On the role of silica in the origin of life and primitive life detection

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Our planet is 4.6 billion years old. We call the first 500 million years the Hadean because until recently, it was thought that the surface of the planet at that time was like hell, a dry wasteland covered by rivers of lava, volcanoes, and bombarded by meteorites, a landscape where life has probability zero to emerge. We have no rocks from that time except some crystals of zircon that tell us that 4.4 billion years ago, just after the formation of the moon, water started to condense on a crust made of iron-magnesium silicates. The interaction of these minerals with water triggers serpentinization. This reaction releases molecular hydrogen that, upon reaction with CO_2, creates a reducing atmosphere rich in methane, an ideal organic synthesis laboratory on a planetary scale. Serpentinization also released high-pH water so that the first seas were alkaline. In contact with the first granitic rocks, these seas became enriched in silica due to the exponentially increasing solubility of silica at high pH. This large-scale mobilization of silica would explain why all the oldest Archean rocks are silicified. As a result, silica was everywhere, and we reason that this molecule played a key role in shaping the environments in which life developed on the infant Earth [1]. But it is not just the ubiquity. In this communication we show that there is much more about why silica is key for the origin of life and early life detection studies, namely:

A) We will show that silica triggers prebiotic reactions. We revisited the famous Miller-Urey [2] experiment and found that the yielding of the reactions strongly depends on the borosilicate reactor used by Miller [3]. We will discuss further self- organized organic structures triggered by silica forming in these prebiotic experiments.

B) We will discuss how, at high pH, silica induces the self-organization of alkaline-earth carbonates into biomimetic structures called biomorphs [4]. These purely inorganic structures emulate the shape of the putative remnants of early organisms preserved in silica, creating an interesting problem in life detection studies and suggesting chemical routes to reverse biomineralization based on their ability to adsorb biological macromolecules [5].

C) We will discuss how silica interacts at higher pH with soluble metals, forming osmotic structures with metal oxide-silica membranes that catalyze the selective condensation of formamide into nucleobases and amino acids [6].

[1] García-Ruiz, J. M., Van Zuilen, M. A. & Bach, W. *Phys. Life Rev.* **34-35,** 62-80 (2020).
[2] Miller, S. L. A production of amino acids under possible primitive earth conditions. Science 117, 528–529 (1953).
[3] Criado, J., Bizarri, B., García-Ruiz, J.M., Saladino, R. & di Mauro, E. Scientific Reports (2021) 11:21009 |
[4] Garcia-Ruiz, J. M., Melero-Garcia, E. & Hyde, S. T. *Science* **323,** 362-365 (2009).
[5] Garcia-Ruiz, J. M. Hyde, S., Carnerup, A.M., Christy, A.G., van Kranendonk, M.J., N. Welham, N.J., Science 302, 1194–1197 (2003)
[6] Saladino, R., Di Mauro, E. & García-Ruiz, J. M. Chem. Eur. J. 25, 3181–3189 (2019).