conferences*, 1, 235-248. doi: 10.1140/epjconf/e2009-0924-9
[4] Weitz, C. M. *et al*. (2008). Gray hematite distribution and formation in Ophir and Candor chasmata. *J. Geophys. Res.*, 113. oi: doi: 10.1029/2007je002930
[5] Fernández-Remolar, D. C. *et al*. (2008). Fossilization potential of iron-bearing minerals in acidic environments of Rio Tinto, Spain: Implications for Mars exploration. *Icarus*, 194, 72–85. doi: 10.1016/j.icarus.2007.10.009
[6] Staudigel, H. *et al.* (2008). 3.5 billion years of glass bioalteration: volcanic rocks as a basis for microbial life? *Earth-Sci. Rev.*, 89, 156–176. doi: 10.1016/j.earscirev.2008.04.005
[7] Ruff, S., andFarmer, J. (2016). Silica deposits on Mars with features resembling hot spring biosignatures at El Tatio in Chile. *Nat. Commun.,* 7, 13554. doi: 10.1038/ncomms13554