How did life get started on Earth? Atmospheric haze might have been the key

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Color-composite of Titan made from raw images acquired by Cassini on April 7, 2014. Credit: NASA/JPL-Caltech/SSI/J. Major

A recent study accepted to *The Planetary Science Journal* and currently posted to the *arXiv* preprint server investigates how the organic hazes that existed on Earth between the planet's initial formation and 500 million years afterwards, also known as Hadean geologic eon, could have contained the necessary building blocks for life, including nucleobases and amino acids. This study holds the potential to not only help scientists better understand the conditions on an early Earth, but also if these same conditions on Saturn's largest moon, Titan, could produce the building blocks of life, as well.

Here, Universe Today discusses this recent study with Dr. Ben K. D. Pearce, who is a Postdoctoral Fellow in the Morton K. Blaustein Department of Earth & Planetary Sciences at Johns Hopkins University and lead author of the study, regarding the study's findings, potential follow-up research, NASA's upcoming Dragonfly mission to Titan, and whether he thinks there's life on Titan.

Dr. Pearce tells Universe Today about how past lab studies involving Carl Sagan discovered that the highest dilution (or addition of a solvent like water) to make the chemical reactions work was 100 micromolar, or approximately 10 parts per million (ppm). If the dilution is too strong, the molecules in the chemical mixture wouldn't find each other, he says.

"After all, early Earth was a hazy place, much akin to Saturn's moon Titan," Dr. Pearce tells Universe Today. "This is because over 4 billion years ago, Earth had an atmosphere rich in hydrogen, methane, and nitrogen, similar to Titan! What's interesting about these haze particles, is that they are essentially biomolecule snowflakes, i.e., big aggregates of life's building blocks bonded together. When these particles settled onto Earth's surface, over 4 billion years ago, and fell into ponds, the bonds would break, and you could get a pond rich in life's building blocks. We wanted to know if this source could exceed the 100 micromolar threshold in ponds, which could be concentrated enough for them to react and begin the process of forming the first information molecules like ribonucleic acid (RNA)."

For the study, the researchers created organic hazes in a laboratory setting under atmospheric conditions containing between 0.5% and 5% methane and analyzed the hazes for traces of amino acids and nucleobases using a gas chromatograph/mass spectrometer (GC/MS). Additionally, they heated samples up to 200°C (392°F) to simulate the samples resting on an uninhabitable surface, as well. The team then compared their results to computer models to investigate the number of nucleobases that would be present in these same environments.

"When we modeled the pond concentrations of nucleobases from organic hazes (making use of our experimental data), we discovered that this source may be the richest, most long-lasting source that we've modeled to date," Dr. Pearce tells Universe Today. "As a reminder, all sources we've studied to date (meteorites, interplanetary dust, and atmospheric HCN) have led to below 100 micromolar concentrations; however, now we have finally found a source that breaches up towards this threshold."

In the end, the team discovered that nucleobases could exist in "warm little ponds" on Earth during the Hadean geologic eon. With the heating experiment, the team ascertained that such samples could not survive on a hot surface. Finally, they concluded that organic hazes could produce the building blocks of life only in a methane-rich atmosphere on ancient Earth, "but not so rich as to create an uninhabitable surface," Dr. Pearce notes to Universe Today. Given these incredible findings, what follow-up research is being conducted or planned?

"I am presently building a new experimental setup to be used in my laboratory in the Department of Earth, Atmospheric, and Planetary Sciences at Purdue University, which opens this fall 2024," Dr. Pearce tells Universe Today. "This lab is called the Origins and Astrobiology

Research Laboratory. This experiment will allow my new research group to simultaneously model the atmospheric chemistry (e.g., HCN and organic haze production) and pond chemistry of early Earth. Our initial goal will be to use this to demonstrate the production of the first information molecules of life, such as RNA, in a simulated early Earth environment."

This study comes as NASA is planning to send its Dragonfly mission to Titan, which currently has a planned launch date of July 2028 and landing on Titan's surface sometime in 2034 in the "Shangri-La" dune fields. Dragonfly is a quadcopter whose goal will be to "hop" around Titan searching for evidence of Titan's potential habitability, and currently has a planned mission timeline of 10 years with the science phase comprising 3.3 years. Its scientific payload will consist of a mass spectrometer, gamma-ray and neutron spectrometer, geophysics and meteorology package, and a suite of microscopic and panoramic cameras.

Dragonfly is slated to operate during the Titan day and remain on the ground at night, with each lasting approximately eight Earth days or 192 hours. It is currently hypothesized that Dragonfly will be capable of flying up to 16 kilometers (10 miles) on a single battery charge, with its batteries consisting of a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) that will charge during the night. MMRTGs have a successful history on space missions, as they are currently used to power NASA's Curiosity and Perseverance rovers on Mars. But how will Dragonfly contribute to or refute this study's findings?

Dr. Pearce tells Universe Today, "Given that there are tons of organic haze on Titan, we could expect that the surface contains preserved organic haze particles rich in life's building blocks. Dragonfly will contain a mass spectrometer and will be able to characterize the building blocks of life in these particles to potentially validate our laboratory studies."

Titan has a rich history of exploration, as numerous spacecraft over several decades have allowed us to gain greater insights into this mysterious world, which is not only the second-largest moon in the entire solar system but the only moon with a thick atmosphere. While the cameras onboard NASA's Pioneer 11, Voyager 1, and Voyager 2 spacecraft were unable to image Titan's surface due to the moon's thick and hazy atmosphere, NASA's Cassini spacecraft successfully used its infrared cameras to image Titan's surface for the first time. It was these images that confirmed previous hypotheses that Titan possessed lakes of liquid methane and ethane that can only exist in extremely cold temperatures, with Titan's surface temperature being –179°C (–290°F).

Cassini carried with it the European Space Agency's Huygens probe, which detached from the orbiting spacecraft and landed on Titan's surface, sending back surface features of rounded rocks that could have only formed under liquid conditions. But, given that Titan could resemble an early Earth with its methane atmosphere and liquid lakes, will we find life on Titan?

"The only habitable environment on Titan is deep in the subsurface, which is not easy to get to without a drill or a geyser spewing stuff onto the surface," Dr. Pearce tells Universe Today. "Thus, I'm not sure we will even be looking in the best places for decades beyond Dragonfly. It is also hard for me to imagine an origin of life on Titan, given that our current best hypotheses involve wet-dry cycles of ponds that would not be available on –180°C Titan. However, if I have learned anything from science in the past decade, it's that we are often proven wrong by new findings, and I absolutely welcome it! It's always better to look, just in case."

More information: Ben K. D. Pearce et al, Organic hazes as a source of life's building blocks to warm little ponds on the Hadean Earth, *arXiv* (2024). DOI: 10.48550/arxiv.2401.06212

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