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ANCIENT ANTARCTICA—A JOURNEY FROM FORESTS TO ICE

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YOUNG REVIEWERS:

ADDY
AGE: 14

LEAF
AGE: 9

TEDDY
AGE: 12

When you think of Antarctica, what pictures come to your mind? Ice, penguins, frozen ocean? While this is what Antarctica looks like now, hidden in its rocks and ice are clues that Antarctica has not always been a freezing, white land. Fossils of plants and animals tell us that, millions of years ago, Antarctica was warm and covered in forests. Dolphins swam in the sea and crocodiles wallowed in the shallows! So what happened to turn this green world into the icy continent it is today? In this article, we go on a journey back through time, exploring ancient Antarctica and discovering what caused ice and snow to creep over the land.

PALM TREES IN ANTARCTICA?

Imagine you are sitting on the beach, the air is warm, and out to sea dolphins are splashing in the waves. Palms trees gently sway in the breeze above you and as you look inland, you see forests reaching up into the hills. You check your watch, it is midnight and the sun is still high in sky. Where are you? It might sound like a tropical beach, but a long, long time ago, as much as 50 million years ago, palm trees similar to those that grow in modern Indonesia lined the coast of Antarctica, our southernmost continent and site of the South Pole. Inland, the forests were full of beech trees, like modern New Zealand or Patagonia [1]. The plants in Antarctica survived for 6 months of the year in darkness during the long polar winter, and 6 months of sunlight during summer. Antarctica today looks very different, covered in huge amounts of ice with some rocks, but no vegetation. So how did a lush, green land change into a frozen continent? And how do scientists find out what Antarctica looked like in the past?

When explorers first started to investigate the rocks of Antarctica they found clues of a warmer past. An expedition in the early 1900s, led by Robert Falcon Scott, collected rock samples of 250-million-year-old fossil leaves as they attempted to be the first people to reach the South Pole. Fossils are ancient remains of life that can be preserved in rocks (Figure 1). Unfortunately, due to the harsh weather, they died trying to return to their boats at the coast. The important rocks with the ancient leaf fossils were found alongside their bodies. Throughout the 1900s, geologists (scientists who study the Earth) discovered more and more plant and animal fossils in rocks and **outcrops** scattered around the small patches of Antarctica that are not covered in ice. These discoveries showed that plant life once thrived on the continent, but our understanding of how and when the climate changed there

OUTCROP

An exposed area of rock on the land.

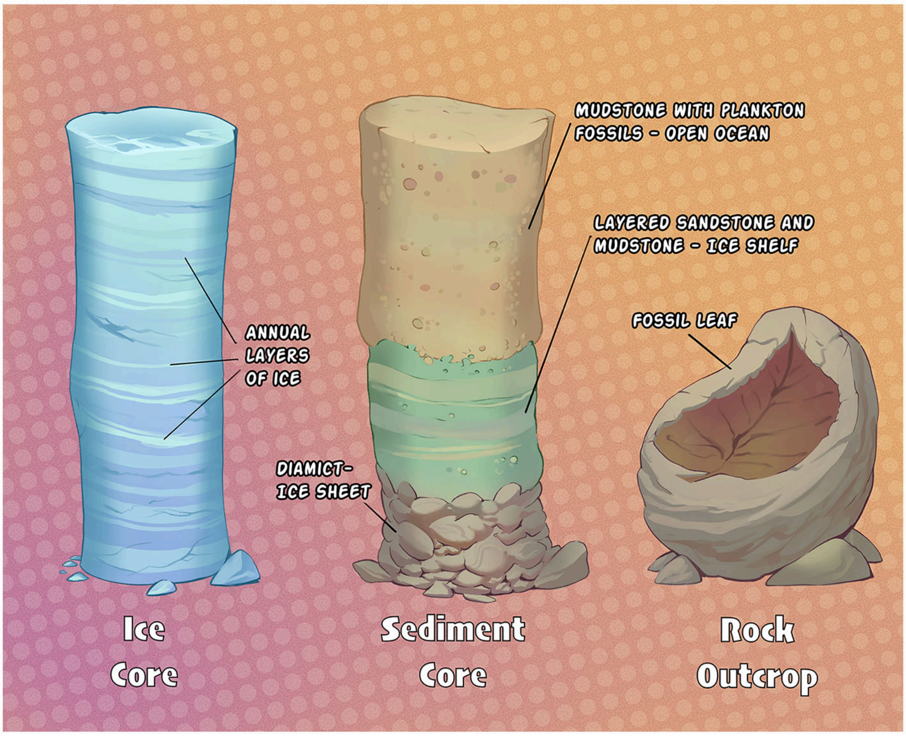

Figure 1

Figure 1

Paleoclimatologists study the past climate in Antarctica using three key methods. Ice cores contain layers of ice built up from annual snow fall. Sediment cores are made of layers of sand, mud, gravel, and fossils which have been deposited at the bottom of lakes and the ocean. The sort of sediment in each layer can be linked to the environment at the core site during the time that layer was deposited. Rock outcrops are an exposed area of rocks on land.

did not start to be pieced together until analysis of the seafloor near Antarctica, in the 1970s.

HOW DO WE KNOW WHAT ANTARCTICA LOOKED LIKE IN THE PAST?

We can get information about the past climate by using drill rigs to drill **sediment cores**, which we can study in laboratories. Sediment cores are a bit like time capsules (Figure 1). Sediments such as soil, mud, sand, and rocks are eroded off the land and transported by natural process like wind, rivers, and glaciers. These sediments are deposited in places like the sea floor or lake beds, where they build up, layer by layer. We can drill down through these layers and pull out a long cylinder of material called a core, in which the sediments get increasingly older as we get deeper. This core can provide us with a huge amount of information about what the environment was like in the past.

SEDIMENT CORES

Long, thin tubes of sediment collected by drilling down into the ground or seabed. Cores can be hundreds of meters long and record increasingly older sediment and they move deeper.

Paleoclimatologists, scientists who study the past climate, use three types of information to understand what Antarctica was like long ago (Figure 1). Ice cores, which contain annual layers of snow deposited on Antarctica, can provide very detailed climate records, but they only cover the more recent past—approximately the last one million years. Exposed rock outcrops on land can give us snapshots of the past, while sediment cores give a more continuous record, going back many tens of millions of years. The type of sediment found in a sediment core shows what happened at the core site in the past. For instance, **ice sheets** carry a messy mix of rocks, sand, and mud at their base, and they leave this material behind in rubble-like layers known as **diamicts**. Fossils in these sediments—like plant pollen, remains of ocean plankton, or chemical compounds that once formed the waxy coating on leaves—can be used to build a more detailed picture of the environment, telling us about which plants and animals were present, what the temperatures were, or how wet or dry the climate was.

PALEOCLIMATO-LOGISTS

Scientists who study Earth's past climate.

ICE SHEET

A huge amount of ice covering more than 50,000 km^2.

DIAMICTS

Rubble-like sediments of rocks, sand and mud deposited under an ice sheet.

WHEN DID ANTARCTICA BECOME ICE COVERED?

When scientists started to collect sediment cores from around Antarctica, they noticed a big change about 34 million years ago (Figure 2). Before this, the sediments and fossils suggested a mostly ice-free, warm landscape, with a wide variety of plant life. But 34 million years ago, evidence of ice started to appear. **Dropstones**, small rocks sitting in the seafloor mud, indicated the presence of icebergs floating in the water above. Changes in fossils showed a cooling climate and plant life became more tundra-like, similar to Arctic landscapes of northern Canada or Russia today (Figure 3). In some cores close to the continent, diamicts started to appear. All this was evidence for the first appearance of large, continent-wide ice

DROPSTONES

Rocks carried by ice bergs, which drop out of the ice berg and fall to the seafloor when it melts.

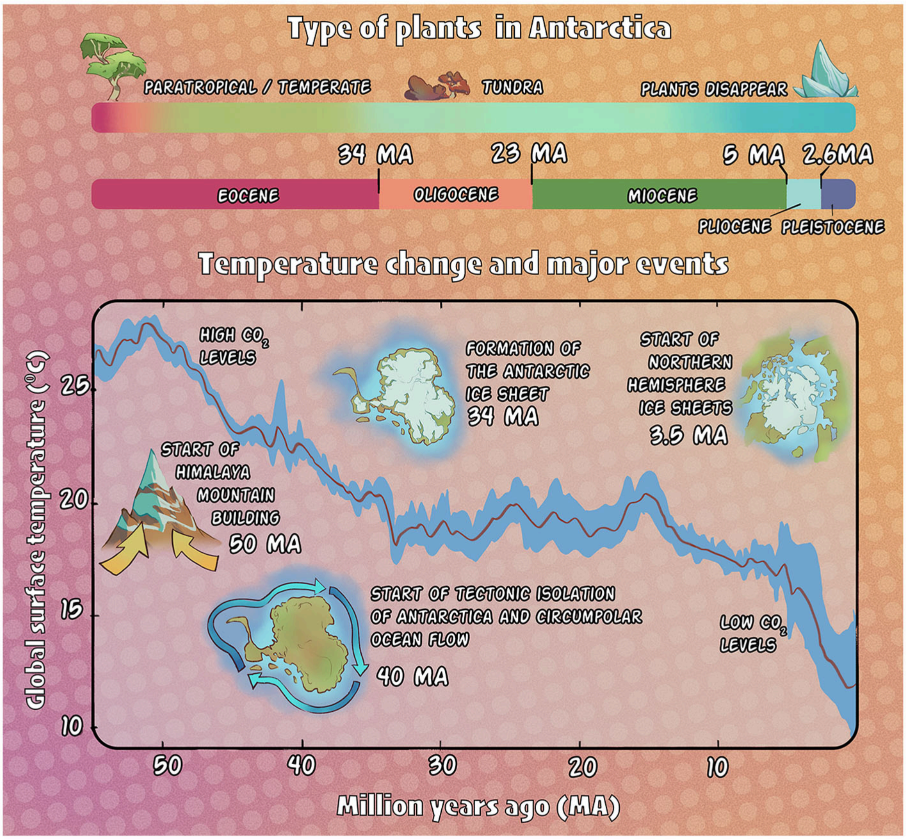

Figure 2

Figure 2

Over the past 55 million years, Antarctica has changed from a warm, forest-covered continent to the frozen land it is today. At the top of this figure, a bar shows the changing vegetation through time. Below are the geological epochs over this time period. Next shows global average temperature over the last 55 million years [2] from warm in the Eocene with high CO_2 levels to cold at present with lower CO_2 levels. Through this time, some important events occurred, like the formation of the Antarctic and Northern Hemisphere Ice Sheets.

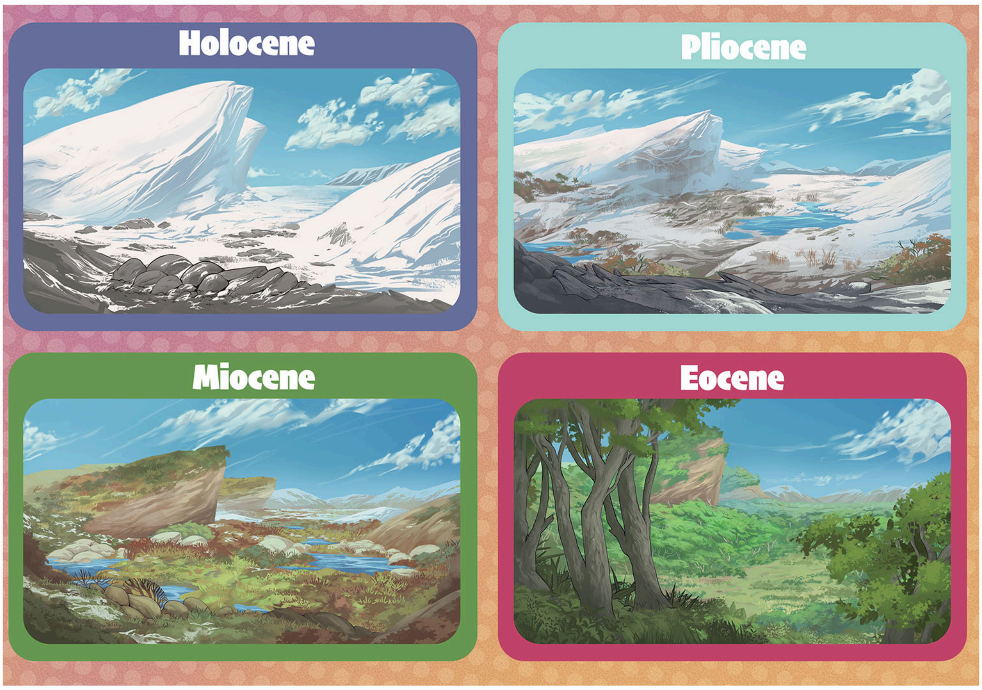

Figure 3

Figure 3

Illustrations of the Antarctic landscape during various periods of geological time called epochs. In the oldest epoch, the Eocene from 55 to 34 million years ago, Antarctica was covered in forests. In the Miocene, from 23 to 5.3 million years ago, vegetation was a cold tundra. In the Pliocene, 5.3–2.6 million years ago, vegetation had mostly disappeared from Antarctica. The Holocene is the current geological epoch and represents modern Antarctica (Figure based on https://thespinoff.co.nz/science/27-01-2022/returning-to-a-green-antarctica).

sheets covering Antarctica, at a time known as the Eocene-Oligocene boundary (Figure 2) [3].

WHY DID ANTARCTICA GET COLD?

The Antarctic climate continued to slowly cool over the last 34 million years, eventually becoming the icy, plant-free place we know today [4]. This cooling was caused by decreasing levels of carbon dioxide (CO_2) in the atmosphere. Earth's carbon is split between separate parts of the environment—the atmosphere, the oceans, the biosphere (vegetation), and sediments. Fifty million years ago, more carbon was stored in the atmosphere, causing the warm, greenhouse-like temperatures that led forests to grow in Antarctica. Since that time, several important environmental processes have played a role in transferring carbon from the atmosphere into sediments at the bottom of the ocean, cooling the global climate.

The surface of the Earth is cracked into huge pieces, called **tectonic plates**. Over time, tectonic plates move, changing ocean currents, building mountains in places like the Himalaya, and changing the shapes of continents. Movement of tectonic plates around Antarctica pushed away Australia and South America, which isolated Antarctica and led to the development of the Southern Ocean and the Antarctic Circumpolar Current, which is a fast flowing ocean current going all the way around Antarctica. This very big, windy area of ocean around Antarctica takes a huge amount of carbon out of the atmosphere, partly because CO_2 dissolves in seawater, and partly due to little ocean creatures that use carbon to grow and build shells. When these organisms die, their shells sink into the sediment at the bottom at the ocean, locking carbon away. Other natural processes can remove CO_2 from the atmosphere and lock it away, too. For example, rocks containing certain minerals can react with CO_2 as they are eroded, removing CO_2 from the atmosphere and transporting it through rivers into the ocean and deep ocean sediments.

TECTONIC PLATES

Massive slabs of Earth's outer crust that move slowly and fit together like a giant puzzle covering the planet.

READING THE PAGES OF ANTARCTICA'S ANCIENT HISTORY

The climate of Antarctica has generally cooled over the last 50 million years but, on shorter timescales, there has been lots of variation. Short cycles of cooling and warming, known as **glacials** and **interglacials**, have happened consistently over millions of years. You might know our most recent glacial, 18,000 years ago, as the last Ice Age. These cycles are caused by changes in the orbit of the Earth, which changes the amount of sun and heat reaching the polar regions. This happens in a periodic way, with glacials occurring every 100,000 or 40,000 years depending on Earth's exact orbit.

GLACIALS

Periods of time with cold climates, like the last Ice Age.

INTERGLACIALS

Periods of time with warm climates, in between glacials.

These cycles also happened many millions of years ago, as shown by repeating changes in layers of sediment in drill cores. Cores in the Ross Sea offshore Antarctica often show a layer of diamict followed by sands and mudstones with occasional dropstones. This represents a change in the environment from an ice sheet (the diamict) to a floating ice shelf. When the ice shelf melts and only the ocean sits above the core site, the sediments become full of fossils of tiny plants and animals that were living in the ocean. This collection of sediment layers, as shown in the sediment core in Figure 1, is usually repeated over and over again in these cores, as the ice sheet grew and shrank through glacial and interglacial cycles. Scientists read these sediment layers like pages of a book, telling the story of how the Antarctic ice sheet has changed in the past.

ANTARCTICA IN THE FUTURE

Paleoclimatologists build a picture of the environment of the past to help us to understand what sort of changes may happen to our planet with current and future climate change. In Antarctica, paleoclimatologists often focus on times when CO_2 and temperatures were higher than they are today, as this gives us guidelines of about what Antarctica might look like if we reach similar temperatures or CO_2 values in the future. As CO_2 levels rise, the world of our future will become more and more like worlds further back in the past. While it is unlikely we will be sitting under a palm tree on a beach near the South Pole anytime soon, retreating ice and a warmer climate may eventually cause the return of a green Antarctica.

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ADDY, AGE: 14

I am in 8th grade and really enjoy volunteering at my local museum. I really like helping animals and I hope to become an environmental lawyer when I get older. My favorite class in school is my dance class (I am very flexible), and I love to travel.

LEAF, AGE: 9

I am in third grade, and my favorite subject is art and science. I love observing changes in the world. I like to work as a Young Reviewer as I can observe many more changes using scientist's equipment. In my spare time, I like hiking, swimming, and riding bikes with my friends.

TEDDY, AGE: 12
I want to be an engineer. I have really enjoyed trying and struggling to learn how to engineer and code things. I am dyslexic. I really love math (especially algebra and geometry). I like to travel. I bike 30 miles a week most weeks.

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Bella is a Research Fellow in the Antarctic Research Centre, Victoria University of Wellington, New Zealand. She has been studying the past climate of Antarctica for the last 10 years, starting during her Ph.D. and continuing now in her postdoctoral research. She uses molecular fossils, the chemical remnants of life, to investigate what the Antarctic environment used to look like in the past. At the start of her Ph.D., she was lucky enough to go to Antarctica, where she found ancient leaf fossils preserved in rocks amongst the ice. This inspired her journey to becoming an Antarctic climate scientist! *bella.duncan@vuw.ac.nz

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