5 Ecoregions of the Continents: The Polar Ecoregions

5.1 100 Polar Domain

Polar and Arctic air masses chiefly control climates of the polar domain, located at high latitudes. With the exception of the ice cap climates, they lie entirely in the Northern Hemisphere. In general, climates in the polar domain have low temperatures, severe winters, and small amounts of precipitation, most of which falls in summer. Polar systems are dominated by a periodic fluctuation of solar energy and temperature, in which the annual range is far greater than the diurnal range (see Fig. 4.2, p. 29). This contrasts with the tropics where the major periodic fluctuation is the diurnal one, and the mid-latitude systems, as we will see, are subject to fluctuations in both annual and diurnal energy patterns.

The intensity of the solar radiation is never very high compared to ecosystems of the middle latitudes and tropics. On the poleward margins, although summer insolation persists for many hours, temperatures do not get very high because the intensity is low and because much of the energy goes to evaporate water and melt snow or ice. More energy is given off by terrestrial radiation than is received from solar radiation. In order for this situation to persist, a supplementary heat source must exist to provide the difference. This supplementary energy source is heat carried poleward by wind and water currents. It maintains the Arctic temperatures at a level much higher than would solar radiation alone.

The high-latitude climates have low annual total evaporation, always less than 50 cm, reflecting the prevailing low air and soil temperatures. The frozen condition of the soil in several consecutive winter months causes plant growth to cease. Snow that falls in this period is retained in surface storage until spring thaw releases it for infiltration and runoff. The growing season for crops is short in the subarctic zone, but low air and soil temperatures are partly compensated for by great increase in day length.

In areas where summers are short and temperatures are generally low throughout the year, thermal efficiency, rather than effectiveness of precipitation, is the critical factor in plant distribution and soil development. Three major regional divisions have been recognized and delimited in terms of thermal efficiency—the *icecap*, *tundra*, and the *subarctic* (tayga). The world map of the polar ecoregions of the continents (Fig. 5.1) shows the locations of these ecoregions. **Climate diagrams** in Fig. 5.2 provide general information on the character of the climate in two of these divisions.

These climate diagrams express differences in the climatic regime of the divisions within the domains by comparing annual temperature and moisture cycles. A relatively dry season is depicted by the precipitation curve falling below the temperature curve. The location of the weather station and its altitude, as well as the average annual temperature and precipitation, are shown above the graphs.

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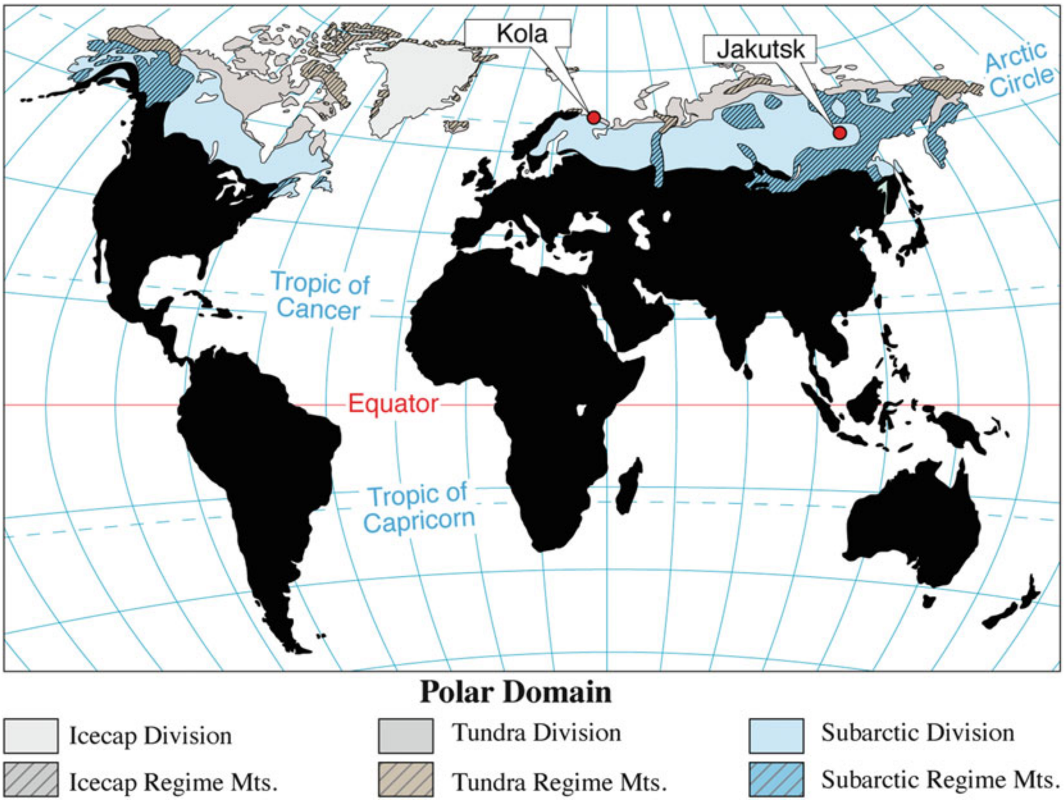

Fig. 5.1 Divisions of the continental polar domain

5.2 110 Icecap Division

These are the ice sheets of Greenland, Ellesmere Island, Baffin Island, and Antarctica. Mean annual temperature is much lower than that of any other climate, with no month above freezing, defining this climate as *Fi*. Precipitation, almost all occurring as snow, is small, but accumulates because of the continuous cold. Driving blizzard winds are frequent. These regions are subjected to long periods of darkness and light.

Because of low monthly mean temperatures throughout the year over the ice sheets, this environment is almost devoid of vegetation and soils (Fig. 5.3). Only a few plant species can survive the Antarctic climate. The dominant plants are algae, lichens, and mosses—plants adapted to limited water supply and scant nutrients and soil. The few species of animals found on the ice margins are associated with a marine habitat. In the Antarctic regions, because of the absence of predatory animals, the flightless penguins find conditions on the coasts and on the isolated islands of the southern oceans ideal as breeding places.

Terrestrial invertebrates include a few species such as nematodes and springtails. Some starve and dehydrate themselves during cold weather because any water left in their bodies would encourage deadly ice crystals to form. Others produce antifreeze chemicals.

5.3 120 Tundra Division

The northern continental fringes of North America, Iceland and Spitsbergen, coastal Greenland, the Arctic coast of Eurasia from the Arctic Circle northward to about the 75th parallel, lie within the outer zone of control of Arctic air masses. This produces the tundra climate that Trewartha

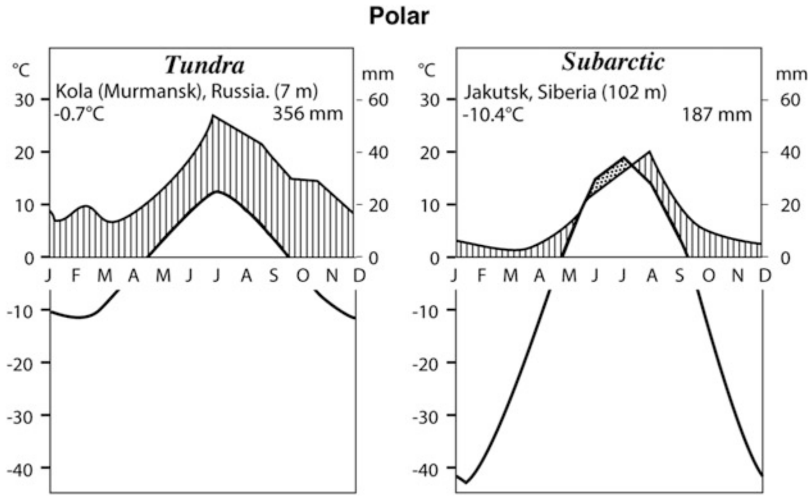

Fig. 5.2 Climate diagrams from the tundra of northern Russia and from the extremely cold, continental boreal (tayga) regions of eastern Siberia. Redrawn from Walter et al. (1975)

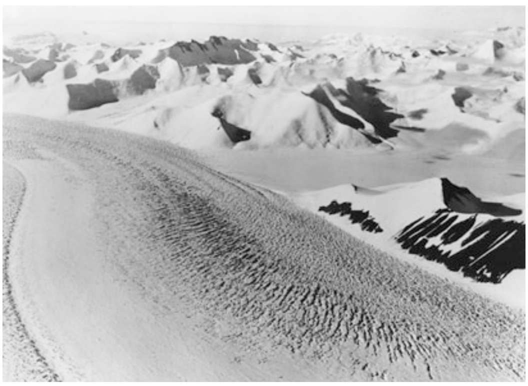

Fig. 5.3 A glacier and mountains in Antarctica. Taken during the Byrd Expedition to South Pole, 1946–47. Image # 123435, American Museum of Natural History, Library

(1968) designated by symbol *Ft*. Average temperature of the warmest month lies between 10 and 0 °C. The tundra regions occupy some 5 % of the land surface of the Earth.

The tundra climate has very short, cool summers and long, severe winters (see Fig. 5.2, climate diagram for Kola [near Murmansk], Russia). No more than 188 days per year, and sometimes as few as 55, have a mean temperature higher than 0 °C. Annual precipitation is light, often less than 200 mm, but because potential evaporation is also very low, the climate is humid. However, because precipitation is usually in the form of snow and ice, animals and plants cannot use it.

Tundra is the characteristic vegetation of the Polar Regions. Three chief types are recognized: these are *grass tundra*, *brush tundra*, and the *desert tundra*. Vegetation in the central part is grass tundra, a treeless plain of low-growing plants adapted to the climate's low temperatures, short growing season, and low precipitation. It consists of grasses, sedges, and lichens, with willow shrubs (Fig. 5.4). As in the Antarctic, mosses and lichens flourish because they can tolerate the freezing temperatures. Farther south, the vegetation changes into brush tundra, or birch–lichen woodland, then into a needleleaf forest. In some places, a distinct tree line separates the forest from tundra. Köppen (1931) used this line, which coincides approximately with the 10 °C isotherm of the warmest month, as a boundary between subarctic and tundra climates. Farther poleward the tundra breaks up into detached "oases" in the sheltered hollows, separated by expanses of bare rock or **regolith**. This is the desert tundra. The arctic flora is poor in plant species; only a few hundred species grow in the entire Arctic, compared to over 100,000 in the tropics.

In contrast to surfaces exposed to tropical rainy climate, soil particles of tundra derive almost entirely from mechanical breakup of the parent rock, by continual freezing and thawing, with little or no chemical alteration. **Tundra soils** (Entisols, Inceptisols, and associated

Fig. 5.4 Grass tundra in Alaska. Photograph by USDA Forest Service

Histosols), with weakly differentiated horizons, dominate. As in the northern continental interior, the tundra has a permanently frozen sublayer of soil known as **permafrost** (Fig. 5.5).[1] The permafrost layer is more than 300 m thick throughout the region; seasonal thaw reaches only 10–60 cm below the surface.

Probably half of the tundra surface is covered by water in the summer and ice in the winter. Poor drainage is a dominant characteristic. Permafrost prevents the percolation of meltwater into the regolith. The continental ice sheets that repeatedly scoured these areas left a rolling topography relatively free of weathered material. The depressions are filled with lakes and swamps, and bogs are everywhere. The streams that exist meander extensively on the surface, from depression to depression, or swamp to swamp. The large rivers that cross the tundra are **exotic rivers** and subject to spring flooding. Since these streams have their headwaters equatorward of the mouth, the spring thaw takes place first upstream. The meltwater starts downstream, only to encounter a channel blocked by a still-frozen stream. The only outlet for the meltwater is out of the channel over the ice and surrounding land. In this fashion, immense areas of the Arctic tundra are flooded in the spring.

One aspect of the hydrologic cycle in the Arctic warrants particular notice. Whereas in most parts of the world the change of water to water vapor is a primary means of heating the atmosphere, in the Arctic this process is greatly reduced. Outside the Arctic, when condensation occurs and the water vapor is returned to a liquid or solid state, the energy utilized in evaporating water is again released into the atmosphere and heats it.

Geomorphic processes are distinctive in the tundra, resulting in a variety of curious landforms. Under a protective layer of sod, water in the soil melts in summer to produce a thick mud that sometimes flows downslope to create bulges, terraces, and lobes on hillsides. The freeze and thaw of water in the soil also sorts the coarse particles from the fine particles, giving rise to such patterns in the ground as rings, polygons, and stripes made of stone. The coastal plains have numerous lakes of **thermokarst** origin, formed by melting groundwater.

The richness and variety of the fauna of the Arctic regions are remarkable. Many of the land animals of the tayga migrate northward onto the tundra during the summer months. The reindeer of Eurasia and the similar, but smaller, caribou of North America are the most important of these. Another large herbivore, the musk oxen, occurs in isolated herds, grazing on the more luxuriant patches of desert tundra. Two small herbivora—the Arctic hare and the lemming—are also widespread.

Following the herds are a number of predatory animals, such as wolf and fox. The drift ice of the polar sea or the immediate coastal margins is the habitat of the polar bear, preying chiefly on marine life, such as the seal and the walrus.

Birds and insects are particularly numerous. Mosquitoes are probably present in greater numbers in summer over the tundra than anywhere else on the Earth. Flies are abundant, especially near human settlements. Attracted in part by this abundance of insect life, many migrating birds make the tundra their goal in summer. The boggy

[1] This map is highly generalized. For a more detailed presentation, see Brown et al. (1997).

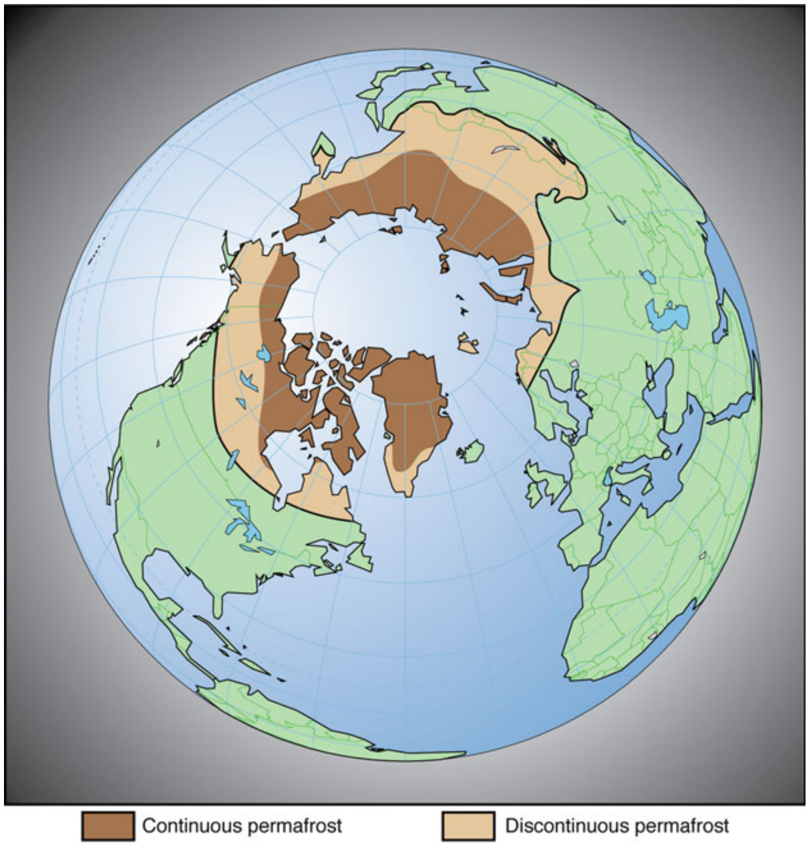

Fig. 5.5 Distribution of permafrost in the Northern Hemisphere. From *Glacial and Quaternary Geology* by R.F. Flint, p. 270. Copyright © 1971 by John Wiley & Sons, Inc. Reprinted by John Wiley & Sons, Inc.

tundra offers an ideal summer environment for waterfowl, sandpipers, and plovers.

Sea life is rich. Although reptiles, amphibians, and freshwater fish are absent, the inhabitants of the polar oceans are varied and numerous.

Direct human impact in the tundra regions has been minimal until recent years. Eskimo and Lapp cultures have lived as part of the ecosystem for thousands of years. Their numbers have been small, in keeping with the relatively low primary production of the tundra and adjacent seas. However, major disturbance to the permafrost terrain became evident in World War II, when military bases, airfields, and highways were hurriedly constructed without regard for maintenance of the natural protective surface. Recently, oil deposits were discovered on the north slope of Alaska with exploration and drilling creating possibilities for environmental damage. Oil spills on the landscape and in coastal waters are attendant problems.

Succession in the Arctic is a very slow process, and the development has the potential for disturbing the local system so that the ecosystem will not recover. The equilibrium of the tundra is based on very low energy flow. This means little chemical weathering, and slow rates of soil evolution and plant growth.

5.4 130 Subarctic Division

The source region for the continental polar air masses is south of the tundra zone between lat. 50° and 70°N. The climate type here shows great seasonal range in temperature. Winters are severe, and the region's small amounts of annual precipitation are concentrated in the three warm months. This cold, snowy, forest climate, referred to in this volume as the boreal subarctic type, is classified as *E* in the Köppen–Trewartha system. This climate is moist all year, with cool,

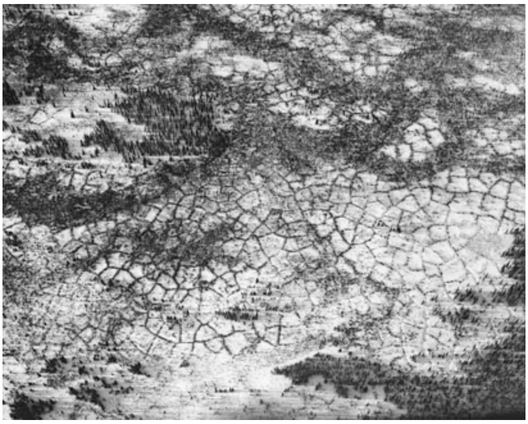

Fig. 5.6 Patterned ground caused by alternating freezing and thawing of the ground overlying permafrost, northeast of Fort Yukon, Alaska. Photograph by T.G. Freeman, Soil Conservation Service

short summers (see Fig. 5.2, climate diagram for Jakutsk, Siberia). Only 1 month of the year has an average temperature above 10 °C.

Winter is the dominant season of the boreal subarctic climate. Because average monthly temperatures are subfreezing for six to seven consecutive months, all moisture in the soil and subsoil freezes solidly to depths of a few meters. Summer warmth is insufficient to thaw more than a meter or so at the surface, so permafrost and patterned ground prevails over large areas (Fig. 5.6). Seasonal thaw penetrates from 0.5 to 4 m, depending on latitude, aspect, and kind of ground. Despite the low temperatures and long winters, the valleys of interior Alaska and Siberia were not glaciated during the Pleistocene, probably because of insufficient precipitation (Fig. 5.7).

The subarctic climate zone coincides with a great belt of needleleaf forest, often referred to as boreal forest, and open lichen woodland known as **tayga**. These species have adapted to the cold winter by greatly reducing their leaf area and by being able to respond rapidly to the short summer. Among the more widespread dominants are pine, fir, and spruce. Most trees are small, with more value to humans for pulpwood than for lumber. Different species occur in extremely wet and dry sites. In burned-over areas a mixture of deciduous trees and evergreen is characteristic during secondary succession. In Siberia this second-growth enclave of broadleaf types is called "white tayga." Slow growing conifers reproduce the climax forest only over a long period of time.

The forests run diagonally across the continents. On the west coast, the boreal forest is more than 10° farther north than on the east coasts. The contrast of warm and cold ocean water on the two sides of the continents in higher middle latitudes causes this diagonal arrangement.

The Arctic needleleaf forest grows on **podzols** (Spodosols) with pockets of wet, organic Histosols. The podzol profile is distinctly shallower than any other mature profiles (see Fig. 6.1, p. 56), in a few places reaching depths greater then 45–60 cm. Soil development is slow because the land is frozen for long periods each year. For various reasons, notably the absence of earthworms, the humus layer on the surface is not mixed with the soil, but remains as a very black, highly acidic accumulation. The lower part of the *A* horizon is strongly leached to a gray or even white color. A distinct layer of humus and forest litter lies beneath the top soil layer. The *B* horizon is reddish from the accumulation of part of the leached material, and is very compact. Agriculture potential is poor, due to natural infertility of soils and the prevalence of swamps and lakes left by departed ice sheets. In some places, ice scoured the rock surfaces bare, entirely stripping off the overburden. Elsewhere rock basins were formed and stream courses dammed, creating countless lakes.

These lakes are only temporary features. Since decomposition is slow in the cold climate, these lakes gradually fill in with peat, organic matter produced by sphagnum moss or sedges, along with a definite succession of vegetation. These deposits have provided a low-grade fuel in northern Europe (Fig. 5.8).

Peat is also an excellent insulator. In the far north, it keeps summer heat from completely thawing the frozen ground below the depth of a 0.5 m or so. This subsoil, or permafrost, remains permanently frozen. Above it in the bog, annual freezing and thawing of the peaty soil pushes

Fig. 5.7 Extensive areas of Pleistocene glaciation are largely confined to the Northern Hemisphere. Adapted from *Glacial and Quaternary Geology* by R.F. Flint, p. 75. Copyright © 1971 by John Wiley & Sons, Inc. Reprinted by John Wiley & Sons, Inc.

Fig. 5.8 A peat bog in boreal forest near the border between Norway and Sweden. Photograph by John S. Shelton; from the University of Washington Libraries, Special Collections, John Shelton Collection, KC4567. Reproduced with permission

Fig. 5.9 Tilting of a line of poles in a bog is also caused by freezing and thawing, Yukon region, Alaska. The cross-poles at the base are to minimize the effect. Photograph by T.L. Pewe, U.S. Geological Survey

against the trees since it cannot push the solid permafrost down. This annual freeze-thaw cycle produces a topsy-turvy forest with tree trunks and utility poles leaning in all directions (Fig. 5.9).

The great north-flowing rivers of these regions, like those of the Arctic tundra, are subject to extensive spring floods, and the lowlands, even where they are not glaciated, do not dry out rapidly after the water recedes. Permanently water-logged surfaces, in many cases underlain by peat, are common in all these regions. In Canada, the name "muskeg" is applied to such surfaces.

This is the habitat of large ground animals—a population which derives most of its food supply from the aquatic life of the numerous lakes, rivers, and swamps. In these forests roam the world's chief fur-bearing animals: minks, martens, foxes, wolves, badgers, bears, beavers, squirrels, sables, and ermines. There are several large ungulata, chief of which are deer, moose, the caribou, and reindeer.

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