SUSTAINABLE LIFEWAYS
Cultural Persistence in an Ever-changing Environment

EDITED BY
Naomi F. Miller, Katherine M. Moore, and Kathleen Ryan

University of Pennsylvania Museum of Archaeology and Anthropology
Philadelphia
# Contents

*Figures*  
*Tables*  
*Contributors*  
*Foreword*  
*Preface*

## Introduction: Sustainable Lifeways
Naomi F. Miller and Katherine M. Moore

1. "Living with a Moving Target": Long-term Climatic Variability and Environmental Risk in Dryland Regions  
   Neil Roberts  
   13

2. Prehistoric Pastoralists and Social Responses to Climatic Risk in East Africa  
   Fiona Marshall, Katherine Grillo, and Lee Arco  
   38

3. Spreading Risk in Risky Environments: An East African Example  
   Kathleen Ryan and Karega-Munene  
   74

4. Risk and Resilience among Contemporary Pastoralists in Southwestern Iran  
   Lois Beck and Julia Huang  
   106

5. Change and Stability in an Uncertain Environment: Foraging Strategies in the Levant from the Early Natufians through the End of the Pre-Pottery Neolithic A  
   Arlene M. Rosen  
   128

6. Explaining the Structure and Timing of Formation of Pueblo I Villages in the Northern U.S. Southwest  
   Timothy A. Kohler and Charles Reed  
   150

7. Mitigating Environmental Risk in the U.S. Southwest  
   Katherine A. Spielmann, Margaret Nelson, Scott Ingram, and Matthew A. Peeples  
   180
8  Farmers’ Experience and Knowledge: Utilizing Soil Diversity to Mitigate Rainfall Variability on the Taraco Peninsula, Bolivia
   Maria C. Bruno

9  Grace Under Pressure: Responses to Changing Environments by Herders and Fishers in the Formative Lake Titicaca Basin, Bolivia
   Katherine M. Moore

10 Periodic Volcanism, Persistent Landscapes, and the Archaeofaunal Record in the Jama Valley of Western Ecuador
    Peter W. Stahl

11 Managing Predictable Unpredictability: Agricultural Sustainability at Gordion, Turkey
    Naomi F. Miller

Index
Explaining the Structure and Timing of Formation of Pueblo I Villages in the Northern U.S. Southwest

TIMOTHY A. KOHLER AND CHARLES REED

Human interactions with the environment structure society in many different ways. Longstanding cultural practices likewise have a structuring effect on the environment. On appropriate time scales, then, practices affect societies through a feedback mechanism provided by the environment (Odling-Smee, Laland, and Feldman 1996). Climate change provides exogenous signals that may affect these interactions because of responses in either the society or the environment. Human population movements and sociopolitical strife play the roles of sometimes endogenous, sometimes exogenous, factors that on small spatial scales may seem inexplicable but which on longer temporal and wider spatial scales may have understandable rhythms (Turchin and Korotayev 2006).

This chapter makes some suggestions about the trajectory of early Pueblo society as seen primarily through a window into prehispanic southwestern Colorado provided in part by recent research through the Village Ecodynamics Project (VEP: Kohler et al. 2007; Varien et al. 2007). That project analyzed the long sweep of Pueblo history in this area, from AD 600–1300. Here we focus on the first half of that period, the Basketmaker III and Pueblo I occupations from about AD 600–900. This makes the research undertaken by the Dolores Archaeological Project (DAP: Breternitz, Robinson, and Gross 1986), which concentrated on those periods, critical to our purposes.1
THE BMIII AND PI PERIODS IN SOUTHWESTERN COLORADO: BRIEF DESCRIPTION

Probably through immigration of farmers rather than adoption of farming by local hunter-gatherers, farming lifeways became evident in our area (Fig. 6.1) in an important way around AD 600, in the Basketmaker III (BMIII) period. These first local farmers inhabited small sites, called hamlets, composed of relatively shallow round, squarish, or D-shaped pitstructures with antechambers, that may be isolated farmsteads or grouped into loose “neighborhoods” of perhaps half a dozen pitstructures whose contemporaneity is typically difficult to assess (pitstructure use-life appears to be short). Surface facilities including ramadas and small, disconnected round or oval rooms may appear in an arc north and west of the pitstructures (Kane 1986:363). Kane and most other archaeologists interpret these pitstructures as the residences of nuclear families. Pottery vessels are present, with small grayware forms such as seed jars and other jars most common;
bowls and decorated vessels are relatively uncommon (Rohn 1977:233–34). Trough metates, relatively simple manos, and stemmed projectile points are all common. By AD 600 maize had been an important component of the Puebloan diet for well over a millennium south and southwest of our study area, whereas beans, the bow and arrow, and ceramic vessels were relatively recent additions (Gumerman and Dean 1989:114–15; Gumerman and Gell-Mann 1994:19).

Beginning around AD 725, roughly the beginning of the Pueblo I (PI) period, the appearance of various decorated ceramics, including local and non-local redwares, began to add variability to the ceramic assemblages (Blinman 1986:72–73). Small bowls became more common at the same time. Later in the PI period, around AD 800, a considerably larger bowl form (with a volume of at least 13 liters) appeared. By about AD 840, this was joined by a jar form with a volume of at least 7 liters, which was also substantially larger than earlier jars (Blinman 1986:87). Ceramic deposition rates and arguments from structure replacement suggest increasing duration of occupation for all sites during this period, but especially in the villages (Kohler and Blinman 1987; Varien and Ortman 2005). Increasing durations of structure use, and site longevity, probably allowed more inter-generational transfers of material, embodied, and relational wealth, augmenting possibilities for inequalities in wealth (Borgerhoff Mulder et al. 2009) and allowing some subtle movement towards economic and power differentials in PI societies.

In the Dolores area, architectural changes from earlier practices became pronounced by about AD 760, and included the construction of double-row surface roomblocks north and west of pitstructures, which greatly increased storage capacity. This increase may have been related to the appearance of new and possibly more productive varieties of maize at about this time, as well as to generally increasing use-lives for structures. The standard DAP interpretation was that by this time pitstructures were shared by two to three households (nuclear families) who lived primarily in the surface structures; or to put it slightly differently, pitstructures after AD 760 were probably shared spaces for extended families. Flannery has recently suggested that the emergence of extended family households is a regular feature of early village life, following on the heels of “true villages of rectangular households” occupied by nuclear families (2002:417), but in the DAP area these developments may be essentially simultaneous.
Explaining the Structure and Timing of Formation of Pueblo I Villages

One “oversized” pitstructure on Grass Mesa is known for the pre-AD 800 period in the DAP. Kane interprets this as a “corporate” structure (following Hayden and Cannon’s [1982] use of this term) and notes that by AD 840 (the beginning of the McPhee Phase) roomblocks became increasingly large, housing up to 20 nuclear families: “This aggregation of household architecture into larger complexes suggests social organization above the household level was a prominent force within . . . communities” (1986:369). Kane infers that the emergence of these corporate groups implies that “unencumbered land in the local area was becoming scarce and competition for croplands probably occurred” and suggests that these corporate groups controlled the transmission of land holdings (1986:369; see also Kohler 1992). By this analysis the leaders of these corporate groups would have overseen the construction and controlled the use of oversized pitstructures which, with their ritual features, would have facilitated group-oriented activities probably including communication and reproduction of social structure and practices, and economic activities. In short these structures would have been key loci for the display and use of structural and organizational power as defined by Schachner (2001).³

Around AD 800 an even larger class of pitstructure, the great kiva, also appears on Grass Mesa (Kane 1986:367; Lightfoot 1988). These structures presumably served functions analogous to those of the over-sized pitstructures, and presented analogous opportunities for aspiring leaders or factions, but at the community or intercommunity level rather than the smaller level of Kane’s corporate groups. (Lipe et al. [1988:1221] suggested that Grass Mesa’s mid-8th century oversized pitstructure [Pitstructure 93] might better be interpreted as an early great kiva of community or intercommunity scope.) It is interesting and possibly significant that within the DAP area, oversized pitstructures, great kivas, and households that are relatively more clustered than elsewhere all appeared first on Grass Mesa. In the context of our argument here, we suggest that its placement on the north side of the Dolores River, from where it enjoyed easy access to the uninhabited, deer-rich highlands to the north, helps explain this precocity.

The village is the most famous characteristic of the later Pueblo I period in the northern Southwest. Pueblo I villages are notable both for their size—they are much larger than earlier sites in the Puebloan Southwest⁴—and for their configuration. In their description of the later portions of the AD 600–850 period in the northern Southwest, Gumerman and Gell-Mann
(1994:20) are struck by the modularity of the larger villages, and note that these “communities were made up of smaller social elements. Since the components of the larger sites are similar in size and morphology, they may represent a common social order for much of the northern region.” Recent research, however, has shown that the spatial organization of PI villages was quite different east of the DAP area, near Durango (Potter and Chuipka 2007), so it seems likely that there were contrasting social organizational principles at work in the eastern and western portions of the northern Southwest during the 8th and 9th centuries AD that may well have their roots in the differing origins and histories of the first farmers west and east of the central Mesa Verde area (Lekson 2009:45–46; Matson 2006).

In the remainder of this chapter we move from these descriptions, and these (mostly) DAP-era discussions of them, to put these phenomena into a wider spatial and temporal explanatory context. We’ll suggest that unprecedented population expansion throughout the Puebloan world (and in fact throughout the Southwest) beginning in the mid-1st millennium AD, abetted by favorable climatic conditions that opened up some of the most productive lands ever cultivated by Pueblo farmers, led to decreased per capita availability of the locally most important big game, mule deer, which in turn led to intensification in hunting (Spielmann and Angstadt-Leto 1996). Social strategies facilitating this intensification included the strengthening and possibly redefining of kinship systems as a way of forming trustworthy groups of hunters who could be relied on for increasingly long-distance deer hunting. Byproducts (or co-evolutions) of these social changes were trustworthy groups of men for warfare. New opportunities for the emergence of persistent social inequalities in these villages stemmed from increased longevity of site use (at least for villages) fostering the conditions for inter-generational transmission of wealth, an inferred increased importance of balanced reciprocal exchanges across roomblocks, status-enhancing provisioning of big game, and defense of village and territory.

**CLIMATIC AND DEMOGRAPHIC CONTEXTS**

In August 2005, VEP researchers re-cored Beef Pasture, a peaty fen located at an elevation of 10,000 ft (ca. 3000 m) in the La Plata Mountains some 40 km northeast of Mesa Verde National Park that was previously sampled and analyzed by Petersen and Mehringer (1976; Petersen 1988). With 72 closely
Explaining the Structure and Timing of Formation of Pueblo I Villages

spaced stratigraphic pollen samples anchored by 16 $^{14}$C dates, this research provides one of the most precisely dated pollen records for the last 2000 years in North America (Wright 2006). Aaron Wright devised pollen ratios from this core—building in part on earlier work by Petersen—that reflect temperature, and summer and winter precipitation (Fig. 6.2, after Wright 2006: Fig. 21). Given that the central Mesa Verde region in which the largest PI villages developed is both north of, and higher in elevation than, much of Puebloan Southwest, these farmers were probably particularly sensitive to fluctuations in temperature. Although it is difficult to calibrate these pollen records against temperature, it seems likely that the late arrival of farmers in the VEP study area (which includes the DAP area)—relative to the much earlier presence of farming further south, and at lower elevations—was partly controlled by the long, slow upward trend in temperature from 100

![Climatic Changes through Time](image)

**6.2** Low-frequency climatic trends in southwestern Colorado from about 100 BC to AD 1400, as reconstructed using pollen indices derived from a core drawn from Beef Pasture, Colorado (Wright 2006). The shaded area identifies the period during which Pueblo farmers occupied the VEP study area. (Figure courtesy of Aaron Wright)
BC to AD 800 that perhaps crossed a threshold where maize agriculture was locally reliable midway through the 1st millennium AD. Likewise, it seems probable that the trough in temperatures in the AD 900s contributed—at the very least—to the partial depopulation of the DAP and VEP areas during that century. Finally, the long-term perspective provided by this record makes it clear that low-frequency temperature and precipitation conditions during the two centuries from AD 600 to almost 800 were unusually propitious for agriculture.

We suspect that when temperatures permitted their use, the high-elevation portions of the central Mesa Verde region, with their deep blanket of fertile loess and orographic precipitation, provided farmers with yields that they could not hope to achieve in other portions of the Pueblo world. A portion of this area today claims to be the “pinto bean capital of the world.”

Our recent attempts to understand the demography of the prehistoric Southwest, and of the Pueblo area, employ a ratio pioneered by Bocquet-Appel (2002). In its numerator is the number of individuals in a site, or in contemporaneous sites within a locality, aged 5–19 years. The denominator contains the count of all individuals from the same population 5 years of age or older. By means of empirical analyses and simulation, Bocquet-Appel has shown that this ratio is reliably positively correlated with both birth-rates and with the instantaneous coefficient of population growth \( r \).

Kohler et al. (2008) have graphed this proxy using skeletal data from throughout the Southwest, showing that the earliest maize agriculture, which dates to slightly before 2000 BC, seems to have had a negligible effect on growth rates. In fact growth rates do not markedly accelerate in the Pueblo portions of the Southwest until about AD 600 (Kohler and Varien 2010), more or less as the upland portions of the central Mesa Verde region opened to dry farmers. The Pueblo world underwent rapid population growth from about AD 600 to 1200, by which time the related processes of climatically induced spatial retrenchment and aggregation conspire to lower the demographic boom.

This spatially general process of population growth is central to our argument. To oversimplify in the interest of making the larger argument clearer, we suspect that population growth among Archaic populations in the Southwest was typically limited by access to carbohydrates. This was alleviated to some extent by the cultivation of maize, which not only contributes general carbohydrates but is also a high-glycemic index food, which
according to Kakos (2003) promotes an insulin response causing the body to store fat, ultimately increasing women’s fertility. For some reason, however, pan-Southwestern population growth remained relatively slow for more than two millennia after maize appeared on the southern Colorado Plateau. Possibly that effect can be explained by a low glycemic index for early maize. Or perhaps populations remained relatively mobile and thus limited their family size. Or perhaps some combination of the bow and arrow, more productive maize, beans, ceramic vessels, dry farming, and the increasing climatic availability of productive uplands that could be dry-farmed “completed” the Neolithic package around the middle of the 1st millennium AD and allowed high population growth rates. Most likely all these explanations contributed in some measure to the delayed but vigorous population expansion.

**EFFECTS OF GROWING POPULATIONS ON LARGE GAME**

Whatever the causes of population growth of the 1st millennium AD, recent simulations undertaken by the VEP demonstrate that it can be expected to have a serious impact on densities of the local highest-ranked game species, mule deer. Using agent-based models that represent key aspects of the paleolandscapes of an 1816-km² area in southwestern Colorado, Bocinsky et al. (2011) show that even when we use relatively conservative assumptions about how much protein from meat people seek, and varying several other parameters that relate to hunting strategies and game abundance, severe deer depletion is very likely once local population levels become as high as those supported in our area at the PI population peak.

We can see evidence for this effect in the faunal bone analyses conducted by DAP investigators. Taking the large assemblage (17,236 analyzed fragments of nonhuman bone) from Grass Mesa as an example, *Odocoileus hemionus* (mule deer) represents, overall, 8.4% of the total assemblage by Number of Identifiable Specimens (NISP), and bone identified only to the level of Cervidae—of which nearly all can be expected to be mule deer—represents another 14.2% of the total (Neusius and Gould 1988:table 15.2). By contrast, three-quarters of the Pueblo III sites tabulated by Driver (2002) contain fewer that 10% artiodactyls by NISP, which demonstrates not only the importance of deer to PI populations, but also the eventual depression of high-ranked game on this landscape.
The PI population history of Grass Mesa roughly parallels that of the DAP and VEP areas as a whole. Kohler (1988:table 3.7) estimates a momentary population for the AD 725–800 period of about 22 households, dipping slightly to 17 households from AD 800–840, then increasing markedly to 92 households from AD 840–880, and again to 124 households between AD 880 and 910. This last period contains the enigmatic Grass Mesa Subphase, in which surface structures disappeared and pitstructures decreased radically in size (Lipe et al. 1988:1272–76).

Over the course of this occupation, Neusius and Gould (1988:fig. 15.19) report that the percentage (by NISP) of the pitstructure faunal assemblages identified as lagomorphs increases regularly from 11.1 to 51.3. Among all of the identifiable bone recovered, the summed total of lagomorphs and rodents constitutes about half of the early assemblages, rising regularly through time to make up about 68% of the latest assemblages (Neusius and Gould 1988:fig. 15.13). In Table 6.1 we present our own tabulation of DAP fauna from Grass Mesa, using only those specimens (numbering over 5000) that can be securely dated to a specific period. Organized in this way, deer and related large game, plus other large mammals, declined from over 36% of the NISP in the AD 725–800 period to about 26% of NISP from 880–920.

Table 6.1a,b. Changes in Fauna through Time at Grass Mesa Village

(a) Cell entries contain column percentages; marginals present raw frequencies (NISP).
(b) Median polish of raw frequencies, after log transform. Tables compiled from DAP data organized by Wilshusen et al. (1999) and maintained at http://golem.anth.wsu.edu/databases/.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PERIOD (AD)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>725–800</td>
<td>800–840</td>
</tr>
<tr>
<td>Deer &amp; related large game spp.²</td>
<td>18.0</td>
<td>13.6</td>
</tr>
<tr>
<td>Large mammal³</td>
<td>18.4</td>
<td>15.0</td>
</tr>
<tr>
<td>Medium mammal⁴</td>
<td>4.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Other mammal⁵</td>
<td>7.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Leporidae⁶</td>
<td>19.7</td>
<td>30.1</td>
</tr>
<tr>
<td>Other small mammal⁷</td>
<td>24.7</td>
<td>24.7</td>
</tr>
<tr>
<td>Bird⁸</td>
<td>3.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Other⁹</td>
<td>2.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Uncertain</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Total</td>
<td>534</td>
<td>528</td>
</tr>
</tbody>
</table>
Explaining the Structure and Timing of Formation of Pueblo I Villages

(b) CATEGORY PERIOD (AD) ROW EFFECTS

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>725–800</th>
<th>800–840</th>
<th>840–880</th>
<th>880–920</th>
<th>EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer &amp; related large game spp.</td>
<td>0.23</td>
<td>0.13</td>
<td>-0.16</td>
<td>-0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>Large mammalb</td>
<td>0.02</td>
<td>-0.04</td>
<td>0.03</td>
<td>-0.03</td>
<td>0.42</td>
</tr>
<tr>
<td>Medium mammalc</td>
<td>-0.06</td>
<td>0.02</td>
<td>-0.02</td>
<td>0.19</td>
<td>-0.06</td>
</tr>
<tr>
<td>Other mammald</td>
<td>0.01</td>
<td>-0.18</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>Leporidaed</td>
<td>0.04</td>
<td>0.24</td>
<td>-0.11</td>
<td>-0.05</td>
<td>0.44</td>
</tr>
<tr>
<td>Other small mammallf</td>
<td>-0.01</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.58</td>
</tr>
<tr>
<td>Birdg</td>
<td>-0.02</td>
<td>-0.05</td>
<td>0.02</td>
<td>0.03</td>
<td>-0.30</td>
</tr>
<tr>
<td>Turkey</td>
<td>-0.40</td>
<td>0.33</td>
<td>0.05</td>
<td>-0.06</td>
<td>-1.16</td>
</tr>
<tr>
<td>Otherh</td>
<td>0.04</td>
<td>-0.06</td>
<td>-0.04</td>
<td>0.05</td>
<td>-0.51</td>
</tr>
<tr>
<td>Uncertain</td>
<td>-0.04</td>
<td>-0.01</td>
<td>0.01</td>
<td>0.07</td>
<td>-0.56</td>
</tr>
<tr>
<td>Column effects</td>
<td>-0.27</td>
<td>-0.30</td>
<td>0.28</td>
<td>0.43</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
a. Artiodactyla, Odocoileus hemionus, Cervidae, Antilocapra americana, Ovis canadensis, and Cervus elaphus
b. Large mammal and Ursus spp.
c. Medium mammal
d. “Mammalia NFS” and “medium or large mammal”
f. Canidae, Canis latrans, C. lupus, Canis spp., Vulpes vulpes, Vulpes spp.; Lynx rufus, Lynx spp.; Mustelidae, Mephitis mephitis, Mustela frenata, Mustela spp., Spilogale putorius, Taxidea taxus; Sciuridae, Cynomys gunnisoni, Marmota flaviventris, Spermophilus lateralis; Erethizon dorsatum; Cricetidae, Microtus montanus, Microtus spp., Neotoma mexicana, Neotoma spp., Onychomys leucogaster, Peromyscus spp., Thomomys bottae, Thomomys spp., and small mammal
g. Bird, large bird, medium bird, small bird, passeriformes, Bubo virginianus, Grus canadensis, falconiformes, Accipitriformes, Accipiter spp., Aquila chrysaetos, Buteo spp., Cathartes aura, Corvidae, Corvus brachyrhynchos, C. corax, Corvus spp., Turdus migratorius, Zenaida macroura, Tetraonidae, galliformes, Branta canadensis, and Anas spp.
h. “Mammal or bird,” fish, reptiles, and snakes

SOCIAL RESPONSES TO DEER DEPLETION

Kohler and Van West (1996) argued that Pueblo villages formed under climatic conditions in which households benefited from sharing maize with other households, and tended to disband under conditions in which it was advantageous for households to hoard.5 We now wish to argue that the specific forms of these villages can also be explained. To preview our argument, as population growth—coupled closely with the introduction of the bow and arrow which represented a significant advance in hunting technology—led to deer depletion, especially near larger settlements such as Grass Mesa, groups in which hunters could reliably form the larger parties required for hunting longer distances were at an advantage relative to those who could not. Coordination failures in forming successful hunting parties were
minimized by drawing on kin, identified in such a way that kinship was un-
ambiguous, thereby rewarding groups which emphasized strong unilineal
kinship bonds. These strongly defined kin systems were localized within
roomblock units that were highly visible in most Pueblo I villages. The
resultant societies would have resembled the segmentary lineage systems
identified by Sahlins (1961) as “organizations of predatory expansion.”

The Stag Hunt

If local depression in mule deer populations created conditions in which
individual hunting for deer was becoming less reliable and profitable, the
potential advantages for cooperative hunting would have generated the sort
of social dilemma depicted by Jean-Jacques Rousseau in his Discourse on In-
equality (1755/1950). In a metaphorical scenario which turns out to literally
depict the situation that we believe obtained in the PI villages, Rousseau
imagined a society in which hunters must decide whether to hunt stag,
which cannot be successfully hunted by individuals, or to hunt hare, which
can be successfully hunted by individuals but with a lower return. Group
hunting of stag results in higher returns for all individuals involved com-
pared to the sum of individual hare returns, so long as these hunting groups can
be reliably formed. In seeking to create such cooperative hunting parties that
could go on longer and more successful hunting expeditions, Pueblo I pop-
ulations were faced with a collective action problem of the sort known as
an assurance game.6 The general payoff structure for such games is shown
in normal form in Table 6.2.

In such situations, hunting stag is unambiguously the highest-payoff
alternative, but it is only possible when all participants have a shared un-
derstanding of what is expected as a result of their cooperation (Alvard
2003:152; Alvard and Nolin 2002:537). Creating the type of cooperative
group needed to participate in risk-sharing activities required forming
groups with unambiguous membership and responsibilities within which
individuals could rely on shared norms and behavioral expectations. To par-
ticipate, individuals must be assured that the potential benefits of cooperat-
ing outweigh the negative potentials of not receiving their fair share, and
that the system cannot be subverted by free riders. This need for shared
normative behavior creates a coordination problem which we argue, follow-
ing a parallel example by Alvard (2003), favored reliance on a unilineal
descent system.
### Table 6.2. The Assurance Game (two-person, one round)*

The generalized payoff matrix is to left, an example with specific payoffs (from Alvard and Nolin 2002:535) is on the right.

<table>
<thead>
<tr>
<th></th>
<th>Hunt Stag (Cooperate)</th>
<th>Hunt Hare (Defect)</th>
<th>Hunt Stag (Cooperate)</th>
<th>Hunt Hare (Defect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunt Stag (Cooperate)</td>
<td>$R_1, R_2$</td>
<td>$S_1, T_2$</td>
<td>$5,5$</td>
<td>$0,1$</td>
</tr>
<tr>
<td>Hunt Hare (Defect)</td>
<td>$T_1, S_2$</td>
<td>$P_1, P_2$</td>
<td>$1,0$</td>
<td>$3,3$</td>
</tr>
</tbody>
</table>

* The first entry in each cell is the payoff to the row player; the second, the payoff to the column player. Plays are simultaneous. Assurance games have payoffs ranked as follows: R (reward) > T (temptation); P (punishment) > S (sucker’s payoff); and R > P. Note that while both hunting stag is the Pareto optimum (it maximizes the group benefit), there is a risk to this choice: for example, if row player hunts stag and column player hunts hare, row player gets the lowest payoff (S=0).

### Unilineality

One might expect that any kinship system, or even knowledge of degree of genetic relatedness, would be equally efficient in identifying members of an in-group (kin) vs. an out-group (non-kin). This is not the case. Figure 6.3 shows an example from Alvard (2003:fig. 6.1) in which Ego, if drawing on either genetic relatedness or the bilateral (kindred, cognatic) model of kinship that is its closest cultural analogue, should want to cooperate equally with both A and B, with whom he shares a coefficient of relatedness of 0.125. A and B, however, are unrelated to each other and would have no motivation to cooperate with each other by the logic of kin selection. The bilateral system thus creates overlapping groups with fuzzy boundaries, whereas unilineal descent unambiguously assigns each individual to one group only (Fox 1967:49).

We suggest that whether or not the unilineal principle was present prior to Pueblo I times, it became dominant in the DAP populations at least during this period. By focusing on one side of Ego’s lineage, unilineal systems create an unambiguous descent group that facilitates the formation of work groups of whale hunters (Alvard 2003:131–32) or deer hunters. Within such groups “sentiments of common membership, expressed and reinforced by informal institutions of sharing, gift giving, ritual and participation in dangerous collective exploits” readily develop (Richerson and Boyd 1999:254). Because we hypothesize that these unilineal descent groups formed under pressures favoring large and reliable hunting groups, we suppose that they were patrilineal. This keeps related males together, since in such systems, as Fox (1967:114) points out, “almost inevitably the residential group is a
patrilocal unit.” The roomblocks within Pueblo I villages therefore, we suggest, represent these patrilineal, patrilocal [virilocal] units. These are the “smaller social units” of Gumerman and Gell-Mann (1994:20)—alluded to above—by which these large villages were organized. They are likewise the “corporate units” postulated by Kane (1986) and Lipe et al. (1988:1268).

By this same logic, we expect that the “oversized” pitstructures that became common in the 9th-century villages represent the houses of senior lineage members—by our analysis, hunting leaders in spirit if not in body. The ritual features in these structures result from the fact that they doubled as assembly houses for the male lineage members. Fox notes the key point that patrilineal, patrilocal systems “manage to combine residence, descent, and authority very neatly” (1967:114).

**Segmentary Lineage Organizations**

What, if anything, can we infer about whether the lineage members residing in different roomblocks within a village also would have considered themselves to be related at a more general level? Some unilineal systems, which Sahlins (1961) called segmentary lineage organizations, exhibit special properties. He considered the Nuer and the Tiv to be the purest examples. These societies are composed of autonomous primary segments

---

**Figure 6.3** In a society reckoning kinship by degree of relatedness, Ego would be equally related to A and B, and hence might like to hunt with both of them, but A and B are unrelated and would have no incentive to hunt together. In a patrilineal system, Ego and B are unambiguously in the same group, and A is unambiguously excluded. (After Alvard 2003: fig. 1)
with no permanent organized leadership above that level. At the time of their ethnographic descriptions, both were expanding into areas occupied by other peoples, and were successful in this competition because their segmentary lineage system provided them with a mechanism for large-scale political “consolidation” despite the absence of permanent higher-level organizations (Sahlins 1961:328).

This capability seems to be due in great measure to the fact that all (or almost all) of the lineages in these societies considered themselves to be on a single patriline, so that at increasing social, spatial, and temporal distance, all the Tiv and most of the Nuer considered themselves relatives. Our Figure 6.4 reproduces a figure used by Sahlins (1961:fig. 1) to show how kinship and geography are related in such systems; Sahlins in turn borrowed this from Paul Bohannon (1954). It is clear that these systems pertain

---

**Figure 6.4** The idealized relationship between descent and territory among the Tiv, as represented by Bohannon and reproduced by Sahlins (1961: fig. 1). All lineages descend from an apical male ancestor I; his sons A and B divided his territory into two adjacent territories, as did their sons, and so forth. The result, as Bohannon says, is that “the geographical position of territories follows the genealogical division into lineages” (Bohannon 1954:3).
to expanding societies. Sahlins suggested that their organizations allowed them to expand in competitive environments because they could draw on a “lineage system uniting local groups” (Sahlins 1961:330). It is probable, we believe, that such organizations could also arise in circumstances where lineages were undergoing rapid population growth and local lineage splitting, without the specific historical circumstances of intrusion into areas occupied by other groups that Sahlins considered typical of such groups. We think, for example, that early adopters of productive maize agriculture would be excellent candidates for having these characteristics. Glenn Stone (1996:63–73) presents a relevant analysis of the “geometry of social affiliation” among the virilocal Kofyar as they spread into an agricultural frontier.

If this analysis is correct, the implication is that the residents of various roomblocks in a village such as Grass Mesa probably considered themselves very closely related to residents of their own roomblock, but also related, though more distantly, to residents of neighboring roomblocks within the village, and still more distantly related to residents of other villages within their own “tribe” (perhaps including most or all of the peoples on the northeast side of the Dolores River). This is the principle that Sahlins (1961) calls “segmentary sociability.”

An implication of this system, in turn, is what Sahlins calls complementary opposition (or the massing effect). Joint mobilization for defense, or for exercise of privileges such as access to hunting territories, will be determined by the social distance of the threat or competition. Quarrels between members of socially adjacent lineages will pit just those lineages against each other, whereas quarrels between anyone in the largest social unit recognized (the tribe) and anyone outside of this social unit will result in the automatic mobilization of the entire tribe against the common enemy. For Sahlins, this characteristic is not part of the political system: it is the political system (1961:333) and if the opposition that evoked the unified response dissipates, the high-order structure and any temporary leadership that it may have permitted will dissolve once more into its component parts, or disappear.

There is osteological evidence that social strife in the VEP area was increasing during the AD 800s as the Pueblo I villages reached their population peak (Cole 2006). Given the importance we have alleged for hunting and the near certainty that much of this would have been non-local, conflict over hunting territories between villages (or possibly between larger
tribal groups) was a likely source of animosity. This might only have added another foundation to the emerging social power of the hunt/lineage heads. There may have been no essential difference between the form of the organizations promoted by efficient response to warfare and efficient long-distance hunting. Depending on the social distance of the threat, temporary positions of leadership beyond that of the corporate heads could have emerged in both cases.

AGENT-BASED MODELS PROVIDE EVIDENCE FOR THE SOCIAL IMPORTANCE OF EARLY PUEBLO DEER HUNTING

The suggestion that deer hunting was instrumental in structuring PI villages in a particular manner may be a little inflammatory. Southwestern archaeologists (including the senior author) have typically focused on how the variable success and particular characteristics of maize agriculture can explain everything from village formation and dissolution, to local and regional migration, to fundamental structures in the Pueblo worldview. Yet we need to remember that at some point in Pueblo history, a primacy for agriculture was not a given. Older practices such as hunting of large mammals had developed authority structures surrounding them which by the Pueblo I period can be thought of as vested interests.

Some readers might grant the importance of deer in the early Pueblo diet, as attested by the zooarchaeological data presented above, and may also accept the suggestions from simulation and the data from zooarchaeology that deer was declining in availability during the Pueblo I period, without being willing to grant deer hunting the potency for structuration suggested here. For these readers we briefly mention another line of evidence speaking to the depth of influence of deer hunting and presumably of deer hunters in early Pueblo society.

Village Ecodynamics Project modeling efforts focused on agent-based models in which we reconstruct, as best we can, the spatial and temporal distribution of those aspects of the natural environment that seem most likely to affect the spatial positioning of human use of this landscape. These include potential maize productivity, fuelwood growth and availability, water availability, and the spatial distributions of three key game animals: deer, hare, and rabbits. These resources are modeled at a spatial resolution of 200 x 200 m, except for deer, which are modeled within “deer cells” one km on
a side. The availability of these resources changes annually both because of exogenous inputs (precipitation as proxied by mid-elevation tree rings for all resources, plus, for maize, temperature as proxied by high-elevation tree rings) and human use. Locally realistic spatial variability is introduced into the model through use of soils maps documenting differential productivity that affects all resource types except water. Estimated water availability is derived from a MODFLOW model that simulates groundwater flows in the primary hydrogeological layer in our study area.

Of the infinite rulesets for household positioning that we could explore, we have been focusing on rules that require agents—which represent households—to approximately and myopically locate themselves so as to minimize their caloric costs for obtaining enough protein through hunting, calories through farming, water, and fuelwood to support their members. Households are seeded randomly onto the landscape at the beginning of the simulation, at AD 600. They remain where they are as long as they can satisfy their needs. Otherwise, they seek a new location within a tunable radius (currently 20 cells, or 4 km) that provides the necessary amounts of these resources with the least travel cost, calculated over all four resources. We give maize production some priority in this calculation, in the sense that households must be able to meet their needs from farming either within their home cell, or within the first row of cells surrounding their home cell.

Without going into details here, we can quantify the degree of fit between the archaeological record in the VEP study area and the agent behavior in the simulation for each of 14 periods between AD 600 and 1280. We can also experiment with various parameters in our simulations, such as how much meat from hunting agents seek, and how far they are willing to go to hunt. Here we report a series of runs examining the effects of varying seven parameters (Table 6.3) on simulated locational behavior. Figure 6.5 (and Table 6.4) display the behavior through time of two measures of spatial efficiency against our three paleodemographic estimates for the VEP study area (Varien et al. 2007). These measures are (1) the proportion of 348 (128 runs x 3 measures of goodness of fit for each) measures of goodness of fit r that are positive (in black); and (2) the proportion of positive correlation coefficients where the probability that r is not zero is less than or equal to .05 (in red).7

For our purposes here, it is most significant that settlements throughout
Explaining the Structure and Timing of Formation of Pueblo I Villages  167

Table 6.3. The Seven Parameters Varied in the Runs Reported Here (v2.72)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interhousehold exchanges in meat and maize (both generalized and balanced</td>
<td>Implemented (COOP=4) (runs 1–64)</td>
</tr>
<tr>
<td>reciprocity)*</td>
<td>Not implemented (COOP=0) (runs 65–128)</td>
</tr>
<tr>
<td>Paleoproductivity dataplane used</td>
<td>First principal component (“PRIN1”) of Almagre and San Francisco Peaks tree-ring series used for temperature proxy (runs 1–32 &amp; 65–96)</td>
</tr>
<tr>
<td></td>
<td>Almagre series only (“ALMA”) used for temperature proxy (runs 33–64 &amp; 97–128)</td>
</tr>
<tr>
<td>Protein consumption goal from meat (g/person)</td>
<td>15 (runs 1–16, 33–48, 65–80, &amp; 97–112)</td>
</tr>
<tr>
<td></td>
<td>25 (runs 17–32, 49–64, 81–97, &amp; 113–128)</td>
</tr>
<tr>
<td>Need meat (protein move) (see Bocinsky et al. 2011)</td>
<td>0 (may move to protein-depleted area if costs are otherwise low) (runs 1–8, 17–24, 33–40, 49–56, 65–72, 81–88, 97–104, 113–120)</td>
</tr>
<tr>
<td>Maize harvest adjustment (acts as denominator to final production estimate</td>
<td>1 (runs 1–2, 5–6, etc.)</td>
</tr>
<tr>
<td>for each cell)</td>
<td>0.8 (increases maize production by 25%) (runs 3–4, 7–8, etc.)</td>
</tr>
<tr>
<td>Soil degradation</td>
<td>1 (moderate: soils under continuous use eventually lose up to 30% of their productive potential) (odd-numbered runs)</td>
</tr>
<tr>
<td></td>
<td>2 (severe: soils under continuous use eventually lose up to 60% of their productive potential) (even-numbered runs)</td>
</tr>
</tbody>
</table>

*See Kohler et al. 2007:89–96
the first cycle of occupation (the Basketmaker III and Pueblo I periods) were well outside what we might call the optimal niche as estimated by the agent-based model. Clearly it was possible to live and even thrive outside the optimal niche as defined by our agents, perhaps in part because the total population on the landscape remained relatively low and the climates fairly forgiving for most of this period. But if the Pueblo I populations were not globally optimizing their access to all these resources, what were they up to?

**Figure 6.5** Settlement efficiency indices (see text and Table 6.3) calculated across 128 runs of the “Village” agent-based model and spline-fit, in relation to population history of the VEP area (histograms).
### Table 6.4. Measures of Settlement Efficiency of 128 Runs of the “Village” Agent-based Model

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>MIDPOINT (AD)</th>
<th>( P ) POSITIVE ASSESSMENTS OF FIT ((R))(^a)</th>
<th>( P ) SIGNIFICANT POSITIVE ASSESSMENTS OF FIT ((R))(^b)</th>
<th>HIGHEST ( R ) (RUN ID)</th>
<th>( P ) OF HIGHEST ( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>663</td>
<td>0</td>
<td>0</td>
<td>-.0000 (89)</td>
<td>.9923</td>
</tr>
<tr>
<td>7</td>
<td>763</td>
<td>0</td>
<td>0</td>
<td>-.0002 (45)</td>
<td>.9872</td>
</tr>
<tr>
<td>8</td>
<td>820</td>
<td>0</td>
<td>0</td>
<td>-.0002 (52)</td>
<td>.9907</td>
</tr>
<tr>
<td>9</td>
<td>860</td>
<td>0</td>
<td>0</td>
<td>-.0007 (56)</td>
<td>.9588</td>
</tr>
<tr>
<td>10</td>
<td>900</td>
<td>.72</td>
<td>.16</td>
<td>.0471 (116)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>11</td>
<td>950</td>
<td>.38</td>
<td>.04</td>
<td>.0379 (3)</td>
<td>.0012</td>
</tr>
<tr>
<td>12</td>
<td>1000</td>
<td>.23</td>
<td>.03</td>
<td>.0626 (35)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>13</td>
<td>1040</td>
<td>.33</td>
<td>.08</td>
<td>.0704 (35)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>14</td>
<td>1080</td>
<td>.08</td>
<td>.05</td>
<td>.0658 (35)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>15</td>
<td>1120</td>
<td>.10</td>
<td>.05</td>
<td>.0706 (19)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>16</td>
<td>1160</td>
<td>.11</td>
<td>.06</td>
<td>.0678 (115)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>17</td>
<td>1203</td>
<td>.13</td>
<td>.06</td>
<td>.0778 (35)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>18</td>
<td>1243</td>
<td>.08</td>
<td>.03</td>
<td>.0310 (99)</td>
<td>.0108</td>
</tr>
<tr>
<td>19</td>
<td>1270</td>
<td>.14</td>
<td>.01</td>
<td>.0313 (3)</td>
<td>.0125</td>
</tr>
</tbody>
</table>

\(^a\) Three assessments of goodness-of-fit \( R \) were made for each run. One of these was calculated on the relationship between the unsmoothed simulated household years in each 200-x-200 m cell, and the same value for each cell in the archaeological record. This comparison is made only for cells that are either (1) within the block survey areas, or (2) have non-zero household years in the empirical record. The other two assessments were made (1) on a uniform smoothing of the empirical record, so that the contents of each central cell in a 3-x-3 block of cells is apportioned evenly across all 9 cells, and (2) on a kernel smoothing across the same local neighborhood, which retains a higher peak in the central cell than does the uniform smoothing. The denominator for all these proportions is 3 assessments of fit x 128 runs = 348.

\(^b\) The proportion of positive Pearson product-moment correlation coefficients \( r \) where \( p < .05 \). The denominator for all these proportions is 3 assessments of fit x 128 runs = 348.

Figure 6.6 shows the known distribution of sites between AD 840 and 880, when our local PI villages were in their prime, against the settlement pattern created by the best-fitting agent-based model during those years. The real populations appear to be located more densely in the northeastern portions of the study area, alongside the Dolores River, than we would expect if they were minimizing their simultaneous access costs to all four of the resource categories we model. This area is at the local northeastern extreme of Pueblo occupation; beyond it, to the northeast, lie unoccupied highlands with dense deer populations.\(^8\)

This visual impression is reinforced by examining the specific parameters that generated the best-fit simulation for each period (Table 6.5). Granting that none of our models fits the first four periods well at all, the least
6.6a, b Real (left) and simulated locations of households from AD 840–880 in the VEP area. Goodness of fit between the two maps is assessed for the areas of block survey, shown in a lighter color.

Table 6.5. Parameters for the Best-Fitting Model in Each Period

<table>
<thead>
<tr>
<th>MIDPOINT (AD)</th>
<th>RUN</th>
<th>COOP</th>
<th>TEMP. PROXY</th>
<th>PROTEIN (G/PERS)</th>
<th>NEED MEAT</th>
<th>HUNT RADIUS</th>
<th>PROD. DIVISOR</th>
<th>SOIL DEGRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>663</td>
<td>89</td>
<td>0</td>
<td>PRIN1</td>
<td>25</td>
<td>1</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>763</td>
<td>45</td>
<td>4</td>
<td>ALMA</td>
<td>15</td>
<td>1</td>
<td>50</td>
<td>.8</td>
<td>2</td>
</tr>
<tr>
<td>820</td>
<td>52</td>
<td>4</td>
<td>ALMA</td>
<td>25</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>2</td>
</tr>
<tr>
<td>860</td>
<td>56</td>
<td>4</td>
<td>ALMA</td>
<td>25</td>
<td>0</td>
<td>50</td>
<td>.8</td>
<td>2</td>
</tr>
<tr>
<td>900</td>
<td>116</td>
<td>0</td>
<td>ALMA</td>
<td>25</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>2</td>
</tr>
<tr>
<td>950</td>
<td>3</td>
<td>4</td>
<td>PRIN1</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1000</td>
<td>35</td>
<td>4</td>
<td>ALMA</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1040</td>
<td>35</td>
<td>4</td>
<td>ALMA</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1080</td>
<td>35</td>
<td>4</td>
<td>ALMA</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1120</td>
<td>19</td>
<td>4</td>
<td>PRIN1</td>
<td>25</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1160</td>
<td>115</td>
<td>0</td>
<td>ALMA</td>
<td>25</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1203</td>
<td>35</td>
<td>4</td>
<td>ALMA</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1243</td>
<td>99</td>
<td>0</td>
<td>ALMA</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
<tr>
<td>1270</td>
<td>3</td>
<td>4</td>
<td>PRIN1</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>.8</td>
<td>1</td>
</tr>
</tbody>
</table>
bad fit for the earliest farming occupation from AD 600–725 is to a model (89) that is unusual in that it does not have interhousehold exchange. It has high protein needs that can be satisfied within a small hunting radius, with no movement to areas of protein depletion allowed, and a low production landscape for maize. For all periods after this, the best-fit models always have the higher maize-productivity landscapes, perhaps reflecting the use of more productive maize, or an increase in ability to use the landscape in a more productive fashion. The first two periods (AD 600–800) are the only periods in our sequence in which the archaeological settlement patterns fit best to models that do not allow relocation to protein-depleted areas. Apparently that luxury was not possible in later periods.

As population grew, the three periods from AD 725–880 all fit best to a model with exchange and high protein needs, and the four periods from AD 725–920 are the only periods in the sequence that fit best to models having high soil degradation rates, reflecting the dominance of a shifting farming regime during this period (as Kohler and Matthews [1988] inferred from...
macrobotanical data). The two periods from AD 725–800 and AD 840–880 are the only two periods in the sequence that fit best to models with the larger hunting radius.

To summarize, the models that provide the best fit to the Pueblo I settlement practices (that is, the four periods from AD 725–920) are unusual, relative to those providing the best fit for later periods, in that they tend to exhibit a larger hunting radius, a higher soil degradation rate, an absolute refusal to move to areas that are protein depleted, and high protein consumption goals.

In light of these results, we think it is clear that site location in the Pueblo I period was biased towards those areas providing the best prospects for deer hunting, even though this increased the global costs for making a living on this landscape. The strength of this bias is possibly a measure of the power of those corporate leaders—the male lineage and hunt leaders whom we would locate in the prokotivas—to influence residential location towards those areas that best served their own needs.

**DISCUSSION AND CONCLUSIONS: DANCING WITH GHOSTS**

We have argued that the continued and even increasing importance of big game hunting in an early southwestern agricultural population favored unilinear reckoning of descent. In our specific example (and it might be otherwise where the tradition of agriculture was longer) we suggest that this reckoning was specifically patrilineal, since patrilineal, patrilocal groups co-locate related male hunters. This organization seemingly provides the best chance of arriving at a favorable outcome in the “assurance game” of hunting deer in increasingly depleted landscapes.

From the perspective of the long-term fate of the early Pueblo way of life, we might argue that this degree of emphasis on deer hunting turned out to be maladaptive, not only because it relied on a depletable resource, but also since in this case it encouraged populations to live in areas that were unusually susceptible to the cold conditions that, as it happened, characterized the 10th century AD. Indeed, local population sizes fell precipitously in the early AD 900s, and those populations who remained employed a radically different settlement strategy more closely resembling the optima as discovered by our agents (Fig. 6.5). We might also suggest that the PI village
location strategy was maladaptive in that it appears to depart so radically from the least-cost settlement poise estimated by the agents. Our results suggest that practices that are far from globally efficient can endure, at least for a while, if they serve the interests of sufficiently powerful members of the society, or if they are so deeply embedded in other aspects of social practice that changing them would have effects that cascade far beyond how much deer one eats.

David Sloan Wilson (2007:51–57) applied the evocative phrase “dancing with ghosts” to the mismatch between behavior and environment that happens whenever a species encounters a new environment. Of course, for humans such adaptational lags will be slight compared to species in which adaptation is mainly achieved by genetic change. Nevertheless, the environment of the PI villagers was different from the environment of their recent ancestors in one most important respect: the number of people. To maintain traditional levels of deer hunting in the face of these increased numbers required ever larger hunting radii and larger hunting groups; these in turn favored changes in social organization that we suspect began with strengthening patrilineal/virilocal structures but eventually contributed to making permanent the temporary leadership structures that arise in segmentary social organizations.

**BEYOND DAP AND PI**

It might be tempting to conclude that the male hunting-based authority structures inferred here expired along with the Pueblo I villages and their settlement strategies, especially since there is evidence from the DAP (reviewed in Wilshusen and Van Dyke 2006:245) that some adult couples were killed and buried in (their?) oversized pitstructures as the PI villages were being abandoned in the late AD 800s or early 900s. Still, many of the occupants of the northern PI villages may have ended up in the Chaco Canyon area by about AD 925, via intermediary locations along the San Juan River (Wilshusen and Van Dyke 2006). The fundamental basis of social power in Chaco Canyon was probably related to regional connections, perhaps involving warfare. The possibility that Chacoan leadership was polygynous is implied by female-biased sex ratios in San Juan basin burial assemblages that were especially strong in the Central San Juan subregion (Kohler and Kramer Turner 2006). Polygyny in turn is most characteristic of patrilineal organizations. We suggest that the
deep connections between power, hunting, warfare, and sex (Potter 2004), which flow particularly easily along the lines provided by patrilineal organizations, were not ruptured by the collapse of the PI villages, but somehow became strengthened in the next century, and in a different location. How that was achieved would be a nice topic for a different paper.

**NOTES**

1. A note on spatial taxonomies: the DAP area is in the northeastern corner of the VEP area, which in turn is a part of the much larger central Mesa Verde region, which in turn is nested within the northern San Juan region.

2. Unlike those of the DAP, VEP estimates of population assume that each pitstructure represents a single household, presumably a nuclear family (Ortman, Varen, and Gripp 2007). If the VEP used DAP conventions, our estimates of numbers of households after AD 760 would be at least twice as high as they are.

3. Schachner (2001:179) however misreads Kane (1986) as suggesting that oversized pitstructures were involved in “community-wide” ritual participation. Kane would have agreed with Schachner (2001:179) that communal ritual conducted in oversized pitstructures was probably restricted to segments of the village or community which are the “corporate groups” of Kane’s analysis.

4. Lekson (2009:65–66) points to two very large BMIII sites with Great Kivas in Chaco Canyon as models for later Pueblo villages. It is difficult though to assess the degree of contemporaneity of the pitstructures in these complexes, and their momentized populations may have been considerably smaller than a large DAP PI village such as Grass Mesa or McPhee Village.

5. We meant this argument to apply to villages from the Pueblo I through Pueblo III periods. In retrospect, Kohler believes that the model is most successful for the PI period, and that by PII/III times Pueblo people had developed institutions that tended to keep communities from dissolving into hamlets under conditions in which PI villages might have done so.

6. Or trust dilemma. See Bowles (2004:42) for an example analyzing planting-time strategies among sharecroppers in India. Wilson (2007:129–32) provides an entertaining account of how the cellular slime mold *Dictyostelium discoideum* solves the coordination game under food stress to move impressive distances and reproduce in a new habitat. Brian Skyrms (2004) discusses many ways in which the basic two-person stag hunt can be complicated, and shows that (as in the prisoner’s dilemma) it is generally easier to achieve cooperation when players are interacting within a local neighborhood, than randomly within a larger population—though much depends on the details of the dynamics of interaction.

7. These runs are based on a version of the simulation that we call version 2.72. We have since completed a new 512-run parameter sweep with a modified model. Please consult chapters in Kohler and Varien (2011) for an update to this discussion.

8. Eventually it would be interesting to try to disentangle two possible reasons for the large size of these PI villages that butt up against uninhabited highland forests northeast of the Dolores River. If we envision population growth as a spatially random process from the inhabited areas, populations can be expected to pile up against the boundaries
of uninhabitable regions. The other possibility—more likely in our view although we
would not rule out some role for the first—is the specific attraction of locations in which
it is possible to farm, but from which relatively difficult-to-deplete areas for deer hunting
are still convenient.

Acknowledgments

An early version of part of this paper was presented at the ”Early Pueblo
World” conference in August 2007; we thank the organizers, Jim Potter and
Richard Wilshusen, for the opportunity to attend and participate. A draft
of another portion was presented in a November 2007 AAA panel entitled
“Computational Models in Anthropology: What are they good for, and why
should you care?” and we also thank Lawrence Kuznar and Laura McNa-
mara, who organized that panel, for the invitation to participate. Kohler
also gratefully acknowledges support from NSF BCS-0119981, fellow mem-
bers of the VEP, especially Sarah Cole, Jason Cowan, David Johnson, Ziad
Kobti, Scott Ortman, Mark Varien, and Aaron Wright, without whom vari-
ous portions of this analysis would not have been possible, and Bill Lipe, for
drafting Kohler to work on the DAP in the first place.

REFERENCES CITED

Alvard, Michael S. 2003. Kinship, Lineage, and an Evolutionary Perspective on
Alvard, Michael S., and David A. Nolin. 2002. Rousseau’s Whale Hunt? Coordi-
chaeological Project: Final Synthetic Report, compiled by D. A. Breternitz, C.
Reclamation.
2011. Hunting Results: How Hunting Changes the VEP World, and How
the VEP World Changes Hunting. In Emergence and Collapse of Early Villages:
Borgerhoff Mulder, Monique, Samuel Bowles, Tom Hertz, Adrian Bell, Jan
Beise, Greg Clark, Ila Fazzio, et al. 2009. Intergenerational Wealth Trans-
mision and the Dynamics of Inequality in Small-scale Societies. Science


Explaining the Structure and Timing of Formation of Pueblo I Villages


Timothy A. Kohler and Charles Reed


Varien, Mark D., Scott G. Ortman, Timothy A. Kohler, Donna M. Glowacki,
Explaining the Structure and Timing of Formation of Pueblo I Villages


