

ENCYCLOPEDIA OF
PHYSICAL
SCIENCE
AND
TECHNOLOGY

1990
Yearbook

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ENCYCLOPEDIA OF

PHYSICAL

SCIENCE

AND

TECHNOLOGY

ROBERT A. MEYERS, EDITOR
TRW, INC.



ACADEMIC PRESS, INC.

Harcourt Brace Jovanovich, Publishers

San Diego New York Berkeley Boston
London Sydney Tokyo Toronto

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ACADEMIC PRESS, INC.

San Diego, California 92101

United Kingdom Edition published by

ACADEMIC PRESS LIMITED

24-28 Oval Road, London NW1 7DX

ISBN 0-12-226917-9 (alk. paper)

ISSN 0898-9842

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PRINTED IN THE UNITED STATES OF AMERICA

89 90 91 92 9 8 7 6 5 4 3 2 1

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PREFACE

The *Encyclopedia of Physical Science and Technology*, published in 1987, is now being used in some two thousand libraries located in centers of learning and research virtually spanning the globe. These include universities, technology-based industries, military facilities, public libraries, government agencies, and school districts.

Two occurrences have encouraged and indeed obligated this Editor, the Executive Advisory Board, and the publisher of the *Encyclopedia of Physical Science and Technology* to proceed with publication of a series of yearbooks. The first is the wide acceptance of the *Encyclopedia* by the scientific community with placement in numerous libraries. The second factor giving impetus to the yearbook series is the inevitable continuation of major advances in key areas of the physical sciences and technology. Wide acceptance of the *Encyclopedia* indicates that there is an equally wide audience for the yearbooks, and the rather striking recent advances in physical sciences provide an abundance of topics for ranking and selection for publication.

The Executive Advisory Board—Chandrasekhar, Pauling, Prelog, Salam, Schwartz, Seaborg, Siegbahn, and Teller—and our fifty-member Editorial Advisory Board were polled for article nominations. This resulted in selection of the articles, prepared by recognized author-experts, which constitute the *Yearbook*.

Each article covers a rapidly advancing scientific or technological field, and the presentation follows the format of the published *Encyclopedia*. This format includes a glossary of terms specific to the discipline covered, a table of contents, an introductory definition of the subject, and a bibliography. The presentation in the style of a mini-book is aimed at providing a working knowledge and introduction to the field for those readers not familiar with the subject.

A total of fifty-nine articles were selected for the *Yearbook*. They cover important advances in virtually all areas of science and technology. The following is a summary of the articles by subject area.

Aeronautics is represented by an article on recent advances in aircraft performance and design. Seven articles were required to cover new information in

astronomy and astrophysics; three of these are on the Solar System and four cover astrochemistry and star phenomena. Recent data and concern on the issue of global change resulted in four articles in atmospheric sciences including an article on acid rain and another on Antarctica. Chemistry and physics are represented by nineteen articles including Ultrashort Laser Pulse Chemistry and Spectroscopy, Superconductivity Mechanisms, Quasicrystals, Positron Microscopy, Strange Particles, CP Violation, and Chaos. Advances in computers and controls are presented in five articles including Computer Viruses and Artificial Neural Systems. Nine articles cover the earth sciences and oceanography, including articles on geomorphology and reclamation of disturbed lands, ocean surface layer, and thermoluminescence dating. Electronics and electrical engineering are represented by six articles, including Diluted Magnetic Semiconductors, Magnetic Bubbles, and Liquid Crystal Devices. There are five articles on recent advances in mathematics. An article on emergency planning for nuclear facilities is presented in the nuclear technology field, and an article on water reclamation represents civil engineering. Space technology is represented by an article on human spaceflight.

Seven of the articles were chosen as features and given an expanded treatment. These were selected based on importance to the physical sciences and technology, their impact on related disciplines, and recent exceptional expansion of theoretical, data, or engineering content. These articles are Antarctica, Astrochemistry, Chaos, Planetary Geology, Quasicrystals, Superconductivity Mechanisms, and Water Reclamation.

The goal of this Editor and the Executive Advisory Board is to make this series of yearbooks useful both as a supplement to the *Encyclopedia* and as a publication equivalent to an "Advances in Physical Sciences and Technology" that will give recognition to, and dissemination of, progress in the physical sciences and technology.

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ANTARCTICA

GUNTER WELLER

University of Alaska

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 - II. The Antarctic Environment
 - III. Scientific Research in Antarctica
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-

GLOSSARY

Crevasse: Break produced by stresses in the ice on the surface of glaciers or icecaps, usually from meters to tens of meters wide and 30–40 m deep.

Ice sheet (ice cap): Ice that completely covers land masses such as islands or entire continents (Antarctica); thickest at the center and thinning toward the edges.

Ice shelf: Floating ice pushed by glaciers and ice streams flowing from the interior of Antarctica into the ocean; when the ice breaks off at the edges, icebergs are produced.

Ice stream: Large, fast glaciers, embedded in slow-moving ice that drains the interior of Antarctica into the ice shelves surrounding the continent; flow velocities are on the order of a few hundred meters to kilometers per year.

Icebergs: Large floating masses of ice, up to 100 km long and 200–300 m thick, that have broken off (calved) into the ocean from ice shelves or glaciers and coastal ice cliffs.

Katabatic: Literally, “downward-moving”; down-slope winds produced when heavy, cold air in the interior of Antarctica drains to the coast under the action of gravity.

Krill: Shrimplike, 3–6-cm-long zooplankton that are the main food of the baleen whales, some species of seals, and penguins; krill are the most abundant animals on Earth.

Nunatak: Isolated mountain peaks completely surrounded by ice; usually the rest of the mountain range is buried under the ice.

Pack ice: Ice produced when the ocean freezes and the ice is broken into floes of various sizes and is compressed into pressure ridges by winds and ocean currents; floes are separated from one another by open water leads.

Polynya: Large bodies of water (in contrast to leads, which are generally small cracks and areas) in the pack ice; kept open by winds and ocean currents.

Sastrugi: Hard, wind-packed snow dunes with very irregular surfaces, up to a meter high, that make travel on the antarctic plateau very difficult.

Antarctica (Fig. 1) is the fifth largest continent (ahead of Europe and Australia) with about 14 million square kilometers and is located in the Southern Hemisphere around the South Pole. About 98% of the continent is buried under a thick ice sheet, which in places is 4 km thick. It is the highest, coldest, and

driest continent on Earth, surrounded each winter by 18 million square kilometers of pack ice. First sighted in 1820, Antarctica is now primarily a scientific laboratory, with a winter population of only a few hundred scientists from different nations and a summer population of a few thousand. Territorial claims have been made by seven nations, but are frozen by an international Antarctic Treaty. While Antarctica is primarily a continent for science, political issues such as resource exploitation (minerals, petroleum, krill), conservation, and tourism have emerged.

I. History of Exploration

A. TERRA AUSTRALIS

1. Ancient Times

As early as the sixth century B.C., the Greeks postulated that the world is a sphere. The concept of a large southern land mass, later known as Terra Australis Incognita, was invented by the Greeks as a balance to the northern known lands. This idea was revived by the great voyages of exploration in the fifteenth century.

2. Sixteenth Century

Voyages of exploration pushed south of 50°S. Magellan in 1519 discovered the southern tip of the South American mainland and the strait that bears his name, separating the mainland from Tierra del Fuego. The latter was believed to be the long-sought-after Terra Australis. Drake in 1578 discovered the Drake Passage and proved that Tierra del Fuego is not connected to the southern continent.

3. Sixteenth to Nineteenth Century

Most of the subantarctic islands were discovered during this period: the Falkland Islands by the English explorer Davis in 1592; the South Shetland Islands by the Dutch sailor Gerritsz in 1622 (although there is some doubt about this); South Georgia by the London merchant Antonio de la Roche in 1675; Bouvetøya by the French Bouvet de Lozier in 1739; Prince Edward Islands and Isles Crozet by Du Fresne, also French, in 1772; and the Isles Kerguelen, discovered by Kerguelen in 1772. The Auckland Islands were discovered in 1806 by Bristow, and the Macquarie Islands were discovered in 1810 by Hasselborough, two sealers operating out of London and Sidney, respectively.

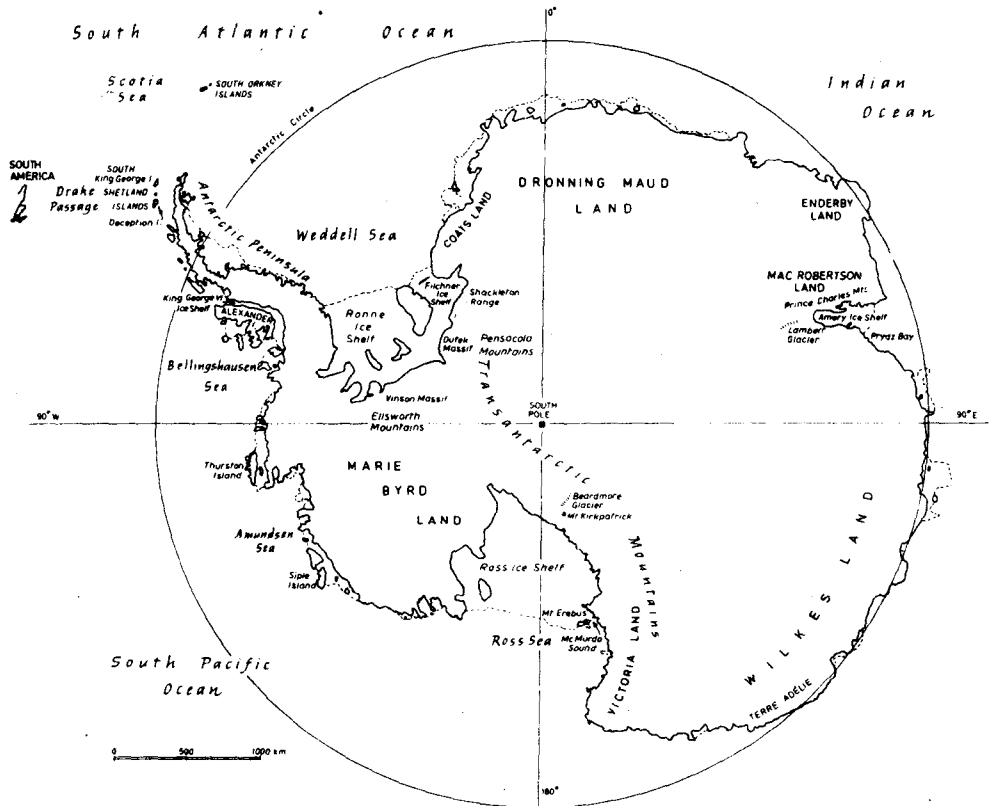


FIG. 1. The Antarctic continent. [From Fifield, R. (1987). "International Research in the Antarctic." Published for the Scientific Committee on Antarctic Research (SCAR) and the ICSU Press by Oxford Univ. Press, London and New York.]

4. 1772–1776

The great English navigator James Cook, in two voyages of exploration intended to settle the enigma of Terra Australis, crossed the Antarctic Circle for the first time and circumnavigated Antarctica, but he failed to sight the continent. He discovered the South Sandwich Islands and discovered or rediscovered South Georgia. His two ships, *Adventure* and *Resolution*, sailed nearly 100,000 km, often through ice-berg-infested unknown waters, in perhaps the greatest sea voyages ever made. Cook's discoveries ended the myth of a fertile, inhabitable Terra Australis.

B. DISCOVERY OF ANTARCTICA

1. 1820

Three different expeditions saw the Antarctic continent for the first time, although doubt and some

confusion surround these sightings. Thaddeus von Bellingshausen, sent by the Russian Czar to be the first to circumnavigate Antarctica since Cook, and at a more southerly latitude, sighted land at 70°S, 2°W but did not clearly recognize the ice field in his view as land. A few days later, the Englishman Edward Bransfield sighted the Antarctic Peninsula, but his log books are now lost, making it difficult to substantiate any claims of discovery. The American sealer Nathaniel Palmer noted in his log book, which is now in the Library of Congress, that he sighted land in the same region that Bransfield saw almost a year earlier, but his log entries are also vague. The controversy is not yet settled.

2. 1821–1822

American sealers discovered new land. John Davis made what was probably the first landing on the antarctic mainland at Hughes Bay on the Antarctic Pen-

insula. Nathaniel Palmer and George Powell discovered the South Orkneys, and Benjamin Morrell made the first landing on Bouvetøya.

3. 1823–1839

British sealer James Weddell sailed his ship to 74°S, in what is now called the Weddell Sea, under very favorable ice conditions. John Biscoe sighted Enderby Land, the first sighting of Antarctica in the Indian Ocean sector, and John Balleny discovered the Balleny Islands south of New Zealand and the Sabrina Coast of Antarctica. Both Biscoe and Balleny were employed by the English sealing firm of Enderby Brothers.

4. 1840–1842

Lieutenant Charles Wilkes, in charge of the four ships of the United States Exploring Expedition sent out to chart and survey the waters around Antarctica, made several sightings of what is now Wilkes Land. Controversy surrounds the validity and accuracy of some of these sightings to this day. At the same time, the French Dumont d'Urville discovered and landed on a stretch of antarctic coast, which he named Terre Adélie after his wife.

5. 1841–1843

Sir James Clark Ross, sent by the Royal Navy to locate the South Geomagnetic Pole, sailed his ships *Erebus* and *Terror* into what is now the Ross Sea. His record of furthest south at 78°S stood until 1900. He discovered Victoria Land, Ross Island with the active volcano Mt. Erebus, and the great ice barrier of the Ross Ice Shelf.

6. 1874

The HMS *Challenger*, as part of a four-year scientific cruise of the world, was the first steamship to cross the Antarctic Circle. The crew carried out extensive scientific work on the Southern Antarctic Ocean and the subantarctic islands.

C. THE HEROIC AGE

1. 1895

The Sixth International Geographical Congress in London proposed major new explorations in Antarctica after little activity for the previous 50 yr. This launched an era of government-sponsored scientific expeditions and signaled the start of the heroic age of

antarctic exploration, a period marked by much personal endurance and bravery.

2. 1898–1899

A Belgian expedition under Adrien de Gerlache spent a year on the *Belgica* trapped in pack ice off the Antarctic Peninsula. They made numerous landings and charted islands and straits before getting caught in the ice. The first to overwinter in Antarctica, they encountered serious medical and psychological problems.

3. 1899–1900

Carsten Borchgrevink, a Norwegian who had migrated to Australia, and companions landed at Cape Adare and were the first to overwinter on the Antarctic continent. Their ship, the *Southern Cross*, sailed along the Ross Ice Shelf and exceeded Ross's furthest south record.

4. 1902–1903

A German expedition under the command of Erich von Drygalski on the *Gauss* discovered Wilhelm II Land and Gaussberg. The *Gauss* was trapped in the ice for a year, but the expedition was scientifically very productive.

At the same time, the Swede Otto Nordenskjöld made the first major sledge journeys in Antarctica over two winters. His ship, the *Antarctic*, was crushed by ice and sunk, but the whole party was saved after surviving the winter.

5. 1902–1904

Robert Falcon Scott's first expedition in *Discovery* was the first attempt to reach the South Pole; Scott, Shackleton, and Wilson were turned back just south of 82°S. The expedition conducted other sledging journeys, and in the most important of these Lieutenant Albert Armitage discovered the route up the Ferrar Glacier to the ice sheet. The *Discovery* was trapped in the ice for two years, but it broke out with the help of explosives in February 1904.

The 1902–1904 Scottish National Antarctic Expedition under William Bruce on the *Scotia* made major scientific and geographic discoveries, including Coats Land, in the Weddell Sea area.

6. 1903–1910

The French explorer Jean Charcot conducted two expeditions to the Antarctic, from 1903–1905 on the *Français* and 1908–1910 on the *Purquois-Pas*. Dur-

ing the expeditions, he surveyed over 2000 km of coastline and newly discovered territory in the Antarctic Peninsula area.

7. 1907–1909

The second attempt to reach the South Pole was made by Ernest Shackleton. Sailing to Antarctica in the *Nimrod*, he established his base camp at Cape Royds on Ross Island. Using ponies on the Ross Ice Shelf and finding a route up to the ice sheet via the Beardmore Glacier, Shackleton and three companions came to within 180 km of the South Pole before they were forced to return. Another sledging party, including Alistair Mackay, Edgeworth David, and Douglas Mawson, walked 2000 km to reach the South Magnetic Pole. Mount Erebus was climbed for the first time.

8. 1910–1912

Roald Amundsen, the Norwegian discoverer of the Northwest Passage, secretly sailed to Antarctica in Nansen's ship, the *Fram*, after his original goal, the North Pole, was reached by Peary. He established his base, Framheim, in the Bay of Whales on the Ross Ice Shelf. With four men, Bjaaland, Wisting, Hassel, and Hanssen and four sledges with 13 dogs each, he crossed the Ross Ice Shelf, discovered and ascended the Axel Heiberg Glacier, and reached the South Pole on December 14, 1911, killing dogs for dog and human food as he traveled. The journey was meticulously planned and executed, with all 5 men and 11 remaining dogs reaching Framheim hale and hearty.

Robert Scott's second expedition to Antarctica also aimed for the South Pole. The *Terra Nova* established Scott's base at Cape Evans on Ross Island. Using ponies as Shackleton did and using the route pioneered by Shackleton, Scott and four men, Wilson, Bowers, Oates, and P.O. Evans, reached the South Pole on January 17, 1912, a month after Amundsen. Bad planning, shortage of food and fuel, scurvy, frozen limbs, and disappointment at being forestalled by Amundsen led to the death of all the members of the party on the return journey, after great sufferings. Six men of the northern party in Victoria Land spent the winter in an ice cave but reached Cape Evans safely.

9. 1911–1912

The second German Antarctic Expedition in the *Deutschland*, under Wilhelm Filchner, discovered the Luitpold Coast and the Filchner Ice Shelf. The *Deutschland* was trapped in the ice and spent the winter drifting through the Weddell Sea.

Japan's first expedition under Lieutenant Shirase reached the Bay of Whales in the *Kainan Maru* and sledged 250 km south on the Ross Ice Shelf.

10. 1911–1913

An Australasian expedition under Douglas Mawson sailed on the *Aurora* to set up bases on Macquarie Island, in Adélie Land (the home of the blizzard), and on the Shackleton Ice Shelf. Six major traverses were carried out, a new section of the coast was discovered, and radio was used in Antarctica for the first time. Mawson lost his two companions (Ninnis falling with most of their supplies into a deep crevasse and Mertz dying from vitamin A poisoning) and barely reached base after a grueling 500-km trek.

11. 1914–1916

Ernest Shackleton attempted the first crossing of Antarctica from bases in the Ross and Weddell Seas. His ship, the *Endurance*, was caught in the ice of the Weddell Sea before landing anyone and was crushed after a nine-month drift. Twenty-eight men camped on the ice and reached Elephant Island in boats. Shackleton with five companions crossed 1300 km of open ocean in a 7-m-long boat to South Georgia and eventually, after 4 attempts, rescued all of his men on Elephant Island on the Chilean steamer *Yelcho*. This was one of the greatest sagas of endurance and survival in antarctic history.

12. 1922

With Shackleton's death on his third antarctic expedition on the *Quest*, the heroic age came to an end. Shackleton was buried on South Georgia.

D. THE MECHANIZED AGE

1. 1925–1939

The British Discovery Committee opened a marine biological station on South Georgia and organized a dozen major cruises, first in Scott's old ship, the *Discovery*, and later in the *Discovery II*. This was the first sustained scientific effort in Antarctica, and it ushered in a new age of exploration in which motorized vehicles and airplanes replaced manhauling and dog teams.

2. 1927–1937

The Norwegian whaler Lars Christensen sponsored nine antarctic expeditions on the *Norwegia* and dis-

covered 3700 km of coastline of Dronning Maud Land.

3. 1928–1929

The Australian Hubert Wilkins made the first flight in Antarctica from Deception Island in a Lockheed Vega. With American pilot Ben Eielson, he flew 1000 km along the Antarctic Peninsula.

4. 1928–1930

Richard Byrd's expedition set up camp at Little America near the Bay of Whales on the Ross Ice Shelf. Utilizing three aircraft, the Rockefeller Mountains were discovered by air, and geological parties were set out, but the highlight of the expedition was the 16-hr-long flight in a Ford trimotor to the South Pole and back on November 29, 1929. Bernt Balchen was the pilot, Byrd was the navigator, and a radio operator and photographer were also aboard.

5. 1929–1931

The British, Australian, and New Zealand Antarctic Research Expedition (BANZARE) under Douglas Mawson discovered Mac Robertson Land and charted long sections of the adjacent coastline. Territorial claims were beginning to be made, and in a meeting between Mawson and the Norwegian Riiser-Larsen, they agreed on a dividing line between British and Norwegian exploration efforts.

6. 1933–1935

Richard Byrd returned with an expedition to Little America to carry out air and ground journeys with three aircraft, an autogiro, and several tracked vehicles, adding a great deal of scientific knowledge. Byrd wintered alone at Bolling Advance Weather Station, about 200 km from Little America, and nearly died from carbon monoxide poisoning.

7. 1934–1937

The British Graham Land Expedition under Australian John Rymill explored and surveyed the western side of the Antarctic Peninsula, using a sea plane, tractor, and dog teams.

8. 1935

American Lincoln Ellsworth with British pilot Herbert Hollick-Kenyon made the first transantarctic flight, from Dundee Island at the tip of the Antarctic Peninsula to Little America.

9. 1939

Alfred Ritscher on the *Schwabenland* photographed 250,000 km² of Dronning Maud Land from two hydroplanes and discovered several mountain ranges. Aluminum darts with swastikas were dropped on the ice and a few landings were made, but no formal German claim was ever made.

10. 1939–1941

The United States Antarctic Service Expedition under Richard Byrd established Little America III on the Ross Ice Shelf and the East Base on the Antarctic Peninsula to explore the Marie Byrd Land coast by ship, plane, and sledge teams. No formal claim was made based on any of the American exploration work in this sector.

11. 1946–1947

Operation Highjump was mounted by the U.S. Navy under the command of Admiral Byrd. With 13 ships, 23 aircraft, and over 4700 men, it was the largest antarctic expedition ever undertaken, designed both as a training exercise and to establish a U.S. presence in Antarctica. A base camp was set up at Little America, ice breakers were used for the first time in Antarctica, and large areas were photographed from the air. Several new mountain ranges were discovered.

12. 1947–1948

Operation Windmill was a follow-up on Highjump to provide ground control points for the aerial photographs taken on Highjump. The ice breakers *Edisto* and *Burton Island* landed surveyors by helicopter at nine points on the Wilkes Land coast, but the survey was not completed because of the onset of winter.

The private Ronne Antarctic Research Expedition under the command of Finn Ronne landed on Stonington Island on the Antarctic Peninsula and explored the peninsula and what is now the Ronne Ice Shelf by aircraft and on sledge trips.

13. 1949–1952

The Norwegian-British-Swedish expedition under John Gjaever established its base, Maudheim, in Dronning Maud Land. The first truly international expedition, it produced a wealth of scientific data. In the same period, the Expéditions Polaires Françaises operated scientific bases at Port Martin and Point Géologie (later Dumont d'Urville) in Adélie Land.