our gratitude for having assembled these wide-ranging essays. They offer es on a topic that could hardly be more important for humanity—but which has matic attention than it merits. Let's hope this book will raise awareness of these , and thereby help ensure a safer world." nomer Royal, University of Cambridge, and Centre for the Study of Existential Risk

ieties crash or reinvent themselves? Can we learn from that? History rhymes. For the search for patterns, this book is a treasure trove."

Wageningen University and Santa Fe Institute

ne on collapse presents twenty original contributions from some of the best The chapters explore collapse theory, case studies on individual historical ings might change for humanity in the future. Collapse is considered from es: theoretical, historical, ecological, and modeling, providing an important duction. It will keep the increasingly important debate on collapse and spotlight for some time to come."

, University of Newcastle upon Tyne

nts the impacts of globalization and global systemic risks—such as financial ange, and epidemics—what can studies of the past tell us about our present. lds Collapse offers case studies of societies that either collapsed or overcame The authors in this volume find commonalities between past civilizations and acing patterns, strategies, and early warning signs that can inform decisiontoday's world presents unique challenges, many mechanisms, dynamics, and es to the foundations of civilization have been consistent throughout history lessons for the future.

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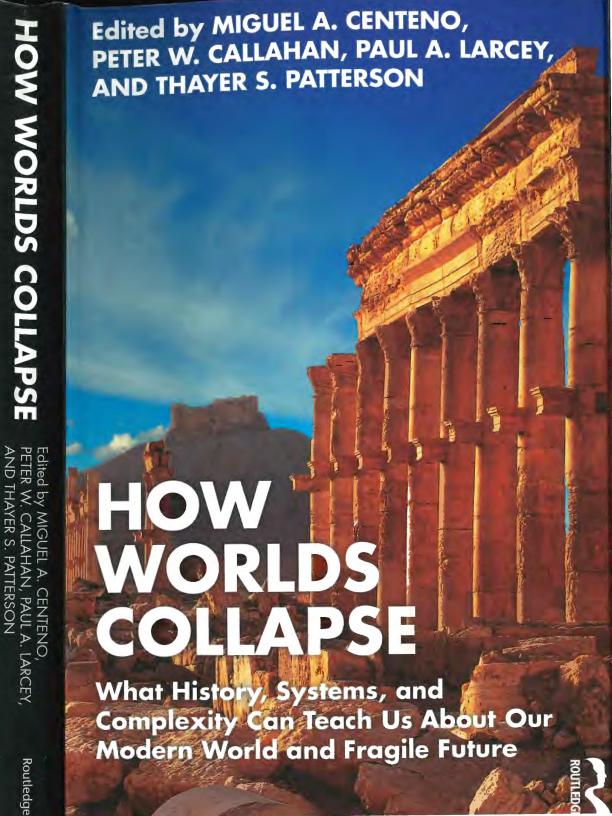
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THAYER S.





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Fluctuat Nec Mergitur

Seven Centuries of Pueblo Crisis and Resilience

Timothy A. Kohler, R. Kyle Bocinsky, and Darcy Bird

8.1 Introduction

Perhaps one-quarter of the world's people-mostly in Latin America and Africa—support themselves as small-holder (subsistence) farmers (Rapsomanikis 2015). The directed climate change of the Anthropocene, unless mitigated, will cause many of the areas they currently inhabit to be hotter in 50 years than almost any area on the surface of the planet today (Xu et al. 2020). If their farms fail, will there be massive demand for immigration into the temperate, developed world? It is helpful to have some knowledge about how past episodes of climate change—even if not driven by human-generated greenhouse gases—affected small-scale farmers in the past. Because of its high temporal resolution and depth of study, the prehispanic history of the Upland US Southwest (UUSS, as defined in Bocinsky et al. 2016) provides a key case for understanding how pre-Anthropocene climatic variability affected small-scale farming societies in semi-arid environments,1 and how such variability interacted with social dynamics to produce outcomes that varied from resilience, to collapse.

Previous work (especially in the heavily researched central Mesa Verde region) has clearly demonstrated that climate variability affected production of dry-farmed maize (corn) in this area in the two millennia prior to the sixteenth-century Spanish conquest and colonization (Van West and Dean 2000). Until about 1300,² most agriculture in the UUSS was rain fed, and in addition to topographic variability that entrains orographic differences in precipitation, there is considerable variability from year to year in the amount of precipitation falling in any single area. Already by the first millennium BCE, maize constituted the main staple, and that increased to the point where it was providing up to 90% of the calories by the 1200s (Matson 2016). The landraces grown by the Puebloan peoples in the UUSS were selections derived from ancestors growing in tropical subhumid portions of south-central Mexico (Buckler and Stevens 2006), suggesting that both temperature and precipitation may have been limiting in the UUSS. Prehispanic dry farmers selected fairly narrow elevational subsets of the available region, also suggesting their crops were susceptible to variability in precipitation and temperature. Production levels

of maize affected local Puebloan population size through both birth rates and mobility, including habitat tracking (Schwindt et al. 2016).

The northern portion of the UUSS is sometimes called the "Four Corners" eince Colorado, New Mexico, Arizona, and Utah meet in this portion of the Colorado Plateau. We will alternately consider the UUSS (our largest context) and three subsets of it: the Four Corners, the central Mesa Verde (CMV) region it contains, and the northern Rio Grande (NRG) region, slightly off the Colorado Plateau and southeast of the CMV (Figure 8.1). Andrew E. Douglas (1929) suggested that drought limiting or precluding successful farming in the late 1200s provoked the famous departure of all farmers from the northern IJS Southwest toward the NRG and other areas to the south. The main goal of this chapter is to review the status of that hypothesis-much debated and refined over the last three decades.

For almost two decades, the Village Ecodynamics Project (VEP) has examined how climate, landscape, and people co-produced the northern Pueblo societies in the centuries prior to the appearance of the Spanish (Kohler and Varien 2012). The VEP concentrated on two study areas, VEPIIN (in the CMV) and VEPIIS (in the NRG) (Figure 8.1). Here we rely on our findings from that project, in addition to other research, to paint a general picture (in

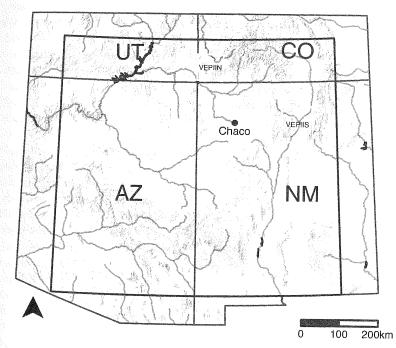


Figure 8.1 The four states containing the Upland US Southwest (UUSS, black box), the VEPII study areas (white boxes), and Chaco Canyon.

Background) which we dissect and discuss in the third section. In the end We will be interested not just in the single collapse episode of the late 1200s, but in weaving a much longer account of the relationships of climate and social dynamics in this time and place. In the end, determining cause and effect requires lots of data subjected to statistical modeling and detailed temporal analyses and replication. Archaeology cannot do this as convincingly as any experimental science, but this particular case allows us to go further down this path than is typical for archaeology. Much of the relevant work is done here by citation, given length restrictions. We try to concentrate first on establishing the big picture, and second, on identifying the main internal (social) and external (climate, non-Pueblo peoples) factors driving the dynamics of interest to this volume.

8.2 Background

Maize is a main actor in our story, like Shiva both as creator and destroyer. Though animal protein, beans, and a wide diversity of other foods of course supplemented the diet, the remarkable population growth typifying much of the two millennia before the arrival of the Spanish was largely made possible by maize (Kohler and Reese 2014). By the late 1900s, maize farmers were colonizing large portions of the central and northern portions of Utah (Richards 2022). On the other hand, these increasing populations became increasingly susceptible to climatic variability by depressing various slowly renewing biotic resources for food, fuel, and construction, locking in reliance on highly variable maize crops and entraining competitive violence contributing to aggregation (Kohler 2012a: table 15.1). By early in the second millennium, population had grown to the point where an increasing number of farmers could not be accommodated in the areas that were most favorable for dry farming. Living in compact villages that by the mid-1200s were sometimes perched in locations that were difficult to access in turn made access to fields more costly.

Of course, the hunter-gatherers in Southwestern Mexico who began to select seeds from highly variable teosinte populations, maize's wild ancestor, more than 7500 years ago (Piperno and Flannery 2001; Piperno et al. 2009) could have foreseen none of this. The maize eventually resulting from their efforts and those of their descendants arrived in the US Southwest by 2100 BCE as a small-eared, small-kernel variety of probably low yield (Diehl 2005).

Although maize cultivation spread throughout many portions of the UUSS during the first millennium BC, including into the NRG, for reasons that are not yet clear farmers did not heavily colonize the CMV until shortly before 600. This might be due to the lack of a maize suitable for the cooler uplands that characterize most of the CMV, in conjunction with the probability that the UUSS was generally cooler in the first half of the first millennium, than from 600 to 1300 (Viau et al. 2012: Figure. 8.3). In any case, populations grew rapidly throughout the Southwest, though slightly more slowly in lowland desert areas where water management was required to grow maize. In the

Southwest as a whole, the rate of population increase likely peaked between 500 and 1000. Population size in the prehispanic Southwest likely peaked in the twelfth or thirteenth century (Dean et al. 1985; Hill et al. 2004; Kohler and Reese 2014).

By the mid-1920s, archaeologists had conducted enough research to pronose a Southwest-wide stage taxonomy (Kidder 1927). Today this is applied only to the northern upland ("Pueblo") portions of the Southwest, which does not include the irrigated desert areas where the Hohokam tradition developed, or the areas south of the Pueblo tradition surrounding those deserts where the Mogollon tradition developed. This taxonomy—known as the Pecos periods since this scheme was hammered together at what is today Pecos National Historical Park—recognized three Basketmaker periods, BMI-III (the first of which is no longer used), and five Pueblo periods (PI-V, where PV postdates contact with the Spanish). These were defined on the basis of relatively internally coherent "diagnostic culture traits" including ceramics, lithics, architecture, and settlement size and layout. In 1927 these periods could already be put into their correct relative sequence, but it would be two years before Douglass and his colleagues were able to cross-date beams permitting an absolute chronology back to 700 (today of course extending much earlier).

At a very high-level overview from BMII to PIV, long-term trends in the Pueblo area can be identified for increasing aggregation, leading to larger settlements. This aggregation, in conjunction with the pattern of dwelling placement, likely signals a gradual reduction in autonomy for households, as first corporate kin groups and later, larger social groupings took on more prominence (Lipe and Hegmon 1989; Rohn 1977; Steward 1937). Household activities came increasingly under the influence of wider social demands that were at once religious/ceremonial, political, and economic in nature (see, e.g., Gumerman and Gell-Mann 1994).

From a closer perspective though various discontinuities become prominent. These include, in the PI period, an early episode of village growth and collapse from the late 700s to the early 900s in the northern Southwest (Wilshusen et al. 2012; Kohler and Reed 2011). These exploited a full Neolithic package of well-adapted domesticates, Colorado Plateau-appropriate farming and building technologies, and increasingly complex forms of supra-household organization needed for larger sedentary communities. In late PI, an unpromisinglooking canyon in northwestern New Mexico hosted the rise of the Chaco regional system which in PII, from about 1030 to 1140, spread its distinctive Great House architecture and settlement pattern throughout much of the northern and eastern Southwest (Lekson 2006). This system partially collapsed amid drought in the mid-1100s, but elements of its operation continued from more northerly centers near the San Juan River, close to the present border between Colorado and New Mexico (Reed 2008). Interpretations of how Chaco worked vary widely, but the present authors, and perhaps most other southwesternists, consider it to have been underlain by the most politically and religiously hierarchical society in the prehispanic Southwest. Not surprisingly

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these features were coupled with the most pronounced degree of wealth inequality seen in the Pueblo Southwest (Ellyson et al. 2019).

Other than the catastrophe of Spanish colonization beginning in the late 1500s, though, the most spectacular discontinuity in the Pueblo area is the late PIII (mid/late 1200s) depopulation of large portions of the upland Southwest. This included the Four Corners, encompassing the CMV. By 1285 there were no farmers left in the northern Southwest, even though 40 years earlier more than 25,000 people lived in the VEPIIN area alone (Schwindt et al. 2016). As the northern Southwest was depopulated, population grew commensurately in the NRG (Ortman 2014). Destinations for farmers leaving more westerly portions of the northern Southwest included locations near the present Pueblo of Hopi in northeastern Arizona (Dean 2010; Clark et al. 2019).

Life in the post-1300s Southwest, especially in the NRG, was dramatically different than it had been in the north. Water-managed farming became more common, mitigating some of the variability in maize production that had previously contributed to conflict (Kohler et al. 2014). Towns take over from villages as the largest settlements, forming around spacious plazas serving various social activities presumably including dances, other ceremonies, and probably periodic markets (Kohler et al. 2004) fueled by increasingly productive specialization and interethnic exchange (Ortman 2019). Ortman and Lobo (2020) argue that agglomeration effects markedly improved material living standards in NRG towns compared with earlier villages in the same area. It must also be noted though that across the Southwest after 1300, life expectancies at 15 years of age and crude birth rates were both in steep decline (Kohler and Reese 2014), possibly reflecting unsolved public health issues in these settlements (Phillips et al. 2018) and limited options for excess offspring to colonize new areas that had typified much of the previous millennium. Post-1300 towns in the NRG were an order of magnitude larger than the largest pre-1300 villages in the CMV (which topped out at about 100 households or 500 people) though the total area occupied by post-1300 Pueblo peoples was dramatically smaller than in the PII period.

Archaeologists agree that the causes for the depopulation of the northern Southwest include climate variability negatively affecting maize production. There is little agreement though as to whether this was itself sufficient to have caused such a massive rupture, which not only moved thousands of families but caused the loss of a large number of distinctive artifact and structure types, architectural practices, and settlement and community patterns (Lipe 2010). Other contributing factors can easily be adduced, but it is difficult to assign them a relative weight. Mark Varien (2010) notes that in addition to climatic variability, human impact on the environment, warfare, and disease have long been invoked as causal factors. These other factors may indeed have played important roles, though at present there is no hard evidence for disease as a factor in the depopulation. Katherine Spielmann and colleagues (2016) note that the depopulation of the CMV was preceded by the appearance and spread of new forms of ceremonial structures that they interpret as

evidence for factionalism (following Glowacki 2015). In the next section we suggest an approach to help distinguish between social crises precipitated by such internal factors, versus those more connected to external drivers such as climatic variability. First though it is useful to put the 1200s in the northern Southwest into a larger climatic context that includes temperature as well as precipitation.

Even though analyses of tree-ring widths (or in a few cases, wood-density measurements) provide the best high-frequency paleoclimatic reconstructions for the UUSS (Van West and Dean 2000), such reconstructions may underestimate long-term trends in temperature (Cook et al. 1995). Pollen analysis on the other hand is useful for understanding low-frequency changes in climate that cause spatial shifts in the abundance of plants and the amount of pollen they produce. In Southwest Colorado, ratios of spruce pollen to ponderosa pine pollen were in decline after about 1150, falling below the long-term mean from about 1220 until 1390. Wright (2010) interprets this ratio as a temperature proxy, though Benson and colleagues (2013) point out that increases in spruce may alternatively reflect increased precipitation. More recent analyses of pollen frequencies, using the Modern Analog Technique which escapes the potential weaknesses of reconstructions based on ratios of two species from one or a small number of sites, demonstrate decreased mean temperature of the warmest month between about 1100 and 1600 for a large "Desert" region that includes the UUSS (Viau et al. 2012). High-frequency temperature reconstructions for the Four Corners area summarized by Wright (2010: fig. 14.3) suggest that the first two decades of the 1200s were especially cold. A recent tree-ring-based spatial reconstruction of temperature in the northern hemisphere shows temperatures were below the long-term mean from 1262 to 1351 for the UUSS, with the completion of the 1285 depopulation corresponding to a nadir (Figure 8.2C) (Anchukaitis et al. 2017).

8.3 Analysis and Synthesis

In the early 1980s archaeologist Michael Berry noticed that the accumulated population of tree-ring samples from archaeological sites throughout the Southwest (i.e., the UUSS as used here) contained several prominent frequency peaks in cutting activity that roughly corresponded to the middle portions of periods BMIII-PIV (Berry 1982). He attributed these construction peaks to wetter periods in which farmers in this semi-arid landscape would be thriving, growing in numbers, and building, though the independent measure of drought he was able to muster did not clearly establish this correlation (Berry 1982: fig. 13).

While suspicions linger that these distributions of tree-ring-dated samples contain sampling biases (Nash 2021), more recent analyses with larger databases, augmented by cultural resource management (CRM) work in which investigator bias is less likely, largely show the same pattern noted by Berry. Using the then-current version of these data, Bocinsky and colleagues (2016)



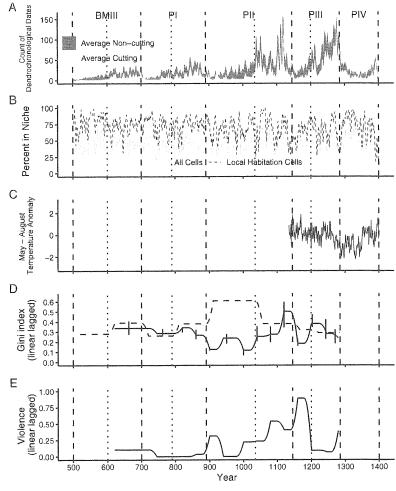


Figure 8.2 Changes in tree-cutting, availability of productive dry-farming plots, history of summer temperatures, wealth inequality, and violence in the UUSS or its subsets. Panels A-C use a 4-year linear smooth plotted on the 4th year; panels D-E use a 21-year linear smooth plotted on the 21st year. A: Stacked histogram of cutting dates + near cutting dates, and non-cutting dates, after Bocinsky et al. (2016: fig. 8.2a); spatial scope, UUSS. B: Percent of cells in dry-farming niche; "All cells" represent the entire UUSS; "Local Habitation cells" are only those with a tree-ring date in the plotted year or any of the previous 3 years, and were therefore demonstrably occupied during the plotted years; after Bocinsky et al. (2016: fig. 8.2c); spatial scope, UUSS. C: Temperature-field reconstruction applicable to the northern portions of the UUSS (Anchukaitis et al. 2017); D: Gini index; spatial scope, dashed line, northern portions of UUSS (see text), after Ellyson et al. (2019): table 2; solid line, CMV, with 80% confidence interval shown with vertical lines. E: Proportion of skeletal remains exhibiting violent trauma, after (Cole 2012); spatial scope, CMV, and adjacent areas to the west. Periods of Exploration and Exploitation after Bocinsky et al. (2016).

proposed that the prehispanic macrohistory of the UUSS between 500 and 1285 can be interpreted as containing four periods of "Exploration" averaging 98 years in length, each followed by a period of "Exploitation" averaging 99 years in length. Exploration periods contain relatively few tree-ring dates overall (Fig. 8.2A), and these come from relatively small, dispersed clusters of sites and contain relatively high proportions of non-cutting dates among the tree-ring samples. Exploitation periods on the other hand contain more dates overall, more cutting dates among those, and the sites from which they were obtained show strong and significant spatial clustering.

The really intriguing thing about this way of looking at the UUSS, though, is that the ends of these periods of Exploitation happen to coincide with the ends of the BMIII, PI, PII, and PIII periods devised almost a century ago to mark internally cohesive patterns of architecture and artifacts. It's important to reemphasize that the definition of the boundaries for the periods of Exploration/ Exploitation was based solely on characteristics of the types, frequencies, and spatial distributions of the archaeological tree-ring records, so this coincidence needs some explaining. We think the periods of Exploitation emerged when combinations of locations, growing conditions, and organization (including local and regional political and religious leadership) successfully converged to allow populations and settlements to grow and thrive (Kohler and Bocinsky 2017). Broadly shared understandings and common purposes must have underlain these episodes. As these periods came to a close (for reasons we'll be exploring), populations tended to disaggregate, explore new settlement locations, and build less (or at least produced fewer tree-ring dates overall, including fewer cutting dates). These were the periods of Exploration. The dotted lines in Figure 8.2E separate the Pecos periods into subperiods of Exploration and Exploitation.

Bocinsky and Kohler (2014) devised an estimator for the spatial and temporal distribution of the maize dry-farming niche based on 205 tree-ring chronologies developed for paleoclimatic research. This estimator determines whether any plot of land in the UUSS got enough precipitation, and was warm enough, to produce a maize crop in any year. These estimates are spatialized at a scale of a little under 1 km², created separately for each of 691,200 such cells within the UUSS. When summed and averaged across space for each year, they show, contra Berry (1982), that on average the periods of Exploitation were no better for maize production than were the periods of Exploration, at least in terms of the size of the maize dry-farming niche. The periods of Exploitation though do typically end in or near times when the maize niche was significantly constricted (Figure 8.2B).

These terminations, around 700, 890, 1145, and 1285, also seem to be points of social crisis. First, the VEPIIN area suffers population declines ca. 890 and 1145 and was completely depopulated by 1285 (Schwindt et al. 2016: fig. 3). Temporal resolution is insufficient to resolve whether there was also a decline ca. 700.

Second, another very direct measure of crisis is interpersonal violence. Figure 8.2E displays the incidence of skeletal remains bearing signs of violent trauma through time (Cole 2012). Sarah Cole derived this series from published and gray literature reporting excavations in and around the VEPIIN (CMV) area. As Fig. 8.2E shows, at least the last three of the four terminations of periods of Exploitation also coincide with peaks in violence.³

Third, another possible indicator of crisis is the history of wealth inequality. Walter Scheidel (2017) has argued that "normally functioning" societies tend to exhibit stable or slowly increasing degrees of wealth inequality, and that only major crises such as widespread conflict or pandemics have the power to decrease wealth inequality. We estimate wealth inequality using a Gini coefficient based on house-size distributions as explained by Kohler and Higgins (2016). Figure 8.2D, derived from recent work by Laura Ellyson and colleagues (2019), 4 shows two series. That for just the CMV can be plotted at a higher temporal resolution, and indeed shows the expected declines at the three later crisis points noted above. As with violence, lower temporal resolution early in this series makes it unclear whether there was also a decline ca. 700.

In a recent paper that focused exclusively on the VEPIIN area, Kohler and colleagues (2020) examined the statistical relationships among wealth inequality, violence, degree of aggregation, momentary population size, maize production per capita, and several other relevant variables.⁵ This was motivated in part by frustration in seeing archaeologists assert the existence of relationships between climatic variability and social transformations with no statistical proof (Kohler and Rockman 2020). Another motivation was the difficulty of finding statistical support for particular episodes of crisis considered individually. Keith Kintigh and Scott Ingram (2018) examined 11 transitions of various types throughout the Southwest, including the depopulation of the CMV between 1250 and 1300. They used a sophisticated procedure to evaluate whether each transition could be directly connected with drought (or in some cases, decrease in the size of the maize farming niche). They showed that not one of the cases examined could be significantly associated with drought using their approach, even though they admit that there are highly plausible arguments that some of these transitions were in fact related to climatic variability.

To go beyond these sorts of problems with "one-shot hypotheses" Kohler and colleagues (2020) examined the entire series (not just one episode) from VEPIIN, starting in the 600s up to 1280, dividing it into 25 temporal snapshots taken every 25 years. Some of the statistically significant conclusions we drew relevant to the problems here are that violence goes up as climatically controlled average production per capita goes down across time slices. Low production per capita also leads to high violence in the next time slice. Moreover, high wealth inequality in one time slice leads to high violence in the next time slice. Somewhat oddly the inverse is also true: high violence in one time slice leads to high wealth inequality in the next time slice. This relationship—it's not quite a contradiction—seems to arise because, through time, this sequence tends to exhibit alternating periods of high wealth inequality, and high violence (compare the solid line in Figure 8.2D with 8.2E).

To summarize then, it might seem that climate variability decreasing the cize of the maize niche, or reducing maize production, has a clear role in causing several classic indicators of crisis: population decline, increases in violence, and declines in wealth inequality.6 While we believe this to be true, a close inspection of the relationship between the Exploitation terminations and the maize-niche size history in Figure 8.2B reveals that although each of these terminations does coincide with a niche constriction, there are other constrictions that do not cause terminations. For example, the end of PII (and its Exploitation period) in 1145 was clearly a time of very poor production, but not markedly worse than the downturn ca. 1100 that did not seem to have had widespread or long-lasting effects. So the relationship between niche constriction and period termination is imperfect, statistically speaking.

Why do some roughly equivalent climatic crises cause major upheavals (including steep declines in construction, decreases in wealth inequality, and violence) while others do not? Marten Scheffer and colleagues (2021) address this question through an analysis of the database of archaeological tree rings from the UUSS, drawing on theory developed in Scheffer et al. (2012) and elsewhere. One symptom of a social system that is losing resilience is a phenomenon called "critical slowing down," commonly thought to be an early warning signal of impending system collapse. Imagine a ball in a two-dimensional valley that readily returns to its lowest point on perturbation.⁷ This is the image of a resilient system. But if the hills on either side of the valley were to decrease in slope, the ball would take longer to return to the low point. A probe that tracked the location of the ball at high frequency would find that there is a stronger temporal autocorrelation in the ball's location in the second system than in the first. This is the phenomenon of critical slowing down. Essentially the system has a stable state, or status quo, in which it operates, and perturbations knock the system from this status quo. As a system experiences increased fragility over time, it will take longer to recover from these perturbations, and this increasingly delayed recovery period is known as critical slowing down.

Scheffer et al. (2021) identify increased critical slowing down in the time series of cutting dates over the duration of each of the BMIII, PI, PII, and early PIII periods using the mounting lag-1 temporal autocorrelation of tree-cutting activity that they demonstrate in each of these periods. But late PIII is different: it begins with very poor maize-growing conditions and a dramatic decrease in construction activity, which is followed by a temporary climate amelioration followed by full-scale emigration from the area as conditions again worsen. Notably, late PIII did not experience increased temporal autocorrelation or variance (another symptom of decreased resilience) in the detrended time series, unlike the four earlier periods, suggesting that this termination was highly anomalous.

What might cause this critical slowing down in the sorts of societies in question? The most likely candidate is some process that slowly mounts on time scales of decades, but is brought to a head by a climatic downturn. A leading

possibility we believe is that growing inequality over the course of the periods of Exploitation, as villages grew in size, led to mounting dissatisfaction which eventually resulted in loss of legitimacy for leadership when a crisis did develop. precipitating departures from existing villages and the collapse of their local and regional systems. Although it is sometimes assumed that the balanced reciprocal relationships that likely structured exchanges among non-kin in such societies (Sahlins 1972) result in fairly equal distributions of wealth, in fact there is no reason that the comparative advantages of more productive farming plots, held within lineages in stable sedentary systems by the founders of a village would not result in differences in lineage size over just a couple generations, Such labor advantages would further multiply productive differences between first and later arrivers, leading to substantial material and embodied wealth differences among lineages such as those driving patron-client relationships (Smith and Choi 2007) unless other leveling mechanisms were in place. Other processes could also mount on the scale of decades as the villages that typify periods of Exploitation grew in size, including depletion of slowly renewing resources such as fuelwood and large game, and increasing distance to fields. We suggest that such material inconveniences in the context of mounting inequalities contributed to social frictions and increasing dissatisfaction with the status quo, needing only a proximate crisis to light the fuse.

There is an old argument in Southwestern archaeology about whether the periodic crises that confronted Pueblo societies were fundamentally social (endogenous) or climatic/environmental (exogenous). What we are suggesting is that slow processes—both material and social in nature if we are correct repeatedly set up pre-1300s Pueblo societies for transformations that were then triggered by climatic events. So we think the correct answer to this old question is, "both."

What are we to make of the fact that the most radical transformation of all, the late PIII depopulation, came to its dramatic climax with no signs of mounting social fragility in the autocorrelation metric developed through construction activity? The clear implication is that this crisis was unique in being fundamentally exogenous in nature. This elevates the prime suspect to be deleterious climate change, quite possibly in conjunction with turmoil caused by (or exacerbated by) the infiltration of hunting-gathering people into the northern Pueblo area. We know from a large body of perishable materials from the Promontory Caves firmly (and recently) dated to the 1250-1290 interval, with numerous items that can be unambiguously linked to the Dene (Diné), that these populations were no further than a few hundred miles to the north (and quite possibly closer) by the time the depopulation was commencing ca. 1250 (Ives 2020). These highly mobile peoples were likely armed with recurved bows which were much more powerful than the self-bows of the contemporary Pueblo peoples.

The demographic dimensions of the quasicycles we have documented above have not gotten the attention they deserve. Figure 8.3 is made by differencing the two lines shown in Figure 8.2B. In that panel, the bottom

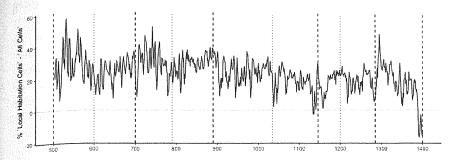


Figure 8.3 Declining freedom in the choice of farmable plots through time, UUSS. This line is made by subtracting the percentage of all cells in the dry-farming niche from the percentage of inhabited cells that are in the dry-farming niche. Decreasing percentages suggest mounting constraints on the ability to find unclaimed farmable land.

line ("All cells") represents the percent of cells in the entire UUSS that are within the maize-growing niche in the current year or any of the previous three years. The line for the "Local Habitation cells" plots the percent of cells having a tree-ring date in the plotted year or any of the previous three years that are in the maize-growing niche. These are therefore demonstrably occupied. Early on, through most of the 500s-700s, the difference between these two lines is quite large, indicating that people were almost always able to select a location within the maize niche, even when the "average cell" in the population of cells is not within that niche. However there is a long-term trend beginning in the mid-700s for the difference between these two lines to decrease.

To be clear, these percentages have different denominators, so when the line in Figure 8.3 is at zero that does not mean, in any straightforward way, that farmers could not find any locations in the niche. The line in Figure 8.3 responds to four main signals. First, there's a strong climatic signal of course, that is mostly purely recorded in the "All Cells" line in Figure 8.2B. Second, growth in population could claim most or all the cells in the niche, constraining marginal populations to settle for locations outside the niche, lowering the line. Third, the process of aggregation could allow choices of places to live that were not necessarily in the niche, even though fields accessible from the village were in the niche. Finally, increased use of water management through time could free farmers from having to live where precipitation made dry farming possible, though adequate temperatures would still be required.

This last factor likely contributes to the extremely low values that Figure 8.3 reveals for the late 1300s (though this was also a period of niche constriction). But the declines prior to the 1300s have to be explained, mainly, by some mixture of the first three processes. We suspect that most of this signal is due to the joint effects of climatic variability and population growth. If this is true, it helps explain why the crises at ca. 700, 890, 1145, and 1285 were increasingly severe: they scaled with the sizes of the contemporaneous population. We'll return to this point in our final section.

This analysis raises a number of interesting culture-historical questions that cannot be systematically addressed here. A leading puzzle is why the large est scale of analysis we undertake in this paper has any coherence whatsos ever. The UUSS is a very large area that contains many subareas that are traditionally treated separately by archaeologists. It is certain that there were considerable ethnolinguistic barriers within this area. Yet we see patterns in tree-cutting activity that seem to speak to some homogeneity in behaviors throughout this area.

One possible explanation might be that the tree-cutting record is severely biased—say for example, mostly made up of samples from the CMV. In fact there is a bias in that direction, but even so, the CMV samples make up only about 35% of the total population, so by themselves they cannot form these patterns. Archaeologists over the past several decades have spent a great deal of time looking for and explaining variability. In the Southwest it now seems that maybe we need to work harder on explaining long-distance similarity. We suspect that the synchrony we see is entrained by large-scale climatic variability. but this suggestion warrants further localized analyses.

One other similarity throughout the UUSS that doesn't get the attention it deserves is that it is not just the northern Southwest that loses Pueblo peoples in the late 1200s and 1300s. Large tracts further south were also depopulated as farmers concentrated in the areas surrounding the currently occupied Pueblos of Hopi, Zuni, Acoma, Laguna, and along the Northern and Middle Rio Grande. We suspect that this poorly understood phenomenon is connected with the cold temperatures and increasing presence of Dene peoples that, we suggest, also contributed to the depopulation of the northern regions in the late 1200s.

8.4 Governance and Mitigation

Until the rise of the Chaco system beginning in the mid-800s and spreading across large portions of the UUSS after about 1030, the dominant political organization throughout our area would have been provided by villages and clans structured at relatively local levels, as described by Johnson and Earle (2000:101-206). For various spatial scales but centered on the CMV, Crabtree and colleagues (2017) analyze a variety of simulated and empirical data to argue for the existence of village-spanning polities (regional systems) beginning in some areas as early as 890, centered on Chaco, expanding to include nearly all the northern UUSS until 1145. Thereafter, at least in the CMV, villagespanning polities probably continued in some form but at smaller spatial scales until the depopulation ca. 1280.

An interesting analysis (not yet done to our knowledge) would be to ask whether, within the domain of the Chaco regional system, there is evidence that this system prevented local collapses under climatic conditions that would have caused local collapses were the system not present. This would provide some insight into how Chaco actually functioned. What we can say is the period under which the lag-1 temporal autocorrelation of tree-cutting activity slowly rises, indicating increasing social fragility, takes longer in the PII (245 years) than in any other period (BMIII, 183 years; PI, 166 years; Early PIII, 58 years) (Scheffer et al. 2021). Assuming that these periods suffer climatic challenges at approximately the same rate, this seems to be a provisional measure of Chaco's robustness, suggesting that it did provide services within its domain that increased the survivability of the system as a whole.

Once again, these analyses raise interesting culture-historical points that cannot be pursued in detail here. The much lower degree of inequality in the CMV from the late 800s to the mid-1000s than among societies just to the south (Figure 8.2D) is rather startling. This has a possible connection to an argument that PI village and ceremonial life in the Dolores Archaeological Project area (a subset of the CMV) may have tended to level social differences and reinforce equality (Kohler and Higgins 2016). It can also be connected to the observation that burials in the heartlands of the Chaco regional system (Chaco in the 1000s, and Aztec in the 1200s) were female-biased whereas they were male-biased in those same periods in the CMV. This has been read as evidence that Chaco periodically raided the CMV for its women (Kohler and Turner 2006). Finally, it has been noted that in the CMV the incidence of violence can be nicely predicted from (lagged) population size until the late 900s and early 1000s, when there is an anomalous spike in violence that precedes the expansion of the Chaco regional system into the CMV by about two generations. We have suggested that this represents an early and ultimately futile resistance to Chaco expansion (Kohler et al. 2009). Put together it seems reasonable to suggest that most local communities in the CMV tended to embrace egalitarianism during PI and for the next century, successfully resisting the advances of the hierarchical Chacoan system even as (and perhaps partly because) they were targets for raiding as Chaco began to expand in the early 1000s.

8.5 Insights, Relevance, and Applicability

The societies of the Upland US Southwest in the last half of the first millennium CE and the first three centuries of the second were inordinately sensitive to climatic fluctuations affecting agricultural productivity. Downturns in production tended to increase violence and decrease local population, and construction activity, and spoil the prospects of emergent elites.

These climate effects though were filtered through societies that—we suggest—were more or less capable of shrugging off downturns so long as the participants had confidence in their leadership and felt that they were part of a shared enterprise. Over the course of each of the periods examined here except the very final one, late PIII—these feelings seem to slowly erode. We have suggested that this erosion was partly due to expanding internal social

differences, including mounting wealth inequality, that were connected with living in villages that were typically founded near the outset of periods of Exploitation. Village-spanning polities (most obviously the Chaco regional system) seem to slow this erosion, perhaps by moving food around when and where it was needed—a suggestion needing further research through isotopic compositions of food remains. Eventually though in each case a climatic crisis also causes a social crisis, bringing an end to one of the periods of Exploitation.

Following the final crisis in the northern Southwest of the mid-late 1200s and the reorganization of the early 1300s, the relationship between climate, production, violence, and inequality changed fundamentally (see contributions to Adams and Duff 2004). After that time, climatic downturns seem to no longer precipitate violence or disaggregation (Kohler et al. 2014) though the record of inequality has so far resisted analysis. There is a hopeful message for contemporary society in the eventual ability of prehispanic Pueblo societies to overcome the boom-and-bust cycles with their periodic violence that we describe above, but the costs as well have to be tallied. These included the hardships during the very difficult years of the 1200s, but also there was the transition to a very slow-growth demography (and eventually even a contraction) as post-1300 sedentary farmers learned to live in compact territories under pressure from hostile, mobile raiders.

Less hopeful perhaps for people today is the positive relationship between the severity of the Puebloan crises from 600 to 1300 and their population sizes through time. In a world approaching 8 billion people that is facing the probability of massive population displacement due to warming, a rational manager would either stop population increase or mitigate climate change, or a little of both. We also need to worry about how our population size in tandem with our extreme connectedness has the potential to allow local or regional crises to rapidly cascade into global disasters (Kemp et al. 2022).

Happily, the Pueblo peoples persist today despite all that we have recounted here—storm-tossed but never sunk—and despite the later insults by Spanish and Euro-American colonists. Perhaps that persistence provides the greatest measure of hope for societies today.

Acknowledgment

We thank Miguel Centeno and Peter Callahan of Princeton for the kind offer to participate in their symposium and this volume. This research could not have been done without our many VEP colleagues over the years, as well as a large number of other archaeologists and tree-ring scientists who for many years have contributed to the records analyzed here. We are also grateful for the insightful comments by Richard Wilshusen and Christina Grozinger on earlier drafts. We dedicate this chapter to Eric Grimm, whose contributions to comparative palynology are not as widely appreciated as they deserve.

Notes

- 1 Much of our study area, most of which lies on the Colorado Plateau, is classified today as having a cold semi-arid climate (BSk in the Köppen-Geiger classification) (Beck et al 2018). We analyze construction activity in the UUSS through the frequency of treering dates, most of which reflect construction activity. These dates are rare at sites below about 6,000'. Even though the UUSS as defined by the rectangle on Figure 8.1 contains large areas below that elevation, sites in these areas fall outside our analyses here.
- 2 All dates herein are either tree-ring or calibrated 14C dates and are CE unless otherwise
- 3 The first termination, ca. 700, falls within the long first period of the VEP chronology which extends from 600-725, so it's unclear if there's also a peak in violence ca. 700. Skeletal remains and Gini indices are dated only to VEP periods, which average 49 years in length. The series in Figure 8.2D and E are therefore much smoother than the series plotted in Figure 8.2A-C, which are derived from annual values with a linear four-year smooth plotted on its final year.
- 4 The "All" series in Figure 8.2D pools data from sites in the central Mesa Verde, Chaco Canyon, Middle San Juan, and the Chuskas, so they emphasize the northern portions of the UUSS. See Ellyson et al. (2019: fig. 1). The "CMV" series is included in the "All" data but when presented by itself it can be plotted at the higher temporal resolution provided by the VEP periods, rather than the "Explore/Exploit" boundaries used for "All."
- 5 For statistical details, see Kohler et al. (2020). In that paper, we used estimates of the absolute amount of maize production as explained in Kohler (2012b), rather than the sizes of the dry-farming maize niche used here. We truncated the long first period to its final portion, so the average period length became 43 years. These series were then smoothed with a 21-year linear filter plotted on its final year. Therefore, the value in 810 for example represents the average over the previous 20 years, including signals from the 725-800 period, and from the 800-840 period.
- 6 The relationship between production and population asserted here is by visual inspection of histograms presented in Kohler and colleagues (2020). In that paper we created the variable "production per capita" (i.e., potential production / momentary population) to assess its relationship with violence and inequality, and did not statistically assess the relationship of production and population through time.
- 7 This intuition is formalized in a simple mathematical model in Scheffer et al. (2021). This process is also described in the "bifurcation-tipping" scenario by Timothy M. Lenton in this volume (2023: Fig. 13.2D), where some slow process causes a progressive shallowing of the adaptive valley until a given perturbation is able to dislodge the system from its current equilibrium and move it to a new one.

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9 Episodes of the Feathered Serpent

Aztec Imperialism and Collapse

Deborah L. Nichols and Ryan H. Collins

The Triple Alliance, or Aztec empire, as it is more widely called, represented the largest state in the history of prehispanic Mexico and Central America. It encompassed approximately 200,000 km² extending from Mexico's Central highland plateau to the Gulf and Pacific coasts and the southern highlands of Mexico (Figures 9.1 and 9.2). The Triple Alliance's homeland, the Basin of Mexico, was the heartland for the development of a series of large and influential cities and states interspersed with episodes of political fragmentation. Mexico City, the capital of the modern nation–state, overlies the remains of the imperial Aztec capital, Tenochtitlan. First contact between the indigenous societies of the Americas and the states of Eurasia was undeniably world-changing, making the collapse of the Triple Alliance an especially instructive and timely case to examine.

Understanding the collapse of the Triple Alliance has undergone significant revisions in recent decades from early views that were based on the narrative accounts of Spanish conquistadores (Carballo 2020; Hassig 2006; Matthews and Oudijk 2007; Oudijk and Castañeda de la Paz 2017; Restall 2018). The role of indigenous politics, along with disease, warfare and invasion, ecology, and Spanish colonialism has received much more attention. Theories of ancient, pre-modern state collapse in recent decades have focused on environmental degradation, over-intensification, climate or environmental changes, and class conflict (Tainter 1988, 2016). These factors were important triggers in other cases (Middleton 2017) and have been invoked in the collapses of Teotihuacan and Toltec Tula that preceded the Triple Alliance empire. Another significant theoretical shift is in recognizing that collapse, entailing a decrease in social complexity or fragmentation of a polity, is as much part of the evolutionary process as is the increase of social complexity and polity expansion (Tainter 2016). In the case of Mexica imperialism, recent scholarship counters popular narratives of Aztec conquest and collapse, pushing us to understand a more complex intersection of indigenous and European politics—emphasizing that Aztec imperialism had internal fissures, factions, and distinct worldviews, and local and inter-continental ecologies. Therefore, it is crucial

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