An expedition to a tropical Arctic Tropical Arctic: Lost Plants, Future Climates, and the Discovery of Ancient Greenland Jennifer C. McElwain, Marlene Hill Donnelly and Ian J. Glasspool (The University of Chicago Press, Chicago, IL; 2021) ISBN: 978-0-226534-435

Book review, *Tropical Arctic*

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The history of life is punctuated by mass extinction events which devastated the biosphere, drawing to a close great lineages that populated the Earth. The most severe of these mass extinctions are known as the 'Big Five' and each has captivated researchers across disparate fields. Studying the Big Five is crucial for understanding the history of life on Earth and also can help us predict how the biosphere may respond to the anthropogenic climate crisis today. However, the majority of literature concerning mass extinctions is centred on animal lineages, leaving open the hugely important question of how the rest of life overcame these huge upheavals. *Tropical Arctic* is a story about how plants, the fundamental underpinnings of terrestrial ecosystems, weathered the Triassic–Jurassic mass extinction event, one of the Big Five. The story is told from the vantage point of East Greenland roughly 200 million years ago, before, during and after the catastrophic boundary between the Triassic and Jurassic periods. What is now Arctic tundra was once home to a lush tropical forest ecosystem at the end of the Triassic, but this forest was about to undergo a catastrophic change. To uncover this ancient forest and the consequences of the mass extinction event we start by travelling with the team of scientists, consisting of palaeobotanists and sedimentologists, to Greenland to collect the fossil and sediment samples that record this ancient environment. We learn about the methods used to reconstruct the environment and painstakingly quantify the changes in biodiversity across the mass extinction event. Next, through a collaboration with a scientific illustrator, this ancient ecosystem is brought back to life. It is not often that a book written about a scientific topic is specifically organized to put emphasis on artwork created from the scientific data, which makes *Tropical Arctic* both fascinating and accessible to a wide readership. The attention to detail in these illustrations is remarkable, from the choice of which hue of green to colour the plants to the illustration of how leaves of long extinct species would have hung from branches and fluttered in the wind. This collaboration between science and art allows the reader to visualise the impact of one of the Big Five mass extinctions on this ancient

ecosystem. The goal of the book is therefore to fully immerse the reader in this changing ecosystem at the time of the mass extinction, and the authors certainly succeed in this task.

The excursion back to the tropical Arctic is led by a collaboration between three authors, palaeobotanists Jennifer C. McElwain and Ian J. Glasspool, and the scientific illustrator Marlene Hill Donnelly. Jennifer C. McElwain holds the prestigious position of the Chair of Botany at Trinity College Dublin and is also co-author of *The Evolution of Plants*, an accessible textbook about plant evolution which is likely to be familiar to those with interests in both living and fossil plants at all career levels. Ian J. Glasspool is a research scientist based at Colby College in Maine and has made significant contributions to palaeobotany in the form of over 50 papers. Marlene Hill Donnelly a scientific illustrator for the Field Museum in Chicago, has won awards for her artwork, and has published three children's books. Together the authors write a unique book which is a fusion of storytelling, scientific discovery, and illustration.

The story begins as we accompany the authors, McElwain and Glasspool, alongside a team of sedimentologists on their initial fieldwork to East Greenland in 2002. The team follow in the footsteps of the famous Palaeobotanist Thomas Harris who explored the boundary between the Triassic and Jurassic rocks in the 1920's and 30's. The Introduction gives a great description of both the highs and lows of Arctic fieldwork, from the excitement of finding strata rich in fossil plants, to the frightening experience of hailing an emergency helicopter. Their exploration and fossil hunt eventually pays off: they are able to locate the key fossil sequence at the site called Astartekløft. Laid out before them on the scree slope are metres of rocks that record the transition from the Triassic to the Jurassic and one of Earth's Big Five mass extinctions.

With the fossiliferous rock sequence identified, the aim now is to collect fossils that would allow them to accurately reconstruct the palaeoecology and biodiversity through the mass extinction. This means not just collecting the best preserved or eye-catching fossils, but instead to quantitatively sample and collect the fossils across the entire rock sequence. The authors describe the methods they use to do this, excavating one cubic metre of sediment in each bed to prevent collection biases. This must have been hard work in the challenging Arctic conditions, but all their future analyses were to hinge on these findings so it was imperative that it was done properly. Every specimen was recorded and bagged ready to be studied further once back in the lab. Before they could be studied further in the lab, however, the next challenge was moving this enormous collection of fossils back to the Field Museum in Chicago – altogether, it was the most expensive bill for transporting fossils at the museum to date. It was at the Field Museum that the metric ton of samples were studied in detail,

allowing the scientists to put together the botanical components of the ecosystem in this area in Greenland across geological time.

A vast number, 4200, fossil leaves and additional reproductive fragments become data points used by the team to investigate changes during the interval. These fossils told a stark story of environmental upheaval. During the mass extinction event the Triassic forest ecosystem collapsed, first to be replaced by a disaster flora dominated by ferns with low species abundance and then only later in the Jurassic did an entirely new forest takes its place. Roughly 85% of plants that were present in the Triassic fossil beds were not found in the Jurassic at Astartekløft, indicating enormous regional species extinction and floristic change. However, to the reader, and to the scientists involved in the study too, it is incredibly difficult to fathom what an extinction of 85% of species would have actually looked like. It is at this point that Marlene Hill Donnelly, the scientific illustrator, joins the story.

We join Donnelly as she endeavours to bring these ancient ecosystems back to life in the form of beautiful but also scientifically accurate art. Donnelly, working closely with the palaeobotanists, goes to great length to make her art as accurate as possible using a wonderfully diverse array of mediums, ranging from paints and ink, to 3D models made with metal, paper and even leaves of living plants. We read how she even performs her own experiments to determine how the leaves would droop from the branches. This attention to detail is key in all of the illustrations: every aspect of the forest is carefully researched and curated, from the colour palate to predictions about how plants grew and interacted. Finally, Donnelly even undertook fieldwork in her kayak for inspiration of what a flooded forest landscape could have looked like. All of this hard work put into her recreations pays off, the resulting artwork illustrates the difference in the landscape before and after the mass extinction in a way that is almost impossible to capture in words.

The fossils brought to life with the reconstructions enables us to see the remarkable change that occurred at this time. The Triassic art features a lush forest ecosystem with ferns, climbing vines and extinct relatives of modern conifers and ginkgo. However after the mass extinction this all changed. The disaster flora looked completely different. The lush forest was gone, instead the sediment was black with charcoal indicating the prevalence of wildfires and there were almost no woody species left, instead ferns and horsetails ran riot. Then eventually a new forest recovered in the Jurassic, with a more open canopy and with species with more highly dissected leaves. The picture is therefore of remarkable upheaval and change over the course of hundreds of thousands of years. Although only one plant family, indicated by the seed plant vine in the Triassic reconstruction, went globally extinct at the time, the species turnover at the ecosystem change was staggering. Although plants

were therefore able to weather this major mass extinction event with the global loss of only one family it is still certainly a time of remarkable upheaval. This drastic change would have been difficult to visualise if it was not for the artwork.

What makes *Tropical Artic* so timely, as the authors point out, is that the information gathered from these fossils and artwork is vital for our current climate situation: we should expect drastic ecosystem shifts as climate change continues. In many previous mass extinction events, such as between the Triassic–Jurassic, there were large scale dominance shifts and regional extinctions for plants rather than the global extinctions of numerous plant families. This implies that plants may have been able to track changes in climate even with extensive ecosystem disruption. It is currently unclear if this will be possible in today's changing and populated world. Today we might have more radical shifts than have been seen across past mass extinction boundaries, because the climate is changing at a faster rate than ever before. The extent of global extinctions or ecosystem dominance shifts of plant groups due to climate change is not yet known, but the data described in *Tropical Arctic* can give us some idea of what we could expect. The glimpse the authors give us into the past therefore provides us with a glimpse into our future.

Tropical Arctic shines a new light on one of the Big Five mass extinctions. The illustrations and language used in the book make it accessible to readers with either a Biological or Earth Sciences background and would be an ideal read for undergraduates. Additionally, the artistic component of the book would make a great introduction to those with an interest in scientific illustration. It is an informative book, but it is also an entertaining read. Rather than a scientific paper, it is written like a journey through both the geological past and the more recent excursion of the authors, and the reader is taken on the adventure through time. Chiefly, *Tropical Arctic* illuminates the importance and present relevance of the field of palaeobotany for helping us predict how plants may respond in the future. The approach used in this book to present the scientific findings through artwork should be an example to all scientists interested in making their research more accessible to a wider audience.