Catena 78 (2009) 310–322

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Geoarchaeology and the search for the first Americans

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ARTICLE INFO

Article history:
Received 7 December 2007
Received in revised form 10 February 2009
Accepted 11 February 2009

Keywords:
Paleoindian
First Americans
Clovis
Folsom
Beringia

ABSTRACT

Research into the origins and subsequent development of the first American cultures ("Paleoindians"), in particular the timing and place of their arrival, has provoked heated, contentious debates in North American archaeology since the 19th century. Many of the questions in this archaeological puzzle are fundamentally geological and thus many of the answers have come from the geosciences, including geology, geography, and soil science, and at a wide range of spatial scales. Stratigraphy, perhaps the most basic principle in both archaeology and geology, first established the antiquity and chronology of the earliest artifact assemblages at sites such as Folsom and Clovis in New Mexico by demonstrating clear association of artifacts and Pleistocene fauna. Geologists and paleontologists further provided age estimates of sites in the absence of other forms of numerical age control. Geologists also were prominently involved in developing the radiocarbon method and applying it to Paleoindian sites. Many Paleoindian sites also yielded not only extinct fauna, but stratigraphic records with evidence of markedly different depositional environments in the past. These sites were inviting to geologists because many investigators had backgrounds in Pleistocene paleontology. The ancient fauna and the striking contrasts between past and present depositional environments drew the attention of archaeologists and earth scientists alike who recognized the paleoenvironmental implications. At regional, subcontinental scales the peopling of the New World has been a question revolving around lowered seas levels and fluctuating glacier margins. Modeling sea-level changes and the paleogeography of the "Bering Land Bridge" and the high-precision dating of ice retreat over Canada is helping to understand the environmental conditions faced by Native American forbears in Beringia and the environment, route(s), and timing of their entry into North America.

1. Introduction

The peopling of the New World is a topic of considerable research and debate (often acrimonious) among American archaeologists and their various interdisciplinary collaborators such as geoarchaeologists. Determining when humans first arrived in the Americas, and where they came from and how they got here, are some of the most fundamental issues in American archaeology and have been so in some form since the initial European colonization of the continent. Because chronology and geography are key themes in these fundamental questions, the geosciences have long been an intimate component of the archaeological investigations.

This paper is a look at the some of the many ways in which geoarchaeology has contributed to our understanding of the peopling of the New World. It provides a sampling of the many geoscientific approaches that have been employed at all scales of space from continental to microscopic to focus on this key issue in American archaeology, known as Paleoindian archaeology. The issues involved in understanding the peopling of the New World include archaeologists and their collaborators in both North and South America, of course. This paper will focus on North America, however, because there is a much larger, more extensive and more integrated English-language literature on the topic from North America. The paper begins with a brief historical sketch of the debate over the antiquity of humans in the Americas and the role of geology in resolving the issue. The historical sketch includes discussion of geology in helping to resolve issues of chronology, but the role and significance of radiometric dating and geochronology is not otherwise dealt with. The topic is vast and its role in Paleoindian archaeology has been addressed elsewhere (Haynes, 1992; Holliday, 2000). The main part of the paper follows, providing examples from a variety of studies across North America to illustrate the broad array of geoscientific approaches to understanding the peopling of the New World.

2. Background

The geosciences is but one of many disciplines that have been brought to bear to enhance our understanding the peopling of the New World. It was the first discipline employed, however, just as American archaeology itself was taking form. The discovery of a human prehistory in "deep time" was first made in Europe in the middle of the 19th century (Grayson, 1983), but the notion quickly spread to the U.S.

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doi:10.1016/j.catena.2009.02.014

scientific community and launched a search for an equally ancient archaeological record in North America (Meltzer, 1983, 1994, 2006a). The result was a ferocious debate that lasted for decades over the antiquity of Native American populations (see Meltzer, 1983, 1991, 1994, 2006a); essentially whether humans had been in the New World since the Pleistocene (an "American Paleolithic") or were very recent arrivals. Geologists were key players in the debate, offering observations and opinions regarding the age of "rude" implements, based on stratigraphic relationships to inferred glacial deposits or to Pleistocene fauna. By the early 20th century the debate shifted somewhat to the antiquity of human remains or obvious artifacts, with the answer usually provided, once again, by demonstrating or disproving stratigraphic relationships with Pleistocene fauna (Meltzer, 1983, 2006a). The debate was finally resolved during excavations near Folsom, in northeastern New Mexico (1926–1928) (Fig. 1), when well-made projectile points were found in intimate and undisputed association with the bones of extinct, Late Pleistocene *Bison* (Meltzer, 2006a,b).

From the outset, geology and what would become geoarchaeology has been an important, even key aspect of Paleoindian archaeology. One of the early investigators, E.B. Howard (not a geologist) was explicit in his belief that interdisciplinary research, especially geology, was a prerequisite to understanding Paleoindian archaeology:

> Geology, particularly its allied branches of palaeontology, physiography, and glacial geology, must be called upon to explain many phases of the subject [of the peopling of the New World] that involve a wide variety of converging lines of research, presenting many peculiar difficulties. The archaeologists, starting from the point where the historian usually leaves off, soon finds it necessary to lengthen his perspective, and eventually he is faced, so far as America is concerned, with a geological problem. The recognition on his part of the importance of special studies relating to such factors as climatic changes, studies of invertebrates, analysis of diatoms, or pollen that may be found in a given deposit marks a step in the right direction. Therefore the archaeologist must familiarize himself with these and other phases of geology which bear upon the problem, such as the study of terraces, buried soil levels, loess deposits, varved clays, ancient lakes and shore lines, and any other factors which may give a clue to the environment in which early man lived in America... [T]he importance of a field of investigation which lies somewhere between geology and archaeology...is becoming increasingly apparent as a number of scientists recognize (1935:62).

Rephrased in a more contemporary context "the prominent role of geology in Paleoindian archaeology...is explained [in part] by...the distinctive archaeological, paleoenvironmental, and evolutionary problems that are addressed by students of the Paleoindian period" (Ferring, 1994:57).

A variety of circumstances explain why geology and geologists were involved in Paleoindian research from the outset. As alluded to above, stratigraphy and paleontology (which was in the domain of geology) were crucial to estimating the age of archaeological sites in the years prior to the development of radiometric dating (e.g., Haynes, 1990; Holliday, 1997, 2000). Further, Paleoindian sites were inviting because many investigators had interests in Pleistocene stratigraphy and paleontology (e.g., Haynes, 1990; Holliday, 1997; Mandel, 2000; Meltzer, 2006a). The presence of a Pleistocene archaeological record in North America was "an enormous stimulus to research" (Bryan, 1941:508) by geologists on Paleoindian sites (Wilmsen, 1965). Geologic research was inseparable from their approach to archaeology. Finally, and more

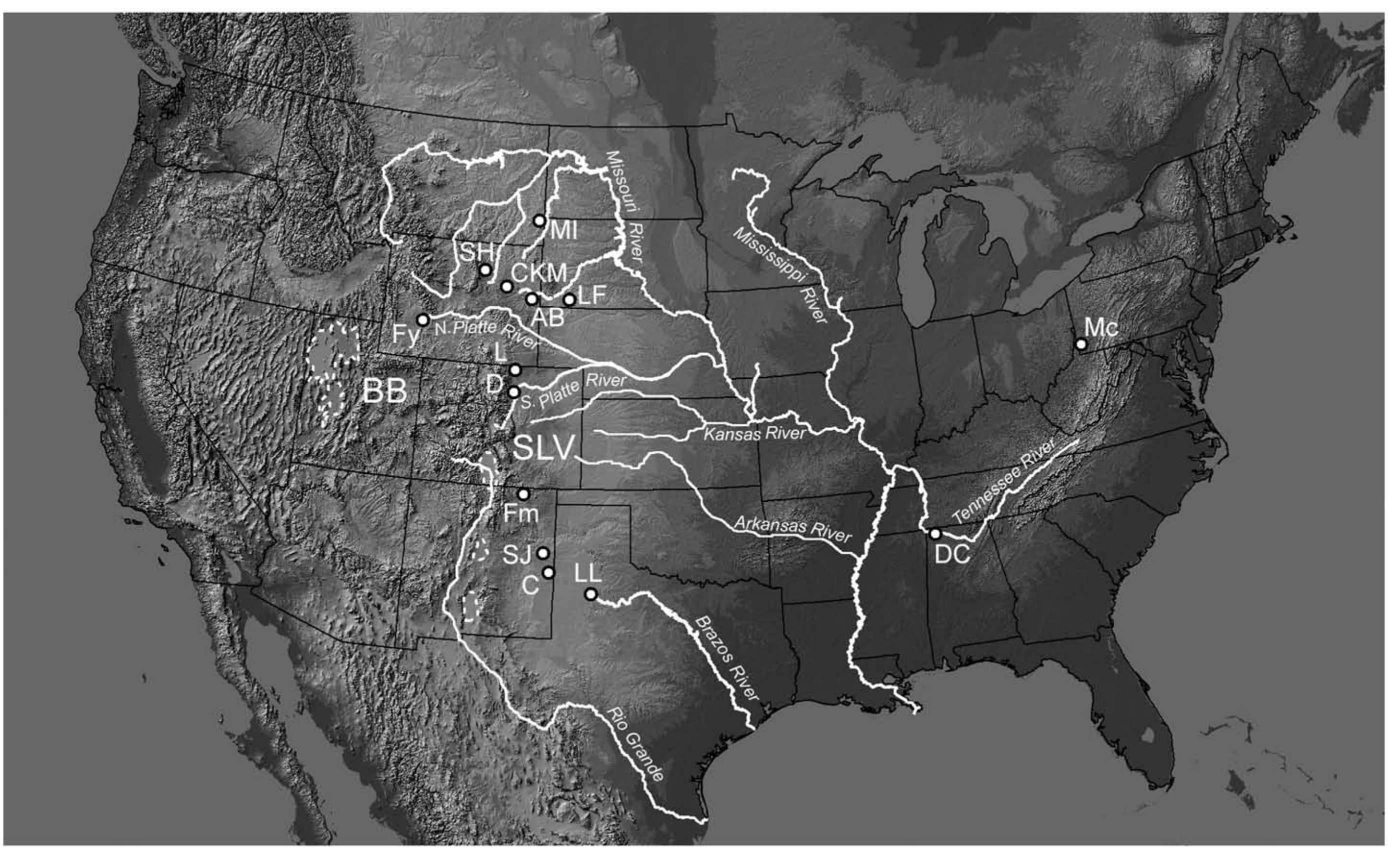

Fig. 1. The Unites States and parts of Canada and Mexico showing the location of sites, rivers, and selected physiographic features mentioned in the text. Archaeological sites: AB = Agate Basin; C = Clovis; CKM = Carter/Kerr-McGee; D = Dent; DC = Dust Cave; Fm = Folsom; Fy = Finley; L = Lindenmeier; LF = Lange-Ferguson; LL = Lubbock Lake; Mc = Meadowcroft; MI = Mill Iron; SH = Sister's Hill; SJ = San Jon. Basins: BB = Bonneville Basin; SLV = San Luis Valley.

specifically, many of the archaeological sites investigated have thick, well-stratified deposits which provide evidence of markedly different depositional environments in the past (e.g., meandering streams where arroyos now prevail or perennial, fresh-water lakes in presently dry basins) owing to the dramatically different environmental conditions at the end of the Pleistocene (Haynes, 1990; Ferring, 1994; Holliday, 1997). These striking contrasts between past and present depositional environments drew the attention of archaeologists and earth scientists alike who recognized the paleoenvironmental implications (Haynes, 1990; Holliday, 1997; Mandel, 2000).

The discoveries near Folsom ushered in a new direction in American archaeology, the study of what is known in North America as Paleoindian (or Paleo-Indian or Paleo-American) archaeology. In short order a series of sites were investigated and reported, providing the initial broad outlines of Paleoindian archaeology and chronology. Fundamental stratigraphic principals and the use of distinctive artifact styles as "index fossils" played an important role in these developments (Holliday, 2000). The artifacts found at Folsom included a very distinctive style of projectile point: a wide, thin, finely made lanceolate artifact of high quality chert. A striking characteristic is its "flutes"—the long, wide, thin grooves on both sides formed by very careful preparation and removal of flakes (Fig. 2). These artifacts became known as Folsom points. Fluted points were soon recognized from collections across the continent, but considerable variation in the size, shape, and technological style and quality of these artifacts were also recognized. Further, some of the fluted artifacts were found in association with mammoth, and other fluted assemblages were found along with finely made lanceolate points that were unfluted (Holliday, 2000; Meltzer, 2006a). Two significant problems were that some of these artifact assemblages were from single-component sites (allowing no stratigraphic comparisons or distinctions with other occupation zones) and other collections were mixed assemblages from surface contexts, in particular, blow-outs that developed across the Great Plains during the "Dust Bowl" of the 1930s. There was no way to assess the age relationships among the various styles.

Excavations and geologic investigations at several well-stratified sites with multiple, sequential Paleoindian occupations slowly clarified the relative ages of some of the better documented artifact assemblages in the two decades following the work at Folsom. At the Lindenmeier site in northeastern Colorado (Fig. 1), unfluted lanceolate points (Fig. 2) overlapped with or were stratigraphically younger than Folsom (Roberts, 1936). Essentially the same relationship was documented at the Clovis site (also called Blackwater Draw Locality 1) in eastern New Mexico (Fig. 1) (Sellards, 1952). More significantly, the excavations at Clovis showed that the larger, less well-made fluted style, which came to be termed Clovis (Fig. 2), was consistently below the more finely made classic Folsom style (Sellards, 1952). Clovis was also consistently associated with mammoth whereas Folsom and the unfluted styles were associated with extinct *Bison* (Cotter, 1938; Sellards, 1952). These faunal/artifact associations seemed to hold at many other sites across North America (Meltzer, 2006a).

Fig. 2. Examples of classic Paleoindian projectile points and point styles from key sites on the Great Plains (a–d are "fluted" styles; e–h are unfluted lanceolate styles): a, b) Clovis points from the Clovis site (Blackwater Draw No. 1) in New Mexico; c,d) Folsom points, also from the Clovis site; e) an Alberta variant of the Scottsbluff style from the Hudson-Meng site, Nebraska; f) a Cody (or Firstview) point from the Clovis site; g) a Plainview point from the Plainview site, Texas; h) a Hell Gap point from the Hell Gap site, Wyoming. These points are plastic casts (color matched, except for g) of the original artifacts; from the C. Vance Haynes cast collection; Department of Anthropology, University of Arizona.

By the 1950s, the broad outline of Paleoindian artifact sequences was emerging based on stratigraphic investigations at a number of sites, but especially on the Great Plains (Holliday, 2000; Meltzer, 2006a). At the same time, the first attempts at assigning numerical ages based on the newly developed radiocarbon method were emerging (Libby, 1952, 1955). Radiocarbon was not the first method for making numerical age estimates of Paleoindian sites and occupations, however. An approach called "geologic–climatic dating" was applied to several Paleoindian sites on the Great Plains following the Folsom discoveries. It was a means of estimating numerical ages via stratigraphic (and usually long distance) correlation. This approach tended to be applied in sites and settings where stratigraphy or geomorphology could be directly traced to glacial or paleo-lake deposits or landforms. The local glacial or lake chronology was then correlated to a varve chronology defined for northeastern North America (Antevs, 1955; see also Zeuner, 1958:20–36; Oakley, 1964:51–57; Haynes, 1990). The method, therefore, could not be applied in all situations. The Folsom site, for example, is in a small tributary of an unglaciated stream and thus did not lend itself to geologic–climatic dating.

One of the best-known applications of geologic–climatic dating is the classic study of Bryan and Ray (1940) attempting to date the Folsom occupations at the Lindenmeier site (see also Haynes, 2003). The site is on the High Plains just a few kilometers east of the Rocky Mountain Front Range in a small, dry, low-order tributary of the Cache La Poudre River, in turn a tributary of the South Platte River (Fig. 1). The strata at Lindenmeier could not be traced directly to the Cache La Poudre, so a correlation was made between the Folsom material in the site and the terrace of the South Platte that contained fluted Clovis points and mammoth at the Dent site (Fig. 1) (at the time of their work, the typological and chronological distinction between Folsom and Clovis artifacts had not been made). The workers then traced the terraces from the South Platte into the Cache La Poudre and up its valley to the glacial landforms and deposits in the headwaters of the drainage in the Rocky Mountain Front Range. They then correlated the local glacial sequence with the varve chronology. Based on these long distance correlations, they decided that the Folsom material at Lindenmeier was between 25,000 and 10,000 years old, most likely closer to the older age. Antevs (1941) disagreed with their correlations and believed that the Folsom material was closer to 10,000 years old.

Geologic–climatic dating was also used to date Paleoindian artifacts at the Clovis site in New Mexico and the Finley site in Wyoming (Fig. 1). At the Clovis site, Antevs (1935, 1949) correlated the deposits containing fluted points (both Clovis and Folsom artifacts) and extinct fauna with the lake level history of paleo-Lake Estancia in central New Mexico (Figs. 1 and 3). Antevs (1949:190) concluded that "The artifacts...appear to be at most 13,000 and at least 10,000 years old." Hack (1943) and Moss (1951) attempted to date unfluted, lanceolate "Eden" artifacts at the Finley site, which was in eolian sand resting atop a terrace of the Eden Valley. The terrace was traced upstream to the moraines of the nearby Wind River Range of the Middle Rocky Mountains. The investigators correlated the terrace below the Finley bone bed and its equivalent moraine system in the Wind Rivers with the terrace-moraine system that Bryan and Ray (1940) considered to be of Folsom age. Thus, the Finley artifacts were believed post-Folsom (but also pre-middle Holocene) in age (Moss, 1951, 1952), probably between 10,000 and 7500 years old (Moss, 1951:80–81).

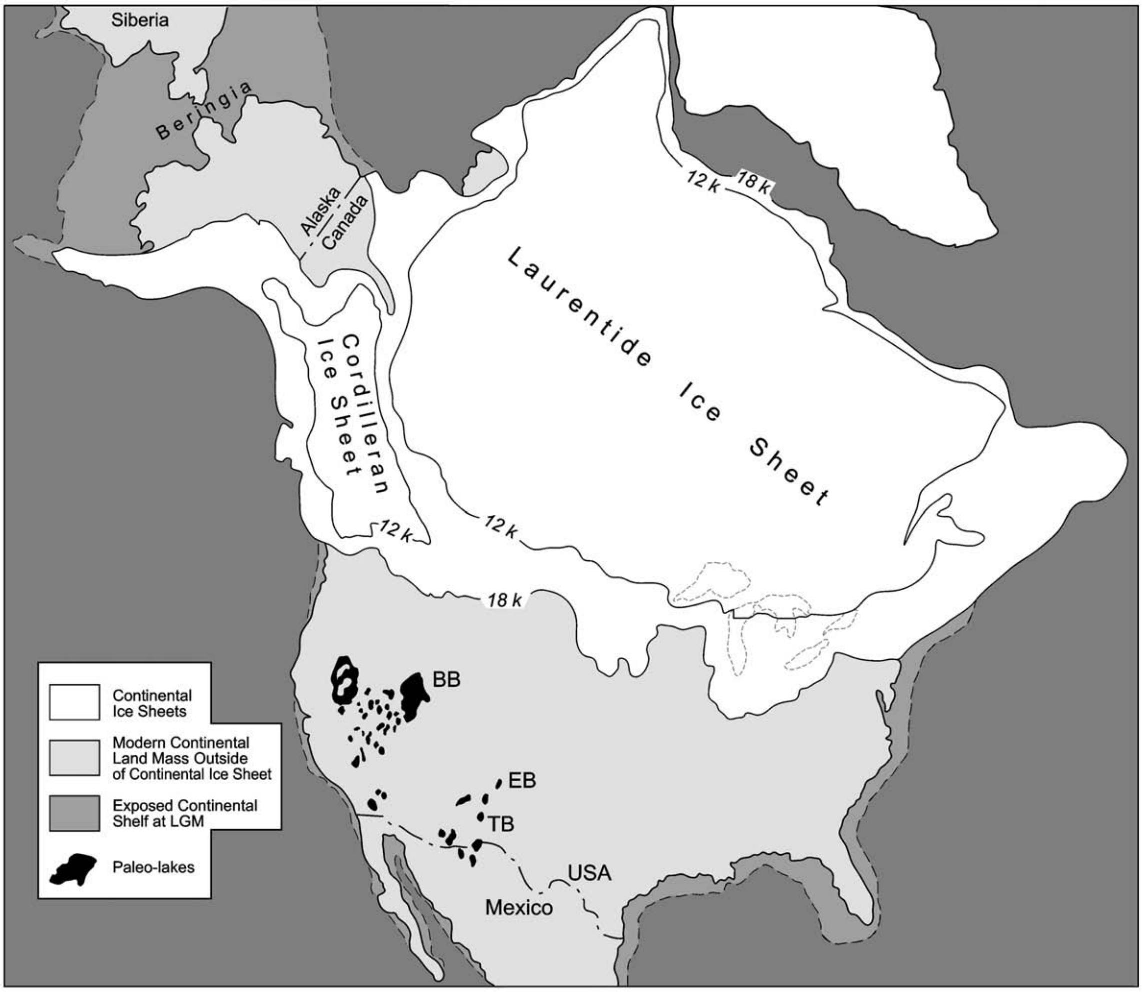

Fig. 3. North America showing: 1) the extent of continental land areas, including Beringia, during maximum LGM sea-level lowering; 2) the extent of the major continental ice sheets (Laurentide and Cordilleran) during the LGM (at 18,000 radiocarbon years BP "18 k") and at 12,000 radiocarbon yrs BP (12 k), just prior to the appearance of the Clovis artifact style (the "Ice Free Corridor" is apparent as the zone separating the two ice sheets at 12 k) (ice sheet positions from Dyke et al., 2003); 3) location of the Great Lakes relative to ice extent (note that the basins were just emerging as ice retreated at 12,000 radiocarbon yrs BP); and 4) location of selected paleo-lake basins in the western U.S. (BB = Bonneville Basin; EB = Estancia Basin; TB = Tularosa Basin).

By the 1960s radiocarbon dating had become well established and widely accepted as a standard method for numerical dating. It also offered a means of checking the age estimates by Antevs, Hack, Moss, and Bryan and Ray for Paleoindian occupations, and they were remarkably accurate (Holliday, 2000; Haynes, 2003).

Geoarchaeology proliferated throughout North America and especially in the U.S. beginning in the 1950s and particularly through the 1960s and 1970s via development of "environmental archaeology" (e.g., Butzer, 1964, 1971) and "cultural resource management" (formerly salvage archaeology or, in Europe, rescue archaeology) (e.g., Mandel, 2000). The rest of this paper is a look at the geoarchaeological approaches and themes that have helped shed light on the chronology, environments, and subsistence of the first Americans, as well as processes that affected the preservation of the early sites.

3. Site and regional stratigraphy

Both historically and still today site stratigraphy remains the most fundamental and most widely applied aspect of geoarchaeology in Paleoindian studies (e.g., Ferring, 1994; Mandel, 2000; Holliday and Mandel, 2006). Along with sedimentology, site stratigraphy provides the primary clues to reconstructing site settings and how they changed through time. Site stratigraphy also continues to play an important role in reconstructing local and regional environments. All of these aspects of geoarchaeology are exemplified in the early research on the Southern Great Plains, as alluded to above, and they continue today. Two of the key sites are Clovis, noted above, and Lubbock Lake, in Lubbock, Texas (Fig. 1), both associated with "draws" or now-dry tributaries to the Brazos River. Older sediments in the draws, especially those associated with Paleoindian archaeology and extinct fauna, indicated that these old drainage-ways reflected very different environmental conditions in the late Pleistocene. Investigators have long noted the similarities in the stratigraphic and archaeological sequences at each site (e.g., Sellards, 1952). The fill at Clovis was exposed in a gravel pit that expanded episodically from the 1930s to the 1960s, providing a sequential look at the stratigraphy but also destroying the site and resulting in an incomplete archaeological and geological record (Hester, 1972). During the initial investigations at the Clovis site, along Blackwater Draw, Howard (1935: 81) observed "bluish-gray sands" containing most of the Paleoindian record. Similar deposits locally rich in bone from extinct vertebrates and associated with stone artifacts were also noted at other nearby localities along the draw (Howard, 1935; Stock and Bode, 1936).

The blue sand, and an underlying "gray sand" were immediately recognized as important geoarchaeological marker beds. Most of the subsequent research at the site focused on these deposits. The blue sand consisted of several different layers: the lower blue sand

Fig. 4. Bone bed of extinct *Bison antiquus* in diatomite (Unit D) at the Clovis site, New Mexico. Folsom artifacts were found in association with the bone.

included organic-rich, diatomaceous muds and local beds of pure diatomite, whereas the upper blue sand contained organic-rich silt and sand. The archaeological investigations focused on the diatomaceous mud, diatomite, and gray sand, all of which produced fossils of extinct vertebrates (Fig. 4) as well as stone tools including fluted lanceolate points. These strata indicated substantial changes in depositional environment, documented by a number of paleoenvironmental specialists, including geoarchaeologists (see Wendorf, 1961; Haynes and Agogino, 1966; Hester, 1972; Wendorf and Hester, 1975; Haynes, 1975, 1995; Holliday, 1997). The interpretations from these various lines of evidence were in basic agreement. The lower, pale gray sands, which contained mammoth and Clovis artifacts, were deposited by flowing water, which was fresh to slightly brackish. The diatomaceous layers, with Folsom bison-bone beds and camps, accumulated first in a lake, and then under more marshy conditions. Initially the water conditions were fresh but became saline. The organic-rich silt and sand, with unfluted lanceolate points and more bison-bone beds, represented eolian fines settling into the basin. The changing conditions were interpreted to indicate gradual drying during the Paleoindian occupation, i.e., from the late Pleistocene into the Holocene.

The Lubbock Lake record is basically similar to Clovis (Fig. 5). The stratigraphy there was exposed in a reservoir that cut through the valley fill of Yellowhouse Draw (Johnson, 1987). A more extensive look at the stratigraphy was provided by backhoe trenches and cores (Stafford, 1981; Holliday, 1985). Extinct fauna of Clovis age were recovered from alluvial (“gray”) sands. Alluviation ended ca 11,000 ^{14}C years BP, replaced by lacustrine and palustrine conditions. Above the sands, bone beds of extinct *Bison* with Folsom artifacts were recovered from muds interbedded with microstratified diatomite beds (Fig. 5). The diatomites represent periods of standing water along the floor of the draw while the muds denote periods when the draw had moist vegetation, but no standing water (Holliday, 1985). Bison kills were carried out on firm, relatively dry lake beds on the floor of the draw. Through time (ca 11,000 to 10,000 ^{14}C years BP), the diatomite beds become thinner and less well expressed, but the muds become thicker. After 10,000 ^{14}C years BP only muds were deposited; standing water was no longer present in the draw. This condition persisted until ca 8500 ^{14}C years BP, during which Late Paleoindian occupants used the floor of the draw to kill bison and to camp. As at Clovis, the sedimentological trend during the course of the Paleoindian occupation suggests that declining amounts of water were available in the draw; i.e., the area was drying. Paleobiological records support this interpretation (Johnson, 1986; Holliday, 1995).

Stratigraphic investigation of the draws of the Southern Great Plains via coring shows that the stratigraphy and depositional chronology is similar throughout (Holliday, 1995). The terminal Pleistocene to early Holocene transition was characterized by a change from deposition of alluvial sands to deposition of palustrine muds and carbonates with localized accumulation of lacustrine sediments. In addition to Lubbock Lake and Clovis, a few other Paleoindian sites are known from within or along the draws (e.g., Sellards et al., 1947; Holliday, 1997). Others are almost certainly present in the draws but are deeply buried and rarely exposed (Holliday, 1995). Clovis and Lubbock Lake are exceptional cases.

Fig. 5. Excavations at Lubbock Lake, Texas, in 1974. The crew is working at several levels in the bedded diatomite (stratum 2d), which shows up as the distinct, horizontal, lighter (diatomite) and darker (mud) beds. The top of the diatomite (on which most of the crew stands) in this area contains the Plainview bone bed reported by Johnson and Holliday (1980). The darker muds within the diatomite contain Folsom-age bison-bone beds. The top of alluvial sands are exposed throughout the area in the lower right. The homogeneous muds of late Paleoindian age are about 50 cm thick and exposed low along the back wall of the excavations. Note the lack of deformation of the diatomite beds despite the multiple bison butchering activities. (From Holliday, 1997, Fig. 3.28. Reprinted with permission of the University of Texas Press).

Besides stratigraphy and depositional environments, another characteristic shared by the Clovis and Lubbock Lake sites and, based on a limited sample, other sites in the draws, is the variable preservation of bones from large vertebrates in the Paleoindian levels. Remains from the Clovis-age alluvial "gray sand" at both sites are relatively well preserved. Bone from the diatomite, in contrast, is usually in very poor shape. In part this may be due to fluctuating water levels during and after the bone was left on the surface. Further, dewatering and compression of the diatomite, as the water table fell and the draws aggraded through the Holocene, crushed the bone. Bone in the muds that overly the diatomite beds at Lubbock Lake are heavily weathered, again likely owing to the variably wet depositional environment, but not crushed like those in the diatomite (the mud is not porous and thus not susceptible to compression).

Other examples of stratigraphic research in Paleoindian studies abound. In addition to the Southern Great Plains, one of the highest concentrations of stratified Paleoindian sites is on the Northern Great Plains, primarily in Wyoming (e.g., Frison, 1991; Frison et al., 1996; Hofman and Graham, 1998). Unlike the Southern Great Plains, the more northerly reaches are undergoing relatively rapid erosion, especially in the headwaters of the Missouri River. This erosion exposed a number of sites along low-order tributaries. Key Paleoindian sites include Carter/Kerr-McGee (Frison, 1984; Reider, 1990), Sister's Hill (Agogino and Galloway, 1965; Haynes and Grey, 1965), and Agate Basin (Frison and Stanford, 1982), all in eastern and northeastern Wyoming, and Lange-Ferguson (Hannus, 1990), in the badlands of southwestern South Dakota (Fig. 1). These sites represent Paleoindian occupations along low-order floodplains (Sister's Hill) or kill/camp sites in arroyos or badlands (Agate Basin, Carter/Kerr-McGee, Lange-Ferguson). Most of the occupation zones are associated with buried soils exhibiting evidence of poor drainage (i.e., redoximorphic features in Bg and Cg horizons), which suggests that local water tables were high at the time (Fig. 6) (e.g., Sister's Hill, Agate Basin, Carter/Kerr-McGee). Such settings likely were attractive to game animals but also must have provided a wide range of resources. These wetland settings that were so attractive to Paleoindians appear to have dried through Paleoindian time. R.G. Reider, a geoarchaeologist who studied soils at these localities (summarized in Reider, 1990), shows that soils associated with Clovis and Folsom occupations are higher in organic mater and are more strongly gleyed and mottled, whereas younger soils associated with later Paleoindian occupations exhibit weaker gleying and mottling (Fig. 6). Given the known trends in early Holocene climates on the Great Plains, drying as expressed in the soils is a likely scenario. However, the differences in soil morphology could also be related to shorter duration of pedogenesis in the younger soils (due to burial), allowing less time for high water tables to modify the soils.

The on-going processes of headward erosion and arroyo cutting in Wyoming and South Dakota, which formed effective traps utilized by Paleoindian hunters, and revealed the resulting sites to the archaeologists, likely destroyed many sites as well. Frison (1984) well-describes the impact of arroyo cutting on the Paleoindian archaeological record on the Northern Great Plains. At Carter/Kerr-McGee, which was in a paleo-arroyo, "headward erosion of the arroyo subsequent to the Paleoindian activity removed most of the site... The present cycle of headward erosion was progressing rapidly toward the remaining site deposits at the time of its discovery" (p. 290). Likewise, at Sister's Hill "a few more meters of lateral stream cutting would have destroyed any evidence of the... site" (p. 308). The Mill Iron site (Frison, 1996), a Goshen/Plainview bison kill in southern Montana (Fig. 1), provides a graphic example of the effects of erosion in the upper Missouri River drainage. The kill was in a swale that once flowed down the gently sloping valley walls of a creek. Holocene erosion left the area of the kill on top of a small butte, now isolated from and ~25 m above the creek. Frison (1984 p. 305–309) further argues that upland erosion likely destroyed many camping sites that would have been near arroyo kill-sites, heavily biasing our view of Paleoindian activities.

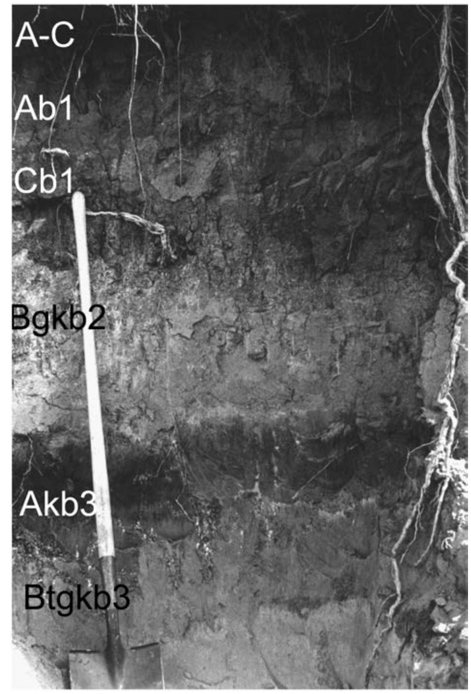

Fig. 6. Soil-stratigraphy at the Carter/Kerr-McGee site, Wyoming (modified from Reider, 1990, Fig. 7; reproduced with permission of the Geological Society of America and R. G. Reider) (photo provided by R. G. Reider). The Akb3 "black mat" is Clovis-Folsom age. It probably formed as a kind of "wet meadow soil" which also resulted in gleying of the B horizon below. The b2 soil contains Agate Basin, Hell Gap, and Cody Complex occupation debris. The carbonate in the b3 and b2 soils probably is from the overlying soils and represents welding of the soils. Horizon designations are modified from the original publication following Holliday (2004, Appendix 1).

4. Landscapes and geomorphology

The investigation of Paleoindian archaeology at a landscape scale or via regional geomorphology has been limited compared to research on site and regional stratigraphy. A few examples illustrate the value of such studies in understanding the relationship of the first Americans to the evolving landscape, however.

One of the first areas to undergo a systematic attempt to locate Paleoindian sites and relate them to the landscape and past environmental conditions is the Albuquerque Basin along the middle Rio Grande in central New Mexico (Fig. 1). The area is composed of thick, extensive early-Pleistocene basin fills incised by the Rio Grande and its tributaries, forming broad floodplains, and a series of terraces and pediments, with localized basalt mesas. The setting and artifact assemblages of 59 Paleoindian sites in the area were investigated by Judge (1973), including several sites that were tested or excavated (Dawson and Judge, 1969; Judge and Dawson, 1972). Additional Paleoindian sites have also come to light (e.g., Huckell and Kilby, 2000; Holliday et al., 2006). Approximately half of the sites include Folsom assemblages. Most of the rest are characterized by unfluted lanceolate styles (Belen/Plainview and Cody/Firstview). One Clovis site is reported.

A large proportion of the sites are located on the Llano de Albuquerque (or West Mesa), a relatively high, flat, open remnant of basin fill on the west side of the Rio Grande. A notable characteristic of this landscape is the presence of numerous depressions that apparently acted as lake or playa basins. Most of the Paleoindian sites are near these depressions. The sites themselves, however, are in the sand sheets and dune fields and generally are shallowly buried. As such, the artifact assemblages were likely subjected to some mixing.

Nevertheless, the sites appear to represent occupations during discrete periods (i.e., assemblages from different time periods are not mixed). Analysis of site distributions (Judge, 1973) shows that Folsom occupations are in proximity to the playas while later occupations are more widely dispersed. This pattern apparently reflects relatively wet conditions during the Folsom occupation, which made the playas particularly attractive resources, but post-Folsom drying and dispersion of occupations across the landscape as the playas became less attractive or reliable resources. Paleoenvironmental analysis of the fill in one of the playas (Holliday et al., 2006) confirms the paleoenvironmental hypothesis generated by the site distribution data.

The Upper Rio Grande of New Mexico and Southern Colorado (Fig. 1) must have been attractive to early people, but relatively few sites have been reported along the valley itself. The above mentioned sites in the Albuquerque Basin are on uplands away from the valley. The other area with numerous well documented early sites is the San Luis Valley in Colorado (Fig. 1). Sites there are buried in dunes and associated with paleo-wetlands at some distance from the river (Jodry, 1999). The relative paucity of sites along the valley is probably due to several geological circumstances. Many of the late Pleistocene strata in the mainstream and fan deposits accumulated under high-energy conditions (e.g., Gile et al., 1981; Pazzaglia and Wells, 1990; Connell and Love, 2001; Connell et al 2005). Sites in these settings would not preserve well. Further, shortly before the Paleoindian occupation of the region the Rio Grande was deeply entrenched and then began to aggrade (Connell and Love, 2001; Connell et al 2005). Occupations in this setting, if they survived the alluvial processes, will now be deeply buried and invisible.

The likelihood that Paleoindian sites are deeply buried and largely invisible along major drainage systems has been recognized by geoarchaeologists working elsewhere in the interior of North America. This situation was graphically illustrated by discovery of the Aubrey site along the Trinity River in north central Texas. There, an extensive Clovis occupation was discovered 8–9 m below the modern floodplain (Ferring, 1994, 2001). Repeated discovery of deeply buried Paleoindian sites along the drainage systems of the Kansas and Arkansas rivers in Kansas (Fig. 1) (Mandel et al., 2004a,b) resulted in a systematic examination of stream valleys, draws, and fans along these drainages to better understand their stratigraphy and depositional history as a means of 1) predicting site locations, 2) understanding site preservation and destruction, and 3) reconstructing paleoenvironments (Mandel, 2008). Paleoindian sites and Paleoindian-age deposits are associated with overthickened or "cumulic" A horizons of buried soils. Following deep incision and then quasistable alluviation in the late Pleistocene, the floodplains became more stable except for incremental additions of flood deposits. The result was development of an over-thickened (up to 2 m) A horizon that forms a distinct stratigraphic marker. Stabilization and soil cumulization began as early as ~11,500 ^{14}C years BP but was underway in most sections by ~11,000 ^{14}C years BP; hence, this process was time-transgressive. The cumulic soils are buried by flood deposits, interpreted to represent the onset of high-magnitude flooding. This shift in depositional environment was likewise time-transgressive, varying from ~10,000 to ~9000 ^{14}C years BP. The stable floodplain landscapes that persisted from >11,000 to as late as 9000 ^{14}C years BP would have been ideal settings for occupation. This research identified a key and easily recognizable stratigraphic marker (a deeply buried cumulic A horizon), but one that is also time-transgressive, as soils tend to be. Further, recognition of high-energy Holocene alluvial activity helps in understanding processes that might destroy sites.

Predicting and understanding site locations and understanding processes of site preservation using regional geoarchaeology has also been applied in geomorphologically complex landscapes. The interior of Alaska is one such setting. The area was on the northwest side of the Cordilleran-Laurentide ice sheet complex that effectively separated the interior of North America from the Old World (Fig. 3). Moreover, interior Alaska was likely an area occupied by populations ancestral to those that eventually became the earliest occupants of the rest of the continent. The landscape was affected by a variety of glacial and periglacial processes in the late Pleistocene as well as various alluvial, colluvial, eolian, and additional periglacial processes in the Holocene. Hoffecker (1988) developed a geoarchaeologically-based survey strategies aimed specifically at finding Paleoindian sites; in particular, sites of "pre-Clovis" age (30,000–12,000 ^{14}C years BP). Likely geological contexts (both surface and buried) for such early sites were identified on the basis of estimated age using stratigraphy and soils, reconstructed paleotopographic setting, and geomorphic history. The most likely settings thought to preserve early sites are old terraces covered by late Pleistocene loess. The terraces would have been well-drained, stable surfaces available prior to 12,000 ^{14}C years BP and then buried by loess 12,000–10,000 ^{14}C years BP. Limited testing revealed no sites, but the approach serves as a good model for finding older sites in complex settings.

Landscape geoarchaeology has also shed light on Paleoindian landuse and subsistence around large lake basins in North America. In the Southwestern U.S. over 100 closed and now mostly dry, desert basins held lakes in the late Pleistocene (Fig. 3) (Smith and Alayne Street-Perrott, 1983; Williams and Bedinger, 1984; Grayson, 1993). In general, lake levels were falling in the final millennia of the late Pleistocene, but many if not most basins still had perennial water and they must have been very attractive resources to the first occupants of the continent. The few studies of Paleoindian site distributions around paleo-lakes suggest a pattern in shifting landuse similar to that noted in the Albuquerque Basin. A systematic survey of a small sample of the Tularosa Basin, with paleo-lake Lucero in east-central New Mexico (Fig. 3), showed that the Folsom occupations were in closer proximity to the ancient lake compared to the later Paleoindian sites, which are more widely scattered throughout the basin (Wessel et al., 1997). These later sites may represent occupations designed to maximize resources in both lacustrine and montane environments, as the former disappeared. In the Great Basin, centered on Nevada and the location of most of the paleo-lakes, fluted points likewise tend to be found near ancient water sources (either on shorelines or along water courses). Unfluted (stemmed) points have a much broader distribution on the landscape; again possibly reflecting broader resource use as the environment dried (Beck and Jones, 1997).

Langford (2003) raises an important point about site preservation in the Tularosa basin of New Mexico that can apply to any of the basins. Though sites may be found along or above high shorelines today, they may well have existed lower in the basins, perhaps along the water's edge. But because the basin floors are often subjected to deflation, such sites were destroyed (or perhaps buried by eolian sediments deflated from the basin).

In contrast to the relatively stable landscapes around paleo-lake basins in the Southwestern U.S., the landscapes in and around the Great Lakes basins have been quite dynamic since initial exposure as glacial ice retreated just after the last full glacial (LGM) (Fig. 3) (Karrow and Calkin, 1985; Larsen, 1987; Teller, 1987, 2004). Predicting and interpreting the locations of sites of any age has proven difficult. Simply recognizing and differentiating coastal versus alluvial landforms and deposits have proven difficult (Larsen, 1985). Further, tracing and dating coastal landforms can be problematic. These difficulties are the result of variations in lake levels through time as the lake basins and lake systems evolved. These variations, in turn, are due to the myriad of factors that influenced lake levels (summarized by Larsen, 1985; Teller, 1987, 2004). Ultimately, the lake levels and lake basins were controlled by the position of the ice sheet. It retreated episodically, but also readvanced several times after the LGM. Lakes therefore formed and changed their extent and depth. When the ice retreated, it retreated downslope opening lower overflow routes and resulting, sometimes abruptly, in lowering lake levels. When the ice readvanced, outlets closed and lake levels rose. Through time, some

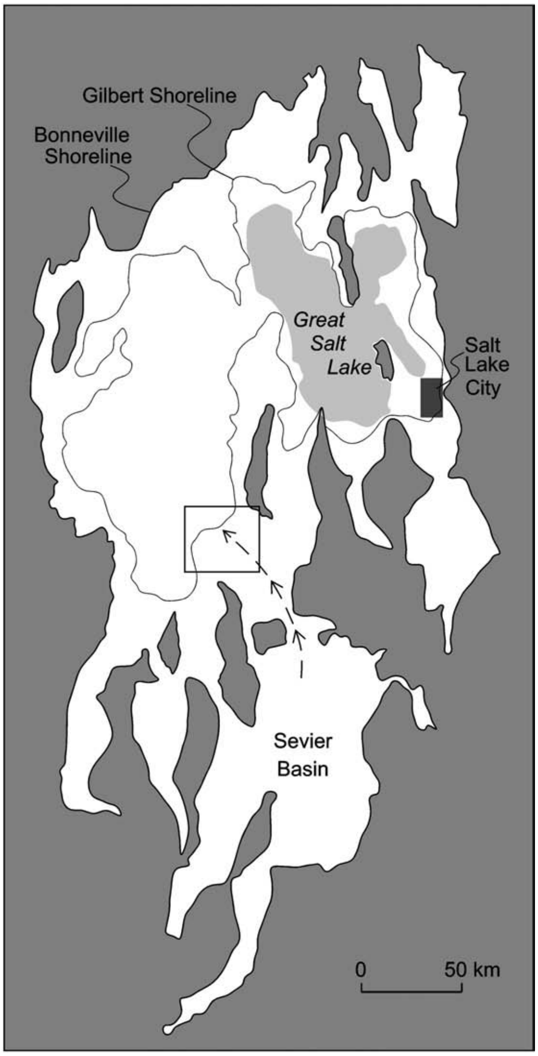

Fig. 7. The Bonneville Basin, Utah, showing the extent of the highstand of Lake Bonneville (~18,000 to ~14,000 radiocarbon yrs BP) and Paleoindian-age Lake Gilbert. The box is the area of flow out of the Sevier Basin into Lake Gilbert (Fig. 8) and the dashed line with arrows shows the drainage connecting the two (modified from Oviatt et al., 2003, Fig. 1A).

lake basins drained from one to another, resulting in some lake levels rising as others fell. Further complicating the reconstruction of lake history and associated landscape evolution are the effects of differential isostatic rebound, which also controlled the depth and extent of lakes, and in some cases resulted in catastrophic lake drainage. Rebound was greatest in the northern part of the great lakes basin because ice was thickest there. Rebound also began in the south where the ice retreat first exposed the landscape. Many of these processes were concomitant with the first peopling of the area. The northern Great Lakes region was still ice covered at 12,000 ^{14}C years BP, but was largely ice free by 9500 ^{14}C years BP.

The impact of these processes on site distribution and preservation were far-reaching. For example, evidence suggests that lakes Huron, Erie, and Ontario were significantly lower during Paleoindian time than they are today and, therefore, many sites are probably submerged (Jackson et al., 2000; Jackson, 2004). Sites associated with paleo-shorelines may represent occupation of substantially older landforms (Jackson et al., 2000). In addition, catastrophic drainage into and out of individual lake basins, both during and after the Paleoindian occupation, undoubtedly destroyed or buried sites (Jackson, 2004). To the northwest, in the Lake Michigan basin, Anderton et al. (2004) used geoarchaeology to understand Paleoindian occupations and site visibility. Their data suggest that Paleoindians populated the south side of the area when ice was perhaps 10–15 km to the north. As ice retreated out of the Lake Michigan basin, through the late Paleoindian occupation, more of the freshly deglaciated landscape was occupied. As in the basins to the southeast, water levels in the Lake Michigan basin were significantly lower just after deglaciation. Thus, many sites in this area were likely inundated as well.

In a very different application of regional, landscape geoarchaeology, the relationship of sites to geomorphology shed some light on the issue of Paleoindian subsistence. Paleoindians were long characterized as "big game hunters," largely owing to repeated finds of Paleoindian artifacts in association with mammoth and bison (Grayson, 1988; Meltzer, 1989). Most of these early finds were on the Great Plains, as discussed above, and most were found because the large bones attracted the attention of archaeologists (and paleontologists in some cases). These biases in the nature of the early finds, plus a much broader sampling of sites across the continent, has resulted in a spirited debate over the nature of subsistence practices, i.e., whether Paleoindians in fact focused on large mammals or if they had a more broad-based economy (e.g., Kelly and Todd, 1988; Waguespack and Surovell, 2003; Cannon and Meltzer, 2004; Byers and Ugan, 2005).

A small window on this debate was opened with geoarchaeological research in the Bonneville Basin (Figs. 1, 3 and 7), which contained the largest, best-known, and most intensively studied of the paleo-lake basins in western North America. The Bonneville Basin contains a series of sub-basins that drained from one into another as the lake level fell from the Bonneville level to the Gilbert level at the close of the Pleistocene. From <12,500 to ~9000 ^{14}C years BP the Sevier sub-basin drained into paleo-lake Gilbert (Fig. 7) (Oviatt et al., 2003). The overflow area had a complex landscape including gravel bars, sand-filled channels, and wetland mudflats (Fig. 8). Archaeological sites are scattered across this landscape; over 50 sites were documented along 52 km of exposed channels. Artifact styles indicate that the humans occupied parts of the old drainage-way throughout most of its existence (Oviatt et al., 2003; Rhode et al., 2005). The sites are on the

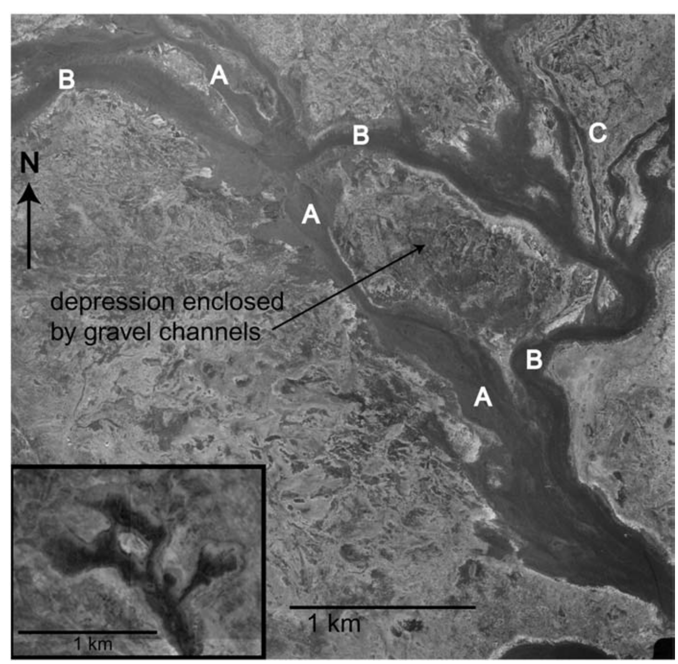

Fig. 8. Vertical aerial photograph of sand channels (A,B) developed on mudflats along the paleo-drainage into Lake Gilbert in the area of the box shown in Fig. 7 (Photo courtesy C.G. Oviatt; modified from Oviatt et al., 2003, Fig. 4; Reprinted from *Quaternary Research*, 2003, vol. 60, pp. 200–210, C.G. Oviatt, D.B. Madsen, D.N. Schmitt, "Late Pleistocene and early Holocene rivers and wetlands in the Bonneville basin of western North America," with permission from Elsevier Publishers).

gravel bars, adjacent to the sand-filled channels and to the mudflats (Fig. 9). The age, number, extent, and location of the sites suggest that this alluvial/wetland environment was an important component of Paleoindian subsistence. These early occupants must have relied on resources other than "big game."

5. Continental and microscopic-scale geoarchaeology

This final section presents vastly contrasting scales of geoarchaeology as it has been applied to the issue of peopling of the New World to illustrate the range in geoarchaeological approaches. At one extreme, understanding the distribution of glacial ice, the record of sea-level fluctuations, and the exposure of the Bering platform have long been an important component in the study of the first Americans (e.g., Haynes, 1964; Hopkins, 1967). At the other extreme, the microscopic study of soils and sediments (micromorphology), though one of the newest and still minimally applied methodological developments in North American geoarchaeology, is shedding light on site activities of the earliest North Americans.

Though rarely discussed as such, understanding the distribution and retreat of late Pleistocene glaciers over northern North America and the record of sea-level changes around the continental margins constitute a kind of continental-scale geoarchaeology. Although the genetics of Native American origins are far from clear (e.g., Powell, 2005), the first North Americans clearly made their way into the continent via northeastern Asia and the exposed Bering platform (Hoffecker and Elias, 2007). The physical constraints on this movement were many and varied, but ultimately were controlled by glaciers and sea level. Further, our understanding of the physical constraints is also determined by these environmental controls. During the last glacial period, lowered sea level (reaching a maximum of ~120 m below modern sea level; caused by the growth of the ice sheets) exposed the Bering platform between present day Alaska and Siberia, "connecting" the two regions (Fig. 3). The term "Beringia" is used to refer to the resulting unglaciated landmass of northwestern Siberia, the exposed Bering platform, and unglaciated Alaska. Although we think of humans "entering" Alaska and North America via Siberia when Beringia was extant, paleogeographically the unglaciated regions of Alaska were essentially an extension of Siberia and Asia.

The principal block for humans that separated Beringia from the rest of North America was glacial ice; thousands of square kilometers of glacial ice that was thousands of meters thick. North America was covered by two ice sheets: the eastern and larger Laurentide ice sheet that stretched westward from the North Atlantic almost to the foot of the Rocky Mountains, and the smaller Cordilleran ice sheet that covered the Canadian Rockies from the Pacific Ocean to the Great Plains and reached into Alaska, covering the Alaska Range (Fig. 3). The Laurentide ice sheet initially formed around Hudson Bay. The Cordilleran glacier began in the higher elevations of the Canadian

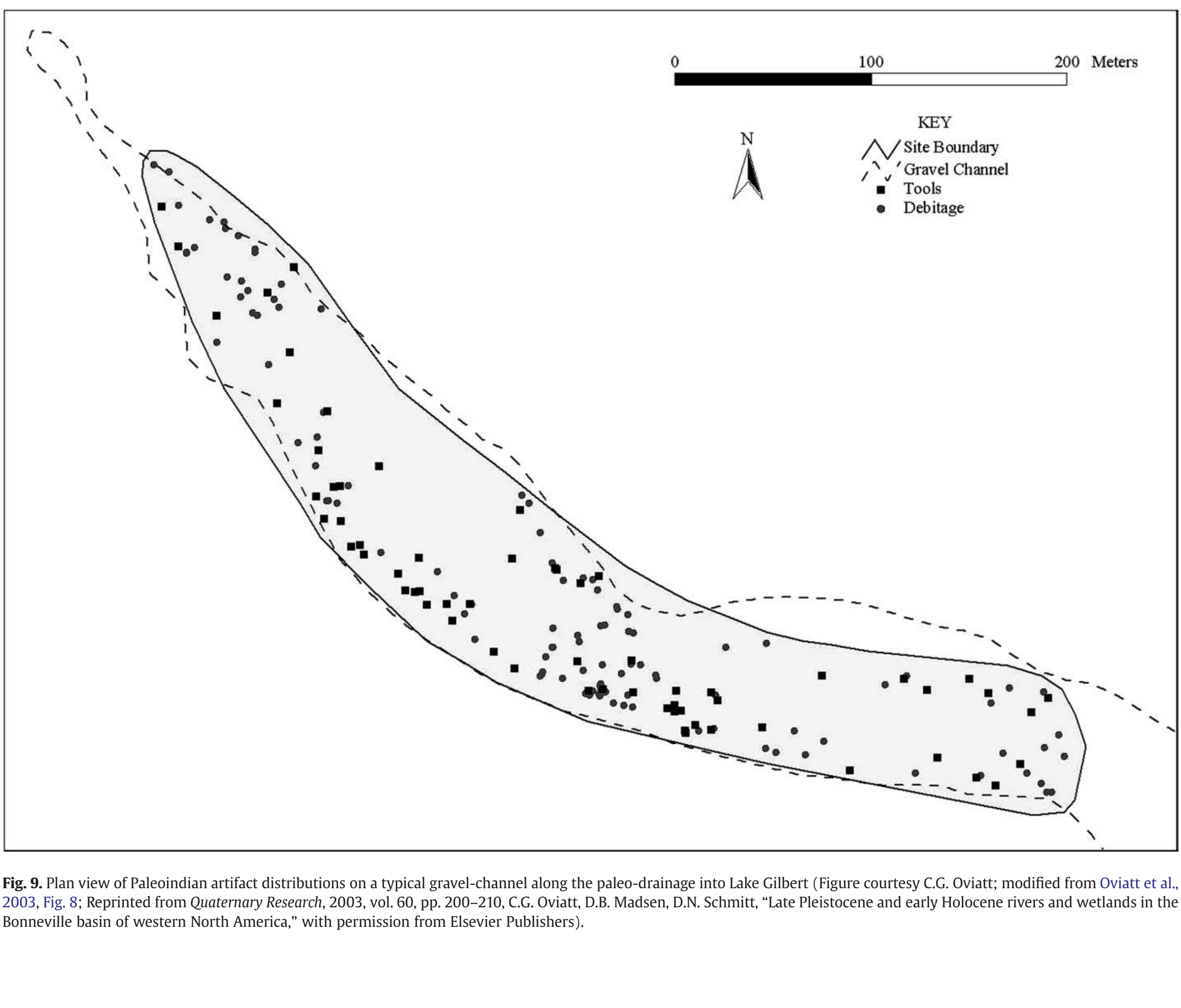

Fig. 9. Plan view of Paleoindian artifact distributions on a typical gravel-channel along the paleo-drainage into Lake Gilbert (Figure courtesy C.G. Oviatt; modified from Oviatt et al., 2003, Fig. 8; Reprinted from *Quaternary Research*, 2003, vol. 60, pp. 200–210, C.G. Oviatt, D.B. Madsen, D.N. Schmitt, "Late Pleistocene and early Holocene rivers and wetlands in the Bonneville basin of western North America," with permission from Elsevier Publishers).

Rockies. During the LGM the glaciers coalesced on the Canadian Prairies in west-central Canada, resulting in continuous ice cover from the Atlantic to the Pacific (Fig. 3).

The movement of humans from Beringia into the rest of the New World has been discussed for decades, but there is very little direct evidence. There is no archaeological "trail of breadcrumbs" from one area into another. In large measure the issue involves preservation, visibility, and accessibility. Late glacial and post-glacial landscapes in Beringia were quite dynamic, due to the effects of glacial melting and sea-level rise. Superimposed over these processes are the effects of periglacial activity, in particular cryoturbation. The archaeological significance of cryoturbation is well described by Schweger (1985, p. 127): "...the greatest handicap to northern archaeology is frost disturbance and its effects on archaeological matrix and the artifacts themselves." Sea-level rise also, of course, has hidden sites across a vast landscape, rendering them completely invisible and inaccessible for practical purposes. On land, large areas of Alaska and eastern Siberia were also covered by loess, burying many sites. Stream erosion rectified this problem in many areas, but an over-riding issue remains the remoteness of Alaska and Siberia. Those areas of Alaska and Siberia (east of the Lena River) that were parts of Beringia cover an area close to the size of the lower 48 states of the U.S. But these remnant regions of Beringia have few roads and towns, a very small population, few scientists scouring the landscape, and a short field season.

The two best-known scenarios for population movement, and those that have received the most serious attention by archaeologists and geologists, are the "Interior" or "Ice-Free Corridor" route and the "Coastal route." The opening of a travel route out of Beringia down between retreating ice sheets via an ice-free corridor (Fig. 3) was perhaps most famously argued by geoarchaeologist C.V. Haynes (1964), though the general notion of a travel route between the receding glaciers was proposed much earlier (Johnston, 1933). A key issue has been one of timing: when were the ice sheets coalesced? When did they separate? Ultimately the answer has depended on accurate radiocarbon dating of recessional glacial landforms (the difficulties therein are discussed by Dyke, 2004). Interpretations varied significantly since the first radiocarbon ages became available (summarized by Meltzer, 2006a, p. 124), as samples were added and then rejected. The most recent and comprehensive summaries (Dyke et al., 2003; Clague et al., 2004; Dyke, 2004) show that the corridor was open until perhaps 20 ka and then reopened before 11.5 ka (i.e., before the Clovis colonization of the continent), probably 12.5–12.0 ka and possibly as early as 13.5 ka.

Migration of the first Americans out of Asia and into the Americas via a coastal route was recognized as a possibility by noted geomorphologist Kirk Bryan (1941), but the issue was first seriously dealt with by Fladmark (1979). Evaluating the likelihood of a "coastal route" has proven difficult, however, because of the geologic complexities along the northwest coast of North America. The basic idea is that along the Pacific coast of Alaska and Canada there were periods when dry land was exposed between the glaciers and the ocean, allowing migration from coastal Beringia to the west coast of what is now the United States. In addition to the record of glaciation, assessing the possibility of a coastal route requires reconstructing the record of isostatic rebound, local sea level history, and in this active plate boundary, the history of tectonic uplift and subsidence. The remoteness and ruggedness of the landscape has hindered research in much of this area, but data are finally emerging and suggest that an open route may have been available soon after the LGM. Unglaciated landscapes exposed above sea-level and supporting resources suitable for humans were locally available during or just after the LGM, and much if not most of the coast was ice-free and above sea level by 13,000 ^{14}C years BP (summarized by Mandryk et al., 2001; Clague et al., 2004; Fedje et al., 2004).

Both an interior and a coastal route seem viable geologically and environmentally as migration corridors from Beringia into North America south of the ice sheets. And there is no reason to believe that only one route was used or even favored. However, no sites older than or even as old as Clovis have been found in either of the proposed migration corridors. The question of migration routes is constrained by a variety of geological issues, and the presence or absence of various routes can be argued on the basis of geological data. But migration is an archaeological one and can only be answered with archaeological data.

At the opposite end of the continental scale, the micromorphological study of soils and sediments is beginning to aid in geoarchaeological interpretations of early sites in North America. "Soil micromorphology" refers to the microscopic study of undisturbed soils and sediments (Courty et al., 1989, xvii). The method was developed in pedology early in the 20th Century and became fairly widespread for the study of soils (Courty et al., 1989, 5–6), especially in Europe. The use of micromorphology to study soils in archaeological contexts developed much later, largely in the 1970s and 1980s, and was applied mainly in archaeological research in the Old World (e.g., see the case histories presented by Courty et al., 1989). Beginning in the 1990s, however, micromorphology began to earn a place, albeit a small one, in North American geoarchaeology, largely through the efforts of Paul Goldberg and his students, especially Sarah Sherwood. This work included applications in Paleoindian contexts. For example, Goldberg and Arpin (1999) document the apparent lack of particulate contamination of radiocarbon samples from the controversial site of Meadowcroft Rockshelter in Pennsylvania (Fig. 1), which may contain one of the oldest occupations on the continent.

Micromorphology has been used in both conventional and innovative ways at the site of Dust Cave in Alabama (Fig. 1) (Sherwood et al., 2004; Sherwood and Chapman, 2005). Simple microscopic mineralogy of fill in a shelter immediately above Dust Cave indicated that the sediment was deposited by the adjacent Tennessee River ~15,630 ^{14}C years BP. Dust Cave, therefore, was not available for occupation until sometime later. In the cave itself, a striking aspect of the stratigraphy is the presence of discrete, localized, red-clay deposits, usually 1–5 cm thick and 0.5–1.0 m in diameter. These oldest of these layers dates to at least 9500 ^{14}C years BP. Micromorphology showed that the clay is not a component of the alluvium filling the cave, but is likely an anthropogenic deposit. Micromorphology and micro-scale stratigraphy further showed that these layers were purposely prepared and fired, and were probably some sort of cooking surfaces. If they are related to cooking, then these features provide further clues to early subsistence practices in the area, which must have included something other than the hunting of large animals.

6. Discussion and conclusions

The origin of Native American populations is a question germane to archaeologists across both American continents. It is fundamentally an archaeological issue, but a host of disciplines have been brought to bear on questions of where they came from, how they got here, and when they arrived. The geosciences and geoarchaeology have been at the forefront of interdisciplinary investigations of the peopling of the New World for well over a century. Indeed, the roots of North American geoarchaeology are based in large part in the study of Paleoindian archaeology, owing to arguments over a human presence in the North American Pleistocene and due to the striking geologic contexts of some of the first Paleoindian sites to be excavated (e.g., ancient artifacts associated with lake beds in modern deserts or Paleoindian occupation zones deep within thick, well-stratified sections) (Rapp and Hill, 1998, p. 10–12; and various chapters in Mandel, 2000). Geoarchaeology has come into its own as part and parcel of both research and CRM archaeology in North America since the 1970s, but was almost always a component of Paleoindian archaeology since at least the 1930s (e.g., Antevs, 1935; Howard, 1935).

The focus in this paper largely has been on geoarchaeology as used in the traditional sense of stratigraphy and geomorphology for dating and for reconstruction of site environments, and local and regional landscapes. But other aspects of geoarchaeology hold promise for increasing our understanding of the peopling of the New Word. Perhaps the most obvious area is use of remote sensing and geophysical prospecting to search for submerged sites in coastal areas. A wide range of seemingly intractable technical and logistical problems are involved in locating such sites; and the issue becomes more complex in trying to determine what to do with an inviting submerged site once it is found. Nevertheless, a variety of methods and several specific sites have appeared that offer some hope for finding and investigating sites submerged along the west coast of Canada and the northwestern U.S., and on the continental shelf of the Gulf of Mexico and the Atlantic Ocean (e.g., Luternauer et al., 1989; Stright, 1990; Josenhans et al., 1997; Fedje and Josenhans, 2000; Lacourse et al., 2003).

We now have more archaeologists and geoarchaeologists looking for or working on more early American sites than ever before. The amount and rate of data gathering in recent decades are staggering (summarized by Meltzer, 2004). But we also have a much more realistic view and more subtle understanding of the peopling of the New World and all of its complexities. Geoarchaeology will clearly continue to play a very important role as we continue to unravel the record of the first great adventure of human hunter-gatherers in the New World.

Acknowledgements

Thanks to Charly French and Karen Milek for organizing the DIG Conference and for inviting me to participate. Thanks also to Jack Oviatt for providing Figs. 8 and 9. D. Shane Miller prepared Fig. 1; Jim Abbott prepared Figs. 3 and 7. Rolfe Mandel and an anonymous reviewer provided helpful comments on an earlier draft of the manuscript.

References

Agogino, G.A., Galloway, E., 1965. The Sister's Hill site: a Hell Gap site in North-Central Wyoming. Plains Anthropologist 10, 190–195.
Anderton, J.B., Regis, R.S., Paquette, J.R., 2004. Geoarchaeological context for late Palaeo-Indian archaeology in the north-central Upper Peninsula of Michigan, USA. In: Jackson, L.J., Hinshelwood, A. (Eds.), The Late Palaeo-Indian Great Lakes. Canadian Museum of Civilization, Mercury Series Archaeology Paper, vol. 165, pp. 251–274.
Antevs, E., 1935. The occurrence of flints and extinct animals in pluvial deposits near Clovis, New Mexico, part III: age of Clovis lake beds. Proceedings of the Philadelphia Academy of Natural Sciences 87, 304–311.
Antevs, E., 1941. Age of the Cochise culture stages. Medallion Papers 29, 31–56.
Antevs, E., 1949. Geology of the Clovis sites. In: Wormington, H.M. (Ed.), Ancient Man in North America. Denver Museum of Natural History, Denver, pp. 185–192.
Antevs, E., 1955. Geologic–climatic dating in the West. American Antiquity 20, 317–335.
Beck, C., Jones, G.T., 1997. The terminal Pleistocene/Early Holocene archaeology of the Great Basin. Journal of World Prehistory 11, 161–236.
Bryan, K., 1941. Geologic antiquity of man in America. Science 93, 505–514.
Bryan, K., Ray, L., 1940. Geologic Antiquity of the Lindenmeier Site in Colorado. Smithsonian Miscellaneous Collections, vol. 99. Smithsonian Institution, Washington, D.C.
Byers, D.A., Ugan, A., 2005. Should we expect large game specialization in the late Pleistocene? An optimal foraging perspective on early Paleoindian prey choice. Journal of Archaeological Science 32, 1624–1640.
Butzer, K.W., 1964. Environment and Archaeology. Aldine, Chicago.
Butzer, K.W., 1971. Environment and Archaeology, 2nd Edition. Aldine, Chicago.
Cannon, M.D., Meltzer, D.J., 2004. Early Paleoindian foraging: examining the faunal evidence for large mammal specialization and regional variability in prey choice. Quaternary Science Reviews 23 (18/19), 1955–1987.
Clague, J.J., Mathewes, R.W., Ager, T.A., 2004. Environments of northwestern North America before the last Glacial Maximum. In: Madsen, D.B. (Ed.), Entering America: Northeast Asia and Beringia Before the Last Glacial Maximum. University of Utah Press, Salt Lake City, pp. 63–94.
Connell, S.D., Love, D.W., 2001. Stratigraphy of Middle and Upper Pleistocene fluvial deposits of the Rio Grande (post-Santa Fe Group) and the geomorphic development of the Rio Grande Valley, northern Albuquerque Basin, Central New Mexico. New Mexico Bureau of Geology and Mineral Resources Open File Report, vol. 454C, pp. 1–12.
Connell, S.D., Hawley, J.W., Love, D.W., 2005. Late Cenozoic drainage development in the Southeastern Basin and Range of New Mexico, Southeasternmost Arizona, and Western Texas. In: Lucas, S.G., Morgan, G.S., Zeigler, K.E. (Eds.), New Mexico's Ice Ages. New Mexico Museum of Natural History and Science, Bulletin, vol. 28, pp. 125–150. New Mexico Museum of Natural History and Science, Albuquerque.
Cotter, J.L., 1938. The occurrence of flints and extinct animals in pluvial deposits near Clovis New Mexico, part VI: Report on the field season of 1937. Proceedings of the Philadelphia Academy of Natural Sciences 90, 113–117.
Courty, M.-A., Goldberg, P., Macphail, R.I., 1989. Soils and Micromorphology in Archaeology. Cambridge University Press, New York.
Dawson, J., Judge, W.J., 1969. Paleoindian sites and topography in the middle Rio Grande Valley of New Mexico. Plains Anthropologist 14, 149–163.
Dyke, A.S., 2004. An outline of North American deglaciation with emphasis on central and northern Canada. In: Ehlers, J., Gibbard, P.L. (Eds.), Quaternary Glaciations—Extent and Chronology. Part II. North America. Developments in Quaternary Science, vol 2b. Elsevier, Amsterdam, pp. 371–406.
Dyke, A.S., Moore, A., Robertson, L., 2003. Deglaciation of North America. Open file 1574, 2 sheets. Geological Survey of Canada, Otawa.
Fedje, D.W., Josenhans, H., 2000. Drowned forests and archaeology on the continental shelf of British Columbia, Canada. Geology 28, 99–102.
Fedje, D.W., Mackie, Q., Dixon, E.J., Heaton, T.H., 2004. Late Wisconsin environments and archaeological visibility on the northern Northwest Coast. In: Madsen, D.B. (Ed.), Entering America: Northeast Asia and Beringia Before the Last Glacial Maximum. University of Utah Press, Salt Lake City, pp. 97–138.
Ferring, C.R., 1994. The role of geoarchaeology in Paleoindian research. In: Bonnichsen, R., Steele, D.G. (Eds.), Method and Theory for Investigating the Peopling of the Americas. Peopling of the Americas Publications, Center for the Study of the First Americans, Oregon State University, Corvallis, pp. 57–72.
Ferring, C.R., 2001. The Archaeology and Paleoecology of the Aubrey Clovis Site (41DN479) Denton County, Texas. Center for Environmental Archaeology, University of North Texas, Denton.
Fladmark, K., 1979. Routes: alternate migration corridors for early man in North America. American Antiquity 44, 55–69.
Frison, G.C., 1984. The Carter/Kerr-McGee Paleoindian site: cultural resource management and archaeological research. American Antiquity 49, 288–314.
Frison, G.C., 1991. Prehistoric Hunters of the High Plains, 2nd Edition. Academic Press, New York.
Frison, G.C. (Ed.), 1996. The Mill Iron Site. University of New Mexico Press, Albuquerque.
Frison, G.C., Stanford, D.J. (Eds.), 1982. The Agate Basin Site. Academic Press, San Diego.
Frison, G.C., Schwab, D., Hannus, L.A., Winham, P., Walter, D., Mainfort, R.C., 1996. Archeology of the Northwestern Plains. In: Frison, G.C., Mainfort, R.C. (Eds.), Archeological and Bioarcheological Resources of the Northern Plains. Arkansas Archeological Survey Research Series, vol. 47, pp. 8–40. Arkansas Archeological Survey, Fayetteville.
Gile, L.H., Hawley, J.W., Grossman, R.B., 1981. Soils and geomorphology in the basin and range area of Southern New Mexico—guidebook to the Desert project. Memoir, vol. 39. New Mexico Bureau of Mines and Mineral Resources, Socorro.
Goldberg, P., Arpin, T., 1999. Micromorphological analysis of sediments from Meadowcroft Rockshelter, Pennsylvania: implications for radiocarbon dating. Journal of Field Archaeology 26, 325–342.
Grayson, D.K., 1983. The Establishment of Human Antiquity. Academic Press, New York.
Grayson, D.K., 1993. The Desert's Past: A Natural History of the Great Basin. Smithsonian Institution Press, Washington D.C.
Grayson, D.K., 1988. Perspectives on the archaeology of the First Americans. In: Carlisle, R. (Ed.), Americans Before Columbus: Ice Age Origins, Ethnology Monographs, vol. 12, pp. 107–123.
Hack, J.T., 1943. Antiquity of the Finley site. American Antiquity 8, 235–241.
Hannus, L.A., 1990. The Lange-Ferguson site: a case for mammoth bone butchering tools. In: Agenbroad, L.D., Mead, J.I., Nelson, L.W. (Eds.), Megafauna and Man: Discovery of America's Heartland. Scientific Papers, vol. 1. The Mammoth Site of Hot Springs, South Dakota, Inc., Hot Springs, South Dakota, pp. 86–99.
Haynes Jr., C.V., 1964. Fluted projectile points: their age and dispersion. Science 145, 1408–1413.
Haynes Jr., C.V., 1975. Pleistocene and Recent stratigraphy. In: Wendorf, F., Hester, J.J. (Eds.), Late Pleistocene Environments of the Southern High Plains. Publication of the Ft. Burgwin Research Center, vol. 9, pp. 57–96.
Haynes Jr., C.V., 1990. The Antevs-Bryan years and the legacy for Paleoindian geochronology. In: Laporte, L. (Ed.), Establishment of a Geologic Framework for Paleoanthropology. Geological Society of America, Boulder, Colorado, pp. 55–68. Special Paper 242.
Haynes Jr., C.V., 1992. Contributions of radiocarbon dating to the geochronology of the peopling of the New World. In: Taylor, R.E., Long, A., Kra, R.S. (Eds.), Radiocarbon After Four Decades: An Interdisciplinary Perspective. Springer-Verlag, New York, pp. 355–374.
Haynes Jr., C.V., 1995. Geochronology of paleoenvironmental change, Clovis type site, Blackwater Draw, New Mexico. Geoarchaeology 10, 317–388.
Haynes Jr., C.V., 2003. Dating the Lindenmeier Folsom site, Colorado, U.S.A., before the radiocarbon revolution. Geoarchaeology 18, 161–174.
Haynes Jr., C.V., Agogino, G.A., 1966. Prehistoric springs and geochronology of the Clovis site, New Mexico. American Antiquity 31, 812–821.
Haynes Jr., C.V., Grey, D.C., 1965. The Sister's Hill site and its bearing on the Wyoming postglacial alluvial chronology. Plains Anthropologist 10, 196–211.
Hester, J.J. (Compiler), 1972. Blackwater Locality no. 1: A Stratified Early Man Site in Eastern New Mexico: Publication of the Ft. Burgwin Research Center 8.
Hoffecker, J.F., 1988. Applied geomorphology and archaeological survey strategy for sites of Pleistocene age: an example from Central Alaska. Journal of Archaeological Science 15, 683–713.
Hoffecker, J.F., Elias, S.A., 2007. Human Ecology of Beringia. Columbia University Press, New York.

Hofman, J.L., Graham, R.W., 1998. The Paleoindian cultures of the Great Plains. In: Wood, W.R. (Ed.), Archaeology on the Great Plains. University of Kansas Press, Lawrence, pp. 87–139.
Holliday, V.T., 1985. Archaeological geology of the Lubbock Lake site, Southern High Plains of Texas. Geological Society of America Bulletin 96, 1483–1492.
Holliday, V.T., 1995. Stratigraphy and paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains. Geological Society of America Memoir, vol. 186. Geological Society of America, Boulder, Colorado.
Holliday, V.T., 1997. Paleoindian Geoarchaeology of the Southern High Plains. University of Texas Press, Austin.
Holliday, V.T., 2000. The evolution of Paleoindian geochronology and typology on the Great Plains. Geoarchaeology 15, 227–290.
Holliday, V.T., 2004. Soils in Archeological Research. Oxford University Press, New York.
Holliday, V.T., Mandel, R.D., 2006. Paleoindian geoarchaeology of the Great Plains, and Southwest, and Great Lakes. In: Ubelaker, D.H. (Ed.), Environment, Origins, and Populations, Volume 3 of the Handbook of North American Indians. Smithsonian Institution, Washington, D.C., pp. 23–46.
Holliday, V.T., Huckell, B.B., Mayer, J.M., Forman, S.L., 2006. Geoarchaeology of the Boca Negra Wash Area, Albuquerque Basin, New Mexico. Geoarchaeology, 21, 765–802.
Hopkins, D.M. (Ed.), 1967. The Bering Land Bridge. Stanford University Press, Stanford, California.
Howard, E.B., 1935. Evidence of early man in North America. The Museum Journal, University of Pennsylvania Museum 24, 61–175.
Huckell, B.B., Kilby, J.D., 2000. Boca Negra Wash, a new Folsom site in the Middle Rio Grande Valley, New Mexico. Current Research in the Pleistocene 17, 45–47.
Jackson, L.J., 2004. Changing our views of Late Palaeo-Indian in southern Ontario. In: Jackson, L.J., Hinshelwood, A. (Eds.), The Late Palaeo-Indian Great Lakes. Mercury Series Archaeology Paper, vol. 165. Canadian Museum of Civilization, Ottawa, pp. 25–56.
Jackson, L.J., Ellis, C., Morgan, A.V., McAndrews, J.H., 2000. Glacial lake levels and eastern Great Lakes Palaeo-Indians. Geoarchaeology 15, 415–440.
Jodry, M.A., 1999. Paleoindian stage. In: Martorano, M.A., HoeferIII III, T., Jodry, M.A., Spero, V., Taylor, M.L. (Eds.), Colorado Prehistory: A Context for the Rio Grande Basin. Colorado Council of Professional Archaeologists, Denver, pp. 45–114.
Johnson, E., 1986. Late Pleistocene and early Holocene vertebrates and paleoenvironments on Southern High Plains, U.S.A. Géographie Physique et Quaternaire 40 (3), 249–261.
Johnson, E. (Ed.), 1987. Lubbock Lake: Late Quaternary Studies on the Southern High Plains. Texas A&M University Press, College Station.
Johnson, E., Holliday, V.T., 1980. A Plainview kill/butchering locale on the Llano Estcado—the Lubbock Lake site. Plains Anthropologist 25, 89–111.
Johnston, W.A., 1933. Quaternary geology of North America in relation to the migration of man. In: Jenness, D. (Ed.), The American Aborigines: Their Origin and Antiquity. The University of Toronto Press, pp. 9–45 (reprinted by Cooper Square Publishers, New York, 1973).
Josenhans, H., Fedje, D., Pienitz, R., Southon, J., 1997. Early humans and rapidly changing Holocene sea levels in the Queen Charlotte Islands—Hecate Strait, British Columbia. Science 277, 71–74.
Judge, W.J., 1973. Paleoindian Occupation of the Central Rio Grande Valley in New Mexico. University of New Mexico Press, Albuquerque.
Judge, W.J., Dawson, J., 1972. Paleoindian settlement technology in New Mexico. Science 176, 1210–1216.
Kelly, R.L., Todd, L., 1988. Coming into the country: Early Paleoindian hunting and mobility. American Antiquity 53, 231–244.
Karrow, P.F., Calkin, P.E. (Eds.), 1985. Quaternary Evolution of the Great Lakes. Geological Association of Canada Special Paper, vol. 30. St. John's, Newfoundland.
Lacourse, T., Mathewes, R.W., Fedje, D.W., 2003. Paleoecology of late-glacial terrestrial deposits with in situ conifers from the submerged continental shelf of western Canada. Quaternary Research 60, 180–188.
Langford, R.P., 2003. The Holocene history of the White Sands dune field and influences on eolian deflation and playa lakes. Quaternary International 104, 31–39.
Larsen, C.E., 1985. Geoarchaeological interpretation of Great Lakes coastal environments. In: Stein, J.K., Farrand, W.R. (Eds.), Archaeological Sediments in Context, pp. 91–110. Center for the Study of Early Man, University of Maine, Peopling of the Americas Edited Volume Series 1, Orono.
Larsen, C.E., 1987. Geological history of Glacial Lake Algonquin and the Upper Great Lakes. U.S. Geological Survey Bulletin, vol. 1801. U.S. Geological Survey, Washington, D.C.
Libby, W.F., 1952. Radiocarbon Dating. University of Chicago Press.
Libby, W.F., 1955. Radiocarbon Dating, 2nd Edition. University of Chicago Press.
Luternauer, J., Clague, J., Conway, K., Barrie, J., Blaise, B., Mathewes, R., 1989. Late Pleistocene terrestrial deposits on the continental shelf of western Canada: evidence for rapid sea level change at the end of the last glaciation. Geology 17, 357–360.
Mandel, R.D. (Ed.), 2000. Geoarchaeology in the Great Plains. University of Oklahoma Press, Norman.
Mandel, R.D., Hofman, J.L., Holen, S., Blackmar, J.M., 2004a. Buried Paleo-Indian landscapes and sites on the high plains of Northwestern Kansas. In: Nelson, E.P., Erslev, E.A. (Eds.), Field Trips in the Southern Rocky Mountains, USA. Geological Society of America Field Guide, vol. 5. The Geological Society of America, Boulder, Colorado, pp. 69–88.
Mandel, R.D., Hofman, J., Bement, L., Carter, B., 2004b. In: Mandel, R.D. (Compiler), Guidebook for Field Trips, 18th Biennial Meeting of the American Quaternary Association. p. 4-1–4-52. Kansas Geological Survey, Open-File Report 2004-33, Lawrence, Kansas.
Mandel, R.D., 2008. Buried Paleoindian-age landscapes in stream valleys of the Central Plains, USA. Geomorphology 101, 342–361.
Mandryk, C.A., Josenhans, H., Fedje, D., Mathewes, R., 2001. Late Quaternary paleoenvironments of northwestern North America: implications for inland versus coastal migration routes. Quaternary Science Reviews 20, 301–314.
Meltzer, D.J., 1983. The antiquity of man and the development of American archaeology. Advances in Archaeological Method and Theory 6, 1–51.
Meltzer, D.J., 1989. Why don't we know when the first people came to North America? American Antiquity 54, 471–490.
Meltzer, D.J., 1991. On "paradigms" and "paradigm bias" in controversies over human antiquity in America. In: Dillehay, T., Meltzer, D.J. (Eds.), The First Americans: Search and Research. CRC Press, Boca Raton, pp. 13–49.
Meltzer, D.J., 1994. The discovery of deep time: a history of views on the peopling of the Americas. In: Bonnichsen, R., Steele, D.G. (Eds.), Method and Theory for Investigating the Peopling of the Americas. Peopling of the Americas Publications, Center for the Study of the First Americans, Oregon State University, Corvallis, pp. 7–26.
Meltzer, D.J., 2004. Peopling of North America. In: Gillespie, A., Porter, S.C., Atwater, B. (Eds.), The Quaternary Period in the United States. Elsevier Science, New York, pp. 539–563.
Meltzer, D.J., 2006a. History of research on the Paleo-Indian. In: Ubelaker, D.H. (Ed.), Handbook of North American Indians, Volume 3: Environment, Origins, and Population. Smithsonian Institution, Washington, D.C., pp. 110–128.
Meltzer, D.J., 2006b. Folsom: New Archaeological Investigations of a Classic Paleoindian Bison Kill. University of California Press, Berkeley.
Moss, J.H., 1951. Glaciation in the Wind River Mountains and its relation to Early Man in the Eden Valley, Wyoming. In: Moss, J.H. (Ed.), Early Man in the Eden Valley. Museum Monographs, The University Museum, University of Pennsylvania, Philadelphia, pp. 9–92.
Moss, J.H., 1952. The antiquity of the Finley (Yuma) site: example of the geologic method of dating. In: Tax, S. (Ed.), Indian tribes of aboriginal America. Cooper Square Publishers, New York, pp. 164–171.
Oakley, K.P., 1964. Frameworks for Dating Fossil Man. Aldine, Chicago.
Oviatt, C.G., Madsen, D.B., Schmitt, D.N., 2003. Late Pleistocene and early Holocene rivers and wetlands in the Bonneville basin of western North America. Quaternary Research 60, 200–210.
Pazzaglia, F.J., Wells, S.G., 1990. Quaternary stratigraphy, soils and geomorphology of the northern Rio Grande Rift. In: Bauer, P.W., Lucas, S.G., Mawer, C.K., McIntosh, W.C. (Eds.), Southern Sangre de Cristo Mountains, New Mexico. New Mexico Geological Society Guidebook, 41st Field Conference, Socorro, pp. 423–430.
Powell, J., 2005. The First Americans: Race, Evolution, and the Origin of Native Americans. Cambridge University Press, New York.
Rapp Jr., G., Hill, C.L., 1998. Geoarchaeology: The Earth-Science Approach to Archaeological Interpretation. Yale University Press, New Haven, Connecticut.
Reider, R.G., 1990. Late Pleistocene and Holocene pedogenic and environmental trends at archaeological sites in plains and mountain areas of Colorado and Wyoming. In: Lasca, N.P., Donahue, J. (Eds.), Archaeological Geology of North America. Centennial Special, vol. 4. Geological Society of America, Boulder, Colorado, pp. 335–360.
Rhode, D., Goebel, T., Graf, K.E., Hockett, B.S., Jones, K.T., Madsen, D.B., Oviatt, C.G., Schmitt, D.N., 2005. Latest Pleistocene-early Holocene human occupation and paleoenvironmental change in the Bonneville Basin, Utah-Nevada. In: Pederson, J., Dehler, C.M. (Eds.), Interior Western United States. Geological Society of America Field Guide, vol. 6, pp. 211–230. Geological Society of America, Boulder, Colorado.
Roberts, F.H.H., 1936. Additional information on the Folsom complex: report on the second season's investigations at the Lindenmeier site in northern Colorado. Smithsonian Miscellaneous Collections, vol. 95 (10). Smithsonian Institution, Washington, D.C.
Schweger, C., 1985. Geoarchaeology of northern regions: Lessons from cryoturbation at Onion Portage, Alaska. In: Stein, J.K., Farrand, W.R. (Eds.), Archaeological Sediments in Context, pp. 127–141. Center for the Study of Early Man, University of Maine, Peopling of the Americas Edited Volume Series 1, Orono.
Sherwood, S.C., Chapman, J., 2005. The identification and potential significance of early Holocene prepared clay surfaces: examples from Dust Cave and Icehouse Bottom. Southeastern Archaeology 24, 70–82.
Sherwood, S.C., Driskell, B.N., Randall, A.R., Meeks, S.C., 2004. Chronology and stratigraphy at Dust Cave, Alabama. American Antiquity 69, 533–554.
Sellards, E.H., 1952. Early Man in America. University of Texas Press, Austin.
Sellards, E.H., Evans, G.L., Meade, G.E., 1947. Fossil bison and associated artifacts from Plainview, Texas. Geological Society of America Bulletin 58, 927–954.
Smith, G.I., Alayne Street-Perrott, F.A., 1983. Pluvial lakes of the Western United States. In: Porter, S.C. (Ed.), Late-Quaternary Environments of the United State, volume 1: The Late Pleistocene. University of Arizona Press, Tucson, pp. 190–212.
Stafford Jr., T.W., 1981. Alluvial geology and archaeological potential of the Texas Southern High Plains. American Antiquity 46, 548–565.
Stock, C., Bode, F.D., 1936. The occurrence of flints and extinct animals in pluvial deposits near Clovis, New Mexico, part III: Geology and vertebrate paleontology. Proceedings of the Philadelphia Academy of Natural Sciences 88, 219–241.
Stright, M.J., 1990. Archaeological sites on the North American continental shelf. In: Lasca, N., Donahue, J. (Eds.), Archaeological Geology of North America. Centennial Special, vol. 4. Geological Society of America, Boulder, Colorado, pp. 439–465.
Teller, J.T., 1987. Proglacial lakes and the southern margin of the Laurentide Ice Sheet. In: Ruddiman, W.F., Wright, H.E. (Eds.), North America and Adjacent Oceans During the Last Deglaciation. Geology of North America, vol. K-3. Geological Society of America, Boulder, CO, pp. 39–69.
Teller, J.T., 2004. Controls, history, outbursts, and impact of large late-Quaternary proglacial lakes in North America. In: Gillespie, A.R., Porter, S.C., Atwater, B.F. (Eds.), The Quaternary Period in the United States. Elsevier, Amsterdam, pp. 45–61.
Waguespack, N., Surovell, T., 2003. Clovis hunting strategies, or how to make out on plentiful resources. American Antiquity 68, 333–352.
Wendorf, F. (Assembler), 1961. Paleoecology of the Llano Estacado. Ft. Burgwin Research Center Publication 1, The Museum of New Mexico Press, Santa Fe.
Wendorf, F., Hester, J.J. (Eds.), 1975. Late Pleistocene Environments of the Southern High Plains. Ft. Burgwin Research Center Publication, vol. 9.

Wessel, R.L., Eidenbach, P.L., Meyer, L.M., Comer, C.S., Knight, B., 1997. From playas to highlands: PaleoIndian adaptations to the region of the Tularosa: Human Systems Research, Inc., Tularosa, New Mexico for MEVATEC Corporation, White Sands Missile Range.
Williams, T.R., Bedinger, M.S., 1984. Selected geologic and hydrologic characteristics of the Basin and Range Province, western United States: Pleistocene lakes and marshes. U.S. Geological Survey Map I-1522D (1:2,500,000), Washington, D.C.
Wilmsen, E.N., 1965. An outline of Early Man studies in the United States. American Antiquity 31, 172–192.
Zeuner, F.E., 1958. Dating the Past: An Introduction to Geochronology, 4th Edition. Methuen, London.