Day 2, Wednesday, 31.8.2022

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Poster

9:00 – 9:40

KEYNOTE

Environmental conditions for the origin of life and the spread of early life.

David Catling[1]

[1]*University of Washington*

I will review advances in our understanding of the co-evolution of life and environment on the Earth from about 4.5 billion years ago to the rise of atmospheric oxygen beginning around 2.4 billion years ago. I will argue that the expected chemical composition of the early atmosphere and surface waters favored prebiotic syntheses and the origin of life. By the Archean eon (4 to 2.5 billion years ago), the geologic record increasingly holds clues to the nature of the atmosphere and biosphere, which are reflected in isotope systems, the composition of marine and non-marine sediments, and occasionally physical aspects of rocks. I will conclude that understanding the young Earth is necessary in the search for biosignatures elsewhere because analogous stages of early evolution arguably occur on other rocky worlds.

9:40 – 10:00

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Volcanic activity and formation of the continental crust in the early earth

Bachmann O[1], Laurent O[2], Moyen J[3], Ulmer P[1], Wotzlaw J[4]
[1]Ethz, [2]CNRS; Géosciences Environnement, [3]Université Jean Monnet, [4]Accelopment

Granitoids of the tonalite–trondhjemite–granodiorite (TTG) series dominate Earth's earliest continental crust. The geochemical diversity of TTGs is ascribed to several possible geodynamic settings of magma formation, from low-pressure differentiation of oceanic plateaus to high-pressure melting of mafic crust at convergent plate margins. These interpretations implicitly assume that the bulk-rock compositions of TTGs did not change from magma generation in the source to complete crystallization. However, crystal–liquid segregation influences the geochemistry of felsic magmas, as shown by the textural and chemical complementarity between coeval plutons and silicic volcanic rocks in the Phanerozoic Eon. We demonstrate here that Paleoarchean (ca. 3,456 million years old) TTG plutons from South Africa do not represent liquids but fossil, crystal-rich magma reservoirs left behind by the eruption of silicic volcanic rocks, being possibly coeval at the million-year scale as constrained by high-precision uranium–lead geochronology. The chemical signature of the dominant trondhjemites, conventionally interpreted as melts generated by high-pressure melting of basalts, reflects the combined accumulation of plagioclase phenocrysts and loss of interstitial liquid that erupted as silicic volcanic rocks. Our results indicate that the entire compositional diversity of TTGs could derive from the upper crustal differentiation of a single, tonalitic magma formed by basalt melting and/or crystallization at <40!km depth. These results call for a unifying model of Hadean–Archean continent nucleation by intracrustal production of TTG magmas, and highlight the importance of silicic volcanism in the early earth.

10:00 – 10:20

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Atmospheric Nitriles for the Origin of Life after Large Asteroid Impacts on the Hadean Earth

Wogan N[1], Catling D[1], Zahnle K[2]
[1]University Of Washington, [2]NASA Ames

While there are several theories for the origin of life, the presence of nucleotide "fossils" in modern biology has led to the RNA World hypothesis. This hypothesis proposes a stage of primitive life with RNA as a catalyst and as a self-replicating molecule that evolved by natural selection, which, at some point, was encapsulated in a cell. RNA needs to be produced abiotically on early Earth in this scenario. Chemists have demonstrated several schemes in the lab, but all pathways require nitriles – hydrogen cyanide (HCN), cyanoacetylene (HCCCN), and cyanogen (NCCN) – to synthesize the nucleobases of RNA.

Abiotic synthesis of nitriles very likely requires a reducing prebiotic atmosphere, i.e., one redox-dominated by hydrogen-bearing reducing gases, and consisting of, e.g., H2, CH4 with CO2 or CO, and N2 and/or NH3. Photochemistry makes HCN from the nitrogenous gases only if CH4 is abundant. Also, HCCCN and NCCN are produced in highly reducing atmospheres, e.g. Titan's.

However, geochemical evidence suggests that volcanoes did not produce very reduced gases in the Hadean, and abundant volcanic CH4, in particular, was unlikely. Instead, impacts are a plausible source.

Asteroid impacts would make a reducing atmosphere because reactions between iron-rich impact ejecta and shock-heated water vapor from the ocean would generate substantial amounts of H2, CH4 and possibly NH3. Subsequent photochemistry would have generated prebiotic molecules like HCN making a "window of opportunity" for abiotic synthesis and evolution of RNA.

We simulated creation and evolution of impact-generated reducing atmospheres with a novel 1-dimensional photochemical model, improving upon previous work (1). We quantified the surface deposition of atmospheric nitriles following impacts with impactor diameters between 300 and 2000 km. We also used a 1-dimensional climate model to estimate the surface temperature of these hydrogen-rich atmospheres to examine the fate of nitriles at Earth's surface.

1. Zahnle, Lupu, Catling & Wogan (2020). Creation and evolution of impact-generated reduced atmospheres of early Earth. Planetary Science Journal. doi:10.3847/PSJ/ab7e2c.

11:00 – 11:20

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Study of habitability of Archean Earth with Earth-like planet Surface Temperature Model (ESTM)

Ivanovski S[1,2], Surtchev Y[1], Bevilacqua R[2], Vladilo G[1], Silva L[1,3], Simonetti P[1,2], Biasiotti L[1,2], Bisesi E[1], Maris M[1,3], Murante G[1,3]
[1]Astronomical Observatory of Trieste, [2]UniTs, [3]IFPU

The question of the existence of extraterrestrial life has been a long-standing aspiration of humanity. Studying the physical, geological, and chemical conditions of exoplanets will advance our understanding of their potential to host life. Our concept of life is based on the life found on Earth. First, we study young Earth as an aqua planet, received energy from a fainter Sun, and had thousands of times more atmospheric CO2, and no oxygen. One of the most important quantities to consider for habitability is temperature. We have performed simulations with an Earth-like planet Surface Temperature Model (ESTM, Vladilo et al. 2015; Biasiotti et al. 2022) to study the habitability of Archean Earth. Sun luminosity and the Earth rotational period between 2.5 and 4 billion years ago were used as input parameters. Two other key parameters were varied: ocean fraction and atmospheric content of CO2. We found that too much CO2 resulted in a blistering hot planet even in the conditions of a faint Sun. Ocean fraction was essential for habitability since our simulations demonstrated that a very dry planet and a moderate amount of CO2, would turn the planet into a snowball. But if there is an abundance of CO2, even a small amount of water would be sufficient to make an Earth-like planet habitable.

We review the recent advances in the modelling of habitability as a function of various hosting star parameters and planetary evolution characteristics using an ESTM model developed at the Astronomical Observatory of Trieste.

References

Biasiotti, L., et al., 2022, MNRAS
Vladilo, G., et al., 2015, ApJ, 804, 50

11:20 – 11:40

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Micropyrite: a promising biosignature?
Insights from modern and ancient sediments

Marin Carbonne J[1], Decraene M[1], Dupeyron J[1], Alléon J[1], Olivier N[2], Thomazo C[3], Bernard S[4]
[1]University Of Lausanne, [2]Université Clermont Auvergne, [3]Université Bourgogne Franche Comté, [4]Sorbonne Université

Identifying (micro)fossils from the Earth's early biosphere is ambitious and challenging due to the scarcity of the oldest rocks and their complex post depositional history. The first form of life was small, like microorganisms, and produce ambiguous fossil forms and chemical and isotopic signatures, which are not unique. Therefore, almost all early life trace discoveries have been strongly discussed and disputed. Here, we propose that pyrite, an iron sulfide, ubiquitous in sedimentary rocks, is a promising biosignature. Indeed, in modern environments, pyrite is a by-product of various metabolic activities, such as microbial sulfate reduction and iron dissimilatory reduction. We will present detailed mineralogical and isotope studies of ancient and modern sediments that highlight the potential of micropyrites to capture (and retain) microbial signatures through time. We have developed an original approach, combining high resolution microscopy with S and Fe isotopes characterization at a micrometer scale using SIMS and NanoSIMS analyses . We will show that studied micropyrites record the oldest signature of dissimilatory iron reduction and microbial sulfate reduction, which suggest the presence of diversified microbial biocoenoses during the (Paleo)Archean.

Poster

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Lagrangian points as the origin of giant impactors

Balsalobre-Ruza O[1], Lillo-Box J[1], Huélamo N[1], López-Ibáñez L[2]
[1]Center for Astrobiology (CAB), [2]Complutense University of Madrid (UCM)

The role of giant impacts in the construction of habitable worlds is known to be a key piece of the Astrobiology puzzle not yet fully explored. These impacts between large bodies during the formation and early stages of planetary systems are known to occur with relatively high frequency. Some of their consequences are the mix-up of materials between the two bodies, the extraction of processed material from the interior of the forming planets or the depletion and replenishment of the planetary atmosphere. Another consequence is the potential formation of natural satellites, known to have an important role in the life sustainability in our own Earth-Moon system. But, where do these bullets come from? Their origin is key to understand the available and deposited material that is then at the disposal for abiogenesis. One of the possible origins of these impactors are the so-called Lagrangian points. In this poster we explore this possibility in the context of the TROY project and the search for co-orbital exoplanets.