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# Environmental Imperatives Reconsidered

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## Demographic Crises in Western North America during the Medieval Climatic Anomaly

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Review of late Holocene paleoenvironmental and cultural sequences from four regions of western North America shows striking correlations between drought and changes in subsistence, population, exchange, health, and interpersonal violence during the Medieval Climatic Anomaly (A.D. 800–1350). While ultimate causality is difficult to identify in the archaeological record, synchrony of the environmental and cultural changes and the negative character of many human responses—increased interpersonal violence, deterioration of long-distance exchange relationships, and regional abandonments—suggest widespread demographic crises caused by decreased environmental productivity. The medieval droughts occurred at a unique juncture in the demographic history of western North America when unusually large populations of both hunter-gatherers and agriculturalists had evolved highly intensified economies that put them in unprecedented ecological jeopardy. Long-term patterns in the archaeological record are inconsistent with the predicted outcomes of simple adaptation or continuous economic intensification, suggesting that in this instance environmental dynamics played a major role in cultural transformations across a wide expanse of western North America among groups with diverse subsistence strategies. These events suggest that environment should not be overlooked as a potential cause of prehistoric culture change.

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*Once there was a famine. . . there was no rain and no food. They ate bleached bones pounded in the mortar, and acorn mush made of manzanitas. There were no deer and no meat; it was a great famine. The poor people ate alfilerillo seeds. One old woman killed and roasted and ate her son; was very hungry. Then her brother came and killed her with three arrows because she had eaten her child. They did not bury her, but left her to be eaten by the coyotes. It was a great famine. But the people who lived on the shore did not die because they ate abalones. But even they were thin because they had nothing but seaweed to eat.*

MARIA OCARPIA, Salinan-speaker, 1918

While the need to recognize paleoenvironmental variability in archaeological models is well established in the study of North American prehistory, the role of environment as an influence on cultural change has in recent years been increasingly overlooked. Misgivings about environmental determinism—the flawed theory, rooted in Greek and Roman philosophy, that attempts to equate climatic regimes with personality types and posits mechanistic responses to climatic change—have encouraged the development of population-based explanations, first as part of cultural evolutionary constructions and most recently in the form of neo-Darwinism and models of economic intensification. Some have rejected ecological approaches altogether in favor of postmodernist foci on power, social conflict, elite conspiracies, and gender inequities, minimally influenced by environmental context (e.g., Bender 1985, Brumfiel 1992). Both postmodernists and neo-Darwinists further point to an overemphasis on adaptationism in many ecological studies that ignores the full spectrum of biological and behavioral variability involved in human evolution. Despite the recent disregard for environment as a cause of cultural change and the success of some neo-Darwinian models in which environmental causality is shunned, we suggest that the categorical rejection of environment as a potential cause of cultural change will lead to unsuccessful if not naïve characterizations of prehistoric human behavior. This is not to say that

other factors do not play pivotal roles, but we suggest that the linkages between the physical/biotic environment and human subsistence and settlement are sufficiently tight to warrant serious consideration of environmental change as a potentially important factor in explanations of cultural change. Environment can and did cause cultural changes in the prehistoric past, and attribution of cause to environment in archaeological models need not be deterministic. A downturn in environmental productivity, in particular, can affect culture change by creating demographic imbalances that require some kind of response, but they do not dictate the character of the response in a given area. Demographic stress can be felt in various ways, but more often than not its effects are negative (e.g., increased mortality, poor health, and decreased fecundity). Downturns related to climate can simultaneously affect large portions of a continent or similar latitudinal zones across continents, so that synchronous cultural changes may crosscut vastly different subsistence regimes. As simple as these points may be, current theories of prehistoric human/environmental relationships increasingly fail to acknowledge circumstances of environmentally induced culture change, particularly those engendering negative human behaviors and outright cultural failures.

In western North America, a theoretical amalgam has emerged from a long, complex history of thought in which hunter-gatherers and agriculturalists have been perceived very differently in their relationships with the physical environment. Cultural ecological theories from the early part of this century, based largely on ethnographic observations, acknowledged subsistence difficulties for both foragers and agriculturalists in arid environments (e.g., Antevs 1948, Douglass 1929, Wormington 1947, Steward 1938) but envisioned a benign environmental past for hunter-gatherers in California (Kroeber 1925). In the 1950s and '60s, these perspectives gave way to models of adaptation in which environmental flux was routinely accommodated by simple cultural adjustments and/or migration (Kroeber 1955) that, with few exceptions (e.g., Moratto, King, and Woolfenden 1978), involved no crises, stress, violence, or demographic or environmental problems. Much of western North American prehistory was linked to incremental population growth and unilinear cultural evolution (Fredrickson 1974, Chartkoff and Chartkoff 1984). These perspectives have recently been supplanted by neo-Darwinian constructs and models of economic intensification applied to both foragers (Baumhoff and Bettinger 1982, Basgall 1987, Bouey 1987, Hildebrandt 1997) and agriculturalists (Ezzo 1992) that ignore environmental flux as a cause of change and posit linear progressions in human subsistence and social complexity (Fredrickson 1994).

Some types of environmental events, however, provoke changes that simply cannot be ignored. Especially critical are those that impact the quality and abundance of basic subsistence resources, most obvious of which are high-intensity, rapidly transpiring environmental

oscillations associated with natural disasters (e.g., floods, fires, hurricanes) and short-term ecological catastrophes (see Torrey 1978, 1979; Oliver-Smith 1996). Such events are commonly overlooked in adaptationist models. They may be hard to recognize in the archaeological record, particularly in the distant past, but intervals of sustained and/or repeated ecological and demographic instability should be detectable. The thesis we develop here is that the interval between A.D. 800 and 1350, known to climatologists alternatively as the Medieval Warm Period, the Secondary Climatic Optimum, the Little Optimum (Ingram, Farmer, and Wigley 1981, Sulman 1982), or the Medieval Climatic Anomaly (Stine 1994), was a time of increased aridity that coincided with a unique pattern of demographic stress and frequent economic crises across much of western North America. Large populations of agriculturalists and hunter-gatherers were confronted with serious and abrupt declines in productivity caused by repeated and prolonged droughts. This interval is increasingly recognized as a time of droughts and warm temperatures in many parts of the world (Lamb 1977, 1982; Hughes and Diaz 1994). It also witnessed a profusion of widespread cultural changes in the archaeological record, many of them quite extreme (e.g., increases in interpersonal violence, declines in health, deterioration of long-distance trade networks, population reductions and/or relocations, site and regional abandonments, and occupational hiatuses). We believe that the plethora of cultural changes and the negative character of many of them reflect widespread crises related to population/resource imbalances, drought-related environmental deterioration, and shortages of food and water. Many current interpretations of regional prehistories, with some recent exceptions (e.g., Arnold 1992a, b), largely fail to consider the possibility of environmentally induced demographic stress in nondeterministic ways. This is particularly true in California, where the biotic environment has been portrayed as rich and reliable, with no sustained intervals of resource shortage. Recent archaeological models (e.g., Basgall 1987, Bouey 1987, Hildebrandt 1997) associate persistent population growth with this perceived environmental richness but fail to consider that economic intensification could place hunter-gatherers in positions of demographic risk similar to those of sedentary agriculturalists.

Our thesis begins with paleoclimatic and paleohydrologic data demonstrating that the period between A.D. 800 and 1350 was punctuated by "epic droughts" (Stine 1994). These droughts and the more broadly timed episodes of increased temperatures attendant upon the Medieval Climatic Anomaly had direct effects on terrestrial ecosystems by impacting water sources and reducing primary production and therefore harvestable biomass. The relationship between effective moisture and primary production is well documented (e.g., Barbour, Bourke, and Pitts 1987, Lieth 1975, Shmida, Evenari, and Noy-Meir 1986). Equally important from the point of view of understanding the constraints on peoples in arid-to-semiarid regions is the steep relationship

between incremental increases (or decreases) in precipitation and ecosystem productivity. The availability of harvestable plant resources in either agricultural or natural ecosystems is a direct function of productivity. The more severe and prolonged the drought, the greater its deleterious effect on ecosystem productivity and consequent terrestrial resource availability. These relationships are not hypothetical; they represent realities faced by traditional peoples in a variety of socioeconomic and political systems. At the same time, we acknowledge that various responses might be possible, as no environmental challenge forces a human population to change in a particular way.

Given the biological realities, we should expect that the prolonged droughts of the Medieval Climatic Anomaly impacted the availability of food and water to the point that human societies experienced significant demographic stress. With this expectation, we turn to the archaeological records of four regions in western North America to determine whether important cultural changes can be explained as direct or indirect effects of stress. Because this study is concerned with the relatively recent past, the archaeological record ought to be sufficiently detailed to provide the information required to demonstrate synchrony and to determine whether changes are consistent with predicted responses to environmental stress and resource shortages. Given the differences in subsistence strategies, population density, social organization, and bioclimatic context between the regions we examine, we should expect to see a spectrum of human responses. Nevertheless, we can also anticipate evidence for population reductions resulting from reduced ecosystem carrying capacity and population shifts to areas with more predictable/productive resources. Sociopolitically, reduced resource availability should be reflected in increased competition between groups and social stress within groups. The alternative hypothesis based on adaptationist perspectives would posit little or no demographic stress and a less tumultuous past; as incremental population growth continued, simple adaptive adjustments would be made (e.g., more low-ranked foods would be added to diets, new extractive technologies would be developed, and intergroup trade would increase).

Our paper has four parts. The first discusses past and current perceptions of prehistoric human ecology in western North America. This is followed by a review of late Holocene paleoenvironmental records showing the evidence for widespread and prolonged aridity during the Medieval Climatic Anomaly. This, in turn, is followed by archaeological case studies from the Colorado Plateau, the central California coast, the southern California coast, and the Mojave Desert (fig. 1), all of which show signs of significant cultural flux synchronous with periods of drought. These droughts cannot be considered the sole cause of major cultural changes, for more often than not human behavior is a response to multiple social and environmental variables (Moratto, King, and Woolfenden 1978:151). Attributing certain significant cultural changes to demographic stress re-

sulting from severe downturns in environmental productivity is nonetheless warranted, since trends in the archaeological record are inconsistent with predictions of economic intensification or simple adaptation.

## Ecological Themes in Western North American Prehistory

The influence of environment has long been a theme in western North American prehistory and ethnology. In 1938, Julian Steward suggested that hunter-gatherer lifeways in the Great Basin were heavily influenced though not determined by difficulties of local ecology: "This, however, must not be construed as 'environmental determinism,' which is generally understood to postulate some kind of automatic and inevitable effect of environment upon culture" (Steward 1938:2). Jesse Jennings's (1957) Desert Culture model was more deterministic. It envisioned a mobile, opportunistic hunter-gatherer lifeway that persisted largely unchanged in the Great Basin for more than 9,000 years as an effective if not necessary adaptation to extreme environmental conditions. A counterproposal was developed by Robert Heizer and his students, who argued that most of the Great Basin was abandoned because of hot, dry conditions during the Altithermal, a warm interval originally defined by Antevs (1948, 1953) and variously dated between ca. 8,000 and 4,000 years B.P. People were thought to have returned to the Basin only when climate ameliorated. A measure of determinism is implied in the putative inability of hunter-gatherers to cope with these conditions for thousands of years. On the California coast, Glassow, Wilcoxon, and Erlandson (1988) suggested that populations of maritime hunter-gatherers in the Santa Barbara Channel were suppressed during the Altithermal but increased dramatically when marine productivity improved afterward. This model perpetuates deterministic thinking about the Altithermal, as it draws parallels between natural productivity and human population with an inevitable human adaptation to increased environmental productivity. Moratto (1984) likewise suggested that human numbers decreased in California during the peak of the Altithermal and that much of the region's settlement and language history can be related to climatic fluctuations, with warm intervals producing retreat from the arid sectors. Moratto, King, and Woolfenden (1978) were the first to suggest that the period between A.D. 600 and 1400 may have been marked by social disruption and violence related to stresses wrought by an intense warm/dry episode. However, the distinctiveness of the Medieval Climatic Anomaly as an interval of crisis unmatched during the late Holocene is lost in Moratto's overarching model of continuous climate change and population migration.

Other recent conceptualizations of human/environment relationships among western North American hunter-gatherers attribute limited measures of cause to

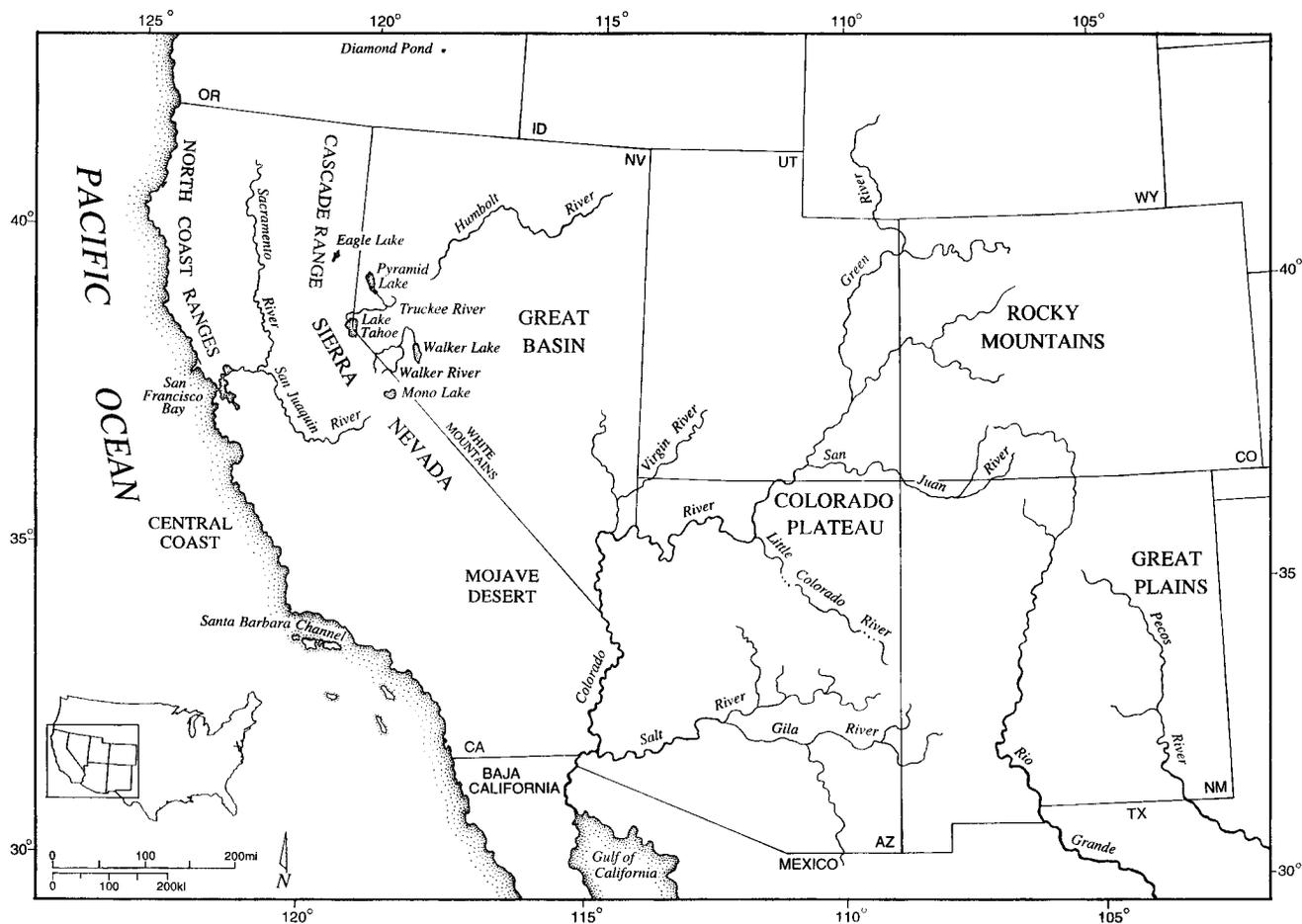


FIG. 1. The Southwestern United States, showing major geographic regions mentioned in text.

environmental change. Larson, Johnson, and Michaelson (1994) have suggested that the final native retreat from San Miguel Island in the Santa Barbara Channel to mainland Spanish missions coincided with a severe El Niño that rendered the island's marine resource base inadequate. This study is unprecedented in California for its consideration of global climatic influences on local culture change, although it attributes ultimate causality to the historical phenomenon of Spanish missionization. Of more relevance to the current discussion is the debate in southern California over the relationships of environmental variability, subsistence, and exchange during the transition between Middle and Late periods of regional prehistory (ca. A.D. 1200–1300). In two provocative papers, Arnold (1992a, b) has linked a dramatic increase in production of exchange commodities (shell beads) on Santa Cruz Island to an interval of warm sea temperatures and depressed marine productivity. Borrowing Gould's (1984) concept of punctuated equilibrium from paleontology, Arnold explains this purported emergence of elite-managed craft specialization as a response to catastrophic environmental change. (More recently, however, Arnold, Colten, and Pletka [1997] have deemphasized the role of environment as a primary

causal variable [Raab and Bradford 1997].) Arnold's thesis helped to precipitate our own interest in the early centuries of the current millennium and the possibility that environmental deterioration was a cause of change over a much wider area than Santa Cruz Island or the Santa Barbara Channel.

Conceptualizations of human/environmental relationships in the American Southwest have taken a course more similar to that in the Great Basin, where explanations of culture change related to the arid and unpredictable physical environment have a long history. Beginning with Douglass's (1929) discovery of the "Great Drought" in the tree-ring record of the late 13th century, periods of sustained drought and corresponding local and regional abandonments have been observed in many cases on the Colorado Plateau. Early efforts (e.g., Fritts, Smith, and Stokes 1965, Wormington 1947), positing somewhat mechanistic responses, have been replaced by more sophisticated models (e.g., Euler et al. 1979, Dean et al. 1985, Dean 1988a, Gumerman 1988, Lipe 1995) that recognize climate change as a significant causal variable within a systemic perspective. Although these models emphasize the potential for adjustment to environmental flux, some hint at the

possibility of crisis emerging when populations exceed carrying capacity. Lipe (1995) has summarized abundant evidence for social turbulence, including warfare, decreased interregional trade, and sociopolitical disintegration preceding the abandonment of large portions of the Colorado Plateau. Haas and Creamer (1992) have likewise suggested that interpersonal violence was among the behaviors exceeding simple cultural adjustment to environmental stress. A growing body of correlations between drought-related environmental stress and population dynamics indicates that simple adaptive adjustment cannot account for many diachronic patterns in Southwestern prehistory (e.g., Larson and Michaelson 1990, Larsen et al. 1996). Arguments against drought-related causality have also been advanced (e.g., Allison 1996, Lightfoot and Upham 1989, Plog 1990), but as Larsen et al. (1996:218) point out it is premature to dismiss the influence of drought on prehistoric Southwestern population trajectories, especially when the ecological effects of large, sedentary populations are taken into account. At the extreme, paleoecological data have been argued to indicate that deforestation of Chaco Canyon was due to fuelwood and construction demands (Betancourt and Van Devender 1981, Samuels and Betancourt 1983, Betancourt 1990). If such ecosystems were already stressed by the intensive land use practices of a sedentary population, a rapid shift to increased aridity could have had a dramatic impact on both environment and human populations.

While assertions that drought-related environmental problems influenced Puebloan agriculturalists have been made for nearly a century, the possibility that similar problems were experienced by hunter-gatherers in adjoining areas of the Great Basin and California has only recently been considered. In addition to the Salinan myth recounted above (quoted by Mason 1918:120), reference to drought-related famines can be found in ethnographic accounts of the Chumash (Walker, DeNiro, and Lambert 1989:351), Pomo (Kniffen 1939:366), and Shoshone (Steward 1938:20). Nonetheless, with few exceptions (e.g., Arnold 1992*a, b*; Walker, DeNiro, and Lambert 1989), there has been little attempt to consider the archaeological implications of such events. Food shortages are thought to have been relatively brief and predictable seasonal phenomena (see de Garine and Harrison 1988:vi) that would have left no lasting, large-scale archaeological signatures.

There appears to have been little attempt to recognize crisis events outside the Southwest, but there has been ample consideration of the effectiveness of hunter-gatherer subsistence practices relative to those of agriculturalists in fending off catastrophic famine. Most of these theories have been developed as explanations for the advent/acceptance of agriculture by some hunter-gatherers and the persistence of foraging lifeways among others (Shnirelman 1992, Testart 1988). Hunter-gatherers of western North America inhabited a full spectrum of environments, from the diverse terrestrial/marine ecotone of the Santa Barbara Channel to the depauperate, arid regions of the Mojave Desert and the Great Ba-

sin. An early opinion on resource diversity and famine was offered by Kroeber (1925:524), who suggested that California's varied environment rendered its inhabitants immune to catastrophe:

The food resources of California were bountiful in their variety rather than in their overwhelming abundance. . . . If one supply failed, there were hundreds of others to fall back upon. If a drought withered the corn shoots, if the buffalo unaccountably shifted, or if the salmon failed to run, the very existence of people in other regions was shaken to its foundations. But the manifold distribution of available foods in California and the working out of corresponding means of reclaiming them prevented a failure of the acorn crop from producing similar effects. It might produce short rations and racking hunger, but scarcely starvation.

For Indians in the resource-poor Great Basin, however, Steward (1938) felt that famine was an intrinsic part of their existence and that it contributed to low population density.

Kroeber's perspective has been replaced in recent years by recognition that groups throughout western North America were dependent upon storage (Testart 1982), including acorns in California and pine nuts in the Great Basin. Acorn economies, in particular, are now seen as highly inefficient and labor-intensive (e.g., Basgall 1987). The dense, sedentary populations associated with them have repeatedly been likened to those supported by agriculture in the Southwest (Baumhoff 1978, Bean and Lawton 1976, Meighan 1959). Nearly all archaeologists assume that these storage-dependent economies arose from nonstoring New World predecessors (see Basgall 1987, Glassow 1991, Wills 1988). Testart (1988) makes a strong case that storage-dependent hunter-gatherers were more at risk from long-term shortfalls than were nonstoring foragers. While storage is a mechanism for countering seasonal shortfalls, storage-reliant hunter-gatherers were inevitably dependent on a few staples suited for long-term storage, the failure of which could cause significant subsistence problems (Testart 1988:173). In these intensive economies, storage did not provide insurance against shortfalls that persisted longer than a few seasons. As a consequence, Testart suggested that the level of susceptibility of storage-reliant hunter-gatherers to food shortages and catastrophic famine was probably comparable to that of agriculturalists. It is worth mentioning Cohen's (1977) likening of the demographic stresses that precipitated the advent/acceptance of agriculture by hunter-gatherers to a crisis-like situation caused strictly by human population growth. If agricultural and intensive hunting-gathering economies incorporated or caused stresses under favorable environmental circumstances, episodes of rapid environmental deterioration would have had the potential to cause serious subsistence stress.

Historical accounts reveal any number of environmentally induced crises among hunter-gatherers in different parts of the world (Shnirelman 1992:28). Among

foragers living adjacent to agriculturalists or pastoralists, such crises often produced shifts in subsistence. Some !Kung San, for example, engaged in farming during periods of abundant precipitation but mostly foraged during normally dry and drought years (Shnirelman 1992:34). Upham (1982, 1984a) argued that a similar dynamic existed among Puebloan societies of the American Southwest, with drought-related crop failures precipitating increased hunting and gathering. In aboriginal economies not exposed to agriculture, economic orientation did not change in the face of periodic resource shortfalls, and death rates sharply increased (Shnirelman 1992:34). Hunter-gatherers can shift to food production in the face of demographic pressure only where conditions allow farming and when the ecological transition is gradual enough to provide people with time to transform their subsistence practices and value systems (Shnirelman 1992:34). Without these factors, a demographic crisis may result in disintegration of economies, interregional aggression, violence, and extinction of some groups. We believe that the archaeological record of the Medieval Climatic Anomaly in western North America reflects a time during which demographic crises of this type were widespread because of a convergence of growing populations and abrupt declines in biotic productivity caused by prolonged and severe droughts.

### Synchrony of Interregional Paleoenvironmental Change

Evidence for significant environmental variability during the Medieval Climatic Anomaly is now available from various locations beyond the limits of the Puebloan area, including the California coast and arid interior deserts in southern California and the Great Basin. During this interval there were widespread and prolonged periods of decreased precipitation and frequent drought (Stine 1990, 1994), warm summer temperatures (Graumlich 1993), and high incidence of fires (Swetnam 1993). Some (e.g., Arnold 1992a, b; Colten 1993) argue that low marine productivity during an extended interval of warm sea temperatures (i.e., a 100-year El Niño [Arnold 1992b:133]) contributed to problems along the California coast. However, more recent studies suggest that the Medieval Climatic Anomaly was characterized by low frequency and intensity of El Niños (Anderson 1994) and that drought-related decreases in terrestrial productivity were much more significant than changes in the marine environment (Colten 1995). Evidence from a variety of interior settings suggests that the period between ca. A.D. 800 and 1350 was a time of generally warm climate (e.g., Hughes and Diaz 1994), but the entire 600-year period was not consistently warm and dry throughout western North America. Rather, it was punctuated by two intervals of extreme drought (Graumlich 1993, Stine 1994) with a shorter intervening period of high rainfall in some localities (Leavitt 1994).

Although some emphasize unusual climatic variability during the period (e.g., Dean 1994), a cursory examination of high-resolution Holocene paleoenvironmental records (e.g., Graumlich 1993, Kreuz et al. 1997) reveals that variability is more the rule than the exception during the late Holocene and that the medieval period stands out as a time of prolonged and severe droughts. What we focus on here are the effects of these droughts in the Great Basin and Sierra Nevada, the southern California coast, the Mojave Desert, and the Colorado Plateau.

#### THE GREAT BASIN AND SIERRA NEVADA

Significant dry intervals are indicated by fine-grained records from the western Great Basin, where Stine (1994:549) has produced compelling evidence for "epic" droughts ca. A.D. 892–1112 and 1209–1350 based on dating of drowned tree stumps at Mono Lake and several other locations. The stumps are derived from trees that grew when lake levels dropped. Stine contends that these droughts were anomalous in their severity relative to the rest of the Holocene and much more severe and prolonged than anything known historically. Data from the bristlecone pine (*Pinus longaeva*) tree-ring sequence in the White Mountains (LaMarche 1974:1047) match the patterns identified by Stine. The early centuries (ca. 800–1050) of the medieval period were marked by cool, dry conditions (overlapping Stine's first epic drought) and were followed by a warm, wet interval ca. 1050–1150 (also reported by Leavitt 1994) and then warm, dry conditions between 1150 and 1330 (approximating Stine's second drought). Relatively coarse-grained paleoenvironmental records from elsewhere in the western Great Basin (e.g., Lead Lake in western Nevada and Diamond Pond in eastern Oregon [Wigand, Davis, and Pippin 1990]) indicate aridity between ca. A.D. 1 and 1400, with some equivocal suggestions of wet conditions between A.D. 500 and 1000 (Currey and James 1982, Davis 1982).

Clear evidence of warm and dry conditions during the Medieval Climatic Anomaly in the Sierra Nevada is reported by Graumlich (1993) on the basis of a tree-ring sequence covering the past millennium. She argues that the period between A.D. 1100 and 1375 is highly unusual because of increased summer temperatures which peaked ca. 1150. Severe droughts are evident at ca. 1020–70, 1197–1217, and 1249–1365, but Graumlich considers them less anomalous relative to the precipitation cycle of the past millennium than the high summer temperatures. She further argues that anomalous temperatures were a product of the convergence of external climatic factors (e.g., volcanic ash, solar events) with internal oscillations (ocean circulation patterns) (Graumlich 1993:254). Corroborating this portrait of Sierran conditions is a 2,000-year record of fire scars in giant sequoias (*Sequoia gigantea*). Citing earlier studies that demonstrated a correlation between areas burned in the United States and the El Niño Southern Oscillation (Swetnam and Betancourt 1992), Swetnam (1993:

887) reports that fire frequencies were higher in the southern Sierra between 1000 and 1300 than during any other interval in the past two millennia.

#### THE SOUTHERN CALIFORNIA COAST

Larson and Michaelsen (1989) and Larson, Johnson, and Michaelsen (1994) summarize a 1,600-year tree-ring record that elucidates the paleoclimate of coastal southern California. This sequence includes evidence for droughts between A.D. 750 and 770, high rainfall between 800 and 980, and rapidly developing drought between 980 and 1030. Conditions were wetter between 1030 and 1100, but the interval between 1100 and 1250 was one of sustained drought, with the period between 1120 and 1150 being particularly harsh (Larson and Michaelsen 1989:23). This last drought partially overlaps with the warm, dry conditions in the Sierra Nevada and at Mono Lake detected by Stine (1994) and Graumlich (1993).

A reconstruction of southern California coastal vegetation from a 7,000-year pollen core from San Joaquin Marsh (fig. 2), located 7 km from the Pacific Ocean at the head of Newport Bay (Davis 1992), also provides evidence for dry conditions during the Medieval Climatic Anomaly. The marsh is a paleoestuary that has alternated between fresh- and saltwater conditions. Decreased stream flow and lower discharge of springs feeding the marsh caused saltwater incursions marked by lower pollen deposition and sedimentation rates, the presence of marine-estuarine organisms such as dinoflagellates and foraminifera, and the pollen of salt marsh plants (Davis 1992:93). Conversely, periods of high stream flow are marked by comparatively rapid sedimentation rates, abundant palynomorphs, and high percentages of Compositae pollen from terrestrial communities (Davis 1992:92–98). Prior to ca. 1000 B.C., Compositae pollen dominates the pollen record, but ca. A.D. 200 it is supplanted by Chenopodiaceae-*Amaranthus*, indicating saltwater incursion and reduced freshwater runoff. These conditions persisted until ca. 1500. Although this record is one of low temporal resolution, suggesting a longer-lived phenomenon than is indicated by tree rings, it is chronologically consistent with other paleoenvironmental indicators from the central and southern California coast.

#### THE MOJAVE DESERT

Although the Mojave Desert is part of the Great Basin culture area, the bioclimatic regimes of the two deserts are distinct. The Great Basin Desert is a largely semi-arid, steppe environment with generally more productive valley-bottom and montane communities, while the Mojave Desert is largely arid and supports vast expanses of low-productivity desert scrub. Late Holocene paleoenvironmental records from the Mojave Desert and the trough of the Lower Colorado River have previously been assessed for evidence of drought during the medieval period. The clearest data come from packrat

midden and paleohydrologic records that indicate enhanced aridity beginning by A.D. 600 and lasting until at least 1200 (fig. 3, table 1). During this period packrat midden records of xeric vegetation are common, and there are few records of mesic vegetation. Furthermore, there are essentially no published records of increased spring activity or desert lake high stands between 900 and 1350. One record (fig. 3, 12) from that period is from a spring in the Las Vegas Valley that remained active even after the local aquifer was significantly drawn down by heavy urban pumping in modern times (deNarvaez 1995). The absence of evidence for such paleohydrologic features during the medieval period is significant, particularly in contrast with the following centuries of cold and wetter climate, referred to by some as the Little Ice Age (see Gribbin and Lamb 1978, Grove 1988). The autecology of plant species that were restricted to higher elevations during this period suggests that the Medieval Climatic Anomaly was characterized by warmer winter temperatures. The paleohydrologic data speak more directly to changes in precipitation and consequent recharge and runoff. General lack of evidence for spring activity and lacustrine events in the desert interior indicates less winter precipitation during the Medieval Climatic Anomaly than during succeeding centuries.

Blackbrush (*Coleogyne ramosissima*) desert scrub is a relatively high-productivity vegetation type currently restricted to elevations above 1,200 m by moisture deficits near its lower limit (Beatley 1975). Packrat midden studies clearly show descent of this vegetation into warmer habitats near the end of the medieval period in the Mojave Desert. The downward migration of this mesic vegetation type suggests that conditions had previously been warmer and drier. Stratigraphic and archaeofaunal evidence for perennial lake stands in the currently hyperarid Mojave Sink (fig. 3, table 1) provide a strong contrast with the preceding Medieval Climatic Anomaly.

Immediately southwest of the Mojave Desert in the Salton Sink, the timing of the episodic filling and desiccation of Lake Cahuilla stands out as sharply distinct from the chronologies of drought related above. Geomorphic analysis and the historical record demonstrate that these lake high stands were forced not by climate change but by the shifting of the Lower Colorado River channel (Fenneman 1931, Waters 1983). Although expansive, the deltaic cone of the Colorado River provides an alluvial barrier only about 15 m high between the river and the Salton Sink, and because the latter is below sea level the river periodically breaches this barrier and fills the basin. This episodically created freshwater lake covered an area of approximately 5,700 km<sup>2</sup>, with a maximum depth of about 96 m, in response to events that have no known relation to climatic change. The earlier chronology of Lake Cahuilla is not well known, but there are sufficient stratigraphic exposures to establish the timing of younger late Holocene lake episodes. The oldest lacustrine interval dates to about 350 B.C. After this time there were four closely spaced lacustrine

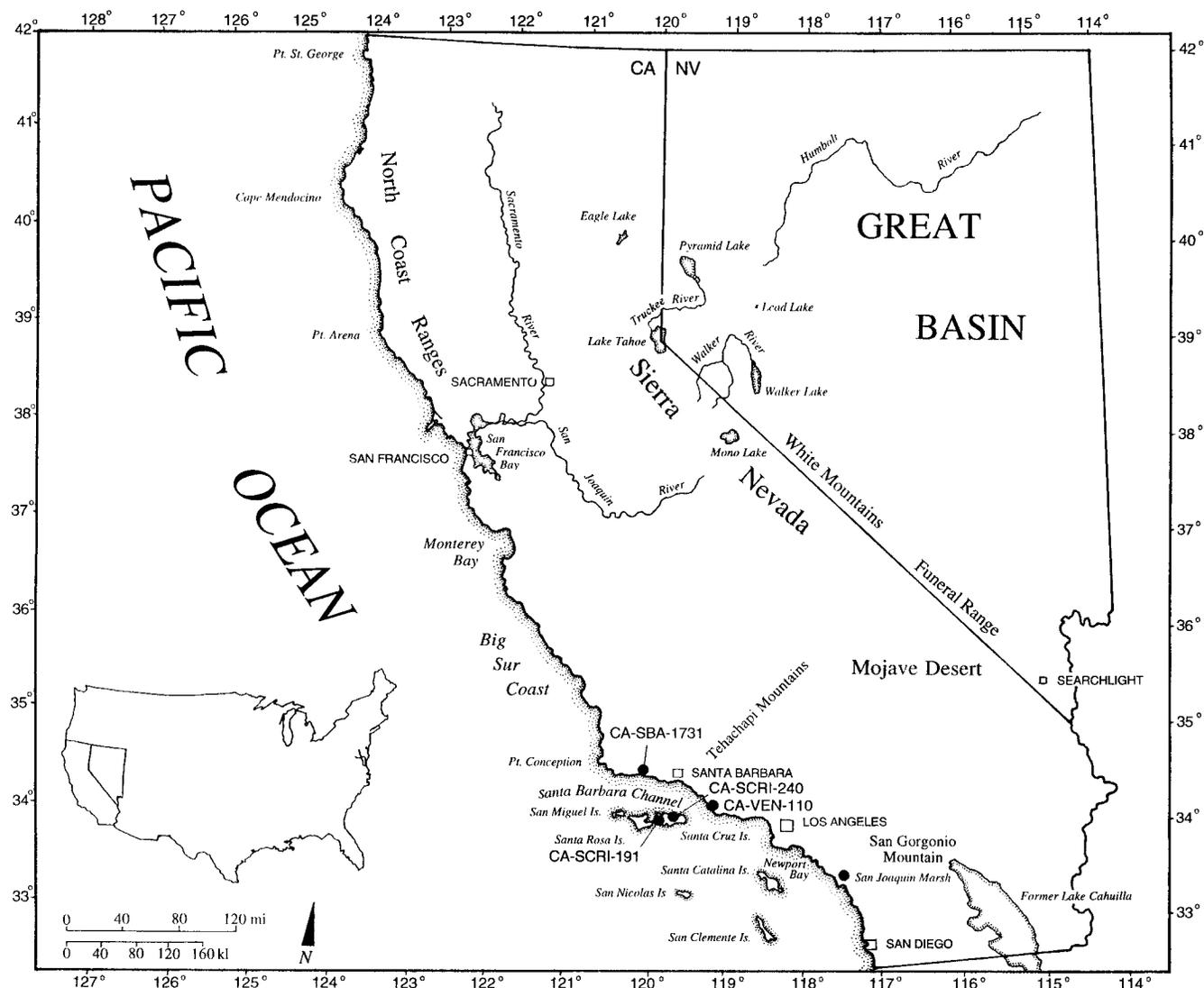


FIG. 2. California, the western Great Basin, and sites mentioned in text.

intervals between ca. A.D. 550 and 1550, each punctuated by abrupt desiccation and refilling (Waters 1983). It appears that Lake Cahuilla was often full during the medieval period, although not necessarily as a result of climatic factors.

#### THE COLORADO PLATEAU

Paleoclimatic reconstructions for the late Holocene on the Colorado Plateau are based on tree rings, pollen, plant macrofossils, faunal remains, and geomorphology. High-resolution dendrochronological data (Dean and Robinson 1977; Euler et al. 1979; Dean 1988a, b) reveal a series of droughts during the 1st millennium A.D., with a major drought at least once every century until ca. A.D. 750, when they decreased in magnitude until the late 900s. The latter period was dry but accompanied by pronounced temporal variability in effective

moisture. After 1000, temporal variability declined, but spatial variability in moisture increased until ca. 1140. A long-term drought (ca. 1065–1100) occurred during this period, the effects of which were probably offset in some areas by spatial variability in effective moisture. A few decades later, another long-term drought (ca. 1130–1150) was followed by a series of shorter, less intense droughts which culminated in the Great Drought dating from 1276 to 1299. These arid conditions were followed by a period of consistently above-average moisture from 1300 to 1350, after which dry conditions returned.

Changes in temperature, evaluated independently from effective moisture reconstructions, are indicated by timberline fluctuations and pollen from montane sediments (Peterson 1987, 1988). Much of the past two millennia was cool, with warmer conditions prevailing from A.D. 800 to 900 and from 1100 to 1200. Most of the



TABLE 1  
Sources of Data on Environmental Change in the Mojave Desert and the Lower Colorado River Trough

No.	Locality	Indicator	Reference
1	Vicinity of Searchlight, extreme southern Nevada	<i>Coleogyne ramosissima</i> presence/absence	Hunter and McAuliffe (1994)
2	Mojave Sink, central Mojave Desert	Lacustrine sediments indicating perennial lake stand	Enzel et al. (1992)
3	Picacho Peak, vicinity of Yuma, extreme southeastern California	<i>Hilaria rigida</i> presence	Cole (1986)
4	Hornaday Mountains, Sonora, immediately northeast of the head of the Gulf of California	<i>Cercidium floridum</i> , <i>Prosopis juliflora</i> presence/absence	Van Devender et al. (1990)
5	Greenwater Valley, Funeral Range, immediately east of Death Valley, eastern California	<i>C. ramosissima</i> and <i>Eriogonum fasciculatum</i> presence/absence	Cole and Webb (1985)
6	Fortymile Wash, eastern Amargosa Desert, southern central Nevada	<i>Purshia glandulosa</i> and <i>Larrea tridentata</i> covariance	Spaulding (1990)
7	Granite Mountains, central Mojave Desert	<i>C. ramosissima</i> , <i>Salvia mohavensis</i> , and <i>Ephedra viridis</i> abundance	Spaulding (1995)
8	Sheep Range, southern Nevada	<i>Pinus monophylla</i> and <i>Juniperus osteosperma</i> abundance	Spaulding (1981)
9	Amargosa Desert, southern Nevada	Peat growth indicating spring discharge	Mehringer and Warren (1976)
10	Northern Las Vegas Valley, southern Nevada	Organic-rich spring-margin sediments	Haynes (1967)
11	Northern Las Vegas Valley, southern Nevada	Organic-rich spring-margin sediments	deNarvaez (1995)
12	Mojave Sink, central Mojave Desert	Freshwater clam ( <i>Anodonta californiana</i> ) middens	Drover (1979)
13	Mojave Sink, central Mojave Desert	Tufa indicating lake high stand	Berger and Meek (1992)

they were accompanied by alluvial instability and the beginning of a shift toward increased erosion and depressed water tables. This generally unstable period appears to have been significant enough to have impacted all traditional subsistence options, not just farming. Shifts from farming to hunting and gathering, as hypothesized by Upham (1984a), may have been theoretically feasible in favorable environments during times of relatively low population density but not when population reached the inflated levels common during the medieval period (see Minnis 1985:146–50).

Agriculture was adopted about three millennia ago in much of the Southwest, but it took on real economic importance within the past two millennia as it spread throughout the Colorado Plateau (Ambler 1966, Berry 1982, Lindsay 1986, Wills 1988, Larson and Michaelsen 1990, Brown 1992, Hogan 1994). Its spread during the 1st millennium A.D. occurred under conditions generally favorable to lowland farming (i.e., regular flooding in major river systems and stable alluvial systems in tributaries). Droughts may have periodically curtailed upland farming, but small populations could have concentrated their agricultural efforts in lowlands. After 1050, paleoclimatic data show more severe deterioration including a variety of climatic, vegetational, and hydrologic processes. The compounded impact on both farmers and hunter-gatherers must have been significant. However, another major reason that these paleoenvironmental changes had deleterious consequences was the great density of population across the

Colorado Plateau by this time (Dean et al. 1985, Dean 1988b, Plog et al. 1988, Larson and Michaelsen 1990, Van West and Lipe 1992).

It is widely recognized that during the Pueblo II period, from A.D. 900 to 1150, a population boom coincided with expansion into many new areas and a wide variety of habitats. Population density in most areas and the regional population level throughout the Colorado Plateau reached unprecedented highs during the late Pueblo II period (Euler 1988, Cordell and Gumerman 1989). This peak coincides with paleoenvironmental conditions conducive to hunting, gathering, and agriculture in both upland and lowland areas as indicated by high groundwater and geomorphic reconstructions (Brown 1996), followed by successive droughts toward the end of the 11th century and early–mid-12th century, preceding the Pueblo II–III transition. The period 1130–1150 marks a major decrease in effective moisture accompanied by heavy flooding and generally unstable alluvial systems, possibly marking a shift from summer-dominant toward winter-dominant precipitation. Puebloan occupation ended in major portions of the Colorado Plateau during the mid-1100s, especially in areas to the west and north. Termination of Virgin Anasazi settlement on the west is frequently attributed to long-term drought between 1120 and 1150 in the context of population growth (Schwartz, Chapman, and Kepp 1980, Schwartz, Kepp, and Chapman 1981, Larson 1987, Larson and Michaelsen 1990), while the end of occupation by many Fremont populations across the

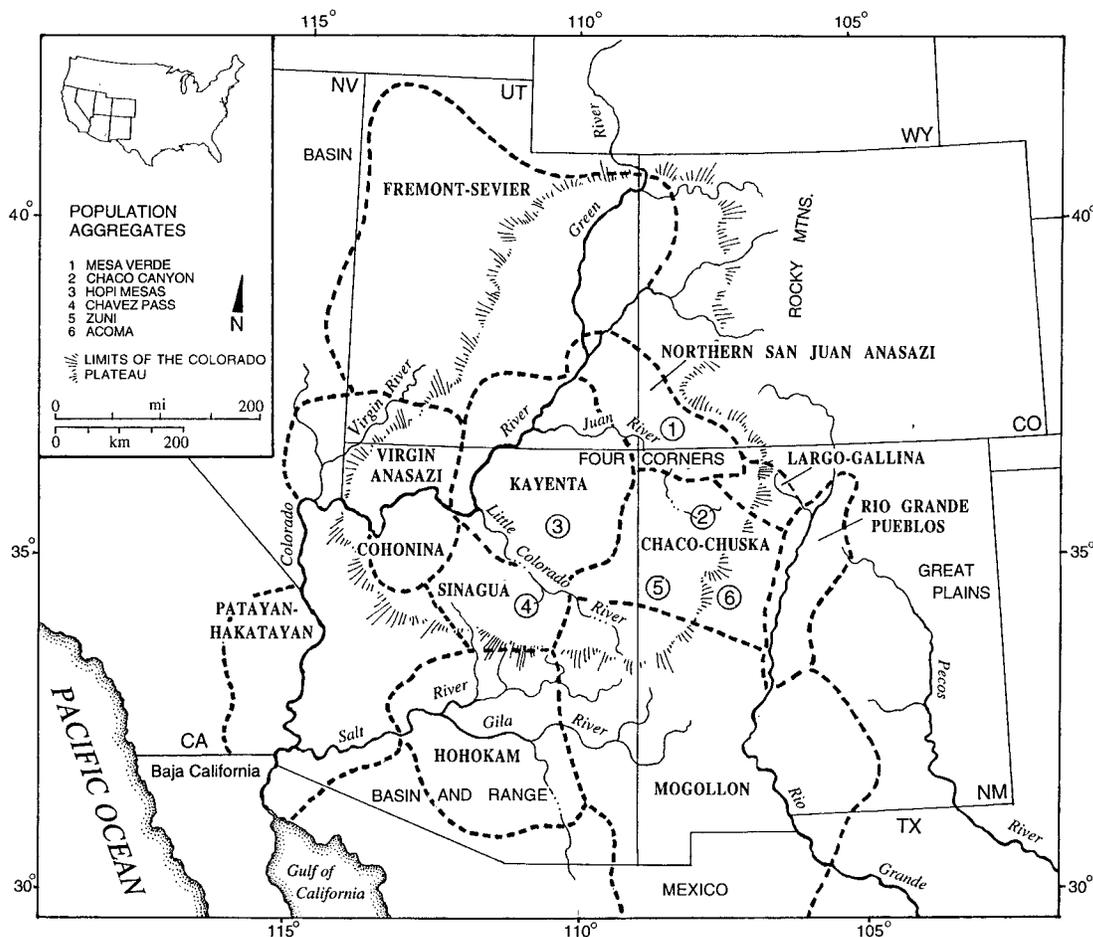


FIG. 4. Major archaeological regions of the American Southwest.

northern half of the Colorado Plateau may also be related to paleoclimatic change (Lindsay 1986). Although paleoenvironmental data suggest a temporary increase in effective moisture after 1150, this may have been too late to help many agricultural groups, particularly those inhabiting areas on the west and north characterized by winter-dominant precipitation patterns that were less beneficial to farmers.

Dean (1988b) cautions against relating phase transitions to paleoenvironmental changes, but the chronological correlations are compelling. Widespread abandonments toward the end of the Pueblo II period precede the marked population aggregation characteristic of the Pueblo III period (ca. A.D. 1150–1300) in the limited areas where Pueblo III sites are represented. Abandonment and concurrent aggregation might be linked as a single trend toward fundamental reorganization. In our view, this transition is not just the kind of recognizable change in diagnostic material traits that Dean assumes to be typical of most phase transitions; it is a cultural transformation. The Pueblo III–IV transition is an even more remarkable instance of organizational change that is at least partially attributable to environmental change. The Great Drought and the shift

to cooler temperatures at the beginning of the Little Ice Age both put considerable stress on agricultural systems. Pueblo III population levels appear to have exceeded the carrying capacity of some areas, and the denser occupation of neighboring areas limited opportunities for relocating the large villages characteristic of this time (Van West and Lipe 1992). In addition, many areas that were abandoned appear to have been undergoing a change toward relatively autonomous “tribal” polities characterized by intergroup warfare (Haas and Creamer 1992, Wilcox and Haas 1994, Lipe 1995), various kinds of sociopathic violence (Nickens 1975; Turner and Turner 1990, 1992; White 1992), and reduced interregional interaction (Neily 1983, Green 1992).

Why cultural systems across so much of the Southwest collapsed rather than splitting or implementing technological options such as agricultural intensification remains an important issue. By A.D. 1300, all the agricultural settlements in the northern Colorado Plateau and most of those in the central portion had been abandoned. The early Pueblo IV period (ca. 1300–1450) is represented in only a few areas on the southern edge of the Colorado Plateau, including the Hopi, Zuni, and

Acoma areas, where Puebloan traditions persist to the present, and the Little Colorado drainage, where large towns were established during this period but abandoned during the 15th century. Although these areas could have absorbed some population from the Four Corners region, evidence of migrations is limited. The Rio Grande Valley east of the Colorado Plateau and the transitional zone to the south are the most widely accepted candidates for recipients of major populations from the Four Corners region. The areas where significant Pueblo IV populations were located thus occur almost exclusively to the south and east, in the directions of greater summer precipitation.

In addition to both agricultural intensification and diversification, Pueblo IV is characterized by some of the most abundant evidence for exchange and specialized production of nonsubsistence commodities in the Southwest. Chavez Pass, on the southwestern margin of the Colorado Plateau, appears to have functioned as a gateway community that facilitated exchanges between the Colorado Plateau and groups inhabiting different environmental zones to the south (Upham 1982, Upham and Plog 1986). Communities such as Chavez Pass may have specialized in nonsubsistence economic activities such as production and exchange of pottery, obsidian, marine shell jewelry, and other exotic items (Cordell and Plog 1979; Upham 1982; Brown 1982, 1990). Such activities would have been crucial to the survival of groups in the area, since they also appear to have exceeded the local carrying capacity (Upham 1984*b*). The systems of economic interdependence typical of this period may have provided alternative forms of organization to the autonomous tribal societies characteristic of many areas that had been abandoned by the end of the Pueblo III period (compare Upham 1982 with Haas and Creamer 1992). Where the issue has been examined, such alternative interregional economies appear to have developed initially about the same time as provincial tribal organizations elsewhere on the Colorado Plateau, that is, during the Pueblo III period (Brown 1982, 1990). Thus, these two types of organization might represent differing means of coping with environmental stress, one of which suffered widespread failure (abandonment) while the other developed into classical Pueblo IV regional systems.

#### SETTLEMENT DISRUPTION AND EXCHANGE DETERIORATION AMONG HUNTER-GATHERERS: THE CENTRAL CALIFORNIA COAST

The suggestion that drought-related problems occurred in central California during the late Holocene was first advanced by Moratto, King, and Woolfenden (1978), who associated signs of social disruption in the southern Sierra Nevada foothills between A.D. 600 and 1500 with warm, dry climatic conditions. The central California coast also shows changes in technology, settlement, and exchange during the Medieval Climatic Anomaly inconsistent with progressive social evolution or economic intensification. Rather, diachronic pat-

terns show some similarities with parts of the Colorado Plateau, as the regional economy apparently reached peak intensity and sophistication during the early medieval period and declined thereafter. The punctuated nature of technological change in this region is striking, as is the chronological correlation with the interval of medieval droughts. Artifact assemblages show little typological or stylistic change between 3500 B.C. and approximately A.D. 500, after which smaller projectile points associated with the bow and arrow begin to appear in small numbers alongside large dart and/or spear points. Between 1200 and 1400, however, bow technology overwhelms the earlier weaponry; arrow points dominate assemblages thereafter (Jones 1995). This technological transition is coeval with a major disruption in settlement indicated by radiocarbon-based occupation sequences showing that few if any sites were continuously occupied through the Medieval Climatic Anomaly (figs. 5 and 6). Sites occupied earlier than 1200 show signs of abandonment, while settlements first inhabited ca. 1200–1400 are single components with no signs of earlier use.

Obsidian frequency profiles show that sites postdating A.D. 1000 yield far less of this trade commodity than earlier deposits. From 3500 B.C. until A.D. 1000, obsidian bifaces were regularly imported to the central coast from nine distant locations (fig. 7). Appearing in small quantities during the Early period (3500–600 B.C.), this commodity was increasingly abundant until A.D. 1000, after which it disappeared from the record and never reappeared in significant quantities. An obsidian-hydration profile depicting results from over 50 excavated sites shows the pattern clearly, as high frequencies of hydration readings fall into the Early and Middle period micron spans but almost none represent the Late period (fig. 8). Interregional exchange networks apparently deteriorated between ca. 1000 and 1300. A study of one of the obsidian quarries (Coso in the Mojave Desert) shows that production declined markedly after ca. 1275 (Gilreath and Hildebrandt 1995).

Chronological correlations between these archaeological transitions and droughts during the medieval period do not prove environmental causality. Nonetheless, they are difficult to overlook inasmuch as the abrupt changes in settlement and exchange are inconsistent with the predictions of incremental population growth and subsistence intensification. Intensification models predict decreases in efficiency as labor-intensive commodities such as acorns and fish increase in dietary significance (Basgall 1987), more diminutive quarry are pursued (Broughton 1994*a*, Hildebrandt and Jones 1992), exchange networks expand, and complex social structures evolve to complement increasingly sophisticated intergroup relationships (Jackson 1986). On the central coast, many diachronic patterns leading up to the Medieval Climatic Anomaly are consistent with these predictions, but changes occurring between A.D. 1000 and 1400 are different in that diets did not continue to broaden and trade horizons contracted. It seems likely that these changes reflect demographic problems

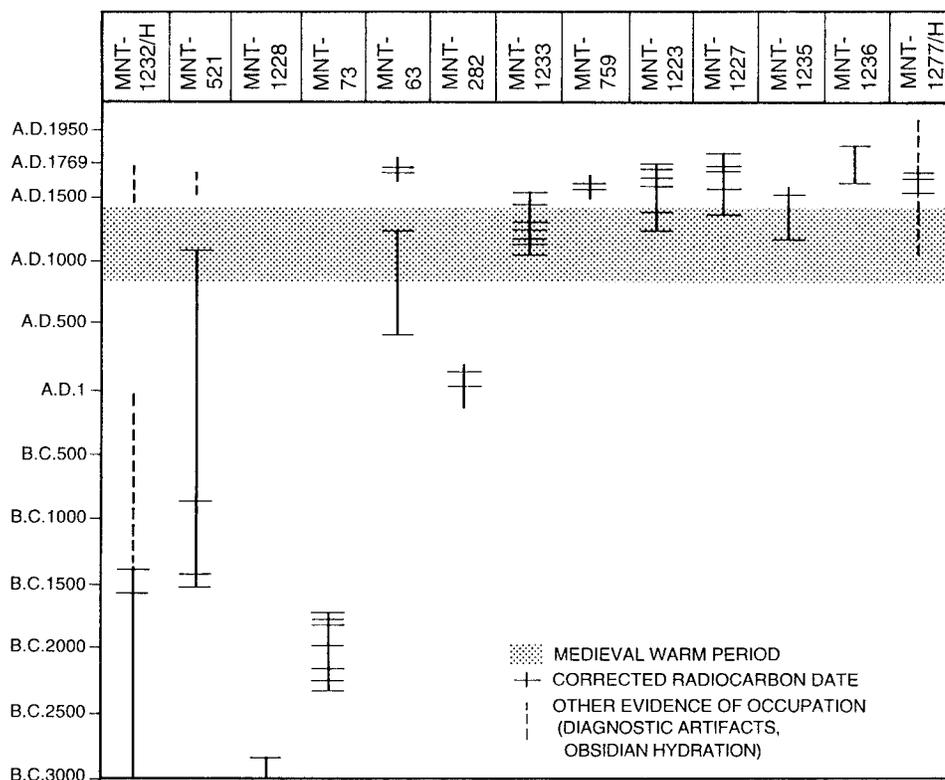


FIG. 5. Settlement disruption during the Medieval Climatic Anomaly on the Big Sur coast of central California.

that could not be solved by simple adaptive adjustment or further intensification and that settlement shifts and deterioration of exchange reflect large-scale population movements akin to those on the Colorado Plateau. The complex distribution of language stocks in California at the time of historic contact has long been recognized as a reflection of multiple prehistoric population movements (Kroeber 1955, Moratto 1984). While the history of these movements is debated, there is growing evidence for massive shifts in central California during the medieval period (Moratto 1984:560). This again reflects a correlation between environment and cultural change that suggests a causal relationship between the two.

VIOLENCE AND SETTLEMENT DISRUPTION: THE SOUTHERN CALIFORNIA COAST

Evidence for abrupt cultural changes during the Middle/Late transition (ca. A.D. 1200–1300), not readily accommodated by economic intensification or gradualist adaptive models, is also apparent along the southern California Bight. Ethnohistorical accounts of drought conditions have been recorded for the Chumash (Walker, DeNiro, and Lambert 1989:351). In the archaeological record, trends in settlement patterns, health conditions, violence, and regional trade are correlated with demographic stress during the Middle/Late transition. Lambert and Walker (1991) and Arnold

(1987, 1992a, b) were among the first to call attention to these patterns, and Arnold (1992a, b) specifically attributed changes during the Middle/Late transition to major climatic shifts. She (1992b:134) reported distinctive signs of settlement disruption on Santa Cruz Island ca. 1200–1300, with many sites exhibiting either an occupational hiatus or abandonment. Detailed stratigraphic studies at sites CA-SCRI-191 (Cristy Ranch) and CA-SCRI-240 (Prisoner’s Harbor) date occupational hiatuses ca. 1250–1300 (Arnold 1992a:76). Islands such as Santa Cruz contain small rain catchments relative to the mainland; persistent drought conditions are likely to have had devastating impacts.

On the mainland, a major settlement shift ca. A.D. 1000 in the San Diego area (Christenson 1992) is generally attributed to migration of Yuman- and Shoshonean-speakers from the interior (Warren 1968), although Moratto (1984:560) argues that this intrusion took place earlier. Marine foods seem to have increased in significance relative to terrestrial resources during the Middle/Late transition, in contrast to Arnold’s findings from Santa Cruz Island, but this trend is consistent with that on the mainland of the central coast. Faunal remains from CA-SBA-1731 suggest that marine resources provided an average of at least 76% of the animal protein consumed (Erlandson 1993:191). At the same time that many sites on Santa Cruz Island were being abandoned, the inhabitants of this mainland site

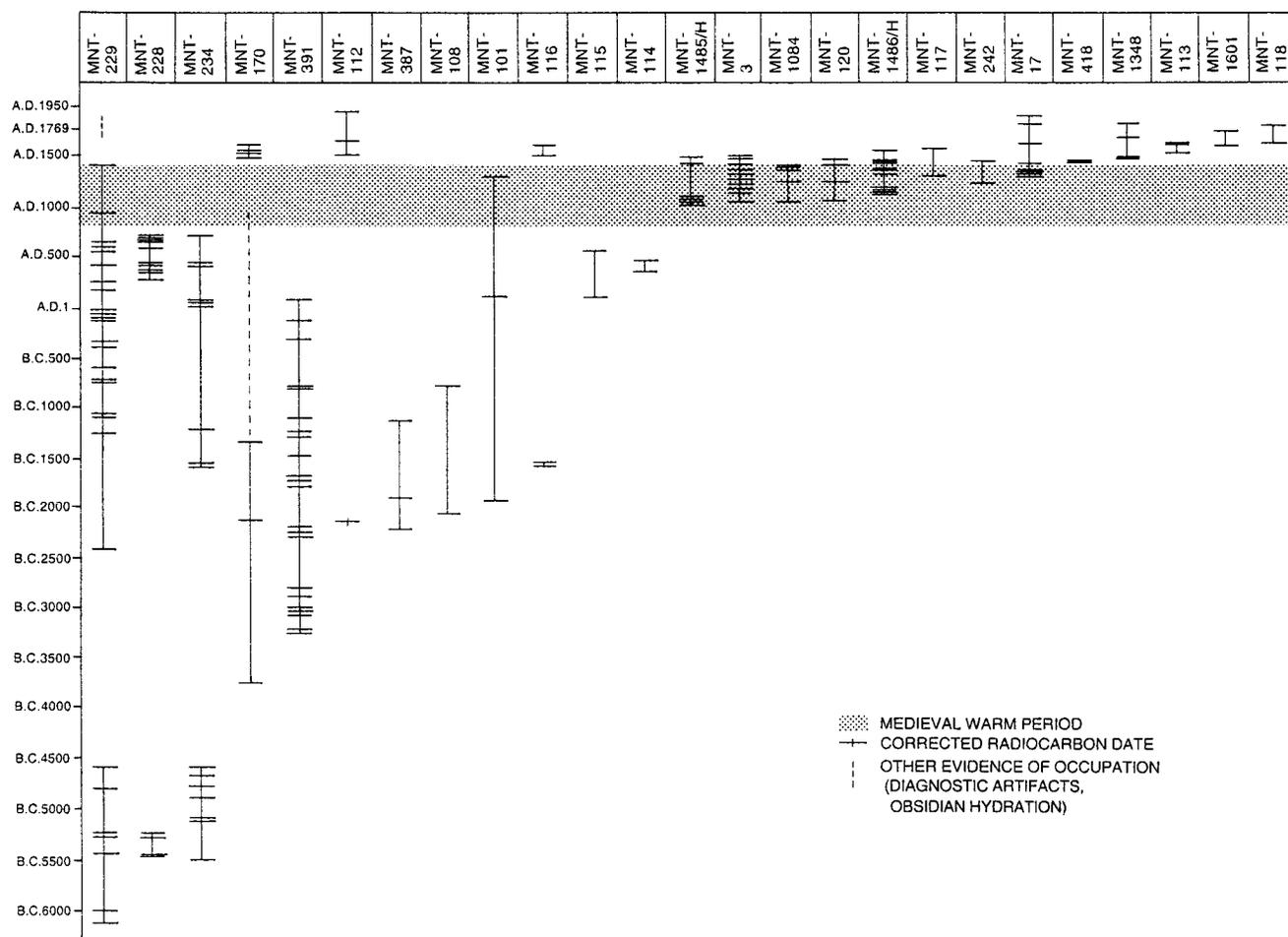


FIG. 6. Settlement disruption during the Medieval Climatic Anomaly in the Monterey Bay area of central California.

apparently turned to the sea for most of their protein needs, consistent with depressed terrestrial productivity during an interval of persistent drought.

Competition for scarce food resources, both marine and terrestrial, was another apparent outgrowth of the Medieval Climatic Anomaly, as the need to control food sources and remain in proximity to reliable sources of fresh water seems to have solidified boundaries and fostered a territorial settlement pattern (True 1990). High population density around water sources is also likely to have promoted disease (Walker 1986). Violent encounters between groups competing for vital resources would be another anticipated outgrowth of resource scarcity. Osteological signs of poor health and violence reached an all-time peak in the Santa Barbara Channel between A.D. 300 and 1150 (Lambert 1993; Lambert and Walker 1991; Walker 1986, 1989; Walker and Lambert 1989; Walker, DeNiro, and Lambert 1989). High levels of interpersonal violence are evident at CAVEN-110 (Calleguas Creek) on the mainland coast near Point Mugu, where a large cemetery was established in the 13th century (Raab 1994). Whereas Walker (1989)

interprets compression fractures of the skull as products of ritualized, sublethal combat, arrow wounds in the individuals interred in the Calleguas Creek cemetery attest to warfare intended to inflict death. Documented projectile wounds are rare in most prehistoric burial populations on the south coast—with the exception of burial populations from the Middle/Late transition. In a study of four prehistoric cemeteries in the Santa Monica Mountains dating as early as 400 B.C., Martz (1984) did not describe a single definite projectile wound. At Medea Creek, a historic-period cemetery, King (1982:151–85) found that only 1.3% of more than 300 burials showed evidence of violence, including possible arrow wounds, skull fractures, dismemberment, and cannibalism. In sharp contrast, up to 10% percent of the burials at Calleguas Creek (1200–1300) showed arrow wounds (Walker and Lambert 1989:210). Moreover, both males and females were victims, suggesting a style of warfare or raiding in which entire communities were exposed.

Arnold (1992a, b) has linked emergent social complexity with environmental stress during the Middle/

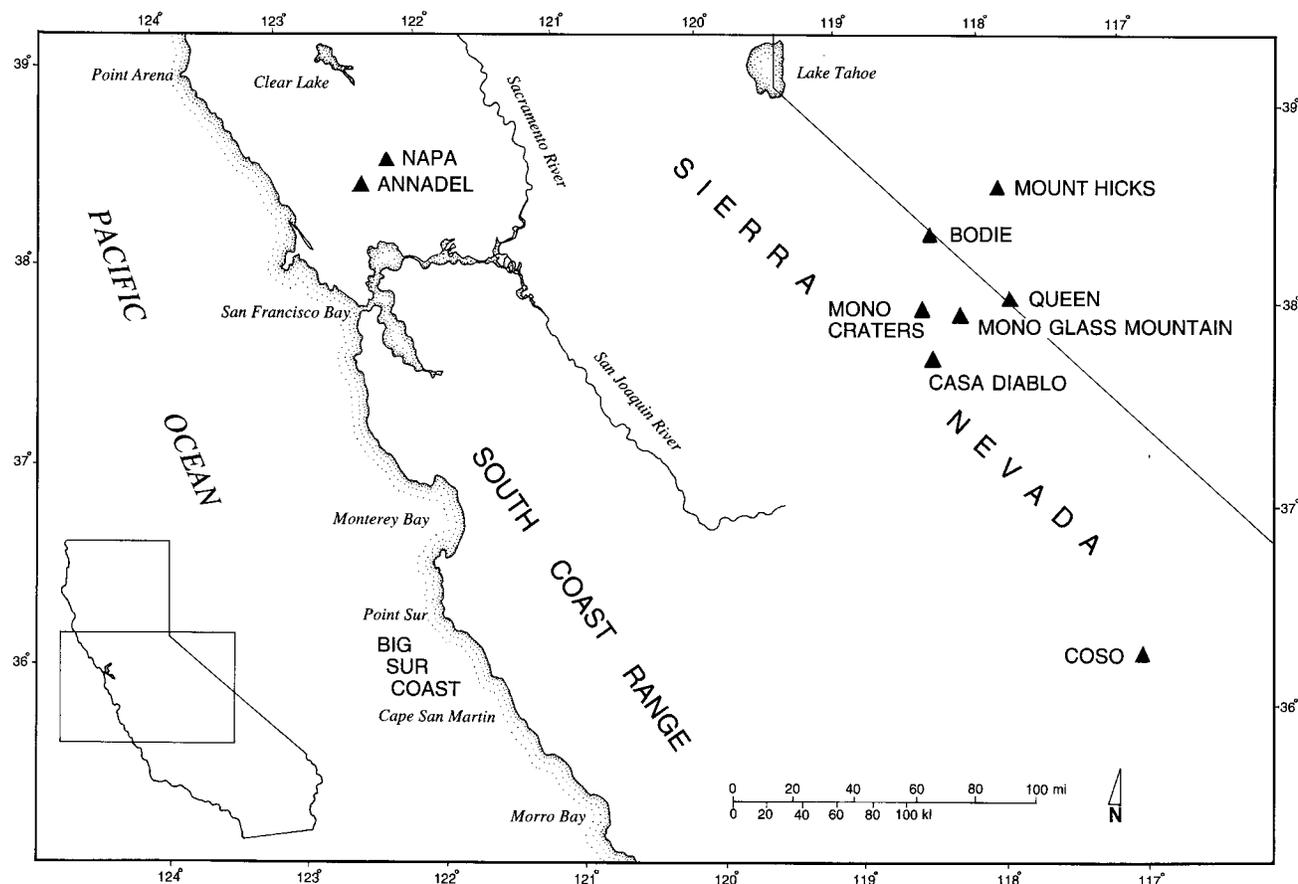


FIG. 7. Obsidian sources represented at archaeological sites on the central California coast (from Jones 1995).

Late transition in the Santa Barbara Channel. She contends that during this critical transition, shell-bead manufacture by specialists was brought under the control of chiefs in a system designed to buffer subsistence failures by providing a commodity that could be traded to groups on the mainland for food. Study of local mortuary patterns confirms that important shifts in social complexity took place ca. A.D. 1100 among the Chumash (Martz 1984:489–90), as a decline in the importance of the religious leaders coincided with an increase in the importance of the hereditary political group. This shift in status and a corresponding increase in the proportion of subadults in burials with status objects suggests the development of a nobility with an emphasis on lineage and ascription.

Trade relationships show significant evidence for change during the Middle/Late transition as well. Although *Olivella* and abalone shells were imported from the California coast to the Puebloan area at least as early as A.D. 500, the volume of trade increased significantly after 1000. Between 500 and 1150, Anasazi settlements on the lower Virgin River were importing large quantities of Pacific coast shells, which are found as burial offerings, but this trade relationship ended when the Virgin River sites were abandoned ca. 1150.

Between 900 and 1150, shells, steatite, and asphaltum from the Pacific coast were being imported by people living at the Willow Beach site near Hoover Dam on the Colorado River (Schroeder 1961). This expanded trade with Yuman peoples probably accounts for the presence of pottery of Anasazi and Hohokam manufacture in late Middle-period sites around the Santa Barbara Channel, including Sacaton Red-on-Buff sherds from the Gila River found at CA-LAN-267 (dating ca. 900–1100) (Walker 1951, Ruby and Blackburn 1964), and Cibola White ware found at the Century Ranch Site (CA-LAN-227) that probably was manufactured ca. 1000 (King, Blackburn, and Chandonet 1968:73). Southwestern pottery disappeared from the southern California coast after 1150.

Arnold (1987, 1992a, b) documents a major increase in shell-bead manufacture on Santa Cruz Island as an apparent strategy for buffering food shortages in this vulnerable insular setting. Manufacture and exportation of steatite artifacts also increased markedly ca. A.D. 1200 on Santa Catalina Island (Wlodarski et al. 1984:342). This increase in trade activities contrasts with the situation on the central California coast and seems to reflect geographically limited exchange tied directly to subsistence; the goods produced on the islands are not

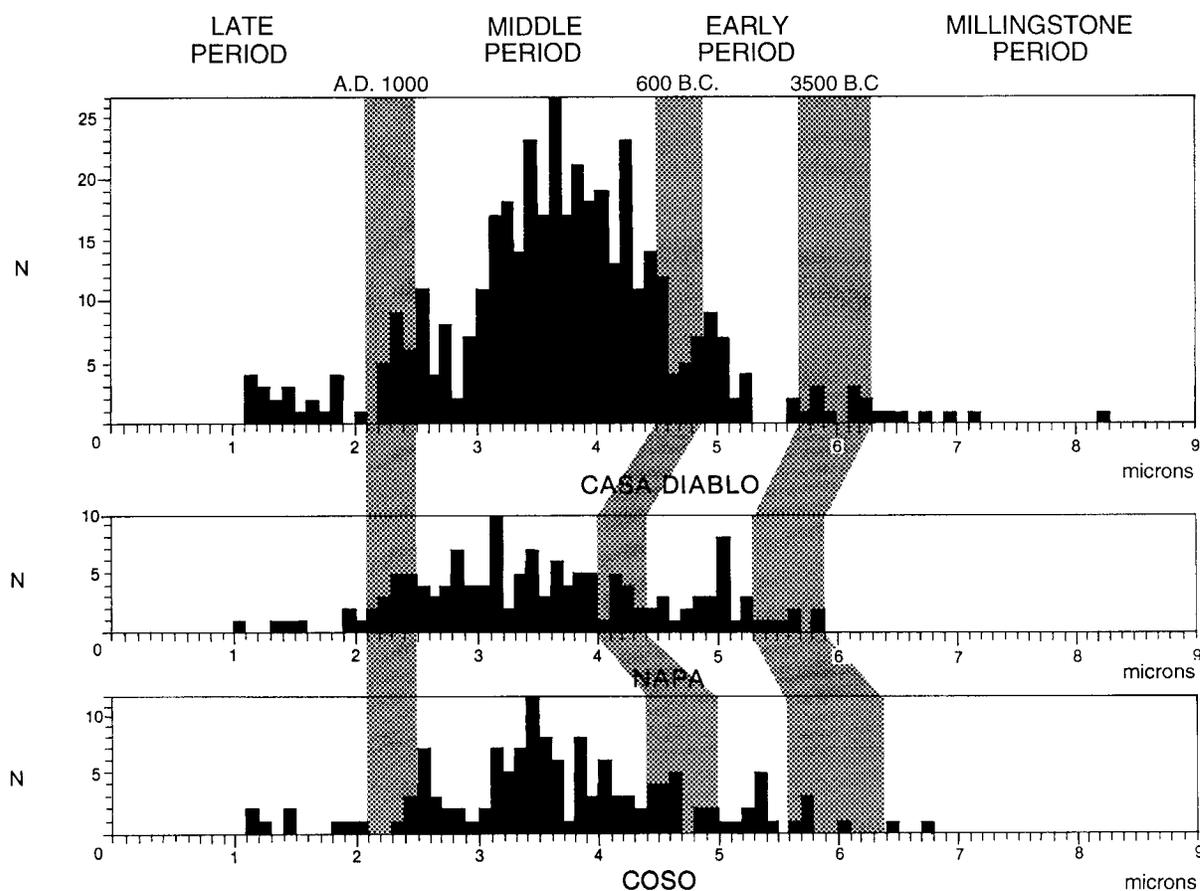


FIG. 8. Obsidian-hydration profiles from the central California coast (from Jones and Waugh 1995).

found in large numbers away from the south coast mainland.

#### POPULATION DECLINE AND AGGREGATION IN ARID ENVIRONMENTS: THE MOJAVE DESERT

The effects of climatic shifts on aboriginal populations in the Mojave Desert have been debated for decades. It has frequently been argued that since the biotic regime was, with minor variation, constant during the Holocene, human use of the region was little influenced by climate change (Basgall and Hall 1992). Water, not food, may have been the critical factor in foraging decisions under extremely arid conditions (Kelly 1995:126). In Australia's desert interior, for example, potential water shortfalls are a major risk factor, and decisions regarding group movement are often based on close monitoring of weather patterns (Gould 1980:60, 69–70; Yellen 1976; cf. Kelly 1995). In response to uncertainty, hunter-gatherers may tether themselves to reliable water sources, sometimes sacrificing foraging efficiency (Cane 1987, Kelly 1995). Extended droughts in the Mojave Desert during the Medieval Climatic Anomaly are likely to have substantially reduced the number of water sources. Spring discharge and seasonal flooding of the Mojave River would have declined, and high stands

in desert playa lakes would have been infrequent. As a result, sources of water would have been widely dispersed and less predictable, and the risk associated with forays into the desert interior would have been greater.

Occupations in the Mojave Desert during the 500-year period preceding the Medieval Climatic Anomaly (ca. A.D. 300–800), the Medieval Climatic Anomaly itself (A.D. 800–1300), and the following 500-year period (A.D. 1300–1800) show signs of significantly reduced use of the desert, probably due to decreased availability of water. Of 84 radiocarbon-dated archaeological components spanning 300–1800, 25 date to 300–800, 12 to the Medieval Climatic Anomaly, and 47 to 1300–1800 (fig. 9). The spatial distribution of components also shows that medieval components are closely associated with a few perennial water sources—major springs and perennial oases along the Mojave River (such as Oro Grande [CA-SBR-72], Afton Canyon [CA-SBR-85], and Bitter Spring) (fig. 10). Oro Grande and Afton Canyon lie along the Mojave River drainage with its vast catchment area (Enzel et al. 1992). Shallow groundwater flow in this drainage would have been among the most persistent during dry periods. Similarly, Bitter Spring is the largest and most reliable spring in the Tiefert Basin area. These patterns suggest that hunter-gatherers of the central Mojave Desert, who were free from the type

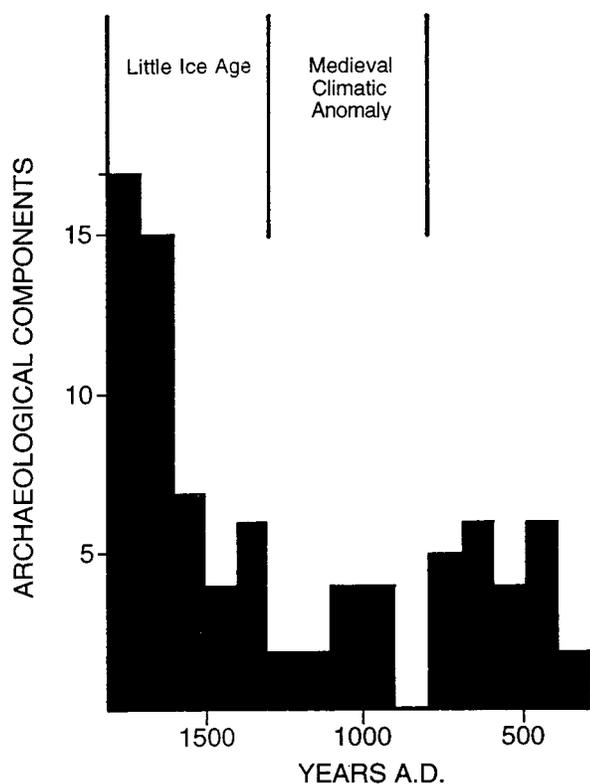


FIG. 9. Radiocarbon-dated archaeological components from the Mojave Desert, California.

of climatic dependence that agriculturalists experienced, were nevertheless affected by the unusual aridity of the Medieval Climatic Anomaly. That fewer dated components from this period exist suggests a reduction in population size as well as a narrower focus on reliable water sources. In the Mojave Desert a decline in annual rainfall would lead to a reduction in the number and reliability of water sources, a critical factor in a region characterized by vast waterless expanses. Moreover, droughts such as those demonstrated by Stine (1994) would have led to a reduction of ecosystem productivity in all habitats (Spaulding 1995). Although these data do not demonstrate that there was a decline in human carrying capacity during the Medieval Climatic Anomaly, the regional decrease in dated components suggests that this may indeed have been the case.

The area in the immediate vicinity of the Salton Sink, however, witnessed a very different sequence of environmental events with the intermittent formation of Lake Cahuilla. As noted above, episodic filling of the lake does not appear to be directly related to climatic changes. The lake's late Holocene chronology clearly shows that it was full during much of the Medieval Climatic Anomaly (Waters 1983). The sudden appearance of a 5,700-km<sup>2</sup> body of fresh water in this hyperarid basin must have been a significant draw for hunter-gatherers throughout the region, particularly during a time of persistent drought. The archaeological record of the Sal-

ton Sink provides strong evidence for human presence around the lake during the medieval period. Some researchers (Aschmann 1959, Wilke 1978) posit a relatively dense, sedentary occupation. Others (Weide 1976; Schaefer 1986, 1988) believe that most lakeshore sites represent short-term temporary camps.

Several factors may have rendered the Lake Cahuilla shoreline more suitable for short-term use and perhaps limited its value as a refuge from medieval drought. First, throughout much of each lacustrine episode, its shorelines would have been either rapidly advancing or rapidly receding, which would probably not have allowed the formation of stable or highly productive shore-margin biotic communities. Second, the lake's salinity may have been too high for much of this time to provide a suitable source of drinking water, even for populations with few options. Laylander's (1994) recent estimates of Lake Cahuilla salinity suggest that dissolved solids in the water would have exceeded the current municipal limit of 330 ppm within a few months and reached 1,000 ppm within 25 years. Thus, while the lake may have provided a productive environment for certain resources such as fish or waterfowl, its effect as a magnet for regional populations during the Medieval Climatic Anomaly was probably limited.

## Summary

A growing body of paleoenvironmental information shows evidence for significant periods of drought during the Medieval Climatic Anomaly. While the chronology of drought-related environmental deterioration is not fully synchronous throughout all of western North America, most areas show evidence for two intervals of decreased precipitation (early medieval, A.D. 900–1100 and late medieval, A.D. 1150–1350) separated by a period of amelioration. Chronological disparity is greatest for the earlier period, although some interregional synchrony is also evident (fig. 11). There are also some intriguing complementary comparisons such as the occurrence of two successive epic droughts on the Colorado Plateau during a period of increased effective moisture in the White Mountains. The late medieval corresponds with the latter of Stine and Graumlich's two epic droughts in the Sierra Nevada and western Great Basin and includes the Great Drought (1276–99) on the Colorado Plateau. Depressed environmental productivity seems to have been a much broader problem during this period in western North America than has ever been previously recognized. Scale and severity conform with Stine's (1994) characterization of climate during the medieval period as anomalous in comparison with much of the late Holocene.

Chronological resolution for the archaeological record of human responses to these dry intervals varies significantly across western North America, but the late medieval droughts seem to have caused more dramatic responses than the first. Temporal control is best on the Colorado Plateau, where most populations survived an

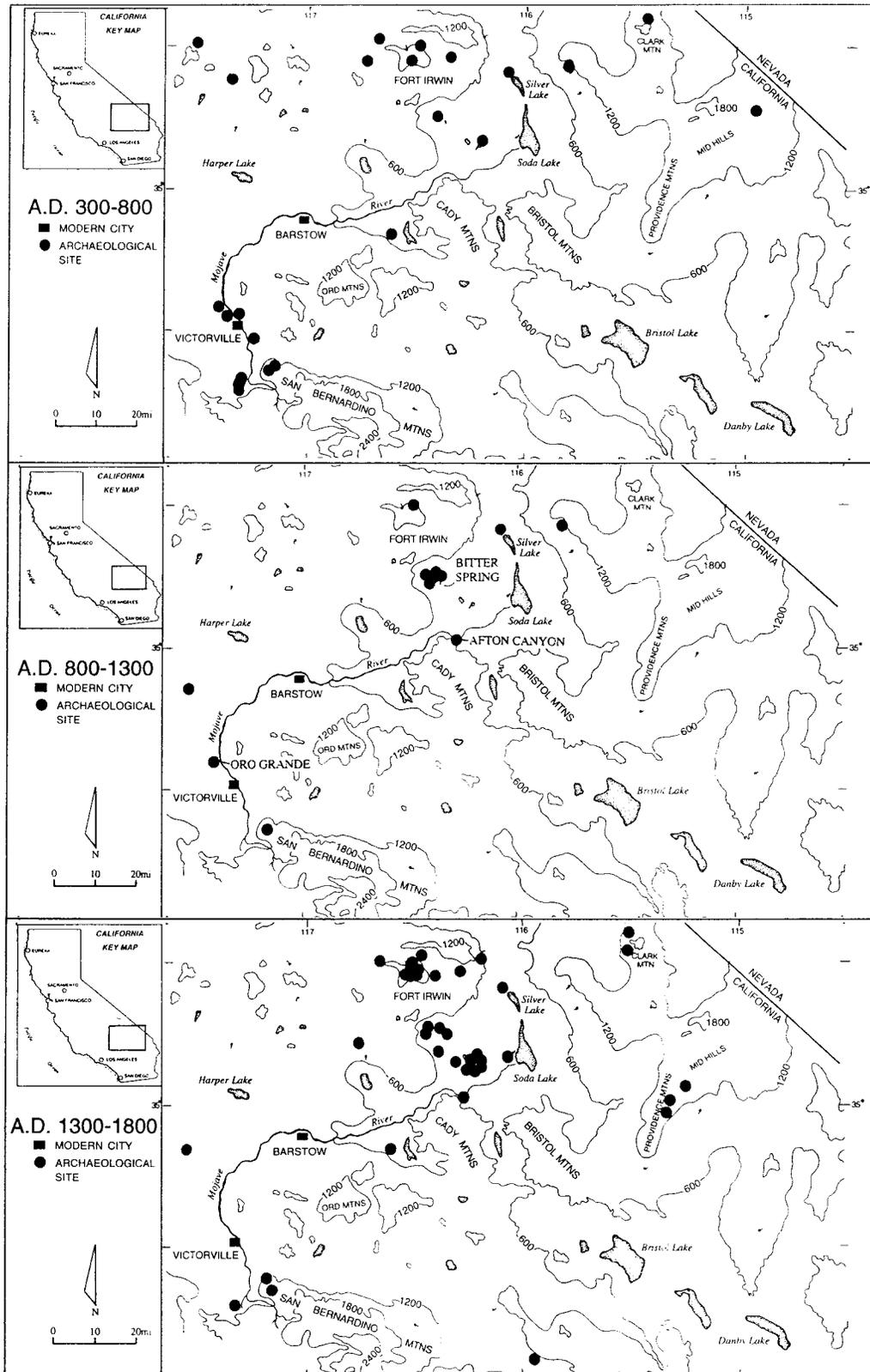


FIG. 10. Site component locations before, during, and after the Medieval Climatic Anomaly in the Mojave Desert, California.

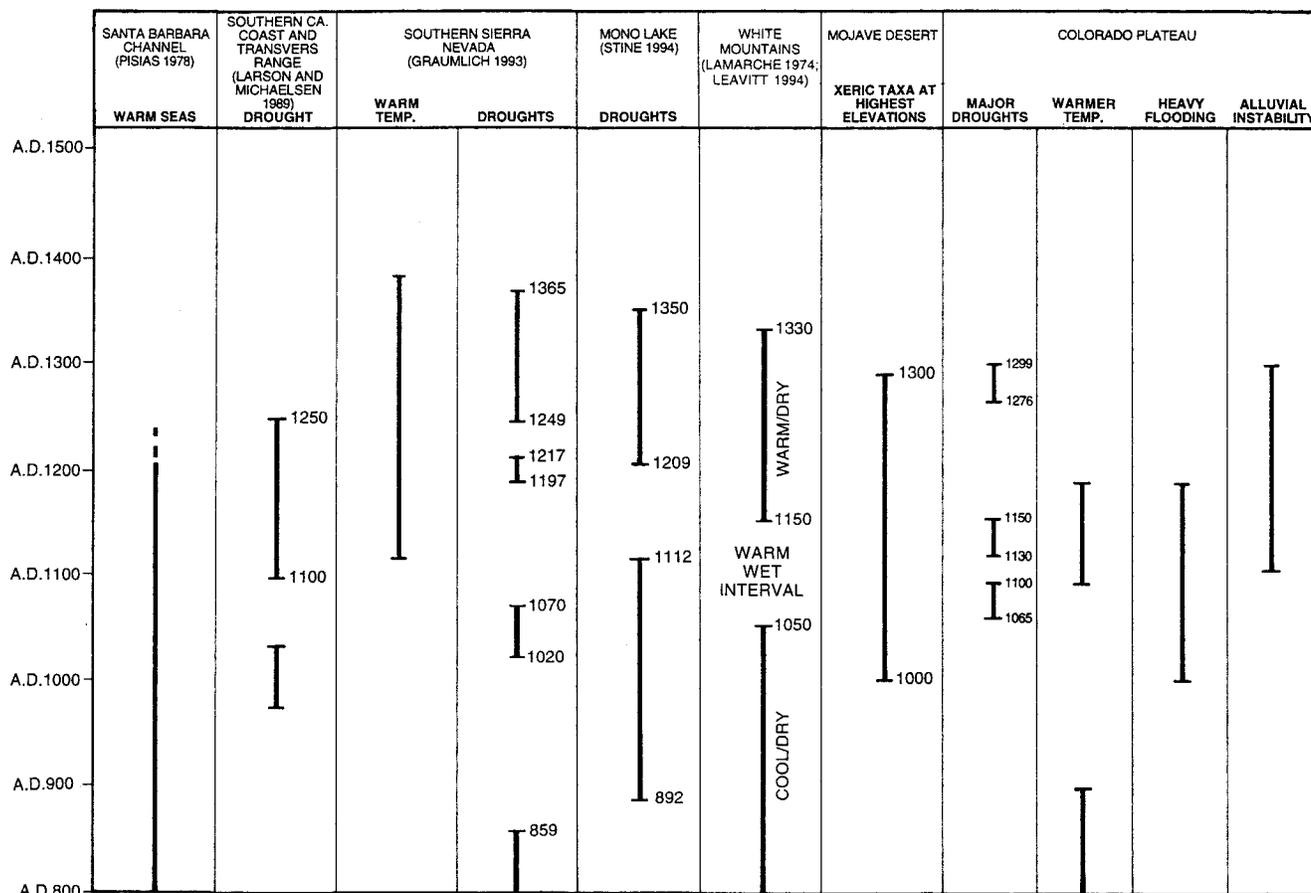


FIG. 11. Comparison of regional paleoenvironmental sequences in western North America A.D. 800–1500.

epic drought between 1065 and 1100 through agricultural intensification that continued into the mid-1100s. Agricultural settlements across much of the northern Colorado Plateau were abandoned during a subsequent epic drought between 1130 and 1150, while populations aggregated to the south and east. Nucleation was ultimately curtailed during the Great Drought with the final collapse of settlements across most of the central Colorado Plateau. Centuries of population growth limited the subsistence options that were formerly available to dispersed farming groups, and during the later droughts many Puebloan populations were beyond a carrying capacity that had declined as a result of extended drought. Throughout the late medieval period there is mounting evidence for intergroup warfare and interpersonal violence in this context of food stress. Interregional commerce and interaction declined in many places but intensified in a few areas.

Forager populations in three regions of California also weathered the early droughts of the Medieval Climatic Anomaly, although chronological resolution is much poorer in those areas. Human exploitation of the Mojave Desert seems to have been suppressed throughout most of the Medieval Climatic Anomaly. Depletion of

water sources (particularly springs) rendered much of the desert uninhabitable and forced people to congregate at locations with reliable water. Depletion of water sources would have serious implications for food availability and social relationships. Shrinking foraging radii would combine with depressed biotic productivity to exacerbate competition for food near the few sources of reliable water. On the coast, there is significant evidence for settlement instability, population movement, exchange breakdown, and interpersonal violence during the terminal centuries of the Medieval Climatic Anomaly. Research of the past several decades has emphasized the high population density of California hunter-gatherers, their intensified economies, and their relatively complex sociopolitical systems. Still, the dependence by these people on a few ubiquitous, labor-intensive, storable resources put them in ecological jeopardy. While much of the Holocene archaeological record may reflect a process of intensification and population growth among California foragers, these economies were at risk from the type of high-intensity environmental change that impacted Puebloan cultures. Widespread and/or repeated failures of the acorn crop, the fundamental subsistence staple of native California, would have readily precipitated major subsistence prob-

lems. Settlement disruption and interpersonal violence represented in the archaeological record are consistent with demographic stress. These trends are not compatible with the predicted outcomes of ongoing intensification or simple adaptive adjustment. Synchrony with the late medieval drought suggests that decreased availability of food and water due to significantly lowered environmental productivity was a major cause of these shifts.

Central and southern California and portions of the Colorado Plateau show complex changes in exchange practices during the Medieval Climatic Anomaly. These changes seem to signal deterioration of broad-scale interregional social/trade networks and their replacement, in some instances, by localized cells of intensive short-distance trading. Intergroup social relationships that facilitated the movement of Puebloan pottery from the Southwest to the shores of southern California and obsidian from distant sources in the western Great Basin to the central California coast apparently broke down during the late medieval period. On the islands off southern California and at certain nucleated settlements on the southern margin of the Colorado Plateau, however, production of trade goods increased dramatically during this period. Arnold (1992*a, b*) provides strong evidence for increased production of shell beads and bead drills on Santa Cruz Island ca. A.D. 1250. On the Colorado Plateau, there is ample evidence for a specialized network of lithic production and exchange that also intensified after 1250 (Brown 1982, 1991). Many exchange models based on the premises of unilinear cultural evolution and/or adaptationism (e.g., Fredrickson 1974, Chartkoff and Chartkoff 1984, Chartkoff 1989) posit simple increases through time in exchange concurrent with incremental population growth. Jackson and Ericson (1994) have proposed a revised "incremental" model for prehistoric California in which, through time, greater numbers of goods were exchanged over shorter distances, but even such a revision (see Hughes 1994) does not accommodate the punctuated nature of changes in trade during the Medieval Climatic Anomaly. Rather, demographic stress caused by drought-related declines in environmental productivity seems to have fostered deterioration of formerly wide-reaching and amiable social relations that facilitated movement of goods across great distances. However, localized intensification of exchange during a period generally characterized by breakdowns in social relationships may have been dependent on individualized sociopolitical situations and opportunities. Environmentally induced stress can be useful for explaining the timing of changes but not the character of all human responses.

## Conclusions

In our opinion, many patterns in settlement, exchange, human health, and intergroup relations during the Medieval Climatic Anomaly (A.D. 800–1350) in the four re-

gions examined—the Colorado Plateau, the central California coast, the southern California coast, and the Mojave Desert—can be explained with a model of decreased environmental productivity caused by severe, prolonged, and widespread drought. The archaeological records in these four cases fail to match the predicted outcomes of unilinear cultural evolution, incremental population growth, adaptive adjustment, or economic intensification. There are too many abrupt changes and too many signs of desperation for these to represent simple and gradual population-based progressions. Human health and social relations were better and settlements were more stable at the onset of the Medieval Climatic Anomaly than they were at its conclusion. In contrast with evolutionary theories that posit different environmental relationships for agriculturalists than for foragers, the late-medieval droughts seem to have caused severe ecological imbalances among both groups. While drought-related problems have been acknowledged for agriculturalists of the Colorado Plateau, most models of western North American hunter-gatherer prehistory, based on theories of cultural ecology, adaptation, and economic intensification, fail to recognize signs of widespread demographic crises during the 12th–14th centuries or the possibility that both hunter-gatherers and agriculturalists could have been simultaneously impacted by environmental change. The paleoenvironmental record for western North America shows evidence for two intervals of prolonged drought during the Medieval Climatic Anomaly, but the effects of the second are more readily apparent in the archaeological record than those of the first. A nondeterministic perspective on human/environmental relationships acknowledges that not all environmental oscillations will force human responses. The later medieval drought seems to have been unusually severe and widespread, but the important point is that it occurred at a unique juncture in the demographic history of western North America, when populations were unusually high. The impact of a sustained drought of this magnitude on the low-density, more widely scattered populations of the early Holocene would probably have been much less profound. Because so many attempts to invoke environment as a primary cause of cultural change have fallen to charges of mechanistic determinism (e.g., linking the Altithermal to events in North American prehistory), many ecologically oriented archaeologists have come to equate environmental causality with determinism and look to other forces for explanation of cultural change. Nonetheless, severe environmental downturns should not be ignored as potential causes of demographic stress because human populations do not exist in an ecological vacuum. Situations in the case studies considered here are best explained in terms of a convergence of rapidly growing human populations and precipitous declines in environmental productivity. To recognize the potential for crises spawned by such factors and to incorporate them into models of change is hardly deterministic; it is simply realistic.

## Comments

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The role of environmental change in the major demographic, economic, and social transitions of western North America is an issue of fundamental importance to prehistorians working in the region, and the theme itself has broad resonance elsewhere. Unfortunately, the present treatment ends up being less than compelling and seems little more than a reworking of the classic but flawed reasoning first articulated for the Desert West by Baumhoff and Heizer (1965). One recognizes some correspondence between certain archaeological data and inferred paleoclimatic anomalies, assumes a causal connection of some sort, and then develops accommodating arguments to explain the linkage. Inasmuch as humans have the capacity to adjust to environmental changes in numerous ways and the archaeological record clearly indicates that many climatic shifts apparently had minimal impact on what past peoples were doing, to explain a particular cultural transition in these terms requires more than a gross correlative argument.

There are, in fact, a fair number of inferential steps necessary in moving from indirect paleoclimatic "proxy" data to a point where it is possible to explore their actual, on-the-ground implications for human populations. It is one thing to posit a general relationship between effective moisture and primary productivity, which is well established ecologically, but quite another to presume that increases or decreases in the same must have had serious consequences for prehistoric hunter-gatherers. To suggest the latter, it is necessary to show how a purported change in effective moisture levels would have directly impacted key resource procurement strategies, settlement prerogatives, or organizational features. In the case of interior Australia, for example, Pate (1986) has shown that periods of extended drought in fact lead to shifts in resource productivity that are counterintuitive, important economic taxa actually having better crops than under normal conditions; in a similar vein, Lee (1979) has indicated that mongongo nut production tends to crash in years of above-average precipitation. In short, for these arguments to be successful requires a demonstration of how critical components of the adaptive pattern in operation at the critical time would have been adversely affected by the environmental deterioration. Anomalies such as droughts, whether of shorter or longer duration, would likely engender a cultural response of some kind, but this might take many forms and might not even be perceptible in the archaeological record.

On another level, the authors of this paper construct a false dichotomy between the so-called demographic-

crisis scenario outlined here and "simple adaptation" or "intensification" models. In fact, few if any of the latter assume relentless population growth through the California sequence, and they do not deny that environmental perturbations might have contributed to patterns of social and territorial circumscription that were already emerging. Because the record fails to disclose associations between economic and social transformations and paleoclimatic anomalies in other times and places, some intensification arguments have given primacy to demographic variables; this is essentially what Jones et al. do when they acknowledge that by the time of the "late" medieval drought (A.D. 1150–1350) relationships between population, resources, and technology were unable to weather conditions comparable to the ones they had experienced during the "early" drought (A.D. 900–1100).

Archaeologists have been bombarded in recent years with the claim that paleoenvironmental data have attained the level of resolution necessary to examine particulars of the culture-environment equation. The reality, of course, is that while some kinds of "proxy" data do have excellent temporal resolution and offer relatively direct reflections of past environmental or climatic conditions, many are as coarse-grained as they ever were and still require fancy inferential gymnastics to translate and interpret. Even when the resolution of these data is superior, archaeological correlates are seldom of comparable quality. Researchers are frequently forced to work at a millennial scale in western North America, regional coverage in most areas remains very incomplete, and most notions about the occupational history of particular places can at best be termed educated guesses. It is just such problems of uneven resolution that make the present argument suspect on a substantive basis.

Limitations of space preclude a detailed discussion of the California record, although several comments are in order. Having no firsthand experience with the Colorado Plateau, I leave assessment of those data to others (but would note that the evidence for environment-induced cultural transformations seems stronger from the standpoint of both temporal correspondence and clearly identified structural consequences). Looking first at paleoclimatic trends as portrayed, one must question whether the records are in fact synchronous or have sufficiently similar levels of resolution to be meaningful. Some of the data sets have contradictory connotations for the same time period (tree-ring sequences from the White Mountains and southern California indicating more effective moisture during much of the interval Stine [1994] assigns to his first "epic" drought), others are clearly too coarse-grained to have any measurable significance (increased fire scarring in the Sierra Nevada from A.D. 1000 to 1300, enhanced aridity in Mojave Desert woodrat midden constituents from A.D. 600 to 1200, and a saltwater incursion at Newport Bay from A.D. 200 to 1500). Thus, while Stine's documentation of dramatic hydrologic changes in the eastern Sierra Ne-

vada is fairly compelling, there is at present little support for comparable concurrent deterioration in coastal California or the Mojave Desert.

Much the same difficulty extends to the archaeological signatures, which either are subject to a wide range of potential explanations, show limited temporal correspondence, or are based on questionable premises. Along the central California coast evidence of cultural stress takes the form of a shift in hunting technology, changes in the occupational profiles of residential sites, and a fall-off in obsidian importation, all at around A.D. 1200. There is no reason to relate these changes to environmental deterioration: the bow and arrow became a dominant weapon system at about this time across much of California (almost certainly because of its strategic advantages); the sudden shift in site locations might not reflect continued expansion in diet breadth, but it could mark a change in settlement organization the better to exploit different microenvironments (intensification, after all, can be marked by increased use of high-cost resources, shifts to more labor-intensive extractive technologies, or enhanced exploitation of sub-optimal resource tracts); and the sudden decrease in obsidian access (which is hardly a trade horizon in itself) tracks a general trend in production at most or all of the western Great Basin quarries, not just Coso. There have been any number of better explanations for the shape of these quarry production curves; people still need tools even under drought conditions.

The southern California data are equally equivocal: settlement disruption on certain of the Channel Islands and the emergence of offshore bead-manufacturing centers have been attributed to various factors other than environmental deterioration; increasing exploitation of marine resources on the mainland does not necessarily follow from the fact that terrestrial productivity decreased; the evident changes in health and rates of interpersonal violence began around A.D. 300, well before these medieval droughts (only a single cemetery population dates to the critical interval). Trade with the Southwest was never very important in this region, and interaction spheres can shift for a multitude of reasons. Finally, the Mojavean data are clearly the most suspect, composite radiocarbon curves being problematic in the best situations as an indicator of population levels. The problem is compounded here by the fact that research across the region has been haphazard and of uncertain coverage; in fact, data from Fort Irwin, the most systematically examined tract in this region, indicate a dramatic increase in assays after A.D. 500 that continues into early historic times. If desert populations were constrained by water during this period as Jones et al. suggest, the spring-poor Fort Irwin environment is hardly a likely destination.

There can be little argument with the position that it would be foolish to ignore the potential effect of climatic change and environmental deterioration on hunter-gatherer populations in western North America or anywhere. These kinds of relationships, however,

need to be examined closely with an eye to identifying crucial structural connections between climatic trends, environmental consequences, and those aspects of the cultural systems that articulated directly with resources and landscapes. Gross correlations and assertions will not resolve this problem, which has hindered processual archaeology since its beginnings. The Medieval Climatic Anomaly may well have had profound impacts on native populations of coastal California and the Mojave Desert, but this paper falls short of demonstrating it.

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The hypothesis that severe drought drastically reduced late prehistoric populations in western North America has attracted much archaeological attention of late, and Jones et al. are to be applauded for formalizing the argument so neatly and summarizing the relevant data in broad geographical perspective. I was surprised, however, to find myself cast as a neo-Darwinian whose arguments about subsistence change "ignore environmental flux." Neo-Darwinian or not, my interpretations of late prehistoric adaptive change in the western Great Basin have never ignored "environmental flux" (e.g., Bettinger 1982:16-19; 1991:670-72; n.d.). They simply do not accord that flux the importance these authors believe it deserves. My reservation derives in part from evidence suggesting that while the frequency of extremely cold, warm, wet, and dry years has varied over time during the Holocene, the severity of annual extremes has not (Curry 1969). I find this point crucial, since, as far as the hunter-gatherers of California and the Great Basin are concerned, one bad year is just as bad as two consecutive bad years and, in theory, one bad year per generation should be enough to keep population in check. In fact, fine-grained paleoclimatic data establish that severe years occurred quite regularly throughout the late Holocene (e.g., Brown et al. 1992, Graumlich 1993, Hughes and Graumlich 1995, Swetnam 1993). Indeed, from Graumlich's data it is quite difficult to discern the Medieval Climatic Anomaly as a separate event at all, even when the data are smoothed by averaging (Graumlich 1993: fig. 4). Paleoclimatic data, of course, are commonly smoothed this way to accentuate trends. Those trends, however, are of little relevance to hunter-gatherers, who cope not with long-term climatic trends but with conditions one year at a time. Following Testart (1988), Jones et al. argue that reliance on storage would have rendered groups in California and the Great Basin more susceptible to long-term drought. This is sensible, of course, since storing permits population to grow larger (Keeley 1988). Here again, however, one bad year is quite enough to upset the applecart, since very few of the groups in question consistently laid up stores for more than one

winter. Belovsky (1987) argues on theoretical grounds that the maximum shortfall period that can be covered by regular hunter-gatherer storage is about 4.7 months. Stores larger than this may occur (e.g., for trade or feasting) but will have very little, if any, effect on local or regional population.

A related but more fundamental objection to the “medieval hypothesis” as currently articulated by Jones et al. is that it fails to draw the essential connections between climatic conditions and human populations. The key problem here is that in almost none of the cases mentioned do we have anything like a clear understanding of precisely what is actually limiting population. There is certainly a basic connection between population and food supply, but the relationship is seldom direct and cannot simply be assumed to be so. It is quite thinkable, for instance, that unproductive (cold, dry) summers followed by long winters would have the greatest impact, but a substantial body of data, including those provided in this paper, seems to indicate that population levels rebounded during the so-called Little Ice Age, during which those conditions likely obtained. It is unlikely, in any case, that drought would have had a uniformly adverse effect on all food sources of interest to human foragers, in part because in regions of highly variable climate successful species typically maintain substantial genetic variety, including drought-resistant strains. Indeed, Graumlich’s data show quite clearly that response to (inferred) drought varies substantially both by individual tree and by location, which is in accord with the data compiled by Koenig (1994 et al.) suggesting that California oak (*Quercus*) masting patterns vary dramatically by species and independently of temperature and precipitation (although the sample period was relatively short). Finally, drought may well create as many exploitative opportunities as it destroys, as Pate (1986) has demonstrated with reference to hunter-gatherers in desert Australia.

What I am arguing is not that the Medieval Climatic Anomaly did not occur or that it did not adversely affect human populations but rather that this has not been convincingly demonstrated. Jones et al. have put together an interesting circumstantial case that clearly merits further archaeological attention. To proceed further will require a more detailed understanding of both the human systems and the climatic anomalies that were involved.

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Jones et al. have chosen a very complex problem: how climatic change influenced the cultural development of different human populations living under rather different ecological conditions in four study regions across western North America. In the Old World the time-span studied, A.D. 800–1350, saw the development and

flourishing of the feudal states—that is, the formation of modern Europe. Meanwhile the pre-Columbian historical development of western North America was proceeding under completely different social and economic conditions, providing us the opportunity to study responses to stress in very different ecosystems reminiscent in their complexity of the Mesolithic/Neolithic cultures of our region. Especially interesting for students of European prehistory is how hunters in contrast to farmers responded to subsistence stress under controlled conditions within various ecosystems.

In Central Europe we face similar problems of the spread/development of productive economies, but the temporal dimensions and the scale of paleogeographic observations are different: the coexistence of hunter-gatherer and farming economies dates back at least 7,000 years (6th millennium B.C. in the Carpathian Basin), and the geographic setting is more restricted. The development of Central Europe seems to have been much more homogeneous: different economic systems were much more widely separated and coexisted within a narrower time-span. Neolithisation in Europe is understood as a gradual northward “sliding” of ideas and/or people, and the mosaic-like coexistence of different economies over an extended period can be observed only in isolated cases. The reason can probably be found in ecological niche size and variety.

Another marked difference for us is that we have only indirect evidence of population dynamics, since most finds come from settlements and there is very little anthropological evidence from the period of hunter-gatherer/farmer coexistence. Thus it is easier to demonstrate periods of bounty than periods of stress, and the concrete response to climate deterioration is typically the absence of something that was once abundant: large mammals are missing by the end of the Pleistocene, and the number of settlements datable to the earliest Holocene correspondingly declines. The Atlantic climate optimum brought about a striking development of farming economies in the formation of tell settlements in the Carpathian Basin, the northernmost limit of their expansion. Again, stress (climate deterioration, mainly the droughts of the Subboreal phase) is reflected by the abandonment of the tell settlements and the collapse of the old settlement system and wetland-based agriculture. It seems that the natural endowments of Transdanubia made it less vulnerable to sudden changes. The Lengyel culture (phase 3) and the subsequent closely related, probably descendant Balaton culture population survived in the western half of the Carpathian Basin while the world to the east of the Danube was being shaken to its very roots—with a change of economy (the appearance of pastoral populations), the disappearance of tells and the scarcity of settlements in general, the appearance of tribal cemeteries, and a complete change in raw-material supply patterns.

Thus, on a much smaller scale and despite a scarcity of details, we can corroborate Jones et al.’s conclusion about the importance of economic factors and the

varying role of these factors depending on local conditions.

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Jones et al. are making a valiant effort to synthesize and integrate large bodies of both environmental and archaeological data from western North America. Their primary point, which they articulate convincingly, is that there is a complex, causal, and nonlinear relationship between people and their environments. They specifically make an effort to correlate in a general way common kinds of adaptive patterns between hunter-gatherers and agriculturalists in response to climatic changes associated with the Medieval Climatic Anomaly. Their study parallels other interesting work being done in Europe today and fits well within the developing field of historical ecology, which "explores complex chains of mutual causation in human-environment relations" (Crumley 1996:558; see also 1994).

We are in substantial agreement with the main thrust and conclusions of the paper, but a number of specific issues are in need of clarification and emendation. Perhaps the most critical issue relates to the comparability of the data sets from the different areas examined. In figure 11 we see that in the two areas that have been well dated with tree-ring data, the southern Sierra Nevada and the Colorado Plateau, the periods of drought are much shorter than in areas without tree-ring dates. It remains a big question whether these are real differences or artifacts of varying kinds of data. On the Colorado Plateau alone, the environmental reconstruction is based on literally thousands of tree-ring dates. In contrast, for the Mono Lake area, where figure 11 shows two long stretches of drought, the data base consists of only 17 radiocarbon dates taken from relict stumps (Stine 1994). Our intent here is not to disparage the Mono Lake data set but to point out that the resolution provided by an accurate dendrochronological reconstruction gives a much more refined and accurate picture of prehistoric climate.

Although Jones et al. argue for broad patterns of environmental similarity during the Medieval Climatic Anomaly, their own data would indicate that when accurate data are available there is considerable *local* variability at any given time (see Dean 1994). Again, the higher resolution provided by tree rings also indicates that the Medieval Climatic Anomaly was not environmentally monolithic. The data presented in the paper show there was actually a lot of variability in the onset, duration, and frequency of drought episodes in different parts of western North America. Looking more closely at the Colorado Plateau, where there are strong paleoclimatological data for the period in question, there were cyclical periods of high and low areal variability in local

environmental conditions (what Dean et al. [1985] refer to as "high-frequency variation" [see also Gumerman 1988]). During periods of high areal variability, two adjoining areas could receive significantly different levels of annual precipitation and have commensurately different annual crop yields. Such inequalities in yield in turn provide circumstances conducive to either increased integration between cooperating neighbors or increased raiding and warfare between haves and have-nots.

A related issue concerns the inferred causal relationships between periods of drought and broad patterns of cultural adaptation. Looking again at the Colorado Plateau, the combination of a precise tree-ring record and a huge data set of surveyed and excavated sites demonstrates that the relationship between culture change and environmental phenomena such as droughts is highly complex. Our own data on warfare in the Kayenta subregion (Haas and Creamer 1993) illustrates the complexity of the relationship at the local level. The available evidence indicates that a low-frequency cycle of environmental degradation began at roughly A.D. 1150 (Dean et al. 1985). Then, as noted, the "Great Drought" descended on the area from 1276 to 1299. In contrast, intergroup violence first arises in the 1240s (long after the start of the environmental downturn) and intensifies for the next 30 years (well before the onset of the Great Drought). The outbreak of warfare is clearly related to the deteriorating environmental conditions; raiding developed as an adaptive strategy for acquiring auxiliary resources in the face of localized shortages. However, the relationship between war and the environment is complex and contingent on specific historical and geographical circumstances. Rather than contradicting the conclusions of Jones et al., this kind of local information based on extensive dendrochronological and archaeological records illustrates more clearly how environmental forces come to play a causal role in the decision making of human populations.

The authors have taken an important first step in this paper in trying to cross boundaries between traditional culture areas and between ecological studies and archaeology. In doing so they have effectively shown that there were broad patterns in the development of human systems in western North America. These patterns crosscut geographical areas, local ecology, and substantial cultural differences between different populations. While higher-resolution environmental and archaeological records for different parts of the region indicate significant temporal and areal diversity, such data help to refine rather than refute their arguments.

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Although the use of paleoenvironmental data has become standard in archaeology, its role is usually estab-

lishing a general framework for past human behavior. Jones and colleagues clearly indicate this in the first part of their article. The use of these data has contributed to the delimitation of periods with specific climatic characteristics, but little attention has been given to environmental variability as a component of cultural and ecological change. Jones et al. show how a global climate alteration such as the Medieval Climatic Anomaly might be seen as one possible trigger of cultural dynamic and change. The major goal of their paper is to alert us to the variability in human responses to the same environmental stress. More traditional interpretive models assume the environment as a constant, focusing mainly on the crystallization of cultural change rather than on its possible causes. This is a consequence of the adaptationist approach in archaeology. The important issue here is to understand that climate and environment are not fixed but constantly changing. By applying an ecological and evolutionary perspective as the authors do, archaeologists can explore under what circumstances cultural change is important and/or just an accommodation to brief climate pulses and minor environmental adjustments. I look forward to a similar contribution by these authors on their interpretation of the cultural change produced by the following Little Ice Age in the same area.

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This is a timely article. It (re)focuses archaeological attention on environmental constraints on past human behaviour while acknowledging the value of recent "postmodern" attempts to break free from the environmental determinism which has long characterized hunter-gatherer archaeology. The insights it offers regarding the response to environmental stress of people on both sides of the supposed divide between farmers and foragers add to its value, as this is an area towards which socially oriented postmodernists have been directing their attention for some time (e.g., Bender 1978). I must take the authors at their word about the archaeological and climatological evidence, as I am only passingly familiar with their North American material. Having said this, I will move on to some broader implications of their findings as they relate to my Australian experience.

Australian archaeology was shaken up in the 1980s by the publication of Lourandos's (1983, 1984, 1985) research on socioeconomic intensification in the mid- to late Holocene (see also Lourandos and Ross 1994). Opinion remains somewhat polarized, with loose clusters of scholars producing evidence and arguments for and against each other's position (e.g., pro-, Barker 1991, Lourandos 1996, David and Lourandos 1997; anti-, Beaton 1983, 1985; Bird and Frankel 1991; Cosgrove 1995).

The pro- scholars have concentrated on demonstrat-

ing that recent archaeological trends do not track environmental changes and thus must be caused by something "social." In their view, it comes down to scales of analytical resolution. At a coarse scale of analysis, they are happy for long-term palaeoenvironmental and cultural trends to coincide. They suggest that it is only at more refined levels of analysis, however, that what really went on at a human scale can be detected. Here social factors will always cause a dramatic divergence between environmental and archaeological trends because of the proximal causal priority of the social in human affairs. This position is neo-Marxist to the core and in many respects reminiscent of Braudel (e.g., 1972), though he is rarely if ever mentioned in the Australian literature.

The position adopted by Lourandos (1996) and his co-workers (e.g., David and Lourandos 1997) places those who seek causal correlations between environmental and archaeological trends at fine-grained scales of analysis (e.g., Cosgrove 1995) in a bind. If one finds such a correlation, one's data are necessarily insufficiently fine-grained, seemingly regardless of how fine-grained they may be. A paper they use to support their position on the grounds that its "finer-grained [though still quite coarse] data have allowed the detection" of cultural divergence from palaeoenvironmental trends (David and Lourandos 1997:15), actually concludes: "Based on correlations with a late Glacial sequence from Pulbeena swamp the southwest caves appear to have been used less frequently every 3 Ka during periods of relatively colder and drier climate" (Holdaway and Porch 1995: 81). How does all this relate to the work of Jones et al.? In two ways. First, contra Lourandos and co-workers, they demonstrate that very fine-grained analysis can produce convincing correlations between cultural and environmental trends. Second, they clearly show that to explore adequately the possibility of such correlations requires not only that scales of archaeological resolution be matched among sites or regions but that such scales also match those of relevant palaeoenvironmental analyses. This may seem self-evident, but both the discussion in Jones et al.'s paper and my experience in Australia suggest that such matters are not always uppermost in the minds of all our colleagues in hunter-gatherer archaeology. By and large, Australian palaeoenvironmental data for the mid- to late Holocene are as coarse-grained as those for more ancient periods. Thus even if an Australian scholar has finer-grained archaeological data than others, it is highly likely that the palaeoenvironmental data will be equally coarse-grained. Little wonder that mid- to late Holocene cultural trends diverge from the environmental record!

This is not to say that Lourandos et al. will not eventually be proved right about intensification in Australia, at least with regard to parts of the continent. However, it is the implications of the research reported by Jones et al. for problems such as those just described that makes me think their work has a lot to offer in this part of the world and indeed in many others including their own. To my admittedly inexperienced eyes, they do appear to

have unambiguous evidence for "striking correlations" between environmental and archaeological sequences over a not insignificant area of western North America. That they have approached this issue in a nondeterministic manner is evident from the flexibility with which they accommodate the differences through space and time among the responses to the Medieval Climatic Anomaly, matters that the more mechanistic might see as troublesome aberrations and the more "postmodern," at least in Australia, as problems of analytical scale. Scholars around the world are right to question mechanistic environmental determinism on the grounds that it is a demonstrably inferior approach. It does not follow, though, that environmental factors should be automatically rejected in explanation because of an implicit or explicit ideological stance that blinds researchers to the evidential imperatives of the archaeological or palaeoenvironmental records. To do so, as Jones and colleagues so aptly put it, is simply unrealistic.

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The arguments Jones et al. make are timely and compelling. Environmental calamities such as the 1997–98 El Niño event, Hurricane Mitch's death toll of over 11,000, and drought-driven famines complicated by war in Africa have made it painfully clear that modern, technologically complex societies are not immune to the forces of nature and concomitant social strife. Environmental perturbations clearly can affect human society. It is sobering to imagine the consequences of a future prolonged drought that might leave large trees growing deep below modern shorelines of large Sierran lakes (Stine 1990, 1994). Such conditions have clearly occurred in the past and would certainly destroy modern California's valuable agricultural commodities and have far-reaching economic and social effects. We would be forced to adapt to such a situation, one hopes with a minimum of violence and transhumance.

Jones et al. weave a tangled web of important facts and observations based on the available literature and their own experience, but I am convinced that they are only scratching an already roughened surface. Worried that their conclusions will be held up as purely environmentally deterministic, Jones et al. take pains to distance themselves from previous studies they and others have proven to be overly simplistic. They show convincingly that different environmental perturbations and important cultural changes occurred at different times in each of the separate regions they describe. These events, however, are not strongly linked temporally region to region.

The article includes a number of comments, among them that the diet did not continue to broaden on California's central coast between A.D. 1000 and 1400, that

are not supported by any references. I would like to see such comments supported, since they fly in the face of conclusions of widening diet breadths and size diminution in contemporaneous San Francisco Bay and Sacramento Delta contexts, strong indications of Late Period vertebrate resource intensification (Broughton 1994a, b, 1997; Simons 1991). If the medieval droughts resulted in the general resource depression proposed, then responses should be discernible in dietary records available in the carbonized plant remains and animal bones left at sites by their depositors. I propose that if vertebrate resources were severely depressed, as Jones et al. imply, then the diet breadths of people dependent on them would have widened correspondingly. No broad analysis of Late Period dietary patterns in California yet exists, but the numerous cultural resource management and academic field investigations in California and the Southwest over the past 20 years have generated a wealth of data ripe for such a synthesis.

The baseline references used to establish the environmental and cultural patterns during the periods highlighted are few and far between. I do not intend to quibble about the results of the environmental and archaeological studies referenced, but the conclusions drawn from them may be premature. There are many temporal and regional gaps, especially in California, that need to be filled before any patterns of environmentally stimulated punctuation of the cultural history of western North America become truly convincing. The regional patterns described need to be tied together tightly and any inconsistencies adequately explained. While the synthesis Jones et al. provide is compelling, it is only a beginning. Ideally this article will serve as a stimulus for further research in this arena and not as a rallying cry for those who believe otherwise. We can ill afford to ignore any lessons the natural environment has taught past human societies, if only for their potential modern implications.

## Reply

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That our article has provoked support (Lanata and Lilley), amplification (Biro, Haas and Creamer), and skepticism (Basgall, Bettinger, and Wake) suggests that we have accomplished at least some of the goals that we set for ourselves in developing the medieval-drought hypothesis. Our primary objectives were to (1) reintroduce large-scale climatic flux as a potential cause of prehistoric culture change in a nondeterministic manner, (2) challenge the traditional dividing line between foragers and agriculturalists, (3) raise a cautionary flag against linear, adaptive arguments based on theories of progressive cultural evolution and/or economic intensification, and (4) argue the specific case for drought-in-

duced crises during the late Holocene in western North America. To the degree that we have accomplished these goals, our colleagues have described our efforts variously as timely, undemonstrated, flawed, and valiant. Researchers from abroad have found both theoretical and empirical similarities to their work, while some commentators in our own study regions have rejected our efforts. In connection with these alternative characterizations, commentators have raised a number of key points in conceptualizations of prehistoric human ecology in general and western North American archaeology in particular. Foremost among these are issues of chronological resolution, economic intensification, spatial and temporal variability, and the burden of proof in archaeological models of the past.

Nearly all of the commentators raise issues of chronological resolution, but Lilley's discussion of this topic in Australia is perhaps most insightful. In Australia, neo-Marxists argue that correlations between environmental variation and changes in human behavior are apparent only when paleoenvironmental and archaeological records are coarse-grained. As resolution improves, this school predicts an inevitable lack of correlation that is taken as evidence for the primacy of social factors in forcing cultural change. Lilley points out that this position allows for no alternative interpretations, as any sequence suggesting a correlation between environment and cultural change is automatically dismissed as too coarse. Comments by Haas and Creamer, however, are extremely important on this issue, as their interpretations are drawn from what are probably the most detailed sequences in the world—the tree-ring-based archaeological and paleoclimatic chronologies of the American Southwest, in particular, the Kayenta region in the central Colorado Plateau. With the precision afforded by what is essentially an annual, calendric chronology, Haas and Creamer see an outbreak of intergroup raiding that they believe is related to environmental deterioration during the late Medieval Climatic Anomaly, but they also caution that the relationship between warfare and environment is complex and at least partially stochastic. The Kayenta study and our more general Southwestern case study are instructive in disproving the Australian neo-Marxist position summarized by Lilley. A relationship between droughts and regional abandonments was recognized by pioneering Southwesternists long ago, but subsequent increase in the quantity and resolution of chronometrically controlled archaeological and paleoenvironmental data has produced even closer correlations. This trend runs strongly counter to the predictions of Lourandos (1996). The development of paleoclimatic sequences of annual resolution has resulted in a highly complicated data base that is not easily linked to patterns in human/environment relationships—a fact well-recognized by tree-ring researchers, who attempt to smooth out stochastic fluctuations and focus on longer-term (e.g., decadal) variability. It is for this reason that researchers such as Dean (1988a) stress the need for collateral paleoenvironmental data to help reduce noise and identify

processes of sufficient magnitude and duration to apply to archaeological models.

Our reason for considering both farmers and hunter-gatherers was to address a broad range of human responses to drought. Basgall's reminder that "humans have the capacity to adjust to environmental changes in numerous ways" and that "many climatic shifts apparently had minimal impact" simply echoes the points made repeatedly in our article. His reluctance to consider prehistoric agriculture on either a theoretical or an empirical level further reveals his limited understanding of our major point—that despite the enormous range of technological and behavioral options, some climatic processes require cultural changes, even if simply the innovation of new technology or behavior. Both Basgall and Bettinger further point out that some plant species produce abundantly under drought conditions. Certainly some plants flourish during brief droughts, but the welfare of most plant and animal populations (especially domesticates) is clearly linked to effective moisture. Paleoclimatic records of the late medieval period from both California and the Colorado Plateau suggest anomalously prolonged periods of drought that would have severely depressed effective moisture for extended periods. We find it hard to believe that these conditions presented a subsistence bonanza for either hunter-gatherers or agriculturalists. Furthermore, while we acknowledge a possible range of responses to such difficult conditions, we emphasize the potential for demographic problems and negative behaviors which are often lacking in linear adaptationist/intensification models.

While focusing on agricultural lifeways, Haas and Creamer greatly expand upon the theoretical and empirical discussion we initiated. Their Kayenta case study provides a fascinating example of conflict rather than cooperation in the context of environmental stress. Their comment is also one of two (the other by Biró) that emphasizes spatial variability in paleoenvironmental trends and its implications for human response. Haas and Creamer suggest that raiding and/or warfare is most likely to be successful when high areal variability creates situations in which some groups are considerably better off than others. Warfare in the Kayenta region in the 13th century occurred during a period when spatial variability was consistently low (Plog et al. 1988) and raiding may not have been productive. Kayenta warfare may therefore defy a purely functional interpretation, but we agree with Haas and Creamer that the increase in raiding must be viewed in the context of environmental decline. Decrease in localized Kayenta exchange networks is also probably best understood in this light, as well as the context of low spatial variability which would have reduced spatial inequity in surpluses and the possibility of profitable trading.

Biró provides yet another example of the importance of spatial variability in prehistoric human/environmental relationships. Her description of events in eastern Europe suggests that climate flux was linked to a wide range of human responses partially reflecting a grada-

tion in the effects of climatic events. Some areas were impacted severely while other, better-endowed provinces (e.g., Transdanubia) were less affected. Ultimately, the situation in western North America during the Medieval Climatic Anomaly should show parallels with that in Europe in that favorably watered regions (e.g., major river valleys or Lake Cahuilla) could have served as refugia where temporary population increases were experienced.

The comparatively low resolution of the hunter-gatherer sequences of central and southern California is troubling to Bettinger and Basgall. We acknowledge the significant drop-off in the precision of cultural and environmental chronologies from the Colorado Plateau to California. On a coarse-grained temporal scale, economic intensification (linked in western North America not to neo-Marxism but to optimal foraging and population growth) provides a powerful explanation for many diachronic patterns in hunter-gatherer settlement and subsistence (e.g., Erlandson 1991, Broughton 1994). Several of us have contributed to broad-scale economic-intensification models (Jones 1991, 1992; Raab 1996), and we suspect that these will continue to demonstrate their value when more detailed paleoenvironmental data become available. We concur with Basgall, the author of the most significant publication on economic intensification in California (Basgall 1987), that in many cases hunter-gatherers could transcend low-intensity/low-frequency environmental flux. Where we diverge, however, and where we feel justified in raising a flag of caution is in our unwillingness to relate all changes to linear trajectories of successful economic adaptation or to ignore major paleoclimatic change. We feel that intensification provides a predictive frame of reference the value of which is demonstrated by archaeological cases that match the predictions as well as those that do not. In the latter instances, investigators should consider alternative explanations (e.g., environment), but change often continues to be viewed in terms of increasingly intensified adaptation, ignoring the character of specific transitions and any possible synchrony with environmental events. Basgall, for example, suggests that the bow and arrow came to dominate weapon assemblages in California ca. A.D. 1200 simply because of its effectiveness, but by most accounts this improved technology had been present in western North America for nearly a millennium and its presumed superiority should have been apparent from the outset. Its sudden domination of weapon systems ca. A.D. 1200 seems more than a simple product of incremental intensification. More troublesome is Basgall's acknowledgment of the decline in production at western obsidian sources during the Medieval Climatic Anomaly. This decline is synchronous with markedly reduced exchange to distant consumers who used this commodity as a nonessential supplement to more readily available stone from other sources. We contend, as has at least one other researcher (see Gilreath 1995: 254), that this drop-off is not consistent with the predicted outcome of intensification, which only provides effective explanation for increases in obsidian produc-

tion and exchange through the Holocene up to the onset of the Medieval Climatic Anomaly.

Basgall's concerns are echoed by Wake, who challenges our statements about central California dietary trends, pointing out that subsistence intensification across the Medieval Climatic Anomaly has ostensibly been documented in faunal assemblages from San Francisco Bay shell mounds. We do not deny these trends but emphasize that they are accompanied by significant disruption in settlement (widespread abandonments and reoccupations) during the Middle/Late transition and Late Period (Lightfoot and Luby 1998) that is suggestive of something other than simple adaptive adjustment/intensification. When the faunal record suggests intensification, possible underlying causes can be evaluated only when the faunal trends are examined in the context of settlement and environment. This seems particularly true in light of Wake's suggestion that drought-related subsistence problems might result in increasing diet breadth. If both incremental population growth and demographic crises can result in wider diets, indices other than fauna need to be investigated.

One specific region where Late Period diets are not broader than earlier (Middle Period) ones is the Big Sur coast, alluded to in our discussion of central California. In that area Late assemblages show fewer species exploited and a proportional decrease in small, labor-intensive taxa (e.g., fish, sea otters, and rabbits) from the Middle through the Late Period (Jones 1995). Other areas where faunal remains from Late Period deposits do not conform with linear schemes of intensification include several of the Channel Islands, where the Late Period is characterized by rebounds in previously suppressed highly ranked marine taxa (Jones and Hildebrandt 1995). These rebounds seem to reflect decreased predatory pressure during the Medieval Climatic Anomaly due to drought-related abandonments of the more poorly watered islands.

Finally, we have the issue of the burden of proof and the question of whether we have conclusively demonstrated that western North America experienced widespread demographic crises between A.D. 800 and 1350 due to prolonged and severe drought. Of course we have not provided a full account of the situation, but we see little reason to characterize this as a failure. We fully acknowledge that what we have detected is a highly suggestive correlation between archaeological and paleoenvironmental sequences. Any argument relying on these two sources will of necessity amount to little more than a correlation. Models asserting no influence from environment are no more secure than those asserting a causal relationship, especially since the former are heavily dependent upon negative evidence. The correlation stands as a hypothesis that provides at least two very different implications for local and regional histories of settlement and exchange. Contra Basgall, we see significant intellectual value in developing broad-scale predictive models that encompass both well-studied and poorly known regions; we see little value in waiting until detailed settlement histories are developed for all localities of western North America.

Our ultimate concern was to encourage the development of fine-grained archaeological and paleoenvironmental records that facilitate such comparisons.

## References Cited

- AGENBROAD, LARRY D., JIM I. MEAD, EMILEE D. MEAD, AND DIANA ELDER. 1989. Archaeology, alluvium, and cave stratigraphy: The record from Bechan Cave, Utah. *Kiva* 54: 335-49.
- ALLISON, JAMES R. 1996. Comments on the impacts of climatic variability and population growth on Virgin Anasazi cultural development. *American Antiquity* 61:414-18.
- AMBLER, J. RICHARD. 1966. *Caldwell Village*. University of Utah Anthropological Papers 84.
- ANDERSON, R. Y. 1994. "Long-term changes in the frequency of occurrence of El Niño events," in *El Niño historical and paleoclimatic aspects of the Southern Oscillation*. Edited by H. F. Diaz and V. Markgraf, pp. 193-200. Cambridge: Cambridge University Press.
- ANTEVS, E. 1948. Climatic changes and pre-white man. *University of Utah Bulletin* 38:168-91.
- . 1953. Climatic history and the antiquity of man in California. *University of California Archaeological Survey Reports* 16:23-31.
- ARNOLD, J. E. 1987. *Craft specialization in the prehistoric Channel Islands, California*. University of California Publications in Anthropology 18.
- . 1992a. Complex hunter-gatherer-fishers of prehistoric California: Chiefs, specialists, and maritime adaptations of the Channel Islands. *American Antiquity* 57:60-84.
- . 1992b. "Cultural disruption and the political economy in Channel Islands prehistory," in *Essays on the prehistory of maritime California*. Edited by T. L. Jones, pp. 129-44. Center for Archaeological Research at Davis Publications 10.
- ARNOLD, J. E., R. H. COLTEN, AND S. PLETKA. 1997. Contexts of cultural change in insular California. *American Antiquity* 62:300-318.
- ASCHMANN, H. 1959. The evolution of a wild landscape and its persistence in southern California. *Annals of the Association of American Geographers* 3:34-57.
- BARBOUR, MICHAEL G., J. H. BURKE, AND W. D. PITTS. 1987. *Terrestrial plant ecology*. Menlo Park, Calif.: Benjamin Cummings.
- BARKER, B. 1991. Nara Inlet I: Coastal resource use and the Holocene marine transgression in the Whitsunday Islands, central Queensland. *Archaeology in Oceania* 26:102-9. [IL]
- BASGALL, M. E. 1987. Resource intensification among hunter-gatherers: Acorn economies in prehistoric California. *Research in Economic Anthropology* 9:21-52.
- BASGALL, M. E., AND M. C. HALL. 1992. Fort Irwin archaeology: Emerging perspectives on Mojave Desert prehistory. *Society for California Archaeology Newsletter* 26:1-7.
- BAUMHOFF, M. A. 1978. "Environmental background," in *Handbook of North American Indians*, vol. 8, *California*. Edited by R. F. Heizer, pp. 16-24. Washington, D.C.: Smithsonian Institution Press.
- BAUMHOFF, M. A., AND R. L. BETTINGER. 1982. The Numic spread: Great Basin cultures in competition. *American Antiquity* 47:485-503.
- BAUMHOFF, MARTIN A., AND ROBERT F. HEIZER. 1965. "Postglacial climate and archaeology in the Desert West," in *The Quaternary of the United States*. Edited by Herbert E. Wright Jr. and David G. Frey, pp. 697-707. Princeton: Princeton University Press. [MEB]
- BEAN, L. J., AND H. LAWTON. 1976. "Some explanations for the rise of cultural complexity in native California with comments on proto-agriculture and agriculture," in *Native Californians: A theoretical retrospective*. Edited by L. J. Bean and T. C. Blackburn, pp. 19-48. Menlo Park, Calif.: Ballena Press.
- BEATLEY, J. C. 1975. Climates and vegetation pattern across the Mojave/Great Basin Desert transition of southern Nevada. *American Midland Naturalist* 93:53-70.
- BEATON, J. 1983. Does intensification account for changes in the Australian Holocene archaeological record? *Archaeology in Oceania* 18:94-97. [IL]
- . 1985. Evidence for a coastal occupation time-lag at Princess Charlotte Bay (North Queensland) and implications for coastal colonization and population growth theories for Aboriginal Australia. *Archaeology in Oceania* 20:1-20. [IL]
- BELOVSKY, G. E. 1987. Hunter-gatherer foraging: A linear programming approach. *Journal of Anthropological Archaeology* 6: 29-76. [RLB]
- BENDER, B. 1978. Gatherer-hunter to farmer: A social perspective. *World Archaeology* 10:204-22. [IL]
- . 1985. Emergent tribal formation in the American mid-continent. *American Antiquity* 50:52-62.
- BERGER, RAINER, AND NORMAN MEEK. 1992. Radiocarbon dating of *Anodonta* in the Mojave River Basin. *Radiocarbon* 34:578-84.
- BERRY, M. S. 1982. *Time, space, and transition in Anasazi prehistory*. Salt Lake City: University of Utah Press.
- BETANCOURT, JULIO. 1990. "Late Quaternary biogeography of the Colorado Plateau," in *Packrat middens: The last 40,000 years of biotic change*. Edited by Julio L. Betancourt, T. R. Van Devender, and P. S. Martin, pp. 259-92. Tucson: University of Arizona Press.
- BETANCOURT, J. L., AND T. R. VAN DEVENDER. 1981. Holocene vegetation in Chaco Canyon, New Mexico. *Science* 214: 656-58.
- BETANCOURT, JULIO, L., T. R. VAN DEVENDER, AND P. S. MARTIN. 1983. "Fossil packrat middens from Chaco Canyon: Cultural and ecological significance," in *Chaco Canyon country*. Edited by S. G. Wells, D. W. Love, and T. W. Gardner, pp. 207-18. American Geomorphological Society Field Guidebook. Albuquerque: University of New Mexico Press.
- BETTINGER, R. L. 1982. *Archaeology east of the Range of Light: Aboriginal human ecology of the Inyo-Mono region, California*. Davis: University of California. [RLB]
- . 1991. Aboriginal occupation at high altitude: Alpine villages in the White Mountains of eastern California. *American Anthropologist* 93:656-79. [RLB]
- . n.d. "What happened in the Medithermal?" in *Models for the millennium: Great Basin anthropology today*. Edited by C. Beck. Salt Lake City: University of Utah Press. [RLB]
- BIRD, C., AND D. FRANKEL. 1991. Chronology and explanation in western Victoria and south-east Australia. *Archaeology in Oceania* 26:1-16. [IL]
- BOUEY, P. D. 1987. The intensification of hunter-gatherer economies in the southern North Coastal Ranges of California. *Research in Economic Anthropology* 9:53-101.
- BRAUDEL, F. 1972. *The Mediterranean and the Mediterranean world in the age of Philip II*. Translated by S. Reynolds. New York: Harper and Row. [IL]
- BROUGHTON, J. M. 1994a. Late Holocene resource intensification in the Sacramento Valley, California: The vertebrate evidence. *Journal of Archaeological Science* 21:501-14.
- . 1994b. Declines in mammalian foraging efficiency during the late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology* 13:371-401. [TAW]
- . 1997. Widening diet breadth, declining foraging efficiency, and prehistoric harvest pressure. Ichthyofaunal evidence from the Emeryville Shellmound, California. *Antiquity* 71:845-62. [TAW]
- BROWN, GARY M. 1982. Lithic exchange and production on Anderson Mesa, north-central Arizona. M.A. thesis, Department of Anthropology, Arizona State University, Tempe, Ariz.
- . 1990. Editor. *Technological change in the Chavez Pass region, north-central Arizona*. Arizona State University Anthropological Research Papers 41.
- . 1991. Embedded and direct lithic resource procurement strategies on Anderson Mesa. *Kiva* 56:359-84.
- . 1992. *Archaeological investigations at the Haul*

- Road site: 1991 excavations at La Plata Mine, San Juan County, New Mexico. Technical Report 577. Albuquerque: Mariah Associates, Inc.
- . 1996. Transformations in Southwestern prehistory: The paleoenvironmental context of cultural change. Paper presented at the 61st annual meeting of the Society for American Archaeology, New Orleans, La.
- BROWN, P. M., M. K. HUGHES, C. H. BAISAN, T. W. SWETNAM, AND A. C. CAPRIO. 1992. *Giant sequoia ring-width chronologies from the Central Sierra Nevada*. Tree-Ring Bulletin 52. [RLB]
- BRUMFIEL, E. M. 1992. Distinguished lecture in archaeology: Breaking and entering the ecosystem—gender, class, and faction steal the show. *American Anthropologist* 94:551–67.
- CANE, S. 1987. Australian aboriginal subsistence in the Western Desert. *Human Ecology* 15:391–434.
- CHARTKOFF, J. L. 1989. Exchange systems in the Archaic of coastal southern California. *Proceedings of the Society for California Archaeology* 2:167–86.
- CHARTKOFF, J. L., AND K. K. CHARTKOFF. 1984. *The archaeology of California*. Stanford: Stanford University Press.
- CHRISTENSON, L. E. 1992. "The late prehistoric Yuman settlement system: Coastal adaptation," in *Essays on the prehistory of maritime California*. Edited by T. L. Jones, pp. 217–30. Center for Archaeological Research at Davis Publications 10.
- COHEN, MARK NATHAN. 1977. *The food crisis in prehistory*. New Haven: Yale University Press.
- COLE, K. L. 1986. The Lower Colorado River Valley, a Pleistocene desert. *Quaternary Research* 25:392–400.
- COLE, K. L., AND R. H. WEBB. 1985. Late Holocene vegetation changes in Greenwater Valley, Mojave Desert, California. *Quaternary Research* 23:227–35.
- COLTEN, R. H. 1993. Prehistoric subsistence, specialization, and economy in a southern California chiefdom. Ph. D. diss., University of California, Los Angeles, Calif.
- . 1995. Faunal exploitation during the Middle to Late Period transition on Santa Cruz Island, California. *Journal of California and Great Basin Anthropology* 17:93–120.
- CORDELL, LINDA S., AND GEORGE J. GUMERMAN. Editors. 1989. *Dynamics of Southwest prehistory*. Washington, D.C.: Smithsonian Institution Press.
- CORDELL, LINDA S., AND FRED PLOG. 1979. Escaping the confines of normative thought: A reevaluation of Puebloan prehistory. *American Antiquity* 44:405–29.
- COSGROVE, R. 1995. Late Pleistocene behavioural variation and time trends: The case from Tasmania. *Archaeology in Oceania* 30:83–104. [IL]
- CRUMLEY, CAROLE L. Editor. 1994. *Historical ecology: Cultural knowledge and changing landscapes*. Santa Fe: School of American Research Press. [JH, WC]
- . 1996. "Historical ecology," in *Encyclopedia of cultural anthropology*. Edited by David Levinson and Melvin Ember, pp. 558–60. New York: Henry Holt. [JH, WC]
- CURREY, D. R., AND S. R. JAMES. 1982. "Northeastern Basin rim region: A review of geological and biological evidence," in *Man and environment in the Great Basin*. Edited by D. B. Madson and J. F. O'Connell, pp. 27–52. Society for American Archaeology Papers 2.
- CURRY, R. R. 1969. *Holocene climatic and glacial history of the Central Sierra Nevada*. Geological Society of America Special Paper 123. [RLB]
- DAVID, B., AND H. LOURANDOS. 1997. 37,000 years and more in tropical Australia: Investigating long-term archaeological trends in Cape York Peninsula. *Proceedings of the Prehistoric Society* 63:1–23. [IL]
- DAVIS, J. O. 1982. "Lahontan Basin paleoenvironments," in *Man and environment in the Great Basin*. Edited by D. B. Madson and J. F. O'Connell, pp. 53–75. Society for American Archaeology Papers 2.
- DAVIS, O. K. 1992. Rapid climatic change in coastal southern California inferred from pollen analysis of San Joaquin Marsh. *Quaternary Research* 37:89–100.
- DEAN, JEFFREY S. 1988a. "Dendrochronology and paleoenvironmental reconstruction on the Colorado Plateaus," in *The Anasazi in a changing environment*. Edited by George J. Gumerman, pp. 119–67. Cambridge: Cambridge University Press.
- . 1988b. "A model of Anasazi behavioral adaptation," in *The Anasazi in a changing environment*. Edited by George J. Gumerman, pp. 25–44. Cambridge: Cambridge University Press.
- . 1994. The medieval warm period on the southern Colorado Plateau. *Climate Change* 26:225–42.
- DEAN, JEFFREY S., ROBERT C. EULER, GEORGE J. GUMERMAN, FRED PLOG, RICHARD H. HEVLY, AND THOR N. V. KARLSTROM. 1985. Human behavior, demography, and paleoenvironment on the Colorado Plateaus. *American Antiquity* 50:537–54.
- DEAN, JEFFREY S., AND WILLIAM J. ROBINSON. 1977. *Dendroclimatic variability in the American Southwest, A.D. 680 to 1970*. Tucson: University of Arizona Laboratory of Tree-Ring Research.
- DE GARINE, I., AND G. A. HARRISON. Editors. 1988. *Coping with uncertainty in food supply*. Oxford: Clarendon Press.
- DE NARVAEZ, CYNTHA. 1995. Paleohydrology and paleotopography of a Las Vegas spring. M.S. thesis, Northern Arizona University, Flagstaff, Ariz.
- DOUGLASS, A. E. 1929. The secrets of the Southwest solved by talkative tree rings. *National Geographic* 54:737–70.
- DROVER, C. E. 1979. The late prehistoric human ecology of the northern Mohave Sink San Bernardino County, California. Ph. D. diss., University of California, Riverside, Calif.
- ELY, L. L., YEHOUA ENZEL, V. R. BAKER, AND D. R. CAYAN. 1993. A 5000-year record of extreme floods and climate change in the Southwestern United States. *Science* 262:410–12.
- ENZEL, YEHOUA, W. J. BROWN, R. Y. ANDERSON, L. D. MC FADDEN, AND S. G. WELLS. 1992. Short-duration Holocene lakes in the Mojave River drainage basin, southern California. *Quaternary Research* 38:60–73.
- ERLANDSON, J. M. 1991. "Shellfish and seeds as optimal resources: Early Holocene subsistence on the Santa Barbara coast," in *Hunter-gatherers of Early Holocene coastal California*. Edited by J. M. Erlandson and R. H. Colten, pp. 89–100. Institute of Archaeology, University of California, Los Angeles, Perspectives in California Archaeology 1.
- . 1993. "Conclusions," in *Archaeological investigations at CA-SBA-1731: A transitional Middle-to-Late Period site on the Santa Barbara Channel*. Edited by J. L. Gerber, pp. 230–45. Report prepared for Exxon Company, USA, Goleta, Calif., by Dames and Moore, Santa Barbara, Calif.
- EULER, R. C. 1988. "Demography and cultural dynamics on the Colorado Plateaus," in *The Anasazi in a changing environment*. Edited by George J. Gumerman, pp. 192–229. Cambridge: Cambridge University Press.
- EULER, ROBERT C., GEORGE J. GUMERMAN, THOR N. V. KARLSTROM, JEFFREY S. DEAN, AND RICHARD H. HEVLY. 1979. The Colorado Plateaus: Cultural dynamics and paleoenvironment. *Science* 205:1089–1101.
- EZZO, J. A. 1992. Dietary change and variability at Grasshopper Pueblo, Arizona. *Journal of Anthropological Archaeology* 11:219–89.
- FENNEMAN, F. N. 1931. *Physiography of the western United States*. New York: McGraw-Hill.
- FREDRICKSON, D. A. 1974. Cultural diversity in early central California: A view from the North Coast Ranges. *Journal of California Anthropology* 1:41–54.
- . 1994. "Spatial and cultural units in central California archaeology," in *Toward a new taxonomic framework for central California archaeology*. Edited by R. E. Hughes, pp. 25–47. Contributions of the University of California Archaeological Research Facility 52.
- FRITTS, H. C., D. G. SMITH, AND M. A. STOKES. 1965. "The biological model for paleoclimatic interpretation of Mesa Verde tree-ring series," in *Contributions of the Wetherhill Mesa Archaeological Project*. Edited by Bernard S. Katz, pp. 101–21. *Memoirs of the Society for American Archaeology* 19.

- GILREATH, A. J. 1995. Archaeological evaluations of thirteen sites for the Ash Creek Project, Inyo County, California. Far Western Anthropological Research Group, Davis, California. Report prepared for the California Department of Transportation, Sacramento.
- GILREATH, A. J., AND W. R. HILDEBRANDT. 1995. Prehistoric use of the Coso volcanic field. Report prepared for the Geothermal Program Office, Naval Weapons Center, China Lake, Calif.
- GLASSOW, M. A. 1991. "Early Holocene adaptations on Vandenberg Air Force Base, Santa Barbara County," in *Hunter-gatherers of early Holocene coastal California*. Edited by J. M. Erlandson and R. H. Colten. pp. 113–24. Los Angeles: University of California, Los Angeles, Institute of Archaeology.
- GLASSOW, M. A., L. WILCOXON, AND J. ERLANDSON. 1988. "Cultural and environmental change during the early period of Santa Barbara Channel prehistory," in *The archaeology of prehistoric coastlines*. Edited by G. Bailey and J. Parkington, pp. 64–77. Cambridge: Cambridge University Press.
- GOULD, R. A. 1980. *Living archaeology*. Cambridge: Cambridge University Press.
- GOULD, S. J. 1984. "Toward the vindication of punctuational change," in *Catastrophes and earth history*. Edited by W. A. Berggren and J. A. Van Couvering, pp. 9–34. Princeton: Princeton University Press.
- GRAUMLICH, L. J. 1993. A 1000-year record of temperature and precipitation in the Sierra Nevada. *Quaternary Research* 39:249–55.
- GREEN, MARJORIE. 1992. "Chipped stone raw materials from Long House, Kletthla, and Kayenta Valleys (Appendix C);" in *Stress and warfare among the Kayenta Anasazi of the thirteenth century A.D.*, by Jonathan Haas and Winifred Creamer, pp. 181–200. *Fieldiana Anthropology*, n.s., 21.
- GRIBBIN, JOHN, AND HUBERT H. LAMB. 1978. "Climate change in historical times," in *Climate change*. Edited by J. Gribbin, pp. 68–82. London: Cambridge University Press.
- GROVE, JEAN M. 1988. *The Little Ice Age*. New York: Methuen.
- GUMERMAN, GEORGE J. Editor. 1988. *The Anasazi in a changing environment*. Cambridge: Cambridge University Press.
- HAAS, JONATHAN, AND WINIFRED CREAMER. 1992. *Stress and warfare among the Kayenta Anasazi of the thirteenth century A.D.* *Fieldiana Anthropology*, n.s., 21.
- HAYNES, C. V., JR. 1967. "Quaternary geology of the Tule Springs area, Clark County, Nevada," in *Pleistocene studies in southern Nevada*. Edited by H. M. Wormington and D. Ellis, pp. 15–104. Nevada State Museum Anthropological Papers 13.
- HILDEBRANDT, W. R. 1997. The relative importance of lacustrine and estuarine resources to prehistoric hunter-gatherer populations: A view from the southern Santa Clara Valley, California. *Journal of California and Great Basin Anthropology* 19: 197–225.
- HILDEBRANDT, W. R., AND T. L. JONES. 1992. Evolution of marine mammal hunting: A view from the California and Oregon coasts. *Journal of Anthropological Archaeology* 11:360–401.
- HOGAN, PATRICK. 1994. "Foragers to farmers II: A second look at the adoption of agriculture in the northern Southwest," in *Archaic hunter-gatherer archaeology in the American Southwest*. Edited by Bradley J. Vierra. Eastern New Mexico University Contributions in Anthropology 13.
- HOLDAWAY, S., AND N. PORCH. 1995. Cyclical patterns in the Pleistocene human occupation of southwest Tasmania. *Archaeology in Oceania* 30:74–82. [IL]
- HUGHES, M. K., AND H. F. DIAZ. 1994. Was there a medieval warm period, and if so, where and when? *Climate Change* 26:109–42.
- HUGHES, M. K., AND L. J. GRAUMLICH. 1995. "Multimillennial dendroclimatic records from western North America," in *Climatic variations and forcing mechanisms of the last 2000 years*. Edited by R. S. Bradley, P. D. Jones, and J. Jouzel, pp. 109–24. Berlin: Springer-Verlag. [RLB]
- HUGHES, R. E. 1994. "Mosaic patterning in prehistoric Great Basin-California exchange," in *Prehistoric exchange systems in North America*. Edited by Timothy G. Baugh and Jonathon E. Ericson, pp. 363–84. New York: Plenum.
- HUNTER, K. L., AND J. R. MCAULIFFE. 1994. Elevational shifts of *Coleogyne ramossissima* in the Mojave Desert during the Little Ice Age. *Quaternary Research* 42:216–21.
- INGRAM, M. J., G. FARMER, AND T. M. L. WIGLEY. 1981. "Past climates and their impact on man: A review," in *Climate and history: Studies in past climates and their impact on man*. Edited by T. M. L. Wigley, M. J. Ingram, and G. Farmer, pp. 3–50. Cambridge: Cambridge University Press.
- JACKSON, T. L. 1986. Late prehistoric obsidian exchange in central California. Ph.D. diss., Stanford University, Stanford, Calif.
- JACKSON, T. L., AND J. E. ERICSON. 1994. "Prehistoric exchange systems in California," in *Prehistoric exchange systems of North America*. Edited by T. G. Baugh and J. E. Ericson, pp. 385–415. New York: Plenum.
- JENNINGS, J. D. 1957. *Danger Cave*. Society for American Archaeology Memoir 14.
- JONES, T. L. 1991. Marine-resource value and the priority of coastal settlement: A California perspective. *American Antiquity* 56:419–43.
- . 1992. "Settlement trends along the California coast," in *Essays on the prehistory of maritime California*. Edited by T. L. Jones, pp. 1–37. Center for Archaeological Research at Davis Publications 10.
- . 1995. Transitions in prehistoric diet, mobility, exchange, and social organization along California's Big Sur coast. Ph.D. diss., University of California, Davis, Calif.
- JONES, T. L., AND W. HILDEBRANDT. 1995. Reasserting a prehistoric tragedy of the commons: Reply to Lyman. *Journal of Anthropological Archaeology* 14:78–98.
- JONES, T. L., AND G. WAUGH. 1995. *Central California coastal prehistory: A view from Little Pico Creek*. Institute of Archaeology, University of California, Los Angeles, Perspectives in California Archaeology 3.
- KEELEY, L. H. 1988. Hunter-gatherer economic complexity and "population pressure": A cross-cultural analysis. *Journal of Anthropological Archaeology* 7:373–411. [RLB]
- KELLY, ROBERT L. 1995. *The foraging spectrum: Diversity in hunter-gatherer lifeways*. Washington, D.C.: Smithsonian Institution Press.
- KING, C. D., T. BLACKBURN, AND E. CHANDONET. 1968. The archaeological investigation of three sites on the Century Ranch, western Los Angeles County, California. *University of California Archaeological Survey Annual Report 1968*, pp. 12–107.
- KING, L. B. 1982. Medea Creek cemetery: Late Inland Chumash patterns of social organization, exchange, and warfare. Ph.D. diss., University of California, Los Angeles, Calif.
- KNIFFEN, F. B. 1939. Pomo geography. *University of California Publications in American Archaeology and Ethnology* 36:353–400.
- KOENIG, W. D., R. L. MUMME, W. J. CARMEN, AND M. T. STANBACK. 1994. Acorn production by oaks in central coastal California: Variation within and among years. *Ecology* 75:99–109. [RLB]
- KREUTZ, K. J., P. A. MAYEWSKI, L. D. MEEKER, M. S. TWICKLER, S. I. WHITLOW, AND I. I. PITTALWALA. 1997. Bipolar changes in atmospheric circulation during the Little Ice Age. *Science* 277:1294–96.
- KROEBER, A. L. 1925. *Handbook of the Indians of California*. Bureau of American Ethnology Bulletin 78.
- . 1955. Linguistic time depths results so far and their meaning. *International Journal of American Linguistics* 21:91–104.
- LA MARCHE, V. C., JR. 1974. Paleoclimatic inferences from long tree-ring records. *Science* 183:4129.
- LAMB, H. H. 1977. *Climate: Present, past, and future*. Vol. 2. London: Methuen.
- . 1982. *Climate, history, and the modern world*. London: Methuen.
- LAMBERT, P. M. 1993. Health in prehistoric populations of the

- Santa Barbara Channel islands. *American Antiquity* 58:509–22.
- LAMBERT, P. M., AND P. L. WALKER. 1991. Physical anthropological evidence for the evolution of social complexity in coastal southern California. *Antiquity* 65:963–73.
- LARSON, D. O. 1987. An economic analysis of the differential effects of population growth and climatic variability among hunters and gatherers and food producers. Ph.D. diss., University of California, Santa Barbara, Calif.
- LARSON, D. O., J. R. JOHNSON, AND J. C. MICHAELSEN. 1994. Missionization among the coastal Chumash of central California: A study of risk minimization strategies. *American Anthropologist* 96:263–99.
- LARSON, D. O., AND J. MICHAELSEN. 1989. Climatic variability: A compounding factor causing culture change among prehistoric coastal populations. MS on file, Department of Anthropology, California State University, Long Beach.
- . 1990. Impacts of climatic variability and population growth on Virgin Branch Anasazi cultural developments. *American Antiquity* 55:227–49.
- LARSON, D. O., H. NEFF, D. A. GRAYBILL, J. MICHAELSEN, AND E. AMBOS. 1996. Risk, climatic variability, and the study of Southwestern prehistory: An evolutionary perspective. *American Antiquity* 61:217–42.
- LAYLANDER, D. 1994. *Phase III data recovery at the Elmore Site (CA-IMP-6427), Imperial County, California*. San Diego: California Department of Transportation.
- LEAVITT, S. W. 1994. Major wet interval in White Mountains Medieval Warm Period evidenced in <sup>13</sup>C bristlecone pine tree rings. *Climate Change* 26:299–308.
- LEE, RICHARD B. 1979. *The !Kung San: Men, women, and work in a foraging society*. Cambridge: Cambridge University Press. [MEB]
- LIETH, H. 1975. "Primary production of the major vegetation units of the world," in *Primary productivity of the biosphere*. Edited by H. Lieth and R. H. Whittaker, pp. 203–16. New York: Springer-Verlag.
- LIGHTFOOT, KENT G., AND EDWARD M. LUBY. 1998. The late Holocene in the greater San Francisco Bay area: Temporal trends in the use and abandonment of shell mounds in the East Bay. Paper presented at the annual meeting of the Society for California Archaeology, San Diego, Calif.
- LIGHTFOOT, KENT G., AND STEADMAN UPHAM. 1989. "Complex societies in the prehistoric American Southwest: A consideration of the controversy," in *The sociopolitical structure of prehistoric Southwestern societies*. Edited by S. Upham, K. G. Lightfoot, and R. A. Jewett, pp. 3–32. Boulder: Westview Press.
- LINDSAY, LA MAR W. 1986. "Fremont fragmentation," in *Anthropology of the Desert West: Essays in honor of Jesse D. Jennings*. Edited by Carol J. Condie and Don D. Fowler, pp. 227–51. University of Utah Anthropological Papers 110.
- LIPE, WILLIAM D. 1995. The depopulation of the northern San Juan: Conditions in the turbulent 1200s. *Journal of Anthropological Archaeology* 14:143–69.
- LOURANDOS, H. 1983. Intensification: A late Pleistocene-Holocene archaeological sequence from southwestern Victoria. *Archaeology in Oceania* 18:81–97. [IL]
- . 1984. Changing perspectives in Australian prehistory: A reply to Beaton. *Archaeology in Oceania* 19:29–33. [IL]
- . 1985. Problems in the interpretation of late Holocene changes in Australian prehistory. *Archaeology in Oceania* 20:37–39. [IL]
- . 1996. "Change in Australian prehistory: Scale, trends, and frameworks of interpretation," in *Australian archaeology '95: Proceedings of the 1995 Australian Archaeological Association Annual Conference*. Edited by S. Ulm, I. Lilley, and A. Ross, pp. 15–21. (Tempus 6.) Brisbane: Anthropology Museum, University of Queensland. [IL]
- LOURANDOS, H., AND A. ROSS. 1984. The great "intensification debate": Its history and place in Australian archaeology. *Australian Archaeology* 39:54–63. [IL]
- MARTZ, P. C. 1984. Social dimensions of Chumash mortuary populations in the Santa Monica Mountains region. Ph.D. diss., University of California, Riverside, Calif.
- MASON, J. A. 1918. The language of the Salinan Indians. *University of California Publications in Archaeology and Ethnology* 14:1–154.
- MEHRINGER, PETER J., JR., AND C. N. WARREN. 1976. "Marsh, dune, and archaeological chronology, Ash Meadows, Amargosa Desert, Nevada." in *Holocene environmental change in the Great Basin*. Edited by Robert Elston, pp. 120–50. Nevada Archaeological Survey Research Papers 6.
- MEIGHAN, C. W. 1959. California cultures and the concept of an Archaic stage. *American Antiquity* 24:289–318.
- MINNIS, PAUL E. 1985. *Social adaptation to food stress: A prehistoric Southwestern example*. Chicago: University of Chicago Press.
- MORATTO, M. J. 1984. *California archaeology*. Orlando: Academic Press.
- MORATTO, M. J., T. F. KING, AND W. F. WOOLFENDEN. 1978. Archaeology and California's climate. *Journal of California and Great Basin Anthropology* 5:147–61.
- NEILY, ROBERT B. 1983. The prehistoric community on the Colorado Plateau: An approach to the study of change and survival in the northern San Juan area of the American Southwest. Ph.D. diss., Southern Illinois University, Carbondale, Ill.
- NICKENS, PAUL R. 1975. Prehistoric cannibalism in the Mancos Canyon, southwestern Colorado. *Kiva* 40:283–93.
- OLIVER-SMITH, A. 1996. Anthropological research on hazards and disasters. *Annual Review of Anthropology* 25:303–28.
- PATE, F. D. 1986. Effect of drought on Ngatjara plant use: An evaluation of optimal foraging theory. *Human Ecology* 14:95–115.
- PETERSON, KENNETH L. 1987. "Summer precipitation: An important factor in the Dolores project area," in *Dolores Archaeological Program, supporting studies: Settlement and environment*. Edited by Kenneth L. Peterson and Janet D. Orcutt, pp. 73–88. Denver: U.S.D.I. Bureau of Reclamation, Engineering and Research Center.
- . 1988. *Climate and the Dolores River Anasazi*. University of Utah Anthropological Papers 113.
- PISIAS, N. G. 1978. Paleoclimatology of the Santa Barbara Basin during the last 8000 years. *Quaternary Research* 10:366–84.
- PLOG, FRED, GEORGE J. GUMERMAN, ROBERT C. EULER, JEFFREY S. DEAN, RICHARD H. HEVLY, AND THOR N. V. KARLSTROM. 1988. "Anasazi adaptive strategies: The model, predictions, and results," in *The Anasazi in a changing environment*. Edited by George J. Gumerman, pp. 230–76. Cambridge: Cambridge University Press.
- PLOG, S. 1990. "Agriculture, sedentism, and environment in the evolution of political systems," in *The evolution of political systems*. Edited by S. Upham, pp. 177–202. Cambridge: Cambridge University Press.
- RAAB, L. M. 1994. The dead at Calleguas Creek: A study of punctuated cultural evolution during the Middle/Late Period transition in southern California. Center for Public Archaeology, California State University, Northridge, prepared for Environmental Division, Naval Air Weapons Station, Point Mugu, Calif.
- . 1996. Debating prehistory in coastal southern California: Resource intensification versus political economy. *Journal of California and Great Basin Anthropology* 18:64–80.
- RAAB, L. M., AND K. BRADFORD. 1997. Making nature answer to interpretivism: Response to J. E. Arnold, R. H. Colten, and S. Pletka. *American Antiquity* 62:340–41.
- RUBY, J., AND T. BLACKBURN. 1964. Occurrence of Southwestern pottery in Los Angeles County, California. *American Antiquity* 30:209–10.
- SAMUELS, M. L., AND J. L. BETANCOURT. 1982. Modeling the long-term effects of fuelwood harvest on pinyon-juniper woodlands. *Environmental Management* 6:505–15.
- SCHAEFER, JERRY. 1986. *Late prehistoric adaptations during the final recessions of Lake Cahuilla: Fish camps and quarries*

- on West Mesa, Imperial County, California. San Diego: Mooney-Levine and Associates.
- . 1988. *Lowland Patayan adaptations to ephemeral alkalis at Superstition Mountain, West Mesa, Imperial County, California*. San Diego: Brian F. Mooney Associates.
- SCHROEDER, A. H. 1961. *The archaeological excavations at Willow Beach, Arizona, 1950*. University of Utah Anthropological Papers 50.
- SCHWARTZ, DOUGLAS W., RICHARD C. CHAPMAN, AND JANE KEPP. 1980. *Archaeology of the Grand Canyon: Unkar Delta*. Santa Fe: School of American Research Press.
- SCHWARTZ, DOUGLAS W., JANE KEPP, AND RICHARD C. CHAPMAN. 1981. *Archaeology of the Grand Canyon: The Walhalla Plateau*. Santa Fe: School of American Research Press.
- SHMIDA, AVISHAI, M. EVENARI, AND I. NOY-MEIR. 1986. "Hot desert ecosystems: An integrated view," in *Hot deserts and arid shrublands*. Edited by M. Evenari, pp. 379–87. Amsterdam: Elsevier.
- SHNIRELMAN, V. A. 1992. Crises and economic dynamics in traditional societies. *Journal of Anthropological Archaeology* 11:25–46.
- SIMONS, DWIGHT D. 1993. "Prehistoric mammal exploitation in the San Francisco Bay area," in *Essays on the prehistory of maritime California*. Edited by T. L. Jones, pp. 73–103. University of California, Davis, Center for Archaeological Research Publications 10.
- SPAULDING, W. G. 1981. The Late Quaternary vegetation of a southern Nevada mountain range. Ph.D. diss., University of Arizona, Tucson, Ariz.
- . 1990. "Vegetational and climatic development of the Mojave Desert: The last glacial maximum to the present," in *Packrat middens: The last 40,000 years of biotic change*. Edited by J. L. Betancourt, T. R. Van Devender, and P. S. Martin, pp. 166–99. Tucson: University of Arizona Press.
- . 1991. A Middle Holocene vegetation record from the Mojave Desert and its paleoclimatic significance. *Quaternary Research* 35:427–37.
- . 1995. "Environmental change, ecosystem responses, and the Late Quaternary development of the Mojave Desert," in *Quaternary environments and deep history: A tribute to Paul S. Martin*. Edited by J. I. Mead and D. S. Steadman, pp. 139–64. Rapid City, S.D.: Fenske Printing.
- STEWART, J. B. 1938. *Basin-Plateau aboriginal sociopolitical groups*. Bureau of American Ethnology Bulletin 120.
- STINE, S. 1990. Late Holocene fluctuations of Mono Lake, eastern California. *Palaeogeography, Palaeoclimatology, Palaeoecology* 78:333–81.
- . 1994. Extreme and persistent drought in California and Patagonia during mediaeval time. *Nature* 369:546–49.
- SULMAN, F. G. 1982. *Short and long-term changes in climate*. Boca Raton, Fla.: CRC Press.
- SWETNAM, THOMAS W. 1993. Fire history and climate change in giant sequoia groves. *Science* 262:885–89.
- SWETNAM, THOMAS W., AND J. L. BETANCOURT. 1992. "Temporal patterns of El Niño/Southern Oscillation–wildfire teleconnections in the southwestern United States," in *El Niño: Historical and paleoclimatic aspects of the Southern Oscillation*. Edited by H. F. Diaz and V. M. Graf, pp. 259–70. Cambridge: Cambridge University Press.
- TESTART, A. 1982. The significance of food storage among hunter-gatherers: Residence patterns, population densities, and social inequalities. *CURRENT ANTHROPOLOGY* 23:523–37.
- . 1988. "Food storage among hunter-gatherers: More or less security in the way of life," in *Coping with uncertainty in food supply*. Edited by I. De Garine and G. A. Harrison, pp. 170–74. Oxford: Clarendon Press.
- TORREY, W. 1978. Natural disasters, social structure, and change in traditional societies. *Journal of Asian and African Studies* 13:167–83.
- . 1979. Anthropology and disaster research. *Disasters* 3: 43–52.
- TRUE, D. L. 1990. Site locations and water supply: A perspective from northern San Diego County, California. *New World Archaeology* 4:37–60.
- TURNER, CHRISTY G., II, AND JACQUELINE A. TURNER. 1990. Perimortem damage to human skeletal remains from Wupatki National Monument, Northern Arizona. *Kiva* 55:187–212.
- . 1992. The first claim for cannibalism in the Southwest: Walter Hough's 1901 discovery at Canyon Butte Ruin 3, north-eastern Arizona. *American Antiquity* 57:661–82.
- UPHAM, STEADMAN. 1982. *Politics and power: An economic and political history of the Western Pueblo*. New York: Academic Press.
- . 1984a. Adaptive diversity and Southwestern abandonment. *Journal of Anthropological Research* 40:235–56.
- . 1984b. "Perspectives on labor-intensive agriculture and exchange during the fourteenth century," in *Prehistoric agricultural strategies in the Southwest*. Edited by Suzanne Fish and Paul R. Fish, pp. 291–307. Arizona State University Anthropological Research Papers 33.
- UPHAM, STEADMAN, AND FRED PLOG. 1986. The interpretation of prehistoric political complexity in the central and northern Southwest: Toward a mending of the models. *Journal of Field Archaeology* 13:223–38.
- VAN DEVENDER, T. R. T. L. BURGESS, R. S. FELGER, AND R. M. TURNER. 1990. Holocene vegetation of the Hornaday Mountains of northwestern Sonora, Mexico. *Proceedings of the San Diego Society of Natural History* 2:1–19.
- VAN WEST, CARLA R., AND WILLIAM D. LIPE. 1992. "Modeling prehistoric climate and agriculture in southwestern Colorado," in *The Sand Canyon archaeological project: A progress report*. Edited by William D. Lipe, pp. 105–19. Crow Canyon Archaeological Center Occasional Paper 3.
- WALKER, E. F. 1951. *Five prehistoric archaeological sites in Los Angeles County, California*. Publications of the F. W. Hodge Anniversary Publication Fund 6.
- WALKER, P. L. 1986. Porotic hyperostosis in a marine-dependent California Indian population. *American Journal of Physical Anthropology* 69:345–54.
- . 1989. Cranial injuries as evidence of violence in prehistoric southern California. *American Journal of Physical Anthropology* 80:313–23.
- WALKER, P. L., AND P. M. LAMBERT. 1989. "Skeletal evidence for stress during a period of culture change in prehistoric California," in *Advances in paleopathology*. Edited by L. Capasso, pp. 207–12. Chieti: Marino Solfanelli.
- WALKER, P. L., M. J. DENIRO, AND P. M. LAMBERT. 1989. "The effects of European contact on the health of Alta California Indians," in *Columbian consequences*, vol. 1. Edited by David Hurst Thomas, pp. 349–64. Washington, D.C.: Smithsonian Institution Press.
- WARREN, CLAUDE N. 1968. "Cultural tradition and ecological adaptation of the southern California coast," in *Archaic prehistory in the western United States*. Edited by C. Irwin-Williams, pp. 1–14. Eastern New Mexico University Contributions in Anthropology 1.
- WATERS, M. R. 1983. Late Holocene lacustrine chronology and archaeology of ancient Lake Cahuilla, California. *Quaternary Research* 19:373–87.
- WEIDE, M. L. 1976. "A cultural sequence for the Yuha Desert," in *Background to prehistory of the Yuha Desert*. Edited by P. J. Wilke, pp. 81–94. Ballena Press Anthropological Papers 5.
- WHITE, TIM D. 1992. *Prehistoric cannibalism at Mancos 5MTUMR-2346*. Lawrenceville: Princeton University Press.
- WIGAND, P. E., J. O. DAVIS, AND L. C. PIPPIN. 1990. "The Lahontan Basin," in *Studies of climatic variations and their impact on the Great Basin*. Final Report on Contract #NA878A-D-CP114, submitted to National Climatic Program Office, NOAA, Rockville, Md.
- WILCOX, DAVID R., AND JONATHAN HAAS. 1994. "The scream of the butterfly: Competition and conflict in the prehistoric Southwest," in *Themes in Southwestern prehistory*. Edited by George J. Gumerman, pp. 211–38. Santa Fe: School of American Research Press.

- WILKE, P. 1978. *Late prehistoric human ecology at Lake Cahuilla, Coachella Valley, California*. Contributions of the University of California Archaeological Research Facility 38.
- WILLS, W. H. 1988. Early agriculture and sedentism in the American Southwest: Evidence and interpretations. *Journal of World Prehistory* 2:445-88.
- WLODARSKI, R. J., J. F. ROMANI, G. R. ROMANI, AND D. A. LARSON. 1984. Preliminary evidence of metal tool use in soapstone quarry mining on Catalina Island: Jane Russell Quarry. *Pacific Coast Archaeological Society Quarterly* 20:35-64.
- WORMINGTON, H. M. 1947. *Prehistoric Indians of the Southwest*. Denver: Denver Museum of Natural History.
- WRIGHT, H. E., JR. 1993. Environmental determinism in Near Eastern prehistory. *CURRENT ANTHROPOLOGY* 34:458-69.
- YELLEN, J. 1976. "Settlement pattern of the !Kung: An archaeological perspective," in *Kalahari hunter-gatherers*. Edited by R. B. Lee and I. DeVore, pp. 48-72. Cambridge: Harvard University Press.