

# Antarctica — Why?

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## *Introduction*

IN 1965, the United States will have completed ten years of continuous activity in Antarctica. Thousands of man-hours and millions of dollars have gone into this effort, and it is appropriate to ask, to what purpose?

Perhaps the answer is no more than the fact that man, like nature, abhors a vacuum, or it may be the pressure of population that drives a human vanguard forward to seek new ground no matter how uninhabitable. It may be an instinctive fear of boredom accumulated through thousands of years of evolution hard won by man's willingness to compete against nature and himself. Perhaps it is the desire for knowledge, the need to satiate his curiosity about his origin and his fate. Whatever the underlying motive of the individual, when translated into a national effort, the purpose of exploration must have definable results and rewards.

Our national presence on the Seventh Continent has been the result of very practical motives from the beginning. Economic gain through exploitation of the fur seal and the whale first brought U. S. sailors to the ice-bound coasts. National prestige kept the U. S. among the "Antarctic" nations in the decades of great geographical exploration. The need for specific scientific data motivated participation in the International Geophysical Year (IGY) and the judgment that it would be constructive to work for settlement of national differences in Antarctica through peaceful scientific cooperation has perpetuated a continuing effort.

The full weight of the 20th Century made itself felt in Antarctica with the beginning of the IGY. The need for longitudinal and latitudinal chains of scientific stations throughout the world dictated that Antarctica would assume a more active and permanent place in the affairs of men and nations. The twelve countries<sup>1</sup> with prior Antarctic interests working

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1. Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, United Kingdom, Republic of South Africa, Union of Soviet Socialist Republics, and the United States.

through international scientific organizations pooled their individual efforts and reached agreement on what each would contribute and where each would establish and maintain stations to provide a research station network commensurate with the goals of the IGY.

In 1956, when this research began, a very limited area of Antarctica had been seen by man or had been described in terms which would satisfy a research scientist or a geographer. The IGY program in Antarctica set out to describe the properties that are peculiar to Antarctica and to determine the influence Antarctica plays on the global environment. By the close of the IGY in December, 1958, Antarctic knowledge was no longer in a dark age of ignorance and superstition.

During the IGY the United States manned seven Antarctic stations, five in West Antarctica (the Pacific Quadrant), one on the Knox Coast and one in the Weddell Sea.<sup>2</sup> These stations served as sites for continuous synoptic observations and as bases from which to begin to explore scientifically the nature of the heart of Antarctica. With no more than three to four months of a year available to conduct programs far afield from fixed stations, only a small part of the unexplored regions of the plateau was covered. Months of darkness plus temperatures of 40° to 100°F. below zero limited the amount of research that could be carried out at the stations. There was always snow to contend with — wind-blown snow filling up tunnels and caches, crushing buildings, burying cargo and vehicles — always requiring long hours of shoveling. Furthermore, the IGY program did not officially include certain areas of science, such as geology and biology, and although some geologists and biologists went ahead with Antarctic studies, such programs were not systematically pursued. The IGY afforded only sufficient time to teach scientists and logisticians how to operate efficiently and in some disciplines to work the bugs out of equipment.

At the close of the IGY program in Antarctica, most of the nations involved found that their investment had been too dear to quit after just three years of effort. Norway, which had heavy commitments in the Arctic, terminated its active field programs in 1959. Japan, whose resupply vessel was suffering severely from age and the battering of ice, discontinued its station in 1961.<sup>3</sup> The other nations decided to continue and to retrench their efforts to permit a long-range approach to the exploration and development of Antarctica.

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2. Byrd, Hallett, Little America, McMurdo, South Pole, Wilkes and Ellsworth Stations.

3. The Japanese Expedition plans to return to Antarctica in 1965.

### *A National Research Program*

All of these continuing programs were national efforts, paid for by the governments from tax revenues. The U. S. Antarctic Research Program (USARP), although no different in this respect, developed uniquely among Antarctic programs. First of all, USARP is an amalgamation of university and Government agency research under the single budgetary and management authority of the National Science Foundation. Also, it is a mutually cooperative effort between civilian researchers and Department of Defense logistic support personnel. To augment the research activity, USARP has included as an integral part of its programs such services as map making, information and data retrieval systems, specimen sorting services, translation services and ways to improve the dissemination of information.

With every National Science Foundation grant to a university or transfer of funds to a Federal agency for research in Antarctica, there is the implied obligation that all necessary services and facilities will be available to the investigator. In order to relieve him from the burden of negotiating all his logistic and administrative requirements with the representatives of the Department of Defense, which provides the basic transportation, communications, and housekeeping services in Antarctica, the Foundation undertakes this service in his behalf. The Foundation also arranges through contract for the maintenance of field laboratories and special field equipment which the researchers may require reducing thereby the detail which tends to distract from the research itself, while at the same time relieving the Department of Defense of the requirement to provide material and services not normally within its capability.

Underlying the management of this national research program, the Foundation maintains and preserves one basic assumption. U. S. science is predicated on the idea that research will prosper as the initiative of the individual scientist is preserved. It is not from the managers but from the doers that the basic impetus and direction is given to U. S. efforts in Antarctica, and within the complex of gigantic logistics and millions of dollars every effort is made to preserve individual inspiration. Such an arrangement requires continuous restraint from the managers and a highly developed sense of responsibility from the individual scientist.

### *International Cooperation*

National research programs in Antarctica are coordinated through the Scientific Committee on Antarctic Research of the International Council of Scientific Unions (SCAR-ICSU). In addition to the immediate objectives of gathering as much knowledge as possible about Antarctica, these

programs serve a longer range objective, the fostering of international cooperation. Antarctica heretofore has been the scene of intense national competition in the hunting of fur seals, in the discovery and sighting of the Continent, in the race for Poles. It has brought nations to the brink of war in the claiming of its territory. To offset these tendencies, the United States has taken the leadership in encouraging nations with Antarctic interests and claims<sup>4</sup> to seek settlement through cooperation rather than discord and force. The vehicle which has provided such a solution to the Antarctic problem has been scientific research. The IGY cooperation was based on scientific needs and requirements to which each nation contributed according to its means and inclinations and in which all were equal and essential contributors regardless of wealth or position. This effort between the scientists of the twelve principal nations established a groundwork of common interest and trust from which to negotiate a treaty to establish a formal arrangement for future peaceful accord in Antarctica.

From the Washington Antarctic Conference in November, 1959, came a treaty unique in the affairs of nations. Signed into force on June 23, 1961, the Antarctic Treaty sets forth two principles with particular application to the future: first that Antarctica, an area as big as the United States and Western Europe combined, can be used only for peaceful purposes; and secondly, that the unique environment should be protected from unnatural contamination. These two facets of the Antarctic Treaty set this agreement in the forefront of man's realization that he can no longer be arrogant with himself and his environment. He has recognized in Antarctica that the process of acquiring knowledge in common purpose with his fellow man, can serve to establish better human understanding and cooperation.

Manifest in this new awareness is the prohibition against use of Antarctica as a place for atomic testing or dumping of radioactive waste, and the right of open inspection. In exercising this right of inspection Australia, New Zealand, the United Kingdom and the United States inspected 14 Antarctic stations in 1963 including those of Argentina, Chile, France, New Zealand, the United Kingdom and the United States and Soviet Union. Activities were found to be in consonance with the Treaty provisions.

At the Third Consultative Meeting of Antarctic Treaty Representatives in Brussels in 1964, detailed provisions to protect Antarctic plants and animals were recommended in the form of Agreed Measures for the

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4. Nations with claims in Antarctica include Argentina, Australia, Chile, France, New Zealand, Norway and the United Kingdom.



Conservation of Antarctic Fauna and Flora. Upon coming into force these measures will provide protection to endangered species, and unique ecological areas. They will prevent the importation of exotic fauna and flora and minimize the accidental introduction of destructive parasites and diseases. They will lay down measures to prevent harmful and unnecessary interference by man with the ecology. These Agreed Measures are a unique international conservation effort because their inception precedes man's efforts to develop the continent.

There are other beneficial facets of international cooperation in Antarctica. The size and harshness of the environment of Antarctica places thorough scientific exploration nearly beyond the resources of a single nation and certainly out of all proportion to what any nation could afford to invest to facilitate progress. The Antarctic Treaty guarantees signatory nations the freedom of access for scientific research to any part of the Treaty area and makes specific provision for the free exchange of scientific personnel, information and data.

### *Scientific Advance*

Scientific understanding of Antarctica has advanced far in the last decade. In 1955, when the first ships set out for Antarctica to establish stations for the IGY, little more of the Continent was known than its gross features. Scientific observations of the past exploratory expeditions had been scattered and unsystematic. Even after the large expeditions of the 1930's and the post-war Naval excursions, much of Antarctica's coastline showed as blanks on the maps that had been compiled. The size and extent of the ice cap and the encircling belt of pack ice were unknown. The structure and history of the rock continent hidden by Antarctica's ice cap were known only in the most general terms. Scientists could only speculate about climate, ocean circulation, the atmospheric events related to polar magnetism. Never had man looked at Antarctica as a total system.

Today after almost nine seasons of scientific investigations, some fundamental tasks near completion: the exposed land areas have been identified, and the major mountain ranges of the continent's interior have been visited by geologists. In the plan to map approximately 700,000 square miles of the Continent, topographers have accumulated 350,000 square miles of suitable aerial photography. Presently, 270,000 square miles of Antarctica's mountain and coastal areas have been mapped on a scale of 1:250,000. More than 15,000 miles of oversnow traverse data have provided a description of the sub-ice topography of nearly one half of Antarctica. U. S. geophysicists are now launched on a four-year program of scientific exploration of the Queen Maud Land area, the last great unknown region of Antarctica.

*Developing Complexity of Geologic History*

The physical structure of Antarctica is emerging from the geologic and geophysical studies which have been carried out. Geologists have recognized since 1914 that there are important differences between the greater and lesser parts of Antarctica. East Antarctica (the larger) was seen as a very old and stable continental shield; West Antarctica (the smaller part joined to the Antarctic Peninsula), a much younger system of mountainous fold belts dating from the late Mesozoic to Cenozoic (c. 100 million years). In recent years, however, geologists have learned that this division is an oversimplification of Antarctica's complex geologic history and because 98% of the bedrock is covered by ice, the compilation of a detailed geologic or structural map of Antarctica may never be possible.

With much of the Transantarctic Mountain boundary between East and West Antarctica mapped, geological interest turns on elaborating the differences between the parts of the Continent, filling in the gaps in our knowledge of the geologic history of Antarctica, and finally approaching the question of the theory of continental drift and Antarctica's relation to the other continents of the Southern Hemisphere.

The physiographic character of Antarctica has begun to emerge from the data of geophysical investigations (see Fig. 1). Much of the bedrock of East Antarctica except for three large basins would be above sea level if the ice cover were removed. The rough topography of much of East Antarctica's mountainous coast suggests that "what is commonly considered to be an ancient stable shield . . . is not so ancient, not so stable and probably not entirely a shield."<sup>5</sup> The oldest rocks in East Antarctica, found along the Adelie Coast and Wilkes Land, date in the Precambrian between 1000 and 1800 million years. But younger rocks of the middle Paleozoic (c. 400 million years), abundant along the coast of the Amery Ice Shelf and Adelie Coast, indicate a long, complex history of deformation, metamorphism, and volcanic activity. Also, distinctly different sedimentary and meta-sedimentary rocks discovered near the Amery Ice Shelf are good evidence for the occurrence of a sequence of sedimentation, volcanism and mountain building in part of East Antarctica during late Precambrian to early Paleozoic. Discovery of sedimentary deposits in East Antarctica has greatly extended the range of shallow marine or terrestrial sedimentary rocks of late Paleozoic age beyond their first known occurrence in the Transantarctic Mountains. The time relationship of the various sedimentary series remains open for further study.

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5. A. B. Ford, "Review of Antarctic Geology", *International Geophysics Bulletin*, No. 82, *Transactions American Geophysical Union*. April 1964.

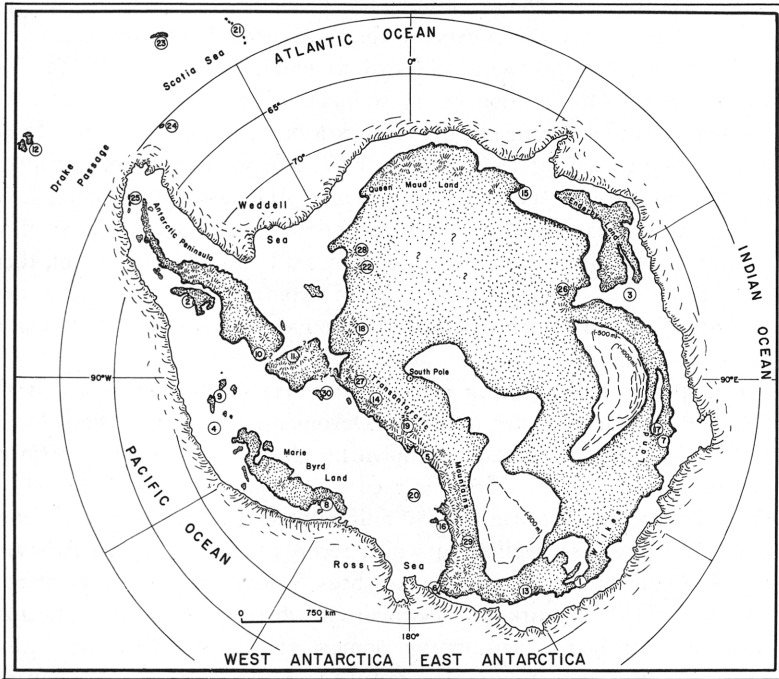


Fig. 1. Physiographic Diagram of Antarctica with Ice Cover Removed. This map is slightly modified from a U.S. Geological Survey map (1962) of the bedrock surface, unadjusted for isostatic uplift. Hachures show continental slope and major mountain areas; stippled regions are above sea level. In alphabetical order, numbered features are as follows: (1) Adelie Coast, (2) Alexander Island, (3) Amery Ice Shelf, (4) Amundsen Sea, (5) Beardmore Glacier, (6) Cape Adare, (7) Denman Glacier, (8) Edsel Ford Ranges, (9) Eights Coast, (10) Ellsworth Land, (11) Ellsworth Mountains, (12) Falkland Islands, (13) George V Coast, (14) Horlick Mountains, (15) Lutzow-Holm Bay, (16) McMurdo Sound, (17) Mount Sandow, (18) Pensacola Mountains, (19) Queen Maud Range, (20) Ross Ice Shelf, (21) Scotia Arc, (22) Shackleton Range, (23) South Georgia, (24) South Orkney Islands, (25) South Shetland Islands, (26) Southern Prince Charles Mountains, (27) Thiel Mountains, (28) Theron Mountains, (29) Victoria Land, and (30) Whitmore Mountains.

FIG. 1. From *IG Bulletin*, No. 82, published by the National Academy of Sciences, reprinted from *Transactions, American Geophysical Union*, No. 82.

The geologic history of the Continent is known only in broad outline. By the lower Cambrian (600 million years) sedimentation was taking place over a wide basin probably extending from the South Pole position into the Queen Maud and Horlick Ranges. Coral-like fossils (archaeocyathids), fossil algae, trilobite fragments, spider-like arthropods, and crus-

taceans were deposited in shallow, clear waters cold enough to permit slow growth. The next major events were a subsidence of some 15-20,000 feet followed by mountain building in the late Cambrian or Ordovician (500 million years) which exposed these sediments to erosion. Later these sedimentary sequences were subjected to granite intrusions. By the Devonian period (400 million years) younger sedimentary rocks were being formed. In the Ohio range of the Horlick Mountains geologists have found early Devonian sandstones and shales rich in fossils from a warm climate. Brachiopod mollusks and primitive vascular plants are the important fossil indicators of this period in which the marine environment was shallow, warm waters with a sandy, slightly muddy sea bottom. At this point, there is a break in the geologic record. Mid-Devonian rocks are yet unknown in Antarctica, and evidence of upper Devonian time is sparse. (See Figure 2.)

Perhaps the most exciting geologic discovery of the last decade is the 900 feet of glacial tillites overlying Devonian strata in the Ohio Range. If this deposit were indeed laid down by glaciers, then we may estimate the onset of Antarctica's first recorded glaciation somewhere between the Devonian and the Permian (c. 250 million years). Atop this glacial debris is another rich fossil collection which records the close of the Paleozoic era. The flora of these sandstone coal beds is dominated by the giant fern *Glossopteris* which marks the Permian elsewhere in the world. The lush vegetation and humid, swamp environment of this period was not unlike coastal Oregon and Washington today. This sequence of tillite covered by the Permian deposit is sufficiently like rocks in India, Madagascar, South Africa, South America, New Zealand and Australia that investigation of the theory of continental drift has taken on new vitality. However, important differences between the Gondwana deposits of the other Southern Hemisphere continents and Antarctica remain to be explored. For example, all other Gondwana deposits show fossils of distinctive terrestrial and aquatic reptiles, but animal fossils of any kind are curiously absent from the Permian sequence of Antarctica.

The record of most of the past 250 million years has been hidden by the series of glaciations which began with the Tertiary (50 million years) and have been continuous to the present. To trace this part of the record geologists have gone to the exposed areas of the Antarctic Peninsula and the Scotia Ridge Islands. The important events of the Tertiary period in West Antarctica were mountain building accompanying the elevation of the Andean chain. At the same time the main mass of the antarctic continent was being uplifted to form the mighty escarpment of the Transantarctic Mountains. Vulcanism occurred in both regions and the climate

TABLE 1. GENERALIZED GEOLOGIC HISTORIES IN TWO CONTRASTED REGIONS OF ANTARCTICA

ERA (AGES IN MILLIONS OF YEARS)*	PERIOD	SOUTHERN VICTORIA LAND EVENTS	ANTARCTIC PENIN- SULA EVENTS
CENOZOIC	QUATERNARY --- (1) ---	LOCAL EXTRUSIONS OF BASALT & TRACHYTE	GLACIATION, LOCAL SEDIMENT- ATION (PECTEN CONGLOMERATE), & VOLCANISM
	TERTIARY  (63)	CONTINENTAL GLACIATION  (NO RECORD)	LOCAL SEDIMENTATION & VOLCANISM  OROGENY & WIDESPREAD INTRUSION OF GABBRO, DIORITE, & QUARTZ DIORITE
	CRETACEOUS --- (135) ---		DEPOSITION OF THICK MARINE BEDS
MESOZOIC	JURASSIC --- (181) ---	DEPOSITION OF TILLITE (?) INTRUSIONS OF DIABASE SILLS & BASALTIC VOLCANISM	ANDESITIC TO RHYOLITIC VOLCANISM LOCAL DEPOSITION IN LAKES
	TRIASSIC  (230)	DEPOSITION OF SANDS, SILTS, & COAL BEDS (BEACON SANDSTONE)	OROGENY & INTENSE FOLDING W/ WEAK METAMORPHISM OF OLDER ROCKS
	PERMIAN --- (280) ---		DEPOSITION OF GEOSYNCLINAL GRAYWACKE, SHALE, & CONGLOM- ERATE (TRINITY PENINSULA SERIES)
PALEOZOIC	CARBONIFEROUS PERIODS --- (345) ---		
	DEVONIAN --- (405) ---	TIME OF EROSION FOLLOWING MOUNTAIN UPLIFT	GRANITIC INTRUSION
	SILURIAN --- (425) ---	FOLDING & LOW-GRADE(?) META- MORPHISM OF OLDER ROCKS, ACCOM- PANIED BY WIDESPREAD GRANITIC INTRUSIONS	(CENTRAL PART OF PENINSULA)  VOLCANISM
	ORDOVICIAN --- (500) ---		
	CAMBRIAN --- (600?) ---	LIMESTONE DEPOSITION LONG HISTORY OF SEDIMENTATION, LOCAL HIGH-GRADE REGIONAL MET- MORPHISM, & PLUTONIC INTRUSION	SEDIMENTATION & METAMORPHISM OF BASEMENT ROCKS (CENTRAL PART OF PENINSULA)
	PRECAMBRIAN  (+ 3000?)		

\*FROM TIME SCALE OF J.L.KULP, 1961 (SEE REFERENCE).

FIG. 2. From *IG Bulletin*, No. 82, published by the National Academy of Science, reprinted from *Transactions, American Geophysical Union*, No. 82.

was warm enough for ancestral forms of conifers (*Araucaria*) and the southern beech (*Nothofagus*) found today in the lands bordering Antarctica. By the mid-Tertiary, however, Antarctica's fauna began to show the effects of isolation. Although the higher plants had developed, Antarctica somehow missed the culmination of animal evolution.

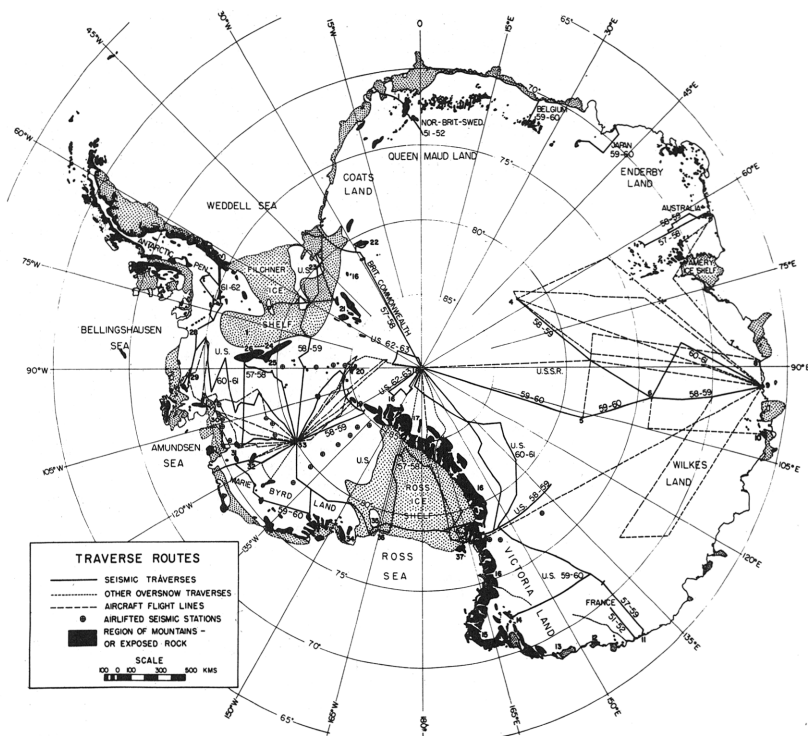


FIG. 3. Locations of traverses. (Key to geographical features: 1. Princess Martha Coast. 2. Prince Charles Mountains. 3. Lambert Glacier. 4. Pole of Inaccessibility. 5. Vostok. 6. Komsomolskaya. 7. Mt. Brown. 8. Gaussberg. 9. Mirny. 10. Bunger Hills. 11. Adelie Coast. 12. George V Coast. 13. Oates Coast. 14. Arctic Institute Range. 15. Admiralty Range. 16. Transantarctic Mountains. 17. Queen Maud Range. 18. Pole Station. 19. Horlick Mountains. 20. Thiel Mountains. 21. Pensacola Range. 22. Shackleton Range. 23. Berkner Island. 24. Nimitz Glacier. 25. Heritage Range. 25 and 26. Ellsworth Mountains. 26. Sentinel Mountains. 27. Antarctic Peninsula. 28. George Bryan Coast. 29. Eights Coast. 30. Walgreen Coast. 31. Toney Mountains. 32. Cray Mountains. 33. Byrd Station. 34. Edward VII Peninsula. 35. Roosevelt Island. 36. Bay of Whales. 37. Ross Island).

### *Ice, Ocean and Atmosphere: The Events of the Present*

A great concentration of research effort in Antarctica is devoted to what is happening today in this region of the earth. The first and most obvious question is the change that may be occurring in the antarctic ice cap. Since 90% of the earth's ice is locked up in Antarctica and since this represents enough water to raise ocean levels 250 feet or more, mankind has a particular interest in its changes. Glaciological and seismic data from more than 15,000 miles of traverses (see Figure 3) combined with the results of meteorological and ice motion studies have enabled scientists to sharpen the estimates of the size of the ice cover and its

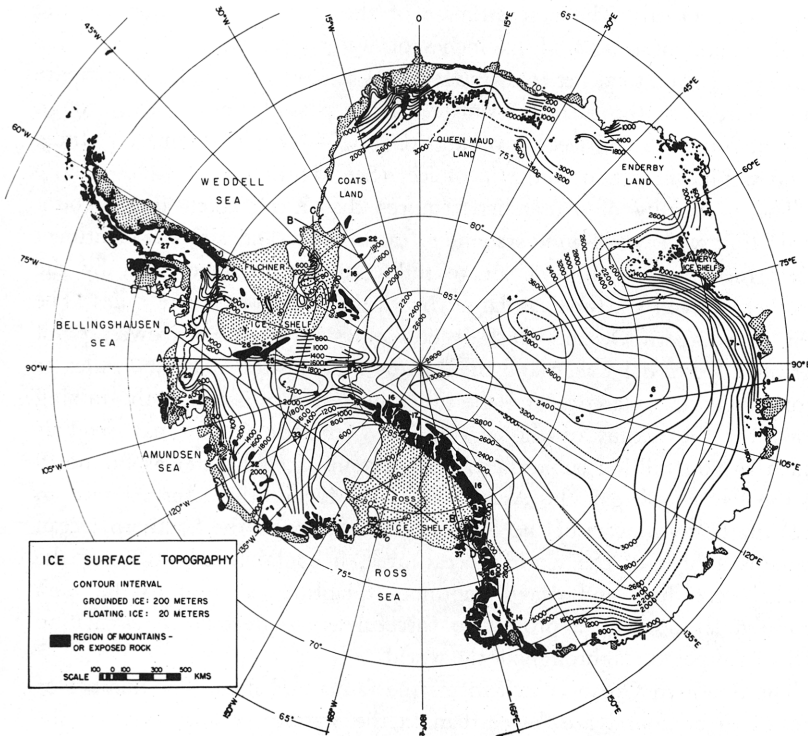


Fig. 4. Map of ice surface topography. (See Fig. 3 for key to geographical factors.)

FIG. 3 and FIG. 4 from Charles R. Bentley's *THE STRUCTURE OF ANTARCTICA AND ITS ICE COVERS*, in *Research in Geophysics*, Vol. 2, *Solid Earth and Interface Phenomena*.

pattern and rates of drainage toward the coast. More precise estimates will result from the present traverse from the South Pole toward Queen Maud Land.

Estimates of the rate of accumulation in the antarctic ice sheet and the net mass budget (ice input/ice loss) are still based on an insufficient number of measurements at scattered points.<sup>6</sup> Snow accumulation at higher elevations in East Antarctica is less than two inches of water equivalent per year. The interior of West Antarctica shows accumulation two or three times greater. Along the Bellingshausen and Amundsen Sea coasts and east of the Amery Ice Shelf snow accumulates at more than

6. This discussion and the estimates of accumulation and wastage are taken from C. R. Bentley, "The Structure of Antarctica and Its Ice Cover", in *Research in Geophysics*, Vol. 2, M.I.T. Press, 1964.

23 inches of water equivalent per year due to the supply of moist air from the Pacific Ocean. The best estimate of the mean accumulation for the whole continent is around six inches of water equivalent per year. This corresponds to a total net mass input of  $2.1 \times 10^{18}$  gm./yr. If we compare this figure with the current estimate for the possible loss of ice through evaporation, melt and iceberg production ( $1.5\text{--}2.2 \times 10^{18}$  gm./yr.) there is no significant net loss or gain of ice. (See Figure 4.)

The immensity of Antarctica requires that it be taken into account in dealing with world-wide systems of earth, ocean and air. The Continent itself measures 15 million square miles, and it is surrounded by the Southern Ocean six times as large covering 90 million square miles. The belt of Southern Ocean, which is 600 miles across the narrowest point between Tierra del Fuego and the Antarctic Peninsula, and 2000 miles or more between Antarctica and the other nearest continents, is the mixing bowl for the oceans of the world. The Antarctic Ocean may send as much as 800 million cubic meters per second of cold water as far north as the Bay of Bengal, the Arabian Sea and  $40^\circ$  north in the Atlantic to cool the bottom layers of the other oceans. Although the Southern Ocean contains a fifth of the world's ocean area, it contains only 10% of the world ocean heat and draws enormous quantities of heat to the high southern latitudes — a process so forceful as to affect ocean circulation and air temperatures throughout the world.

The Southern Ocean is rich in marine fauna and flora. The number of species to be found are fewer than in the warmer oceanic areas of the world, but nowhere are there greater quantities of each species. The Antarctic came first to man's attention as a source of food, oil and skins, and its contribution to mankind may someday again be as the greatest natural food source on our planet. The deep antarctic water, mixing with and being replaced by northern waters rich in nutrients, produces upwelling which sustains the plankton that is the basis of higher order life in the oceans. Here are found a dozen species of whale as well as other cetacea and eight species of seal. On this ocean thrive 43 species of pelagic birds including the Antarctic's "national" bird, the penguin.

If Antarctica is imagined as two concentric rings one inside the other, the outer ring of air and water is the point of interaction with the rest of the world. The inner ring of land and ice is an isolated and insulated cold core separated from the rest of the world by the outer ring.

The continent's primary insulating force is the air. Circling west to east around Antarctica and constantly fed by cold air pouring off the plateau, the strong westerlies tend to prevent penetration of Southern temperate air thus perpetuating and increasing the cold temperatures at



the center of the system. Only when the sun rises for a few months to cause stratospheric warming does warm temperate air invade the Antarctic winter stratospheric vortex. The insulating effect of the antarctic air circulation plays a very important role in the earth's heat budget. Despite the fact that the high polar plateau receives and retains more energy by solar radiation than the Arctic, the Antarctic represents a radiator three times larger than the Arctic. Because of the general height of the continent and the small amount of water vapor, there is little atmospheric impedance to the escape of heat. The difference between Arctic and Antarctic weather can be seen by comparing the average mid-summer and mid-winter temperatures of the Arctic Basin ( $0^{\circ}\text{C.}$  and  $-35^{\circ}\text{C.}$ ) with the Antarctic: South Pole,  $-25^{\circ}\text{C.}$  to  $-62^{\circ}\text{C.}$ ; McMurdo  $-4^{\circ}\text{C.}$  to  $-24^{\circ}\text{C.}$  These extremes of temperature greatly reduce the quantities of moisture vapor in the air and make Antarctica the world's driest desert.

### *Life in Antarctica*

However, Antarctica is not a total desert. The Continent was once well vegetated, and life continues to cling tenaciously to every available niche. Today, in contrast to everything else in Antarctica the endemic terrestrial fauna and flora is small in number, types and sizes. In the whole of Antarctica there is estimated to be only 4000 square miles which is suitable for sustaining biological life. Observation of endemic antarctic terrestrial fauna requires at least a very sharp pair of eyes and in some cases a microscope to discern the individual members. A full collection of preserved specimens of all the land species could be put in a large box. This collection would consist of protozoa, gastrotrichs, rotifers, tardigrades, flatworms, and round worms, a few fresh-water crustaceans, mites and ticks, springtails, biting and sucking lice, midges, and a flea — about 150 species in all. There are no terrestrial vertebrates, no land birds, no amphibians, no reptiles, no fresh-water fish, no mollusks, no earthworms on the continent of Antarctica. The largest permanent inhabitant of Antarctica is a fly!

Terrestrial plants are likewise found in few quantities and in very simple ecosystems. In addition to bacteria, primitive fungi, and other micro-plant organisms, the flora consists of diatoms, fungi, mosses and lichens. Surprisingly, it is not the cold but the availability of moisture that is the basic factor in Antarctic plant and animal survival. During the summer months, some ice-free areas protected from the wind are warmed by the sun to nearly temperate summer conditions. In such areas where melt water is available, these simple and hardy plants can survive.

Terrestrial and marine ecology are two of the most fascinating areas

of study in Antarctica. While the Arctic presents an advanced faunal and floral development of an interglacial period, the continental edge of Antarctica still presents a Pleistocene picture. Here is the laboratory in which to study the physiological adaptation and ecological succession that accompanies the marginal condition between life and extinction during periods of intense glaciation similar to the Quaternary glaciation that once covered half of North America. Some Antarctic species are believed to be vestigial remnants of earlier fauna and flora. Others may have migrated from surrounding continents, but today we still have no answer to questions about the how and when of migration and distribution. In such investigations, the Antarctic Peninsula provides a latitudinal ladder by which to study the physiological and ecological effect upon fauna and flora of a steadily ameliorating environment.

### *Antarctica's Higher Atmosphere*

In contrast to its geographical and environmental isolation, the continent of Antarctica is in the center of activity associated with the earth's magnetic field and other higher atmospheric phenomena. The southern geomagnetic pole is located within the Continent near the Soviet Vostok Station. The slope of the force lines of the magnetic field are nearly perpendicular to the earth's surface in the vicinity of the geomagnetic pole, and provide a window to space past the radiation belts that screen the equatorial and temperate regions. Cosmic and solar radiation, therefore, approach closer to the earth near both northern and southern geomagnetic poles. However, Antarctica presents a freer and less inhabited platform than the Arctic upon which to establish stations to measure upper atmospheric phenomena.

Atmospheric studies in Antarctica have contributed to solving worldwide problems, but the ultimate research objective remains the definition of the basic mechanisms involved. This study has required simultaneous observations in both hemispheres at the ends of selected magnetic force lines. In terms of geomagnetic coordinates the northeastern portions of Canada and the United States are opposite, or conjugate to, the area of West Antarctica in which the United States has concentrated its activities. As a result of this convenient bi-polarity, the United States has established in cooperation with Canada a network of conjugate stations:

Shepherd Bay — McMurdo Station

Quebec City & Baie St. Paul — Eights Station

Great Whale River — Byrd Station

In a three-way agreement between Denmark and the United States and the Soviet Union, a conjugate pair of stations are operated between the village of Kanaq near Thule, Greenland, and the Soviet Station, Vostok.

*Laboratory Antarctica*

Not all ingenuity and research devoted to Antarctica has gone into science alone. The Antarctic laboratory is equipped with some strange tools and the techniques for supporting scientific research have evolved to fit the particular conditions which are inherent to the Continent. Instead of computers, accelerators, spectrographs and the usual hardware of the stateside laboratory, the Antarctic scientist is accustomed to the C-130 ski-equipped Hercules, helicopters, icebreakers, giant tracked vehicles, and mobile field stations. He has become accustomed to traveling half way around the world to do his field work in Antarctica during the more hospitable summer months, returning to his home laboratory to analyze his specimens and results during the dark and unproductive months of the Antarctic winter. He has learned that simplicity is an essential ingredient of a successful experiment and that thoroughness of planning beforehand is required in a land where the nearest hardware store may be three thousand miles away. He has learned in a land where the sun never sets during the summer months, that time is the most important factor.

The difference in Antarctica between the days of Robert Falcon Scott and the modern explorer is time. No longer does sheer existence take most of man's energy. He has the time to think, to observe and reflect. We have come a long way in our knowledge of how to ameliorate the effects of the climate and provide facilities in which to live and work. The original IGY stations served their purpose, but they were crude affairs which leaked and sagged as the snow melted from above and below. Their ventilation was bad, their storage areas inadequate and their electrical systems dangerous and undependable. The scientific working space was crowded, makeshift and badly lit and heated.

In 1962, Byrd Station was rebuilt inside milled tunnels and topped with stressed arches of snow, wood and metal. Into these tunnels were placed buildings removed from the crushing and deforming effect of the snow, and insulated from the cold and wind by the snow itself. The buildings and tunnels were laid out to minimize electrical interference. Tunnels provided storage space. Laboratories are spacious and well lit and ventilation has been improved. At McMurdo Station a nuclear reactor has been installed to provide ultimately dependable electric power free from the disadvantages and cost of diesel-operated generators.

The biggest change in construction, however, has occurred in small station concepts. In 1959, the United States for reasons of cost was forced to reduce the number of its active stations and concentrate its logistic support capability.<sup>7</sup> New concepts of station construction and delivery were

7. Little America was closed in 1959, custody of Ellsworth and Wilkes was transferred to Argentina and Australia respectively, leaving Byrd, Hallett, South Pole and McMurdo Stations.

necessary if the United States was again to move into new areas of interest. In 1957 when the South Pole Station was established to accommodate 18 men, it had taken several months to complete the minimum construction required to shelter the inhabitants and the rest of the winter to complete the facility. It cost several million dollars to build. In 1962, Eights Station was set up in the Ellsworth Highland to serve upper atmospheric physics experiments during the International Quiet Sun Year. Eights Station was a modular construction. Mobile units were fully equipped in the United States, shipped to Antarctica and flown to location. The complex was designed to house eleven men. Each unit could be plugged into the others and hopefully unplugged and salvaged at some later date. It took 30 days to deliver the components the 1340 miles from shipboard at McMurdo to the desired site, 21 days to fit the units together and its cost was in the hundreds of thousands — not millions — of dollars. Such relatively inexpensive stations have again provided the United States with a means to extend its activities into new areas of interest. Currently a mobile facility is being built on the Antarctic Peninsula at Anvers Island to accommodate programs in marine biology, geology and glaciology. Another mobile, temporary facility is in the planning state for the high plateau of East Antarctica.

It is in the area of transportation that the biggest changes have come. In 1955, when the IGY Antarctic plans were first conceived, those interested in glaciological programs raised the question whether or not it would be possible for field scientists to obtain one, possibly two, aircraft flights during the austral summer season in support of field studies. Today, scientific field parties utilize many hundreds of flying hours from a variety of aircraft. It is the airplane that has made possible the large scale penetration and exploration of the interior and distant coast of Antarctica. The C-130 Hercules has replaced the tractor and the parachute as the prime movers of cargo. These planes can set field parties, mobile stations and traverses on location completely equipped and ready to carry on their programs. Such planes also serve as laboratories for instruments and cameras. The magnetic surveys of Antarctica today measure hundreds of thousands of miles of flight lines of data obtained by towing an instrument from the plane. Albedo studies of the sea ice have been made and 350,000 square miles photographed for mapping.

Helicopters are among the most productive tools in Antarctica. For example in 1962, the need for good geodetic control over a large area of Antarctica was apparent. By conventional means of motorized field parties, it would have taken years to gain this control. But turbine-powered U. S. Army helicopters capable of considerable altitudes as well as distances,

established field depots from which survey parties using optical equipment and tellurometers, have established in three years a system of geodetic control extending from the northern coast of Victoria Land through the Transantarctic Mountains to the eastern edge of the Horlicks and laterally into the Sentinels and other non-ice covered ranges of West Antarctica.

Techniques of ground transportation have improved. The Dodge power wagon has come into its own at stations located on the ice-free areas. The Australians have found a Volkswagen can be a useful personnel carrier in Antarctica. The motor toboggan has supplanted the dog and outmaneuvered larger gasoline eaters in moving geological and glaciological field parties hundreds of miles over rugged terrain. Where conditions demand mobile laboratories, sophisticated traverse vehicles have been developed with diesel engines hauling giant tires which carry fuel, and portable sled-mounted drilling equipment.

One of the most difficult regions in Antarctica to study is the water area immediately below the surface of the floating ice. It is an important region for measuring the heat exchange and for certain biological studies. To overcome the problem of access, a sub-ice chamber has been built and operated at McMurdo this year. This two and a half ton chamber is attached to a four-foot-diameter tube and can be lowered up to 22 feet below the ice surface. The chamber at the bottom is big enough for two seated men surrounded by windows. The chamber is equipped with listening devices and illumination.

The USARP has also equipped a ship for the specific purpose of Antarctic ocean study. Converted from an Arctic freighter and operated for the National Science Foundation by the Military Sea Transportation Service, the USNS *Eltanin* is conducting systematic research cruises in the Drake Passage and the South Pacific. She displaces 3900 tons, is 266 feet long and has a 51-foot beam. The *Eltanin*, a double hulled vessel, is equipped to accommodate not only research programs in marine biology and physical oceanography, but also in the atmospheric sciences. With 47 officers and crew, the *Eltanin* has a scientific complement of 35 and is equipped with facilities for handling helicopters. Since the commencement of Antarctic cruises in July, 1962, the *Eltanin* has completed twelve voyages and steamed more than 40,000 miles and made more than 500 scientific stations.

Plans are being drawn now for a small trawler equipped to assist marine biological studies in the Antarctic Peninsula. This vessel will be designed and operated to work in conjunction with land-based facilities on Anvers Island to give the maximum access to the rugged and dangerous coastal waters of the Peninsula.

*The Future*

There are still virgin areas of Antarctica to be explored. There remains the area of seasonal ice, the unobtainable fringe of Antarctica which moves with ocean current and wind, expanding each winter a third again the size of Antarctica, dissipating each summer. So far this region has only been visited by passing icebreakers. For systematic knowledge, it will have to be approached by icebreakers assigned specifically to support research activities complemented by spot aircraft landings on thick ice, and drifting stations on pack ice and icebergs.

Since so much of the land area of Antarctica is buried in ice, some of its future geological secrets may well be found in the ocean bottom sediments below the floating ice shelves. The Ross Ice Shelf alone is as big as France (204,633 square miles) and all the ice shelves together comprise an area of 540,000 square miles. These ice shelves are the terminus of many of the great ice drainage systems from the plateau. From there has occurred a continual deposit of rock from the interior of Antarctica. Access to these areas will be one of the great technical challenges in Antarctica. Likewise, the ice-shelf ocean interface is one significant parameter for determining the heat and water budget of Antarctica. It also is an important boundary region for marine flora. Direct observation of this area of Antarctica will require submersible craft or highly sophisticated automatic instrumentation.

We have already cored nearly 1400 feet into the ice cap of Antarctica. But this is a mere scratch of the surface. In the near future, the capability will exist to drill thousands of feet to retrieve deep ice cores and samples of the ice-rock interface. These cores can further our perception of the climatic changes which triggered the Antarctic ice age and of the history of Antarctic glaciation.

Finally, there are the outer limits of the atmosphere above Antarctica where further challenges lie. Already, satellites are providing data on ionospheric events and meteorological parameters. Soon a program will begin to obtain experimental data for navigational satellites.

The next major operational achievement which can be anticipated in Antarctica will be winter flying. It has already been demonstrated that McMurdo can, in emergencies, be reached by air in the dead of winter. An established capability to keep this line of communication open plus occasional flights to inland stations would make certain research work possible and would permit senior research personnel to participate in Antarctic field work during their normal vacation months. All construction problems have not yet been solved. While tunnel and stressed arch provided an answer for a strong Byrd Station, the snow at Pole Station

is too cold for such an approach. Perhaps the answer for such high plateau stations will lie in a Texas tower-like construction, or a village buried beneath a geodesic dome with a completely ameliorated climate inside. In coastal regions of Antarctica, research stations in the future may be established under ice and water. The average ocean temperature is higher than the mean annual air temperature and such a location could be better insulated and removed from the inconveniences that accompany stations in ice-free areas.

These are some of the technical challenges that lie ahead in Antarctica. Further off, one can speculate about other uses and activities to which Antarctica will be put. Perhaps the ice-free areas or continental shelf will at some distant time provide minerals which can compete in cost-to-benefit ratios on the world market. Unless aircraft technology bypasses Antarctica with ultra long-range aircraft, the Continent may serve as a Southern Hemisphere way-station for great circle routes between Southern Hemisphere countries. And certainly Antarctica is one of the most beautiful places in the world and a potential thrill to tourists and people in search of recreation.

However, when one starts contemplating the possibilities for Antarctica, he must always bear in mind that the cost of any trip will be borne by the taxpayer. It takes very roughly \$25,000 science dollars to winter over a research scientist, \$13,000 for a summer researcher, and for every science dollar spent, roughly three logistic dollars goes to support him. A C-130 Hercules cost in 1963 \$630.00 per hour to operate and a gallon of diesel fuel for a snow-cat ride at Byrd Station costs \$1.50.

In using public money to support a program in Antarctica there must be well-defined priorities consonant with national goals. Besides the long-range objective of international accord in Antarctica, the United States has established as its immediate goal the scientific exploration of the Continent. It is upon the knowledge and experience derived from this exploration that other beneficial uses of Antarctica will be determined. Scientific requirements in Antarctica are projected five years ahead and these next five years will feature research activity in Queen Maud Land including the new mobile temporary station, the augmentation of research in the Peninsula area including the trawler, the completion of geological reconnaissance of the inland mountain ranges and the exploration of the ice-covered Weddell Sea, extensive mapping of ice-free areas, and the commencement of deep ice coring. Research activities will also include the use of satellites for data and photographs, and initiation of further rocket projects.

The accomplishment of these programs will dominate the attention of

science and logistic capability in the next few years. In assessing the rate of progress in the development of Antarctica, certain comparisons can be borne in mind. During the first ten years that our ancestors lived in North America, they explored little more than the immediate environs of their settlements. In the 19th Century, when the industrialized countries of Europe set out to exploit Africa, a century of intense colonial activity brought less knowledge about the overall ecology and environment than the past ten years of effort have afforded in Antarctica.

The rapid rate of successful scientific exploration in Antarctica is an index of man's increased ability to comprehend and adapt himself to his environment. Each time that man begins new exploration he starts with more in his favor. Successful exploration and development in Antarctica stem from the availability of sophisticated scientific techniques, highly developed technology, the peaceful and cooperative application of resources available to many nations. The effectiveness of these assets is being proven in Antarctica and may equip man to deal still more effectively and wisely with other unknown areas of this earth and with space.

