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INTRODUCTION

Our Glacial Earth

Forty thousand tourists visit Antarctica each year. Millions more have seen nature documentaries about the frozen continent and its charismatic wildlife: penguins, seals, and whales abroad on their favorite feeding grounds. Every southern summer—from December through February—hundreds of scientists descend on Antarctica armed with research grants. Over eighty research stations, accessed by air and sea, are scattered across a continent the size of the United States and Mexico combined. These stations support scientific studies of all kinds: from polar geology and glaciology to marine microbiology and paleoclimatology. Antarctica is remote from all human habitation, but not from human consciousness and endeavor.

For all the recent interest in Antarctica, myths and misperceptions persist. For example, many people assume that Terra Australis Incognita was discovered in the early twentieth

Fig. I.1. Mountainous East Antarctica forms the bulk of the continent, while West Antarctica and the Antarctic Peninsula are lower-lying and more vulnerable to glacial melt.

century—during the so-called Heroic Age of polar exploration—with the British *Endurance* expedition, and the tragic deaths of Captain Robert Scott and his men on their return from the South Pole, having been beaten to the prize by Roald Amundsen. But, in fact, the discovery of the Antarctic continent was achieved seventy years earlier, with a tri-nation race to the pole launched in the first years of Queen Victoria's reign. This book tells the story of these forgotten nineteenth-century expeditions, and of the vast ice kingdom that almost swallowed them whole.

Land of Wondrous Cold also speaks to our present anxiety over global warming and the melting of Antarctica's glacial rim. A long history of Antarctic climate change requires the interweaving of multiple, complementary timeframes. When the Victorian polar explorers converged on the high southern latitudes in 1840–41, they discovered a mountainous land of ice that seemed limitless in space and untouched by time. More than a century later, their scientist descendants, scouring the same Antarctic coasts under the aegis of the international Ocean Drilling Program, finally determined the origin of this continent-sized ice cap in a drastic climate upheaval that helped shape modern Earth millions of years ago. This breakthrough deep-sea research of the late twentieth century uncovered how Antarctica's remarkable refrigeration helped reset the global thermostat, air-conditioning the planet to human specifications.

Fast forward to the present, the world's attention is focused on the potential reversal of this epic Antarctic glaciation. Currently, two hundred feet (sixty meters) of sea-level rise is locked up in Antarctica's towering ice cap. If even a small portion of this glacial imperium were to melt, the great port cities of our modern world would sink beneath the resurgent waves. Already, millions of the world's island and coastal-dwelling pop-

ulations live under the threat of rising seas. With Antarctica looming once more as a central player in the human story, this book tells the full history of our climatic connection to the white continent—past, present, and future.

In January 2017, I traveled to Antarctica in the mode of the nineteenth-century explorers—by ship. I grew up in the Southern Hemisphere, on that temperate coast where the Antarctic and Australian landmasses were long ago united; but, like most Australians, I had been raised facing resolutely northward. Only after more than a decade as an environmental writer in the United States did my thoughts turn to southerly explorations and polar climes. Encountering, as the Victorian voyagers did, a vast ice pack off the coast of the Antarctic Peninsula, the limitless white plain appeared to me fully alien, a thing that could not possibly intersect with human interests.

For an author, the most forbidding challenge presented by Antarctica's glaciated shore, and the snow-crested ranges beyond it, was its inhuman blankness. Like the Victorians, I was mostly confined to the ship, with nowhere to land along an endless coast buttressed by sheer cliffs of ice. As I gazed out day after day from an icy deck onto a pure, unchanging vista, the metaphor of the blank white page appeared to me really too obvious, but disabling nevertheless. Luckily, on our very last day in Antarctica, on a rocky cape at the northern rim of the Ross Sea, my shipmates and I were treated to a day to write home about.

Cape Adare, at the foot of the Admiralty Mountains, is usually a storm zone charged with dangerous ice. Here Captain James Ross and the crews of the British discovery ships *Erebus* and *Terror*, sailing south from Tasmania in January 1841, were dumbstruck by their first sight of the Antarctic continent. But where they kept a wary distance from the wave-lashed cliffs,

the bay was invitingly blue and calm during our visit. On the beach—a rare commodity in Antarctica—the largest Adélie penguin colony in the world awaited us, its photogenic chicks molting in readiness for their swimming debut. Back from the beach stood an explorers' hut from the dawn of the Heroic Age, 1898–99, when a Norwegian named Carsten Borchgrevink established an onshore party on behalf of the British Empire with the goal of being the first to overwinter in Antarctica. These next-generation polar adventurers succeeded, but were miserable and occasionally mutinous. The expedition scientist died and was buried among the penguins.

As if this history were not tantalizing enough for the modern Antarctic tourist, northward across the bay the Admiralty Mountains rose in unspeakable splendor, threaded with glaciers—and we had helicopters to explore them. As we flew along a glacial valley, skimming the river of ice, the physical dimensions of the frozen continent became palpably real to me. If there was this much ice in a single valley—on a continent bigger than the United States—then it might be possible to conceive of Antarctica as home to 70 percent of the world's fresh water, sealed up in these glaciers, and for thousands of miles inland across the endless, dune-like plateaus.

Back on the ship's deck, I watched the helicopter turn toward the southern mountains, expecting at any moment to see the pilot pull up to avoid crashing into the cliff face. But the helicopter disappeared from view long before I could witness the maneuver. In that moment, I felt a fresh affinity with the Victorians, who had likewise been bamboozled by the dry and dust-free air of Terra Australis, which sets objects much farther away than they appear. The epic scale of Antarctica—which was the true revelation of being there—became a few degrees less abstract.

For our shipbound party, a day ashore at Cape Adare was a godsend. Penguins, glaciers, and explorer huts offered limitless photo opportunities, while helicopter flights were Instagram gold. To cap the day, a young couple who had met onboard were married on the beach by the ship's doctor, a ceremony witnessed by a penguin legion wearing nature's own tuxedo. Most importantly, from a writer's point of view, Cape Adare completed the all-important guiding metaphor for a book on Antarctica. My weeks spent skirting the ice pack and the blank, icebound cliffs would represent my telling the deep-time history of Antarctic ice, while the action-packed day on the beach at Cape Adare stood for the human-scaled adventure narrative of the first explorers that I interweave here with my glaciological tale.

To its Victorian discoverers, as well as legions of latter-day tourists, Antarctica has appeared pristine and unchanging. But its miles-long glaciers only masquerade as the still point of a turning world. They *flow*, and have ebbed and flowed for millions of years, transforming Earth's climate and biosphere in their transit. Today, parts of Antarctica are the fastest-warming regions on Earth. But if Antarctica is not the immutable ideal it appears to be to the naive tourist, how much has it changed over time? And when?

Since a meteorite brought an abrupt end to the sweltering Cretaceous period with its "great lizards," the interval of greatest sustained warmth in our planet's history was the early Eocene epoch, which began fifty-four million years ago and lasted six million years—so-called Hothouse Earth or, in official terms, the Early Eocene Climatic Optimum. On Hothouse Earth, the Antarctic coast supported diverse forests of warmth-loving palms and flowering evergreens reminiscent of modern-day New Guinea. Farther inland, at higher elevations, stretched

a rainforest canopy and sunlit clearings dense with ferns. Though situated near its current latitude, Antarctica managed to sustain its greenhouse botany through fifty days of polar darkness each year. Baking atmospheric carbon levels and mild winter temperatures kept the forest ecosystem running through the unending night. No landscape could be more at odds with Antarctica as it is now—bleak, frozen, and blasted by winds—a continent-sized icehouse.

The Apollo 17 space mission in 1972 was the first to chart a path between Earth and the moon providing a clear view of modern, glaciated Antarctica. One iconic photograph—taken at a distance of eighteen thousand miles from Earth—underscores the dominance of the south polar ice cap in our planet's current geography. Ours is a glacial world, with a narrow tropical band, and higher latitudes and elevations bound by ice (the reason average global temperatures may not suggest icehouse conditions is because we are currently enjoying a brief interglacial period, determined by Earth's orbit of the sun). The Apollo image—one of the most reproduced in history—became known as "Blue Marble." But with signature white awnings spread out at the poles, "Glacial Earth" would be as fitting.

Antarctica's glaciation played a decisive role in the creation of the Blue Marble: our modern, human-habitable planet. Beginning in the 1970s, sedimentary cores drilled in the Southern Ocean floor have revealed the deep climate history of the white continent, in particular its critical shift from hothouse to icehouse. First, in the Mid-Eocene, Australia slipped its hold on Antarctica and drifted northward, creating a cold, globe-girdling ocean in the south. Then, thirty-four million years ago, the end of the Eocene was marked by the most drastic change of climate on Earth since an asteroid suffocated the dinosaurs. Torn from the warming embrace of its ancient Gondwanan neighbors, Antarctica was gradually transformed from

ERA	PERIOD		EPOCH (and Ma)		
CENOZOIC	QUATERNARY		Holocene	0.01	
			Pleistocene		Late
					Middle
				2.54	Early
	TERTIARY	Neogene	Pliocene		Late
				5.33	Early
			Miocene		Late
					Middle
				23.03	Early
		Palaeogene	Oligocene		Late
				33.09	Early
			Eocene		Late
					Middle
				55.8	Early
			Palaeocene		Late
					Middle
				65.5	Early
MESOZOIC	CRETACEOUS		Late	99.0	
			Early	144	
	JURASSIC		Late	159	
			Middle	180	
			Early	206	
	TRIASSIC		Late	227	
			Middle	242	
			Early	248	

Fig. I.2. After the climatic optimum of the Middle Eocene, when Earth experienced hothouse conditions, the world has generally cooled, with a dramatic temperature plunge at the Eocene-Oligocene Transition, about thirty-four million years ago.

a humid land of forests, swamps, and beaches, rich in exotic creatures, into a frozen mountain fortress almost destitute of terrestrial life. Meanwhile, the world's volcanoes abated, lowering CO_2 levels in the atmosphere, cooling the planet a further 5°C and more.

This extraordinary temperature depression—combined with the dynamic power of the new circumpolar Southern Ocean—recast the thermal character of the world. The now worldwide supercooling event devastated the globe's plant and animal life. Everywhere, dense forests gave way to grassland plains, driving an entire weird menagerie of ancient mammals into extinction, from western Europe to the steppes of Asia. Time-lapse photographs from space would have shown an ice cap expanding from isolated flecks of white to the size of a great icy hand holding up the world.

This transition from the Eocene hothouse to the glacial Oligocene epoch was brutally sudden, with over half the temperature change occurring in fifty thousand years. For a planet four and a half billion years old, it was like waking up in sweat-soaked sheets one morning, only to be shivering under the blankets that same night. Earth's shock climate deterioration spelled extinction for a multitude of hothouse creatures and opened the door for a new order of cold-tolerant species: our human precursors.

The overall territory for primates shrank dramatically during the climate crash, but prehuman anthropoids in Africa flourished in habitats abandoned by their thermophilic rivals. A fresh zoology of mammals appeared—a distinctly modern retinue of horses, dogs, and ruminants that our opportunistic ancestors would later domesticate. Human-friendly plants, too—the forerunners of modern cold-resistant grains, and the grass our cattle would eat—emerged from the global cooling event thirty-four million years ago, the age of Antarctica's first ice.

Scientists call it by various unpoetic names: the Eocene-Oligocene Transition; the Oi-1 Glaciation; or, more satisfyingly, La Grand Coupure—the "Big Break." If you were to take a time machine back thirty-five million years, before the Big Break, you would stumble into an unrecognizable faunal extravaganza, with CO_2 levels a sweltering thousand parts per million. Before long, you'd be eaten by a giant prehistoric bird or rat. Now punch in thirty-three million years. As you step out, a strange world greets your eye, but it is not one you mistake for another planet. The atmosphere, most importantly, is accommodating: CO_2 concentrations have dropped from their Eocene highs to modern levels. This is a planet you might, with luck, inhabit. La Grande Coupure was, remotely considered, *our* big break. This book tells the story of the Big Break—of Antarctica's original glaciation, and the planetwide revolution it triggered—through the eyes of a notable band of human beneficiaries: the Victorian south polar explorers and the modern ice scientists who sail in their wake.

To call the Victorians latecomers to Antarctica's story is a spectacular understatement. As a stand-alone continent, Antarctica is thirty-four million years old, whereas our modern ancestors ventured out of Africa a mere sixty thousand years ago. The narrative is familiar. Forests rich in hardwood provided tool-adept humans with the raw material for building ships, which soon crisscrossed the globe: first Polynesians in the Pacific, then Europeans across the Atlantic. Ocean transit opened the world's continents, and even its remote islands, to colonization—with one notable, frozen exception.

Then, at last—less than two centuries ago—the prospect of whale oil, sealskins, and treasures unknown lured ships from Britain, France, and the United States to risk an attempt on the South Pole. The 1838–42 Antarctic discovery missions were the

Apollo moon shot of the nineteenth century—and might never have happened at all. What began as a hopeful idea floated by a few well-connected merchants and scientists snowballed into a full-blown competition with national honor at stake: a race to the South Pole. France sent the brilliant Pacific navigator Dumont D'Urville, while Britain chose its Arctic veteran James Clark Ross to outdo the French. The Americans, meanwhile, with no hall of fame explorer to call upon, gambled on an untested surveyor named Charles Wilkes, whom a certain novelist of renown would later redub "Captain Ahab."

The tri-nation discovery voyages of 1838–42 were the first official expeditions to the Antarctic. But, in another sense, they were also the last of their kind. There is an air of Alice's white rabbit about these Victorian-era explorers, running late for their date with history. By the late 1830s, the four-hundred-year history of European seafaring exploration—begun in the days of Magellan and Columbus—was petering to an end.

The heroics of Scott, Shackleton, and Amundsen in the early 1900s have long overshadowed the remarkable history of Victorian Antarctic discovery. In the much-recycled stories of the Heroic Age, Captain Scott appears larger than life against the backdrop of a brutal polar wilderness, while Shackleton overcame a crushed ship and all that pack ice by sheer force of human will. But Amundsen, to his credit, knew public neglect of the Victorian voyages was a travesty: "few people of the present day," he wrote in 1914, "are capable of rightly appreciating th[ese] heroic deed[s], this brilliant proof of human courage and energy . . . these men sailed right into the heart of the ice pack, which all previous explorers had regarded as certain death. These men were heroes—heroes in the highest sense of the word."

A century after the Edwardian dramas of Scott and company, the Victorians' turn has come around again. The first

south polar generation—D'Urville, Wilkes, and Ross—pitifully exposed in their wooden sailing ships and awed into submission by the polar landscape, are explorers custom fit for our current era of climate anxiety. As the Victorians learned, there is no better place to feel the hollowness of fame—as well as time and space—than the looking-glass world of Antarctica. In *Land of Wondrous Cold*, their wandering ships pop up here and there, like Alice's white rabbit, across the vast space-time fabric that was Terra Incognita Australis. Their experience in Antarctica was something closer to what we newly realize today: that human heroics amount to little compared with the greater planetary motions of the continents and climate.

To pursue this point a step further: in my telling of the Victorian discovery voyages, the explorers themselves do not play an outsized role, like actors spotlighted on a stage. Rather, my goal has been to adjust the telescope and bring humans and nature into focus at their proper scale. I recount here the story both of Antarctica's first refrigeration—the origin of its ice sheet—and, millions of years later, the first human encounter with that world-changing phenomenon. *Land of Wondrous Cold* thus interweaves a science-rich story of glaciation and climate change with a more conventional discovery tale set in the South Seas—an unusual blend, admittedly. Any structural resemblance to *Moby-Dick* is strictly intentional.

Antarctica, throughout, is my lead protagonist. The polar explorers of 1838–42—their ambitions, suffering, and wonderstruck observations—are the lens of this Antarctic history, not its subject. Instead of detailing the full story of each expedition (which has been done satisfyingly by others), *Land of Wondrous Cold* re-creates key episodes that link these discovery voyages to the modern era of polar research—to our current understanding of Antarctica's precarious glacial history. Polar science today is booming, courtesy of global warming, glacial

melting, and the threat of rising seas. The Victorians' contributions to this new "heroic age" of Antarctic research have long been overlooked, while the harrowing extremes they endured for their exotic polar specimens, observations, and charts make for a discovery legend undeservedly obscured by the expert mythmakers who followed in their wake.

Because Antarctica's discovery was, at its heart, a mythic seagoing adventure—pushing southward beyond the known—my narrative is organized by space rather than time. Beginning with the windswept sub-Antarctic islands, each episode in *Land of Wondrous Cold* takes us degrees farther south toward the elusive pole, deeper down the rabbit hole, curiouser and curiouser. Time, by contrast, is elastic—sometimes spanning eons in a single sentence, sometimes contracting so that whole pages tell the story of a single, crowded hour in Antarctica's 1840s discovery. I invite my readers to speed up or slow down as they wish.

In this telling, the south polar discoverers are not heroic men of destiny. Faced with an alien land utterly inhospitable to humans and resistant to conventions of discovery, the Victorians make no meaningful conquests and plant flags only for show. Instead, they emerge as exemplary slow tourists, absorbing the Antarctic environment at an observational pace unobtainable today. Antarctica, they will discover, tells a story far larger than any single explorer—larger, indeed, than humanity itself.

What has been mostly forgotten, even by polar scientists themselves, is that these discovery vessels of the Victorian Age—the British *Erebus* and *Terror*, the French *Astrolabe* and *Zélée*, and the American flagship *Vincennes*—brought with them the first human beings ever to venture into and beyond the Antarctic ice pack for the purpose of scientific inquiry. What they found baffled, fascinated, and horrified them. They

charted ambiguous coastlines, sketched glaciers, collected tiny marine creatures and great seabirds, gathered weather data, monitored the effects of cold on their suffering bodies, and theorized about the currents of the great Southern Ocean. Their collective achievements culminated in arguably the most monumental geographical discovery of the nineteenth century: the Ross Ice Shelf, a great white plateau the size of France, rising sheer from the blue polar waters of West Antarctica from beneath the southernmost active volcano on Earth. In return, the explorers barely escaped with their lives (in most cases).

"Antarctica" is the name of both a continent and an ocean, as well as a more ineffable idea of human limits. It is host to great congregations of seals, birds, and the iconic penguins but has no indigenous peoples. For us humans, Antarctica is not a home but a land of science and imaginative journeying. One hundred eighty years ago, sailing ships from Britain, France, and America burst through the perennial belt surrounding the last undiscovered continent. They entered a hostile glaciated realm whose creation, more than thirty million years ago, helped fashion the planet we inhabit—its climate, ocean currents, and creatures. Now, when Antarctica's melting ice sheet threatens baseline conditions for the human civilization that sent those ships, the land of mist and snow beckons us again. In *Land of Wondrous Cold*, our newly urgent encounter with Antarctica begins with the resolute but forgotten icemen of the Victorian Age.

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