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How Scientists Uncovered Arctic Clues to a Past Where a Tiny Fern Changed the Planet

Researchers attempt to puzzle out how Earth got its ice caps

ClimateWire

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This may come as a shock, but only 55 million years ago, our planet had no polar ice caps; in fact, it nearly became a steamy, runaway greenhouse world, with CO_2 levels exceeding 2,500 ppm. Then, all of a sudden, something intervened, causing a shift.

A close-up of Azolla. Carbon sequestration power sometimes comes in small packages.
Credit: Mygaia via Wikimedia Commons

Atmospheric carbon dioxide began to drop, steadily generating today's world, with ice caps at both poles. But why did this happen? And better yet, could whatever triggered this drastic switch be used to temper today's climate?

Good questions. But the answers lay buried deep in the Arctic, hidden to researchers.

"Even up to 2004, the Arctic was still a big unknown," recalled Jonathan Bujak, a renowned palynologist, a person who studies dust and fine particles, such as fossil spores and pollen grains. "But as the ice sheets began to recede, we finally had our chance."

A research project called the Arctic Coring Expedition linked to the Integrated Ocean Drilling Project headed north, hoping to find traces of this phenomenon to explain how it had happened. What the researchers found to be the likely culprit was a complete surprise.

Encompassing the period of time in question was a 26-foot-thick column of fossilized ferns, a species so small it can fit on your fingernail but is capable of doubling its mass in two days. It is called *Azolla*.

"Quite frankly, we were all shocked," Bujak said. "What was this freshwater fern doing in Arctic waters, thousands of kilometers from shore, and how had it possibly had the power to begin to change our climate?"

Bujak wasn't the only person asking questions about *Azolla*. At the same time, a botanist from Duke University, Kathleen Pryer, was appealing to the government for funding to sequence the fern's genome.

Crowdfunding a genome

Pryer worried that because no fern genome had ever been sequenced, what might be learned about these ancient plants—some of the oldest known vegetative of life forms on Earth—was highly limited. But because ferns don't carry the same economic clout as major agricultural crops do, her requests were denied.

This didn't stop her. Pryer knew there was a global need to decipher *Azolla*'s genetics. It had been used for thousands of years as a fertilizer in rice paddies, fixing nitrogen at unheard-of rates. Over time, people from all spectrums of science had already begun expanding its uses to include wastewater treatment, bioremediation, a source of food for both humans and livestock and even a biofuel.

On top of all this, *Azolla* has the capacity to trap an astounding amount of carbon, at maximum rates sequestering 60 tons a year of CO_2 per hectare, equivalent to the emissions of almost two hours of flight by a Boeing 747.

"This tiny fern houses within it secrets on how to sequester carbon, fix nitrogen and ultimately increase food production without sending the Earth to hell in a handbasket," Pryer said.

"Someone had to open the gates for all other work, and we decided the only way to do this would be to look to the masses for help."

Pryer's team began a crowdfunding project with the help of the online site Experiment.com, hoping to gain $15,000 to sequence the fern's genes. Two weeks ago, one of the largest sequencing laboratories in the world, the Beijing Genomics Institute, signed on to help Pryer's dream come true. That means *Azolla*'s playbook on how to save the Earth's climate could become open access in as little as one year.

Pryer said they have added an additional bonus round to their fundraising, to keep those already involved in the loop and also to prepare the perfect sample to send to China to be sequenced, providing the most beneficial results. The campaign ends this week.

"We'll have the Rolls-Royce of *Azolla* samples to send, thanks to this extra round," Pryer said.

Ancient plant and a mysterious woman

It took a real adventurer to find *Azolla*. Jeanne Baret, the first woman to circumnavigate the globe, was likely the first Westerner to identify the plant. Beginning as a contracted house worker for Philibert Commerson, the naturalist for Louis XV, Baret continued her work for him when Commerson was allotted a stipend for an assistant on a circumnavigation voyage.

Disguised as a man, she helped Commerson collect a good deal of his plant samples. Her efforts needed to be particularity fierce, as she constantly was in the position of having to defend her masculinity against the sailors on board, who became increasingly suspicious about her gender.

A 2001 paper by Vassar College's Lizabeth Paravisini-Gebert recounts that "voyagers witnessed him [Baret] accompanying his master on all his expeditions amidst the snows and icy hills of the Straits of Magellan, carrying with courage and strength provisions, weapons and portfolios of plants."

Eventually, Baret's identity was discovered, but little fuss was made over the mishap by the superiors on board, and Baret continued her work. On the return voyage, Commerson died in 1773 in what is today Mauritius. Baret chose to stay on the island, marrying a former petty officer.

When their samples returned to France, another famous French scientist of the time, Jean-Baptiste Lamarck, come across them and attempted to classify the tiny plant, mistaking it for a member of a family of flowering plants. He had, of course, not seen *Azolla* in all its glory, floating in open water.

When Baret finally returned to France in the 1780s, she faced an unexpected homecoming. Due to the intervention of the ship's master and some of Commerson's friends, she was not only pardoned by the courts, but given an annual pension from France's navy, which referred to her as a "femme extraordinaire."

In 1878, German naturalist Heinrich Aton de Bary used *Azolla* to first illustrate his definition of the term symbiosis, or two unlike biological identities living together in unison. He used the example of *Azolla* paired with lichen to exemplify his new term but also noted a bacteria that seemed to be inherent to the fern, serving as an even more extreme example of symbiosis.

With their spongy, lobe-like leaves only a fraction of an inch long, *Azolla* float on the surface of bodies of fresh water, dangling long tendrils below. In these leaves, *Azolla* have created a microenvironment, co-evolving with tiny bacteria called cyanobacteria for an estimated 100 million years.

Over time, the bacteria lost the ability to live independently of the fern, but their photosynthetic machinery increased its nitrogen-fixing capability by a factor of between 12 and 20. The bacteria became the powerhouse of the fern leaf, super-concentrating its photosynthetic power, while gaining shelter and a continuous food source from the fern.

"To these bacteria, they know no other home than the inside of an *Azolla* leaf. To each species of *Azolla*belongs a different species of accompanying bacteria, and the bacteria is passed on from one fern to the next in their spores," said Francisco Carrapico, a cell biologist and *Azolla* expert at the University of Lisbon. "It's the ideal relationship."

Being able to fix nitrogen so well also makes the fern a fantastic carbon sequesterer. But this still didn't explain what *Azolla* was doing in the Arctic. A research team based at Utrecht University was set up to study the question, called the Darwin *Azolla* Project. This brought together many different types of scientists from around the world, and finally, a proposed explanation to *Azolla*'s Arctic presence arose.

"We remained dumbfounded," Bujak said, "that was, until Carrapico piped up that we also needed to consider the fern's carbon-capturing power in the context of this time period."

Researchers hadn't considered this property a likely factor in the fern's Arctic success, and for good reason. Even with abundant carbon and nitrogen to consume, the size of the plant and its limited access to fresh water make it almost inconceivable that it could even survive in the Arctic, let alone muster up enough power and mass to change the Earth's entire climate, saving our planet, perhaps, from a Venus-like, overheated oblivion.

As with most good science stories, as soon as one question had been answered, another had to be asked.

If *Azolla* had grown to such proportions that it could have affected the climate to such a degree, what had stopped the so-far invincible fern in its tracks and led to the initial climate plunge? The more the team looked, the more they found evidence that made the *Azolla* saga even more unbelievable.

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