COLORADO PREHISTORY: 
A CONTEXT FOR THE 
SOUTHERN COLORADO RIVER BASIN

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Submitted by
Crow Canyon Archaeological Center
Cortez, Colorado

Colorado Council of Professional Archaeologists
1999
INTRODUCTION

This chapter is organized into two major sections. The first section by Adams focuses on aspects of the modern environment that have the most relevance for foragers and agriculturalists. This begins with a description of the biotic communities present in the southwestern Colorado context area, and is followed by a discussion of the biotic communities found in each drainage-unit subdivision of the context area. Next, the geology, soils and available domestic water in the study area are described. There follows a discussion of climatic aspects particularly important for maize agriculture, such as precipitation, "corn growing degree day" units, and frost-free periods. In the final part of the first section, the drainage unit subdivisions are each evaluated in terms of the potential for both foragers and agriculturalists. The second major section of this chapter by Petersen presents a reconstruction of the paleoenvironment for southwestern Colorado.

MODERN ENVIRONMENT OF THE STUDY AREA:
POTENTIAL FOR FORAGERS AND AGRICULTURALISTS

Description of Biotic Communities

Seven separate biotic communities occur in various combinations in the seven drainage units (Figure 2-1). A separate discussion of each biotic community is presented here, based on Brown (ed. 1982) and his colleagues, and arranged in order of relative position on the landscape from low to high elevations. Emphasis is placed on plants and animals that would be of interest to humans, and estimates are given of the relative amount of each biotic community in the study area as a whole. For extensive lists of plants and animals found in each biotic community, the reader is referred to Brown (ed. 1982).

Sagebrush-Saltbush (Great Basin Desertscrub)

Within this biotic community, which occupies approximately 19.6 percent of the study area, species diversity is usually low and big sagebrush (Artemisia tridentata) is dominant. Common taxa include other species of sagebrush (Artemisia spp.) and saltbush (Atriplex), along with rabbitbrush (Chrysothamnus) and winterfat (Ceratoideae). These principal species are often much-branched aromatic shrubs with soft wood and evergreen leaves that have affinities with the most northerly of the North American deserts, the Great Basin (Turner 1982:145-155). Cholla and prickly pear (Opuntia spp.) cacti, along with hedgehog cacti (Echinocereus) are also present. If not eliminated by grazing, grasses can play an important role within this community. Mesic (wetter) areas host New Mexican privet (Forestiera) and greasewood (Sarcobatus). The sagebrush-saltbush community usually occurs between 1200 and 2200 m elevation. Succession within this community is most affected by fire and grazing, and by the introduction of weedy, aggressive annuals, largely from Eurasia (e.g., Bromus spp., Salsola, Erodium, Sisymbrium, Hordeum). Of interest to humans would be grasses, including ricegrass/needlegrass (Stipa), grama (Bouteloua), dropseed...
PALEOENVIRONMENTAL RECONSTRUCTION:
THE LAST 40,000 YEARS IN THE NORTHERN SAN JUAN RIVER DRAINAGE BASIN

Introduction

Precipitation during the summer months in the southern Colorado Plateau, critical for the dry farming of certain crops, results primarily from moisture sweeping in from the south and southwest (Figure 2-2). Climate in the western United States is complex, and general patterns are linked to much larger global weather systems and to a deep geologic history. For the interested reader, Petersen (1994a) provides a brief review that contains an extended bibliography of more detailed modern climate studies, and Adams and Comrie (1997) and Woodhouse (1997) provide additional coverage and references. Petersen (1988, 1994b) and Davis (1994, 1996) provide evidence that the boundary for the summer monsoon has shifted both north and south in the past, affecting the ability of some prehistoric peoples to dry-farm maize and other crops. The following section discusses these findings in the context of other climatic studies from the region. Although this document is primarily focused on southwest Colorado, discussion of climatic systems both present and past requires a much broader treatment.


Tree-ring Climate Reconstruction and Berry's Theory

Since the creation of continuous tree-ring chronologies in the Southwest beginning in 1929 (Douglas 1929, 1935), archaeologists have attempted to correlate the movements of peoples with critical changes in climate. One theory that most clearly relies on the impact of climate on culture to explain relocations and abandonments is that of Berry (1982), who sees the stages of the Pecos Classification as real time-and-space entities that are separated from one another by abrupt transition events. Berry (1982) maintains that these discontinuities were initiated by periodic, Colorado Plateau-wide droughts that left their mark in the numerous tree-ring records available...
Figure 2-2. Climatic boundaries for the Southwest monsoon (after Petersen 1994b). Precipitation is greatest east and south of the southwest monsoon boundary of Mitchell (1976), where more than half of the annual precipitation occurs during the warm season (Dorreah 1946). North of that boundary the amount of warm-season precipitation decreases until it reaches the summer precipitation limit of Pyke (1972). Arrows show the main paths of moisture in the southwest United States during the summer (adapted from Miller et al. 1973).
from the Southwest. These extensive droughts caused widespread abandonments of low-elevation Puebloan sites and consequent migration to high-elevation refuge sites. The forced coexistence and coalescence of immigrant groups in these various refugia produce the syntheses of material culture traits that have been identified as the hallmarks of the ensuing stage(s). Berry's (1982) model sees the simple link between severe droughts as reconstructed from tree rings and large-scale population movement as the primary explanation of rapid cultural change. Berry's (1982) treatment of demographic movement is from a much larger geographic perspective than many previous studies but it has come under some methodological criticism (for example, see Dean 1985).

However, apparent support for some parts of Berry's (1982) model comes from Wilshusen and Ortman's (1999) survey of the Pueblo I period (A.D. 750-900) in the southern Colorado Plateau region. They indicate that by A.D. 860 there may have been more than 10,000 people settled in the higher elevation villages north of the San Juan River in southwest Colorado and southeast Utah, and that the population of these large villages appear to have moved into the area from at least two areas with distinctly different cultural backgrounds. However, by A.D. 890 the population for the entire San Juan River drainage region had declined by at least two-thirds, suggesting a substantial migration to the south and east. This regional abandonment was likely followed by an ensuing Pueblo II expansion back into the region.

**Pollen Records and Black Mesa Climatic Reconstructions**

During the late 1950s and early 1960s, Paul S. Martin and his students and associates at the University of Arizona undertook investigation of pollen preserved in alluvial, lacustrine and archaeological sediments in the Southwest—a region noted for its lack of more traditional basins of pollen deposition such as lakes and bogs (Martin 1963; Martin and Byers 1965). One of Martin's associates, James Schoenwetter (1966, 1967, 1970, 1987; Schoenwetter and Eddy 1964) compared modern pollen ratios and pollen spectra with those from dated alluvial and archaeological sites in the Colorado Plateau. From these, Schoenwetter was able to reconstruct an effective moisture curve for the Navajo Reservoir and Chuska Valley areas of northwest New Mexico (Figure 2-3, bottom curve). Higher arboreal (tree) pollen values are interpreted by Schoenwetter as indicating greater effective moisture at his research localities, likely due to greater winter-dominant precipitation. Schoenwetter (1966) was the first to propose such a chronology of winter precipitation fluctuation for the Four Corners region. Schoenwetter (1966) also suggested that the times of low winter precipitation were likely offset by increased summer precipitation although he had no direct pollen evidence to show it.

Another of Martin's students, Richard H. Hevly, became involved in the study of the paleoenvironments of Black Mesa in northeast Arizona (Euler et al. 1979). By far, this long-term, integrated effort has been one of the most productive and most fruitful of all Southwestern studies examining Puebloan and climate interactions. Dean (1988, 1996) presents the preliminary model for behavioral adaption for Puebloans in the northern Southwest by looking at the interaction of behavior with two other major classes of variables: environment and demography. The environmental variables are divided into two types: those termed “low frequency” with base periodicities greater than or equal to 25 years, and those with shorter periodicities termed “high frequency” variation. One of the reasons that such a distinction is made is that each record type can provide information that is unobtainable from the other. For instance, short-term drought may be reflected in tree rings, but it takes a very long-term drying trend to shift a vegetational boundary. High frequency climatic change includes proxies for precipitation and temperature
Figure 2-3. Long-term oscillations exhibited by arboreal pollen in a lacustrine pollen record from Beef Pasture (La Plata Mountains, Colorado), and archaeological and alluvial pollen data from Arizona (Flagstaff-Elden Pueblo, Black Mesa, and Hay Hollow Valley), and New Mexico (Chuska Valley and Navajo Reservoir). Data from Hevly 1981, Hevly et al. 1979, Petersen 1985a; Schoenwetter 1966, 1967, Schoenwetter and Eddy 1964. Note that different pollen types have been used at different localities to illustrate these long-term trends, which appear to be generally parallel over a wide geographic area. (Reprinted with the permission of Cambridge University Press.)
derived from tree-ring studies on scales ranging from days to decades. The low frequencies variables include the deposition and erosion of flood plain sediments along drainage and the rise and fall of alluvial ground water levels (Karlstrom 1988). Because Force and Howell (1997) and Huckleberry and Billman (1998) have reviewed this and other alluvial studies in the Colorado Plateau, such studies are not discussed in depth here other than to indicate that, by nature, such paleoenvironmental records are discontinuous and correlation between areas must be demonstrated rather than taken as a given.

Other low-frequency environmental variables used at Black Mesa are the changes in effective moisture and the composition and elevational boundaries of plant communities (Hevly 1988). Hevly (1988) also presents a thorough review of prehistoric vegetation and paleoclimate for other portions of the Colorado Plateau and indicates that although pollen records have been obtained from numerous lacustrine environments, only a few have yielded data which are radiometrically or archaeologically dated within the last 2,000 years. He presents a selection of these in the three center panels of Figure 2-3, including data from Hay Hollow near the headwaters of the Little Colorado in east-central Arizona, Black Mesa, and Elden Pueblo near Flagstaff, north-central Arizona. Each of the samples has been plotted in such a way that "up" indicates greater effective moisture.

Before discussing this figure, some background information needs to be presented. Much of the pollen sampling in the Southwest has been done directly in archaeological sites or nearby sedimentary alluvial sequences. Samples from archaeological room floors and features, potentially datable within 25 years of the occupation of the room, are desirable. However, pollen spectra from archaeological sites may have been affected by such activities as tree clearance (e.g., Wyckoff 1977), local disturbance and subsequent invasion by weedy plant species, and intentional or incidental introduction of pollen into the sites from plants gathered elsewhere. Thus, these pollen spectra from archaeological sites may not represent an unbiased picture of the natural pollen rain. In addition, records constructed from archaeological pollen samples are, by their nature, discontinuous.

To overcome the possible biases that may be associated with pollen samples recovered from archaeological sites, researchers have used standard and adjusted pollen sums, ratios of arboreal to nonarboreal pollen, pine to juniper pollen, and large to small pine pollen to filter out the human effects and to reconstruct the natural vegetation surrounding the archaeological sites (e.g., Hevly 1981, 1988; Schoenwetter 1970). Climatic reconstruction is accomplished by comparing and contrasting the prehistoric pollen spectra or ratios to modern pollen spectra or ratios from an elevational transect through different vegetation types and their associated climates (Davis 1995).

Hevly (1988) also plots the spruce/pine pollen ratio from a continuous, radiocarbon-dated pollen record from Beef Pasture, La Plata Mountains, southwest Colorado (Beef Pasture is located in the La Plata drainage unit 5). Beef Pasture (3060 m elevation) is currently located within the spruce forest but near its lower elevational limit (top panel Figure 2-3). Modern surface pollen transects indicate that as one goes down the mountain, the ratio becomes smaller (Petersen 1988). Or, if conditions were to become drier, and the ponderosa pine forest followed the spruce forest retreat upslope, the ratio would also become smaller. In this figure, any value lower than a ratio of 0.60 indicates a drier condition than that of the present (Petersen 1988). The dotted line in the top panel of Figure 2-3 is the mean ratio for the last 2,800 years.
After developing this figure, Hevly (1988) concludes that despite the different pollen types that have been used at different localities, the long-term trend for the Colorado Plateau is amazingly similar over a large geographic area (see Figure 2-3). Because they were derived and dated independently suggests that they are truly reflecting a robust vegetational signal that is responding to long-term changes in climate.

As part of the Black Mesa work, the paleoenvironmental reconstruction from the high- and low-frequency records are then coupled with regional population trends for specific periods to specify periods of regional population-resource stress that should have elicited a behavioral response (Dean 1996; Dean et al. 1985; Plog et al. 1988). These researchers then use their high-resolution paleoenvironmental and archaeological data obtained from the Black Mesa region to provide the analytical control necessary for a specific local-level test of their model. Then the model is applied to a much larger area. They found that to provide adequate explanation for cultural change, equal consideration had to be given to the relationships among various high- and low-frequency environmental processes. Additional factors to be considered include the physiographic setting, the regional demographic situation, and the degree to which populations were approaching the carrying capacity. When the permutations are considered, the Puebloans probably had a complex suite of adaptive strategies that they employed differentially in response to a wide variety of discreet environmental and demographic situations. In contrast to Berry (1982), Dean et al. (1985) conclude that because of the complex interrelationships, it is not surprising that specific adaptive situations only rarely recurred throughout Puebloan prehistory (see also Dean 1996, Plog et al. 1988).

DAP Environmental Archaeology

Like the Black Mesa work, another thoroughly integrated archaeological project was undertaken by the DAP on the Dolores River in southwest Colorado in the late 1970s and early 1980s (Robinson et al. 1986). However, the scale of the DAP was much more massive than that of the Black Mesa (the DAP was one of the largest archeological in itigation projects ever carried out in the U.S.) and the many volumes of research results could fill a large shelf.

To facilitate interpretation of the DAP findings, a number of researchers in the DAP Environmental Archaeology Group developed a model of past climatic change and related it to physiographic and agricultural conditions in the DAP reservoir area (Petersen 1985a, 1985c, 1986, 1987a, 1987b, 1987c, 1987d, 1988, 1994b; Petersen and Clay 1987). The climatic model was based on non-DAP-supported studies begun by another student of Paul S. Martin, Peter J. Mehringer, Jr., in the early 1970s. These studies were subsequently taken over by Kenneth L. Petersen, one of Mehringer's students (Petersen 1981; Petersen and Mehringer 1976). Earlier, work by Mehringer et al. (1967) had demonstrated that pollen analysis of discontinuous alluvial sediments could be used to document an increase in summer precipitation even when other geologic evidence might suggest otherwise. The pollen analysis that was undertaken in the La Plata Mountains was an attempt to obtain a continuous and well-dated pollen record of climatic change that could be applied to archaeological questions in the Four Corners region.

The model developed for the DAP by Petersen and colleagues (Petersen 1985a, 1985c, 1986, 1987a, 1987b, 1987c, 1987d, 1988, 1994b; Petersen and Clay 1987) included palynological data from two bogs (Beef Pasture and Twin Lakes—located in the La Plata drainage unit) at different elevations within the spruce forest of the La Plata Mountains (which falls within the Dolores, La Plata, and Animas drainage units) and tree-ring data from several areas of the Four
the DAP area from a dated but discontinuous record from a Marsh (located in the Dolores drainage unit), which allowed a local calibration of the data obtained from the La Plata Mountains. Using these data, Petersen and colleaguesconstructed relative measures for annual precipitation (primarily jet-stream derived), summer Station (primarily monsoon derived), and summer warmth, as well as the effects of topography on cold-air pooling. Based on these, and taking into account elevation, aspect, curvature, and cold-air drainage, Petersen (1987a, 1988, 1994b) proposed that for the period from A.D. 500 through 1300, there were episodic changes in the width and elevation of the “dry-belt” (today, located between 2000 m and 2300 m elevation in the DAP area). Using the on the frequency of droughts and short summers enabled measures of agricultural costs and ses to be derived (Orcutt 1986, 1987; Kohler et al. 1986).

The DAP model of environmental and subsistence potential showed generally good agreement with estimates of project area populations and settlements (Schlanger 1986, 1988). The sixth and ninth centuries in particular showed declines in annual precipitation that would have ade the high elevation environment of the Dolores Valley (in the Dolores drainage unit) active for farmers who would have had less favorable results from farming at lower elevation in their parts of southwest Colorado in the very late A.D. 800s and early 900s. This narrowed farm belt, coupled with the probably short growing seasons in the early 900s, may have contributed to a push” for abandonment or near-abandonment of the McPhee Reservoir area at that time (Petersen 1988, 1994b) as well as to the regional abandonment described above (Wilshusen and Ortman 1999).

Push and Pull Factors

In any given case, it is almost certain that a combination of factors was involved in population settlements and abandonments. There must almost certainly be a reason to leave one area as well as a reason to go somewhere else, called informally “push-pull” motivation, and exemplified in this presentation as unfavorable and favorable climatic conditions affecting the ability to farm maize. Even then, cultural and political (or other environmental factors) may have further influence. Schlanger (1988) examined population movements along the great slope between the DAP (high elevation and to the east) through Woods Canyon to Mockingbird Mesa (low and to the west) (Woods Canyon and Mockingbird Mesa are located in the Monument-McElmo drainage unit). Schlanger (1988) found that Petersen’s (1988) changing dry-farm belt model was adequate to explain population movements for certain periods but not others. For example, in Schlanger's (1988:756) period 7.4 (A.D. 1175 - 1250; Pueblo III), the extended drought evidenced in the tree-ring record from the Mesa Verde and the DAP (Petersen 1986:Figure 4.19) rendered her entire area unsuitable for rainfall farming except on the highest eastern mesas where cold temperatures would then limit growing season length. Yet Mockingbird Mesa and Woods Canyon showed their highest population levels at this time (Schlanger 1988:786), though the higher DAP area had been abandoned. Woods Canyon and Mockingbird Mesa are low-elevation uplands that adjoin headwater segments of large flood plains. Schlanger (1988) suggests that the agriculture intensification strategies described by Winter (1976, 1977) for the Hovenweep area were likely utilized at Woods Canyon and Mockingbird Mesa at this time. This entailed a shifted from rainfall-dependent upland farming to farming the adjoining flood water drainages. Force and Howell (1997) draw the very same conclusion of a likely shift in farming strategy during Pueblo III times based on their work in McElmo Canyon.
As discussed, although unfavorable climatic factors may provide a "push" for population settlements and abandonments, even larger "pull" factors may have been involved in population dislocation at various times (Lipe 1986, 1995; E. Adams 1991). For instance, Van West (1994a) does a marvelous job of converting tree-ring indices into a paleoproduction model encompassing a 1,816 km$^2$ area of southwestern Colorado within the Monument-McElmo drainage unit to examine the potential effects of past climatic variation on dry-land maize agriculture and sustainable population during the period A.D. 901-1300. Based on her results, Van West (1994a) concludes that after A.D. 900 climatic variability was never severe enough to totally disrupt agriculture and hasten abandonment of the area. Because all of her area was abandoned by A.D. 1300, it can be surmised that attractive "pull" factors from other areas may have contributed to abandonment and should be examined further (e.g., Ahlstrom et al. 1995; Lipe 1995).

**Medieval Warm Period and Little Ice Age**

As mentioned, Petersen (1988, 1994b) interprets an integrated record of tree-ring and pollen analyses from a number of sites in the La Plata Mountains, the DAP area, and elsewhere as showing changes in summer temperature and the monsoonal-wind systems strength in the Colorado Plateau during the last 2,000 years. However, he also interprets his record as showing that the fluorescence of Puebloan occupation coincides with the Medieval Warm period (approximately A.D. 800-1200; Hughes and Diaz 1994) and that final regional abandonment coincides with the onset of the Little Ice Age (approximately A.D. 1250-1850; Porter 1986). A discussion of these findings follows.

Petersen (1988, 1994b) reconstructs the strength of the summer monsoon in southwest Colorado from the inferred changes in the areal distribution of pinyon pine as reflected by the annual numbers of pinyon pine pollen grains wafted up to the Beef Pasture pollen site and deposited on a 1 cm square area. Using modern analogies and calibration, Petersen (1985c, 1988, 1994b) argues that pinyon seedling establishment is a good proxy of monsoon strength. Davis (1994, 1996) concludes from pollen analysis of other sites within the monsoon boundary (see Figure 2-2), such as Peck Lake, in central Arizona (see Figure 2-4), that there was an increase in lake levels from A.D. 700 to 1350, thereby suggesting supporting Petersen's (1988, 1994b) contention that summer precipitation during the Medieval Warm period was much higher than that of the subsequent Little Ice Age.

As presented here, the Little Ice Age is a period characterized by lower summer temperatures and reduced summer monsoon strength than the preceding Medieval Warm period. Based on the pollen evidence shown in Figure 2-4, during the Little Ice Age monsoon rains arrived later in the early summer, did not penetrate as far north, and left earlier in the fall than those of today. Using annually dated ice cores from the Antarctic and also central Greenland, Kreutz et al. (1997) also found that a major difference between the Medieval Warm period and the subsequent Little Ice Age was a fundamental difference in global atmospheric circulation patterns—the Little Ice Age was characterized by increased meridional circulation intensity variability. For an expanded discussion of the characteristics and timing of the Medieval Warm period and Little Ice Age in the western U.S., see Porter (1986), Petersen (1988, 1994b), and Grove and Switsur (1994). It was not until the close of the Little Ice Age (after 1850 in the western U.S.) that continental heating again increased, the monsoon system could again take on its modern character of warmer and wetter summers in the Colorado Plateau (see Figure 2-4), and farmers (this time modern Anglos) could again farm the DAP area.
Figure 2-4. Climatic reconstruction of the southwest U.S. for the Medieval Warm period (after Davis 1996:Figure 12-5). Beef Pasture and Pecks Lake indicate greater summer precipitation and higher lake levels during the Medieval Warm period, suggesting strengthened monsoonal precipitation.
Paleoenvironmental Studies at Chaco Canyon

Besides Black Mesa and the DAP, another region that has had many paleoenvironmental studies undertaken is that of Chaco Canyon, northwest New Mexico (Betancourt 1984; Betancourt and Van Devender 1981; Betancourt et al. 1983; Betancourt et al. 1986; D'Arrigo and Jacoby 1991; Fredlund 1984; Fredlund and Johnson 1984; S. A. Hall 1977, 1980, 1983, 1985b; Mathein 1985; Samuels and Betancourt 1982; Schoenwetter 1967; Wright et al. 1973). As shown in Figure 2-3, the pollen record for the Chuska Valley (Schoenwetter 1967) seems to reflect what has been found in other regions. However, a number of other climatic studies do not seem to match that presented here. For instance, Hall (1977, 1985b) uses changes in pine pollen frequencies and taxa in the discontinuous alluvial record of Chaco Canyon to reconstruct climatic change in an area that is now modern pinyon and juniper woodland. Hall (1977) concludes that conditions during Puebloan occupation in the canyon were more arid than that of today and that the pinyon woodland on Chacra Mesa may have been less than one-half as extensive as that of today. After this arid period during the Puebloan occupation, there was a large expansion of pinyon cover to almost that of the modern range between 860 and 600 years ago. Hall’s period of pinyon expansion falls within the Little Ice Age. Using the dating scale for Pecks Lake in Figure 2-4, the interpretation by Hall (1977, 1985b) is exactly 180 degrees out of phase with that of Petersen (1988, 1994b), who reconstruct a reduction of pinyon cover in the Four Corners region during the Little Ice Age. Elsewhere, Petersen (1981:157-161) attempts to reconcile the differences between the discontinuous Chaco Canyon alluvial record of pinyon and the continuous pollen record from the La Plata Mountains by suggesting that Hall’s (1977:Figure 9) Post Bonito Fill unit from Gallo Wash I (with its relatively high pine content and high concentrations of Zea pollen) may have been incorrectly dated. The deposition of maize pollen into sediments for hundreds of years after regional abandonment does not seem very likely, while deposition of maize pollen during Puebloan occupation does seem much more likely.

Betancourt and Van Devender (1981) use plant macro-fossils in a well-dated series of fossil packrat (Neotoma) middens to reconstruct past vegetation below 1950 m on the north, xeric side of Chaco Canyon. The midden record is, by its very nature, a periodic sampling of local vegetation at discrete periods of time. The composition of the local vegetation between the dated midden samples is then extrapolated. Using these samples, Betancourt and Van Devender (1981) conclude that there had been a persistence of pinyon-juniper woodland for at least 5,500 years prior to their last midden containing pinyon (dated at about A.D. 720). The next midden is dated at about A.D. 1490 and contains no pinyon remains. They suggest that the lack of pinyon in their youngest midden is best explained by the fuel needs of the resident population, which overtaxed the local stands of pinyon and juniper to the point that they were never able to recover. Samuels and Betancourt (1982) use computer simulation to show that such a scenario is possible. However, examination of Figure 2-4 suggests that the midden sample intervals at A.D. 720 and again at A.D. 1490 likely missed the expansion of pinyon during the Medieval Warm period caused by the increase in monsoonal rain. The lack of pinyon in the youngest packrat midden is more congruent with Petersen’s characterization of the Little Ice Age as a time of reduced pinyon cover owing to reduced summer monsoons. Also, the lack of pinyon in the A.D. 1490 sample may not support Hall’s reconstruction of a pinyon cover in the region during the Little Ice Age as equivalent to that of modern times.
Late Pleistocene and Holocene Climate of the Four Corners Region

Figure 2-5 depicts a present-day elevational distribution of vegetation, temperature, and precipitation in the Four Corners region (Waugh and Petersen 1995). Assuming some consistency of vegetational and climatic interactions, evidence of past changes in the distribution of plants preserved along the elevational gradient is the basis for reconstructing past climates. Temperature and precipitation curves were derived from meteorological data compiled by Petersen (1987f) for 12 sites located between 1300 m and 2700 m elevation in southwestern Colorado and southeastern Utah. The generalized plant species distribution curves are based on numerous sources (Arno and Hammerly 1984; Betancourt et al. 1990; Hevly 1988; Maher 1961; Petersen 1987f, 1988). Lower limits of plants are generally considered to be set by moisture deficiencies and upper limits by low temperature. Table 2-8 presents the types of proxy data, dates, and references for the paleoclimatic data of sites presented here. Figure 2-6 is a map that includes the locations shown in Table 2-8.

The records in Table 2-8 indicate that plant distribution in the Four Corners region shifted hundreds of meters in elevation since the Late Pleistocene (nominally considered here as the period from 40,000 to 13,000 years before present [B.P.]) up through the present in response to fluctuations from subhumid to arid climates (Figure 2-7). Presented here is a brief discussion of the reconstruction of vegetation and climate for the Four Corners region beginning in the Late Pleistocene (see also Petersen 1994a), through the post-glaciation period (13,000 to 10,500 years ago), and the Holocene (the last 10,500 years). For a more comprehensive discussion of climatic change during the last 15,000 years or so, see Fall (1997).

The records from 18,000 B.P. to the present are well constrained by radiocarbon dates. These paleorecords reflect long-term shifts in vegetation and not the high variability that exists in meteorological (Nielsen 1986) and tree-ring records (Dean 1988). Records of past climatic change in the Four Corners region provide working limits for ranges of temperature and precipitation. For example, the modern vegetation at Monticello, Utah, (2135 m elevation; see Figure 2-6) is scrub oak with pinyon-juniper on southern exposures and ponderosa pine on northern exposures (see Figure 2-5). Present mean annual temperature and precipitation are 8°C and 38 cm (46°F and 15 in.) respectively (see Figure 2-5). During the Late Pleistocene, subalpine forests dominated vast areas now occupied by the pinyon-juniper woodland (see Figure 2-7). This predominance of cold-tolerant species, downward expansion of subalpine trees, and the apparent absence of warm-season species reflect a much wetter and colder climate than that of today (Lao and Benson 1988; Thompson 1990). The Laurentide ice sheet, thrust up into the lower atmosphere, may have split the jet stream into two branches with the southern branch forced south across northern California, Nevada, Utah, and Colorado (Cooperative Holocene Mapping Project [COHMAP] Members 1988), resulting in long wet winters, cool summers, and an essentially nonexistent summer monsoon in the Four Corners region. On the basis of a synthesis of Late Pleistocene paleorecords, Waugh and Petersen (1995) set working-level values of mean annual temperature at 2°C (36°F) and precipitation at 80 cm (32 in.) for Monticello.

Paleoclimatic data from Table 2-8 sources record a post-glaciation climate (13,000 to 10,500 B.P.) that continued wetter but warmer, with the upper plant limit moving upslope, but little change in lower plant limits (see Figure 2-7). Conditions of global warming increased the moisture holding capacity of Pacific air masses; however, the jet stream continued tracking south of the slowly retreating continental ice (Ruddiman and Wright 1987), sustaining wet winters in the Great Basin and Colorado Plateau. By the early Holocene (approximately 10,000 B.P.), the Four Corners climate was significantly warmer and drier than previously, although seasonal patterns of
wet winters and dry summers persisted. A shift toward a more modern summer monsoonal climate was delayed until the ice sheet retreated into northeast Canada.

Table 2-8. Proxy data sources, dates, and references for paleoclimatic sites used to reconstruct climate of the Four Corners region.

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<th>Reference</th>
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<td>Pollen</td>
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<td>Wright et al. 1973</td>
</tr>
<tr>
<td>Fishmouth Cave</td>
<td>Packrat middens</td>
<td>13,800 B.P. to present</td>
<td>Betancourt et al. 1990</td>
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<tr>
<td>Cowboy Cave</td>
<td>Packrat middens, pollen, and plant macrofossils</td>
<td>13,000 B.P. to present</td>
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<td>Chaco Canyon</td>
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<tr>
<td>Allen Canyon Cave</td>
<td>Packrat middens</td>
<td>11,300 B.P. to present</td>
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<td>Duck Lake</td>
<td>Pollen</td>
<td>Late Pleistocene</td>
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</tr>
<tr>
<td>Bridger Jack Mesa</td>
<td><em>Pinus edulis</em> dendro-chronology</td>
<td>500-yr record</td>
<td>Van Pelt 1978</td>
</tr>
<tr>
<td>Beef Pasture</td>
<td>Pollen</td>
<td>6,000 B.P. to present</td>
<td>Petersen 1988</td>
</tr>
<tr>
<td>Twin Lakes</td>
<td>Pollen</td>
<td>10,000 B.P. to present</td>
<td>Petersen 1988</td>
</tr>
<tr>
<td>Molas Lake, San Juan Mountains</td>
<td>Pollen</td>
<td>16,000 B.P. to present</td>
<td>Maher 1961</td>
</tr>
<tr>
<td>San Juan Mountains Timberline</td>
<td>Macrofossils and pollen in timberline bogs</td>
<td>10,000 B.P. to present</td>
<td>Carrara et al. 1991</td>
</tr>
<tr>
<td>Sagehen Marsh</td>
<td>Pollen</td>
<td>5,000 B.P. to present</td>
<td>Petersen 1985b</td>
</tr>
<tr>
<td>Navajo Reservoir</td>
<td>Pollen</td>
<td>2,000 B.P. to present</td>
<td>Schoenwetter 1966</td>
</tr>
<tr>
<td>Chuska Valley</td>
<td>Pollen</td>
<td>2,000 B.P. to present</td>
<td>Schoenwetter 1967</td>
</tr>
<tr>
<td>Pecks Lake</td>
<td>Pollen</td>
<td>1,800 B.P. to present</td>
<td>Davis 1996</td>
</tr>
<tr>
<td>Hay Hollow</td>
<td>Pollen</td>
<td>2,000 B.P. to present</td>
<td>Hevly 1988</td>
</tr>
<tr>
<td>Black Mesa</td>
<td>Pollen</td>
<td>2,000 B.P. to present</td>
<td>Hevly 1988</td>
</tr>
</tbody>
</table>
Figure 2-5. Elevational distribution of present-day vegetation, mean annual temperature, mean annual precipitation, and paleoclimate sites in the Four Corners region. Monticello, Utah is shown as an example (after Waugh and Petersen 1995:Figure 5).
Figure 2-6. Map of sites with paleoclimatic data in the Four Corners region (after Waugh and Petersen 1995:Figure 6).
Figure 2-7. Generalized late Pleistocene and Holocene shifts in forest boundaries in the Four Corners region (north is to the right). The present lower extent of pinyon pine, a late Holocene newcomer, is marked with a dashed line (after Waugh and Petersen 1995:Figure 7).
The middle Holocene (8000 to 4000 B.P.) was warmer and wetter than today—approximately 10°C (50°F) and 60 cm (24 in.) precipitation at Monticello (see Figure 2-7). The packrat midden record of vegetative change reflects cold and relatively dry winters, an increase in both summer and annual temperatures, a shift to monsoon-dominated summers, and greater effective moisture than at present (Betancourt 1984; Betancourt and Biggard 1985). Upper treeline was at least 80 m to as much as 140 m higher than at present (Carrara et al. 1991).

The middle Holocene period, also known as the Altithermal, has most often been characterized as being warmer and drier than the present. For instance, Hall (1985b) concludes from his survey of the literature and his pollen work in Chaco Canyon that it was very hot and dry in the western U.S. during this period and that Martin (1963) and Mehringer et al. (1967) were in error in proposing that there was increased monsoonal activity in the western U.S. during mid-Holocene times. Hall's conclusion is counter to that presented here (and shown in Figure 2-7) and that presented by Fall (1997). The North American monsoon is essentially a giant sea breeze laden with moisture and drawn inland by the heating and rise of air above the highlands of western North America including Mexico (Adams and Comrie 1997). Thus, the greater the heating of the western continental highlands (such as during the middle Holocene), the stronger the monsoon in the Southwest. As discussed above, one possible reason for the discrepancy is that discontinuous pollen records such as those based on archaeological or alluvial sequences may be hampered by missing portions of the record and dating problems.

After 4000 B.P., the paleoclimatic record for the Four Corners region become a little more complicated. By about 3500 B.P., tree line had dropped to near its present elevation and by 2800 B.P., the lower limit of the spruce forest had retreated upslope to its present elevation. All forest boundary changes after these times are minor compared to those of the earlier periods but were enough to be interpreted as indicating critical differences in the extent of the dry-farming belt in the Four Corners region as discussed above.

Finally, it should be noted that pinyon is a relatively newcomer in the Four Corners region. Betancourt and Van Devender (1984) and Van Devender et al. (1984) indicate that at 11,000 B.P., pinyon began its northward expansion from its late Pleistocene refugia in the northern Chihuahuan Desert and arrived in Chaco Canyon between 10,000 and 8,000 B.P. However, it does not seem to have expanded north into eastern Utah and western Colorado until mostly after 4500 B.P., although it may have arrived in central Nevada as early as 6200 B.P. (see Petersen 1985c, 1988 for reviews). As discussed, once pinyon arrived it seems to provide a good proxy for the strength of the summer monsoon in the Four Corners region with major expansions during Pueblo occupation and during the last 150 years (see Figure 2-4).

Conclusion

Climate in the Four Corners region is complex, and general patterns are linked to much larger global weather systems and even a longer geologic history. A brief look at climatic conditions from the late Pleistocene (Petersen 1994a) through the present (Waugh and Petersen 1995) suggests that the Four Corners region has been subject to significant climatic changes. Such changes would have affected resources available to prehistoric peoples (for instance the availability of pinyon nuts). With the arrival of maize horticulture in the region, a different suite of climatic parameters became important to the inhabitants. Currently (and during Puebloan occupation) the region is near the northern and upper elevational limits of where rainfall farming of maize can take place.
Proxy record suggest that ideal growing conditions have fluctuated in the past and these fluctuations undoubtedly affected where farming could be practiced and, ultimately, if it could be undertaken at all. As more proxy climate data become available, the interpretations presented here may have to be revised (for instance, Matt Salzer of the University of Arizona Tree-Ring Laboratory has been analyzing a 2,000-year, high-elevation bristlecone pine chronology from the San Francisco Peaks near Flagstaff, Arizona, that will soon be available).* At present however, it appears that the Medieval Warm period and the Little Ice Age were key elements in the Puebloan ability to dry-farm maize in the Four Corners region and the inherent climatic characteristics of each period may have produced environmental gradients of the proper proportions to contribute to population movements within the region and ultimately to the complete abandonment of the northern San Juan River drainage (units 1-5) in the thirteenth and fourteenth centuries (Petersen 1996).


[This presents summer temperature reconstruction from high elevation bristlecone pine tree-rings from the San Francisco Peaks, northern Arizona, that show a coincidence of a period of cool summers and abandonment of high elevation farming areas].
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