Archaeology of the Southwest

SECOND EDITION

Linda Cordell

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University of Colorado
Boulder, Colorado

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deserts, hot deserts, etc.), vegetation zones (Transition, Upper Sonoran, etc.), or dominant plant and/or animal communities (short grass prairie, shadscale-kangaroo rat association, etc.). In general, the natural environment of the Southwest is best characterized by its diversity, with respect to land forms, temperature regimes, precipitation patterns, vegetation, fauna, and mineral resources. Dean and others (1994) suggest that the environments of the Southwest may be characterized by three overlapping classes of variability: stable, low frequency, and high frequency processes. Stable factors show change over space but have remained the same over long periods of time, essentially the last 2000 years. Their current states reflect past conditions. Stable factors include bedrock geology and climate type. Low frequency variability includes processes that occur over periods of time that are longer than a human generation. Cycles of erosion and deposition are examples. High frequency variability is controlled by processes with periodicity less than about 25 years. Among those that are most familiar are seasonal, annual, and short-term changes in precipitation or temperature. Because the characteristics of any natural environment are the result of interactions between the stable processes of the atmosphere (including climate type) and the lithosphere, it is reasonable to begin a discussion of the environments of the Southwest with these.

THE MODERN ENVIRONMENT

Physiographic Provinces

The culturally defined Southwest does not correspond to a single physiographic province, but rather includes portions of four major provinces. These are described here and illustrated in Figure 2.1. The western and southern portions of the cultural Southwest lie within the Basin and Range Physiographic Province, but are not coincident with it. The Basin and Range extends from about Agua Caliente and San Luis Potosi in Mexico to portions of Idaho and Oregon. In general, the Basin and Range Province is characterized by a series of narrow, rugged, usually north-south trending parallel ranges of mountains interspersed with structural basins. In the southern section of the Basin and Range Province in the United States, which includes part of the cultural Southwest, mountains compose less than half the surface area. As one moves south into Mexico, the massive range of the Sierra Madre Occidental composes far more surface area. Although the mountains generally rise abruptly from the basin floors, the ranges are usually not so vast as to impede travel. The province depends primarily on winds from the Pacific to bring essential moisture over the high California Sierra to the west, which trap most of this moisture so the province itself is dry. Internal drainage, frequently resulting in ephemeral lakes or playas (termed *barriales* in Mexico), is characteristic of much of the province. The southern section, however, is drained in part by the Rio Grande, and the Gila, Colorado, Yaqui, and Conchos rivers. Most land surfaces within the province are underlain by deep detrital sediments and consist of gravel fans, gentle slopes (*bajadas*) rising from valleys to the base of the surrounding mountains, either dry lake beds or river flood plains in the central portions

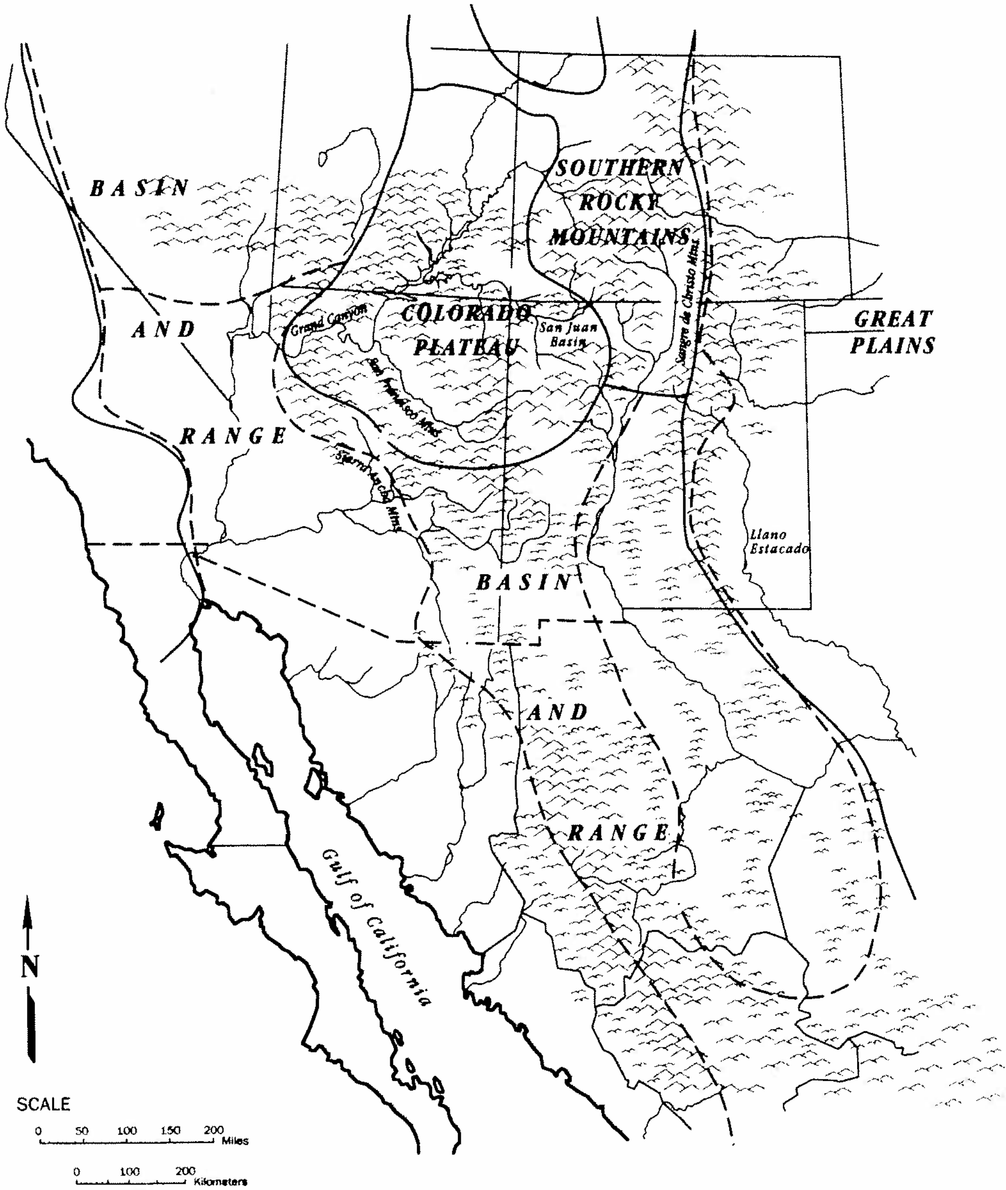

FIGURE 2.1 Physiographic provinces and regional climatic divisions of the Southwest. The Southwest includes portions of the Basin and Range, Southern Rocky Mountains, Colorado Plateaus, and Great Plains physiographic provinces. (Map by David Underwood.)

of the basins, and rugged mountains. Deposits of salt, copper, and lead are among the resources commercially exploited today in the southern section of the Basin and Range and important to ancient populations as well.

The central and north-central part of the cultural Southwest lies within the Colorado Plateaus Province, although the province extends north beyond the Southwest. This province is characterized by relatively high elevations—most of the land surfaces are higher than 1524 m and some mountain peaks reach elevations of more than 3657 m. The plateaus manifest extensive areas of nearly horizontal sedimentary rock formations, but there are also down-warped basin structures such as the San Juan and Gallup-Zuni basins, and elevated igneous structures, particularly along the plateau margins. Examples of the latter are the rock formations of the Grand Canyon section (including the San Francisco Mountains of Arizona), the Datil volcanics of central Arizona and New Mexico, and the San Juan Mountains of southern Colorado and northwestern New Mexico.

Aridity is also a feature of the plateaus province. The principal drainage is through the Colorado River system, including important tributaries such as the San Juan and Little Colorado rivers. Most of the rivers within the province are deeply entrenched and have high gradients. Land surfaces may consist of nearly flat plateau segments (referred to as mesas) and tilted plateau segments (termed cuestas) with steep-walled canyons and escarpments. The volcanic areas contain obsidians that were important ancient lithic sources. Much of the spectacular stone architecture of the Anasazi is made of the local sandstones of this province. Today, coal and uranium are extensively mined in a few areas of the plateaus. Although certainly not of major economic importance, coal was used in pre-Columbian times in some locations as a fuel for firing ceramics.

The cultural Southwest extends into the southernmost portion of the Southern Rocky Mountain Province, which includes the San Juan Mountains on the west slope and the Sangre de Cristo Mountains on the east. Between the two groups of ranges are the San Luis Valley in the north and the Rio Grande Valley in the south. The southern Rocky Mountains are primarily composed of metamorphic rock, but there are extensive areas of igneous inclusions in the San Juan ranges. Elevations within the province range from about 1524 m in the valleys to peaks of more than 4267 m. The Southern Rocky Mountains greatly influence weather patterns (discussed below). Generally though, the mountains themselves are quite well-watered. The mountains provide a significant watershed for large areas of the Southwest. The major drainage to the east is the Rio Grande and its tributaries; the Dolores and San Juan rivers and their tributaries drain the area to the west. The province is well-known for its mineral resources; however, few of these were used in pre-Columbian times. Those that were include igneous rock, primarily basalts and obsidian, fine-grained chert, galena (lead ore), turquoise, and malachite.

At times during the pre-Columbian period, the cultural Southwest extended short distances onto the Great Plains Province; thus, portions of the Raton Section, the Pecos Valley, and the Llano Estacado were occupied, visited, or used extensively by Southwestern peoples. Elevations generally range from about 1828 m to 2133 m in the Raton Section to between 609 m and 1524 m in the Llano Estacado. Topographic relief is slight. Most of the rocks are flat-lying sedimentary deposits overlain by silts, sands, and gravels that were washed eastward from the Rockies. The Raton Section is exceptional in having high mesas capped by lava flows. Past climatic changes enabled southwestern agriculturists to establish communities on the margins of the plains. The important drainages within the area are the Cimarron and the Pecos rivers. The generally arid southwestern plains contain extensive salt deposits that were used in the precontact period. Other resources Native peoples procured from the Great Plains included bison and cherts from the Edwards Plateau of Texas.

In sum, the Southwest encompasses a tremendous amount of physiographic diversity. Elevations range from about 30.4 m above sea level in the basins of the western Basin and Range Province to peaks up to 4267 m high in the Southern Rocky Mountains. Rugged mountains, mesas, narrow canyons, and broad valleys all occur within the area, as do formations of sedimentary, igneous, and metamorphic origin. The physiographic provinces of the Southwest extend far beyond the area included within the cultural boundaries. In general, the cultural boundaries in the west, north, and east are defined by the limits of indigenous farming. These limits, as well as the diversity of natural vegetation found, are largely conditioned by the regional climate.

Climate

At the broadest, most inclusive level, subcontinental areas of related climates are grouped in the same domain (Bailey 1980). At this very general level, the entire Southwest falls within the Dry Domain. Occupying about one-fourth of the earth's land surface, dry climates are characterized by water deficits; that is, the rate at which water is lost annually through evaporation is greater than that gained through precipitation. Beyond this very general characterization, diversity is, once again, the rule.

By definition, moisture is a limiting factor for vegetation in all of the earth's dry areas. Precipitation derives from cyclonic, orographic, and convectional storms, each of which is described below. Cyclonic rainfall patterns are the result of large air masses of low pressure moving across a path determined by the jet stream. Because of the large size of these low-pressure systems, they influence precipitation in a general way over large areas. The Southwest has cyclonic rainfall patterns of two different types: a biannual pattern characteristic of the west and rainfall with a single maximum in the east (Figure 2.2). The biannual pattern centers in Arizona and extends into southern Utah, Nevada, southwestern Colorado, eastern California, and Sonora, Mexico. The primary maximum precipitation in the western area occurs in July and August and derives its moisture from the Gulf of Mexico. The secondary maximum occurs in winter, from December to March, usually peaking in February. The moisture for the winter storms, originating from the Pacific Ocean and the Gulf of California, consists typically of soaking rains or snowfall in the higher elevations. This moisture is absorbed by the soil and encourages early greening of rangeland. The winter precipitation is followed by a very dry period from April through June. The summer maximum may account for 50 percent of the annual precipitation, but the storms are of a different type. Summer rainfall is produced largely by high-intensity thunderstorms of generally short duration. Partly a result of the intensity of the storms, and also because the ground has dried out during the spring, the summer rains do not penetrate the soil

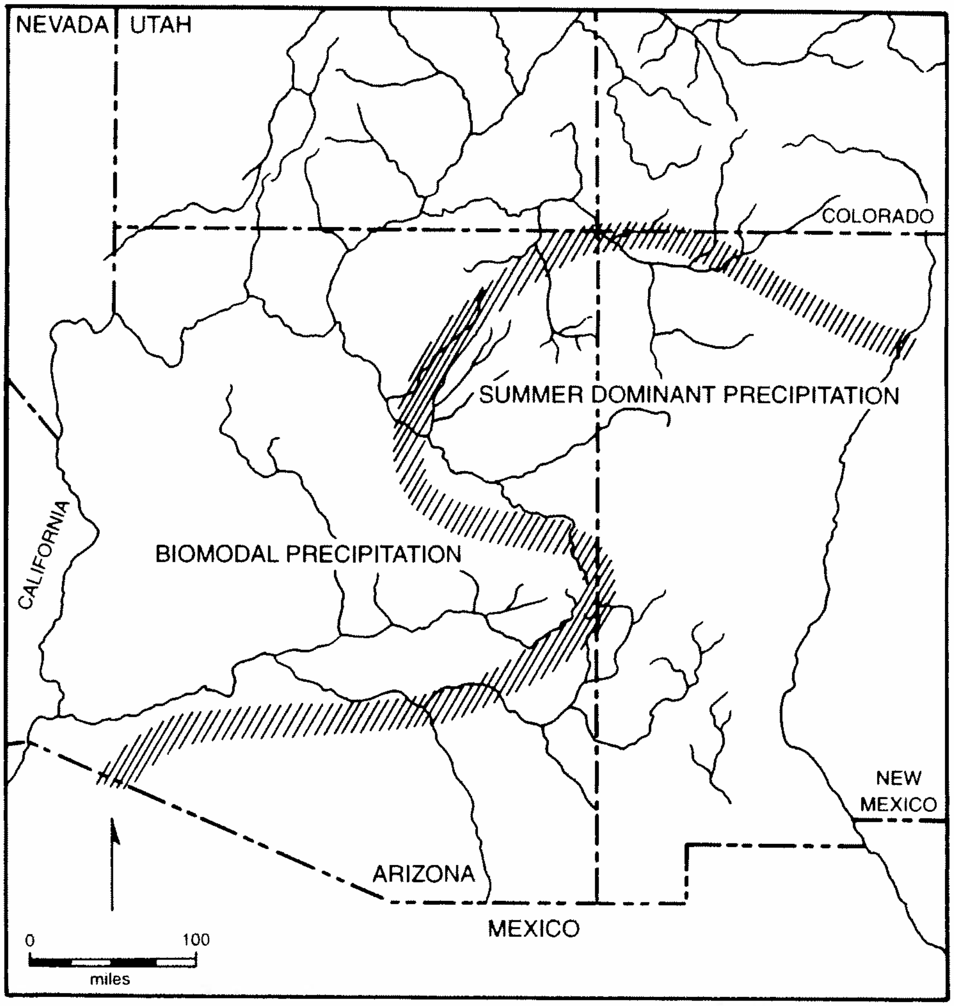

FIGURE 2.2 Spatial distribution of seasonal precipitation in the Southwest over the last century. (Illustrated by Marjorie Leggitt, Leggitt Design; adapted from Dean 1988a.)

as well as the winter precipitation. Much of the summer moisture is lost to runoff (Comeaux 1981; Trewartha 1966).

The eastern portion of the Southwest, including most of New Mexico and Colorado, westernmost Texas, and much of Chihuahua, Mexico, has a different pattern of cyclonic rainfall. In this area, there is a single maximum in the late summer months of June and July. These storms derive their moisture from the Gulf of Mexico in the same way that summer storms are produced in the west, and like the western storms they are of high intensity and short duration. Because cyclonic storms are conditioned by the jet stream, shifts in that stream can have a great impact on storm patterns in the Southwest. Of note, though, such changes will affect the western and eastern parts of the Southwest differently. For example, a northward shift in the jet stream would deprive the western area of important winter precipitation but have little effect in the east. This observation is important because paleoclimatic reconstructions (discussed in detail below) that are derived from one part of the Southwest cannot be generalized across the entire region. Also, it has been suggested that at some specific times in the past, this subregional patterning may have broken down, an issue that is also discussed below. The differences in local precipitation patterns are emphasized by examining the distribution of convectional and orographic storms.

Convectional storms occur in the summer when the ground surface receives maximum solar radiation. Heat from the ground is transferred to the air, which rises rapidly above the earth's surface, cooling quickly. This type of air movement produces violent thunderstorms of a local nature. The high-intensity storms generally begin in the afternoons when the ground has had sufficient time to heat. A great deal of rain is generated by these storms, but the velocity is also high and crops may be damaged, washes flooded, and soil eroded. In general, the storm tracks of convectional rainfall are not very predictable and areas just outside the track receive no precipitation.

Orographic precipitation occurs when winds carrying moisture are forced upward to cross a mountain barrier. The amount of precipitation depends on the moisture content of the air and the height and mass of the mountains. Generally, large mountain masses act as catchment areas for precipitation. The Southern Rocky Mountains, the Mogollon Mountains, and the central mountains of Arizona (the Bradshaws, Sierra Anchas, and Gilas) receive more orographic precipitation than the small mountain ranges of the southern Basin and Range country. Orographic precipitation may occur at any time of year when there are moisture-bearing winds. At times, during the winter, winds from the Gulf of Mexico predominate over the eastern portion of the Southwest. The orographic winter storms provide the snowfall for the Southern Rockies. Also in winter, moisture-bearing winds originating in the Gulf of California occasionally enter Sonora and Arizona, causing orographic snowfall in the high mountains. Orographic precipitation, of course, occurs primarily on the windward side of mountains. The ranges themselves are barriers to precipitation on their leeward sides. Thus, the northeastern portion of Arizona receives very little winter precipitation because it is on the leeward side—or in the rain shadow—of the central mountains.

It is common to discuss the distribution of precipitation in terms of average yearly amount. From this perspective, the Southwest is divided into two regional climatic divisions (Figure 2.3). The desert division is characterized by fewer than 20 cm of annual precipitation. The steppe division receives generally fewer than 50 cm of precipitation annually. It should be obvious, given the foregoing discussion, that average precipitation is misleading. Yearly deviations from the average may be extreme, and not all precipitation is useful for vegetative growth. For example, although the mean annual precipitation in Santa Fe, New Mexico, is 35.9 cm, recorded deviations since 1950 have ranged from 16.9 to 51.2 cm. The annual timing of precipitation is more critical for crops than the average amount. Throughout the higher elevation steppe

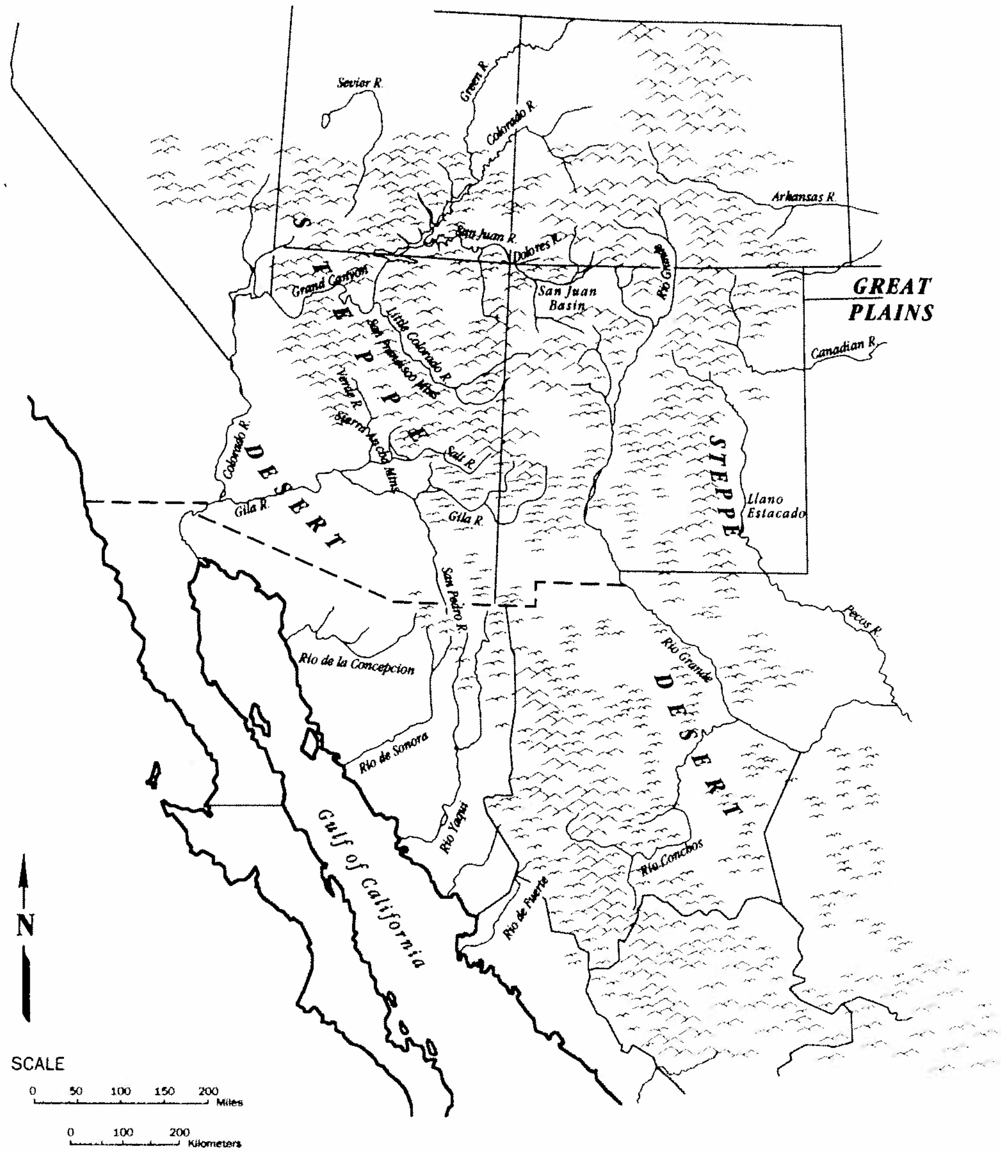

FIGURE 2.3 This map locates the major rivers in the Southwest and shows two broad climatic divisions, the Steppe Region which has an average of 50 cm annual precipitation and the Desert Region with an average of 20 cm annual precipitation. (Map by David Underwood.)

division, winter snows melt and penetrate the soil, allowing wild seeds and crops to germinate during the generally dry spring. In the low, desert division, the scant winter precipitation is inadequate for crops. In the absence of irrigation technology, it is summer precipitation that is crucial for desert agriculturalists. As noted, however, the particularly high-intensity summer thunderstorms in either steppe or desert setting may damage natural ground cover and crops. The most precise methods of paleoclimatic reconstruction available generally are better indices of winter than summer moisture. Given the generally dry climatic regime of the Southwest as a whole and the erratic nature of the distribution of precipitation, reliable sources of water are of critical importance to contemporary and ancient populations.

The major rivers of the Southwest (Figure 2.3) are clearly important; however, not all of them are either completely useful or beneficial for crops. For example, most of the northern portion of the San Juan is so deeply entrenched that its waters are not useful for irrigation. Irrigation using water from the Rio Grande was and is extremely important to contemporary peoples of the area; however, flooding does occur and can be disastrous. In 1886, for example, floods destroyed not only the fields but also much of the village of Santo Domingo, New Mexico, and the town of San Marcial, New Mexico, was destroyed by floods in 1886 and again in 1929. Seeps and springs may be more important sources of water for domestic use (and for hand-watering crops) than the rivers. Over much of the Colorado Plateaus, where many drainages are entrenched, this is especially true. The presence of seeps and springs is conditioned by overlying rock of differential permeability. For example, at Mesa Verde relatively permeable sandstones overlie impervious shales. The seeps and springs that occur at the contact zone of the two formations were an important source of water for the indigenous population. The differences in permeability at the contact zone are also responsible for the formation of rock shelters and cliff overhangs under which the native peoples built their stone dwellings.

In addition to precipitation, the length of the growing season and the temperature and humidity ranges are critical for successful agriculture. Modern hybrid corn requires about 40 to 60 cm of water during the growing season. Water deficiencies at specific times during the growing season, such as the period during which corn tassels, can decrease yields between 50 and 75 percent (Classen and Shaw 1970; Minnis 1981). The high temperatures and low humidity of the Southwest create the characteristic water deficit. The unpredictability of summer rainfall can dramatically decrease yields of maize. In addition, the frost-free period, which is that portion of the year during which vegetation will normally grow, presupposing an adequate amount of moisture, can be quite a bit shorter than the 120 days required by modern corn. Experiments with indigenous varieties of maize suggest that some may have been selected for their ability to tolerate somewhat shorter growing seasons. Growing seasons that are frequently too short even for these varieties are especially likely in locations above 2000 m in elevation (Snow 1991).

In general, temperature range is determined primarily (not exclusively) by latitude and altitude. In the Southwest, temperature decreases northward from 1.5 to 2.5 degrees F for every degree of latitude. Temperatures also generally correlate inversely with elevation, but this is conditioned by several factors related to local and regional topography. The direction of exposure is important for the amount of insolation received and, therefore, for temperature. Contrasts are marked, especially in deep, narrow valleys and canyons with east–west orientations. Canyons of this sort are common on the Colorado Plateaus and in mountainous country. For example, temperatures recorded at the same elevation on the north and south walls of Frijoles Canyon, New Mexico, differed by 13 degrees F. Temperature differences are also noted between the east and west flanks of north-south oriented mountains, with temperatures on the west flanks generally being higher. Other well-known factors of topography that influence temperature are air drainage and wind shifts that cause temperature changes in narrow valleys. Especially on clear, still evenings, cool, heavy air drains into canyon bottoms so that temperatures at these locations may be several degrees below those on the sides of canyons. For example, at Mesa Verde the shortest growing season is in canyon-bottom settings, at elevations of about 1920 m and not on the mesa top, at an elevation of about 2590 m (Erdman *et al.* 1967).

Two other general observations about temperatures are important to germination and the growing season of crops. In many areas of the Southwest, daily temperature changes are greatest in spring, which may endanger the germination of seeds. For example, in New Mexico the daily average range in temperatures in April may be as much as 39 degrees F (Houghton 1959:70–71). Also, variability from year to year in the length of the growing season, particularly in mountainous areas, may be extreme; thus, although the mean length of the growing season at Taos, New Mexico, was recorded as 138 days over a 10-year period, variations of more than 30 days occured from one year to another during the same period (Houghton 1959; Tuan *et al.* 1973).

Over much of the Southwest, particularly in the low-elevation areas of the Basin and Range Province, the growing season is adequate for corn and other crops. The limiting condition for crops in these areas is moisture. Over the portions of the Southwest that consist of mountains and high-elevation mesas, the growing season is frequently not sufficient for corn, and the annual variability in the length of the growing season and the amount of precipitation work together to make agriculture risky. As noted, the combination of high temperatures and direct solar radiation, most marked in the low-elevation areas of the western and southwestern Basin and Range Province, conditions evaporation and evapotranspiration rates. For example, the average evaporation and evapotranspiration rates (combined) at Phoenix, Arizona, are 381 cm, but Phoenix receives an average of only 17.8 cm of precipitation (Comeaux 1981). The general aridity in the Southwest and the ranges in temperature are important factors affecting the natural vegetation found in the region. The varieties and distribution of natural vegetation are discussed below.

Natural Vegetation

A consideration of the plant life found in the Southwest is important for two reasons. First, many of the plants were sources of food, medicines, and raw materials for the indigenous population. Second, the natural vegetation provides habitat for animals that were equally important resources.

Most models of ecosystems describe paths of energy flow because radiant energy from the sun is the limiting factor for life. In dry climates, however, water is the critical variable, and models that reflect this situation are more useful (Noy-Meir 1973).

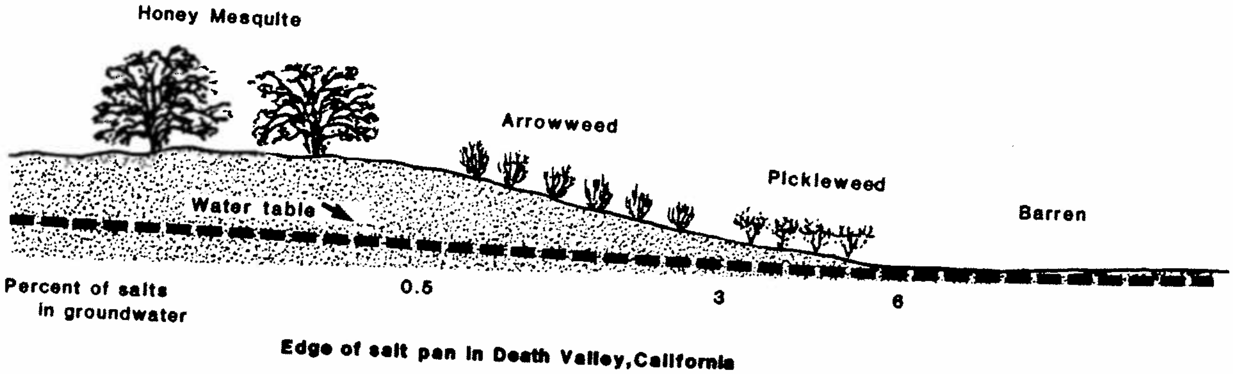

FIGURE 2.4 Edge of salt pan: The plant distribution reflects salt tolerance. Desert plants such as pickleweed and arrowweed tolerate higher percentages of salt in soil than does mesquite. (Adapted from Charles B. Hunt [1967] by Charles M. Carrillo.)

Vegetation in dry regions must be adapted to using moisture that enters the system in short duration "events" (such as a thunderstorm), which occur unpredictably in any one area. In addition, edaphic factors, such as soil depth, friability, moisture-retention characteristics, and mineral composition, are important.

A number of adaptive mechanisms are found in plants that enable them to withstand arid conditions. Some plants (drought-evaders) remain inactive during dry periods and photosynthesize only when moisture becomes available. These include desert annuals that produce seeds that remain viable for long periods of drought, and perennial plants that store water and nutrients in bulbs and rhizomes. Drought-persistent plants (xerophytes) maintain some photosynthesis throughout dry periods. Many desert shrubs persist through drought by shedding most of their leaves, stems, and rootlets, which reduces their activity level and water requirements. Other desert plants maintain nearly constant levels of photosynthesis but have evolved adaptive structures that minimize water loss. For example, some have waxy substances on their leaves that retard transpiration. Others, such as the succulents and cacti, store water internally. Still other plants (phreatophytes) develop specialized root systems and long tap roots that enable them to use ground water (Comeaux 1981; Hunt 1967; Noy-Meir 1973).

Soils form as a result of the interaction between weathering rock and decaying organic matter. Because organic matter is sparse in deserts, soils are generally poorly developed. Soil types have a marked effect on vegetation. With respect to soil texture, clayey, silty, and loamy soils retain moisture near the surface. Where these soils predominate, shallow-rooted plants, such as desert grasses, are common. Sandy, gravely, and rocky soils allow percolation of water to deeper levels. On these soils, deep-rooted perennial shrubs predominate. Yucca is a common deep-rooted Southwestern plant that prefers gravely soil. Plants also have different capacities for tolerance of salts and other minerals that accumulate in desert soils, particularly along the edges of playas, which are characteristic features of the southern Basin and Range country. Salt grass, arrowweed, and pickleweed are among plants that tolerate considerable salinity and

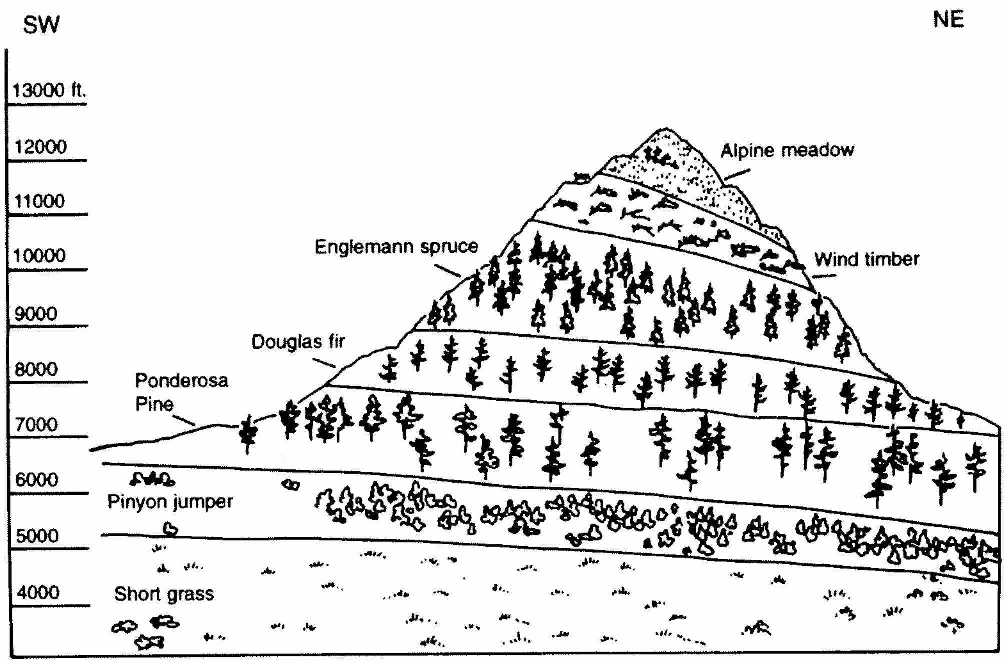

FIGURE 2.5 This schematic diagram of plant communities at the San Francisco Peaks, Arizona changes due to elevation and the direction of exposure. (Adapted from C. H. Merriam [1890] by Marjorie Leggitt, Leggitt Design.)

are found in zones along the edges of saline playas, according to the amount of salt present in the soil (Figure 2.4).

The direction of exposure is important for the moisture-retention capabilities of soil and will, therefore, influence vegetation cover. Generally, north- and east-facing slopes are wetter than south- and west-facing slopes. North slopes may support stands of trees and shrubs, whereas south-facing slopes at the same elevation may support only desert annuals and cacti. Any areas within the Dry Domain that contain fresh water, such as spring-fed ponds, rivers, and streams, will support riparian plant communities that might consist of cottonwoods, willows, reeds, and ferns.

Overviews of the southwestern environments usually present vegetation patterns as if they were determined exclusively by latitude and elevation. A common, and useful, characterization is provided by Merriam's (1880) famous diagram of plant communities at the San Francisco Peaks in Arizona (Figure 2.5), which reflects the direction of exposure in addition to elevation. While it is certainly true that broad vegetation zones exist and are a useful shorthand for characterizing plant communities, they obscure some of the diversity found at any one elevation and latitude, which is conditioned by soil type and water availability as well as by exposure. Zonal characterizations also minimize some of the comparability among disparate latitudes and elevations that are conditioned by the same factors of soil type and water availability.

Plant Provinces The system of description used here follows Bailey's (1980) descriptions of provinces, modified by Spaulding and others (1983) floristic delineation of North American deserts. A province is a contiguous geographic area characterized by a broad vegetation type and a uniform regional climate. The provinces making up major portions of the Southwest are the Sonoran and Chihuahuan deserts of the American Desert Province, the Mexican Highlands Shrub Steppe Province, the Upper Gila Mountains Forest Province, the Colorado Plateaus Province, the southern segment of the Rocky Mountain Forest Province, and a small portion of the Great Plains Shortgrass Prairie Province.

The Sonoran Desert occupies nearly 300,000 square km in Arizona, Sonora, southeastern California, and Baja California. The most widely distributed plant in both the Sonoran and Chihuahuan deserts is the creosote bush. Cholla, a type of cactus, is also common. The vegetation on rocky slopes consists of paloverde, agave, sotol, ocotillo, and saguaro, with bitterbrush as a common shrub. Fish and Nabhan (1991) point out that within the Sonoran Desert, there are major differences between the upper bajadas (slopes) in the eastern and northern portions of the desert and the lower western sections. The upper bajadas are relatively well-watered compared with the western desert and are covered with plants of the paloverde-cacti mixed scrub series. This series is structurally complex, consisting of the giant saguaro, tree-legumes, annuals, and root perennials. In the western Sonoran Desert, there are fewer perennials but more ephemeral plants. Although there is less diversity of both plants and of animals at the lower elevation western Sonoran Desert, many of the ephemeral plants produce abundant high-calorie seeds. Low-elevation playa margins and areas subject to flooding and salinization support stands of salt-tolerant plants such as mesquite, saltbush, arrowweed, and pickleweed.

The Chihuahuan Desert Province consists of short grasses and shrubs, with creosote again covering extensive areas. Mesquite dominates in places where soils are deep, while ocotillo, agave, yucca, and sotol occur on slopes. Mountains within the province will, if they are high enough, support a belt of oak and juniper woodland; on some of the highest mountains, piñon grows interspersed with oak. Along the southeastern margin of the Sonoran Desert and the northern edge of the Chihuahuan Desert are highlands that support a variety of grasses, piñon, and oak. At the highest elevations (above 1900 m), there are quite extensive stands of Douglas fir. An important point made by Fish and Nabhan (1991) is that from virtually anywhere in the habitable Sonoran Desert, one can access coniferous forest within 200 km.

Freshwater streams and oasis marshes are rare in both the Sonoran and Chihuahuan deserts. Fish and Nabhan (1991) estimate that far less than 0.1 percent of the Sonoran Desert consists of wetland areas. Nevertheless, in these deserts, as elsewhere in the Southwest, wetlands contribute disproportionately to habitat heterogeneity. Wetlands support riparian forests (termed *bosques*) that may include cottonwood, willows, cattails, and a variety of shrubs and grasses.

The Upper Gila Mountains Forest Province covers more than 93,000 square km in Arizona and New Mexico. Within the province, vegetation is zoned primarily by elevation. Below 2100 m, mixed grasses, chaparral brush, and mixed woodlands of oak, juniper, and piñon occur. From about 2100 m to about 2400 m, the vegetation is an open forest of ponderosa pine with piñon and juniper on the south-facing slopes. On dry rocky ground above about 2400 m, Douglas fir and aspen occur with limber pine.

Throughout the Colorado Plateaus Province are extensive areas of bare rock, devoid of vegetation. At low elevations arid grasslands are extensive, though not dense. Sagebrush is common in locations with fairly deep soils. The most extensive vegetation zone in the province, the piñon-juniper woodland, is generally quite open with grama and other grasses, herbs, and shrubs occurring among the trees. Above the piñon-juniper woodland is a montaine zone. In the southern part of this zone, ponderosa pine is dominant and may be associated with Douglas fir, although the latter generally occurs in more sheltered sites or at higher elevations. In the northern part of the province, lodgepole pine and aspen are the dominant trees of the montaine zone, while at the highest elevations, Englemann spruce and subalpine fir are characteristic. In the San Francisco Mountains of Arizona, bristlecone pine is associated with spruce. San Francisco Peak is the only mountain within Arizona that contains alpine meadowlands; however, a few more northern mountains in the province have small areas of alpine meadows above timberline.

The southern Rocky Mountain Province is also characterized by well-marked altitudinal zones. The woodland zone adjacent to the Colorado Plateaus has extensive areas of piñon and juniper, often alternating with ponderosa pine, depending on the direction of the exposure. Rocky slopes may host dense stands of mountain mahogany and scrub oak, with sagebrush and grasses covering large areas extending to the ponderosa pine and Douglas fir forest. Above this forest, a zone of subalpine vegetation is dominated by Englemann spruce and subalpine fir, succeeded finally at even higher elevations by areas of treeless alpine meadows.

Only a small portion of the Great Plains Shortgrass Prairie Province occurs within the Southwest. The characteristic grasses (grama and buffalo grass) are a ground cover for sunflower and locoweed, the typical plants. Scattered piñon and juniper occur over some of the area, particularly on slopes near the foothills of the Southern Rockies. Riparian plants are found along the limited watercourses.

A comparison of the plants characterizing each of the provinces indicates that many are found throughout the Southwest, although they may be more abundant in one province than another. For example, cholla, bunchgrass, and chenopodium (goosefoot) are virtually ubiquitous. Widespread distributions of understory plants associated with the woodlands and forests are also characteristic. Some widely distributed understory plants are hackberry, serviceberry, and mountain mahogany. The density of the understory plants and their particular configurations vary with elevation, direction of exposure, and soil conditions.

Economic Uses of Plants A great many plants of the Southwest have edible parts and were used as sources of food by both modern native peoples and their ancestors. Some of the more important are mentioned here. (The interested reader is referred to Castetter 1935; Fish *et al.* 1985; Harrington 1967; Minnis 1989, 1991; Nabhan 1985; Spielmann and Angstadt-Leto 1995; Wetterstrom 1986.)

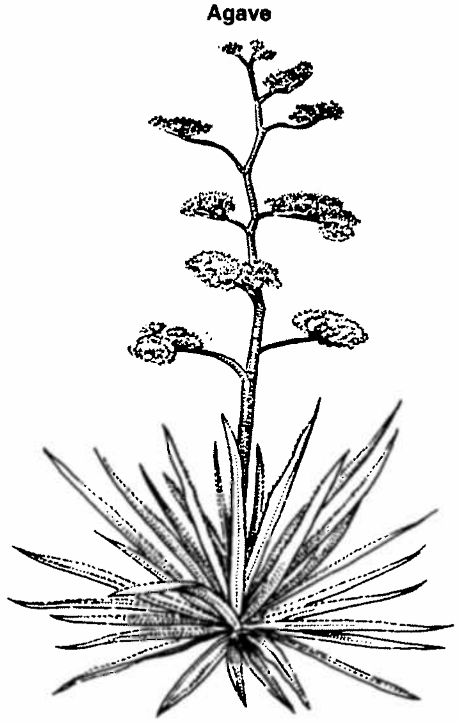

FIGURE 2.6 Agave is found throughout the low desert areas of the Southwest and was used for fiber as well as food. (Illustrated by Marjorie Leggitt, Leggitt Design.)

Agave (Figure 2.6) was an important food source throughout the low desert areas. The leaves and centers (crowns) of the plant are roasted and may be stored. Sotol hearts were used in a similar way. The young stems and hearts of saltbush and yucca were eaten, as was yucca fruit, which could also be boiled and stored. Cactus fruits from the prickly pear cholla, hedgehog cactus, and saguaro were made into a variety of foods. In addition, cholla joints were roasted and stored. The bulbs of wild onion were eaten, and wild potato tubers were eaten fresh or stored and later made into a gruel. The fruits and pods of various plants were eaten alone or mixed with other foods. Among the more important were evening primrose, lamb's quarter, Rocky Mountain bee plant, bunchgrass, Indian ricegrass, sunflowers, paloverde, oak, and piñon. In addition, many varieties of plants were used as greens and, importantly, as medicinal herbs.

In addition to being eaten, plants served a wide variety of other economic uses in ancient times. Timbers for building were made from piñon and Douglas fir; fibers for baskets and sandals from yucca, agave, and apocynum (Indian hemp); paint pigments from Rocky Mountain bee plant; roofing thatch from riparian grasses and reeds; and firewood from the woody portions of shrubs and from woodland and forest trees. In general, Southwestern peoples possessed an intimate knowledge of the plant resources available in their environments, using most of them for food, medicinal purposes, clothing, shelter, or fuel.

In conclusion, the characteristics of vegetation distributions in dry regions cannot be overemphasized. First, as noted, many species either are dormant entirely (the drought evaders) or limit the production of seeds (xerophytes and phreatophytes) until moisture conditions are adequate for successful reproduction. Hence, the most nutritious parts of plants, and the parts most often used for food, are the reproductive parts —the fruits, seeds, and nuts—which are not available at all times of year or even every year. Also, because the weather conditions that trigger plant reproduction are erratic, the ability to predict—on a long-term basis—when and where plant foods will be available is very low. For example, although piñon nuts are a highly nutritious source of food and piñon is widely distributed throughout the Southwest, good nut crops are not available in any one area from one year to the next. Second, because the distributions of plants are controlled by microenvironmental factors such as soil depth, soil salinity, direction of exposure, and soil composition, very large stands of a single plant type in one area are rare. For this reason, it is often difficult to gather sufficient quantities of wild plant food without moving over great distances. For example, Wetterstrom (1986) estimates that if the archaeological site of Arroyo Hondo (a large Pueblo ruin in the Galisteo Basin of New Mexico) housed 400 people, slightly less than 2 percent of the caloric needs of the population could have been satisfied by seeds of wild plants growing within 1 km of the site. The potential harvest of the fruits of prickly pear cactus from within 1 km of the pueblo could have supplied 0.4 percent of the required calories and 6.6 percent if cactus fruits were collected within a radius of 4 km of the site. On the other hand, Sullivan (1995) has suggested that other groups of Anasazi increased the abundance of wild plant foods by controlled burning of piñon-juniper woodland. Yet, both the unpredictability of wild plant foods and small areas of pure stands affect the density and mobility of game animals, discussed below. Finally, compared with other parts of North America, the overall productivity of the Southwestern environments is relatively low. The average annual net above ground productivity in arid regions varies between 30 and 200 g/m^2 (Noy-Meir 1973). For human populations dependent on plant resources, the Southwest is a low productivity, high-risk environment.

Fauna

Animals not only require food and water for survival, they must maintain their body temperatures within tolerable limits. In dry climates, animals generally display considerable flexibility in behavioral patterns, which, combined with their mobility, allows them to use the temporally and spatially heterogeneous resources available. In part resulting from the sparse nature of nutritious plant food in arid climates, most dryland herbivores are indiscriminate feeders, subsisting on a variety of less desirable foods as preferred foods disappear (Noy-Meir 1974). This dietary flexibility allows these animals to colonize a wide variety of vegetation zones. It therefore is not surprising that the larger herbivores, those that are particularly important game animals for humans, may be found in virtually all parts of the Southwest. For example, although mule deer are most abundant in the ponderosa pine forests, they are nearly ubiquitous in the Southwest and may be encountered regularly among the paloverde and cactus shrub land of the desert provinces, the piñon-juniper woodlands and slick rock areas of the Colorado Plateaus, and the grassland communities characteristic of the lower elevations of the Southern Rocky Mountains. There are two generalizations about the differential distributions of animals within the Southwest that are useful to consider. First, there is generally more diversity in larger animals in the mountain and plateau areas and more diversity in small animals in the lower desert areas. Second, the differences in the distributions of animals may relate more to their specific behavioral responses to predators or to key climatic factors, such as amount of winter snowfall, than to their food requirements (see Osborn 1993 for a discussion of ungulate ecology).

The three most common southwestern game animals—with very extensive distributions—are mule deer, pronghorn antelope, and Rocky Mountain bighorn sheep. As noted, mule deer occur throughout the Southwest. They are not selective browsers, but prefer oak, piñon, juniper, Douglas fir, ponderosa pine, and the understory plants associated with these trees. They are usually found most abundantly in broken country and along the borders of dense forest areas. They are found less frequently in more open settings. Pronghorn antelope occur at a variety of elevations from northern Colorado through northern Mexico and from the Shortgrass Prairie to the Chihuahuan Desert. Despite the variety of elevations they inhabit, they prefer open plains and open valleys and avoid rough terrain. This preference relates primarily to their defensive strategy of outrunning predators. Rocky Mountain bighorn sheep, in contrast, require steep, rocky terrain for protection; it is the terrain rather than the elevation that is critical. Bighorn sheep are relatively rare today (except where herds have been reintroduced into areas and are protected). The archaeological record suggests that in the past, they occurred virtually throughout the Southwest.

Four fairly large game animals are important but have more restricted distributions in the Southwest. White-tailed deer occur in the Chihuahuan Desert, although their numbers there are not as great as those of the mule deer. Elk are today of local importance only in the Colorado Plateaus, the Southern Rocky Mountains, and the Upper Gila Mountains, although they may have had more extensive ranges in the past. Bison were, of course, very abundant on the shortgrass plains. In the very remote past (see Chapter 3), their range extended west into south-central Arizona. Bison require extensive grasslands. In the past 300 years, their range has been coincident with the grasslands on the easternmost margins of the Southwest. Finally, the collared peccary, occurring primarily in the desert areas of the southern Southwest, are fairly common in the paloverde communities of the southern portions of the Chihuahuan Desert Province, although its range may extend farther north.

Large predators are generally not important sources of food for people because, although they are of large body size, they usually hunt singly or at night, which increases the difficulty involved in searching for and pursuing them. Nevertheless, large predators are more numerous, and more diverse, in the highlands and mountains that also support the more abundant herbivore populations. Mountain lions and bobcats occur in the Southern Rockies and the Upper Gila Mountains. Black bears are found primarily in the Southern Rockies. The smaller carnivores are more numerous and more widely distributed throughout the Southwest: The coyote is found everywhere in the region and foxes are common.

Smaller animals generally account for the bulk of the animal bones found in archaeological contexts. Jackrabbits and cottontail rabbits proliferate throughout the Southwest and are frequently the major components of archaeological assemblages of fauna. The ranges of these two animals overlap considerably. Nevertheless, jackrabbits prefer open terrain that allows them to escape predators by outdistancing them, whereas cottontails prefer dense vegetation in which they escape predators through concealment. In addition to rabbits, animals such as pocket gophers, prairie dogs, kangaroo rats, wood rats, squirrels, and voles are abundant in the Southwest and are frequently encountered in archaeological sites. Some of these animals burrow into abandoned rooms and trash, but most were probably sources of food.

Within the Southwest, the low desert areas generally have the fewest large and medium-size animals. In the desert provinces, there are few large mammals, but kangaroo rats, pocket mice, and ground squirrels are common, and there is considerable variety in reptiles such as snakes and lizards. These small animals, as well as the jackrabbits and cottontails, were important sources of food in the remote and more recent past. For example, Szuter (1991) argues that rodent-size game animals were essential to the agricultural populations in the Sonoran Desert.

Along water courses, muskrats and beavers are locally significant. The remains of fish and turtles occur in archaeological sites, and fish are depicted on some kinds of pottery. These animals were probably eaten, but their contribution to human diet is not known and is likely not to have been great even among people living near rivers. Insect remains have been found in human coprolites from Southwestern archaeological sites. Most of these were probably accidentally incorporated into food and ingested (Elias 1994:125–127). In one case, however, Stiger (1977) argues that cicadas and grasshoppers were food sources for some Mesa Verde populations.

Various birds are important to the contemporary and ancient peoples of the Southwest. The feathers of certain species of birds are required for items of religious paraphernalia, such as dance costumes, prayer plumes, and katcina representations (see Tyler and Ormsby 1991). Among the more important birds are various raptors: species of hawks, owl, and eagles. Bones of these birds occur in archaeological contexts, as do those of turkeys and various waterfowl. Throughout the arid Southwest, rivers and ponds continue to be the important habitat areas for migrating waterfowl that they were in the past. It also has been suggested that ancient agricultural practices, such as the diversion of floodwater from streams to fields, may have created larger areas of wet habitat for these birds (Emslie 1981). Turkeys were domesticated by some groups in the Southwest and seem to have been used for their feathers as well as for meat. The only other ancient North American domestic animal is the dog.

In sum, the arid and semiarid conditions of the Southwest encourage generalized feeding strategies in animals. For this reason, most of the fauna are able to colonize and adapt to diverse habitats. The modern distribution of game animals and the archaeological record both reflect considerable homogeneity in fauna represented.

Mule deer, pronghorn antelope, jackrabbits, and cottontails are the most characteristic southwestern food animals. Locally, other animals are important. In the southern desert areas, reptiles and small rodents are more abundant. In the mountains and the high plateau country, elk, mountain lions, and bears occur. The archaeological record indicates that throughout the Southwest a great diversity of animals were hunted, including birds. Largely because agriculture is a risky strategy in much of the region, gathering and hunting were always of economic importance. As noted, gathering would not consistently provide secure sources of food in sufficient quantity to feed very many people. Hunting may have been similarly risky as an economic base. In the very early periods of southwestern history, when human population density was low and groups were highly mobile, hunting and gathering were sufficient for subsistence. Later, with higher population densities, agriculture became critical, although gathering and hunting always retained important subsistence roles.

Some of the practices for agriculture may have had adverse effects on some game animals. Clearing woodlands and forests for agricultural fields and for firewood may have reduced the amount of habitat preferred by elk and wild turkey. It has also been noted that in areas of dense human occupation, overhunting may have greatly reduced the availability of game such as bighorn sheep. On the other hand, agricultural fields themselves are important habitat for smaller animals, such as rabbits, that are hunted for food. As noted, agricultural practices, such as irrigation, would have expanded the habitats of some animals, particularly several species of birds. The diverse effects of agricultural production are discussed in Chapter 5. Here it is important to note that the general aridity of the Southwest and the erratic patterns of rainfall limit the natural productivity of the entire region. Even relatively minor changes in climate can have rather marked effects on the landscape and concomitantly on the flora and fauna. Southwestern climates have not been stable throughout either the recent or very ancient past. As noted, many interpretations of change in the archaeological record are attributed to environmental fluctuation. In order to evaluate these interpretations, it is necessary to understand how paleoenvironmental reconstructions are derived. This is the topic of the following section.

PALEOENVIRONMENTAL RECONSTRUCTION

The intent of the following paragraphs is not to describe a series of past climatic events. Rather, it is to present the kinds of data used to infer past environments, the information that each data source provides, and particular interpretive problems associated with specific data sources. Throughout the history of Southwestern archaeology, changes in climate and environment have been invoked as causes of human behavior. For example, sites and regions are said to have been abandoned because of drought, flood, or erosion. This is in part a reflection of our modern American attitude toward the difficulties in making a living from the harsh landscape. Nevertheless, because of