

Comet craters—literal melting pots for life on Earth

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The Trinity Sudbury Research Group, left to right: PhD student Paul Guyett, first author Edel O'Sullivan, Dr Teresa Ubide, and PhD student Gavin Kenny. Credit: Trinity College Dublin

Geochemists from Trinity College Dublin's School of Natural Sciences may have found a solution to a long-debated problem as to where - and how - life first formed on Earth.

In a paper just published in the journal *Geochimica et Cosmochimica Acta*, the team proposes that large meteorite and comet impacts into the sea created structures that provided conditions favourable for life. Water then interacted with impact-heated rock to enable synthesis of complex organic molecules, and the enclosed crater itself was a microhabitat within which life could flourish.

It has long been suggested that the meteoritic and cometary material that bombarded the early Earth delivered the raw materials - [complex organic molecules](#), such as glycine, β -alanine, γ -amino-n-butyric acid, and water - and the energy that was required for synthesis. The Trinity group's work has provided the new hypothesis that impact craters were ideal environments to facilitate the reactions that saw the first 'seeds of life' take root.

First author Edel O'Sullivan, now a PhD candidate in Switzerland, said: "Previous studies investigating the origin of life have focused on synthesis in hydrothermal environments. Today these are found at mid-ocean ridges - hallmark features of plate tectonics, which likely did not exist on the early Earth. By contrast, the findings of this new study suggest that extensive hydrothermal systems operated in an enclosed impact crater at Sudbury, Ontario, Canada."

The research was part of a wider project funded by Science Foundation Ireland and led by senior author, Professor of Geology and Mineralogy at Trinity, Balz Kamber.

Although no very ancient terrestrial impact structures are preserved, the Sudbury basin provides a unique opportunity to study the sediment that

filled the basin as a guide to what the earlier impact craters would have looked like. The Sudbury structure is distinctive among the known terrestrial [impact craters](#). It has an unusually thick (nearly 2.5 km) basin fill, and much of this is almost black in colour (due to carbon) containing also hydrothermal metal deposits.

Professor Kamber said: "Due to later tectonic forces, all the rocks of the once ~200 km-wide structure are now exposed at the surface rather than being buried. This makes it possible to take a traverse from the shocked footwall through the melt sheet and then across the entire basin fill. To a geologist, this is like a time journey from the impact event through its aftermath."

Representative samples across the basin fill were analysed for their chemistry and for carbon isotopes, and they revealed an interesting sequence of events.

The first thing that became evident was that the crater was filled with seawater at an early stage, and remained sub-marine throughout deposition. Importantly, the water in the basin was isolated from the open ocean for long enough to deposit more than 1.5 km of volcanic rock and sediment. The lower fill is made up of rocks that formed when the water entered the crater whose floor was covered by hot impact melt. Fuel-coolant reactions deposited volcanic rocks and promoted hydrothermal activity. Above these deposits, reduced carbon starts to appear within the basin fill and the volcanic products become more basaltic.

Previously the puzzling presence of carbon in these rocks was explained by washing in from outside the crater basin. However, the new data show that it was microbial life within the crater basin that was responsible for the build-up of carbon and also for the depletion in vital nutrients, such as sulphate.

"There is clear evidence for exhaustion of molybdenum in the water column, and this strongly indicates a closed environment, shut off from the surrounding ocean," added Edel O'Sullivan.

Only after the crater walls eventually collapsed did the study show replenishment of nutrients from the surrounding sea. These sub-marine, isolated impact basins, which experienced basaltic volcanism and were equipped with their own hydrothermal systems, thus present a new pathway to synthesis and concentration of the stepping stones to life.

A copy of the journal article is available on request.

More information: Edel M. O'Sullivan et al, Chemostratigraphy of the Sudbury impact basin fill: Volatile metal loss and post-impact evolution of a submarine impact basin, *Geochimica et Cosmochimica Acta* (2016). [DOI: 10.1016/j.gca.2016.04.007](https://doi.org/10.1016/j.gca.2016.04.007)

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