

Human Responses to Middle Holocene (Altithermal) Climates on the North American Great Plains

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Received February 23, 1999

The climate of the Great Plains during the middle Holocene varied considerably, but overall it was marked by a north-south gradient of increasingly warmer and drier conditions, with a reduction in effective moisture, surface water, and resource abundance, and an increase in resource patchiness, sediment weathering, erosion, and aeolian activity. Pronounced drought conditions were most evident on the Southern High Plains. Understanding the human responses to middle Holocene climates is complicated by a lack of archaeological data, which is partly a result of geomorphic processes that removed or deeply buried sites of this age, and by the varying adaptive responses of hunter-gatherers during this period. On the Southern High Plains, where drought was most severe, surface and groundwater sources dried and bison populations were diminished, prompting substantial adaptive changes, including local abandonment, well-digging to tap underground water, and a widening of the diet breadth to incorporate higher-cost, lower-return seed and plant resources. Sites of this age on the Central and Northern Plains also show a possible increase in diet breadth (with the incorporation of plant foods in the diet), and perhaps changes in settlement mobility (including possible shift into higher elevation areas, or mapping-on to extant rivers and springs). But linking those changes to middle Holocene drought is less straightforward. © 1999 University of Washington.

Key Words: Archaic archaeology; Altithermal; drought adaptations; middle Holocene; Plains, North America.

INTRODUCTION

The adaptive response of human foragers to middle Holocene (ca. 7500–5000 B.P.) climates on the North American Great Plains has long been a subject of discussion, if not dispute (e.g., Bender and Wright 1988; Frison 1975; Meltzer 1995). Sites from this period are rare, their remains often ephemeral, and their climatic context poorly known. Many assume, however, that these sites represent adaptations to severe aridity and drought, as originally conceived in Antevs' (1948) concept of an "Altithermal" (which he put squarely within the middle Holocene). Yet, middle Holocene climates have proven highly complex, with considerable variability in the timing and intensity of Holocene warming and drying, and in the attendant ecological impact (Albanese and Frison, 1995,

p. 13; Toomey *et al.*, 1993, pp. 314–315, 317). Put simply, it was not hot and dry everywhere on the Plains, nor did this region experience wholesale environmental degradation during the middle Holocene. In this regard, the Plains is little different from other areas of the American west (Dean *et al.*, 1996; Whitlock and Bartlein, 1993, pp. 235–236).

Possible causes aside (see Whitlock and Bartlein, 1993; Whitlock *et al.*, 1995), the fact of middle Holocene climatic variability has several important implications for the archaeology of this period (not always appreciated by archaeologists). First, a site dating to the middle Holocene was not necessarily occupied during the "Altithermal drought," nor can the absence of such sites necessarily be attributable to abandonment in response to harsh climates. Demonstrating that cultural patterns were a response to drought requires demonstrating that drought existed locally, then directly linking its effects to specific human response(s) detected archaeologically (Meltzer, 1991, p. 237).

Second, we should expect that middle Holocene adaptations varied, just as the climate and environment of the period varied: they may look different in different areas at different times simply as a consequence of local ecological and climatic conditions (Frison, 1975, p. 289; Wedel, 1986, p. 78). As a corollary, while Antevs underestimated the ecological complexity of this period, he thought in some places middle Holocene climates were severe, and in that he was correct. This is particularly evident on parts of the Plains, which experienced conditions much as he envisioned for the Altithermal, a long episode of warming and drying, and a landscape that was largely waterless, devegetated, wind-scoured, and (relative to humans) resource-poor (Holliday, 1989, 1995; Meltzer, 1995).

Finally, the number, kind, distribution, and visibility of archaeological sites may also vary, owing to differential effects of weathering, erosion, and deposition through the middle and late Holocene. That may help explain why archaeological sites of this age are rare and help us better assess whether this scarcity of evidence is evidence of scarcity (Meltzer, 1991; also Collins, 1995; Greiser, 1985, p. 86).

The purpose of this review is threefold: to summarize middle Holocene climates and environments of the Great Plains that would have affected human foragers; to assess the potential impact of middle and late Holocene geomorphic processes on the

archaeological record from this period; and then to identify broad spatial and temporal trends in human adaptations of this period, and assess the manner in which foragers responded to those climatic, ecological, and hydrological conditions. (It should be noted that some of the archaeological trends seen on the Plains—notably, an expansion of the diet to include lower-ranked/higher-cost resources, repositioning of settlements in better-watered areas, and a decrease in the number of sites which may represent a decrease in population—are variously represented in other parts of the American west during this period, particularly the Great Basin and Southwest; for a discussion of the middle Holocene archaeology of those areas, see Cordell (1997), Grayson (1993, in press), Huckell (1996), and Kelly (1997)).

MIDDLE HOLOCENE CLIMATES AND ENVIRONMENTS ON THE GREAT PLAINS: PATTERNS AND VARIATION

In general, while the Plains experienced increased warming and drying throughout the Middle Holocene, their intensity varied through time and across space. Latitudinal variation may be important here, for the obvious reason that precipitation on the Plains generally varies east to west, but temperature and evaporation rates vary from north to south. (There was a longitudinal component as well: the eastern margin of the Plains expanded further into the Midwest during this period. For a recent discussion, see Dean *et al.* (1996).) Hence, effective moisture decreases from north to south (Muhs and Maat, 1993, p. 353), which is why the Southern Plains is the warmest, driest, and (historically) the most drought-prone portion of the Plains (Bamforth, 1988, pp. 54, 72; Borchert, 1971; Gutentag *et al.*, 1984, p. 3; Muhs and Holliday, 1995; Thomas *et al.*, 1963, p. 24; Weeks and Gutentag, 1988, p. 157). It likely was in middle Holocene times as well.

The amount of surface water on the Great Plains sharply declined during the middle Holocene (Ferring, 1995, p. 33; Holliday, 1995, p. 90). On the Northern and Central Plains, streams and springs fed primarily by rainfall or groundwater discharge may have had lowered water levels or may have been intermittently dry. There is evidence, however, that rivers which originated in the Rocky Mountains (e.g., the Missouri, Platte, Arkansas), likely carried water along most or all of their courses during this period (Fredlund, 1995; Wedel, 1986, p. 79). Lake levels in many areas fell and lakes became highly saline (Valero-Garcés *et al.*, 1997, pp. 365–366; Vance *et al.*, 1992). On the Southern High Plains, the roughly 25,000 playa lakes and salinas that dotted the Pleistocene landscape shrank or evaporated altogether (Holliday *et al.*, 1996; Sabin and Holliday, 1995). Groundwater-fed seeps and springs declined or disappeared in places as aquifer recharge failed to keep pace with discharge. Surface water became rare, unpredictable, unpotable,¹ or vanished (Holliday, 1995).

¹ The potability or drinking quality of Altithermal water sources can be inferred from their salinity, which in turn can be measured by the occurrence of particular diatom species and assemblages within water-laid sediments (e.g., Meltzer, 1991, pp. 242–245; Winnsborough in Holliday, 1995, p. 73).

But again there was variation (Holliday, 1989, 1995). Recharge rates of the Ogallala aquifer—the High Plains' principal water source (Fig. 1)—are lowest on the Southern High Plains owing to higher evaporation and lower surface permeability (Cronin, 1964, p. 2; Heath, 1984, p. 36; Gutentag *et al.*, 1984, Table 7; Weeks and Gutentag, 1988, p. 160). Recharge rates, storage capacity, and overall volume of the aquifer are greater on the Central and especially the Northern High Plains, the difference reflecting in part the greater extent of unconsolidated Quaternary sands (such as the Nebraska Sand Hills) that overlay large areas of the aquifer on the Central and Northern High Plains, as opposed to the low permeability caliche caprock that covers the Ogallala formation across much of the Southern High Plains (Cronin, 1964, pp. 2, 54; Heath, 1984, p. 36; Weeks and Gutentag, 1988, pp. 161–162). During historic droughts, the more northern areas stayed wetter longer, and likely did so in prehistoric times as well (Cronin, 1964, p. 35; Heath, 1984, pp. 35–36, 1988; Weeks and Gutentag, 1988, pp. 157–164). However, even in those areas water flow may have been affected.

Within the Ogallala, groundwater flows west to east on a slope ($\approx 2\text{--}3$ m/km), roughly paralleling the bedrock and land surface (Cronin, 1964, pp. 3, 42; Gutentag *et al.*, 1984; Heath, 1984, p. 36), with aquifer-fed surface water courses generally being ephemeral on their upper reaches and perennial where their channels are incised below the water table (Weeks and Gutentag, 1988, p. 160). That flow boundary would shift to the east during long periods of drought, when water in storage was depleted and the water table lowered.

Ground water salinity is highest on the southern portions of the High Plains (and, correspondingly, water potability is lowest), because of both higher evaporation precipitating dissolved solutes and salt leakage into ground and surface water systems from underlying Permian halite beds (Gustavson *et al.*, 1980, pp. 3–9; Gutentag *et al.*, 1984, Fig. 15). This pattern was likely magnified during long-term drought.

The disappearance of surface water and the overall decline in groundwater during this period bespeaks a sharp drop in effective precipitation (Gutentag *et al.*, 1984, p. 58). This drop would have, in turn, reduced primary productivity (there is a strong curvilinear relationship between mean annual precipitation and net annual primary productivity—the rate of increase in productivity falls off at higher precipitation levels (Pianka, 1978, p. 49; Rosenzweig and Abramsky, 1993)). That reduction would have been more pronounced in areas of lower mean annual precipitation, such as the more westerly and southerly areas of the Plains, and especially if it occurred in the growing season.²

Given seasonal patterns of modern precipitation and historic drought on the Great Plains (e.g., Mock, 1991; Tomanek and

² This occurs because a comparable reduction in the amount of precipitation (say, 5 cm/yr) represents a greater net loss in an area where precipitation averages 40 cm/yr than in an area where it averages 75 cm/yr—all other things being equal (Ellis *et al.*, 1995).

Hulett, 1970; Woodhouse and Overpeck, 1998), it has been hypothesized that the Altithermal was a spring–summer drought (Meltzer and Collins, 1987, p. 27). That hypothesis remains mostly untested (but see Holliday, 1989, p. 79; Meltzer and Collins, 1987, pp. 27–28). It is not, however, untestable. Nativ and Riggio (1990, p. 171) found that winter and summer precipitation on the Southern Great Plains have isotopically distinct signatures (the former and isotopically lighter moisture is derived from Pacific air masses, the latter from air masses coming off the Gulf of Mexico; see also Woodhouse and Overpeck (1998)). It might therefore be possible, using fossil evidence, to track changes in the dominant isotopic signal during this period, and thus detect long-term rainfall patterns and trends.

Regardless, it is evident from the meager pollen and phytolith records (Ferring, 1995, p. 23; Fredlund, 1995; Fredlund and Tieszen, 1997, p. 215) that there was a reduction in the density of the vegetation cover. There was a change in northern areas to a more xeric grassland, and on the Southern Great Plains to a “desert-plains grassland”; along the eastern edge of the Plains there was a replacement of tall and mixed grass by short-grass prairie (Albanese and Frison, 1995, pp. 4, 13; Barnosky *et al.*, 1987, p. 265; Ferring, 1995, p. 23; Frison, 1975, p. 295; Greiser, 1985, pp. 21–22; Johnson and Holliday, 1989, p. 155; Mandel, 1995, p. 59; Toomey *et al.*, 1993, p. 309; Valero-Garcés *et al.*, 1997). Isotope studies suggest the middle Holocene landscape was marked by a rise in warm season (C_4) grasses (Holliday, 1995, pp. 54–58; Nordt *et al.*, 1994, pp. 117–118; cf. Humphrey and Ferring 1994, p. 211).³

Such changes had an impact on the Plains fauna, which during this period underwent range shifts and population changes, and the extirpation and replacement of microvertebrates with higher moisture requirements by more drought tolerant species (though this varied by area, changes being less pronounced on the eastern edge of the Plains; Wendland *et al.* (1987, pp. 466–467), also Semken and Falk (1987, pp. 185–188)). Among the species that may have become locally rare or absent during this period were the birds that seasonally or annually inhabit the surface lakes and marshes of the Plains, and bison. Bison during this time also underwent accelerated species evolution from *Bison antiquus* to *Bison bison* (Frison, 1991, p. 272, Fig. 5.5; Johnson and Holliday, 1989, p. 158; McDonald, 1981, p. 250; Toomey *et al.*, 1993, p. 308). The drop in bison numbers, most pronounced further south (Ferring, 1995, Fig. 3; McDonald, 1981, p. 255), was likely a function of scarce surface water and forage. If the Altithermal was marked by summer drought, it would have especially impacted the warm season (C_4) grasses that dominate the short-grass plains—buffalo grass and blue grama grass

(Weaver and Albertson, 1956, pp. 79–80). This, and the fact that the grass crop that did survive would not have been as rich and nutritious, would have reduced bison health and numbers (Frison, 1975, p. 296; Meltzer and Collins, 1987).

A decline in bison populations, depending on its magnitude and extent, could have significantly impacted human foragers. While there is a bias in the archaeological record toward highly visible bison kill sites (Frison, 1975), it is nonetheless apparent that bison were a highly ranked resource for Plains Paleoindians prior to the middle Holocene (Bamforth, 1988; Frison, 1991; Hofman, 1996). Were their numbers reduced, bison would likely still be a preferred prey. However, with a decline in return rates, human foragers had to either expand their diet to include lower-ranked resources (smaller animals and plants) or abandon particular regions for areas where bison might still be present (assuming there were not already resident human populations in those new areas). Complicating those options would be the decline in surface water which, depending on its severity, could require human foragers to tether their movements to known or predictable water sources (as discussed below and in Meltzer (1995, pp. 353–354)).

The reduction in available moisture and surface cover allowed winds to scour the surface, and the resulting mobilization of sediment and extensive aeolian activity likely included the formation and activation of large-scale dune fields and sand sheets (Muhs and Maat, 1993; Muhs and Holliday, 1995). However, few aeolian features survive from this period, an apparent result of their being reworked and then stabilized in late Holocene times (e.g., Muhs *et al.*, 1997; Olson *et al.*, 1997). Lunettes (clay dunes) associated with playa basins or draws and dating to this period have been recorded on the Southern Plains (Holliday, 1997). (For general summaries of aeolian features and their ages, see Albanese and Frison (1995, pp. 10–14), Artz (1995, pp. 75–77), Ferring (1995, pp. 31–32), Holliday (1989, p. 78; 1995, pp. 89–90), Madole (1995, pp. 169–170), and Muhs *et al.* (1997)). Unusually heavy and irregular wear in Southern High Plains bison teeth dating to this period testify as well to excess blowing dust and grit on the vegetation (Johnson and Holliday, 1986, p. 43).

Overall, the middle Holocene Plains was marked by a general north to south gradient of decreasing effective moisture, surface water, and resource abundance (particularly, bison abundance); along that same gradient there was increasing resource patchiness, sediment weathering, erosion, and aeolian activity. It is less certain how those changes may have been expressed through time. Although there are hints of temporal variability in climates during this time (Benedict and Olsen, 1978; Ferring, 1995; Holliday, 1989, 1995), resolution of the archaeological and paleoenvironmental records is still too coarse to identify precise patterns. The decline in a highly ranked prey resource (bison) and the reduction in surface water were perhaps the most significant changes to which middle Holocene human foragers had to adapt, at least in some areas. On the Southern High Plains, for example, the middle Holo-

³ Humphrey and Ferring (1994) observe that on the eastern margin of the Southern Plains there is evidence for middle Holocene drying, but not necessarily warming. Ferring notes (personal communication, 1996), that the common mid-grasses such as little bluestem are C_4 species, which makes it difficult to see if mid/tall grasses were replaced by short warm-season grasses.

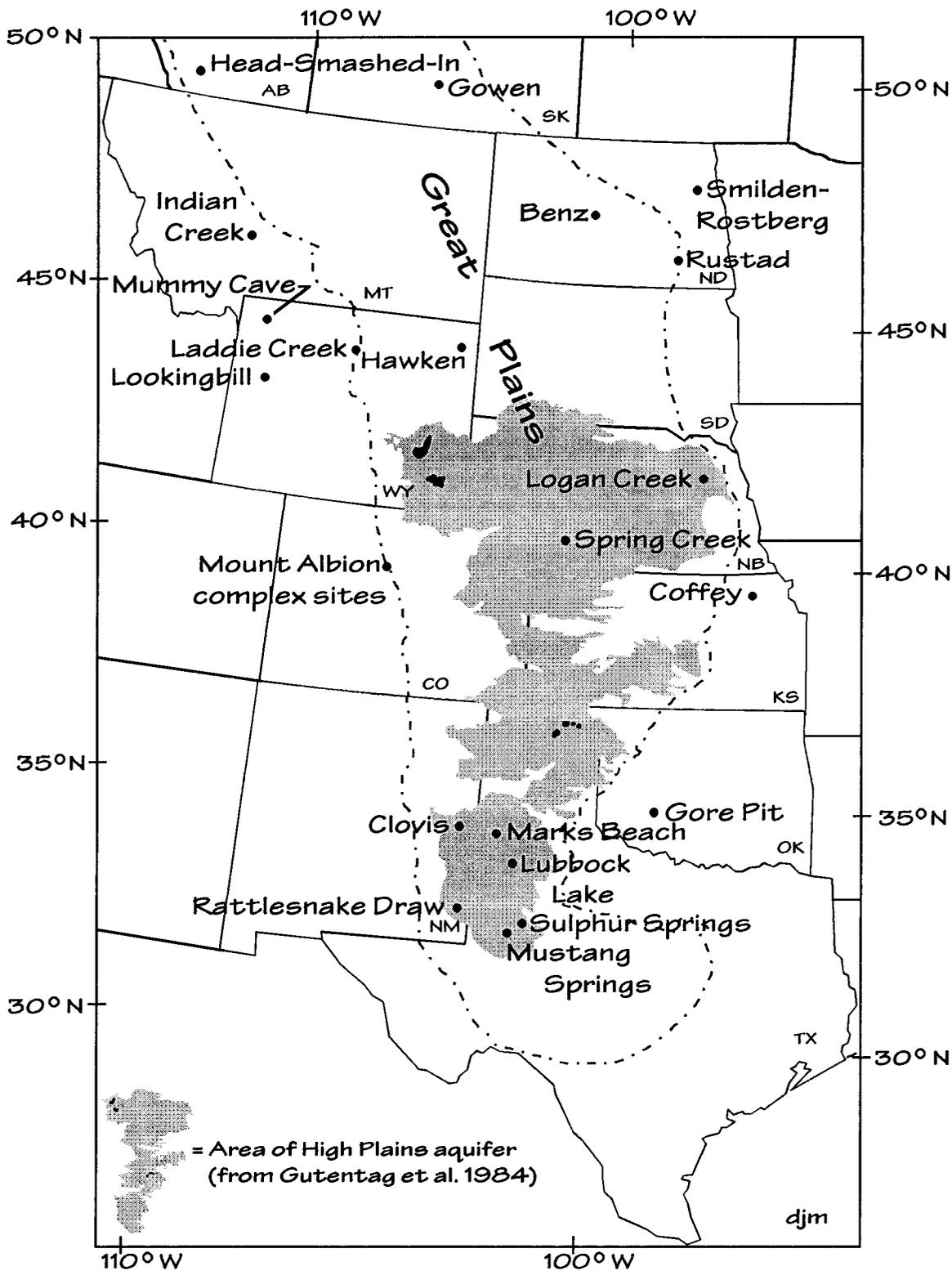


FIGURE 1

cene could be described by the oft-used term “climatic optimum” only if you did not have to live there.

GEOMORPHIC CONTROLS ON MIDDLE HOLOCENE AGE SITES

Clearly, however, hunter-gatherers were inhabiting the Plains during this period. Nonetheless, it is still the case that there are relatively few middle Holocene archaeological sites across this region (Albanese and Frison, 1995, p. 15; Artz, 1995, p. 67; Collins, 1995, pp. 379–380; Frison *et al.*, 1996, p. 19). The scarcity of evidence, however, may simply reflect the degree of erosion and deposition during this period, which acted to remove, rework, or deeply bury the archaeological features and surfaces of interest, particularly in valleys (including draws) where sites were often located.

As Mandel (1992, 1995) and others have shown, during this period reduced vegetation cover and infrequent but intense rainfall in the Central and Northern Great Plains triggered extensive erosion and sediment transport out of small tributary upland valleys (see also Artz (1995) and Ferring (1995, p. 24)). This sediment accumulated on the floodplains of trunk streams and particularly in alluvial fans at the mouths of the eroded tributary stream valleys. Thus, deposits in upper tributary valleys that might have contained Altithermal traces are missing, while Altithermal-age surfaces in larger and deeper valleys—which might have been frequented by human foragers owing to the presence of still-flowing water—are now deeply buried by subsequent middle and late Holocene deposits (Albanese and Frison, 1995, p. 15; Arbogast and Johnson, 1994, pp. 301–302; Artz, 1995, p. 81; Collins, 1995, pp. 368–369; Ellis *et al.*, 1995, p. 418; Mandel, 1995, pp. 59, 80). Redeposited Altithermal-age archaeological material might occur in alluvial fans in larger valleys, but obviously would not be in a primary context, and may not be recognizable as dating from this period (in the absence of diagnostic artifacts).

While the draws and drainages of the Southern High Plains are more poorly developed, they too show evidence that erosion and deposition have removed or buried (mostly beneath later Holocene aeolian sediments) the Altithermal archaeological record (Holliday, 1995, p. 90; Meltzer, 1991, p. 245). At Clovis, Lubbock Lake, and Mustang Springs, on the Southern High Plains, middle Holocene surfaces are, on average, 2–3 m below the present surface (Johnson and Holliday, 1986; Meltzer, 1991); Spring Creek was upwards of 3–4 m below surface (Grange, 1980, p. 21). Sediment deposition is even more pronounced just off the margins of the High Plains: at the Gore Pit site, in Oklahoma’s Osage Plains, the middle Holocene occupation level was buried beneath 6 m of overburden (Hammatt, 1976, p. 272).

Unfortunately, most large-scale archaeological surveys on the Great Plains have focused on the modern surface, with the consequence that mostly recent sites have been found and “substantial numbers” of earlier, buried sites may have escaped

detection (Artz, 1996). If there is a more extensive middle Holocene record than is now apparent, it will remain mostly inaccessible or undiscovered, save in those cases where erosion or heavy equipment expose those deeply buried surfaces, or following more systematic searches for Altithermal age surfaces, remains, and sites (Frison, 1975, p. 292; Meltzer, 1991).

MIDDLE HOLOCENE ARCHAEOLOGY ON THE PLAINS

The archaeological record for this period varies across the Plains, though there are some general patterns and trends that emerge. This section reviews that record, starting on the Southern High Plains, then moving north (sites discussed in the text are shown in Fig. 1). More detailed, region-specific reviews of the archaeological evidence are available in Frison *et al.* (1996), Gregg *et al.* (1996), Hofman (1996), and Meltzer (1995).

In keeping with the regional evidence of a substantial decline in available surface water, on the Southern High Plains at least four sites have produced Altithermal-age hand-dug water wells (efforts to confirm a report of wells at a fifth locality—Marks Beach, Texas—were unsuccessful; LaBelle and Meltzer (1996)). The frequency of these features varies: a single one (undated) was reported from Rattlesnake Draw, New Mexico (Smith *et al.*, 1966); two wells were found at the Sulphur Springs locality, Texas (Quigg *et al.*, 1994, pp. 141–142); nineteen were recorded over several decades at the Clovis site, New Mexico (Evans, 1951; Green, 1962; Hester, 1972, summarized in Meltzer, 1995); and, finally, over sixty wells were found at Mustang Springs in west Texas (Meltzer, 1991). These features ranged in age from 6800–6600 B.P. (Mustang Springs) to post-6500 B.P. (Clovis).

At both Clovis and Mustang Springs, the wells were dug from the wind-deflated floors of dry lake beds. Measuring their depth—the deepest were 3 m below the pre-Altithermal lake levels—provides a precise gauge of the drop in the local water table (Meltzer, 1991, p. 254). That the wells varied in depth indicates fluctuations in the local water table over the course of the well-digging episode (which at Mustang Springs lasted at least ~200 yr).

There is evidence at Clovis and Mustang Springs of repeated occupations, as might be expected of foragers who relied on such sources but could not stay near them permanently. Doing so would foul the water sources, and in this low-productivity setting would inevitably lead to a decline of the food resources in the local foraging radius—generally, an area of ~10–15 km out from the residential camp (Kelly, 1995; Silberbauer, 1981, p. 267). Groups may have over-stayed somewhat, depending on the season, the patchiness or abundance of the resources, and the prospects of finding water elsewhere. Still, high settlement mobility (more moves, farther distances), was characteristic of this period in this part of the Plains, indicated by the reliance in these assemblages on stone from several distant, nonlocal sources (Hester, 1972, p. 145; Johnson and Holliday,

1986, pp. 29–37; Meltzer, 1991, p. 257). This is in contrast to the pattern evident on the Northern Plains, and in foothill/mountain “refugia” areas (noted below).

The scarcity of surface water shown by the wells indicates a potentially dangerous situation for human groups, who must drink often to maintain hydration. Travel across waterless landscapes could have been risky, as attainable distances fall when temperature rises and the water available for transport decreases (Larson, 1977, p. 184; Schmidt-Neilsen, 1964). This raises the possibility that groups may have avoided the area altogether during the hottest and/or driest times of the year (or during longer dry periods), but in the absence of seasonal indicators or more precise paleoclimatic evidence or chronological control, that possibility cannot be tested.

None of the well-bearing sites have yielded direct evidence of subsistence remains, but at the Lubbock Lake site in Texas (where surface water, at times brackish, appears to have been present throughout this period), the Altithermal age features yielded a variety of faunal remains (mainly bison and pronghorn antelope) and a heavily worn sandstone metate, found with a caliche-capped, ash-filled pit identified as a baking oven and “vegetal processing area” (Johnson and Holliday, 1986, p. 41). No identifiable organic remains were recovered from this feature, dated to 4800 B.P. In later periods stone ovens were used for bulk processing and cooking of starchy and xerophytic plants such as lechuguilla, sotol, prickly pear, mesquite, sunflower, and several forbs and grasses—plants used ethnohistorically by the Apache during drought (Basehart, 1960, p. 38; Newcomb, 1961, pp. 41, 115–116; for a thorough review, see Wandsnider, 1997).

The relatively few bison remains at the Lubbock Lake site dating to this interval, but still during a time of aridity, hint at more thorough use of meat resources, the apparent result of bison being rare and of poorer quality (Johnson and Holliday, 1986). A mixed desert-plant and meat related diet has been inferred (albeit in the absence of direct evidence) to characterize other Southern Plains sites (Johnson and Holliday, 1986; also Meltzer, 1995; Greiser, 1985, pp. 39–40; Hofman, 1996, p. 83). East and off the Southern High Plains, Johnson and Goode (1994, p. 26) correlate the development of burned rock middens on the Edwards Plateau with middle Holocene drying that led to the eastward expansion of xerophytic succulents (e.g., sotol) and their exploitation by groups who baked them in rock ovens (Collins, 1995, pp. 385, 388; Ellis *et al.*, 1995, pp. 413–414; Johnson and Holliday, 1986).

A broader diet breadth is characteristic of the very few middle Holocene sites known from the Central Plains, as the evidence from Logan Creek and Spring Creek (Nebraska) indicate. These sites, both located alongside water courses, contain bison remains, but also a variety of other fauna, from deer and antelope to small mammals, migratory birds, and even fish (Grange, 1980, p. 44; Hofman, 1996, p. 84; Wedel, 1986, pp. 73–75). A similar pattern is seen in contemporary localities off the eastern edge of the Plains, such as the Coffey (Kansas)

and Gore Pit (Oklahoma) localities (Hammatt, 1976; Schmitts, 1978). The Coffey site is particularly instructive. Located on the margins of an aggrading oxbow lake, the site yielded from a series of thin, artifact-rich layers dating to ~5200 B.P. the charred remains of half a dozen plant species which frequent drying pond margins and creek banks, and a wide range of fauna, including bison, deer, small mammals, birds (migratory waterfowl)—and fish (mostly catfish), constituting the largest class of identifiable remains (Schmitts, 1978, pp. 134–144). Obviously, by this time and in this area immediately east of the Plains, surface water was present (though Schmitts (1978, pp. 104–106) nonetheless believes there were substantial changes in the nearby uplands as a consequence of Altithermal drying). Stone ovens and/or grinding stones occur at virtually all of the previously noted sites, and are widely assumed to mark an increased use of or reliance on seed and plant processing (Hammatt, 1976, p. 255; Johnson and Holliday, 1986; Meltzer, 1991; Schmitts, 1978).⁴

Moving northward, it is yet unclear how (or whether) human adaptive strategies on the Central or the Northern Plains were influenced by the scarcity of water. Evidence of well digging in these regions has not been found. If that pattern holds, it might suggest that water—even if relatively scarce (as at one-time freshwater lakes)—was at least above ground where it did occur; as, for example, along rivers with headwaters in the Rocky Mountains.

Sheehan hypothesizes there was a broad reshuffling of Altithermal settlements around “refugia”—places on the Plains where water was present (Sheehan, 1994, p. 120). He tests this proposition by examining the distribution of early Archaic (middle Holocene) sites in sixty 160 km² quadrats across the Plains. A quadrat is identified as a refugia if an aquifer-replenished stream is currently present within it. Sheehan assumes minimal stream flow would have been maintained in these quadrats even during periods of aridity, because of the “relative immunity of aquifer supplied waterways to drought” (Sheehan, 1994, p. 118). Of course, reduced precipitation and stream flow, and/or higher evapotranspiration demand, over just a few consecutive years reduces recharge, which can lower the ground water table (Rogers and Armbruster, 1990, p. 126–127), though there may initially be a lag between surface drought and groundwater depletion, depending on the volume of water in storage (larger volumes can buffer brief drying episodes). Long-term low annual recharge results in depletion of groundwater in storage (Gutentag *et al.*, 1984, p. 28), and given the slope of the High Plains aquifer this would shift the flow boundary to the east. In effect, not all quadrats with surface water present today can be assumed to have had water during periods of drought.

Sheehan’s study nonetheless found a statistically significant

⁴ However, at the Spring Creek site, the grinding stones (both manos and metate) had small amounts of ground red pigment adhering to the use surfaces (Grange, 1980, p. 38), presumably hematite or red ochre.

association between early Archaic sites and quadrats with aquifer-replenished perennial streams. But then that pattern also holds true for later Holocene, middle Archaic sites, as well. It was only in the case of early Holocene, Paleoindian sites that localities were distributed independent of quadrats with aquifer-replenished perennial streams (Sheehan, 1994, p. 129). That early and middle Archaic sites are so patterned suggests that water is important to foragers on the Plains, even in nondrought times (in effect, the pattern is so general as not to be attributable unequivocally to Altithermal drought). That Paleoindian sites have a different distribution is interesting, and suggests that surface water may have been more widely available then than in later periods. However, these results, coupled with analytical vagaries of the study (half the samples of early Archaic sites come from regions off the Plains, including several sites in the Rocky Mountains at elevations upwards of 3500 m asl), make it difficult to support the conclusion that human settlement patterns on the Plains during the middle Holocene were a drought response.

Potentially more significant, in any case, than a reshuffling of the human population on the Plains-proper is the possibility that areas of the Central and Northern Plains were abandoned in favor of better-watered and ecologically richer refugia in the foothills and Front Range of the Rocky Mountains. Even granting the effects of geomorphic processes, there remain very few sites of middle Holocene age on the Central and Northern Plains (Frison *et al.*, 1996, p. 19). There is an increase after 6000 B.P. in the number of archaeological sites in the Colorado and Wyoming Front Range (Larson, 1992)—including a dozen in Benedict's "Mount Albion Complex"—at elevations between ~2000 and ~3700 m asl (Benedict and Olson, 1978, p. 179; Frison, 1975). That increase, if significant (see Bender and Wright, 1988), might only reflect better archaeological visibility in these areas. But it is attributed by Benedict to an in-migration of groups fleeing drought on the Plains, an inference based on an apparently "rudimentary" transhumance system that he believes is indicative of new arrivals in the region (Benedict, 1992, p. 12).

The subsistence remains at these foothill-mountain sites indicate regular use of large mammals other than bison. Among the faunal remains at Indian Creek (Montana), and Laddie Creek, Lookingbill, and Mummy Cave (Wyoming), are bighorn sheep, elk, and mule deer, with a variety of smaller mammals and birds, such as marmot, rabbit, and grouse (the latter from False Cougar Cave, Montana) (Bonnichsen *et al.*, 1986; Davis, 1984; Frison *et al.*, 1996, p. 19; Larson *et al.*, 1995, Table 17; see also Larson 1997, p. 360). While the appearance of other large mammals (elk, mule deer, mountain sheep) is seen as part of an overall expansion of diet breadth, and linked to Altithermal climate changes, it should be noted that groups in these areas were already exploiting those same large mammal species in earlier, Paleoindian times (Davis and Greiser, 1992, pp. 265–266; Frison *et al.*, 1996, p. 153; Hof-

man, 1996, p. 82) and did so in later times, as well (see Benedict, 1999).

Also among the subsistence remains in some of the foothill-mountain sites are plants, which may be especially important in these settings, not as low-ranked but critical drought-foods, but because they can be efficiently stored through the winter (Larson, 1997, pp. 360, 362–364). Several dozen such localities contain pithouses, along with associated storage pits and features with charred and uncharred seeds, and grinding stones (for seed processing) (Larson, 1997, pp. 360–361; also Benedict and Olson, 1978, p. 116; Frison, 1998, pp. 149–150; Frison *et al.*, 1996, pp. 154–155). The season of occupation of these pithouses is not known (Larson, 1997, p. 362), and they may have been places where groups over-wintered to avoid the strong winds and cold temperatures of the less protected lower-elevation Plains and basins, or they may have been locations for summer hunting camps (Bender and Wright, 1988; Benedict, 1992; Frison *et al.*, 1996, p. 19).

These pithouse sites generally postdate 6000 B.P. (Larson, 1997, p. 358) and testify to reduced settlement mobility for at least part of the year. Correspondingly, the stone used in the manufacture of the tools in these sites was predominantly acquired from local outcrops or sources (and occasionally recycled from artifacts left at a site from earlier times), though occasionally an assemblage might include material brought in from more distant sources (Benedict and Olson, 1978, pp. 74, 183; Benedict, 1992, p. 12; Frison *et al.*, 1976; Gregg *et al.*, 1996, p. 82; Larson, 1992, p. 116; Reeves, 1990, p. 179).

Returning to the Plains proper, sites on the Northern and northwestern Plains are no more frequent during this period than in other areas of the Plains, and as in other areas to the south, there is reason to suspect that here too archaeological and geological biases have created a "false picture" of their abundance and distribution (Walker, 1992, pp. 126–127). The few sites known tend to be located on water courses that were flowing at the time of the occupation: one of the Gowen localities (Saskatchewan) yielded remains of muskrat among the fauna.

Bison were present in this area as well and were an important food source at Gowen and Head-Smashed-In (Alberta), as well as at sites just off the margins of the northeastern Plains (including the Rustad and Smilden-Rostberg localities, in North Dakota) and at high elevation "islands" within the Plains, such as the Black Hills (as at the Hawken site in eastern Wyoming) (Frison *et al.*, 1976; Reeves, 1978; Running, 1995; Walker, 1992, pp. 130, 143). These sites range in age from ~7200 B.P. (Rustad) to 5700 B.P. (Head-Smashed-In) and indicate that bison occurred in sufficient numbers to allow repeated hunting—occasionally larger-scale communal hunting reminiscent of Paleoindian kills. Communal hunts were perhaps possible as these areas of higher latitude and elevation were not so severely impacted, and served as bison refugia (Frison, 1998, p. 161; Frison *et al.*, 1996, pp. 153–154; Reeves, 1990; Walker, 1992, p. 128). That there are not more bison

kills in these areas and settings is attributed to the masking effects of geomorphic processes (Frison *et al.*, 1996, p. 154).

Overall, middle Holocene climate changes probably were not as significant on the Northern Plains as they were further south (Bender and Wright, 1988; Root and Ahler, 1987; Walker, 1992). At the Benz site (North Dakota), for example, despite “several meters” of wind-blown sediment burying an early Holocene paleosol, Root and Ahler report there was neither an occupational hiatus nor any significant variation in the stone tool technology, assemblages, or site activities, beyond what one might expect in “a continuum of change” from Paleoindian times. A possible expression of the Altithermal was a decline in the intensity of site use, though whether that was a function of harsher climates is uncertain (Root and Ahler, 1987, pp. 95–96, 102–103).

MIDDLE HOLOCENE ADAPTIVE STRATEGIES: PATTERNS AND TRENDS

Several key points emerge from a review of the Plains middle Holocene archaeological record: (1) for whatever reason (and there may be several), there are few sites from this period throughout the Plains; (2) those sites that do occur are widely scattered in space and time, and hence there are few localities or areas that provide fine-grained evidence of adaptive change through time; (3) the adaptive strategies evident in these sites vary across the Plains; and (4) the apparent effects of the Altithermal are most evident on the Southern Plains.

Based on this evidence, a number of trends in human subsistence, technology, settlement, and demographics have been perceived and have been attributed to forager responses to Altithermal climates. These include an expansion of the diet breadth to incorporate a variety of animals and (especially) plants in the diet, the advent of new technologies to cope with diminished food and water resources, large-scale settlement shifts, from the Plains to the western foothills and mountains or to local refugia (springs and watercourses) on the Plains, which in turn implies abandonment of parts of the Plains and (in some settings) reduced settlement mobility (marked by increasing reliance on local stone sources and construction of residential pithouses), and, finally, an overall decline in human population density (e.g., Frison *et al.*, 1996, pp. 18–19; Frison *et al.*, 1996, pp. 153–154; Gregg *et al.*, 1996; Hofman, 1996, pp. 82–83; Larson, 1997; Meltzer, 1995; Reeves, 1990, pp. 177–179; Sheehan, 1994; Walker, 1992, pp. 128–129; Wedel, 1986, pp. 79–80).

There are two issues that must be addressed in evaluating these trends: how well-founded is the evidence on which they are based (particularly a concern regarding regional abandonment and population decline)? And, are these trends attributable to forager responses to drought? After all, reduced settlement mobility and an expansion of diet breadth occurred in other parts of North America—such as the eastern woodlands—at a time for which there was no evidence of

significant drought. Would such changes have occurred on the Plains, whether or not the Altithermal ever happened? The latter question cannot be easily answered. However, it is possible to assess the empirical support for these trends, and whether they can be linked to Altithermal drought conditions.

Expansion of Diet Breadth

The range of the fauna, and especially the evidence for plant use at sites across the Plains in middle Holocene sites, are of particular interest as they apparently mark a shift away from bison hunting as the dominant subsistence activity and an increase in diet breadth. Leaving aside for the moment the issue of whether such changes were a response to drought, it is appropriate to state two caveats. First, this trend is based on a series of sites scattered widely over time and space. These sites and assemblages are “time-averaged” (Grayson and Delpech, 1998, p. 1121) accumulations of subsistence remains that represent episodes ranging from short-term events to (more commonly) long-term palimpsests of occupations. They can also represent very different aspects of an adaptive strategy played out seasonally or annually across space. What appears to be a long-term expansion of the diet, therefore, may actually be a cumulative sample of subsistence activities that were only rarely part of the diet at any one time, thus inflating the apparent dietary diversity.

Second, some of these other resources may have been present in the diet of Plains foragers all along—even in Paleoindian times—but were simply less visible archaeologically than the large, communal bison kills (the massive bones of bison in bonebeds containing tens to hundreds of animals may have, all other things being equal, a better chance of being preserved in sites than the more fragile bones of small mammals). Again, what appears as a long-term expansion of the diet may instead result from a change in bison hunting tactics (a consequence of the decline in bison populations under evolutionary stress) that enabled other aspects of the foraging and subsistence systems to come into archaeological focus.

The question of diet breadth expansion therefore becomes one of archaeological resolution. To determine the degree to which middle Holocene subsistence strategies expanded as a consequence of an Altithermal-induced reduction in bison populations (or an overall reduction in ecosystem productivity), we would need precise data on bison abundance and distribution across space and through time, in order to examine and measure, among other things, effects of local climate change on their numbers and the energetic return rates for this resource, as well as for other potential prey resources. This would need to be done over many sites across the Plains, all of which should have fine-grained chronological control. All that will ultimately require a much finer-grained record than now exists.

For the moment, attributing dietary expansion to Altithermal conditions remains a plausible, though untested hypothesis. It is relevant to add that with the amelioration of Holocene climates on

the Plains after 5000 B.P., the subsequent rebound of bison populations (McDonald, 1981, p. 256), and the attendant increase in communal bison kills (Frison, 1975, p. 296), there is not an immediate return to the specialized bison hunting of earlier, Paleoindian times (Frison *et al.*, 1996; Hofman, 1996; Reeves, 1990). Instead, post-Altithermal groups continue to exploit plant resources, and in some areas of the Plains the apparent intensity of that exploitation is even greater than that seen in middle Holocene times, with sites showing greater numbers of slab milling stones and manos, bedrock mortars, and food preparation and roasting pits (Frison, 1975, p. 297). In effect, the return of bison did not cause the disappearance of the lower-ranked resources, as might be expected were the incorporation of those lower-ranked resources solely a response to the loss of the higher-ranked resource. At least by post-Altithermal times, plant foods had become an integral part of the diet of Plains foragers, perhaps reflecting the fact that larger human populations at the time required a greater range and amount of food in the diet (by then, presumably, processing costs had gone down from earlier times).

New Technologies for Coping with Diminished Resources

The most distinctive and novel technology evident in these sites is the water wells on the Southern Plains. While there have been reports of wells in two Paleoindian localities in the same region, these have not yet been confirmed. Regardless, the scale and intensity of well-digging is considerably greater in these middle Holocene sites. Wells made it possible to follow falling water tables and reach underground water several meters below the surface.⁵

Plant and seed processing and storage artifacts and features—manos, metates, earth ovens, storage pits—the tools demanded by the labor-intensive processing needed to prepare plant foods for consumption, increase in number and diversity during the middle Holocene (Greiser, 1985, pp. 114–115). This does not imply that these groups were the first on the Plains to exploit plants; earlier Paleoindians may have as well (e.g., Bamforth, 1985), but being highly mobile and not returning regularly to specific localities, their technology had to be relatively portable. The appearance of large and largely non-portable stone tools and features (so-called “site furniture”) need not signal the advent of plant processing as much as the appearance of plant processing among groups with more limited mobility on the landscape who are using localities in a redundant manner.⁶

⁵ Well-digging will recur later on the Southern Plains, but not at a comparable scale nor because of aridity, but as a tactical response by Comanche and other native tribes to U.S. Army military actions against them (Meltzer and Collins, 1987).

⁶ Changes in mobility will later—at least on the northwestern Plains after 4500 B.P.—prompt yet another change in technology: storage facilities will decline in number and stone ovens will change in character, as groups shift to more portable storage practices, notably the use of basketry and the production of pemmican, which enabled easier transport of bison meat (Larson, 1997, pp. 364–365; see also Frison, 1998, p. 152; Reeves, 1990, p. 169).

Settlement Shifts and Regional Abandonment

Virtually all of the known middle Holocene sites on the Plains occur alongside perennial streams or rivers, or at one-time spring or seep sites. Where such freshwater sources were especially scarce—as on the Southern High Plains—the sites were used repeatedly. These occurrences may well reflect a larger pattern of settlement, in which group movements were tied to water sources, as Sheehan (1994) suggests. Unfortunately, and in the absence of a more representative record, the data to support such a conclusion are unavailable. If there was a concentration around water sources, then the places most likely to have attracted human foragers—higher-order, low-lying drainages where permanent water would occur during drought—are also the places where sediment deposition was often substantial, making sites in these settings less likely to be encountered archaeologically (Mandel, 1992; Wedel, 1986, p. 80).

On the western edge of the Plains, one aspect of Altithermal mobility may have been upward movement, as groups exploited better-watered higher elevations in the Front Range and Black Hills (Alex, 1991; Black, 1991; Greiser, 1985, p. 113). Admittedly, however, linking that archaeological spike to specific Plains groups has proven difficult (see the discussion in Black, 1991, pp. 18–19). While there is a correlation between a decline in sites on the Plains and an increase in sites in the foothills/mountains (Benedict and Olsen, 1978), there are few high-altitude assemblages with artifacts or raw materials diagnostic of the Plains.

The correlation itself is not altogether secure. Measured either in absolute or relative terms, there is a scarcity of middle Holocene sites on the Plains. Yet, not only is the archaeological record meager, it may not be representative either, as geomorphic processes have “*non-randomly* altered, buried, and destroyed sites” of this age (Collins, 1995, p. 367, emphasis in original). That said, there remains a strong suspicion that while there was not complete abandonment of the Plains during this period, there was local, episodic abandonment of certain regions, such as parts of the Southern High Plains, which experienced demonstrably intense drought (Meltzer, 1995; Walker, 1992, p. 128).

A Reduction in Settlement Mobility

Settlement mobility varied during this period, but with the exception of the sites on the Southern High Plains, most middle Holocene stone tool assemblages are composed largely of stone procured locally (Gregg *et al.*, 1996, p. 82; Reeves, 1990, p. 179). This is in contrast to earlier, Paleoindian times, when assemblages often contained high-quality stone from sources that outcropped several hundred kilometers distant. That reliance on local stone is commonly taken as an indicator of reduced settlement mobility, an interpretation that seems reasonable on its face, and one that would have necessitated broader diet breadth.

What might have caused that reduction in mobility is less clear. Reeves attributes it to two factors: (1) reduced ecosystem productivity, which required groups to spend more time procuring food, with less time to devote to traveling long distances to trade or acquire stone; and (2) a scarcity of surface water that would have further hampered travel (Reeves, 1990, p. 179). Alternatively, Gregg *et al.* (1996, p. 82) argue that the decline in human populations during this period disrupted alliance and exchange relations, precluding long-distance movement. The matter cannot be readily resolved, given the difficulty of measuring the presumed causal variables, but it is perhaps appropriate to observe that a decline in human populations can have just the opposite effect on mobility: it can increase long-distance movement, as groups aggregate annually or at other intervals to exchange information, mates, and so on (Kelly, 1995). Furthermore, depending on the structure of the resources, a reduction in productivity can also have the effect of increasing mobility, as groups seek to maintain access to more widely dispersed patches.

Unless, of course, there are other groups already in other areas. If, as ecological indicators suggest, the middle Holocene landscape had become more heterogeneous and patchy, it may have been economically advantageous for groups to become territorial where resources were dense or defensible (Dyson-Hudson and Smith, 1978). Populations may not have thinned on the landscape so much as redistributed themselves in clusters around key areas and resources, and stayed in those areas longer—effectively precluding access by other groups.

A Decline in Human Populations

It is inferred that middle Holocene populations declined in number, but that inference is based entirely on a drop in the number of sites and radiocarbon dates during this period (Benedict and Olson, 1978, p. 142; Frison *et al.*, 1996, p. 153; Gregg *et al.*, 1996, p. 82; Nance, 1972, p. 172; Walker, 1992, pp. 128–129). Thus, that inference must be tempered by: (1) the clear evidence that geomorphic processes have insured we have only glimpsed a small (and possibly unrepresentative) fraction of the middle Holocene record; and (2) the recognition that long-term changes in settlement patterning (such as the size of a group's annual and extended range, degree of aggregation, and frequency of use and reuse of particular localities) may make a reshuffling of a group on the landscape (and attendant local abandonment) appear as a population decline (Binford, 1983). For now, evidence of Altithermal human population decline is unproven.

CONCLUSIONS

In summary, while it has been a working assumption that the middle Holocene was a time of severe drought and decline in ecological productivity across the Plains, this assumption is not fully supported in the paleoenvironmental record. Rather, there is

evidence that climatic, ecological, and hydrological conditions varied across the Plains—and possibly throughout this period (though, again, evidence for temporal variability is unavailable).

Drought conditions—the Altithermal, as classically envisioned—were most pronounced on the Southern High Plains. Correspondingly, that area provides the most direct and secure evidence of forager responses to drought. There seems little doubt that hand-dug wells on the floors of drainages (within which were one-time spring-fed lakes and ponds), were prompted by a region-wide decline in the water table, which in turn was produced by a long-term rainfall deficit, high temperatures, or both. Under such climatic conditions, bison numbers were also reduced, and though they clearly remained a highly ranked resource for human foragers, their scarcity required an expansion of the diet to include other, lower ranked animal and plant resources. And given the distances these groups were tracking (as measured by their reliance on stone sources off the Plains), it seems reasonable to infer as well that these foragers were not permanent inhabitants of the area—in effect, there was local abandonment and a decline in the human population during this period.

On the Central and Northern Plains, middle Holocene conditions were not as severe, and though they apparently triggered adaptive responses among foragers, notably to the decline in bison populations on which these groups had historically relied, there is considerable variability in subsistence and settlement strategies during this period. In some areas, notably the northernmost Plains, the impact of middle Holocene climate change seems relatively inconsequential.

It is tempting, therefore, to suggest as a working hypothesis—with the explicit caveat that data are limited—that middle Holocene adaptive responses may ultimately sort roughly along latitudinal (and altitudinal) lines. Undoubtedly, as additional data become available the picture of middle Holocene adaptations will become more, rather than less, complex, both across space and through time.

ACKNOWLEDGMENTS

Earlier versions of this paper were presented at the 1996 Biennial Meeting of the American Quaternary Association (Flagstaff, Arizona) and the 1998 Annual Meeting, Geological Society of America (Toronto, Canada). For the invitations to participate in those meetings, I thank Russell Graham and Stephen Wolfe (respectively), and I also thank colleagues at those meetings who were kind enough to offer their advice and thoughts on these matters, especially Reid Ferring, Rolfe Mandel, Dan Muhs, and Vance Holliday. My field research on middle Holocene archaeology and paleoecology has been supported by grants from the National Geographic Society, the National Science Foundation (SBR-9423198), and the Potts and Sibley Foundation (Midland, Texas). For valuable comments on a draft of this manuscript, I am grateful to Donald K. Grayson, Vance Holliday, Mary Lou Larson, and an anonymous reviewer.

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