Alliance and Landscape on Perry Mesa in the Fourteenth Century

edited by

David R. Abbott
and Katherine A. Spielmann

The University of Utah Press
Salt Lake City

CHAPTER 2

Climatic, Demographic, and Environmental Influences on Central Arizona Settlement Patterns

Scott E. Ingram

This chapter addresses two distinct but related research questions. First, why did so many people move to Perry Mesa during the late thirteenth and early fourteenth centuries? Second, what factors influenced the formation of settlement clusters and unoccupied zones around Perry Mesa? I approach these questions from a landscape perspective (see Chapter 1), considering regional-scale climatic, environmental, and demographic influences on settlement patterns on and around Perry Mesa.

It is important to investigate these settlement patterns because they are an integral part of the Verde Confederacy model, a prominent case study of endemic warfare and alliance formation in the late prehistoric Southwest (Wilcox 2005; Wilcox et al. 2001b). Settlement patterns are the "clearest and strongest" indirect evidence used to infer prehistoric warfare in the Southwest (LeBlanc 1999:43–44). Thus, investigating factors influencing settlement patterns will advance our understanding of the settlement of Perry Mesa as well as the events of this critical period in prehistory.

The purpose of this research is not to challenge the Verde Confederacy model or to argue for the absence of warfare and alliances. Evidence of climatic, demographic, and environmental influences on settlement patterns does not preclude a coincident rise in warfare or the formation of alliances. Multiple models and working hypotheses of factors that influenced the settlement patterns of Perry Mesa and the rest of central Arizona are essential. Results from testing these models and hypotheses advance our understanding of the influence of warfare, demography, climate, and environment on human behavior.

To understand why so many people moved to Perry Mesa, I investigated regional-scale climatic, demographic, and environmental conditions that likely "pushed" and "pulled" people to Perry Mesa. I focus on regional-scale conditions because the pulse of settlement on Perry Mesa was coincident with unprecedented settlement and social changes occurring throughout the U.S. Southwest. Most important, population increases on Perry Mesa were not unique but part of a massive influx of immigrants moving from northeastern Arizona toward central Arizona during the late 1200s and early 1300s. I argue that dry-period declines in resource productivity contributed to the push out of northeastern Arizona and that the arrival of these immigrants contributed to the reorganization of existing settlement patterns in central Arizona. I demonstrate the relative demographic and environmental attractiveness of Perry Mesa and the rest of central Arizona for arriving immigrants or local residents displaced by these immigrants. I do not, however, discuss the specific origins of the people on Perry Mesa. I also identify unprecedented wet conditions and a hiatus in dry conditions during the early 1300s that could have further stimulated and contributed to population growth on Perry Mesa.

To understand the formation of settlement clusters and unoccupied zones coincident with population increases in central Arizona, I investigate inherent differences in potential resource productivity on and around Perry Mesa. These investigations document lower productivity in the unoccupied zones than in locations where settlements were clustered. Movement from areas of lower to higher productivity is one potential response to climatic dry periods. Thus, these inherent environmental differences likely contributed to the formation of settlement clusters and unoccupied zones.

This chapter establishes an interpretation of settlement patterns on and around Perry Mesa that does not invoke the influence of increasing warfare, the formation of political alliances, or a strategy of defense or offense against hostile neighbors. The identification of regional-scale influences also suggests that factors affecting Perry Mesa settlement patterns were not confined to local-scale conditions, including local feuding or retaliation for endemic raiding (cf. Rice 2001; Wilcox et al. 2001a, 2001b; Wilcox and Holmlund 2007). These findings demonstrate that the settlement patterns on and around Perry Mesa that have been used to support models of warfare in the region can also be explained by population movements in response to changes in climatic conditions and inherent differences in resource productivity across the landscape.

I begin by delineating the spatial boundaries of northeastern and central Arizona and its watersheds, which form the primary analytical units of this chapter. After explaining the research design, data, and methods of this study, I address the question of why so many people moved to Perry Mesa. Next I consider factors that influenced the formation of settlement clusters and unoccupied zones. I conclude by discussing the implications of the study.

Study Area

The study area for this research includes central and northeastern Arizona (Figure 2.1) to accommodate the likely source areas for populations that migrated into central Arizona in the late thirteenth and early fourteenth centuries. Wilcox and Holmlund (2007:38) argue that to demonstrate "that the reason Perry Mesa was selected in the middle 1200s for occupation was environmentally driven, providing superior agricultural potentials (Kruse 2005), research would be needed on alternative areas to establish that the contrast really existed." A regional-scale study area allows these alternative areas and contrasts to be identified and evaluated.[1]

Watersheds are the primary analytical spatial unit used in this analysis. A watershed is an area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel (Dunne and Leopold 1978). Watersheds are also referred to as drainage basins or catchment areas, and they occur at multiple scales. Perry Mesa is located within the Agua Fria watershed whereas the proposed Verde Confederacy is contained within the Agua Fria, Upper Verde, and Lower Verde watersheds. The Verde watersheds include the area referred to as the "middle Verde Valley" throughout this book.

This analysis uses the smallest watershed units ("cataloging units" or "sub-basins") identified by the U.S. Geological Service (Seaber et al. 1987). Watersheds are used as an organizing spatial unit of analysis because there is some homogeneity of climatic and resource conditions within each watershed. Watersheds also delineate a reasonable spatial boundary that may approximate actual resource acquisition zones.

Research Design, Data, and Methods

This section provides the rationale for adopting a regional-scale approach and describes the demographic, environmental, and climatic conditions I consider and the data used to identify these conditions.

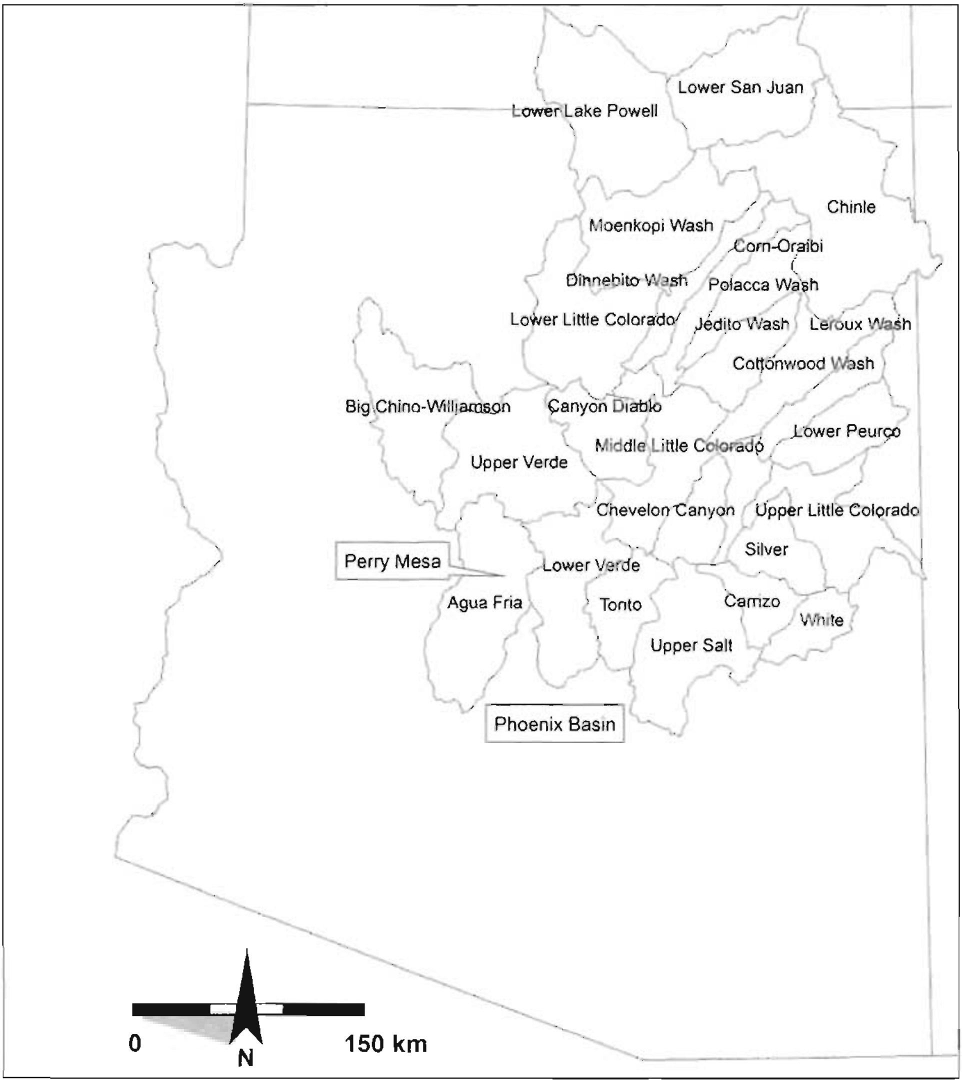

FIGURE 2.1. Central and northeastern Arizona study area watersheds. Watershed boundaries ("cataloging units") adapted from data available from the USGS (Steeves and Nebert 1994).

Regional-Scale Approaches

I use a regional-scale approach to understand why people moved to Perry Mesa because the pulse of settlement on the mesa was coincident with dramatic settlement and social changes occurring throughout the Southwest (Cordell 1997:365–441). Settlement changes include the depopulation of the northern Southwest, population increases in central Arizona, and settlement aggregation in central and southern Arizona (Ciolek-Torrello 1997; Hill et al. 2004; Stark et al. 1995; Wallace and Doelle 2001; Wilcox et al. 2001b; Wilcox et al. 2007). Social changes include a reorganized and reduced Hohokam interaction sphere (Bayman 2001:280–283; Doyel 2000; Gumerman 1991), the flourishing of new religious forms (Crown 1994), and increasing competition and conflict (LeBlanc 1999; Wilcox and Haas 1994). It is reasonable to expect that these settlement and social changes had some effect on the settlement patterns of Perry Mesa and the rest of central Arizona.

Regional-scale approaches are receiving increasing attention in the U.S. Southwest (e.g., Hegmon 2000; Hill et al. 2004; LeBlanc 1999; Varien et al. 2007; Wilcox et al. 2001b, 2007) as spatially comprehensive archaeological datasets become available and demonstration of their interpretive value increases. For example, in a recent study of population dynamics and historical ecology in the Mesa Verde region, Varien and colleagues (2007:293) find that the scale of the effective environment that Pueblo people were responding to was much larger than their 1,917-km² study area. Similarly, I assume that the factors influencing movement into the Perry Mesa area exceed what can be explained by local-scale studies. Thus, to understand the settlement of Perry Mesa, we consider the larger context in which this settlement occurred.

My approach is inspired by and similar to the work of Ahlstrom, Van West, and Dean (1995) and their study of factors motivating migration from the Mesa Verde region to the Northern Rio Grande region in the late thirteenth century. Ahlstrom and colleagues (1995:125) argue, "Considerable evidence exists for an environmental gradient having the proper magnitude, direction, slope, timing, and location to help explain population movement from the Mesa Verde region to the Northern Rio Grande." They also argue for the strong role of sociocultural factors in the migration. My efforts in this chapter are to establish a similar environmental gradient toward central Arizona, including Perry Mesa. Establishing this gradient and the influence of regional-scale conditions expands our focus beyond current approaches that emphasize the potential for violent and local-scale origins of the Perry Mesa settlement patterns.

Demographic Conditions

The primary demographic process I examine is population movement. Population movements are most likely to occur when there are push factors at the population origin and pull factors at the population destination and when the costs of movement between the two are acceptable (Anthony 1990; Herberle 1938; Lee 1966). Push factors (stresses) at the point of origin can include a poor economy or overpopulation, and pull factors (attractions) at the destination can include improved economic conditions or social advantages (Anthony 1990; Cameron 1995:111). The push factors considered here are dry periods that decrease resource productivity and increase the risk of resource shortfalls and the disruptive influence of a massive influx of immigrants into central Arizona. The pull factors considered are areas of low population density and environmental and climatic conditions that increase potential resource productivity. The "push-pull" concept for archaeological research is well articulated by Cameron (1995) and has been effectively applied by Ahlstrom et al. (1995) and Lipe (1995).

Population movement in the study area is identified by calculating compound annual population growth rates (CAGR) by watershed during the 1250 to 1299 and 1300 to 1349 intervals. The CAGR describes population change as a constant percentage each year (Hassan 1981: 140; Kintigh et al. 2004:440). The formula is CAGR = $(p2/p1)^{1/n} - 1$. In this study, $p2$ and $p1$ are the number of identified rooms in the 1300 to 1349 interval and in the 1250 to 1299 interval, respectively, and n is the number of years in the interval. Growth rates in excess of 0.7 percent exceed what can be expected from changes in fertility and mortality (Cowgill 1975), and thus in-migration is strongly implicated.

Settlement data to calculate growth rates came from the Coalescent Communities Database (Wilcox et al. 2003; see Wilcox et al. 2007 for a description of the development of the database). This database is the most comprehensive source of settlement data available for the study area. It has recently been employed in several studies with implications for the extent of warfare, alliances, and population decline in the U.S. Southwest (Hill et al. 2004; Wilcox et al. 2001a, 2001b; Wilcox et al. 2007). Wilcox and colleagues (2001a, 2001b) used the same database to detect the settlement patterns used to infer the Verde Confederacy. I follow Hill et al. (2004:693) and the Coalescent Communities Database authors (Wilcox et al. 2003) and consider only settlements with at least 13 rooms.

Data on settlements with fewer than 13 rooms are less complete and less reliable due to lower surface visibility and detection. The 50-year intervals (1200 to 1249 and 1300 to 1349) used to identify population movements are based on the strengths of the data and the realities of chronological resolution in the region (Hill et al. 2004).

In addition to changing demographic conditions created by population movements, differences in population density are considered at the watershed scale. Population density affects the demand for resources; more people consume more resources and increase the rate of resource consumption in a given area. I assume that low-density areas were more attractive areas for settlement than high-density areas if potential productivity among alternatives was similar. Low-density areas offer fewer constraints on resource acquisition and mobility (e.g., Varien et al. 1996) and may result in less competition for resources. Differences in population density are identified by summing the number of rooms occupied during a 50-year interval and dividing the total by the number of square kilometers in each watershed. The result is the rooms per square kilometer. The Coalescent Communities Database is used to identify the number of rooms occupied in each watershed.

Environmental Conditions

The environmental conditions I consider are inherent differences in resource productivity across the landscape and natural geographic features that influence the extent of arable land and its associated productivity. Long-term precipitation levels across the region are used to identify inherent differences in resource productivity. Precipitation levels are linked to resource productivity through the effects of water on plant and animal growth. Resources are defined as the plant (wild and cultivated) and animal foods necessary to meet food needs and social obligations (after Hegmon 1989). Precipitation affects resource productivity because plant growth requires water and excesses or deficiencies may stress a plant and affect its growth and productivity (Levitt 1980; Muenchrath and Salvador 1995:309–310). Animals that rely on plant foods are also affected by changes in precipitation that influence plant growth (Bright and Hervert 2005). Water deficits are a common production constraint in the Southwest, where precipitation levels are below the moisture requirements of most crops (Muenchrath and Salvador 1995). Other factors, such as soil type and quality (e.g., Sandor et al. 2007) and temperature, affect resource productivity but are beyond the scope of this study given the extent of the spatial area considered.

I use the PRISM (Parameter-Elevation Regressions on Independent Slopes Model) climate mapping system to identify average annual precipitation throughout the study area (PRISM Climate Group 2007). The averages are calculated from 1961 to 1990 and are considered a "climatic normal" (National Climate Data Center 2010). PRISM incorporates instrumental point data, a digital elevation model, and expert knowledge of complex climatic extremes, including rain shadows and temperature inversions (Daly et al. 1994). The model provides the U.S. Department of Agriculture's official climatological data and is recognized as offering the highest-quality climate data available (PRISM Climate Group 2010); tree-ring data cannot capture spatial differences in precipitation at the same level of resolution. Differences in precipitation levels establish inherent and relatively constant differences in potential productivity between settlement areas.

Three natural geographic features are considered here: (1) perennial rivers that could have enhanced potential resource productivity, (2) areas with relatively short growing seasons that would have challenged successful farming, and (3) areas with sloping land that would have limited the extent of arable land and decreased potential productivity. Current and historic perennial rivers and portions of rivers identified to be perennial have been determined by an assessment conducted by The Nature Conservancy (2006). The Conservancy's project synthesized and updated previous and similar maps and work by Brown et al. (1977, 1981) for the Arizona Game and Fish Department and the U.S. Forest Service and by Miller (1954). It is possible that modern diversions and groundwater extractions have decreased the extent of perennial resources; however, the perennial resources identified were certainly flowing in the past. I use the Conservancy's assessment and data in combination with the Coalescent Communities Database to identify settlements adjacent to the perennial portions of rivers in the study area. Growing season durations are identified using modern climatic data (Western Regional Climate Center 2010). I identify the slopes of land with GIS analysis of a digital elevation model.

Climatic Conditions

Two climatic conditions are considered: (1) dry periods that decrease productivity and (2) wet periods that increase productivity. Dry periods are assumed to increase the real or perceived risk of resource shortfalls. Wet periods are assumed to decrease these risks. Resource shortfalls occur when there is not enough food to eat and a behavioral response is necessary to manage this risk. Risk has been defined and used in a number of ways (e.g., Cashdan 1990; Tainter and Tainter 1996) but is generally understood as the probability of a loss (Cashdan 1985; Wiessner 1982; Winterhalder 1986) or negative consequence (such as a shortfall) multiplied by the magnitude of the consequence. These risks can be real or perceived; human perceptions of changing conditions and associated risks may differ from actual changes in conditions (Burton et al. 1993; Ortiz 1979; Whyte 1985).

To manage the real or perceived risk of resource shortfalls, people employ a wide range of strategies, including mobility, resource diversification, physical storage, and exchange (Braun and Plog 1982; Burns 1983; Dean 2006; Halstead and O'Shea 1989:3–4; Minnis 1985; Rautman 1993; Slatter 1979:80, 84). These strategies can address shortfall risks by increasing resources or access to resources. The focus of this analysis is on population movement as a possible response to the real or perceived risk of shortfalls; people can move away from areas of food scarcity and low productivity to areas of higher productivity (Halstead and O'Shea 1989). In the U.S. Southwest, population movements and the settlement pattern changes they produced have been closely examined and correlated at some places and times with changes in climate conditions, especially multi-year dry periods (e.g., Ahlstrom et al. 1995; Adams 1998; Cordell 1975; Cordell et al. 2007; Dean et al. 1985; Euler et al. 1979; Gumerman 1988; Judge 1989; Lipe 1995; Minnis 1985; Orcutt 1991; Schlanger 1988; Van West and Dean 2000). Climatic conditions are not the only factor that affects the risks of shortfall. Decisions to move from one place to another are not solely influenced by climate and resource productivity considerations (e.g., Cameron 1995). Nevertheless, previous research has demonstrated that population movement is an effective strategy for lessening climate-related resource shortfalls (Halstead and O'Shea 1989), and ample ethnohistoric evidence in the region documents movement in response to resource shortfalls (Slatter 1979).

I use the San Francisco Peaks (SFP) tree-ring precipitation reconstruction to represent precipitation conditions in central Arizona and on Perry Mesa. Three tree-ring chronologies were used by Salzer (2000) and Salzer and Kipfmueller (2005) to develop the reconstruction: Flagstaff, Navajo Mountain, and Canyon de Chelly. These chronologies were originally developed as a part of the Southwest Paleoclimate Project (Dean and Robinson 1978) and are composed of archaeological and living tree specimens from elevations of approximately 1,890 to 2,290 m in northern Arizona and southern Utah (Salzer 2000:28). Combining the chronologies typically strengthens the climate signal by increasing sample sizes and buffering the influence of nonclimatic factors at individual sites (Salzer 2000: 28). Furthermore, "spatial networks of tree-ring chronologies usually explain more of the variance in a climate variable than a single chronology can" (Salzer 2000:28 citing Cook et al. 1994; Meko et al. 1993). Thus, the regional-scale focus of my study is compatible with the strengths of the paleoclimatic data.

I evaluate the representativeness of the San Francisco Peaks chronology for the Perry Mesa vicinity and the rest of central Arizona in three steps. First, modern instrumental precipitation

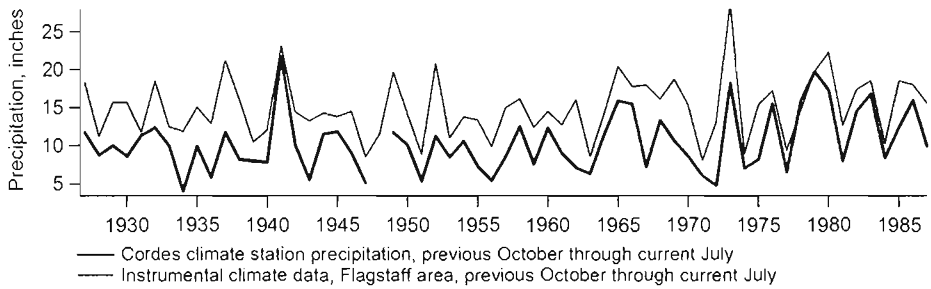

FIGURE 2.2. Cordes precipitation and Flagstaff area precipitation. Data from the Western Regional Climate Center (2010). The gap in the Cordes precipitation values in the late 1940s is due to missing data.

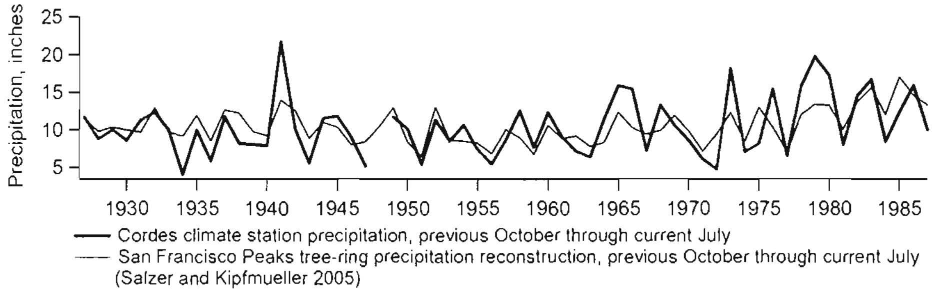

FIGURE 2.3. Modern precipitation near Perry Mesa (Cordes Station; Western Regional Climate Center 2010) and San Francisco Peaks precipitation reconstruction (Salzer and Kipfmueller 2005).

records from the Cordes meteorological station are compared to the cluster of modern meteorological stations in the San Francisco Peaks area used to calibrate the SFP precipitation chronology (Figure 2.2). The Cordes station is approximately 13 km northwest of Perry Mesa and at a similar elevation (~3,700 feet). The period from the previous October to current July was determined by Salzer (2000:31) to be the interval when precipitation had the greatest effect on tree growth; thus, the SFP tree-ring precipitation chronology is an October–July reconstruction. An examination of the period of overlap between the modern Cordes records and the SFP area meteorological stations (1927 to 2007, previous October to current July) produced a strong Pearson's r correlation coefficient ($r = .82$). The strength of this correlation reflects a high degree of spatial homogeneity in climate in the region even though the absolute values of precipitation vary largely by elevation.

Second, I compare the SFP tree-ring chronology to the Cordes precipitation records for the period of overlap (1927 to 2007, previous October through current July; Figure 2.3). As expected based on the strong relationship between the modern climate data for the two areas,[2] the SFP chronology is well correlated with the Cordes precipitation records ($r = .67$).

Third, to assess the strength of the San Francisco Peaks reconstruction to represent climate variation throughout central Arizona, I examined the relationship between modern precipitation data as represented by precipitation totals from previous October to current July for Climate Divisions 3 and 4, making up all of central Arizona, and compared them to the SFP reconstruction (Figures 2.4 and 2.5). Perry Mesa and most of the postulated Verde Confederacy are in the eastern portion of Climate Division 3 and to a lesser extent in the western portion of Division 4. The correlation between the SFP reconstruction and Climate Division 3 is $r = .75$ (Figure 2.4) and for Climate Division 4 is $r = .72$ (Figure 2.5). High precipitation years are less accurately retrodicted by tree-ring proxy data because years

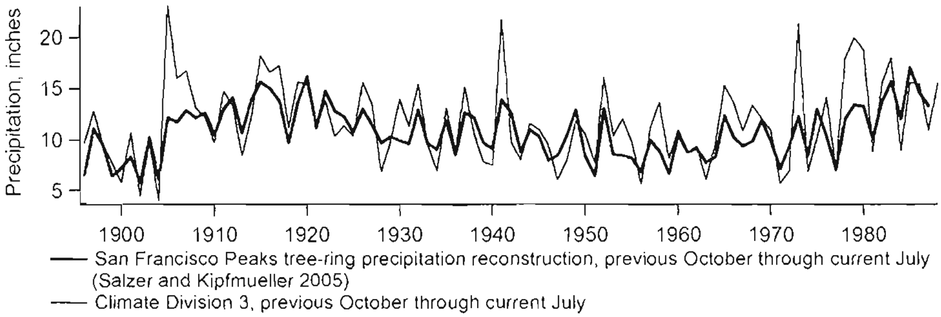

FIGURE 2.4. Climate Division 3 and San Francisco Peaks precipitation reconstruction. Division data from the National Climatic Data Center (2009).

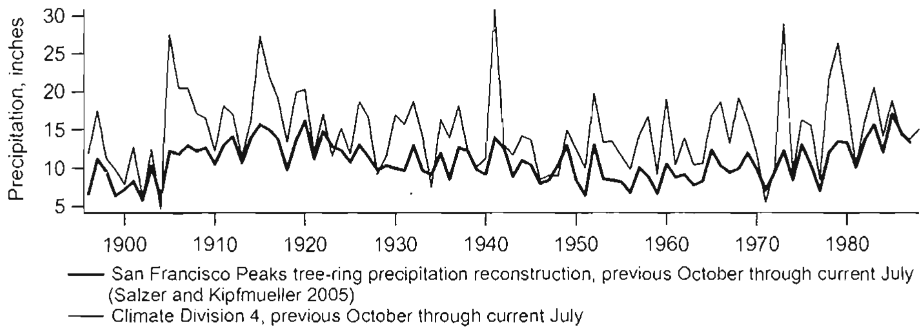

FIGURE 2.5. Climate Division 4 and San Francisco Peaks precipitation reconstruction. Division data from the National Climatic Data Center (2009).

with above-average precipitation allow nonclimatic processes to exert a greater influence on tree growth (Fritts 1976).

Dry and wet periods during the period of study are identified using a nine-year-interval-centered moving average throughout the duration of the tree-ring precipitation reconstructions (AD 571 to 1988). Dry periods are sometimes referred to as droughts, but definitions of drought are ambiguous and contested. To avoid these problems, I use the term "dry period" and define it as those intervals in the lowest quartile of the distribution of all nine-year intervals in the reconstruction (see Ingram 2010: 100–104 for a complete methodological discussion). "Very dry periods" are defined as those intervals in the lowest decile of the distribution of all nine-year intervals in the reconstruction. "Wet periods" are defined as those intervals in the highest quartile, and "very wet periods" are defined as those intervals in the highest decile.

I use the Canyon de Chelly precipitation reconstruction to represent precipitation conditions in northeastern Arizona. This reconstruction was developed by the Southwest Paleoclimate Project of the University of Arizona's Laboratory of Tree-ring Research (Dean and Robinson 1978).

Why Did People Move to Perry Mesa?

To address the question of why people moved to Perry Mesa during the late thirteenth and early fourteenth centuries, I place Perry Mesa in its regional context (central and northern Arizona) and compare it to other places and conditions in this region. I pursue a comparative approach because people were on the move in the region at the time of population increases on Perry Mesa. Comparing Perry Mesa to other potential destinations helps answer the question of why Perry Mesa was selected for settlement by so many people. The analyses in this section demonstrate the relative climatic, demographic, and environmental attractiveness of Perry Mesa and environs for settlement. Seen in this regional context, Perry Mesa no longer seems a harsh and unlikely place to live. Rather, the question becomes explaining why Perry Mesa was not substantially settled earlier—but that question is beyond the scope of this chapter. I also identify unique and unprecedented wet climatic conditions in the early 1300s. These conditions should have increased resource productivity on and around Perry Mesa and may have supported or stimulated the population growth that occurred there.

Immigration into Central Arizona

Settlement and population growth in central Arizona during the late thirteenth and early fourteenth centuries occurred in the context of substantial immigration into central and southeastern Arizona, matched by equally substantial emigration out of northeastern Arizona and central portions of the Southwest (Clark 2001; Clark et al. 2008; Colton 1946; Reid and Whittlesey 1997; Stark et al. 1995). Social, environmental, and climatic causes of this massive migration of people out of the northern Southwest in the late 1200s have been advanced (e.g., Ahlstrom et al. 1995; Jett 1964; Kohler et al. 2008; Lipe 1995; Varian et al. 1996; Van West and Dean 2000; see also Kohler 1993:295–297 for a summary).

Patterns of population movement in the Southwest are illustrated in Figure 2.6 using compound annual growth rates by watershed during the 1250 to 1299 and 1300 to 1349 intervals. During the 1250 to 1299 interval, immigration took place throughout much of eastern Arizona (darkest shading in the figure). During the 1300 to 1349 interval, those areas in northeastern Arizona with high growth rates during the previous interval experienced rapid population loss while growth rates increased and immigration became concentrated in the Agua Fria (including Perry Mesa) and the adjacent Upper and Lower Verde watersheds. In absolute terms, the number of identified rooms in the Agua Fria, Lower Verde, Tonto, Upper Salt, and Upper Verde watersheds increased 44 percent (from 10,163 to 14,643 rooms) between the 1250 to 1299 and 1300 to 1349 intervals. These watersheds make up the primary areas of occupation in central Arizona outside the Phoenix Basin. In the Agua Fria watershed, the number of identified rooms increased 353 percent (from 427 to 1,937 rooms) during the 1300 to 1349 interval compared to the previous interval. The compound annual population growth rate was 3 percent from the 1250–1299 to 1300–1349 interval, far in excess of what can be expected from changes in fertility and mortality (Cowgill 1975). Wilcox and colleagues (2001b:164, Table 7.4) estimate that there were about 1,751 rooms on Perry Mesa in the early 1300s.

From these maps, I infer a strong northeastern to central Arizona direction for population movements during the late 1200s and early 1300s. This pattern of movement has been demonstrated by ceramic and obsidian sourcing (Clark et al. 2008), analyses of Puebloan enclaves within traditionally Hohokam settlements (Clark 2001; Haury 1958; Stark et al. 1995), and analyses of changes in population density throughout the Southwest (Hill et al. 2004). The identification of a direction of population movements from these maps does not, however, suggest the specific origin or cultural identity of peoples living on Perry Mesa. Population loss and movements from adjacent watersheds (Big Chino, Burro, Santa Maria, Hassayampa) to the north and west of the Agua Fria and Perry Mesa as well as from the foothills north of the Phoenix Basin could also have contributed to population increases on Perry Mesa. Arguments tracing migration pathways to their destinations are fraught with interpretive challenges (Cordell 1995) and are best left to others with more appropriate data to consider.

Nevertheless, I argue that this massive influx of immigrants into central Arizona was a contributing factor, or push, for the reorganization of settlement patterns in central Arizona. The arrival of immigrants would have been disruptive to existing central Arizona populations, and people may have shifted and reorganized existing settlements to accommodate the influx. Hill and colleagues (2004:699), using Kowalewski's

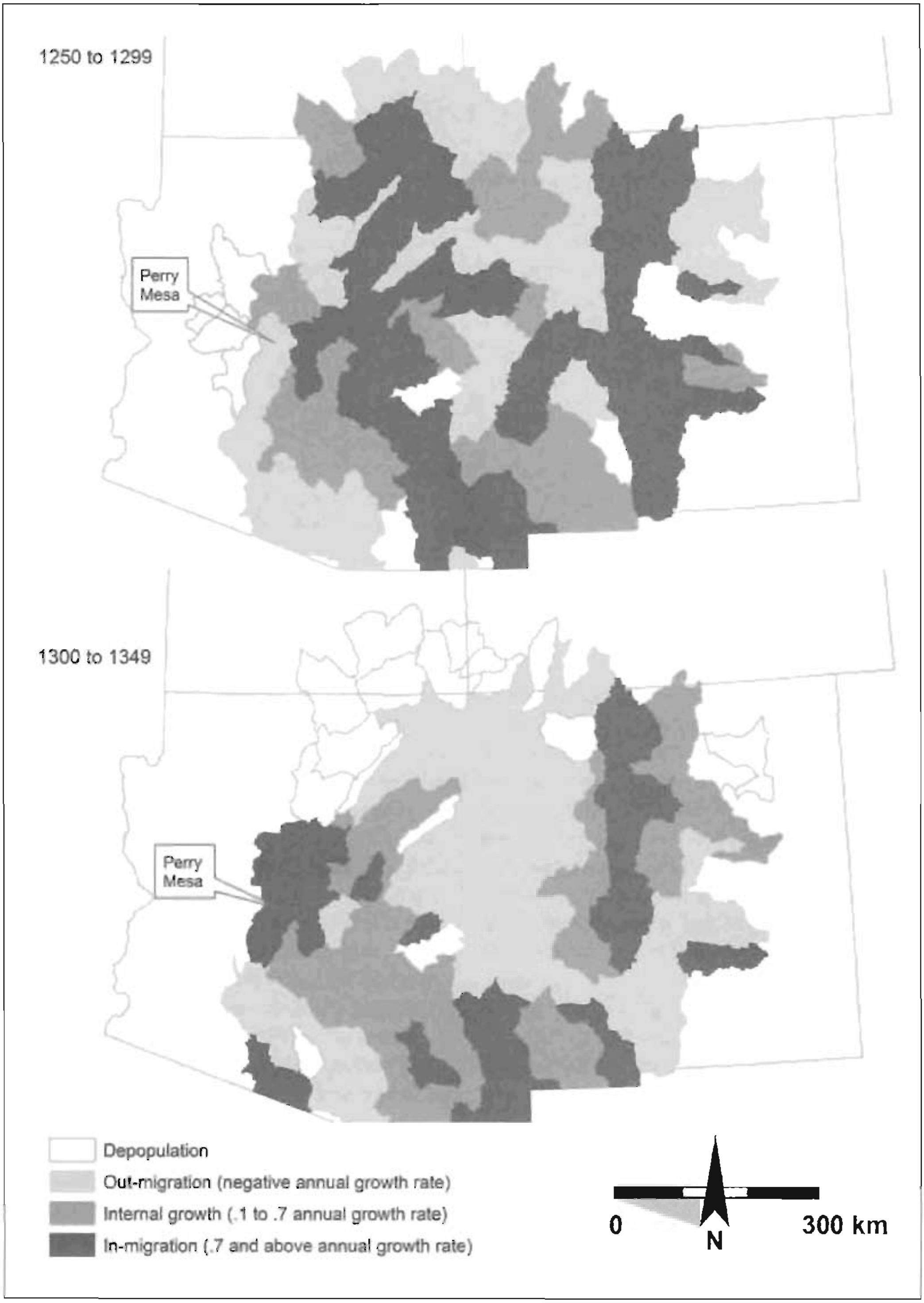

FIGURE 2.6. Changes in population growth rates, 1250 to 1349. Growth rates calculated from settlement data in the Coalescent Communities Database (Wilcox et al. 2003).

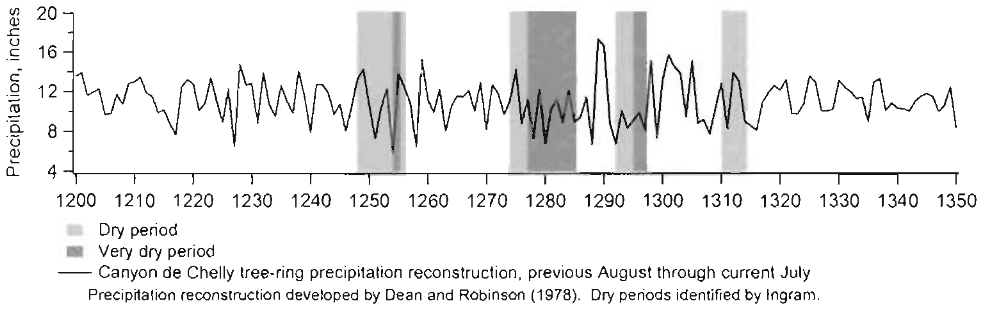

FIGURE 2.7. Reconstructed precipitation levels and dry periods in northeastern Arizona.

(2001) model of community coalescence, argue "migration [into central and southern Arizona] was an important catalyst in coalescence, generating economic pressure and causing social disruption on a large scale." Similarly, Colton (1946) has argued that the southward migration of the Northern Sinagua, perhaps stimulated by the 1276–1299 drought, displaced resident Hohokam populations in the middle Verde Valley (east of Perry Mesa).

I focus on this massive influx of immigrants into central Arizona because it is a parsimonious explanation of why population increased on Perry Mesa. Population increased because there were thousands of people moving to central Arizona looking for places to live. In the process, they probably threatened and displaced existing residents. Those who made up the population increases on Perry Mesa, then, could have been residents of nearby locales displaced or threatened by the immigrants or new amalgamations of previously distinct groups. Explaining population increases on Perry Mesa as a strategic deployment to protect the western flank of a political alliance (Wilcox et al. 2001b:167–168) seems unnecessarily complex and especially difficult to demonstrate.

Climatic Push and Pull in the Late Thirteenth Century

Using the available but limited temporally diagnostic ceramics, Wilcox and Holmlund (2007: 94) have proposed an approximate initiation date of 1275 for settlements on and around Perry Mesa and an increase in settlement in other parts of the Verde Confederacy. This date is also based on the temporally coincident depopulation of adjacent territories and the initiation of compound architecture in the Phoenix Basin. Thus, conditions during the 1250 to 1299 interval are the best approximation of the climatic context of the initial pulse in settlement founding on Perry Mesa and the rest of central Arizona. This interval includes the so-called Great Drought (Douglass 1929) of approximately 1274 to 1299 (see also Van West and Dean 2000).

Dry periods (defined above) during the 1250 to 1299 interval were more prolonged and severe in northeastern Arizona (Figure 2.7) than in central Arizona (Figure 2.8). Dry periods made up 48 percent of the 1250 to 1299 interval in northeastern Arizona compared to 28 percent of the interval in central Arizona. The dry periods in northeastern Arizona were also more severe: 22 percent of the 50-year intervals there included "very dry" years while only 8 percent of the intervals in central Arizona included "very dry" years. Thus, a climatic push from very dry conditions in the late 1200s in northeastern Arizona combined with a climatic pull from less prolonged and severe conditions in central Arizona seems likely to have been among the many factors stimulating population movements out of northeastern Arizona. Reid (1989) and Redman (1993) have also suggested that population movements from the Colorado Plateau toward the Mogollon Rim of central Arizona were drought-induced, and Van West et al. (2000) have suggested a similar basis for movements to the Tonto Basin.

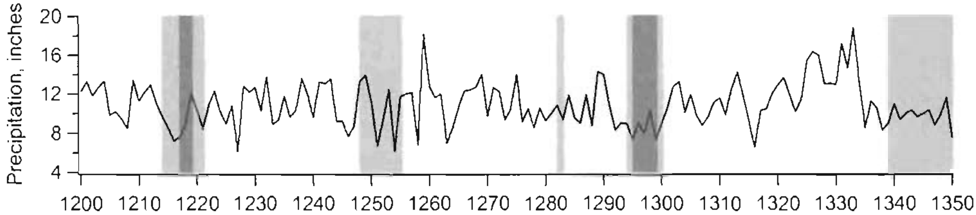

FIGURE 2.8. Reconstructed precipitation levels and dry periods in central Arizona near Perry Mesa.

TABLE 2.1. Average Annual Precipitation, 1895 to 2006, by Arizona Climate Division.

Climate Division	Average annual precipitation (inches)[a]
Arizona 4	18.7
Arizona 3 (Perry Mesa)	15.6
Arizona 2	14.6
Arizona 7	14.2
Arizona 6	9.8
Arizona 1	9.6
Arizona 5	4.7

[a] Computed using data from the National Climate Data Center (2009).

Environmental and Demographic Pull Factors

The analysis in this section considers the relative environmental and demographic attractiveness of the Agua Fria watershed (including Perry Mesa) compared to watersheds throughout northeastern and central Arizona. Environmental conditions influence the potential productivity or supply of resources and are assessed with long-term average precipitation levels. Demographic conditions influence the demand for resources and are assessed with watershed population density (as previously discussed). I examine density during the 1250 to 1299 and 1300 to 1349 intervals because decisions to move to the Agua Fria watershed and the rest of central Arizona were likely made based on information obtained during these intervals. To compare the attractiveness of all watersheds in the study area, I combine demographic and environmental conditions into an "attractiveness index" for each watershed, as discussed further below.

Environmental conditions as indicated by precipitation levels are more favorable for resource productivity in central Arizona than in northeastern Arizona. Figure 2.9 shows the distribution of average precipitation across Arizona, with darker-shaded areas receiving more precipitation than lighter-shaded areas. Perry Mesa and the rest of central Arizona are on a northwest to southeast oriented "island" of relatively high precipitation and potential productivity. The six numbered polygons across the map are the designated climate divisions of central Arizona. The absolute precipitation values by climate division are presented in Table 2.1. The postulated Verde Confederacy is located primarily in the eastern portion of Climate Division 3 and minimally in the western portion of Climate Division 4. The area covered by these divisions receives the highest average annual precipitation of any area in Arizona.

Demographic conditions were also favorable for settlement in the Agua Fria watershed during the 1250 to 1299 interval. Population density in the Agua Fria was the lowest of any of the populated watersheds of central Arizona and the fourth lowest among the 25 populated watersheds of central and northeastern Arizona (Table 2.2). During the 1300 to 1349 interval, the Agua Fria watershed had the second-lowest population density among the watersheds of central Arizona and the seventh-lowest density among the 19 populated watersheds of central and northeastern Arizona.

An "attractiveness index" that considers both demographic and environmental condi-

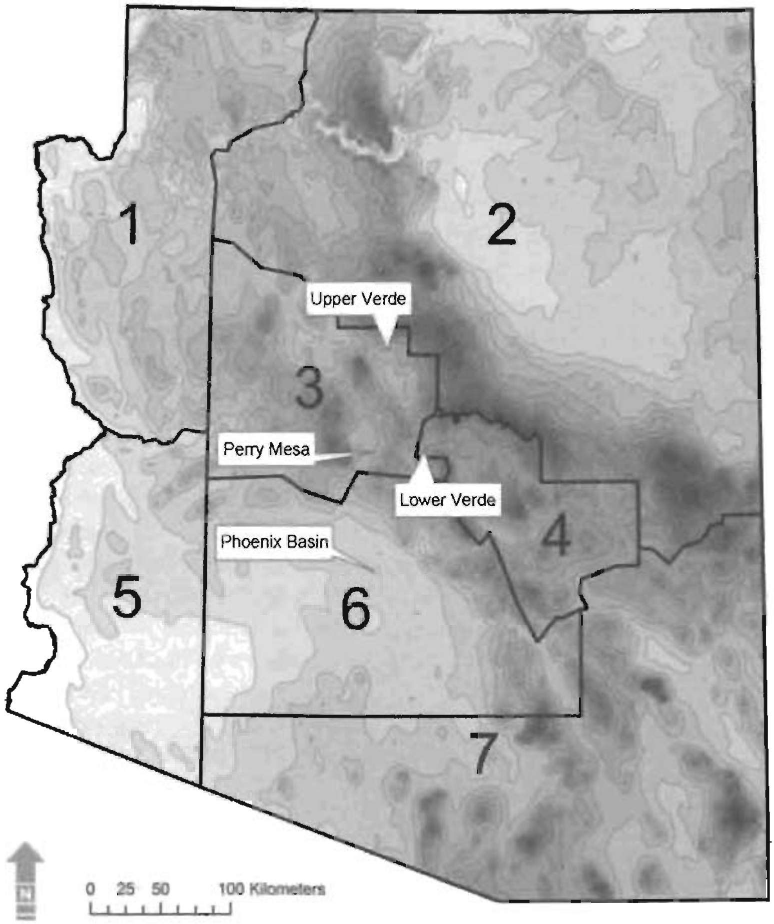

FIGURE 2.9. Average precipitation (1961 to 1990) in central Arizona (PRISM 2007, Oregon State University) and climate division boundaries (National Climate Data Center 2009). Each contour interval represents a two-inch average annual precipitation range (e.g. nine to eleven inches). Darker shaded areas receive more precipitation than lighter shaded areas.

tions also allows inter-watershed comparisons. The index is a watershed's average precipitation level divided by its population density. I identify watershed precipitation levels based on average precipitation levels in the climate division that includes the watershed (Table 2.1). Low index scores represent less attractive areas (low precipitation and high density) than high index scores (high precipitation and low density).

During the 1250 to 1299 interval, the Agua Fria watershed ranked fourth highest in terms of the attractiveness of all 25 study area watersheds (Table 2.2). During the 1300 to 1349 interval, it ranked eighth highest. The relatively high attractiveness of the Agua Fria watershed, particularly during the 1250 to 1299 interval, when decisions to move into the Agua Fria watershed were likely considered or initiated, identify the probable influence of resource productivity (supply) and population density (demand) considerations on population destinations.

These results are consistent with the work of Van West and Altschul (1994), who modeled potential agricultural productivity in the Tonto Basin (Tonto watershed) and compared it to conditions on the Colorado Plateau during the prehistoric period. Van West and Altschul (1994: 430) argue that "it seems reasonable to consider

TABLE 2.2. Precipitation, Density, and Relative Attractiveness of Study Area Watersheds.

Watershed	Average annual precipitationa	Area (km2)[b]	Number of rooms, 1250–1299[c]	Density, 1250–1299[d]	Relative attractiveness, 1250–1299[e]	Number of rooms, 1300–1349[c]	Density, 1300–1349[d]	Relative attractiveness, 1300–1349[e]
Agua Fria	15.6	6,355	427	.07	223	1,937	.30	52
Canyon Diablo	14.6	3,098	569	.18	81	1,140	.37	39
Carrizo	18.7	1,786	505	.28	67	555	.31	60
Chevelon Canyon	14.6	2,219	219	.10	146	350	.16	91
Chinle	14.6	10,565	2,700	.26	56	175	.02	730
Corn-Oraibi	14.6	2,236	1,900	.85	17	1,200	.54	27
Cottonwood Wash	14.6	4,140	666	.16	91	765	.18	81
Dinnebito Wash	14.6	1,927	110	.06	243	—	—	—
Jeddito Wash	14.6	2,734	2,775	1.02	14	3,175	1.16	13
Leroux Wash	14.6	2,103	1,335	.63	23	—	—	—
Lower Lake Powell	14.6	7,744	438	.06	243	—	—	—
Lower Little Colorado	14.6	6,211	204	.03	487	—	—	—
Lower Puerco	14.6	2,829	1,085	.38	38	875	.31	47
Lower Salt (Phoenix)	9.8	3,442	7,121	2.07	5	8,126	2.36	4
Lower San Juan	14.6	6,214	682	.11	133	—	—	—
Lower Verde	15.6	5,019	1,764	.35	45	3,318	.66	24
Middle Little Colorado	14.6	6,345	694	.11	133	819	.13	112
Moenkopi Wash	14.6	6,776	785	.12	122	—	—	—
Polacca Wash	14.6	2,780	2,925	1.05	14	2,400	.86	17
Silver	14.6	2,440	1,222	.50	29	1,010	.41	36
Tonto	18.7	2,694	2,221	.82	23	1,444	.54	35
Upper Little Colorado	14.6	4,219	1,181	.28	52	605	.14	104
Upper Salt	18.7	5,612	3,701	.66	28	4,922	.88	21
Upper Verde	15.6	6,372	1,115	.17	92	1,667	.26	60
White	18.7	1,703	430	.25	75	800	.47	40

[a] Based on average precipitation levels in the climate division (National Climatic Data Center 2009) that includes the watershed.
[b] Calculated using watershed boundaries (Steeves and Nebert 1994) and ArcGIS 9.1 software.
[c] Calculated using the Coalescent Communities Database (Wilcox et al. 2003) and an overlay of watershed boundaries.
[d] Rooms per square kilometer calculated by dividing the number of identified rooms in a watershed by the watershed's area.
[e] The index is a watershed's average precipitation level divided by its population density. Low index scores represent less attractive areas (low precipitation and high density) than high index scores (high precipitation and low density).

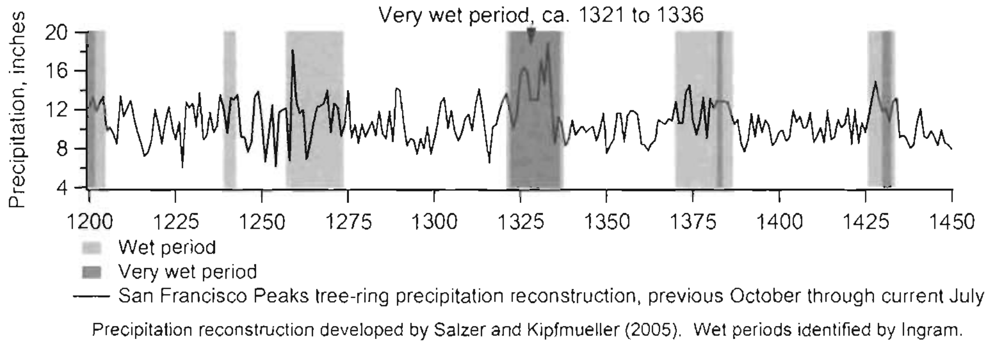

FIGURE 2.10. Reconstructed wet periods nearest the Perry Mesa area, 1200 to 1450.

that the relative attractiveness of the basin was a draw for risk-prone agricultural populations, particularly those from the Colorado Plateau." Citing opportunities for irrigated agriculture, including runoff and water-harvesting agricultural systems, along with relatively abundant wild foods in the Tonto Basin, they concluded that dry periods would likely not have been as disastrous to the economy in the Tonto Basin as they were for the Colorado Plateau (Van West and Altschul 1994:430).

Unprecedented Favorable Climatic Conditions in the Early 1300s

Room counts and inferred population levels in central Arizona peaked during the 1300 to 1349 interval. We do not yet know when population levels on Perry Mesa reached their highest points. The 1300 to 1349 interval includes an exceptional 16-year wet period from 1321 to 1336 (Figure 2.10), which is the wettest in the entire 1,418-year precipitation reconstruction (see Salzer and Dean 2006:110, 117; Dean and Robinson 1982:53; and Rose 1994 for similar results). During this wet period, precipitation levels averaged 26 percent above the long-term average for the reconstruction. Based on the modern average precipitation level for the Cordes weather station near Perry Mesa (15.24 inches; Western Regional Climate Center 2010), a 25 percent increase suggests that precipitation was about 19 inches annually. At the peak of this wet period (1333), precipitation levels reached 75 percent above the long-term average for the reconstruction. This result suggests an annual precipitation level of 26 inches on Perry Mesa. Actual precipitation values on Perry Mesa were likely considerably higher because high precipitation years, as noted above, are understated by tree-ring proxy data (Fritts 1976).

To place these approximations of actual precipitation values in perspective, we can compare them with averages from other locales. For example, maize is cultivated on the Hopi Mesas of northeastern Arizona with a variety of water management strategies and annual precipitation averages of 11 or 12 inches (Hack 1942). Maize was cultivated on Mesa Verde in southwestern Colorado with an average of 17.8 inches of precipitation (Western Regional Climate Center 2010). Precipitation conditions on Perry Mesa, then, were exceptionally favorable during the early 1300s, if we assume that greater precipitation levels did not create other problems for cultivation.

The unprecedented conditions of the 1300 to 1349 interval also include a 39-year hiatus in multiyear dry periods from 1300 to 1338 (see Figure 2.8). This hiatus was the longest such period that had occurred in this area for 475 years. Thus, a combination of wet-period increases in resource productivity and a hiatus in dry-period decreases in productivity probably contributed to the population buildup on Perry Mesa and throughout central Arizona during the early 1300s.

Summary

In summary, population increases on Perry Mesa were not a unique local-scale phenomenon but part of a massive influx of immigrants moving from northeastern Arizona toward central Arizona during the late 1200s and early 1300s. The analyses presented above identified a climatic push for these movements out of northeastern Arizona and a climatic pull toward central Arizona. The relative demographic and productive attractiveness of Perry Mesa and environs was also demonstrated. Moreover, unprecedented wet conditions and a hiatus in dry conditions characterize central Arizona during the early 1300s. These conditions could have further stimulated population growth on Perry Mesa. The identification of regional-scale influences on central Arizona settlement patterns also suggests that the pulse and location of settlements on and around Perry Mesa during the late thirteenth and early fourteenth centuries do not, alone, provide strong evidence of increasing warfare in the region.

Why Settlement Clusters and Unoccupied Zones?

Analyses of resource productivity are also informative for understanding why some areas became unoccupied while others supported settlement clusters. Differences in potential productivity suggest that spatial heterogeneity in landscape productivity plays a significant role in settlement location decisions.

Background

Settlement clustering becomes evident when settlements are located in relatively close proximity to one another and separated from other similar clusters by unoccupied zones of little or no settlement. Unoccupied zones can be the unintentional result of settlement clustering or an intentional effort to create open spaces between socially distant or hostile peoples. Evidence that an area was settled and later abandoned has been used to infer that an unoccupied zone served a defensive function (LeBlanc and Rice 2001:15; Wilcox et al. 2001b:158). Conflict models often refer to unoccupied zones as "buffer zones" or "no-man's-lands" (DeBoer 1981; LeBlanc 1999; Wilcox et al. 2001b; Wilcox and Haas 1994). In this analysis, I follow LeBlanc and Rice (2001:15) and refer to these areas as "unoccupied zones" because it does not presuppose the intentional creation, use, or function of an area lacking settlement.

Settlement clustering is also referred to as "aggregation" among U.S. Southwestern archaeologists, and there is a rich history of debate as to its causes (Haury 1962; Kohler and Sebastian 1996; Leonard and Reed 1993; Longacre 1966; Plog et al. 1988). Key dimensions of explanatory models of aggregation include "population density, the nature of the subsistence base and agricultural technology, paleoenvironmental factors, and methods of social integration" (Cordell et al. 1994:111). Of particular interest in this study are explanations of aggregation that consider changes in climatic conditions and/or increases in conflict and warfare.

Climatic conditions and changes in these conditions can create settlement clusters and unoccupied zones through several processes. For example, population movements from areas of lower to greater productivity to reduce the real or perceived risk of resource shortfalls associated with dry periods can create unoccupied zones in areas of low productivity where shortfall risks likely prevailed. If patches of land offering greater potential productivity are surrounded by less productive places, clustering in the most productive places can be expected (e.g., Plog et al. 1988). Settlement clustering could also reflect an enlargement of the basic social unit for cooperation in response to climatic deterioration (Hill and Trierweiler 1986; Longacre 1966).

Conflict can produce settlement clusters and unoccupied zones if people aggregate to decrease their real or perceived risk of harm associated with increases in hostilities. Settlements in close proximity may gain defensive or offensive strength in numbers and provide early warnings of attack to nearby settlements (e.g., Wilcox and Haas 1994; Wilcox et al. 2001a, 2001b; Rice 2001). Unoccupied zones may reduce the potential for conflict by raising the transportation costs between people and providing resources in emergency situations (DeBoer 1981; LeBlanc 1999; Martin and Szuter 1999). Unoccupied zones also delineate settlement clusters, and spatial associations may indicate a political relationship or polity (Wilcox 1981; Upham 1982). Unoccupied zones have been documented in central and southern Arizona and throughout the Southwest at various times (see Wilcox and Haas 1994:230–232 for some examples).

LeBlanc (1999:70) argues that site (settlement) clusters and unoccupied zones "are probably the most legible 'signatures' of warfare." He further argues that settlement clusters and unoccupied zones were inefficient because they concentrated resource utilization, causing overexploitation of immediately adjacent resources and underutilization of more distant ones (also see Wilcox 1981). Clustering of people, he believes, was so "nonoptimal" that under many circumstances "people would have avoided forming such concentrated settlement clusters unless strongly compelled to do so" (LeBlanc 1999:70; but see Chapter 3 for an argument favoring aggregation for efficient resource access). Reducing the risks of harm associated with conflict and defense are the presumed compelling reason for assuming these "nonoptimal" settlement patterns.

An examination of changes in the distribution of settlements over time in central Arizona indicates that the settlement clusters were the result of an increase in settlement founding in specific areas on the landscape and that the unoccupied zones were in some places the result of settlement abandonments. Wilcox et al. (2001b) describe this process, and it is supported by an examination of maps of settlement distributions at 50-year intervals developed with the Coalescent Communities Database (Wilcox et al. 2003).

Differences in Resource Productivity between Unoccupied Zones and Settlement Clusters

Unoccupied Zones

Wilcox et al. (2001b:162) identified three unoccupied zones in the Agua Fria and Verde watersheds that surround the postulated Verde Confederacy: (1) between the middle Verde Valley and Chavez Pass, (2) between Polles Mesa and the northern Tonto Basin, and (3) between Perry Mesa, the lower Verde Valley, and the Phoenix Basin (Figure 2.11). In this section I identify the productivity characteristics of each of these zones and some physiographic factors to understand why they were unoccupied.

According to Wilcox et al. (2001a:125; 2001b:162–163), the unoccupied zones were initiated about 1100 and widened around 1250, and the unoccupied zones were clearly evident between multi-settlement site clusters by the late 1200s and early 1300s. The protracted 200-year duration of their initiation and spread challenges our attempts to empirically identify and evaluate specific potential causes. It is important to note, however, that in only one of the three unoccupied zones (number 3) is there evidence of extensive settlement and a subsequent pattern of abandonment. A pattern of abandonment is one indicator marking the emergence of a buffer zone (LeBlanc and Rice 2001:15; Wilcox et al. 2001b:158). The absence of this pattern of abandonment in two of the three unoccupied zones suggests the important influence of the productivity characteristics on discouraging settlement in these areas.

Unoccupied zone 1, between the middle Verde Valley and Chavez Pass, is characterized by several features that would have made the area undesirable for settlement due to challenges to agricultural productivity. First, the length of the freeze-free period in the unoccupied zone is 91 to 120 days (National Climatic Data Center 2006). It is possible that this was sufficient for successful "short season" maize production (Muenchrath and Salvador 1995:311 and references contained therein); however, the risk of shortfall due to early or late freezes is much greater here than elsewhere in central Arizona, where freeze-free periods typically exceed 180 days (such as on Perry Mesa). Second, the Middle Verde and Chavez Pass are separated by a 1,400-m elevation change (Figure 2.12). This area, referred to as the Mogollon Rim, is where the Colorado Plateau begins its transition to the lower elevations of the Sonoran Desert. Farming on associated slopes would have been difficult in comparison to opportunities along the floodplain of the middle Verde Valley or the gently

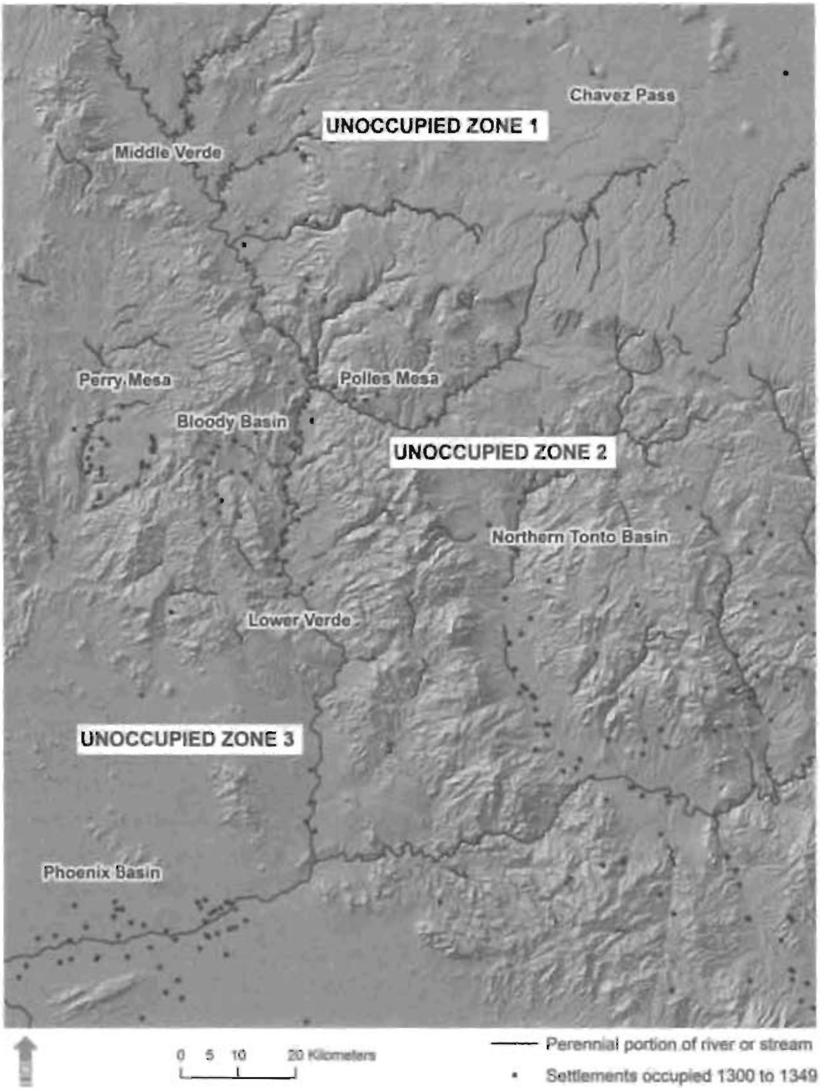

FIGURE 2.11. Unoccupied zones around Perry Mesa. Perennial portions of rivers and streams identified with data developed by The Nature Conservancy 2006; Brown et al. 1977, 1981; and Miller 1954. The settlement data are from the Coalescent Communities Database (Wilcox et al. 2003).

sloping land of Perry Mesa. Third, there are no perennial streams in the unoccupied zone between the inhabited tributaries of the Verde River and the Chavez Pass settlement. Fourth, the biotic community of the unoccupied zone is classified as "Petran Montaine Conifer Forest" (Brown et al. 1979; The Nature Conservancy in Arizona 2004), and it was virtually uninhabited from 1200 to 1450 throughout its roughly 350-km length and 30-km width. The lack of settlement in this vast area suggests that the potential productivity of this biotic community may have been less than surrounding areas. In sum, while the precipitation levels in the unoccupied zone are relatively high (see Figure 2.9), this potential productivity advantage was likely offset by characteristics that would have made farming relatively risky.

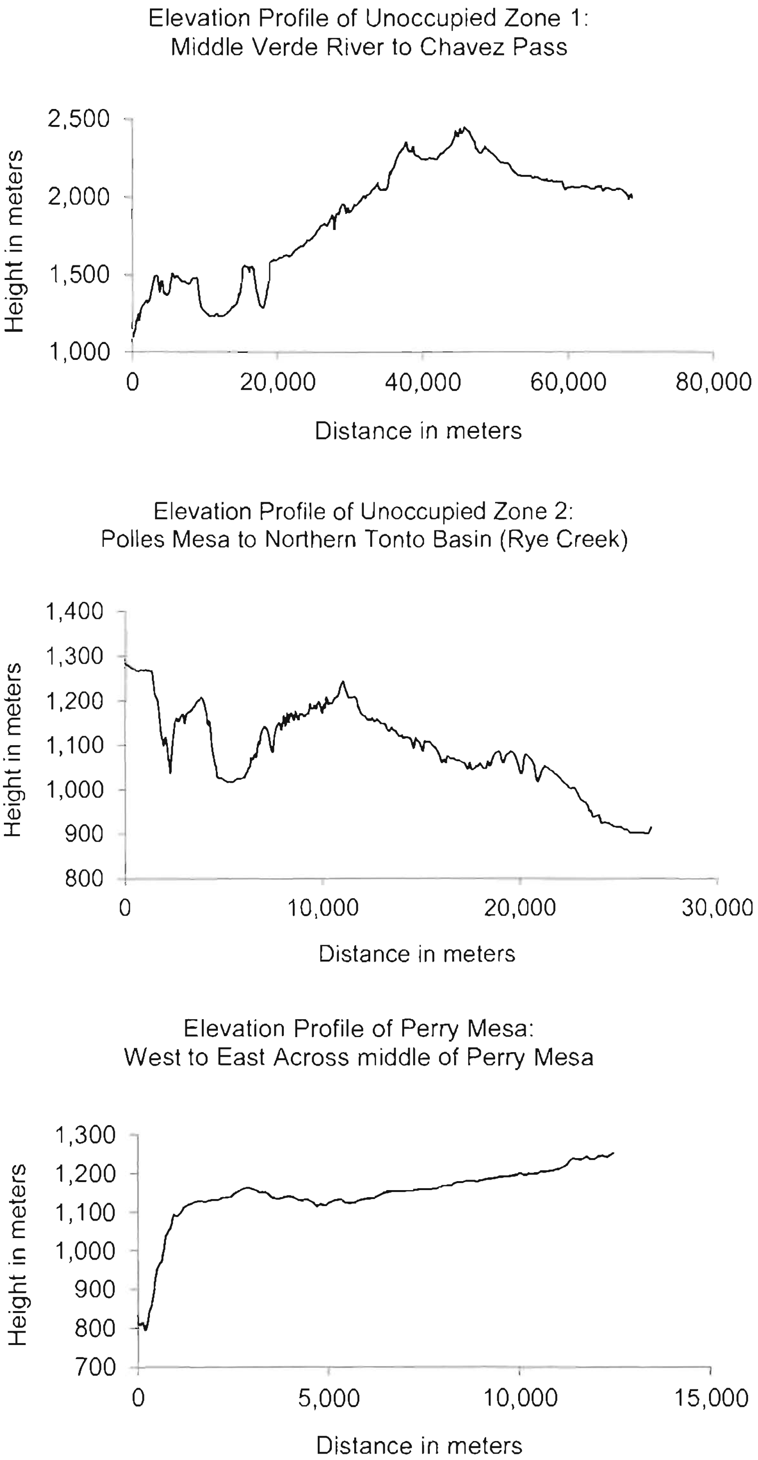

FIGURE 2.12. Elevation profiles of unoccupied zones and Perry Mesa. Calculated from United States Geological Survey (2009) digital elevation models using ArcGIS 9.1.

Unoccupied zone 2, between Polles Mesa and the northern Tonto Basin, is characterized by incised and sloping topography (see Figure 2.12) that would have challenged successful maize cultivation. The zone also lacks perennial riverine resources beyond the East Verde River near Polles Mesa. It is also significant to note that settlements on Polles Mesa are located on the northwestern side of the mesa, leaving the entire eastern side of the mesa, nearest Tonto Basin, unoccupied. This was not a defensive, "castle-like" settlement configuration as observed on Perry Mesa.

Unoccupied zone 3, between Perry Mesa, the lower Verde Valley, and the Phoenix Basin, was previously occupied. Abandonment of this zone began sometime in the early 1100s and was apparently complete sometime in the late 1200s (Wilcox et al. 2001a:110, 125). Two factors likely contributed to the abandonment of this zone.

First, water-related resource productivity is relatively low in this zone. Between Perry Mesa and the Phoenix Basin there is a steep decline in annual precipitation and associated productivity. In the roughly 60 km that separates the two areas, precipitation drops about 50 percent (from 15 inches on Perry Mesa to 8 inches in the Phoenix Basin; Western Regional Climate Center 2010). Areas of settlement abandonment along the lower Verde River are also in this zone of low precipitation, although access to the perennial riverine resources along the lower Verde (the only perennial river in this zone) could have decreased the dependence on local precipitation. Inspection of settlement patterning and precipitation contours throughout central Arizona reveals very few settlements in areas receiving less than 13 inches a year in average precipitation. In fact, no more than 2 percent of the population from 1200 to 1450 lived in areas receiving on average less than 13 inches of precipitation annually. This percentage includes people living next to perennial rivers but excludes those living next to the extensive irrigation systems along the lower Salt River in the Phoenix Basin, people who would have been substantially less dependent on local rainfall. Therefore, the areas receiving below 13 inches of annual precipitation form an extensive no-man's land with likely climatic and productivity origins. For farmers occupying these areas, declines in resource productivity during the late 1200s very dry period (see Figure 2.8) may have provided a final push out of this zone.[3]

Second, the abandonment of settlements that created this unoccupied zone occurred in the context of a significant sociocultural shift among the Hohokam, referred to by archaeologists as the Sedentary to Classic transition. This transition involved the abandonment of a region-wide system of ball courts and a variety of social, architectural, burial, and material culture changes (Abbott et al. 2007; Bayman 2001; Doyel 1980, 1991; Fish 1989). Addressing the causes of the initiation of this unoccupied zone thus involves an understanding of the factors that contributed to the cultural transition (and is beyond the scope of this chapter). I note, however, that settlement abandonment in this zone was initiated as much as 200 years before settlement clustering on Perry Mesa. The elapsed time, about eight human generations, does not support a clear relationship between settlement abandonment in this zone and the pulse of settlement on Perry Mesa.

Settlement Clusters

The most obvious settlement clusters visible in Figure 2.11 are on and around Perry Mesa and the group of settlements in Bloody Basin between Perry Mesa and the Verde River. In addition to the demographic and productive attractiveness of Perry Mesa and vicinity (previously demonstrated) and proximity to the only perennial portion of the Agua Fria River, settlement clustering on Perry Mesa was likely strongly affected by the extent of arable land available on the mesa. Kruse-Peeples (Chapter 3; Kruse 2007) has demonstrated that on Perry Mesa the location of potentially arable land was a major factor in the placement and development of large residential sites. Further research on the distribution of arable land throughout the central Arizona region may yield similar results and demonstrate a strong relationship between the extent of arable land and settlement locations. Visual inspection of the distribution of land in the watersheds of central Arizona with slopes less than 10 percent (using GIS-generated maps not included here) reveals that if extensive gently sloping land was a criterion for successful and substantial cultivation, then Perry Mesa was one, perhaps the largest, tract of unoccupied arable land in central Arizona in the late 1200s. Perry Mesa is approximately 17 km from north to south and 11 km from west to east.

The environmental conditions contributing to the selection of settlement locations southeast of Perry Mesa (the Bloody Basin area) are less obvious, however. Although some settlements are near perennial creeks, most are not. Precipitation in this area averages 17 to 19 inches annually, which is higher than on Perry Mesa. Higher precipitation levels and associated groundwater conditions may have been sufficient for successful cultivation in these areas.

Beyond the Perry Mesa and Bloody Basin settlement areas, settlements are clustered mostly along the perennial Verde River and its tributaries and Tonto Creek. The Verde has one of the highest discharge levels in central Arizona (United States Geological Survey 2010), ensuring access to water year-round and during dry periods. Proximity to perennial rivers also offers extensive riparian resources and opportunities for irrigated and floodplain agriculture. Beyond the Verde, settlements within the northern Tonto Basin cluster are also preferentially located near riverine resources. The largest pueblo in the cluster, Rye Creek, is positioned at the intersection of three intermittent creeks (Rye, Deer, and an unnamed creek). Current mapping also shows that the perennial portion of Deer Creek is less than 3 km from Rye Creek. The other settlements in this cluster are located along the perennial Tonto Creek.

In addition to proximity to perennial riverine resources, settlements along the Verde River had several other productivity advantages. First, settlements on the eastern side of the Verde and along tributaries that originate at higher elevations near the Mogollon Rim are in an ideal position to receive the benefits of pulses of streamflow useful for runoff agriculture from summer monsoon storms. Settlements on the eastern side of the river also had the benefits of warmer temperatures inherent in west-facing slopes. Warmer temperatures could have offset the cooler temperatures that prevail in low-lying areas adjacent to higher elevations where cool air drains. This offset could have lengthened the growing season and reduced the risk of frost damage to crops in these higher-elevation settlement areas. Wilcox et al. (2001b:159) have argued that the absence of settlement along the western side of the Verde River suggests a defensive strategy. The productivity advantages noted here may explain preferential settlement on the eastern side of the river.

If dry conditions and the availability of arable land influenced decisions to cluster settlements in areas of relatively high productivity on and around Perry Mesa in the late 1200s, why did this clustering persist as conditions improved in the early 1300s? If, as LeBlanc (1999:70) suggests, resources are rapidly depleted in this "nonoptimal" clustered configuration, we should expect people to begin abandoning these configurations when conditions no longer require them. If conflict and hostilities increased in the early 1300s, village clustering would have been an advantageous defensive strategy. In the absence of conflict, clustering might have been maintained simply because there was no push out of this configuration during the 1300 to 1349 interval. Rising productivity associated with the very wet period may have compensated for continued localized resource utilization.

Summary

The unoccupied zones are primarily areas of relatively lower resource productivity than areas where settlements were clustered. Avoiding settlement in relatively less productive areas is thus not an "inefficient" or "nonoptimal" strategy (cf. LeBlanc 1999:70). Dry-period declines in resource productivity would have made less productive areas among the least desirable places to live. Movement away from areas of relatively low productivity when climate conditions that support productivity decline, such as during the late

1200s, is a reasonable strategy for lessening the risk of shortfalls.

Implications

This chapter has considered the factors that influenced population movements to Perry Mesa and central Arizona and the formation of settlement clusters and unoccupied zones on and around Perry Mesa. Several implications arise from this analysis.

First, the identification of regional-scale influences and differences in potential resource productivity between settlement clusters and unoccupied zones establishes an interpretation of settlement patterns on and around Perry Mesa that does not invoke the influence of increasing warfare, the formation of political alliances, or a strategy of defense or offense against hostile neighbors. This introduces a problem of equifinality associated with the settlement patterns used to support the warfare models. That is, multiple processes (warfare, demography, climate, environment, immigration) can result in the same settlement pattern. Consequently, substantiation of the warfare model will require that more weight be placed on the other supporting lines of evidence for increasing conflict (e.g., defensive site locations and architecture, line-of-sight connections, hilltop "forts" or lookouts, patterns of burned or abandoned settlements on the edges of clusters). Positing an increase in warfare during this critical period in central Arizona prehistory has important implications for how past sociocultural systems in the U.S. Southwest are understood.

Second, warfare models that rely on settlement patterns as evidence must consider climate-related changes in resource productivity and inherent spatial heterogeneity in landscape productivity. These factors can influence population movements and settlement location decisions that result in settlement clusters and unoccupied zones. Further evaluation of warfare models in the U.S. Southwest should focus on the productivity characteristics of other unoccupied zones and areas where settlements were clustered. Finding similar potential productivity in unoccupied zones and settlement clusters can strengthen the defensive interpretations of a settlement pattern.

Finally, warfare and climatic explanations for the dramatic shifts in settlement patterns suffer from poor chronological resolution. This poor resolution makes it difficult to discern the order of events, which is critical for the separation of cause and effect. For example, the key element to consider with respect to unoccupied zones is the root cause of their initial formation. Once formed, unoccupied zones likely would increase the energy costs of conflict and provide resources that could be periodically exploited by neighboring communities (LeBlanc 1999, 2006). These benefits of unoccupied zones could have been the by-products or effects of the zones rather than the cause of their formation. Moreover, instead of settlement clustering being the result of alliances, such clustering may have contributed to the formation of alliances because of greater social interaction among neighbors. Similarly, LeBlanc (1999) and Wilcox et al. (2001b) use the formation of settlement clusters and unoccupied zones as evidence for a regional-scale increase in conflict. But if the formation of settlement clusters and unoccupied zones occurred before other evidence of rising conflict, then settlement clustering and the associated overexploitation of resources could have been a primary cause of any increase in conflict rather than the effect of it.

Notes

1. Wilcox and Holmlund (2007:94) later revised the date of initial occupation to approximately AD 1275.
2. To simplify the correlation analyses in this section, I do not log transform the annual values before calculating correlations. Log transformation is common in the verification of the strength of the relationship between tree-ring indices and modern climate station data. Transformation increases the strength of

the correlations by minimizing differences in the absolute precipitation data values expected based on elevation or other location differences.

3. While unoccupied zone 3 is increasingly distant from the tree-ring chronologies of the San Francisco Peaks precipitation reconstruction, the late 1200s dry period is a regional-scale event extending throughout the Southwest (e.g., Cook et al. 2007:111).

References

Abbott, David R., Alexa M. Smith, and Emiliano Gallaga
2007 Ballcourts and Ceramics: The Case for Hohokam Marketplaces in the Arizona Desert. *American Antiquity* 72(3):461–484.

Adams, E. Charles
1998 Late Prehistory in the Middle Little Colorado River Area: A Regional Perspective. In *Migration and Reorganization: The Pueblo IV Period in the American Southwest*, edited by Katherine A. Spielmann, pp. 53–63. Anthropological Research Paper No. 51. Arizona State University, Tempe.

Ahlstrom, Richard V. N., Carla R. Van West, and Jeffrey S. Dean
1995 Environmental and Chronological Factors in the Mesa Verde–Northern Rio Grande Migration. *Journal of Anthropological Archaeology* 14:125–142.

Anthony, David W.
1990 Migration in Archaeology: The Baby and the Bathwater. *American Anthropologist* 92(4): 895–914.

Bayman, James M.
2001 The Hohokam of Southwest North America. *Journal of World Prehistory* 15:257–311.

Braun, David P., and Stephen Plog
1982 Evolution of "Tribal" Social Networks: Theory and Prehistoric North American Evidence. *American Antiquity* 16:301–313.

Bright, Jill L., and John J. Hervert
2005 Adult and Fawn Mortality of Sonoran Pronghorn. *Wildlife Society Bulletin* 33(1): 43–50.

Brown, David E., Neil B. Carmony, and Raymond M. Turner
1977 Inventory of Riparian Habitats. In *Importance, Preservation and Management of Riparian Habitat—a Symposium*. General Technical Report No. MR 43. U.S. Forest Service, Fort Collins, Colorado.
1981 Drainage Map of Arizona Showing Perennial Streams and Some Important Wetlands. Arizona Game and Fish Department map.

Brown, David E., Charles H. Lowe, and Charles P. Pase
1979 A Digitized Classification System for the Biotic Communities of North America, with Community (Series) and Association Examples for the Southwest. *Journal of the Arizona-Nevada Academy of Science* 14 (suppl. 1):1–16. Reprinted 1982 in *Desert Plants* 4 (1–4), edited by David E. Brown. University of Arizona for the Boyce Thompson Southwestern Arboretum, Superior, Arizona.

Burns, Barney Tillman
1983 Simulated Anasazi Storage Behavior Using Crop Yields Reconstructed from Tree Rings, AD 652–1968. Unpublished Ph.D. dissertation, University of Arizona, Tucson.

Burton, Ian, Robert W. Kates, and Gilbert F. White
1993 *The Environment as Hazard*. 2nd ed. Guilford Press, New York.

Cameron, Catherine M.
1995 Migration and the Movement of Southwestern Peoples. *Journal of Anthropological Archaeology* 14:104–124.

Cashdan, Elizabeth
1985 Coping with Risks: Reciprocity among the Basarwa of Northern Botswana. *Man* 20(3): 454–474.
1990 *Risk and Uncertainty in Tribal and Peasant Economies*. Westview Press, Boulder, Colorado.

Ciolek-Torrello, Richard
1997 Prehistoric Settlement and Demography in the Lower Verde Region. In *Vanishing River: Landscapes and Lives of the Lower Verde Valley*, edited by Stephanie M. Whittlesey, Richard Ciolek-Torrello, and Jeffrey H. Altschul, pp. 531–595. SRI Press, Tucson.

Clark, Jeffery J.
2001 *Tracking Prehistoric Migrations: Pueblo Settlers among the Tonto Basin Hohokam*. Anthropological Papers of the University of Arizona No. 65. University of Arizona Press, Tucson.

Clark, Jeffery J., Patrick D. Lyons, J. Brett Hill, Anna A. Neuzil, and William H. Doelle
2008 Immigrants and Population Collapse in the Southern Southwest. *Archaeology Southwest* 22(4):1–15.

Colton, Harold S.
1946 *The Sinagua: A Summary of the Archaeology of the Region of Flagstaff, Arizona.* Bulletin No. 22. Museum of Northern Arizona, Flagstaff.

Cook, Edward R., Keith R. Briffa, and Phillip D. Jones
1994 Spatial Regression Methods in Dendroclimatology: A Review and Comparison of Two Techniques. *International Journal of Climatology* 14(4):379–402.

Cook, Edward R., Richard Seager, Mark A. Cane, and David W. Stahle
2007 North American Drought: Reconstructions, Causes, and Consequences. *Earth-Science Reviews* 81:93–134.

Cordell, Linda
1975 Predicting Site Abandonment at Wetherill Mesa. *Kiva* 40(3):189–202.
1995 Tracing Migration Pathways from the Receiving End. *Journal of Anthropological Archaeology* 14:203–211.
1997 *Archaeology of the Southwest.* 2nd ed. Academic Press, San Diego.

Cordell, Linda S., David E. Doyel, and Keith W. Kintigh
1994 Processes of Aggregation in the Prehistoric Southwest. In *Themes in Southwest Prehistory,* edited by G. J. Gumerman, pp. 109–134. Advanced Seminar Series. School of American Research Press, Santa Fe.

Cordell, Linda S., Carla R. Van West, Jeffrey S. Dean, and Deborah A. Muenchrath
2007 Mesa Verde Settlement History and Relocation: Climate Change, Social Networks, and Ancestral Pueblo Migration. *Kiva* 72(4): 391–417.

Cowgill, George L.
1975 On Causes and Consequences of Ancient and Modern Population Changes. *American Anthropologist* 77:505–525.

Crown, Patricia L.
1994 The Salado Polychromes in Southwestern Prehistory. In *Ceramics and Ideology: Salado Polychrome Pottery,* pp. 211–225. University of New Mexico Press, Albuquerque.

Daly, Christopher, Ronald P. Neilson, and Donald L. Phillips
1994 A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountainous Terrain. *Journal of Applied Meteorology* 33(2):140–158.

Dean, Jeffrey S.
2006 Subsistence Stress and Food Storage at Kiet Siel, Northeastern Arizona. In *Environmental Change and Human Adaptation in the Ancient American Southwest,* edited by David E. Doyel and Jeffrey S. Dean, pp. 160–179. University of Utah Press, Salt Lake City.

Dean, Jeffrey S., Robert C. Euler, George J. Gumerman, Fred Plog, Richard H. Hevly, and Thor N. V. Karlstrom
1985 Human Behavior, Demography and Paleoenvironment on the Colorado Plateaus. *American Antiquity* 50:537–554.

Dean, Jeffrey S., and William J. Robinson
1978 *Expanded Tree-Ring Chronologies for the Southwestern United States.* Chronology Series No. 3. Laboratory of Tree-Ring Research, University of Arizona, Tucson.
1982 Dendrochronology of Grasshopper Pueblo. In *Multidisciplinary Research at Grasshopper Pueblo, Arizona,* edited by William A. Longacre, Sally J. Holbrook, and Michael W. Graves. Anthropological Papers of the University of Arizona No. 40. University of Arizona Press, Tucson.

DeBoer, Warren R.
1981 Buffer Zones in the Cultural Ecology of Aboriginal Amazonia: An Ethnohistorical Approach. *American Antiquity* 46:364–377.

Douglass, Andrew E.
1929 The Secret of the Southwest Solved by Talkative Tree-Rings. *National Geographic Magazine* 56:737–770.

Doyel, David E.
1980 Hohokam Social Organization and the Sedentary to Classic Transition. In *Current Issues in Hohokam Prehistory,* edited by David Doyel and Fred Plog, pp. 23–40. Anthropological Research Papers No. 23. Arizona State University, Tempe.
1991 Hohokam Exchange and Interaction. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. A. Crown and J. Judge, pp. 225–252. School of American Research Press, Santa Fe.
2000 The Santan Phase in the Phoenix Basin. In *The Hohokam Village Revisited,* edited by David E. Doyel, Suzanne K. Fish, and Paul R. Fish, pp. 221–244. Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science, Fort Collins, Colorado.

Dunne, Thomas, and Luna B. Leopold
1978 *Water in Environmental Planning.* W. H. Freeman, New York.
Euler, Robert C., George J. Gumerman, Thor N. V. Karlstrom, Jeffrey S. Dean, and Richard H. Hevly
1979 The Colorado Plateaus: Cultural Dynamic and Paleoenvironment. *Science* 205(4411): 1089–1101.
Fish, Paul R.
1989 The Hohokam: 1,000 Years of Prehistory in the Sonoran Desert. In *Dynamics of Southwest Prehistory*, edited by Linda S. Cordell and George J. Gumerman, pp. 19–63. Smithsonian Institution Press, Washington, D.C.
Fritts, Harold C.
1976 *Tree Rings and Climate.* Academic Press, London.
Gumerman, George J. (editor)
1988 *The Anasazi in a Changing Environment.* Cambridge University Press, Cambridge.
1991 *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest.* Amerind Foundation Publication. University of New Mexico, Albuquerque.
Hack, John T.
1942 *The Changing Physical Environment of the Hopi Indians of Arizona.* Reports of the Awatovi Expedition, No. 1. Peabody Museum of American Archaeology and Ethnology, Harvard University, Cambridge.
Halstead, Paul, and John O'Shea
1989 Introduction: Cultural Responses to Risk and Uncertainty. In *Bad Year Economics: Cultural Responses to Risk and Uncertainty*, edited by Paul Halstead and John O'Shea, pp. 1–7. Cambridge University Press, Cambridge.
Hassan, Fekri A.
1981 *Demographic Archaeology.* Academic Press, New York.
Haury, Emil W.
1958 Evidence at Point of Pines for Prehistoric Migration from Northern Arizona. In *Migrations in New World Culture History*, edited by Raymond H. Thompson. University of Arizona Bulletin No. 29, Social Science Bulletin No. 27. University of Arizona Press, Tucson.
1962 The Greater American Southwest. In *Courses toward Urban Life: Archeological Considerations of Some Cultural Alternates*, edited by Robert J. Braidwood and Gordon R. Willey, pp. 106–131. Aldine, Chicago.
Hegmon, Michelle
1989 Risk Reduction and Variation in Agricultural Economics: A Computer Simulation of Hopi Agriculture. *Research in Economic Anthropology* 11:89–121.
2000 *The Archaeology of the Regional Interaction: Religion, Warfare, and Exchange across the American Southwest.* University Press of Colorado, Boulder.
Herberle, Rudolph
1938 The Causes of Rural-Urban Migration: A Survey of German Theories. *American Journal of Sociology* 43(6):932–950.
Hill, J. Brett, Jeffery J. Clark, William H. Doelle, and Patrick D. Lyons
2004 Prehistoric Demography in the Southwest: Migration, Coalescence, and Hohokam Population Decline. *American Antiquity* 69(4):689–716.
Hill, James N., and W. Nicholas Trierweiler
1986 Prehistoric Responses to Food Stress on the Pajarito Plateau, New Mexico: Technical Report and Results of the Pajarito Archaeological Research Project, 1977–1985; Final Report to the National Science Foundation. Manuscript on file, Department of Anthropology, University of California, Los Angeles.
Ingram, Scott E.
2010 *Human Vulnerability to Climatic Dry Periods in the Prehistoric U.S. Southwest.* Ph.D. dissertation, Arizona State University, Tempe. University Microfilms, Ann Arbor, Michigan.
Jett, Stephen C.
1964 Pueblo Indian Migrations: An Evaluation of the Possible Physical and Cultural Determinants. *American Antiquity* 29(3):281–300.
Judge, W. James
1989 Chaco Canyon—San Juan Basin. In *Dynamics of Southwest Prehistory*, edited by Linda S. Cordell and George J. Gumerman, pp. 209–261. Smithsonian Institution Press, Washington, D.C.
Kintigh, Keith W., Donna M. Glowacki, and Deborah L. Huntley
2004 Long-Term Settlement History and the Emergence of Towns in the Zuni Area. *American Antiquity* 69(3):432–456.
Kohler, Timothy A.
1993 News from the Northern American Southwest: Prehistory on the Edge of Chaos. *Journal of Archaeological Research* 1(4):267–321.

Kohler, Timothy A., and Lynne Sebastian
1996 Population Aggregation in the Prehistoric North American Southwest. *American Antiquity* 61:597–602.
Kohler, Timothy A., Mark D. Varien, Aaron Wright, and K. A. Kuckelman
2008 Mesa Verde Migrations. *American Scientist* 96(2):146.
Kowalewski, Stephen A.
2001 Coalescent Societies. Paper presented at the 58th Annual Southeastern Archaeological Conference, Chattanooga, Tennessee.
Kruse, Melissa
2005 The Agricultural Landscape of Perry Mesa, Central Arizona. Unpublished Master's thesis, Arizona State University, Tempe.
2007 The Agricultural Landscape of Perry Mesa: Modeling Residential Site Location in Relation to Arable Land. *Kiva* 73(1):85–102.
LeBlanc, Steven A.
1999 *Prehistoric Warfare in the American Southwest.* University of Utah Press, Salt Lake City.
2006 Warfare and the Development of Social Complexity: Some Demographic and Environmental Factors. In *The Archaeology of Warfare: Prehistories of Raiding and Conquest*, edited by Elizabeth N. Arkush and Mark W. Allen, pp. 437–468. University Press of Florida, Gainesville.
LeBlanc, Steven A., and Glen E. Rice
2001 Southwestern Warfare: The Value of Case Studies. In *Deadly Landscapes: Case Studies in Prehistoric Southwestern Warfare*, edited by Glen E. Rice and Steven A. LeBlanc, pp. 1–18. University of Utah Press, Salt Lake City.
Lee, Everett S.
1966 A Theory of Migration. *Demography* 3:47–57.
Leonard, Robert D., and Heidi E. Reed
1993 Population Aggregation in the Prehistoric American Southwest: A Selectionist Model. *American Antiquity* 58(4):648–661.
Levitt, J.
1980 *Responses of Plants to Environmental Stresses.* Vol. 2. Academic Press, New York.
Lipe, William D.
1995 The Depopulation of the Northern San Juan: Conditions in the Turbulent 1200s. *Journal of Anthropological Archaeology* 14:143–169.
Longacre, William A.
1966 Changing Patterns of Social Integration: A Prehistoric Example from the American Southwest. *American Anthropologist* 68(1): 94–102.
Martin, Paul S., and Christine R. Szuter
1999 War Zones and Game Sinks in Lewis and Clark's West. *Conservation Biology* 13(1): 36–45.
Meko, David, Edward R. Cook, David W. Stahle, Charles W. Stockton, and Malcolm K. Hughes
1993 Spatial Patterns of Tree-Growth Anomalies in the United States and Southeastern Canada. *Journal of Climate* 6(9):1773–1786.
Miller, Robert Rush
1954 A Drainage Map of Arizona. *Systematic Zoology* 3(2):81.
Minnis, Paul E.
1985 *Social Adaptation to Food Stress: A Prehistoric Southwestern Example.* University of Chicago Press, Chicago.
Muenchrath, Deborah A., and Ricardo J. Salvador
1995 Maize Productivity and Agroecology: Effects of Environment and Agricultural Practices on the Biology of Maize. In *Soil, Water, Biology, and Belief in Prehistoric and Traditional Southwestern Agriculture*, edited by H. S. Toll, pp. 303–333. Special Publication, Vol. 2. New Mexico Archaeological Council, Albuquerque.
National Climatic Data Center
2006 Mean Length of the Freeze Free Period, Gis Data for Arizona. Electronic document, http://www.ncdc.noaa.gov/oa/ncdc.html, accessed July 2006.
2009 U.S. Division Data. Electronic document, http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.htm, accessed May 2009.
2010 Historic Normals. Electronic document, http://lwf.ncdc.noaa.gov/oa/climate/normals /usnormalshist.html, accessed May 2010.
Orcutt, Janet D.
1991 Environmental Variability and Settlement Changes on the Pajarito Plateau, New Mexico. *American Antiquity* 56:315–332.
Ortiz, Sutti
1979 Expectations and Forecasts in the Face of Uncertainty. *Man* 14(1):64–80.
Plog, Fred, George J. Gumerman, Robert C. Euler, Jeffrey S. Dean, Richard H. Hevly, and Thor N. V. Karlstrom
1988 Anasazi Adaptive Strategies: The Model, Predictions, and Results. In *The Anasazi in a Changing Environment*, edited by George J. Gumerman, pp. 230–276. Cambridge University Press, Cambridge.

PRISM Climate Group, Oregon State University
2007 Average Annual Precipitation 1961 through 1990. Electronic document, http://www.prismclimate.org, accessed December 2007 through the Natural Resources Conservation Service, National Geospatial Dataset, http://www.ncgc.nrcs.usda.gov/.
2010 Prism Climate Group. Electronic document, http://www.prismclimate.org, accessed May 2010.
Rautman, Alison E.
1993 Resource Variability, Risk, and the Structure of Social Networks: An Example from the Prehistoric Southwest. *American Antiquity* 58(3):403–424.
Redman, Charles L.
1993 The Past Revisited. In *People of the Tonto Rim*, edited by Charles L. Redman, pp. 155–173. Smithsonian Institution Press, Washington, D.C.
Reid, J. Jefferson
1989 A Grasshopper Perspective on the Mogollon of the Arizona Mountains. In *Dynamics of Southwestern Prehistory*, edited by Linda S. Cordell and George J. Gumerman, pp. 65–97. Smithsonian Institution Press, Washington, D.C.
Reid, J. Jefferson, and Stephanie M. Whittlesey
1997 *The Archaeology of Ancient Arizona*. University of Arizona Press, Tucson.
Rice, Glen E.
2001 Warfare and Massing in the Salt and Gila Basins of Central Arizona. In *Deadly Landscapes: Case Studies in Prehistoric Southwestern Warfare*, edited by Glen E. Rice and Steven A. LeBlanc, pp. 289–330. University of Utah Press, Salt Lake City.
Rose, Martin R.
1994 Long Term Drought Reconstructions for the Lake Roosevelt Region. In *The Roosevelt Rural Sites Study, Vol. 3: Changing Land Use in the Tonto Basin*, edited by Richard Ciolek-Torrello and John R. Welch, pp. 311–359. Technical Series No. 28. Statistical Research, Tucson.
Salzer, Matthew W.
2000 *Dendroclimatology in the San Francisco Peaks Region of Northern Arizona, USA*. Ph.D. dissertation, University of Arizona, Tucson. University Microfilms, Ann Arbor, Michigan.
Salzer, Matthew W., and Jeffrey S. Dean
2006 Dendroclimatic Reconstructions and Paleoenvironmental Analyses for the U.S. 89 Project Area. In *Sunset Crater Archaeology: The History of a Volcanic Landscape*, edited by Mark D. Elson, pp. 103–131. Anthropological Papers No. 33. Center for Desert Archaeology, Tucson.
Salzer, Matthew W., and Kurt F. Kipfmueller
2005 Reconstructed Temperature and Precipitation on a Millennial Timescale from Tree-Rings in the Southern Colorado Plateau, USA. *Climatic Change* 70(3):465–487.
Sandor, Jonathan A., Jay B. Norton, Jeffrey A. Homburg, Deborah A. Muenchrath, Carleton S. White, Stephen E. Williams, Celeste I. Havener, and Peter D. Stahl
2007 Biogeochemical Studies of a Native American Runoff Agroecosystem. *Geoarchaeology* 22(3):359–386.
Schlanger, Sarah H.
1988 Patterns of Population Movement and Long-Term Population Growth in Southwestern Colorado. *American Antiquity* 53:773–793.
Seaber, Paul R., F. Paul Kapinos, and George L. Knapp
1987 *Hydrologic Unit Maps*. Water-Supply Paper No. 2294. U.S. Geological Survey, Denver, Colorado.
Slatter, Edwin D.
1979 *Drought and Demographic Change in the Prehistoric Southwest United States: A Preliminary Quantitative Assessment*. Ph.D. dissertation, University of California, Los Angeles. University Microfilms, Ann Arbor, Michigan.
Stark, Miriam T., Jeffery J. Clark, and Mark D. Elson
1995 Causes and Consequences of Migration in the 13th Century Tonto Basin. *Journal of Anthropological Archaeology* 14:212–246.
Steeves, Peter, and Douglas Nebert (USGS)
1994 1:250,000-Scale Hydrologic Units of the United States. Electronic document, http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml#Identification_Information, accessed May 2008.
Tainter, Joseph A., and Bonnie Bagley Tainter
1996 *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*. Santa Fe Institute Studies in the Sciences of Complexity No. 24. Addison-Wesley, Reading, Massachusetts.
The Nature Conservancy in Arizona
2004 Digital Representation of Brown and Lowe's "Biotic Communities of the Southwest" Map

(1979). Electronic document, http://azconservation.org/downloads/data/biotic_communities_of_the_southwest_gis_data/, accessed January 2005.
2006 Arizona Statewide Freshwater Assessment Gis Data Package. Electronic document, http://azconservation.org/projects/water/, accessed February 2008.

United States Geological Survey (USGS)
2009 Digital Elevation Models. Electronic document, http://earthexplorer.usgs.gov/, accessed June 2009.
2010 Water Data for the Nation. Electronic document, http://waterdata.usgs.gov/nwis, accessed March 2010.

Upham, Steadman
1982 *Polities and Power: An Economic and Political History of the Western Pueblo.* Academic Press, New York.

Van West, Carla R., and Jeffrey H. Altschul
1994 Agricultural Productivity and Carrying Capacity in the Tonto Basin. In *Roosevelt Rural Sites Study, Vol. 3: Changing Land Use in the Tonto Basin*, edited by R. S. Ciolek-Torrello and J. R. Welch, pp. 361–435. Technical Series No. 28. Statistical Research, Tucson.

Van West, Carla R., Richard S. Ciolek-Torrello, John R. Welch, Jeffrey H. Altschul, Karen R. Adams, Steven D. Shelley, and Jeffrey A. Homburg
2000 Subsistence and Environmental Interactions. In *Salado*, edited by Jeffrey S. Dean, pp. 27–56. Amerind Foundation Publication. University of New Mexico Press, Albuquerque.

Van West, Carla R., and Jeffrey S. Dean
2000 Environmental Characteristics of the AD 900–1300 Period in the Central Mesa Verde Region. *Kiva* 66(1):19–44.

Varien, Mark D., William D. Lipe, Michael A. Adler, Ian M. Thompson, and Bruce A. Bradley
1996 Southwestern Colorado and Southeastern Utah Settlement Patterns: AD 1100 to 1300. In *The Prehistoric Pueblo World, AD 1150 to 1350*, edited by Michael A. Adler, pp. 86–113. University of Arizona Press, Tucson.

Varien, Mark D., Scott G. Ortman, Timothy A. Kohler, Donna M. Glowacki, and C. David Johnson
2007 Historical Ecology in the Mesa Verde Region: Results from the Village Ecodynamics Project. *American Antiquity* 72(2):273–299.

Wallace, Henry D., and William H. Doelle
2001 Classic Period Warfare in Southern Arizona. In *Deadly Landscapes: Case Studies in Prehistoric Southwestern Warfare*, edited by Glen E. Rice and Steven A. LeBlanc. University of Utah Press, Salt Lake City.

Western Regional Climate Center (WRCC)
2010 Historical Climate Information. Electronic document, http://www.wrcc.dri.edu/, accessed January 2010.

Whyte, Anne V. T.
1985 Perception. In *Climate Impact Assessment—Studies of the Interaction of Climate and Society*, edited by Robert W. Kates, Jesse H. Ausubel, and Mimi Berberian. John Wiley, Chichester, U.K.

Wiessner, Polly
1982 Beyond Willow Smoke and Dogs' Tails: A Comment on Binford's Analysis of Hunter Gatherer Settlement Systems. *American Antiquity* 47:171–178.

Wilcox, David R.
1981 Changing Perspectives on the Protohistoric Pueblos, AD 1450–1700. In *The Protohistoric Period in the North American Southwest, AD 1450–1700*, edited by David R. Wilcox and William B. Masse, pp. 378–409. Anthropological Research Paper No. 24. Arizona State University, Tempe.
2005 Perry Mesa and Its World. *Plateau* 2(1): 24–35.

Wilcox, David R., William H. Doelle, J. Brett Hill, and James P. Holmlund
2003 Coalescent Communities GIS Database: Museum of Northern Arizona, Center for Desert Archaeology, Geo-Map, Inc. On file, Center for Desert Archaeology, Tucson.

Wilcox, David R., David A. Gregory, and J. Brett Hill
2007 Zuni in the Puebloan and Southwestern Worlds. In *Zuni Origins: Toward a New Synthesis of Southwestern Archaeology*, edited by David A. Gregory and David R. Wilcox, pp. 165–209. University of Arizona Press, Tucson.

Wilcox, David R., and Jonathan Haas
1994 The Scream of the Butterfly: Competition and Conflict in the Prehistoric Southwest. In *Themes in Southwest Prehistory*, edited by G. J. Gumerman, pp. 211–238. School of American Research Press, Santa Fe.

Wilcox, David R., and James P. Holmlund
2007 *The Archaeology of Perry Mesa and Its World.* Occasional Papers No. 3. Bilby Research Center, Northern Arizona University, Flagstaff.

Wilcox, David R., Gerald R. Robertson Jr., and J. Scott Wood
2001a Antecedents to Perry Mesa: Early Pueblo III Defensive Refuge Systems in Western Central Arizona. In *Deadly Landscapes: Case Studies in Prehistoric Southwestern Warfare*, edited by Glen E. Rice and Steven A. LeBlanc, pp. 109–140. University of Utah Press, Salt Lake City.
2001b Organized for War: The Perry Mesa Settlement System and Its Central Arizona Neighbors. In *Deadly Landscapes: Case Studies in Prehistoric Southwestern Warfare*, edited by Glen E. Rice and Steven A. LeBlanc. University of Utah Press, Salt Lake City.

Winterhalder, Bruce
1986 Optimal Foraging: Simulation Studies of Diet Choice in a Stochastic Environment. *Journal of Ethnobiology* 6:205–223.