Chapter 13

The Clovis Landscape

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ABSTRACT
Clovis is the most geographically extensive occupation of any time in the archaeological record of the Americas. One aspect of this geographic diversity is the remarkable mobility and adaptability of Clovis people. Understanding adaptability requires, in part, understanding the environmental conditions at the time and the rate and direction of environmental change. Another aspect of adaptability, and one more germane to archaeological research, is that of land use. Where were Clovis people on the landscape, and can we tell how they used the local environment? This chapter addresses issues of climate and landscape conditions that Clovis populations had to contend with. The Clovis landscape, both in terms of geomorphology and vegetation, was undergoing significant changes before, during, and after the Clovis occupation. Continental ice sheets were retreating, and sea level, though 40 to 50 m lower than today, was rising, rapidly inundating the Gulf and Atlantic coastal plains. Stream systems were undergoing changes in discharge, sedimentology, and flow regime whether or not they had glaciated headwaters. Discharges generally were declining, but remained higher or variable compared with today. Paleo-lakes were changing dramatically, but also must have provided a wide array of resources to the early foragers. Proglacial lakes evolved as a function of changes in ice-margin position and drainage direction, and as a result of isostatic rebound. In the Great Basin and Southwest, some paleo-lakes and pluvial lakes were low or completely dry in the late LGM and then came up just before or during the YDC, while others were high before the YDC and then declined just before or during the YDC. Nonetheless many basins had either standing water or wetlands, and, therefore, an array of resources for humans.

KEYWORDS: Clovis, Landscape, Geomorphology, Younger Dryas

Introduction

Clovis is the oldest archaeologically visible, well-defined, and relatively homogeneous technocomplex in North America. It is also the most geographically extensive occupation of any time in the archaeological record of the Americas. A significant implication of this geographic diversity of the Clovis occupation is the remarkable mobility and adaptability of those people. This characteristic of Clovis has long been recognized and discussed (e.g., Ellis 2011; Haynes 1964; Haynes 2002; Meltzer 1985, 1988, 2003, 2004, 2009; Kelly and Todd 1988). Addressing the question of adaptability requires, in part, understanding the environmental conditions at the time and the rate and direction of environmental change. Another aspect of adaptability, and one more germane to archaeological research, is that of land use. Where were Clovis people they on the landscape and can we tell how they used the local environment?

This paper is an attempt to address issues of climate and landscape conditions that Clovis populations had to contend with. The topic of Clovis environments is a broad and complex issue. Most discussions deal with site-by-site or perhaps somewhat broader interpretations of stratigraphy, landscape evolution, and vegetation and faunal changes, or with broad climate trends (wetter vs drier; colder vs warmer). The char-

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acter of the fauna, in particular the megamammals and the late-Pleistocene extinctions, are the topic of a very large literature. We are taking a different approach and describe the Clovis environment across the continent from a largely geomorphic perspective along with a paleo-climate summary. This approach helps to develop a "snapshot" or "slice" of the landscape literally under the feet of Clovis foragers. It is also an approach that helps to understand the distribution of Clovis sites, including their preservation and visibility, and the character of local resources on the landscape that would attract foragers.

More broadly, a synthesis of Clovis-age landscapes and climate provides a look at environmental changes through the final millennia of the Pleistocene, including the beginning of the Younger Dryas Chronozone. Ice-core data from Greenland clearly show that there were abrupt and dramatic shifts in climate at the onset of the YDC, but how or even whether this "event" was translated through various components of the environment across North America is far from clear (Eren 2012; Meltzer and Holliday 2010; and papers in Straus and Goebel 2011). A region-by-region examination of the landscape processes and climate at and around Clovis time sheds light on this issue. Relatedly, the environmental data summarized here provides a good test of the Younger Dryas Impact Hypothesis or the "Clovis comet," which proposes that at ~12.9k cal (at the onset of the YDC) North America was affected by some sort of extraterrestrial "event" (a bolide impact or impacts or some sort of airburst) that had a catastrophic effect on the landscape, climate, flora, fauna, and people of the continent (Firestone et al. 2006, 2007). Simply put, does evidence for some sort of continent-wide, extraterrestrial "event" appear in the geomorphic or paleoclimate record of North America?

Several general remarks should be made regarding our use of the term "Clovis" and regarding dating conventions (both following Miller et al., in this volume). Clovis is clearly the oldest widespread artifact style in the North American archaeological record. That generalization is one of the few that can be applied to Clovis, however. Clovis and its look-alikes, as a group, are found from coast to coast. But there are significant morphological and technological variants in both space and time. Further, fluted points may not be the only projectile point style 13.5k –13.0k cal yr BP. The generalized "Classic Clovis" design (well-crafted lanceolate point partially fluted on both faces and usually made of high-quality raw material) dates to ~13.4k–12.7k cal yr BP (~ 11,600–10,800 ^{14}C yr BP). It includes two principal variants or look-alikes: the Northeastern Fluted Tradition and the Western Fluted (or Great Basin fluted) tradition. Both have a more pronounced concave base. The Western Fluted styles also tend to be shorter. The Eastern variant overlaps in time and is younger than Classic Clovis, continuing until perhaps ~11.9k cal yr BP (10,200 ^{14}C yr BP). The Western variant is very poorly dated, but like the Eastern variant it probably overlaps Classic Clovis in time and is also younger. In the Great Basin and Northwest, the Western Stemmed artifact style, which is significantly different from Clovis (unfluted, thicker in cross section, and longer and narrower) is both coeval with and younger than Clovis, but also possibly predates Clovis.

Classic Clovis in buried, reasonably intact dated contexts is best known from the Great Plains, where it was first formally recognized, and from neighboring areas. Classic Clovis formed the core of the fluted-point tradition. It appears to have started on the Great Plains, although the very sparse age control for Classic Clovis off the Great Plains limits our understanding of its origins. Clearly the basic style was a late arrival in the Northeast based on dating of NF. Dating of Classic Clovis in southern Arizona and in the northwestern tier of states also suggests a relatively late arrival in those areas as well. These data support the argument that the Classic Clovis

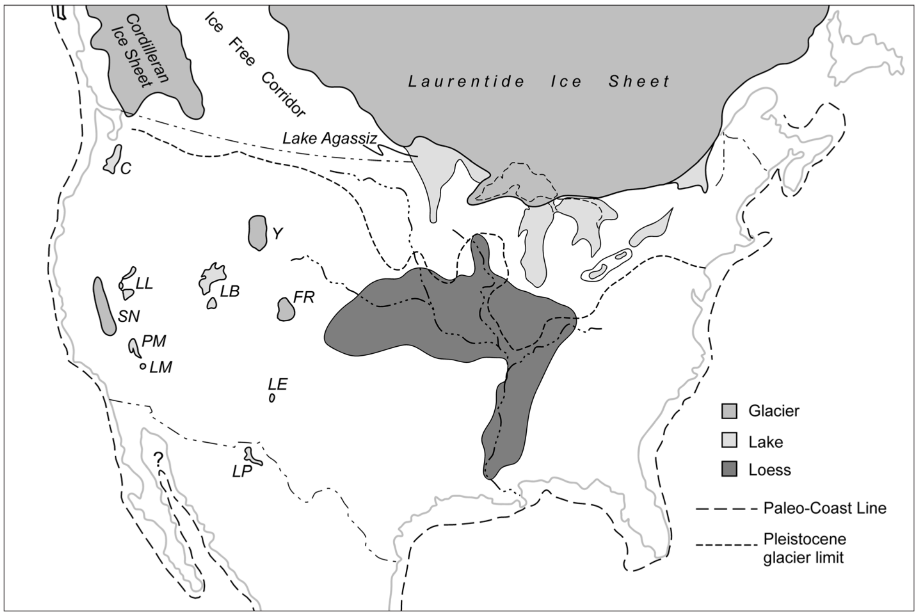

Figure 13.1 Map of North America at ~13.0k cal BP, showing the two ice sheets (based on Dyke et al. 2003), sea level (based on data in this paper for the Atlantic and Gulf coasts; general estimate for the Pacific Coast), and loess (from Busacca et al. 2004). Selected paleo-lakes and mountain glaciers (with general estimates of ice extent) are also shown: **C,** Cascade Range glaciers; **SN,** Sierra Nevada ice cap; **Y,** Yellowstone ice cap; **FR,** Front Range (Rocky Mountain) ice cap; **LL,** Lake Lahontan; **LB,** Lake Bonneville; **PM,** Panamint–Lake Manly system; **LM,** Lake Mojave; **LE,** Lake Estancia; **LP,** Lake Palomas. Compare ice-sheet margin in the Great Lakes at ~13.5k cal BP (Figure 19.2).

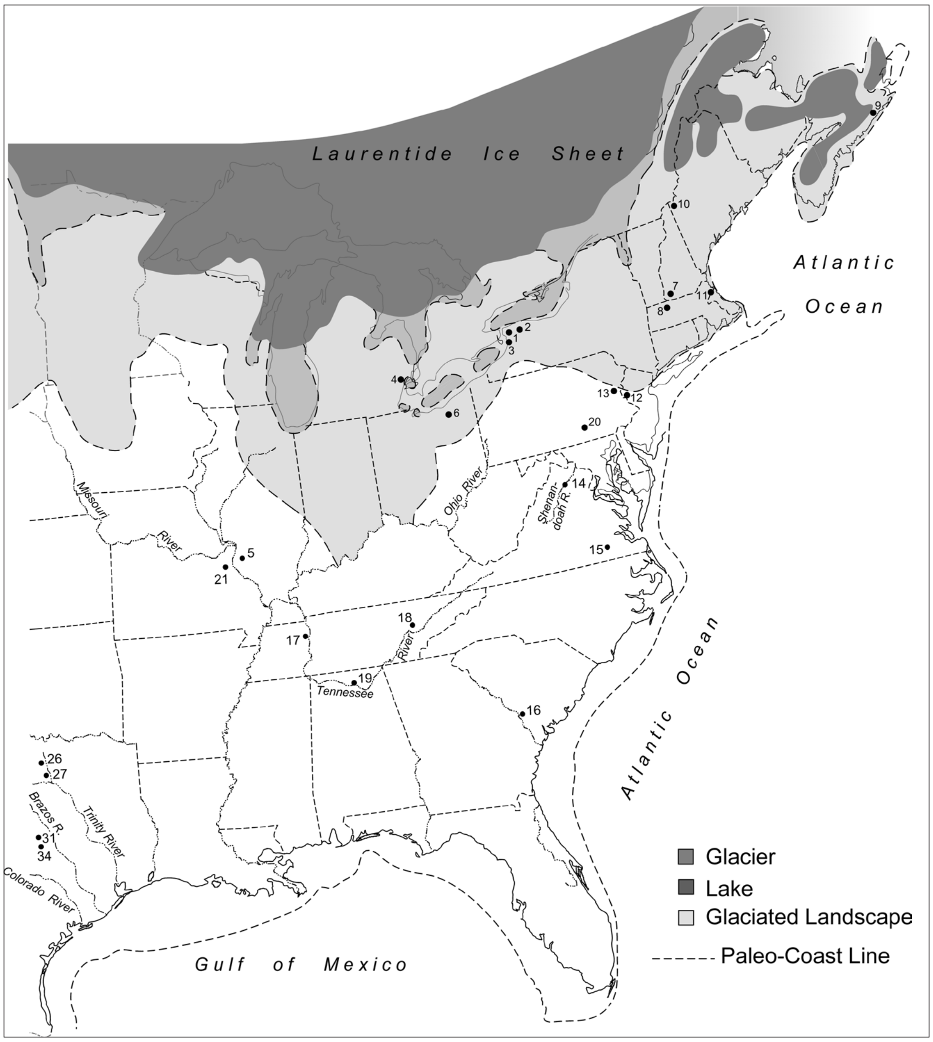

Figure 13.2 Eastern North America at 13.5k cal yrs (from Hill 2006a, fig 5; Hunt 1986, map plate) with locations of glacial ice, pro-glacial lakes (including ancestral Great Lakes), the deglaciated landscape (including pre-LGM glaciers), the paleo-coastline, and selected fluted-point sites (Tables 19.1, 19.3) (based on Lepper and Funk 2006, fig 1). Compare position of glacial ice over the Great Lakes at this time vs. 13.0k cal BP (Figure 19.1).

style spread into the Far West via movement to the north and south of the glaciated Rocky Mountains.

In terms of frequency of artifact finds, Classic Clovis is most abundant in the middle South, but almost exclusively from surface contexts. Curiously, it is relative rare in collections from the lower South. This may be owing to absence of high-quality raw material for stone-tool manufacture along with an attraction to the now-buried coastline and its abundant resources (D. G. Anderson, pers. comm. 2012). West of the Great Plains, Classic Clovis seems to be much more widely scattered, though present almost to the Pacific Coast.

Several dating conventions should be mentioned. Dates are presented in calendar years (cal yr) BP. Most are now published as calendar years, but in those cases where they are not calendar corrected, corrections are applied (following Calib Version 6.0 and the IntCal09 dataset; after Grayson 2011, Appendix 1). Radiocarbon years are presented in parentheses. The "late LGM" refers to the recessional phase of the Last Glacial Maximum, ~19,150–12,900 cal yr BP (~16,000–11,000 ^{14}C yr BP), based on beginning of substantial retreat of the Laurentide ice sheet (after Dyke 2004; and Mickelson and Colgan 2004) and the beginning of the Younger Dryas Chronozone (YDC). The YDC is ~12,900–11,500 cal yr BP (11,000–10,000 ^{14}C yr BP) (Bjork 2007; Bjork et al. 1998). The term "Late Pleistocene," for the purposes of this paper, refers to the Late LGM and the YDC. The Pleistocene/Holocene boundary is the end of the YD. The age range for Clovis is ~13,400–12,700 cal yr BP (11,600–10,800 ^{14}C yr BP), following Miller et al. (this volume)

North America in the Terminal Pleistocene

The early Paleoindian occupants of North American dealt with a climate and landscape unlike any experienced by subsequent peoples living on the continent. Sea level was lower, but rising, and glaciers were still widespread (Figures 13.1, 13.2). Moreover, the continent was undergoing rapid environmental changes from the late LGM to the post-glacial conditions of the Holocene. Very few overviews of the late-Pleistocene environment of North America focus explicitly on this time slice. Most reviews of the late Pleistocene examine conditions of the LGM (e.g., Orme 2002; Porter 1988), broad reviews or reconstructions (e.g., Porter 1983; Ruddiman and Wright 1987; Gillespie et al. 2004; Wright et al. 1993), models (Wright et al. 1993) or they report specific site data through time. Understanding the LGM and specific geomorphic, biotic, or climate systems is certainly important in the context of Quaternary research, but in the context of the archaeological record, understanding what the continent was like in terms of all of these systems during the first widespread and visible colonization is particularly important. The following discussion presents a sketch of North America around Clovis times.

Climate

Research into the climate systems of the late Pleistocene, based on paleobotanical and paleontological data, has a long, rich history because conditions clearly were so different at the time. Reconstruction of the Clovis-age flora and fauna will not be presented here, however. A number of comprehensive studies of the late-Pleistocene paleobiological records are available, though none focus exclusively on Clovis times (e.g., Eren 2012; Graham 2006; Grayson 2011; Porter 1983; Wright 2006; Bousman and Vierra 2012; Delcourt and Delcourt 1981, 2004; Ruddiman and Wright 1987; Strauss and Goebel 2011; Betancourt et al. 1990; Gillespie et al. 2004; Graham et al. 1987; Thompson et al. 2004; Viau et al. 2006; Williams et al. 2004; Wright et al. 1993; and http://www.neotomadb.org/ the NEOTOMA data base). The focus of this section is on climate reconstructions based on the various proxy indicators.

Several general comments on Late Quaternary plant communities and biomes as a basis for climate reconstructions are in order, however. The spatial and temporal distribution of past plant communities indicates a rapid transition from 16.0k to 11.5k cal yr BP; i.e., during most of the Paleoindian occupation North America, "consistent with the climatically controlled pacing apparent in the rate-of-change maps" (Williams et al. 2004:321, 329). Further, and as has long been known, LGM plant associations existed that have no floristic counterpart today (Williams et al. 2004:309 and references therein). "Non-analog vegetation types indicate different climate in the past, but precisely because these vegetation types do not exist anywhere at present, they are a challenge for quantitative reconstruction of past climate" (Grimm and Jacobson 2004:389).

Along the southern margin of the ice sheet from the Great lakes to New England, the late LGM and YDC were cool and generally drying, although there is evidence for a local, slightly wetter YDC (Ellis et al. 2011). New England and the Maritime provinces saw significant cooling and likely wetter conditions following the late LGM (Lothrop et al. 2011). In the Midwest, conditions were warmer and wetter in the late LGM (Grimm and Jacobson 2004:389). Wang et al. (2012) interpret wetter environments in the late LGM on the basis of wetlands that developed 14.7k–12.8k cal BP. They interpret dune development 12.8k–11.8k cal BP as indicative of a dry YDC. During the late Pleistocene across the Southeast, conditions were cool to temperate along the eastern Gulf coast, present-day Florida panhandle, and into the south-central Atlantic coast (Delcourt and Delcourt 1981; Grimm and Jacobson 2004; Williams et al. 2004). In the Florida peninsula, however, conditions changed from cooler to warmer and from drier to wetter (Grimm and Jacobson 2004; Williams et al. 2004).

On the northern Great Plains, cooler conditions prevailed during the late LGM up to ~12.0k cal BP (in the middle of the YDC), followed by a shift to warmer conditions (Grimm 2001; Yansa 2006; Nordt et al. 2008). Throughout much of the central and southern Great Plains, the late LGM was a time of declining moisture. Drying continued through the YDC and into the Holocene (Johnson and Willey 2000; Cordova et al. 2011; Feggestad et al. 2004; Miao et al. 2007). Sometime during the YDC effective precipitation declined and drying began. Likewise, on the Southern Plains, a distinct shift toward drier conditions began ~13.0k cal yr BP (Holliday 1995, 2000).

In summarizing paleovegetation and climate reconstructions for the terminal Pleistocene along the West Coast, Reeder et al. (2011:465) note that "many pollen cores reflect changes in climate out of synch with the onset of the Younger Dryas, suggesting complex regional interaction with global climate trends." Environmental changes at the time were "not very dramatic." Temperature may have varied through the terminal Pleistocene, but precipitation changes are harder to track. "Climate change was evidently insufficiently intense or sustained to have had widespread ecological impacts" (Reeder et al. 2011:470).

The considerable work on the late-Pleistocene paleovegetation of the Great Basin is summarized by Goebel et al. (2011) and Grayson (2011:127–30). Broadly speaking, the terminal Pleistocene was cooler and effectively wetter than today, but as the earliest foragers arrived in the late LGM the region was relatively arid, while the YDC was more mesic. Goebel et al. (2011:484) emphasize, however, that "most paleovegetation records have not been of a sufficiently high resolution to detect specific vegetation changes before, during, and after the Younger Dryas. Woodrat midden studies suggest relatively cool, but not necessarily wet conditions persisted through the late glacial, and pollen records from Blue Lake in the east and Owens Lake in the west indicate significant warming and aridification after the Younger Dryas."

Paleo-climate reconstructions for the terminal Pleistocene in the Southwest are spotty. Packrat (*Neotoma*) middens provide high-resolution "snapshots" of limited areas more or less at a moment in time. Most pollen records are from a few scattered alluvial, lacustrine or palustrine settings with varying degrees of preservation and age control. In general, packrat middens indicate persistently wetter conditions through the late Pleistocene until or during the YDC followed by drying (Van Devender 1990a,b; Van Devender and Spaulding 1979; Holmgren et al. 2003, 2006; Koehler et al. 2005). In the Grand Canyon, however, temperatures apparently fell during all or parts of the YDC (Cole and Arundel 2005; Wurster et al. 2010).

Well-dated pollen records for the late Pleistocene are available from a limited number of upper and mid-elevation bogs and small lakes, and still fewer intermediate elevation valley sites (Hall 2005). On the southern margin of the Colorado Plateau, the terminal Pleistocene was generally cooler and more moist, with warmer and drier conditions established during the YDC (Anderson 1993). In northern New Mexico, Cisneros-Dozal et al. (2010) distinguished a wetter late Pleistocene and YDC, with a cooler YDC. Very limited data from and near the Clovis sites in the upper San Pedro River valley in the Chihuahuan desert of southeastern Arizona provide conflicting interpretations of climate. A "desert grassland" was proposed for the Lehner site during Clovis times (Mehringer and Haynes 1965), but a nearby record in Palominas arroyo shows no indication of Clovis-age desert nor of a dramatic shift in temperature or precipitation from the late-LGM to the YDC (Ballenger et al. 2011). In contrast, speleothems (Polyak et al. 2004; Wagner et al. 2010), and stratigraphy (Haynes 1991; Haynes and Huckell 2007) suggest a drier late LGM and more moist YDC.

Ballenger et al. (2011:512) summarize the varied records of late-Pleistocene paleoclimate across the Southwest: "Records have not been articulated to form a coherent model of YDC temperature, precipitation, floral, and geomorphological responses in the Southwest, and they highlight the importance of distinguishing the effects of global climate change in different systems and at local scales." Furthermore, their review of "multi-proxy paleoenvironmental records clearly indicates significant and widespread paleoenvironmental changes coincident with the YDC, but the amplitude and even the direction of those changes are inconsistent across and sometimes within proxies" (Ballenger et al. 2011:515).

Glaciers and Effects of Glaciation

Two key continent-scale questions that arise when attempting to address questions about the Clovis landscape and how Clovis hunter-gatherers were distributed across the landscape are:

1) where was glacial ice? and
2) where was the Clovis-age coastline (relative to today's)?

The answers to these questions get at fundamental issues of where the First Americans came from (i.e., what is the distribution of Clovis archaeology relative to the Ice-Free Corridor) and what landscapes were available for occupation (as determined by ice and sea-level position). Further, identifying sea-level position during Clovis time tells us not only how much of the Clovis-age landscape we cannot see, but also where sites could be located.

At ∼13,500 cal yr BP, glaciers still covered large parts of Canada (Figures 13.1, 13.2). A comprehensive compilation of radiocarbon dates from around the margins of the ice sheet (Dyke 2004; Dyke et al. 2003; see also summaries by Hill 2006a,b,c and Dixon 2013) suggests that a viable "ice-free corridor" between the Laurentide (eastern) and Cordilleran (western) ice sheets was open by ∼13,450 cal yr BP (∼11,500 ^{14}C yr BP). OSL dating at the south end of the corridor suggests that it was open by ∼15,000 cal yr BP or even sooner (Munyikwa et al. 2011). The southern margins of the ice sheets also were rapidly receding by ∼13,500 cal yr BP (∼11,500 ^{14}C yr BP). The southern Cordilleran ice sheet was largely out of Montana, Idaho, and Washington (where the Puget Lowland was ice free by ∼16,900 cal yr BP (∼13,800 ^{14}C yr BP) (Figures 13.1, 13.3) (Porter and Swanson 1998; Booth et al. 2004; Dyke et al. 2003). To the east, most of the southern Laurentide ice sheet was out of the U.S. with the exception of the northern Great Lakes (Figures 13.1, 13.2). Lake Superior was still ice covered during Clovis times, but the northern ends of lakes Michigan and Huron underwent rapid deglaciation ∼13.3k–12.9k cal yr BP (∼11,500 to ∼11,000 ^{14}C yr BP) (compare Figures 13.1 and 13.2) (Hill 2006a; Dyke et al. 2003). The margin of the ice sheet was also north of the St. Lawrence River before ∼13.3k cal yr BP (∼11,500 ^{14}C yr BP) (Figure 13.2) (Hill 2006a; Ridge 2003; Dyke et al. 2003; Occhietti et al. 2001).

Glacial ice also covered much of the higher Cascade and Sierra Nevada ranges as well as the higher ranges of the central and southern Rocky Mountains (Figure 13.3) (Pierce 2004; Kaufman et al. 2004). As with the continental glaciers, most of these mountain systems were retreating long before the arrival of Clovis populations. Most small mountain glaciers were likely gone by Clovis time and the larger ice caps of Cascades, Sierra Nevada and Rockies were greatly reduced (J. Licciardi, pers. comm., December 2012), although some glacial ice may have formed or re-advanced at about this time in the northern Cascades (Kaufman et al. 2004). Very few mountain or high-altitude Clovis adaptations are reported, but glacial meltwater from these systems fed rivers and lake basins of importance to Clovis subsistence and settlement, discussed below.

The massive ice sheets had a dramatic and direct effect on Canada and much of the modern-day U.S. In addition to sea level and continental hydrology, both discussed below, large parts of the continental interior, both glaciated and non-glaciated, were further modified. As the LGM ice front retreated it left behind a vast till plain (Holliday et al. 2002). Combined with older till plains (Figure 13.2), the region includes drumlins, eskers, kames, kettles, ice-thrust features, and high-relief hummocky moraines on the glacial landscape of Michigan, eastern and northern Wisconsin, northeastern Minnesota, and much of west-central North Dakota. To the south and southeast in Illinois, Indiana, Ohio, and north-central Iowa, the landscape is a flat or gently undulating till plain with classic end moraines, along with scattered kames and kettles. Generally speaking, the deglacial landscape was poorly drained. Depressions on these landscapes became wetlands that, as did the various glacial ridges (e.g., moraines, kames, and eskers), attracted Paleoindian hunter-gatherers (Table 13.1).

To the northeast of the Till Plain, in New England, the St. Lawrence Lowland, and the Maritime Provinces, the landscape had significantly more post-glacial relief than the Till Plain (Mickelson et al. 1983). The resulting landscape included glacial landforms (morainal ridges and poorly drained lowland bogs), draining lakes and river valleys, and coastal landscapes including a narrow plain (e.g., Lothrop et al. 2011; papers in Cremeens and Hart 2003). Fluted-point sites and isolates are common in some of these settings (Curran 2003;

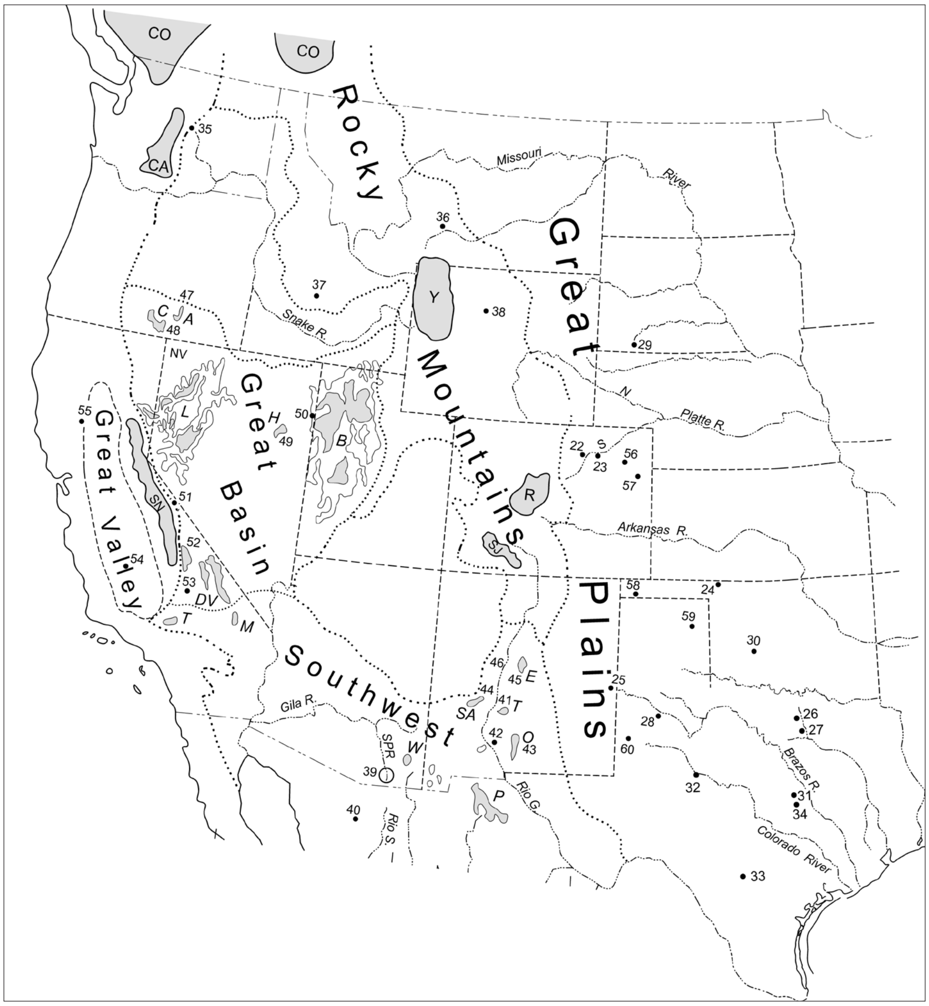

Figure 13.3 Western North America at ~13.0k cal BP (based on Orme, 2008b, fig. 1) with selected paleo-lakes (**A**, Alkali, **B**, Bonneville, **C**, Chewaucan, **DV**, Death Valley system, **E**, Estancia, **H**, Hubbs, **M**, Manly, **O**, Otero, **P**, Palomas, **SA**, San Agustin, **T**, Thompson [California], Trinity [New Mexico], **W**, Willcox), the southern margin of the Cordilleran ice sheet (CO), mountain glaciers (with very general estimates of ice extent) (**CA**, Cascades, **R**, Front Range, **SJ**, San Juans, **SN**, Sierra Nevada), and fluted point or Western Stemmed sites (Tables 19.4–19.8). For sea-level estimates, see Mackie et al. chapter, this volume.

Keenlyside 1991; Frink and Hathaway 2003), including some well-known buried sites along paleo-wetlands and coastal embayments (Table 13.1).

Sediment deposited as outwash far from the receding ice front was deflated by wind and deposited as loess (Figure 13.1). Loess was also derived from Great Plains valleys that drained the Rockies. Deposition ended ~14,600–13,300 cal yr BP ^{14}C (Mason et al. 2008), and soil formation began on the stabilized landscape. This soil represents the Paleoindian landscape of the central Great Plains uplands.

South of the loess (southeast Colorado, southwest Kansas) on down to the High Plains of northwest Texas and eastern New Mexico, the Paleoindian landscape was essentially that seen today in the surface of the Blackwater Draw Formation, a sheet of older Pleistocene eolian sand and clay (Holliday 1989, 1990). Clovis and other Paleoindian artifacts are common across this upland landscape (Holliday 1997a).

Late-LGM Pleistocene and Holocene eolian sand locally is a common component of the uplands of the Coastal Plains from south Texas to New England, likely derived from or related to drainage evolution (discussed below) and locally covering Paleoindian landscapes if not Paleoindian sites (Otvos 2004, 2005a,b; Thorson and Tryon 2003; Boulter et al. 2010; Busacca et al. 2004; Forman et al. 2009; Frederick et al. 2002; Rink et al. 2011; Wilder et al. 2007).

Upland deposits of late-Pleistocene and Holocene age are relatively rare inland of the coastal plain. For example, the Interior Low Plateau contains the densest concentration of Paleoindian bifaces in North America (Buchanan 2003; Prasciunas 2011; Anderson and Faught 2000). The absence of upland deposits, combined with the presence of several chert-bearing limestone formations, may account for the very high density of Clovis and later-Paleoindian artifacts.

Sea Level

As the glaciers melted and the ice fronts receded in the terminal Pleistocene, sea level rose (eustatic sea-level changes). By ~13,500 cal yr BP and the beginning of the Clovis occupation of North America, sea level was still down by some tens of meters, exposing significant coastal areas for occupation, particularly along the Atlantic and Gulf coasts (Figures 13.1, 13.2). Further, estimating where sea level was at a specific locality at a particular moment in time (in this case at ~13,500–13,000 cal BP) is a very difficult task (e.g., Milne and Mitrovica 2008; Tamisiea and Mitrovica 2011; Milne et al. 2002; Muhs et al. 2004). Besides the change in sea level

Table 13.1 Clovis and Northeast fluted sites, Midwest Till Plain, New England, and the Maritime Provinces.

Site[1]	Number[2]	Drainage	Setting	References
Midwest Till Plain				
Arc, NY NF	1	Erie-Ontario Plain	Strandline of Paleo-Lake Tonawanda	Vanderlaan 1986, Gramly 1988, Tankersly et al., 1997
Hiscock, NY NF	2	Erie-Ontario Plain	Boggy divide between Paleo-Lakes Tonawanda & Tcakowageh	Gramly 1988, Laub et al. 1988, Laub, 2002, 2003
Lamb, NY NF	3	Unintegrated drainage	Adjacent to kettle pond between two moraines	Gramly 1999
Holcombe Beach, Paleo-II, Paleo-II-W, Paleo-II-W-A, MI	4	Glacial Lake Clinton	Sandy spit formed by recessional moraine	Fitting et al., 1966
Bostrom, IL	5	Above small tributary of the Kaskaskia R.	Loess-mantled spur	Tankersley & Koldehoff 1993
Paleo Crossing, OH	6	Unintegrated drainage	Below the crest of a kame near a series of kettles	Brose 1994
New England and the Maritime Provinces				
Whipple, NH NF	7	Asheulot River, tributary to the Connecticut River	Buried in terrace alluvium	Curran 1984
Sugarloaf, MA NF	8	Sugarloaf Brook tributary to the Connecticut River	Buried in terrace alluvium	Gramly 1998
Debert, NS NF (Canada	9	Cobequid Bay (off of Bay of Funday)	Creek flowing across forested bay plain (or coastal flats?)	MacDonald 1985
Vail, ME NF	10	Magalloway R.	Floodplain	Gramly 1982, 2009
Bull Brook, MA NF	11	Bull Brook/ coastal salt marsh	Kame terrace	Byers 1954 Robinson et al 2009

[1] NF = Northeastern fluted

[2] See Figure 19.2

itself, the land was moving in some areas. The west coast of the continent was and remains tectonically active; rising in many areas as sea level came up, subsiding in other areas (see Mackie et al., this volume).

A further complication is the broader impact of the ice itself. “As ice sheets gain or lose mass, and as water moves between the continents and the ocean, the solid Earth deforms and the gravitational field of the planet is perturbed. Both of these effects lead to regional patterns in sea level change that depart dramatically from the global average” (Tamisiea and Mitrovica 2011:24). In particular, the weight of the ice produced a “forebulge” ahead of the ice. This forebulge collapsed as the ice melted and sea level rose. These changes in the elevation of the Earth’s surface (isostatic adjustments) can confuse local sea-level reconstructions. Measurements of relative sea-level positions in areas not affected by isostacy will be different from those in areas that were affected by isostatic changes.

A few estimates, based on models of isostatic adjustment, are available for the continental U.S. For ∼13,000 cal yr BP, Simms et al. (2007, fig 4) model the western and central Gulf as -60 m (50 km offshore today). Faught (2004a,b) and Faught and Donoghue (1997) (following Frazier 1974; Dunbar et al. 1992), hypothesized that the Clovis (YDC onset) shoreline was at or a little more than -40 m (only ∼25 km offshore of the Florida Panhandle, but up to 150 km offshore of the Big Bend of Florida) (Figure 13.2). Like the Gulf Coast, the Atlantic Coast of North America has a wide, shallow shelf (Figures 13.1, 13.2). If abundances of terrestrial surface finds are an indicator (e.g., Anderson et al. 2010), many Clovis and later Paleoindian sites are likely underwater. Stanford and Bradley (2012, fig 4.9) place middle Atlantic sea level at -50 m at ∼11,300 ^{14}C yr BP, but the basis for the sea-level and radiocarbon determinations are not provided. Lowery et al. (2012a), in contrast, used depths of offshore dated peat deposits to estimate Clovis sea level along the middle Atlantic Coast at -55 m to -50 m. Radiocarbon dating of offshore deposits suggests that the coastline from Massachusetts to New York around Clovis time was 70–60 m below modern sea level (Horton 2007 and references therein).

Throughout the late LGM, including Clovis and later Paleoindian time, sea level was rising, inundating the exposed continental shelves. The period 16.0k–12.5k cal yr BP was one of particularly rapid rise, referred to as “meltwater pulse 1a”(Lambeck et al. 2002; see also Gregoire et al., 2012). Globally sea level was coming up at mean rate of 16.7 mm/year (Lambeck et al. 2002:358). This was particularly significant for the continental shelf along the Atlantic and Gulf coasts because of its very gentle slope. Along the middle Atlantic Coast, dated sediments offshore indicate that sea level rose from -55 m at ∼14.0k cal yr BP to -51 m at ∼13.0k cal yr BP (Lowery et al. 2012b, fig. 2.1). The middle Atlantic coastal plain offshore of the Delmarva Peninsula has a slope of 1m per 1500 m of horizontal distance. The marine transgression during the millennium just before and during Clovis time was ~6.0 km. Applying the same rate of sea-level rise to the middle Texas Gulf Coast shelf (mean slope of 1m per 1000 m of horizontal distance; Eckles et al. 2004, fig 1) resulted in a transgression of ~4.0 km. The Big Bend of the Florida Gulf Coast shelf has a very low slope of 1m per 3770 m of horizontal distance (Faught 2004a, fig. 1). A sea-level rise of ~4.0 m resulted in a transgression of ~15 km for the period ~14.0k–13.0k cal yr BP. These calculations suggest a marine transgression of at least several hundred meters in a century, an event clearly noticeable for several human generations and almost certainly part of memory and oral tradition. This rapid transgression also must have resulted in rapidly changing settlement, but also rapid burial of sites.

Hydrology

Continental hydrology was also significantly different when North America was first colonized, owing to melting glaciers, shifted storm tracks, and increased effective precipitation. Most rivers had substantially higher discharges compared with today (Table 13.2). Areas of the Great Plains and the intermontane West were dotted with perennial lakes, and along the retreating continental ice fronts large pro-glacial lakes formed, evolved in shape and position, and drained (Figures 13.1–13.3). The following discussion is a sketch of the hydrologic environment ~13,500–13,000 cal yr BP. The discussion of rivers focuses primarily on the eastern and central U.S. owing to the number of sizeable perennial streams and because a significant body of literature on late-Pleistocene alluvial systems is available.

Rivers and River Basins The relation between Clovis archaeology and alluvial systems includes sites both directly along drainageways and on nearby stable upland surfaces. In the eastern U.S. and on the Great Plains these stable landscapes included older terraces and other stable uplands in proximity to the channels (Tables 13.3, 13.4.). In the mountain West, stable landscapes suitable for and sought out for occupation along integrated basins with through-flowing drainages included older terraces and other stable surfaces such as older lake beds and alluvial fans (Table 13.5).

Table 13.2 Clovis-age alluvial conditions across North America.[1]

Rivers	Setting	Discharge	Bedload	Flow regime	Channel morphology	References
Middle Delaware River, PA	Nonglaciated	Variable	Gravel & sand	Stable? Incision of outwash >11.5k cal yr	Braided?	Schuldenrein 2003
Atlantic Coastal Plain[2]	Nonglaciated	Declining w/high bankful discharge	Gravel & sand	Aggrading	Large meanders, shift from braided 16.0k–15.0k	Leigh 2004, 2006, 2008
Middle Tennessee, N AL	Nonglaciated	High	Mixed shifting to fine	Aggrading LP-EH	Braided?	Driskell et al. 2012
Upper Mississippi	Glaciated headwaters & headwaters of northern tributaries	Variable to higher	Pebbly sand	Aggrading & incising Entrenchment 12.8k–12.4k	Braided; shift to island-braided 12.8k–12.4k	Bettis et al 2008
Lower Mississippi, LA	Glaciated headwaters & headwaters of northern tributaries	Variable to higher	Pebbly sand	Aggrading & incising	Multiple braided belts shifting to meandering[3]	Kidder et al 2008 Rittenour et al 2007
Gulf Coastal Plain, TX[4]	Nonglaciated	Higher	Sand, mud	Incising & aggrading; deep incision & formation of terraces before Clovis time[5]	Large meander belts	Blum & Aslan 2006 Blum 2007
Upper Brazos, TX	Nonglaciated	Higher?	Gravel, sand, mud; coarser tributary deposits	Incising & aggrading; deep incision & formation of terraces before Clovis time	?	Blum et al 1992
Concho & Upper Colorado, TX	Nonglaciated	Higher?		Deep incision & formation of terraces before Clovis time	?	Blum & Valastro 1992
Middle Trinity, TX	Nonglaciated	High	Fines	Aggrading	Meandering?	Ferring 1995, 2001
Draws, eastern NMx, northwestern Tx[6]	Nonglaciated	High	Gravel & sand	Stable; shift to aggrading lacustrine or palustrine <12.9k	Meandering? Shift to standing water <12.9k	Holliday 1995
Nebraska & Kansas[7]	Nonglaciated	Higher?	Mixed?	Stable w/soil cumulization[8]	Meandering?	Mandel 2008
Middle South Platte, CO[9]	Glaciated headwaters; major tributary to the Mississippi	Higher	Sandy gravel	Aggrading to stable	Braided	Holliday 1987 McFaul et al 1994 Haynes et al 1998

Most rivers carried relatively large discharges in the post-LGM late Pleistocene (Table 13.2) (e.g., discussions and references in Blum 2007; Knox 1995). During the LGM, higher effective precipitation, and perhaps absolute precipitation, and glacial meltwater introduced large amounts of water, along with higher and coarser sediment load, into the headwaters of many rivers in North America. In the late LGM discharges were declining relative to LGM time as the glaciers continued to shrink and climate warmed, which contributed to decreased effective precipitation, although the discharges were still significantly higher than today. Concomitantly, most streams and rivers were shifting channel forms and flow regime, though these changes were not necessarily synchronous nor in the same direction (Table 13.2) (Blum 2007; Tornqvist 2007; Blum and Tornqvist 2000). "All elements of drainage systems are not equally responsive to environmental change, nor do changes in stream response or sediment movement occur concurrently throughout drainage basins" (Bettis et al. 2008:362). Further, low-order tributaries tend to respond more to local conditions, while the higher-order mainstream is a sort of average of regional environmental factors including changes in base level due to eustatic sea-level position (Blum 2007; Blum and Tornqvist 2000). Besides simply representing more water on the landscape, these evolving characteristics of alluvial systems also have important implications for predicting the locations and understanding the site-formation histories (including preservation and visibility) of Clovis and other Paleoindian sites.

A common characteristic of many streams, particularly those east of the Rocky Mountains, in Clovis time was meandering channels that evolved from late-LGM braided channels (Table 13.2). The timing of this change is not well dated, but seems to have varied from region to region (i.e., during or just after Clovis time) (Table 13.2). Channel incision also accompanied the change in channel morphology in many settings (Table 13.2). Further, Clovis sites are relatively common along both mainstreams and tributaries in the eastern U.S. (Table 13.3). On the Atlantic Coastal Plain, the meanders had sandy, scrolled point bars (Table 13.2); many locally deflated to form sand dunes (Ivester and Leigh 2003). Dune formation

Table 13.2 Cont'd.

Rivers	Setting	Discharge	Bedload	Flow regime	Channel morphology	References
Upper Dry Cimarron, NM	Nonglaciated	Higher	Mixed	Aggrading[10]	?	Mann & Meltzer 2007
Middle Rio Grande, NM[11]	Minimal glaciation in headwaters	Higher	Gravel	Aggrading, then incising	Braided shifting to meandering?	Connell et al 2007
Rio San Pedro, N Chihuahua	Nonglaciated	High?	Mixed?	Stable, then incised, then stable[11]	Braided, then meandering after incision	Nordt 2003
Willamette Valley, OR	Glaciated tributaries in the Cascade Range; filled by Glacial Lake Missoula mega-floods	High?	Mixed shifting to fine	Aggrading	Braided shifting to meandering	O'Connor et al. 2001

[1] Relative to modern conditions; all dates in cal yrs BP; LP = Late Pleistocene; EH = Early Holocene

[2] N Carolina, S Carolina, Georgia

[3] Timing of the shift from braided to meandering belts varies from belt to belt, but happened more or less during Clovis time.

[4] Lower Colorado, Lower Trinity, Lower Brazos river systems

[5] Lower Trinity remained incised; Lower Colorado and Lower Brazos aggraded 14k–5k cal yr BP

[6] Tributaries of the Brazos and Colorado rivers

[7] Loup River, and Kansas, Arkansas, and upper Cimarron river systems.

[8] Stabilization and soil cumulization was time-transgressive; began as early as ∼13,300 yr BP (∼15,600 cal yr BP) but was underway in most sections between ∼11,400 and ∼11,000 yr BP (13,300 and 12,900 cal yr BP); soils continued to cumulize through the YDC; burial likewise time-transgressive, varying from ∼10,000 to ∼9,000 yr BP (∼11,400 to ∼10,200 cal yr BP).

[9] The Dent Clovis site, dated ∼10,990 yr BP (∼12,900 cal yr BP) (Waters and Stafford 2007), is in the upper alluvium of the Kersey/ Broadway terrace (Haynes et al. 1998), as is the Klein Clovis site (Holliday, 1989; McFaul et al 1994). That date provides an approximation for the end of Kersey alluviation. If the bones were redeposited (Brunswig 2007), the alluviation must have continued somewhat later. Incision of the Kersey surface was followed by formation of the next lower surface, the Kuner (Holliday, 1987; McFaul et al., 1994; Haynes et al., 1998). A date of ∼10,105 yr BP (∼11,650 cal yr BP) from fill below the Kuner surface (Haynes et al. 1998) shows that abandonment of the Kersey terrace, incision, and the start of the next cycle of alluviation took place sometime between ∼11,000 and ∼10,105 yr BP (∼12,900 and ∼11,400 cal yr BP); i.e., the YDC was expressed by geomorphic instability following quasi-stable conditions at about and before Clovis times. Dunes bury both Clovis and Folsom sites along and above the south side of the Kersey terrace (Roberts 1937; McFaul et al 1994), probably representing floodplain deflation before incision.

[10] System-wide incision >13.4k cal BP; aggradation ∼12,900 to ∼11,400 cal BP, but at the Folsom site, alluviation or colluviation is dated before 13,200 cal BP followed by eolian sedimentation until ∼11,400 cal BP (Meltzer 2006:112-153).

[11] Poor age control.

[11] Poor age control ∼14,000–9000 RCYBP.

Table 13.3 Clovis sites, in and east of the Mississippi River valley, in alluvial settings.

Site	Number[1]	Drainage	Setting	References
Mainstream				
Plenge, NJ	12	Musconetcong River, tributary to Delaware River	Terrace	Kraft 1973, 1977 Gingerich 2013a
Cactus Hill, VA	15	Nottaway River	Terrace; buried in eolian sand	Wagner & McAvoy 2004
Fifty, VA	14	South Fork, Shenandoah River	Alluvial fan on terrace	Gardner 1974, 1983 Carr et al 2013a
Thunderbird, VA	14	South Fork, Shenandoah River	Terrace	Gardner 1974, 1983 Carr et al 2013a
Shawnee-Minisink, PA	13	Delaware River	Terrace	McNett 1985 Gingerich, 2011, 2013b
Topper, SC	16	Savannah River	Terrace & adacent uplands; buried in eolian sand	Goodyear 2006 Waters et al 2009 Miller 2010 Smallwood et al 2013
Carson-Conn-Short, TN	17	Tennessee River	Relict levee	Broster & Norton 1996 Broster et al 2013
Johnson, TN	18	Cumberland River & tributary confluence	Terrace	Barker & Broster 1996
Quad, AL	19	Tennessee River	"Levee" or terrace	Futato 1996
Low-Order Tributaries				
Shoop, PA	20	Armstrong Creek, tributary to the Susquehanna River	Buried in thin colluvium on bedrock ridge	Wittoft 1952 Cox 1986 Carr et al 2013b
Kimmswick, MO	21	Confluence of Rock & Black. creeks, tributaries to the Mississippi R.	Buried in fill of low terrace; buried by colluvium	Graham et al. 1981

[1] See Figure 19.2.

resulted in local burial of Clovis occupations adjacent to or near the meandering streams (Table 13.2, 13.3).

The Mississippi River and its northern tributaries were the largest and principal drainages for meltwater and sediments discharged from the receding southern margin of the North American ice sheets. As such, much of the system underwent major changes in discharge and sediment load in late-LGM time. Widespread cutting and filling along the Upper Mississippi Valley (UMV) took place just before and during the Clovis occupation (Table 13.2). Eolian sand was deposited on adjacent uplands at the same time. Entrenchment, alluviation, and eolian sedimentation all could obscure or destroy Clovis sites. The Lower Mississippi Valley (LMV) evolved into a braided pattern during or just after Clovis times (Kidder et al. 2008; Rittenour et al. 2005, 2007). Kidder et al. hypothesize that areas of the LMV in proximity to the braided channels may have been inhospitable due to flooding by pulses of meltwater and by high concentrations of dust due to wind deflation of the wide silt-laden channels. Further, the silty stream waters may have been low in fish populations. Meltwater flooding was probably a significant but transitory hazard, largely a result of overflow from Glacial Lake Agassiz in the headwaters of the Mississippi River (see below).

Farther west, the stratigraphy and geochronology of the larger drainages of the Texas Coastal Plain and inland (the Colorado, Brazos, and Trinity) provide further insights into site visibility and preservation. On the coastal plain, the lower Trinity was deeply incised during Clovis time, whereas the lower Colorado and Brazos rivers were filling (Tables 13.2, 13.4). Inland, all these drainages were subjected to deep incision prior to the Clovis occupation, followed by quasi-stable or aggrading conditions by and following Clovis time (Tables 13.2, 13.4). Clovis sites, therefore, are either on old Pleistocene uplands such as terraces (e.g., Lewisville) or are deeply buried and only fortuitously exposed (e.g., Aubrey, Clovis, Lubbock Lake, McLean) (Table 13.4).

In the continental interior, significant variability is apparent in streams with glaciated headwaters versus unglaciated streams. The South Platte River and the Rio Grande, both with glaciated headwaters, had coarse bedloads in the late Pleistocene, and both also incised at some point just before or during the YDC (i.e., during or just after the Clovis period) (Tables 13.2, 13.4). In contrast, the unglaciated drainages of the central Great Plains (Table 13.2) had quasi-stable and meandering streams in the late LGM. The floodplains stabilized and were buried by incremental additions of flood deposits just before and during the YDC, but the process was time-transgressed starting before Clovis time (Table 13.2).

In and west of the Rocky Mountains, most Clovis sites in alluvial settings are along low-order tributaries in intermontane basins around the core of the Rockies (Table 13.5). This is due at least in part to erosion or deep burial along the mainstream. The Missouri River basin, for example, was subjected to considerable glacial and post-glacial erosion (Holliday et al.

2002). The highest concentration of in situ Clovis sites and mammoth kills in North America is in the San Pedro River valley in southeast Arizona (Table 13.5; Figure 13.3). Along the mainstream San Pedro, late-Pleistocene strata are poorly preserved or rarely seen. Limited data suggest that the river was in equilibrium at about its current level from 12.6k to 9.5k cal yr BP (Ballenger et al. 2011). The well-known Clovis/mammoth sites are all in tributaries of the San Pedro, buried in local valley fill (Table 13.5). To the south and southwest of the San Pedro Valley Clovis sites, in northern Sonora, Mexico, more Clovis sites are scattered across the surface of the Hermosillo Plain on either side of the Rio Sonora (Table 13.5), but none are along the river (Gaines et al. 2009). The lower Rio Sonora is probably quite young owing to sea-level rise in the Gulf.

In the basins of the Southwest, but away from the paleo-lakes, playas, and streams, older, stable landscapes are common on LGM-age lake beds, lunettes, sand sheets, fans, and bajadas. Paleoindian sites are common in these settings. Clovis sites, for example, are known from these older uplands in southern New Mexico, southern Arizona, and northern Sonora (Table 13.6) (Holliday, in press)

Drainage systems along the West Coast of the continent have yielded very few fluted points. “Sea level rise and marine erosion have undoubtedly submerged or destroyed many early sites, and very few areas are likely to retain evidence of Pleistocene coastal occupations along modern shorelines” (Erlandson et al. 2008:2234). Further, “the combination of episodic subsidence earthquakes, tsunamis, landslides, and coastal erosion provides a powerful explanation for the dearth of Early Holocene . . . sites along the southern Northwest Coast [Canadian border to northern California]” (Erlandson et al. 2008:2237 and references therein). These issues are further discussed by Mackie et al. in this volume. Farther south along the California coast, “especially impressive clusters of early sites have been documented along the mainland coast in the San Diego, Santa Barbara, and San Luis Obispo areas . . . , many associated with extinct estuaries created by rapid sea level rise during the terminal Pleistocene and Early Holocene” (Erlandson et al., 2008:2238 and references therein). “South of Cape Mendocino, much of the Alta and Baja California Coast is affected by tectonic uplift, but sea level rise and coastal erosion since the end of the LGM have been the dominant geological forces shaping coastal landscapes and the archaeological record” (Erlandson et al. 2008:2234).

Besides being an obvious resource, the rivers of North America at ∼13,000 were likely useful travel corridors (see

Table 13.4 Clovis sites on the Great Plains in alluvial settings.

Site	Number1	Drainage	Setting	References
Mainstream				
Dent, CO	22	South Platte River	Buried in terrace alluvium; redeposited?	Brunswig 2007 Haynes et al. 1998
Klein, CO	23	South Platte River	Buried in terrace alluvium	Zier et al. 1993
Jake Bluff, OK	24	Arroyo cut in bedrock bench along N. Canadian River	Buried arroyo fill	Bement and Carter 2010
Blackwater Draw Loc 1 (Clovis type site), NM	25	Blackwater Draw (Brazos system)	Buried in spring alluvium below valley fill	Haynes & Agogino 1966; Haynes 1975, 1995 Holliday 1995, 1997
Aubrey, TX	26	Elm Fork tributary, Trinity River	Buried in alluvium	Ferring, 1995, 2001
Lewisville, TX	27	Trinity River	Buried in terrace alluvium	Crook & Harris 1957, 1958 Stanford 1983
Lubbock Lake, TX	28	Yellowhouse Draw (Brazos system)	Buried in alluvium below valley fill	Stafford 1981 Johnson 1987 Holliday 1985b, 1995, 1997 Holliday & Allen 1978
Low-order tributaries				
Lange-Ferguson, SD	29	White River Badlands, arroyo tributary to White R.	Marsh or bog	Hannus 1990
Domebo, OK	30	Tributary canyon of the Washita R.	Buried in alluvium	Albritton 1966 Leonhardy 1966 Stafford et al. 1987
Gault/Freidkin, TX	31	Upper Buttermilk Ck, Brazos R. tributary	Buried in floodplain fines with fan gravel	Waters et al. 2011a,b
McClean, TX	32	Mulberry Ck tributary of the Colorado R.	Buried in alluvium	Bryan and Ray 1938 Ray & Bryan 1938 Ray 1942 Leighton
Pavo Real, TX	33	Leon Creek, San Antonio River	Mixed in thin alluvium	Collins et al. 2003
Wilson-Leonard, TX	34	Upper Brushy Creek, Brazos R. tributary	Buried in alluvium	Bousman 1998 Collins 1998a,b Bousman et al. 2002

[1] See Figure 19.3.

Table 13.5 Clovis sites along low-order alluvial settings in the Columbia Plateau, Northern Rockies, and Southwest.

Site	Number[1]	Drainage	Setting	References
Northern Rocky Mountains & Columbia Plateau				
Richey-Roberts, WA	35	Columbia River Valley	Swale in mega-ripple[2]	Mehringer & Foit 1990 Gramly 1993
Anzick, MT	36	Shields River valley	Talus slope of limestone outcrop	Wilke et al 1991 Morrow & Fiedel 2006
Simon, ID	37	Camas Creek; tributary of Snake River	Terrace of Deer Ck; fan slope tributary to Camas Ck	Terrace of Deer Ck; fan slope Kohntopp 2010
Colby, WY	338	Slick Ck tributary to the Big Horn River	Buried in arroyo fill	Frison & Todd 1986
Southwest Basins				
Lehner, AZ	39	Arroyo tributary, San Pedro River	Buried in stratified arroyo fill	Haury et al. 1959 Haynes 1982
Murray Springs, AZ	39	Curry Draw, tributary of the San Pedro River	Buried in stratified arroyo fill	Haynes & Huckell 2007
Naco, AZ	39	Greenbush Draw, San Pedro River	Buried in stratified arroyo fill	Haury et al 1953
Leikem, AZ (Naco II)	39	Greenbush Draw, San Pedro River	Buried in stratified arroyo fill	Agenbroad 1967
Navarette, AZ	39	Greenbush Draw, San Pedro River	Buried in stratified arroyo fill	Huckell 1982
Escapule, AZ	39	Horsethief Draw, San Pedro River	Buried in stratified arroyo fill	Hemming & Haynes 1969
El Bajio, Sonora	40	Unnamed tributary to the Rio Sonora	Surface site on bajada of Sierra San Jeronimo	Robles 1974 Robles & Manzo Taylor 1972 Sanchez & Carpenter 2012

[1] See Figure 19.3.

[2] From the Missoula or "Scablands" Flood.

discussion by Jodry 2005). Anderson (1995, 1996 and references therein) argues that major drainages of the eastern U.S., in particular the Ohio, Cumberland, and Tennessee river valleys, were important travel routes from the Great Plains to the Coastal Plain/Appalachians, based on high concentrations of Clovis points in the area. Anderson (1996:36–37) proposes that these settings were "staging areas" where initial populations may have settled in, taking advantage of plant and animal resources and "some of the best lithic raw material in the region." Concentrations of early- and middle-Paleoindian artifacts along other drainages in the East further suggest that the staging areas provided initial "settlement nuclei from which later Middle Paleoindian regional cultural traditions emerged." In northern Sonora, Mexico, the San Pedro River (just above the concentrated Clovis/mammoth sites in Arizona) shares a low, easily traveled divide with the Rio Sonora (Figure 13.4), which flows into the Gulf of California. The San Pedro and Sonora systems, both with a high concen-

Table 13.6 Clovis vs. Folsom sites in basins of the Greater Southwest (sites and isolates).

Basin	Number[1]	Number of sites (Clovis/Folsom)	References
N Jornada del Muerto, NM[2]	41	3/13	Holliday, in press
S Jornada del Muerto, NM	42	1/5	Holliday, in press
Tularosa Basin, NM	43	4/21	Holliday, in press
Trans-Pecos Texas (west of the Pecos River)[3]		1/12	Seebach 2011
Northern Chihuahua, Mexico		9/7	Holliday, in press
Plains of San Agustin, NM	44	6/29	Hill & Holliday 2011
Estancia Basin & Pinos Wells Basin, NM	45	4/9	Holliday, in press
West Mesa, NM[4]	46	8/135	Judge 1973; Holliday, in press

[1] See Figure 19.3.

[2] Includes Mockingbird Gap Clovis site (Holliday et al. 2009).

[3] Mostly isolates but includes Chispa Creek Folsom site (Seebach 2004).

[4] Includes Boca Negra Wash site (Holliday et al. 2006).

tration of Clovis sites, together would have been an excellent "highway" for Clovis foragers moving through the greater Southwest (Gaines et al. 2009).

The larger rivers such as the Mississippi and the Rio Grande also likely presented formidable travel barriers owing to their width and velocity. There must have been times when the water was relatively quiet and even frozen in higher latitudes or, in the case of the Rio Grande, at higher altitudes; but likewise there must have been times when crossing these large drainage-ways was very dangerous, such as during spring snow-melt or, in the case of the Mississippi, following paleo-lake outburst floods, noted below. Data from the study of raw-material sources in sites on either side of the Rio Grande and Mississippi suggest that the larger rivers were indeed obstacles. On the western side of the Mississippi River there is an almost complete absence of artifacts made of cherts from the Interior Low Plateaus (Fort Payne Formation) of Alabama, Mississippi, and Tennessee. On the other hand, bifaces made of chert from the Edwards Plateau in Texas, a source more than twice the distance away, have been found in the area (Gibson 2001). A similar dichotomy in raw-material sources is reported from Paleoindian sites on either side of the Rio Grande in central New Mexico; cherts from the Edwards Plateau or more local sources are more common on the east side of the valley, whereas sources from west of the river are more common in sites on the west side (O'Brien et al. 2009; B. Huckell, pers. comm. 2012)

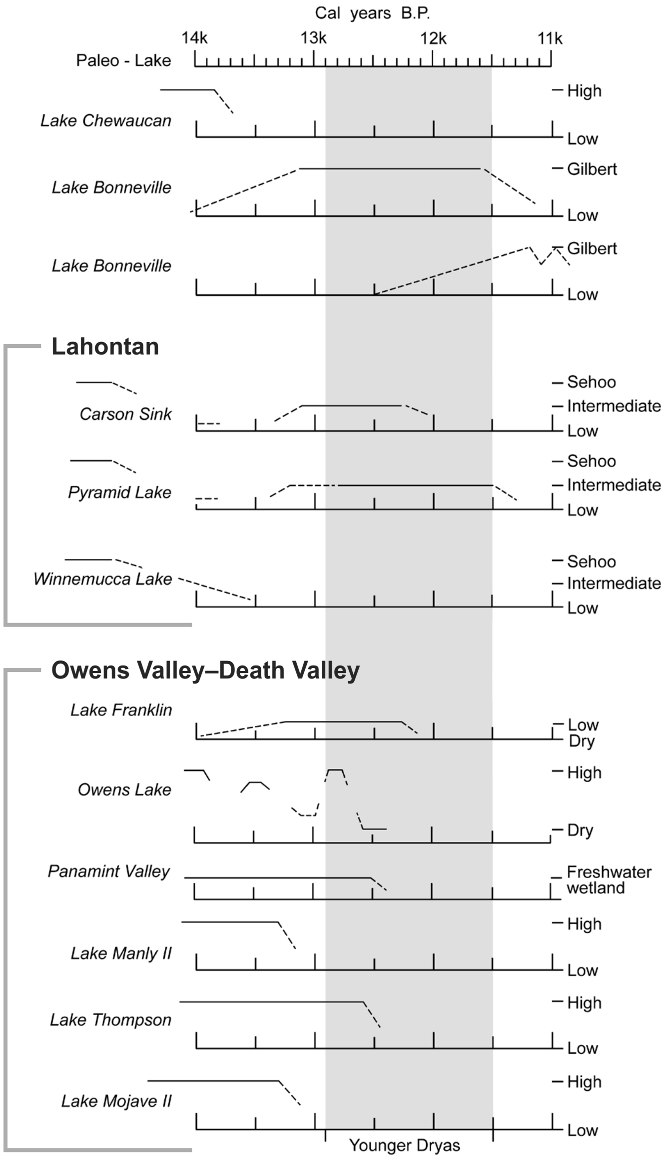

Figure 13.4 Comparison of relative lake-level histories of paleo-lakes in the Great Basin during the terminal Pleistocene. Sources: Lake Chewaucan from Licciardi (2001); Lake Bonneville, upper diagram, from Oviatt et al. (2005); Lake Bonneville, lower diagram, from Benson et al. (2011); Carson Sink from Adams et al. (2008); Pyramid Lake from Adams et al. (2008); Winnemucca Lake from Adams et al. (2008); Lake Franklin from Grayson (2011:144) and Munroe and Laabs (2013); Owens Lake from Orme and Orme (2008, but see also Phillips, 2008); Panamint Valley from Jayco et al. (2008); Lake Manly II from Grayson (2011:118); Lake Thompson from Orme (2008a); Lake Mojave II from Grayson (2011:119).

Paleo-lakes and Lake Basins In addition to abundant water in alluvial systems, the combined effects of still-cooler conditions and melting ice produced large lakes on the landscape, all of which are now gone or greatly reduced in size. These lakes included pro-glacial lakes formed at the margins of the receding ice front, the classic "pluvial" paleo-lakes of the intermontane west, and small "playas" on the Great Plains. All these lakes, which evolved during the terminal Pleistocene owing to climate and other related environmental changes, must have attracted Paleoindian hunter-gatherers because of the abundant resources they offered. Stable landscapes suitable for and sought out for occupation around or near paleo-lakes included the various coastal landforms, older lakebed surfaces, and also localized lunettes. In the Western closed basins with pluvial lakes and paleo-wetlands, older lakebed surfaces and also alluvial fans and other piedmont settings were favored. (Tables 13.5, 13.6) (e.g., Murray Springs, Mockingbird Gap, El Bajio, El Fin del Mundo).

Most of the better-known pro-glacial lakes formed along the southern and southwestern margins of the Laurentide ice sheet. These lakes formed from the complex interaction of ice melt, retreat and re-advance of the ice front, and isostatic depression and rebound (Teller 2004). The largest of these lakes was Glacial Lake Agassiz (Figure 13.1). It formed sometime after ∼13.5k cal yr BP (∼11,700 ^{14}C yr BP), i.e., at the beginning of or shortly before Clovis time and was essentially gone by ∼8.3k cal yr BP (∼7500 ^{14}C yr BP). Lake waters overtopped the southern sill and flowed down the Mississippi several times until ∼12.8k cal yr BP (∼10,900 ^{14}C yr BP) (Teller 2004, fig 9), possibly affecting Clovis groups (Kidder et al. 2008). Few data are available, however, on possible Clovis occupations from the margins of this large lake.

A series of smaller lakes formed to the east of Lake Agassiz and acted as catchments and throughways for its overflow. These lakes included precursors to the Great Lakes. During Clovis time they included somewhat larger versions of lakes Michigan, Huron, Erie, and Ontario (Figures 13.1, 13.2). Surface finds of Clovis artifacts and variants are common around the lakes (Anderson et al. 2010, fig 2), and several in situ Clovis sites are known from the margins of lakes Erie and Ontario (Table 13.1). Ice-sheet reconstructions show a significant change in the size and shape of some of the lakes just between 13.3k and 12.9k cal yr BP (11,500 and 11,000 ^{14}C yr BP) (compare Figures 13.1 and 13.2) (Dyke et al. 2003). At 13.3k cal yr BP (11,500 ^{14}C yr BP) the lake basins not under ice were covered by water over a larger area than the same region today owing to the effects of isostatic depression of the Earth's surface (isostatic "rebound" is slower than ice retreat, so the land remained depressed long after the ice left). By 12.9k cal yr BP (11,000 ^{14}C yr BP), the more-recently deglaciated northern end of the lakes was likewise covered by more water (relative to lake area today), but isostatic rebound progressed to the point where water in Lake Erie and southern Lake Michigan covered a smaller area than today. Some lake-margin sites from early Clovis time, therefore, could be far from the present lake margin, while a late Clovis lake-margin site could be underwater today. There may have been Clovis occupations along the St. Lawrence, but they would now be below sea level.

In the Basin and Range region of the Great Basin and southwestern U.S., there were possibly as many as 95 lakes scattered among the intermontane basins in the late Pleistocene (~80 in the Great basin, Grayson 2011:94; 15 in southern New Mexico, west Texas, northern Chihuahua, and southeast Arizona; Hawley 1993). The chronologies of only a handful are well established, however (Figure 13.4), and the position of Clovis-age shorelines or lake levels is very poorly known. Likewise, archaeological records in many of these basins are poorly known. Most of the available data on Paleoindian occupations are from surface contexts.

Nearly all these lakes reached their high stands in post-LGM time and were in decline by ~13.9k cal yr BP (~12,000 ^{14}C yr BP) or earlier. Data from some lakes suggest they were quite low by Clovis time, but came back up as a result of Younger Dryas cooling (Figure 13.4). In other areas the late-LGM lake desiccation was apparently unidirectional (Figure 13.4). Further, some lake records are at odds with others from the same basin (e.g., Lake Bonneville, Figure 13.4). In detail, therefore, individual lake-level records vary (Grayson 2011; Goebel et al. 2011; Oviatt et al. 2005). This means that geomorphic/environmental systems varied from region to region during Paleoindian (or "Paleoarchaic"; see Graf and Schmitt 2007) time.

Nevertheless, many of the basins held substantial bodies of water or at least were wetlands during Clovis time and must have been attractive resources. Indeed, in the Great Basin finds of fluted points and stemmed points in proximity to ancient shorelines, and assumptions about subsistence activities led to designation of the "Western Pluvial Lakes Tradition" in earlier decades, a concept that has outlived its usefulness (Madsen 2007; Grayson 2011:301; Beck and Jones 1988). Fluted points, either classic Clovis or Western Fluted, are generally found on basin floors in proximity to the margins of ancient lakes and wetlands (Table 13.7), whereas Western Stemmed Tradition are much more broadly distributed across basins and into the ranges (Grayson 2011:289–300; Taylor 2003; Beck and Jones 1997, 2012). Paleo-lakes in the Great Valley of California were also attractive to early foragers (Table 13.7).

In southern New Mexico and adjacent regions, several basins with paleo-lakes have reasonably well reported archaeological records (Table 13.6). All Clovis sites, however,

Table 13.7 Classic Clovis, Western Fluted, and Western Stemmed sites in the Far West.

Site/Site area[1]	Number[2]	Drainage/paleo-lake	Setting	References
Dietz, OR C, WF? WS	47	Alkali Lake	On old lake beds	Willig 1988 Pinson 2011
Paisley Caves, OR WS	48	Lake Chewaucan Basin	Caves facing paleo-lake basin	Jenkins 2007 Jenkins et al 2012 Licciardi 2001
Sunshine, NV WF, WS	49	Sunshine Wash, Lake Hubbs	Buried in alluvial fill	Beck & Jones 2009 Willig 1988
Bonneville Estates, NV WS	50	Lake Bonneville	Shelter facing basin	Graf 2007
Komodo, CA[3] WF?	51	Long Valley	Buried along caldera margin	Basgal 1987, 1988
Owens Lake, CA WF?	52	Owens Valley	Surface, basin floor	Dillon 2006 & refs
China Lake, CA C, WF? WS	53	Owens Valley	Surface, basin floor	Dillon 2006 & refs
Searles Lake, CA WF?	53	Owens Valley	Surface, basin floor	Dillon 2006 & refs
Borax Lake, CA C	54	Borax Lake	Alluvial fan	Meighan & Haynes 1970
Tulare Lake, CA C, WF, WS	55	Tulare Lake	Shorelines of paleo-lake	Dillon 2002 & refs Negrini et al 2006

[1] Site area:
C Classic Clovis
WF Western Fluted
WS Western Stemmed.

[2] See Figure 19.3.

[3] More similar to unfluted Black Rock Concave according to M. Rondeau (personal communication, 2013).

are surface localities or covered by thin layers of Holocene eolian sand. They are thinly scattered across the basins compared with the immediately subsequent Folsom occupation (Table 13.6). Some Clovis localities are in proximity to the ancient lakes, and others are in piedmont settings but overlooking the lakes (Holliday, in press).

Thousands of small (mostly < 1.5 km^2) "playa" basins dot the southern and central Great Plains, largely in northwest Texas, eastern New Mexico, the Oklahoma Panhandle, eastern Colorado, and western Kansas (Bowen and Johnson 2012; Sabin and Holliday 1995; Holliday et al. 1996, 2008). In addition, similar small basins dot the West Mesa and Llanos de Albuquerque in the Albuquerque Basin in the middle Rio Grande Valley of New Mexico (Holliday et al. 2006). Some playas have "lunettes," which are dunes on the downwind margin of the basins (Holliday 1997; Bowen and Johnson 2012). Most of the playa basins formed in the late Pleistocene. The fills are mostly organic-rich muds. These deposits likely represent wetland deposits, and, as such, the playa basins must have been attractive resources for hunter-gatherers. The playa floors in the late Pleistocene were slowly aggrading or stabilized under moist to drying but not wet conditions. The lunettes were likewise stabilized at this time. A few Clovis sites or isolated artifacts are reported from within or adjacent to the playas or in the lunettes (Table 13.8). Several of these sites are mammoth kills. More sites are likely buried in these settings, but await discovery. Natural and artificial exposures through these basins and dunes are rare.

The North American landscape, both in terms of geomorphology and vegetation, was undergoing significant changes before, during, and after the Clovis occupation. The Great Lakes area, for example, changed dramatically as ice retreated ~13.5k–13.0k cal yr BP. Ice retreat also affected the landscape far beyond the ice margin. Retreat of LGM and earlier ice sheets created an extensive till plain across much of the midwestern U.S. Much of the region was poorly drained, providing an array of wetland resources. Silts deflated from outwash in the headwaters of the Mississippi system and on down the Mississippi to the Gulf of Mexico left vast layers of loess. These deposits predate the Clovis occupation of the continent, but not by much. Most of the loess of the continental interior, therefore, defines the upland Clovis landscape.

Stream systems were undergoing changes in discharge, sedimentology, and flow regime whether or not they had glaciated headwaters. Discharges generally were declining, but remained higher or variable compared with today. Broadly speaking, glaciated rivers underwent significant changes in flow regime just before or during the YDC. Unglaciated rivers were more variable. On the Atlantic Coastal Plain the major shifts in flow regime took place just after the LGM, whereas on the Texas Coastal Plain and inland, deep incision and then aggradation began before Clovis time. Unglaciated drainages of the Great Plains were quasi-stable or slowly aggrading from Clovis through the YDC. Along many drainages, regardless of location on the continent, terraces along the valleys, affording well-drained settings, viewsheds, and access to both floodplains and uplands, were attractive settings. Locally, Clovis and other Paleoindian sites on terraces were buried beneath eolian sand derived from the floodplains.

Paleo-lakes were changing dramatically, but also must have provided a wide array of resources to the early foragers. The record of proglacial lakes is complex, owing to evolving water bodies as a function of changes in ice-margin position and drainage direction, and to isostatic rebound. Catastrophic drainage of some pro-glacial lakes along the southern margin of the Laurentide ice sheet could have resulted in dramatic changes in levels of neighboring lakes and in stream discharge far beyond the ice front. Some of these remarkable geomorphic events were almost certainly witnessed by Clovis and other Paleoindian people. In the Great Basin and Southwest, pluvial lakes likewise have variable records. Some were low or completely dry in the late LGM and then came up just before or during the YDC, while others were high before the YDC and then declined just before or during the YDC. Regardless, many basins with available records had either standing water or wetlands and therefore an array of resources for humans. On the southern Great Plains, small playa basins were heavily vegetated and perhaps wet, and attracted animals and humans.

The emerging picture of North America during the spread of the Clovis technocomplex ~13.5k–13.0k cal yr BP is one

Table 13.8 Clovis sites in or around small playas on the Great Plains.

Site	Number[1]	Paleo-lake	Setting	References
Claypool, CO[2]	56	Unnamed small playa Malde 1960 Reider 1990 Stanford & Albanese 1975	Buried in playa	Dick & Mountain 1960
Dutton, CO	57	Unnamed small playa Reider, 1990	Buried in playa	Stanford 1979
Nall, OK	58	Unnamed small playa	Buried in sand sheet adjacent to playa	LaBelle et al. 2003
Miami, TX	59	Unnamed small playa Holliday et al. 1994	Buried in playa	Sellards 1937
Poverty Hill, TX	60	Unnamed small playa	Buried in lunette	Holliday 1997

[1] See Figure 3.

[2] Claypool: unclear association of Clovis and mammoth.

of a remarkably dynamic environment, including complex changes in geomorphology, hydrology, and climate. One of the single most striking aspects of this review is seeing that there are very broad trends in changes in all these aspects of the environment, but in detail they were all changing at different rates and in different directions at both local and regional scales.

Two specific questions raised at the outset of this review are whether physical data provide evidence for

1) abrupt cooling coincident with the beginning of the YDC, and
2) an extraterrestrial impact at the beginning of the YDC ($\sim$12.9k cal yr BP).

Both would have happened late in Clovis time and would have affected Clovis environments if not Clovis foragers. A review of the literature focusing on the Great Plains indicates that, characteristic of the late Pleistocene, the period around $\sim$13.0k cal yr BP saw a variety of changes in paleovegetation and stratigraphic records, but no unidirectional trend toward colder or wetter or drier conditions (Meltzer and Holliday 2010). At the continental scale reviewed here, the same pattern emerges. At the higher latitudes, especially in the Northeast, cooler conditions did appear during the YDC. Elsewhere, temperature patterns were more variable. The same applies to precipitation. Geomorphic systems were also widely variable, likely reflecting local and regional changes in vegetation and climate. But geomorphic changes respond at different rates depending on the nature of the geomorphic system (e.g., lakes vs. rivers) and the nature and rate of change of the external environmental drivers (e.g., climate, vegetation). YDC cooling, so apparent in Greenland ice cores and in the paleovegetation records of Scandinavia, appears to have most significantly and directly affected northeastern North America, which is the region in closest proximity to the classical or "type" YD area.

The above synthesis of the environmental data presented in this paper for $\sim$13.0k further shows that there is no paleo-environmental evidence for any sort of "cosmic catastrophe"at that time. An extraterrestrial impact producing the sort of continental-scale destruction of the natural and human environment that has been proposed (Firestone et al. 2006, 2007) should show up as a distinct marker in geomorphic, biological, and archaeological records at and just after $\sim$12.9k cal yr BP, but it clearly does not (see also Holliday and Meltzer 2010; Boslough et al. 2012). The North American foragers who made Clovis and similar artifact styles 13,000 years ago clearly thrived amid a very wide array of environmental conditions that were undergoing rapid changes. The artifact assemblages evolved, perhaps as a means of keeping up with some changes in the environmental system (e.g., changes in faunal assemblages). Consequently, the Clovis archaeological record provides an extremely valuable case study that illustrates the ability of our species to adapt to a myriad of novel, dynamic ecological contexts.

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