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A Regional Geography of Antarctica and the Southern Ocean

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PHYSICAL ASPECTS: RESOURCES, ENVIRONMENT AND ECOLOGY

A Regional Geography of Antarctica and the Southern Ocean

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In this article, the author first analyzes the various regional definitions used to delimit the area of Antarctic influence. A brief historical background of Antarctica is followed by a geographical analysis of the Southern Region. The author concludes with an overview of the Southern Region in the world today.

I. INTRODUCTION

The salient geographic property of Antarctica is its distance from the inhabited world. It is farther from the developed states of the Northern Hemisphere than is Australia. The landmass of Antarctica does not lie in the path of any consequential ocean route, historic or modern. Alone among the world's islands, large and small, Antarctica was never settled. On earth, the Antarctic continent is the epitome of remoteness and inaccessibility.

Even the nearest neighbors of Antarctica, Argentina and Chile, are countries of the middle latitudes, not the Southern Region. The core of Argentina lies north of latitude 40° S., and is oriented towards the central Atlantic Ocean. Chile's heartland lies even farther north and overlooks the Pacific near the Tropic of Capricorn. The nearest substantial population concentration to Antarctica is New Zealand's South Island. However, even the South Island is 2,560 kilometers (1,600 miles) away. Australia is still farther, and South Africa's Cape of Good Hope lies 3,840 kilometers (2,400 miles) from the nearest shore of Antarctica. Thus, the geographic region cen-

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tered on the Antarctic landmass may be defined as the area enclosed by the fortieth parallel. This boundary delimits a realm which constitutes no less than one-fifth of the surface of the globe.[1] So defined, the Southern Region consists of two subregions: the Southern Ocean and the mainland of Antarctica.

Although traditional maps of the Southern Hemisphere show the Atlantic, Indian and Pacific Oceans extending to the Antarctic, bases exist that support the identification of a Southern Ocean. The boundary between the Southern Ocean and the three major world oceans may be determined by the Subtropical Convergence. Along this zone, the cold, extremely dense waters of the Antarctic seas meet the warmer, southward-moving currents of the world oceans. The warmer waters are swept up in the eastward-moving Circumpolar Current (also known as the West Wind Drift, a reference to the prevailing storm track surrounding mainland Antarctica). The Subtropical Convergence lies at approximately latitude 40° S. and displays considerable latitudinal stability, thus making it useful as a regional delineator. It is sharply defined by changes in water temperature, salinity and marine fauna and can often be observed visually from high-altitude imagery.

Still another regional definition is used by the Antarctic Treaty,[2] which stipulates an arbitrary boundary for the area at latitude 60° S. Because the terms of the Treaty have primarily involved the land area of the Antarctic, the sixtieth parallel has been a suitable legal limit, enclosing even the great mass of the pack ice that surrounds the mainland. However, the water area of the Antarctic, the Southern Ocean, is likely to become a focal point for increased international activity in the near future. In this regard the Treaty limit may become an obstacle. Since the sixtieth parallel bisects the Southern Ocean, it straddles an area of marine resources and, possibly, resources in the subsoil as well. In future negotiations, therefore, the Treaty limit will present difficulties; as a regional boundary, it is the least suitable geographic option.[3]

1. A similar delimitation in the Northern Hemisphere would produce a line running approximately through New York City, Madrid, Ankara, Peking and Reno (Nevada), thus incorporating the northern half of the contiguous United States, most of Europe, virtually all of the Soviet Union and northern China.

2. The Antarctic Treaty, Dec. 1, 1959, [1961] 12 U.S.T. 794, T.I.A.S. No. 4780, 402 U.N.T.S. 71 [hereinafter referred to as the Treaty].

3. Regional definition constitutes a significant and sometimes crucial preliminary to successful international legal negotiation. Another marine region, the North Sea, is clearly defined by transition into the English Channel, the Skagerrak and the North Atlantic Ocean beyond the Shetland Islands. This regional identity was a crucial factor in the achievement of the international agreements involving maritime boundaries and resource exploitation in the North Sea. *E.g.*, Convention for Regulating the Police of the North Sea Fisheries, May 6, 1882, IX Marteus Nouveau Recueil 2d 556.

A similar objection can be raised against the use of the Antarctic Convergence as a potential geographic boundary for the Southern Region.[4] Like the more northerly Subtropical Convergence, the Antarctic Convergence is a coalescence of waters possessing contrasting temperature and salinity properties. Differences in biological content exist as well. Both the Subtropical Convergence and the fifty kilometer (thirty mile) wide Antarctic Convergence can be felt at sea and observed from the air. However, the Antarctic Convergence neither marks the northern limit of Antarctic influences nor coincides with the actual or potential zones of resource use. Fluctuating between latitudes 50° S. and 62° S., the Antarctic Convergence lies astride fishing grounds, whaling zones and krill fields. Oceanographers have used the regional term "subantarctic" to identify the zone between the Subtropical and Antarctic Convergences, a further indication of the extension of Antarctic influences beyond the Antarctic Convergence.

In light of the relative advantages and disadvantages of the various regional definitions, the Southern Region should be delimited by the Subtropical Convergence as it is the most functional and practical boundary.

II. Historical Perspective

It is likely that Polynesian canoeists first saw the icebergs and pack ice which surround the mainland of Antarctica more than a millenium ago. But serious exploration by European expeditions did not commence until the eighteenth century. Uncertainty surrounds the date and identity of the first contact with Antarctica. Before James Cook circumnavigated the frozen continent (1772-75), there may have been visits by French and Dutch explorers (of whom De Lozier was probably the first, in 1738).[5] The early reports from these travellers included little to stimulate more intensive exploration except by seal hunters and whalers. Members of a seal hunting expedition in 1820 reached the South Shetland Islands, on the fringe of the pack ice, and claimed these islands for the United Kingdom. The first to see the mainland beyond the pack and shelf ice may have been the Russian, Bellinghausen, who commanded two Russian vessels in a circumnavigation of the continent between 1819 and 1821. At approximately the same time an American seal hunter, Captain Nathaniel Palmer, encountered the peninsula extending from the compact Antarctic mainland toward the southern tip of South America. The neck of the peninsula is now called Palmer

4. H. King, The Antarctic 2 *passim* (1969).
5. *Id.* at 15.

Land. In 1839, James Clark Ross sailed south to lead an expedition aimed at reaching the magnetic South Pole. Although Ross failed to reach the Pole, he apparently was the first to see:

> [a]n ominous white line extending from High Island directly across his course as far as the eye could reach to the eastward. As he got nearer, the extraordinary spectacle proved to be a perpendicular wall of ice between 150 and 200 feet high, perfectly flat and level and presenting an unblemished face that towered above the mast-head and looked unlike anything ever before seen by man. Here was the end of the line by water. . . .
>
> . . . [T]here was no more chance of sailing through such a barrier than there was of sailing through the cliffs of Dover.[6]

Ross had encountered the most extensive of several ice shelves that adjoin the Antarctic mainland, and until the properties of the shelves were understood, his discovery was known as the Ross Ice Barrier. Today, the Ross Ice Shelf and the Ross Sea commemorate his 1840 sighting.

During most of the remainder of the nineteenth century the powerful states of the Northern Hemisphere engaged in imperial scrambles, but the remoteness and forbidding physiography of Antarctica still limited contact. Seal hunting and whaling in the Southern Ocean did continue, however, and occasional national claims emanated from landings by sealers and whalers.

In the mid 1890's, the invention of a harpoon gun boosted the whaling industry, and the tempo of exploitation and competition quickened. The adventures of the whalers captured the public imagination in Europe and in North America, and professional scientific associations and exploration societies turned to Antarctica as the last unconquered and still untamed frontier. Reaching the South Pole became an international obsession which motivated several parties to attempt the hazardous overland journey. Shackleton came within 155 kilometers (97 miles) of the South Pole in January 1909. Scott reached the Pole during his heroic sledging trip of 1911-12, just one month after Roald Amundsen, the Norwegian explorer, had planted his country's flag there.[7]

Inevitably these explorations led to larger national claims. An early focus for such claims was the Antarctic Peninsula, where British acquisition of Antarctic territory, announced in 1908, was challenged by Chile in 1940 and by Argentina in 1942.[8] Geographically,

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6. E. DODGE, THE POLAR ROSSES 200-01 (1973).

7. E. EVANS, SOUTH WITH SCOTT (1921). *See also* A. CHERRY-GARRARD, THE WORST JOURNEY IN THE WORLD (1951).

8. *See* Figure 1 p. 303 *supra*.

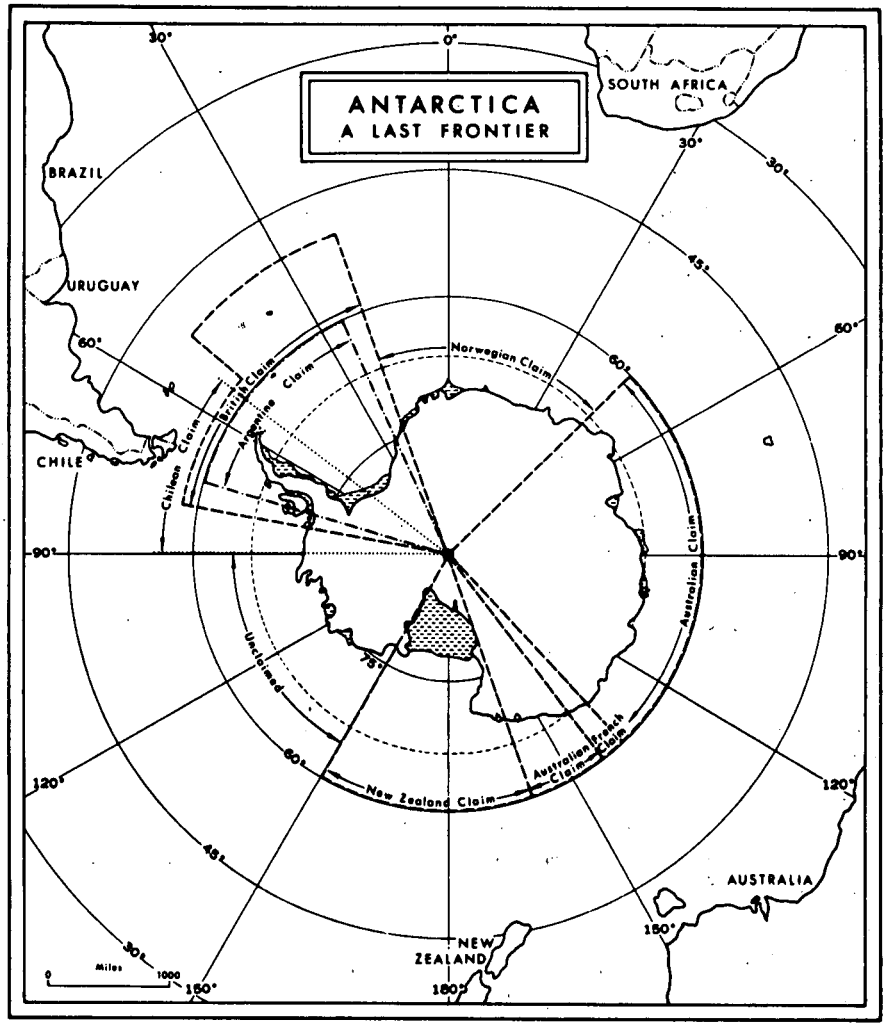

Figure 1 National Claims in the Southern Region

these territorial claims in Antarctica had the effect of partitioning the continent into pie-shaped sectors centered on the South Pole. Britain transferred its Ross Dependency to New Zealand in 1923, and Australia's administration of its huge claim was established in 1933. France had tied its Antarctic interests to the administration of its southernmost large dependency, Madagascar, in 1924, but the French did not formally announce their acquisition of Adelie Land (which divides the Australian Antarctic territory into two sectors) until 1938. Amundsen planted Norway's flag at the South Pole in 1911, and Norwegian interest in the region was confirmed first by the acquisition of several small islands and later by the 1939 claim

to the enormous area of Queen Maud Land. Chile in 1940 and Argentina in 1942 laid claim to the Antarctic Peninsula sector (already claimed by the United Kingdom) and to adjacent sectors to the west and east respectively. Thus, as the period of acquisition came to a close, seven states had laid claim to sectors of the Antarctic continent, but a huge zone, Marie Byrd Land, remained unattached.[9]

The Second World War focused the competitive attentions of world powers elsewhere, and their encroachments in Antarctica were temporarily halted. It is noteworthy, however, that nearly as many interested states had refrained from claiming Antarctic territories as had done so. The United States, the Soviet Union, Germany, Sweden, Belgium and Japan had explorers and researchers whose initiatives in Antarctica were not followed by national claims. On the contrary, as early as 1924 the United States had announced that it would not recognize claims in Antarctica by any national state unless "actual settlement" of the acquired territory had taken place.[10] This was also the position of other nonclaimant states, including the Soviet Union.

Following World War II, however, the claimant states began to establish research and surveillance stations in increasing numbers. The nonclaimant states also carried out experiments in various parts of the continent. A settlement map of Antarctica was indeed in the process of taking shape, and the states with interests in the continent became aware that the opportunity for regional cooperation would soon vanish. Thus began the negotiations that were to lead, in 1959, to the Treaty, originally signed by twelve states: Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the Soviet Union, the United Kingdom and the United States.[11] Eight states have since acceded to the Treaty. They are Brazil, Czechoslovakia, Denmark, East Germany, the Netherlands, Poland, Romania and Bulgaria.[12]

Several discrete stages can be identified in the history and the

9. The overlapping political claims produced some geographic controversies as well. United States historians credit the discovery of the Antarctic Peninsula to Palmer, and Americans identify this area as Palmer Land. The British called their claim Graham Land, after their First Lord of the British Admiralty. When the Chilean government claimed the sector, it announced that the region's name would be Tierra O'Higgins. Finally, when Argentina followed with its overlapping claim, the geographic nomenclature was declared to be San Martin Land. Many maps carry all four names.

10. Hanessian, *National Interests in Antarctica,* in ANTARCTICA 41 (T. Hatherton ed. 1965).

11. The Antarctic Treaty, *supra* note 2. *See generally* Daniels, *The Antarctic Treaty,* in FROZEN FUTURE 31 (1973).

12. U.S. DEP'T OF STATE, TREATIES IN FORCE 260 (1978). Bulgaria has only recently acceded to the Treaty. 78 U.S. DEP'T OF STATE BULL. No. 2020, at 56 (Nov. 1978).

historical geography of the Southern Region: (1) the period of peripheral exploration, seal hunting and whaling (to 1895); (2) the "heroic era" of mainland exploration (1895 to World War I); (3) the interwar period of territorial acquisition; (4) the postwar period of research and base-building which culminated in the International Geophysical Year (I.G.Y.) of 1958; and (5) the Treaty regime (post 1959). It is evident also that a new period of intensified marine exploitation and mainland research and exploration lies ahead.

III. GEOGRAPHICAL PERSPECTIVE

In the most general sense, the Southern Region consists of two subregions: the marine zone and the Antarctic mainland. These subregions interdigitate in a unique manner since the mainland is fringed not only by ice shelves but also by a ring of pack ice that varies enormously in size with the seasons. When winter envelops Antarctica, the fringe of pack ice becomes thick, compact and virtually impenetrable and, in a real sense, the continent temporarily expands over 1,500 kilometers (900 miles) from the mainland.[13] No other continental landmass has such a relationship with its adjacent seas.

A. *The Antarctic Mainland*

Compact and nearly circular, Antarctica is indeed a landmass of continental proportions, although it is the ice sheet, and not the fundamental geological infrastructure, that gives it its present structure and form. Only the Antarctic Peninsula, extending northward in the approximate longitude of South America, forms an extension from the mainland. With a surface area of some 14.2 million square kilometers (5.5 million square miles), Antarctica is nearly twice as large as Australia. The average diameter of the continent is over 4,000 kilometers (2,500 miles) and the distance from the tip of the Antarctic Peninsula to the opposite coastline is 5,600 kilometers (3,500 miles).

The Antarctic continent contains four regional landscapes: the ice sheet topography, the terrain of the ice shelves, the exposed areas of bedrock and the fluctuating marginal pack ice.

13. A case can be made that the pack ice constitutes a form of territorial extension. As one source suggests, "glacial ice is an environmental agent of the present, as well as of the past, and is itself a landform." A.N. STRAHLER & A.H. STRAHLER, ELEMENTS OF PHYSICAL GEOGRAPHY 399 (1976). *See generally* Hanessian, *supra* note 10, at 3.

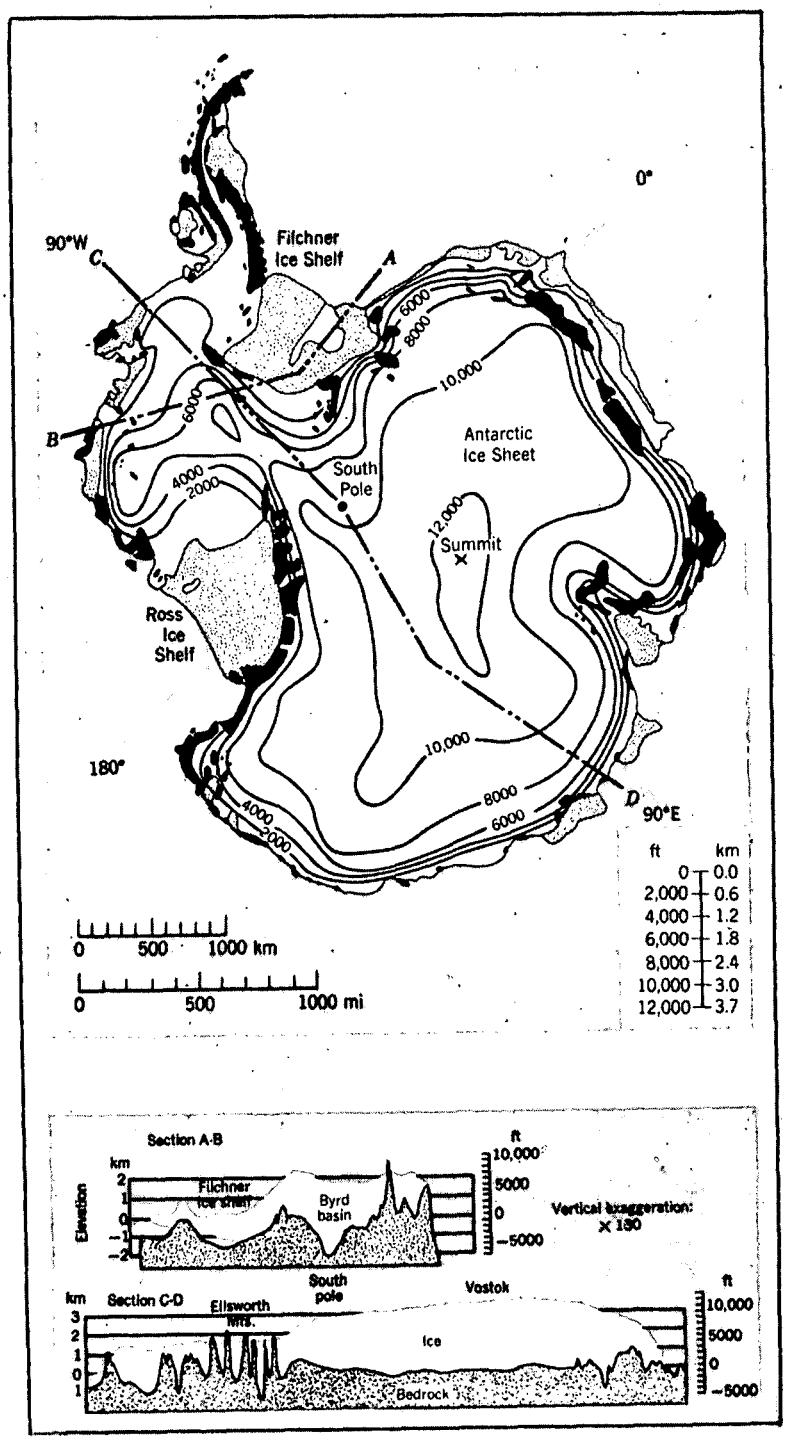

Figure 2 Landscape Regions and Cross Sections of Antarctic Mainland[15]

1. THE ICE SHEET

The Antarctic ice sheet covers as much as ninety-eight percent of the underlying geology, and by its enormous thickness, it raises average elevations to the highest among the continents.[14] The surface of the ice sheet is somewhat dome-shaped, reaching a broad summit in the heart of the landmass. Elevations exceed 3,600 meters (12,000 feet) around the summit and the ice is nearly 3.2 kilometers (2 miles) thick. Elsewhere in the center of Antarctica the ice sheet is even thicker, and it is estimated that as much as ninety percent of the world's ice and two percent of the world's fresh water are contained in this huge frozen mass.[16]

The ice sheet at present is apparently in a state of equilibrium because its slight annual outward "flow" toward the continental margins is approximately balanced by an equally slight replenishing precipitation. The average annual precipitation in the form of snowfall—as rainfall is virtually nonexistent—has a water equivalent of 12 to 15 centimeters (4.7 to 5.9 inches) per year, which classifies the Antarctic interior as a polar desert.[17] Even along the coastlines annual snowfalls rarely amount to a water equivalent exceeding thirty centimeters (twelve inches).[18]

The ice sheet environment is among the harshest on earth. The altitude, the clear air, the dimensions of the ice sheet and the remoteness from ameliorating marine influences combine to render Antarctica the coldest zone on this planet, far exceeding even the coldest Arctic areas. The world's lowest recorded surface temperatures have been measured at Vostok station (operated by the Soviet Union). Interior areas frequently record temperatures below -80° C. (-112° F.), and coastal stations commonly experience temperatures below -70° C. (-94° F.). Only in the Antarctic Peninsula during the short Antarctic "summer" do temperatures on rare occasions climb over the +10° C. (+50° F.) level. Temperature averages are still speculative, but during the coldest winter months they may range from -40° C. (-40° F.) to -70° C. (-94° F.) in the frigid interior and from -20° C. (-4° F.) to -35° C. (-31° F.) along the coasts.[19]

The Antarctic environment is worsened considerably by the prevailing high winds in the region. Antarctica, the "white desert,"

14. Gow, *The Ice Sheet*, in ANTARCTICA 221, 222, 225 (T. Hatherton ed. 1965).

15. These diagrams appear in A.N. STRAHLER & A.H. STRAHLER, *supra* note 13, at 407, and are reproduced with permission of the authors and publisher.

16. Gow, *supra* note 14, at 229.

17. *Id.* at 225.

18. *Id.* Table 3, at 253.

19. Rubin, *Antarctic Meteorology*, in FROZEN FUTURE 146, 162 (1973).

has been called the "home of the blizzard," and indeed the wind chill factor is the most severe environmental element in the region. Coastal areas are sometimes afflicted by sudden, violent, blizzard-like bursts of high-velocity wind that originate as katabatic flow (cold-air drainage) on the slopes of the interior highlands. Although these storms sweep up loose snow cover and, at the surface, produce the impression of a true blizzard, there is no precipitation involved and the upper air is clear. Wind speeds have been known to exceed 145 kilometers per hour (90 miles per hour), and in 1960 an especially destructive storm on MacRobertson Land produced wind gusts exceeding 250 kilometers per hour (155 miles per hour).[20]

2. THE ICE SHELVES

The compact, nearly circular morphology of Antarctica is the product of the unifying influence of the ice cap, which not only extends over most of the land area but also covers adjacent waters. More than one-tenth of the ice sheet extends beyond the coastline as ice shelves. The largest of these shelves, the Ross Ice Shelf, has an area which matches that of Texas and Louisiana combined. The ice shelves are not mere extensions of the continental ice; rather, they are floating ice sheets held together by their confinement in large bays or behind tiers of islands. As a result, they help disguise the contours of the Antarctic land mass. The upper surface of the ice shelves presents vistas of flat, monotonous, blinding whiteness which is intensified by the freshness of the accumulating snow. The ice shelves are sustained mainly by the arrival and compaction of snow on their upper surface, and, to a much lesser degree, by glacial movements from the interior.[21]

The ice shelves are thickest near the mainland where they may reach over 1,300 meters (about 4,000 feet), and they become irregularly thinner toward their ocean boundary where they average over 200 meters (about 600 feet).[22] Occasionally, huge segments of the ice shelf break away and float, like unattached islands, into the Southern Ocean. In recent years the idea that these icebergs could be towed to water-deficient coastal areas, such as those in the Middle East, has been seriously discussed.[23] Even after the inevitable loss of ice through melting, a substantial volume of fresh water would still be available for use.

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20. 1 MACROPAEDIA, ENCYCLOPEDIA BRITANNICA 953-54 (15th ed. 1975).

21. Swithinbank, *The Ice Shelves*, in ANTARCTICA 199, 199-200 (T. Hatherton ed. 1965).

22. *Id.*

23. In 1977, this concept was the subject of the First International Conference on Iceberg Utilization at Iowa State University, Ames, Iowa. Wall St. J., Oct. 5, 1977, at 1, col. 4.

3. THE EXPOSED BEDROCK AND THE UNDERLYING LANDMASS

Only small areas of Antarctica remain ice-free, but as a result of their uniqueness, these exposed bedrock zones take on added significance. They consist of several areas near the coast and numerous mountaintops that rise above the ice sheet, jutting out like islands in a sea of snow.

The coastal regions of bedrock landscape are located primarily in parts of the Antarctic Peninsula and of Victoria Land. The valleys and slopes of Victoria Land form the exposed end of a great buried mountain chain that rises above the ice in the interior, the Transantarctic Mountains. It is in the Transantarctic Mountains that some of the highest bedrock elevations in Antarctica are found, especially behind the Ross Ice Shelf in the Queen Alexandra Range where Mount Kirkpatrick extends over 4,500 meters (14,764 feet) into the air. The highest point in Antarctica, however, is part of the Sentinel Range, near the landward end of the Antarctic Peninsula. Here the Yinsun Massif has a maximum elevation of 5,140 meters (16,863 feet). The Antarctic Peninsula itself is lower, but its coastline, deeply fjorded against a background of mountains that reach 2,500 meters (8,200 feet), has some of the continent's most spectacular scenery.

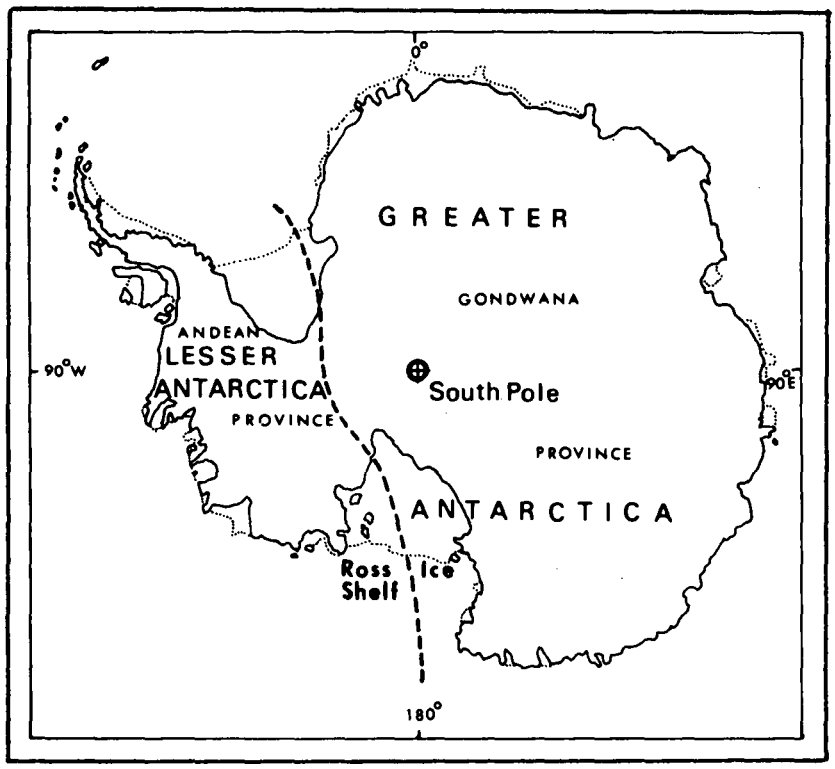

Figure 3 Regional Divisions on the Antarctic Continent[24]

Evidence from rock faces has been supplemented by seismic research to produce a profile of the unseen geology of the Antarctic landmass. The unity imposed by the ice sheet is not confirmed by the geology itself; Antarctica divides clearly into two regions. One (Greater Antarctica) is part of an ancient geologic shield, while the other (Lesser Antarctica) is a younger, topographically more varied region of mountains and basins. The boundary between these two provinces runs approximately through the middle of the Ross Ice Shelf, across the "neck" of the continent and through the southern sector of the Filchner Ice Shelf. By conventional orientation, Greater Antarctica, also known as the Gondwana Province, would thus be Eastern Antarctica and would include the South Pole, the summit of the ice sheet and the Transantarctic Mountains. Lesser Antarctica, also called the Andean Province because of its structural similarities to the Andes Mountains, would be Western Antarctica. This area incorporates the Antarctic Peninsula and the Sentinal Range, thus encompassing the continent's highest elevations.

The reconstruction of an ice-free Antarctica is necessary in the search for mineral resources; the results may also have geopolitical and legal implications. Such a reconstruction, however, is not merely a matter of envisaging the landmass without its ice cover. Since the weight of the ice depresses the bedrock below, a theoretical depiction of an ice-free Antarctica would have to take into account a substantial "rebound" in the lithosphere. Such a rebound would raise the presently buried Gondwana Province well above its low-average elevation[25] and create much more land area in the Andean Province. Still, even assuming a rebound of nearly 300 meters (about 1,000 feet), Antarctica would be a compact landmass with an adjacent archipelago.

A 500 meter (about 1,600 foot) rebound might well be a reasonable assumption, based in part upon the character of the continental shelf of Antarctica. In other landmasses of fractured Gondwana (the Southern Hemisphere supercontinent of which Antarctica was a part until its breakup more than 100 million years ago), the continental shelf extends from the shoreline to a depth of approximately 100 fathoms (slightly under 200 meters or about 600 feet). In the case of Antarctica, however, the landward margin of the continental shelf lies almost 500 meters (about 1,600 feet) below sea level, and the shelf descends seaward to a depth of about 850 meters (about 2,800 feet). This circumstance may be attributable to the weight of

24. This diagram appears in H. KING, *supra* note 4, at 61, and is reproduced with permission of the author.

25. *See* Figure 2, text accompanying note 13 *supra*.

the ice and may provide a measure of the degree of sinking the landmass has undergone since formation of the southern ice cap.

4. THE PACK ICE

The fourth Antarctic landscape is also the most unusual, and, indeed, it may not be appropriate to describe it as a *land*scape. The Antarctic mainland and shelf ice are fringed by a mass of pack ice that fluctuates in size with the seasons. During the "summer" months, the girdle of mobile pack ice shrinks to a discontinuous belt, sometimes separated from the mainland by a zone of open water up to eight kilometers (five miles) wide. The pack ice is then comparatively thin, weak and riddled by channels which can be kept open for shipping.

As winter approaches, however, the pack ice begins to expand and consolidate and by August or September, it may extend as far as latitude 54° S. in the Atlantic zone of the Southern Ocean (the approximate latitude of Tierra del Fuego in South America). In the Indian and Pacific sectors the pack ice tends to remain south of latitudes 56° S. to 59° S. and latitudes 60° S. to 63° S. respectively.[26] In unusually severe winters these limits may be exceeded by as much as nine degrees latitude, so that the Antarctic ice region more than doubles in size when the pack ice reaches its full development.

The fluctuating size of the ice pack complicates questions involving the relationship between ice and land. There is a major difference between ice shelves, which are permanent, and the ice pack, which is semi-permanent. An ice shelf is stationary, while the ice pack is mobile and drifts slowly but perceptibly in the currents and winds of the Southern Ocean, following a circular, clockwise path. Both shelf ice and pack ice, however, lie on waters of the Southern Ocean, which by modern definition is equivalent to waters of the high seas.

B. *The Southern Ocean*

If the vast Southern Ocean is delineated by the Subtropical Convergence as previously proposed, that boundary would be further supported by the limit of iceberg dispersal, which coincides closely with the Convergence near latitude 40° S. Again, the icebergs spread farther north in the Atlantic and Indian Ocean sectors than in the Pacific sector, an asymmetry that is somewhat mirrored by the Subtropical Convergence.

26. H. KING, *supra* note 4, at 28.

The Southern Ocean consists of two concentric zones: the Inner Antarctic Sea, between the mainland and the Antarctic Convergence, and the Outer Antarctic Sea, between the Antarctic Convergence and the Subtropical Convergence. These two zones have also been called, respectively, the "Antarctic" and "subantartic" sectors of the Southern Ocean. At the Subtropical Convergence, the temperatures of surface water fall by as much as 5° C. to 9° C. (9° F. to 16° F.), signaling a reduction in salinity as well. At the Antarctic Convergence, a further temperature decline of 4° C. to 8° C. (7° F. to 14° F.) occurs, so that the surface water in the Inner Antarctic Sea is just above freezing in winter and only 3° C. to 4° C. (37° F. to 39° F.) in summer.[27]

Water exchanges at the Subtropical and Antarctic Convergences result from circulation systems generated by the earth's rotation and strong wind patterns. Cold, dense Antarctic water flows northward in the Inner Antarctic Sea and descends at the Antarctic Convergence beneath the somewhat warmer surface water of the Outer Antarctic Sea. Here it becomes part of a set of persistent ocean-bottom cold currents that radiate far northward, even into the Northern Hemisphere.

The fauna in the Southern Ocean reflect the plentiful supply of plankton, an important ingredient in the diets of whales, seals and many fish. The distribution pattern of the Southern Region's marine fauna reveals the effectiveness of the Antarctic Convergence as a biological boundary. Thus, the dense schools of small, shrimp-like krill exist only in the Inner Antarctic Sea, south of the Antarctic Convergence, where they sustained the large population of whales and seals that existed there before the whalers and seal hunters decimated their numbers. Perhaps in part because the whale population has been so vastly reduced, the krill now inhabit Antarctic waters in such quantities that an estimated fifty million metric tons or more could be harvested annually without endangering the species.[28]

Antarctic fish are present in fewer species than in other oceans, but some of the 100 species in the Southern Region (out of 20,000 known worldwide) exist in enormous quantities. The Antarctic perches of the Notothenia group move in large schools, feed on krill and for many years have been harvested and marketed commercially, principally by the Soviet Union.[29] Among the known re-

27. 1 MACROPAEDIA, *supra* note 20, at 955.

28. MacKintosh, *Whales and Krill in the Twentieth Century* in ANTARCTIC ECOLOGY 195, 203 (1970).

29. Llano, *A Survey of Antarctic Biology*, in FROZEN FUTURES 205, 226 (1973).

sources in the Southern Region, the marine fauna afford the greatest opportunities for increased exploitation, but not without uncertainties and risks.

IV. CONCLUSION

The Southern Region is not normally included in enumerations of the world's geographic cultural realms because it does not possess certain indicators of cultural development—cultural landscape, regionally expressed cultural traditions, permanent population, circulation systems and so forth. Yet, by virtue of its dimensions, its multinational geopolitical accommodations and its resource potential in a world of shrinking reserves and growing needs, the Southern Region merits recognition as an area of worldwide significance.

It is evident that the impact of Antarctic environments upon those of the rest of the world has been underestimated. For example, it was realized comparatively recently that variations in the extent of ice on the Southern Ocean may be an important factor influencing global climatic trends.[30] Cold "bottom" water from Antarctic latitudes emerges in oceanic areas of the Northern Hemisphere. Antarctic krill have been found in the stomachs of more than thirty species of fish caught in distant parts of the world's oceans. From the stratosphere to the ocean floor, Antarctic influences extend to the rest of the world.

The apparent equilibrium condition of the Antarctic ice sheet has recently given rise to considerable interest. It is possible that such periods of balance are followed by a sudden dislodging of the entire ice cap, which would slide into the Southern Ocean and cause a worldwide rise in sea level of between 50 and 70 meters (160 to 230 feet), inundating all coastal cities and plains. Some scientists suggest that a similar event several thousand years ago might have given rise to biblical descriptions of the great flood. The possibility that such a catastrophic development could be produced by seismic testing on the Antarctic ice cap has become a matter of concern.

As human activity in the Southern Region intensifies, the risks increase. A serious pollution accident in Antarctic waters could have worldwide consequences. Overfishing of krill might damage fishing industries thousands of miles away and as yet, no one knows what global impact might result from interference with the Antarctic food web. The states with Antarctic interests have in the past cooperated in scientific spheres, but the Treaty that governs their co-

30. Fletcher, *Polar Ice and the Global Climate Machine*, in FROZEN FUTURES 122, 129 (1973).

operation does not address resource exploitation. The Southern Ocean, remote even from the two hundred mile economic zones of Southern Hemisphere countries, is a last vestige of the high seas, and the Antarctic continent constitutes the last of the world's frontiers. The Southern Region stands at the threshold of an era of change for which it and the world are inadequately prepared.