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Could life emerge on the icy moons of the Solar System?

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Abstract. It has been proposed that the origin of life on Earth occurred at the bottom of the ocean in hydrothermal vents. Recently, an oceanographic expedition to the Gulf of California was carried out to investigate the field of hydrothermal vents that was discovered in 2015 at Pescadero Basin (Goffredi et al. 2017). In this field, which is at 3800 meters deep, the hydrothermal fluids record maximum temperatures of 290ºC and, among their geochemical characteristics, the presence of methane and calcite stands out. However, in spite of all these extreme conditions of temperature, pressure, darkness, and pH a great diversity of organisms was found. We assume that the hydrothermal vents found at Pescadero Basin harbor a community of archaea and thermophilic bacteria intimately related to the geology of the region. In Astrobiology, it has been proposed that on the ocean floor of the satellites Europa and Enceladus there are hydrothermal systems similar to terrestrial that could harbor extremophiles. We want to compare the physical, chemical, biological and geological characteristics of the Pescadero Basin with the conditions estimated in the oceans of Europa and Enceladus to propose a habitability model for the existence of life on them.

Key words. Hydrothermal vents — Extremophiles: Bacteria — Astrobiology: Icy moons

1. Introduction

The systems of hydrothermal vents are closely related to the formation and planetary evolution so they can be considered relics of the primitive Earth. It has been hypothesized that microorganisms in these systems harbor residual physiological characteristics that reflect the first microbial ecosystems on Earth (Martin et al. 2008). It has been proposed that the origin of life on Earth occurred at the bottom of the ocean in hydrothermal vents.

Scenarios for how life emerged include a prebiotic mix under a reducing atmosphere enriched in CH_4, NH_3, H_2, H_2S, and H_2O, in which the essential building blocks of life, like the amino acids, would have been synthesized (Lineweaver & Chopra 2012). Hydrothermal vents have a continuous, concentrated source of energy that produces a multiplicity of physical and chemical gradients that could have provided the necessary multiple pathways for the abiotic synthesis of chemical compounds; as a direct result of interactions between the

Earth's crust and the overlying oceanic and atmospheric environments (Baross & Hoffman 1985).

Many molecules required for life, such as formic acid or metal co-factors of essential enzymes, are found in large concentrations near hydrothermal vents. The biochemistry of the extremophiles might harbor clues about the kinds of reactions that initiated the chemistry of life (Martin et al. 2008). So it is also likely that the first living organisms would have been autotrophs using chemical energy (Pirajno 2009).

Recently, an oceanographic expedition to the Gulf of California was carried out to investigate the field of hydrothermal vents that was discovered in 2015 at Pescadero Basin (Goffredi et al. 2017; Paduan et al. 2018). In this field, which is at 3800 meters deep, the hydrothermal fluids record maximum temperatures of 290ºC and, among their geochemical characteristics, the presence of methane and calcite stands out. However, in spite of all these extreme conditions of temperature, pressure, darkness, and pH a great diversity of organisms was found. We assume that the hydrothermal vents found at Pescadero Basin harbor a community of archaea and thermophilic bacteria intimately related to its geology.

In Astrobiology, it has been proposed that on the ocean floor of the satellites Europa (Jupiter) and Enceladus (Saturn) there are hydrothermal systems similar to terrestrial that could harbor extremophiles.

The recent confirmation of geysers of water vapor coming out of the surface of the icy moons are evidence that beneath the ice crust of between, 5 and 10 km depth of each satellite, an ocean of liquid water lies and that the gravitational forces of its corresponding planet (tidal forces), are responsible for maintaining some geological activity that causes the water inside to be in a liquid state (Hand et al. 2007; Schubert et al. 2007). In addition, the fractures of the frozen crust of Europe are covered by compounds derived from sulfur, such as $MgSO_4$ and SO_2 (Muñoz-Iglesias et al. 2014). This project intends to evaluate for the first time the Pescadero basin as a possible site of astrobiological interest. In this work we present the bases of the project, which is a PhD thesis in its initial process.

2. Objectives

To compare the physical, chemical, biological and geological characteristics of the Pescadero Basin with the conditions estimated in the oceans of Europa and Enceladus to propose a habitability model for the existence of life on the icy moons.

3. Discussion and conclusions

Hydrothermal vents could be key sites where organic compounds are formed or produced, such as methanol and formic acid, necessary for the origin of life. The study of the Pescadero Basin hydrothermal vents and their biodiversity are of great importance for the understanding of the physical and chemical phenomena that take place in the marine ecosystem and that could also affect the presence of life on Europa or Enceladus satellites.

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