Arctic Rocks Hold Secrets to a Hotter Past

Adam Voiland, Writer

While activists protest, politicians waffle and journalists flood the papers with ominous stories of global warming, research on this environmental phenomenon is relatively young and fraught with uncertainty. Scientists agree that the Earth is warming and that human activities are largely responsible. Deforestation and the burning of fossil fuels (coal, oil and gas), for example, hurl massive amounts of carbon dioxide (CO_2) into the atmosphere, causing it to heat up. Yet estimates vary widely about how this will affect our planet's climate patterns, sea level, flora and fauna. Jennifer McElwain, PhD, a Field Museum curator of paleobotany, is hoping to provide some much needed answers.

Along with a team of geology experts, Dr. McElwain spent a month in Greenland last summer contending with treacherous terrain and inhospitable camping conditions to collect 1.5 tons of plant fossils. Between the Triassic and Jurassic periods about 200 million years ago (Mya), a CO_2-induced global warming significantly altered or killed a high percentage of the planet's plants and animals. Since plants require CO_2 to make complex sugars and starches, they serve as excellent barometers for documenting changes in CO_2 levels. Understanding more about the Triassic-Jurassic extinction may better inform the effects of today's and future global warming on our planet's biodiversity.

MARK WIDHALM/GEO863660

Sphenobaiera spectabilis, *a fossil plant from Greenland*

CO_2 rising

On the eve of this biological disaster, Earth scarcely resembled what it is today. The continents were joined together in a massive supercontinent called Pangea. Sweltering temperatures prevented the formation of polar ice, and moist, subtropical forests flourished as far north as Greenland. In the forests, ancestral mammals scurried beneath canopies of palm-like cycads, slender ginkgos and magnificent conifers, while flying reptiles called pterosaurs stalked careless insects. The most familiar and abundant plant group on Earth today, Angiosperms (flowering plants), had not yet evolved. Beneath a young Atlantic Ocean, lava began to seep from the Earth's fiery interior, releasing tons of CO_2 and other noxious gasses into the atmosphere.

With nowhere to go, the CO_2 accumulated, quadrupling its atmospheric concentration by the early Jurassic. This increased volume of CO_2 acted like glass, enabling the sun's heat energy to enter the atmosphere but preventing a higher proportion from escaping. Like the inside of a car on a hot day, the Earth's temperatures rose by three to four degrees Celsius (7 to 10 degrees Fahrenheit), resulting in global warming due to the "greenhouse" or "glasshouse" effect of CO_2.

Dr. McElwain hypothesized that the scorching temperatures took their toll over time. In all, 95 percent of plant species gradually disappeared, as did 80 percent of marine invertebrate life and 50 percent of vertebrates. This extinction—the third greatest in Earth history—rivaled in magnitude even the well-known Cretaceous-Tertiary extinction that killed the dinosaurs 65 Mya.

Searching for a climate threshold

Dr. McElwain wants to know when, why and how the plant die-off occurred. By examining how fossil plant diversity changed over the Triassic-Jurassic boundary, and how the abundances of different fossil plant groups changed relative to one another, she hopes to determine a CO_2 threshold—the precise concentration of atmospheric CO_2 that caused climate to short circuit and ecosystems to collapse, resulting in the Triassic-Jurassic extinction.

"Climate change isn't as gradual a process as we originally believed," Dr. McElwain said. "It has been likened to turning on a fluorescent light. When you switch on a light, the room does not go from complete darkness to full illumination in an instant, but flickers on and off first.

"Climate change works the same way. Records trapped in the arctic ice, for example, have revealed that climate 'flickered' or fluctuated rapidly, and often

JENNIFER MCELWAIN

Stephen Hesselbo (foreground) and Matthew Haworth trek up an outcrop at Astartekløft.

violently, between hot and cold during the transition from a cooler to a warmer climate mode." According to Dr. McElwain, drastic changes in climate can occur over a period of only a few hundred years—a mere nanosecond on the geologic time scale.

Dr. McElwain studied fossils originally collected from Jameson Land, Greenland, in the 1920s and '30s by Tom Harris, the first person to document the area's paleo-flora. Pointing to volcanic activity associated with the breakup of Pangea, she concluded that skyrocketing CO_2 levels killed large-leaved species. They were replaced with plants that had smaller and narrower leaves, which release heat more efficiently and can stay cooler. Apparently, according to Dr. McElwain's "thermal damage hypothesis," large-leaved species couldn't stand the heat. Ultimately, this suggests that severe increases in global temperatures can have rather disastrous effects on plant communities.

Fresh fossils

While Harris' fossil collection supported Dr. McElwain's theory, it is relatively small and the methodology for assembling it unknown, limiting the fossils' full potential for ecological interpretation. Dr. McElwain needed fresh fossils, and Greenland, with its rocky exposures and fjords cut deeply into the landscape, was the choice destination. With funding from the National Geographic Society, The Field Museum and the Women's Board, she assembled a world-class team of experts that included Finn Surlyk, a sedimentologist from Denmark, Stephen Hesselbo, a geologist from England, and Mihai Popa, a paleobotanist from Romania.

Following an onerous period of preparation, and a patient wait for the one-month window that Greenland is accessible via helicopter, Dr. McElwain's team finally arrived. After setting up camp on the permafrost, they hiked to one of the world's most fossil-laden outcrops of Triassic-Jurassic age. All it took was a quick tap of the 500-foot cliff face to split the rocks along natural points of weakness, sending 200 million-year-old "leaves" fluttering in the breeze. Dr. McElwain's team extracted fossil after fossil—including one fern frond that is more than two feet across—from outcrops that have recorded the destruction of ecosystems and the emergence of others in scrupulous detail.

Dr. McElwain and her team were meticulous in their collection techniques. They scoured 11 fossil plant beds, each one approximately three feet thick, for equal amounts of time. They collected every possible fossil remain, including bark, leaves, seedcones, scales and wood. Sampling required thoroughly identifying each sedimentary level and the precise location of each fossil. After collection, the fossils were wrapped with protective material, carried to base camp and shipped out via helicopter.

Dr. McElwain expects that it will take nearly two years and at least one more expedition to chip through the plant fossils, identify them and examine their past ecology before any definitive conclusions can be made on the CO_2 threshold at which biodiversity loss occurred. While these plants are quite different than those of today, scientists can be guided by the past to help indicate what's potentially in store in a higher CO_2 world. **ITF**

As part of the Year of Biodiversity and Conservation, Dr. McElwain will speak about her Greenland expedition on Sunday, Sept. 21, at 2pm. Free with Museum admission. You can also purchase her book, The Evolution of Plants, *co-written by K.J. Willis, in the Museum store.*

Mihai Popa, Stephen Hesselbo and Jennifer McElwain at Ranunkeldal.

MATTHEW HAWORTH

JENNIFER MCELWAIN