10
An intensity of green

> … a feeling for green seems to be universal in us … a new leaf, the return of greenness, is a seasonal fact of the world we live in, part of a cycle that gives shape to our lives and to the way we see living itself.
>
> David Malouf, *A First Place*, 2015, p.162.

Coming into Christchurch

Site 274 Site 11 (68° 59.81′S; 173°25.64′E) Water depth 3,326 m.

Occupied 16–19 February 1973

After the last drill hole—Site 274 right at the entrance to the Ross Sea, lying to the northeast of Cape Adare, had been successfully completed, *Glomar Challenger* turned for home—her temporary home in this case being Christchurch, New Zealand. We arrived in Lyttelton Harbour, Christchurch, on 27 February 1973. The last day's sailing was memorable; Vivaldi's *Four Seasons* was playing on the stereo; the sea had a sparkle, and the coast of New Zealand's South Island seemed intensely green in the early morning sun. When we arrived, the icebreaker *Burton Island* was already moored at the dock showing the great rusty dent in her bow resulting from her encounter with a 'bergy bit' in the Ross Sea.

Figure 10.1. The US icebreaker *Burton Island* in Lyttelton Harbour, February 1973, showing the dent above the belt line after meeting a bergy bit in the Ross Sea.

Source: Elizabeth Truswell.

Success of the voyage?

The end of the voyage was suffused with both regret and relief. The 69 days at sea that we had enjoyed—or endured, depending on one's experience and point of view—had produced results that were outstanding for the time. Our mandate, when we left Fremantle in December 1972, had been to explore the history of the Antarctic icecap and the high-latitude circulation of the seas surrounding that continent; and to investigate the timing and nature of sea-floor spreading between Australia and Antarctica. Within that broad spectrum, my personal aim had been to explore the evidence for the land vegetation of Antarctica before the modern ice cover eliminated it.

Overall, the most demanding of aims was to test the feasibility of drilling the sea floor in high southern latitudes under the constant threat of icebergs and the storms that characterise those regions.

By all measures, the voyage had been a success. We had succeeded in pushing back the age of the icecap from the 3–5 million years that was accepted when we left port, to something close to 26 million years. This was largely on the evidence from ice-rafted debris—the pebbles and sand grains recovered from cores close to the continent—and is detailed in chapters 7 and 8.

We had been able to see that waters around Antarctica had cooled steadily from the initiation of the first ice; then the boundary between the warm and cooler waters had made a rapid jump northward around 5 million years ago. This could be seen in the distribution of calcareous (limy) versus silica-rich sediments in the sea floor. These show a change from relatively warmer waters—signalled by the calcareous oozes—to cooler conditions and the deposition of diatom oozes. This change is best seen in those boreholes well away from the Antarctic landmass where there is less input of material eroded from the continent.

We had tested the age and rates of sea-floor spreading across the Southeast Indian Ridge separating Antarctica and Australia, using ages from tiny fossils in the sediments lying atop the volcanic basement of the sea floor. We confirmed that these were in accord with magnetic ages deduced from earlier seismic mapping.

Drilling in the continental shelf of the Ross Sea was another first—this was the shallowest drilling then attempted by the *Glomar Challenger*—even though the continental shelf of Antarctica is deeper than most of the world's continental shelves due to the weight of ice. The area had its own problems in the technical difficulties of recovering cores loaded with pebbles from the developing Ross Ice Shelf. However, it did show, in a preliminary way, how that ice shelf had previously sheared off the tilted sediments as it expanded beyond its present limits. As an additional surprise—one that was more than a little alarming—we had penetrated pockets of gas in the Ross Sea. We did not believe that this was significant in the overall picture of Antarctica as a future source of hydrocarbons. Nevertheless it was enough to stir the international press at a time of a global oil crisis.

While we, scientists and crew, were euphoric about the results achieved on Leg 28, it was pointed out by Ken Hsü in his overview of the *Glomar Challenger*'s achievements that the success of our pioneering voyage might have reflected unusually good luck! True, the weather had mostly been calm and mild enough for us to undertake most of the planned drilling. Icebergs had caused the shifting of one site, but the accompanying icebreakers had steered us through potential hazards, particularly in the Ross Sea.

So there was an element of good luck, to be sure. In the Operations Resumé of Leg 28, the operations manager, Lamar Hayes, suggested that we had just escaped Antarctica before its legendary malice found us. He wrote:

> perhaps we slipped into Antarctica and recovered a few of her secrets and were well on our way to Christchurch before our presence had been discovered. Twenty-four hours after the completion of our last site, a cloud-cover picture from the satellite indicated the entire Ross Sea was involved in a major storm lasting over 72 hours. (Hayes 1974, p.40)

More recent reviews of the whole program of drilling the sea floor of the deep oceans, reviews that can now look back over 50 years, classify the Deep Sea Drilling Project (DSDP), and its rugged *Glomar Challenger*, as belonging to an initial phase of 'curiosity driven' exploration—a rather simplified 'looking to see what's there' approach. In contrast, according to these reviews, more recent phases have singled out particular issues in Earth science and have sought answers to global problems through focusing on carefully selected drilling programs. Perhaps that is so in general, but the history of the polar ice sheet, an issue to which several DSDP expeditions contributed substantially, is a subject of ongoing scientific concern at a global level. However, one extensive review of the entire program of sea floor drilling—published by the US National Academies Press in 2011—noted that:

> DSDP Leg 28 drilled on the Antarctic continental shelf in the Ross Sea, providing the first physical evidence of continental glaciation extending back into the Oligocene, and dispelling the then prevailing hypothesis that Antarctica had only been extensively glaciated since the beginning of the Quaternary (2.58 million years ago). (National Research Council 2011, p.44)

Surely a sound foundation on which to build a comprehensive history and understanding of Earth's climate.

Again, being dubbed a sedimentologist on this cruise had advantages. Moving me outside my area of expertise as a palynologist involved me more closely in exploring past climates than if I had simply been searching for the pollen evidence of Antarctica's ancient vegetation. The pollen evidence I sought was rare, with slim recovery from only two drill sites, but it was enough to set me on a search for the vegetation history that was to involve me in many years of research.

Bringing it together—a post cruise meeting

Some months after the end of the Leg 28 cruise, the scientific party met in La Jolla, California, to coordinate our results and to plan the inputs to the formal publication. In such meetings, the scientific results of each particular leg were brought together and published as hard copy (hard and very heavy—the Leg 28 volume weighed in at 3.75 kg!) in large volumes—at first with a distinctive turquoise cover. These volumes gave descriptive and photographic details of all the cores recovered on each cruise, general syntheses of the results, and reports of the specialists—including those who were on board and those from other institutions who worked on core material after the cruise completion.

The trickiest part of the post cruise meeting was reaching agreement in establishing a chronology—a geological time frame—against which the events we recorded could be set. The information we had to hand came both from palaeontology and from the igneous rocks of the sea floor—rocks that often underlie the sequences of fossil-bearing sediments. The palaeontologists on the cruise were specialists in several fossil groups, usually microfossils. We had experts in diatoms and radiolaria—the organisms with walls of silica; we had folk who worked with foraminifera and nannofossils, with limy walls; and then there was me, working with fossil pollen, with its tough organic walls made of the complex protein-like substance sporopollenin, and with dinoflagellates, whose cysts are preserved with a similarly structured protein.

In dating, the application of each fossil group relies on a system of palaeontological zones or biozones—the known extent of strata through which key fossil species are shown to occur. But for these to be expressed in terms of millions of years, or the 'absolute dates' of common parlance, they have to be linked back to the scale of ages derived radiometrically from volcanic rocks and, increasingly, from the patterns of reversals in the Earth's magnetic field—where the magnetism of rocks preserve the normal, or reversed, state of Earth's magnetism. The development of accepted time scales is an ongoing process. Now, it is regularly summarised by the International Commission on Stratigraphy, a body set up in 1977 that incorporates current knowledge in all fields—palaeontological, geochemical and geophysical. The most recent compilation shows the state of knowledge in 2017, and is reproduced in summary form in Chapter 1 (Figure 1.2) of this volume.

What was available to us in 1973, and accepted by the DSDP, was a less formal, but adequate version summarising knowledge available then. In spite of differences among palaeontologists—who are notorious for quibbling about the fine issues of stratigraphy—the information garnered at sea or shortly after the cruise ended was brought together and published in the sturdy 1975 volume. A digital version was made available in 2007 where the main results are summarised under the names of the two chief scientists (see Hayes and Frakes et al. 1975). It is a satisfying—or perhaps a sobering—thought that preserved in these published versions are the observations made at sea and first pencilled on the paper strips that were tacked to my cabin wall in 1973.

While the results from Leg 28 were, in our estimation and in Ken Hsü's words, 'spectacular', they were just a small beginning in our understanding the history of the Antarctic icecap and its associated ocean circulation. Today the continent bears ice sheets on both East and West Antarctica; it lacks a cover of higher vegetation; it is surrounded by the Antarctic Circumpolar Current that links all the world's oceans; it is the source of the cold and salty Antarctic Bottom Water, formed beneath ice shelves and annual sea ice, which flows widely in the world oceans; and its icebergs carry sediment and rock clasts north into Subantarctic waters, well beyond latitude 60°S. At the Polar Front ocean upwelling supports a rich biota.

Leg 28 showed that the beginnings of a continental icecap were present at least as long ago as the Oligocene—around 26 million years ago—and gave hints that something akin to a Polar Front might have been established by then. What we still don't know is precisely when that ice sheet might have first developed, how it has fluctuated since its inception and how, and when, the other features of ocean circulation linked to it have evolved since that time.

The Deep Sea Drilling Project; pressing on in Antarctic waters

After the success of Leg 28, the planning committees of the DSDP—including those of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) and the US National Science Foundation's Office of Polar Programs—decided that further cruises planned for high southern latitudes could go ahead. So in March 1973 Leg 29 ventured into the Subantarctic and cool temperate waters south of Australia and New Zealand and the Tasman Sea between latitudes 40°S and 57°S. In spite of encountering severe weather—including a 100 kilometre per hour gale on Site 276—little drilling time was lost, and they drilled 16 sites that told much of the history of separation between Australia, New Zealand and Antarctica. But there was a ringing affirmation in that drilling—through the isotopic analyses of foraminifera—that Antarctic glaciation had indeed reached sea level by the Oligocene. This was the same early date we had determined on Leg 28.

Then another leg, Leg 35, left from Callao, Peru, in February 1974, and ended in Ushuaia, the capital of Tierra del Fuego, Argentina, on 30 March. It was a short leg, dogged by problems of weather and the nature of the sediments drilled. There were only four drill holes—two in the Bellingshausen Abyssal Plain and two on the continental rise of Antarctica. Most were in deposits of detritus coming from Antarctica, and soft sediments and coarse ice-rafted pebbles hampered operations. It was difficult to take continuous cores. The sediment recovered showed the oldest dropstones to be of Early to Middle Miocene age—that is, about 10–20 million years old. Positioning the ship was difficult in high winds and high seas, and at least one site was abandoned due to the vessel's constant pitching. Clearly it was a case of some information gained under impossible circumstances.

Leg 36 followed in 1974 but through unforeseen circumstances left Ushuaia seasonally late in the autumn month of April and returned to Rio de Janeiro in May. Their hopes were to get a more detailed story of the Antarctic Circumpolar Current. But, in the words of their report 'weather, darkness, and ice' combined to ensure that no sites were successfully drilled south of 51°S.

The *Glomar Challenger* never again ventured south of 50°S. Given the notable successes of the Leg 28 drilling, it may just be possible that we were indeed very lucky in that weather and technology combined to allow us to draw a broad picture of an ancient icecap and the embryonic features of the surrounding ocean circulation.

Glomar Challenger docked for the last time in November 1983 after a lifetime of service, drilling at some 624 sites during 96 expeditionary legs, drilling through some 170,000 metres of sediment and rock, and recovering and storing around 97,000 metres of core. These are now stored and carefully curated in core libraries around the world. The demise of this ship, covered by the dismissive verb 'scrapped', evokes a little sadness, although the preservation of at least a few body parts in the Smithsonian is tribute of a kind.

There is just one other tribute to the *Glomar Challenger*. In 1988, the Advisory Committee for Undersea Features—yet another committee of those that seem to entangle the natural world—named a northeast trending depression on the continental shelf of the Ross Sea the Glomar Challenger Basin. It is not yet a name that finds wide circulation in public conversation.

Further drilling off the Antarctic edge; the *JOIDES Resolution*

The DSDP was followed by the Ocean Drilling Program (ODP) and the Integrated Ocean Drilling Program (IODP) with the vessel *JOIDES Resolution*, the name bringing Cook's epic voyage to mind.

Several more cruises to the Antarctic seas were undertaken to address questions of the ice cap origins and the history of related ocean circulation. Beginning in the 1980s the *JOIDES Resolution* sailed from Punta Arenas, Chile, and ended in the Falkland Islands after drilling sites in the Weddell Sea (Leg 113). The tentative conclusions from that expedition suggested that the ice sheet on West Antarctica may have developed later than that on East Antarctica—it probably didn't begin to form until the Late Miocene—10 to 12 million years ago. Pollen in one of the sites near the tip of the Antarctic Peninsula showed that there was a southern beech forest with a fern understorey there in the Eocene.

Another leg (ODP 114) followed, this time in the subantarctic sector of the Atlantic, in latitudes north of 55°S. This focused on the development of boundaries in the ocean, linked to a developing Antarctic ice sheet. Ice-rafted debris was identified there in the Early Miocene, around 23 million years ago.

All of the sites drilled on Leg 114 showed that there were gaps, or hiatuses, in the sediments drilled, and these were probably related to the opening of Drake Passage in the Early Miocene—perhaps enabling the beginnings of something like the Antarctic Circumpolar Current.

Attention then swung to the eastern edge of Antarctica and focused on Prydz Bay, where the Lambert Glacier flows into the Amery Ice Shelf. Leg 119 was drilled in Prydz Bay in the summer of 1987–88 (see Chapter 9) and showed glaciation—or at least phases of it—beginning in the mid- to late Eocene, tentatively dated at 42 million years ago, but the subsequent record there was eroded off and lost.

In the year 2000, Leg 188 of the same ODP drilled in the same bay, penetrated and recovered core spanning the transition from pre-glacial to full glacial conditions—this was probably close to the boundary between the Eocene and Oligocene, some 34 million years ago. By then glaciers had reached sea level. At the same time, a flourishing vegetation—perhaps akin to an alpine heath—covered the surrounding coastal plain and delta landscapes.

Further to the east, in the summer of 2010, drilling off the Wilkes Land coast during Expedition 318 of the succeeding IODP recovered sediments that were older than those known from Prydz Bay. These were truly pre-glacial, identified as Early Eocene, somewhere in the range of 48–55 million years old. These yielded pollen produced by a tropical forest. This, and the vegetation story from the Prydz Bay drilling I have described in the previous chapter.

The emerging picture of the development of Antarctica's icecap, with the accompanying changes in ocean circulation, is an increasingly complex one. More recent evidence, based not on deep sea drilling but on shallow cores and geophysics, taken seaward of the Aurora Basin—which lies beneath the ice still further east on the coast of East Antarctica—revealed even older evidence for glaciation. Its beginnings would appear to lie somewhere in the Early Eocene, possibly as long as 50 million years ago. Its history since then has been one of a complex stepwise development. What is emerging from ongoing research is an intricate story of ice advances and retreats across the continental edge including its continental shelf.

A new greening of Antarctica

Much of the story of the higher vegetation—the flowering plants, conifers and other gymnosperms, ferns, clubmosses and horsetails—of the Antarctic continent that I have outlined in Chapter 9 has to do with the road to extinction of this flora. We are aware now that there were rainforests of tropical aspect in coastal Antarctica in the Eocene, some 40–50 million years ago, and that there followed a progression through floras resembling alpine heaths, then eventually to tundra, some with scattered and dwarfed trees, leading ultimately to the extinction of the land flora by the Miocene or Pliocene, somewhere between 3 and 10 million years ago.

Flowering plants in Antarctica today are restricted to two species, a grass and the Antarctic pearlwort—a member of the carnation family. These grow on warmer areas of the Antarctic Peninsula and its islands and are likely to have migrated into Antarctica in recent geological times. The present terrestrial vegetation—growing in the 2 per cent of the land not covered by ice and snow—consists of mosses, liverworts, lichens and fungi. Given that there is increasing evidence of shrinking of the ice cover under currently warming climates, it is interesting to speculate what vegetation might return to an Antarctica with more ice-free areas.

There is little possibility that the earlier vegetation, the tundra with trees such as the southern beech and the podocarps, would ever reappear, given the apparent inability of those to cross the wide oceanic gaps that now separate Antarctica from other southern landmasses where the groups currently grow. But an increased presence of grasses and other flowering plants, and of the lower plants remains a possibility, and could well colonise Antarctica should the cover of ice decrease. Indeed, the Antarctic pearlwort has been shown to be producing more seeds, with more germination, under recently warming conditions, and to be extending its range southwards on the Antarctic Peninsula.

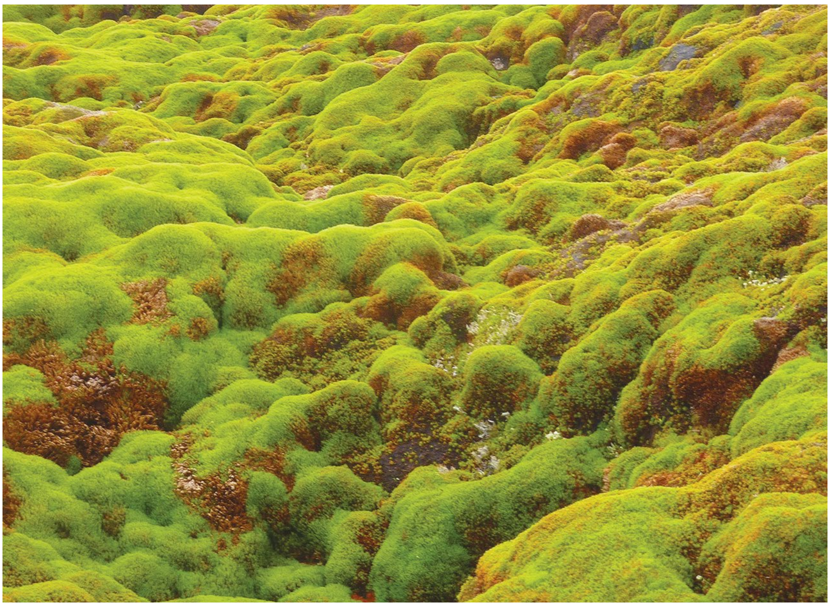

Figure 10.2. Moss growth on the Antarctic Peninsula.
Source: Courtesy of Dr Matthew Amesbury, University of Exeter.

A more dramatic increase in the greening of Antarctica has been observed with the growth of mosses. On the eastern side of the Antarctic Peninsula, which has been identified as one of the most rapidly warming places on Earth, botanists have measured an unprecedented surge in the growth of mosses along some 600 kilometres of the coastline since the 1950s. While direct records of temperatures in that region, including on some of the offshore islands, are relatively short, it has been possible to core the hummocks of moss to give a longer picture, measuring both the mass accumulation of the moss and the activity of associated microbes. The increased growth of mosses has been attributed to temperature increases, changes in the availability of water and to the ability of mosses to effectively colonise newly bare ground. As has been reported by researchers in the area, if temperatures continue to warm, the Antarctic Peninsula is likely to get a whole lot greener, in line with what is happening in the Arctic.

Postscript

As I write, the *JOIDES Resolution* is again in the Ross Sea in the course of Expedition 374 of the International Ocean Discovery Program. This is the first visit there of a deep sea drilling ship since *Glomar Challenger* in 1973. The plan is to drill five holes, sited to illuminate the history of the West Antarctic Ice Shelf. There are regular, almost daily, postings from the ship—logs, Facebook, Twitter, Instagram; multimedia and educational material; email is a ready form of communication. Today the activities on the drilling ship reach out instantaneously to a much wider audience, to schools, universities and an interested general public. There are onboard Education and Outreach Officers who encourage conferences from ship to shore, and specialist scientists are there to outline their roles in simple language, suitable for instantaneous broadcasts to schools. There are light-hearted stories of the comforts and trials of life on board; stories of the wildlife encountered; stories of the food; and all of these are delivered in simple languages with illuminating visual images. How comparatively isolated we were in 1973 when we relied on the radio and telegraph! The *Glomar Challenger* did have satellite navigation, with navigational information provided by satellites of the US Navy—four satellites in polar orbit, but not always easy to contact. This was a much less sophisticated system than the GPS system of the *JOIDES Resolution*.

Communicating from the Southern Ocean and Antarctica

The daily reports from the *JOIDES Resolution* are but the most recent phase in a long history of communicating results from exploration in the Southern Ocean and Antarctica. The history begins with the diaries of officers and sailors, and with the work of artists specially appointed to record events and scenes encountered on the voyages that were new to both science and a public eager for information. The young William Hodges fulfilled this role on Cook's second voyage. But even then, other individuals from the crew were moved to put pen or brush to paper to preserve the novelty of seascapes. Peter Fannin, who was Master of HMS *Adventure*, the vessel accompanying *Resolution*, produced his own distinctive paintings of Antarctic waters. The young naturalist Georg Forster also contributed images, recording the phenomena of icebergs and icy seas.

Publishing the results of the early expeditions was a far more lengthy process, and was in some cases dogged by controversy. Again, using the example of Cook's voyage, it was understood by Lord Sandwich, the First Lord of the Admiralty, that Cook's account of the voyage should be the official one. The official naturalist, Johann Reinhold Forster, who could see a financial gain for himself in being the first to publish, vehemently contested this view. The astronomer William Wales sided with Cook in this argument and contributed a lengthy dissertation in Cook's account in which he roundly criticised Forster.

There were specialist artists appointed to these recording roles on some of the voyages of the mid-nineteenth century. The French under Dumont D'Urville carried two young artists; the US Exploring Expedition under Wilkes employed the young Alfred Agate, although Wilkes himself made creditable drawings. The *Erebus* and *Terror* voyages under James Clark Ross in contrast, carried no dedicated artists, but John Edward Davis, Second Master of the *Terror*, produced maps, sketches and lively watercolours that were included in the official account given by Ross.

The enthusiasm to draw in order to record the events of the voyages is evident in the records from HMS *Challenger*, where the sub-lieutenants William Spry and Herbert Swire illustrated their diaries with competent and colourful sketches and paintings. Drawing had been an official part of their training—this was especially the case in the British navy. But it was during the same expedition on HMS *Challenger* that photography was introduced, although we have no record of a designated photographer.

This rapidly became the preferred medium for communicating images from the southern continent and seas. The first aerial photograph—of the vessel *Gauss* trapped in the ice—was taken from a hot air balloon in 1902 during the German expedition led by Erich von Drygalski.

Photography was taken to a high aesthetic peak in the heroic age expeditions of Scott and Shackleton. Herbert Ponting, who travelled with Scott, called himself a 'photographic artist'. Frank Hurley, who was an innovator in the use of a camera, against all odds produced unforgettable images of the crushing and sinking of Shackleton's *Endurance* in the ice of the Weddell Sea. He later sailed with Mawson, taking not only still photographs of onboard activities and equipment for dredging, but also film sequences, some of which were widely shown to boost funding for further expeditions. The images of both Ponting and Hurley have come to symbolise Antarctica in the minds of a curious public.

A final postscript

Since writing the above the *JOIDES Resolution* moored briefly in March 2018 in Lyttelton Harbour, Christchurch, after the completion of Expedition 374 to the Ross Sea. Their drilling program appears to have been successful, although only the most preliminary results have been released. Site 1522 of the program, which was located in the Glomar Challenger Basin, bottomed in sediments of glacial marine origin, of Late Miocene age, perhaps around 9 or 10 million years old. But significantly, Site 1522, the furthest south of that recent drilling program, was situated at 76°33.22′S. Site 270, drilled by the *Glomar Challenger* in 1973, was sited at 77°26.48′S. Somehow it is immensely satisfying that the pioneer vessel has retained the mantle of drilling further south than any other scientific drilling ship!

This text is taken from *A Memory of Ice: The Antarctic Voyage of the Glomar Challenger*, by Elizabeth Truswell, published 2019 by ANU Press, The Australian National University, Canberra, Australia.