9 The Mountain Ecoregions

9.1 M Mountains with Elevational Zonation

Highland systems are characterized by change more than any other regional system. On the geologic time scale they are subject to rapid changes in topography. Highland areas are associated with the margins of crustal plates, and the great elevations result from the upwarping of the crust along the plate boundaries and the upwelling of magma that forms the volcanic peaks and massive lava flows. These are the zones where volcanic activity is common and where earthquakes may be expected. The high relief, steep slopes, and generally higher precipitation accelerate erosional processes. Mass wasting is a widespread phenomenon in highlands, including avalanches and landslides (Fig. 9.1). It is these relatively high rates of geologic modification by both internal and external forces which give the highlands their rugged aspect.

Mountain climates are vertically differentiated, based on the effects of change in elevation. Air cools while ascending a mountain slope, and its capacity to hold water decreases, causing an increase in rain and snow. The thin, dry air loses heat rapidly as it ascends, and after sunset, temperatures plummet.

Elevations show typical climatic characteristics, depending on a mountain range's location in the overall pattern of global climatic zones. The climate of a given highland area is usually closely related to the climate of the surrounding lowland in seasonal character, particularly the form of the annual temperature cycle, and the times of occurrence of wet and dry seasons. For example, the Ethiopian Plateau is subject to a diurnal energy pattern, a nonseasonal energy pattern, and a seasonal moisture regime consists of a rainy summer and a dry winter (Fig. 9.2).

Since high mountains extend vertically through several climatic zones, their vegetation is usually rather sharply marked into zones. The elevational limits of various types of vegetation also correspond to the pattern of vertical temperature distribution. Roughly, the same succession of types is found in ascending mountains near the equator as it is found proceeding poleward along the continental east coasts. As discussed in Chap. 4, each mountain within a zone has a typical sequence or spectra of altitudinal belts (Table 9.1). For example, in the tropical rainforest, the tropical forest occupies the lower slopes, higher up are the mixed montane forests of broadleaf types with epiphytes (Fig. 9.3), and beyond the upper limit of trees but below the snow line, is a zone of alpine meadows. Conifers do not appear at higher elevations south of Nicaragua.

As far as vegetation and other forms of life are concerned, the vertical differentiation reaches a maximum in the low latitudes. Here we find the greatest variety of zones. Vertical differentiation remains a conspicuous feature of mountains in the middle latitudes, but disappears altogether in the high latitudes. The effect of latitude was first

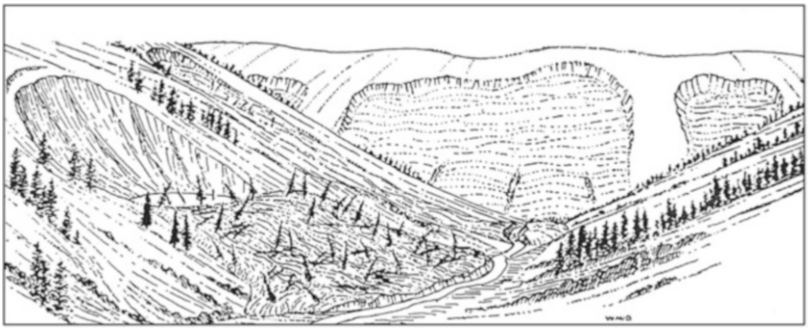

Fig 9.1 Landslides that produce a variation in landform are widespread in highlands. From a drawing by W.M. Davis

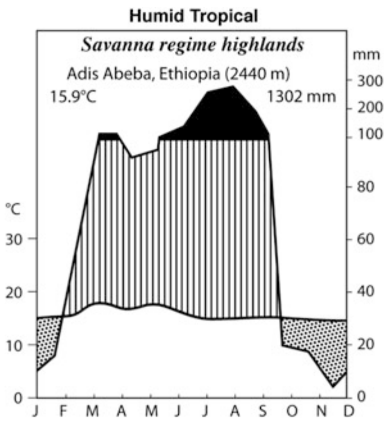

Fig 9.2 Climate diagram of Adis Abeba, 2,440 m above sea level, a tropical savanna regime highland. Data from Walter et al. (1975)

recognized by Alexander von Humboldt (1817). Much later Carl Troll developed a classification of the mountainous regions of the tropical Americas (1968), Eurasia (1972), and then expanded it worldwide (1973). The latitudinal variation in southern Rocky Mountain forests was analyzed by Peet (1978).

The position of the montane zone varies with latitude. It starts at 2,700 m in the Himalayas, 1,200 m in the Sierra Nevada of California, 900 m in the western Alps of Europe, and sea level in the Chugach Mountains of Alaska. Long, cold winters and heavy snowfall create ideal conditions for evergreen conifers, such as pines, fir, and spruce (Fig. 9.4). Food is limited in coniferous forests, and mountain animals, such as deer and many birds migrate to higher elevations as the weather warms and food becomes abundant. In the fall, they reverse the migration. Animals not adapted to living in the cold mountain winters migrate to the lowest slopes. Year-round residents, such as bears and chipmunks, hibernate.

In mid-latitudes, the climates of these montane coniferous forests range from hot and relatively dry to cold, wet, and snowy. The nature of the forest vegetation reflects this wide climatic span. In the United States, the sparse woodland of pinyon and juniper on the desert mountains of southern California and Nevada contrast strongly with the mossy and cool spruce-fir forest of cloud-shrouded Great Smoky Mountains of North Carolina and Tennessee.

The subalpine zone is a transitional area between the lush montane forest below and the harsh alpine zone above. It is characterized by scattered, stunted, and misshapen coniferous trees, such as pines, spruces, and hemlocks. As the upper limit of forest, or tree line, is approached, the trees grow in prostrate thickets, called **krummholz**. Animals in this zone are a mixture of the animals found in the alpine zone above and the montane below. Many montane animals move to the higher elevations in summer and retreat down to more protected areas during the winter. The ibex, a goat of the European Alps, lives in the alpine area in summer and the subalpine zone in winter. Year-round residents include the yellow-bellied marmot and the alpine chipmunk.

Table 9.1 List of the types of elevational spectra

Name of division	Elevational spectra
110 Icecap	Polar desert
120 Tundra	Tundra—polar desert
130 Subarctic	Open woodland—tundra; taiga—tundra
210 Warm continental	Mixed forest—coniferous forest—tundra
220 Hot continental	Deciduous or mixed forest—coniferous forest—meadow
230 Subtropical	Mixed forest—meadow
240 Marine	Deciduous or mixed forest—coniferous forest—meadow
250 Prairie	Forest—steppe—coniferous forest—meadow
260 Mediterranean	Mediterranean woodland or shrub—mixed or coniferous forest—steppe or meadow
310 Tropical/subtropical steppe	Steppe or semi-desert—mixed or coniferous forest—alpine meadow or steppe
320 Tropical/subtropical desert	Semi-desert—shrub—open woodland—desert steppe or alpine meadow
330 Temperate steppe	Steppe—coniferous forest—tundra; steppe—mixed forest—meadow
340 Temperate desert	Semi-desert woodland—meadow
410 Tropical savanna	Open woodland—deciduous forest—coniferous forest—steppe or meadow
420 Tropical rainforest	Evergreen forest—meadow or paramos

Fig 9.3 Montane forest in the Kenya uplands. The tree limb is completely covered with epiphytes. Photograph by Carl Akeley. Image #211362, American Museum of Natural History, Library

Fig 9.4 Open montane forest of ponderosa pine in Coconino National Forest, near Happy Jack, Arizona, elevation 2,284 m. Photograph by Robert G. Bailey

If the mountain is high enough, the climate of the crest may be too severe for forests. In such places there will be a more or less marked timberline, above which is the alpine zone. The alpine zone has many extreme climatic conditions found in arctic climates, and because the atmosphere is thinner at high altitude, the light intensity is much greater. Most alpine plants grow near the ground where they are protected from the wind. Very few animals inhabit the alpine zone year-round. Those that do, such as the pika, tend to be small because of the scarcity of food. Large mammals, such as the mountain goat and the guanaco, rely on well-insulated coats for protection.

Above the tree line and the alpine zone is the climatic snow line, the boundary of the area covered by rock and permanent snow and ice (Fig. 9.5).

Other climatic elements reinforce the effects of temperature on vertical differentiation.

Fig 9.5 Snowfields above valley glaciers near Mount McKinley, Alaska. Photograph by Norman Herkenham, National Park Service

Rainfall, for instance, develops a somewhat vertical zoning. Up to 2–3 km of elevation in the middle latitudes, for example, the rainfall on mountains slopes increases. Unbroken mountain ranges are effective barriers to the passage of moisture (Fig. 9.6). The mountain ranges along the Pacific Coast of the United States, for example, intercept moisture transported from the Pacific Ocean by prevailing westerly winds, so that coastal ranges are moist and inland regions are dry. However, the effect of mountains in producing rain depends on the character of the air blowing against them. Cold air can rise only sluggishly and may produce only low stratus (sheetlike) clouds, as along the Peruvian coast (see Fig. 7.8, p. 74). The heaviest rains in the world, however, are received on mountain slopes which lie in the path of warm, buoyant, moisture-laden air, as the island of Kauai and the southern slopes of the Himalayas.

East–west mountain ranges act as temperature divides. The lowlands on the poleward side of a mountain range are made colder than they would otherwise be, and the lowlands on the equatorward side are made warmer.

Mountain climates in mid-latitudes are an important influence on river flow and floods. The higher ranges serve as snow storage areas, keeping back the precipitation until early or midsummer, releasing it slowly through melting. This maintains continuous river flow.

The upper tree line in mountainous regions is caused by the lack of adequate warmth. The lower tree line found in arid regions is related to the lack of adequate moisture. This combination restricts the growth of forests in arid regions to more or less wide bands along the slopes of mountains (Fig. 9.7).

Soils also change their character with increasing altitude, responding to the changes in climate and vegetation. Figure 9.8 shows how soil profiles change with life zones in the western United States.

Man has caused many changes in the mountain ecosystems by mining, agriculture, grazing, and fire. The elevational limits of the various forms of human settlement are similar to the horizontal limits of the lowlands. The highest settlements are associated with mining. The next highest settlements are commonly supported by the pasturage of domestic animals. Lower down, the various types of agricultural settlement appear. Both the animals and the crops supporting these settlements show fairly distinct upper limits in any one region. Because sheep can exist on much scantier pasturage than cattle, they are driven highest in the mountains. Cattle and horses usually occupy the richer pastures lower down. Of the crops, the potato reaches the highest altitude. Lower down, the various grains arrange themselves in the expectable sequence: barley, rye, wheat, maize, and rice, in descending order. The tropical crops occupy the lower slopes of low-latitude mountains.

In many areas where agriculture has been the main objective, it has been a disaster for the ecosystem. The hill lands of southern China were stripped of their once-rich soils by careless land use. The same has happened in southern Europe, in the Andes, and in the Appalachians and Ozarks of the United States. There are areas, however, where steep slopes have been tilled, using terraces to reduce erosion, for long periods of time without substantial loss. The best

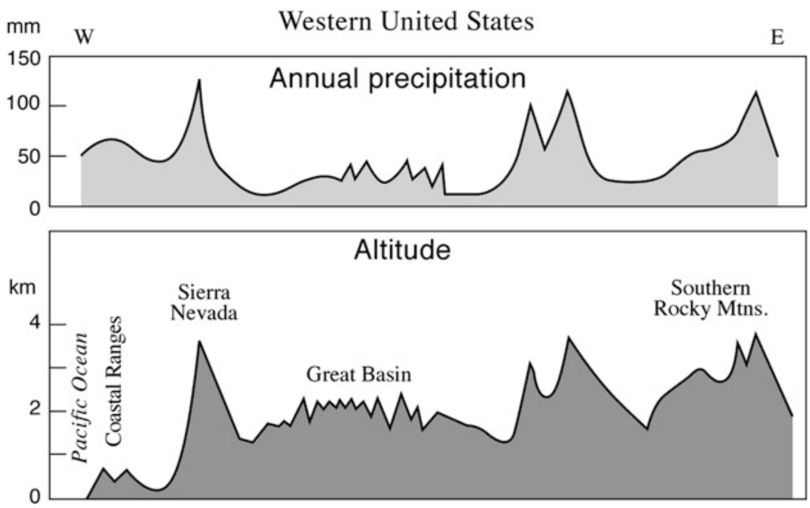

Fig 9.6 Annual precipitation correlates well with the elevation of the land in an east–west section at about 38°N in the western United States. From Bailey (1941), p. 192

Fig 9.7 Elevational zonation in the Ruby Mountains in Nevada, with sagebrush semi-desert in the foreground, coniferous forest on the lower mountain slopes, and alpine tundra toward the top. Photograph by Robert G. Bailey

examples are found in the Himalayas, the Philippines, and the Andes.

In middle latitudes, with marked seasonal change and fewer vertical zones, mountain people tend to establish their homes at the lower altitude and to ascend each summer with their domestic animals. The movements up and down the mountains in response to seasonal rhythm are called **transhumance**. It occurs on nearly all the lower middle-latitude mountains of the world, except in Japan.

The incidence of forest fires has increased, despite forest-fire protection services restricting the once wide-ranging ground fires to relatively small areas. Exclusion of fires may cause changes in the composition and density of the vegetation, sometimes with disastrous consequences when fuels build up. Many subalpine areas in the Rocky Mountains are now occupied by successional lodgepole pine forest, which covers old burned areas in the spruce-fir zone. Our suppression of wildfires has extended the intervals between major fire events. These efforts have resulted in fires such as the infamous Yellowstone National Park fire in 1988. This fire not only had a different character from past natural fires but also burned a far larger area.

The majority of American forest and grassland ecosystems are adapted to fire of varying frequencies and magnitude. Fire is critical in maintaining ecological processes and biodiversity. Fire-excluded systems are susceptible to catastrophic fire and invasion by nonnative species. The cause of the problem in many areas includes more than a century of fire prevention and suppression along with increased human development in the **wildland-urban interface**. To correct this problem, planning for fire and land management must incorporate an improved understanding of **fire regimes**. The various kinds of fire regimes and how understanding fire regimes can abate the threat of fire exclusion and restore fire-adapted ecosystem, are discussed in Chap. 13.

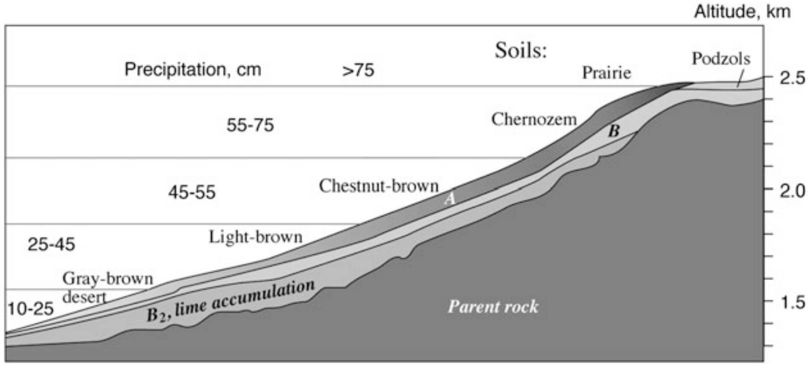

Fig 9.8 Gradation of soils from a dry steppe-climate basin (*left*) to a cool, humid climate (*right*) ascending the west slopes of the Big Horn Mountains, Wyoming. (Note that the soil profile is an extreme exaggeration for purpose of illustration.) From Thorp (1931)

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