CHAPTER TWO

Historical Perspective on the Geoarchaeology of the Southern High Plains

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INTRODUCTION

Geoscientific studies have been an integral part of archaeological investigations on the Southern High Plains for more than sixty years. Few regions in North America have such a long history of geoarchaeological research at so many sites involving so many of the century's leading archaeologists and geoscientists. Their studies tended to focus on Paleoindian sites, but they addressed all cultural periods geoarchaeologically. This interdisciplinary research adds significantly to our understanding of cultural sequences and of people's relationships to their immediate surroundings, as well as our broader view of late Quaternary environments and environmental change.

There are several reasons for this long record of fruitful interdisciplinary research on the Southern High Plains. In the years immediately following the discoveries at the Folsom site, where from 1926 to 1928 the human association with extinct fauna in North America was finally confirmed, archaeologists were attracted to the Plains because it was the area that repeatedly yielded discoveries of human artifacts and Pleistocene fauna. Many of these archaeological sites have thick, well-stratified deposits that provide evidence of markedly different depositional environments than those found in the areas today, that is, meandering streams or perennial, freshwater lakes instead of dry valleys or
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dry lake basins. These striking contrasts drew the attention of archaeologists and earth scientists alike (Holliday 1997a).

Dating artifacts was one of the most immediate concerns of archaeologists in the early decades of Paleoindian studies. Geologists and paleontologists were called upon to provide age estimates of sites in the absence of radiometric dating methods (Hofman 1989:44; Ferring 1994; Holliday 1997a:21–30, 2000a; Rapp and Hill 1998:11–12). Much of the research was conducted by archaeologists with training or experience in geology or interdisciplinary research (E. B. Howard, Frank H. H. Roberts, Fred Wendorf, James J. Hester, Eileen Johnson) and, more commonly, geologists or paleontologists with an abiding interest in human prehistory, especially Paleoindian archaeology (E. H. Sellards, Glen L. Evans, Grayson E. Meade, Claude C. Albritton, F. Earl Green, C. Vance Haynes Jr.). For these scientists, geologic research was inseparable from their approach to archaeology. Finally, beginning in the 1950s, interdisciplinary research became more common in North American archaeology, and this development influenced work on the Plains (Holliday 1997a).

This chapter is a review, not an exhaustive discussion, of the history of geoarchaeological research on the Southern High Plains. It summarizes the chronology of earth science involvement in archaeology, highlights some of the more significant geoarchaeological contributions, and presents some of the current archaeologically significant interpretations based on the results of geoscientific research. Also included is a short chronology of geoarchaeological and related research in the region, identifying the major players and establishing timelines for the subsequent discussion of contributions in stratigraphy, soils, and paleoenvironments, as well as in studies of Paleoindian cultural chronology.

ENVIRONMENTAL SETTING AND REGIONAL GEOLOGY

The Southern High Plains or Llano Estacado ("stockaded plains") is a vast, level plateau covering approximately 130,000 km² (map 2.1). The region has a warm, semiarid, continental environment (Lotspeich and Everhart 1962; Carr 1967). The natural vegetation is shortgrass prairie with scattered trees along the escarpments and in the valleys (Blair 1950; Wendorf 1975a). The Llano Estacado comprises the southernmost portion of the High Plains physiographic section.
Map 2.1. The Southern High Plains, showing the physiographic features and archaeological sites mentioned in the text (AB = Anderson Basin) and selected cities. Inset in upper left shows the location of the region in Texas.

(Hunt 1974) (map 2.1). The plateau is defined by escarpments along the west, north, and east sides. To the south, the surface of the Southern High Plains gradually merges with the Edwards Plateau province of central Texas (map 2.1).

The Southern High Plains is almost featureless, one of the most nearly level regions in the United States. Small basins, dry valleys, and dunes provide slight
topographic relief (Reeves 1965, 1966, 1972, 1991; Wendorf 1975a; Hawley et al. 1976; Walker 1978; Holliday 1985a, 1995a) (map 2.1). Approximately 25,000 small (<5 km²) depressions dot the landscape and contain seasonal lakes or playas and about 40 larger (tens of km²) basins, also called playas or salinas. The playa and salina basins contain the only available, naturally impounded surface water on the Llano Estacado although the water is seasonal and sometimes brackish or saline. The dry valleys or draws are northwest-southeast trending tributaries of rivers on the Rolling Plains to the east (map 2.1). Today, the draws contain no flowing water and hold standing water only after heavy rain. Several large dune fields lie along the western Llano Estacado (map 2.1) with crescent-shaped dunes (lunettes) near some playas.

The draws, playas, dune fields, and lunettes are the sites of most late Quaternary sedimentation and, therefore, are also the areas where in situ archaeological deposits occur in stratified contexts. Virtually all geoarchaeological research in the region has focused on sites in one of these settings.

Extensive Cenozoic deposits that overlie Paleozoic and Mesozoic bedrock comprise most of the exposed sections and surficial deposits of the Southern High Plains. The bulk of these deposits are Miocene-Pliocene eolian and alluvial sediments of the Ogallala Formation, largely derived from mountains to the west in New Mexico (Hawley et al. 1976; Reeves 1972; Gustavson 1996; Reeves and Reeves 1996). The Ogallala Formation contains the economically significant Ogallala or High Plains aquifer. The upper Ogallala has a thick, highly resistant, pedogenic calcrite, known as the “caprock caliche” because it is a prominent ledge-forming unit near the top of the escarpments bordering the plateau. The Pliocene is represented by the Blanco Formation, an extensive lacustrine deposit of dolomite and some sand deposited in large basins cut into the Ogallala (Evans and Meade 1945; Harbour 1975; Hawley et al. 1976).

The modern surface of the Southern High Plains is composed of the Blackwater Draw Formation, which is a widespread eolian deposit derived from the Pecos River Valley (Reeves 1976; Holliday 1989a; Gustavson and Holliday 1999). This deposit blankets all older deposits and varies in thickness and texture from a thin veneer of sandy loam in the southwest to a thick deposit of clay loam in the northeast. Pleistocene lake sediments occur below, within, and inset against the Blackwater Draw Formation (Habour 1975; Reeves 1976, 1991; Schultz 1986; Holliday et al. 1996).

Most of the rest of the archaeologically significant surficial deposits are the late Quaternary sediments found in the draws, lake basins, and dunes. The
draws are inset into the Blackwater Draw Formation and locally cut into the Blanco or Ogallala Formations; they probably developed or at least took on their present shape during the late Pleistocene period (Holliday 1995b). Within these dry tributaries are a variety of late Pleistocene and Holocene lacustrine, paludal, alluvial, and eolian deposits (Holliday 1995a,b, 1997a). The playa and salina basins also are cut into the Blackwater Draw Formation or older deposits and contain late Quaternary lacustrine and paludal sediments (Reeves 1991; Holliday et al. 1996). The lunettes and dune fields rest on top of the Blackwater Draw Formation. The lunettes contain late Pleistocene and Holocene eolian sediments deflated from adjacent playas, and the various dune fields consist primarily of Holocene sands (Huffington and Albritton 1941; Green 1961; Holliday 1985a, 1995a, 1997b). Archaeological sites are reported in all of this late Quaternary sediment, although sites in the draws have been the most intensively studied (archaeologically and geologically) and are the best known.

A BRIEF CHRONOLOGY OF RESEARCH

Geoarchaeology on the Southern High Plains had its inception in the 1930s with the archaeological research into the Paleoindian occupation of the Llano Estacado. In 1933, interdisciplinary archaeological work began in a gravel pit at the now famous Clovis site (Blackwater Draw Locality 1) (map 2.1). The work was jointly sponsored by the University of Pennsylvania Museum and the Academy of Natural Sciences of Philadelphia, led by E. B. Howard, an archaeologist with advanced degrees in both anthropology and geology (Roberts 1943), and subsequently directed by archaeologist John L. Cotter (Antevs 1935, 1949; Howard 1935; Stock and Bode 1936; Cotter 1937, 1938; Patrick 1938). The research focused on valley fills with archaeological material (especially artifacts in association with late Pleistocene fauna) along and in tributaries of the upper Blackwater Draw. The Clovis site is located in a basin that drains into the draw proper. The locality is one of the most significant archaeological sites in the region, and research, which continues to the present, has almost always been interdisciplinary. This is partly because of the rich, extensive, stratified Paleoindian and later archaeological remains, and partly because of its late Quaternary paleoecological record. Hester (1972) summarizes the history and results of the early research at Clovis and discusses the more significant geoarchaeological contributions.
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In 1937 geologist and paleontologist E. H. Sellards, under the auspices of the Texas Memorial Museum at the University of Texas at Austin, excavated the Miami site (Sellards 1938) (map 2.1). This was in a small playa and was one of the first archaeological sites where mammoth was excavated in North America (Holliday et al. 1994). The work at Miami marked the beginning of almost twenty-five years of research by Sellards into the Paleoindian archaeology and geology of the High Plains, with much of the fieldwork conducted by geologist G. L. Evans and paleontologist G. E. Meade (Holliday 1997a). Sellards’s Paleoindian research grew out of a heated debate that he inadvertently became involved in early in the century (Meltzer 1983). In several papers (Sellards 1916, 1917), he presented evidence for the association of human bone with extinct animals at a site near Vero, Florida. He was apparently unprepared for the storm of criticism that followed his publications (e.g., Hrdlička 1918) and it affected him deeply (Evans 1986). The result, beginning several decades later when he was director of the Texas Memorial Museum (TMM), was his fieldwork in Texas and New Mexico aimed at proving that humans and extinct Pleistocene species were contemporaneous. Geology was a key component of these investigations, because Sellards was trained in geology and paleontology and because recognition of stratigraphy and various depositional environments was a key to dating and interpreting the sites.

Several other significant geoarchaeological investigations occurred just prior to the entry of the United States into World War II. Frank H. H. Roberts, a veteran field archaeologist for the Smithsonian Institution fresh from his fieldwork at the Lindenmeier Folsom site, was contacted in 1941 by Frank Hibben of the University of New Mexico regarding Paleoindian finds in another playa near San Jon, New Mexico (Roberts 1942; Hill et al. 1995) (map 2.1). Roberts tested the San Jon site in 1941 and, with geology graduate student Sheldon Judson, studied the stratigraphy at and near the site. Judson was a student at Harvard, and his involvement in the project was the result of his association with Kirk Bryan, noted for his interest in and research on geoarchaeological as well as geomorphological topics (Haynes 1990). The subsequent reports by Roberts (1942) and Judson (1953) discuss their work on the site’s archaeology and geology and led to one of the first regional studies of playa origins and stratigraphy (Judson 1950). When the Works Progress Administration (WPA) began sponsoring archaeological research, the first of a series of investigations began at the Lubbock Lake site in Yellowhouse Draw. Joe Ben Wheat, another archaeologist with training in geology, conducted this investigation in 1939
and 1941 (Black 1974; Wheat 1974). Although geology was not a major component of these WPA studies, the stratigraphy at Lubbock Lake was obvious and played a key role in the archaeological interpretations (Wheat 1974).

In the decade after World War II, Sellards, Evans, and Meade worked at a number of archaeological sites on and off of the Southern High Plains. Their studies resulted in a remarkable body of research on Paleoindian archaeology and late Quaternary stratigraphy and geochronology (Holliday 1995b, 1997a). On the Llano Estacado, this work included the Clovis site (Evans 1951; Sellards 1952), Lubbock Lake (Sellards 1952), the Plainview site in Running Water Draw (Sellards et al. 1947), the Milnesand site in dunes on upper Sulphur Draw (Sellards 1955a), and the Midland (Scharbauer Ranch) site in dunes on Monahans Draw (Sellards 1955b) (map 2.1).

Sellards's work in the High Plains, in addition to his earlier research in Florida, resulted in several important publications. His summary of Paleoindian archaeology in the New World (Sellards 1952) is a classic because it was the most comprehensive study of the topic of its time and because it remains the only source of information for some of his fieldwork. Sellards and Evans's research also resulted in the first comprehensive summary of Paleoindian archaeology of the Llano Estacado (Sellards and Evans 1960). In both these works, Sellards employs a strong geoscience orientation, more so than in most subsequent reviews of Paleoindian archaeology.

Sellards also worked at the Midland site, but his investigations followed the more substantive geoarchaeological research of Wendorf et al. (1955) and Wendorf and Krieger (1959). This site, in a small dune field overlapping Monahans Draw, was studied and became well known because it yielded some human remains of late Pleistocene or early Holocene age (Holliday and Meltzer 1996). The dune stratigraphy is a key to dating the human bone, but the geochronology remains somewhat uncertain (Holliday and Meltzer 1996).

The initial work at the Midland site led to another significant development in late Quaternary research on the Llano Estacado in the late 1950s and early 1960s. Fred Wendorf and colleagues from the Museum of New Mexico, Texas Technological College (now Texas Tech University), and other institutions established the High Plains Paleoenecology Project (HPPP). This interdisciplinary research program not only focused on reconstructing the late Pleistocene environment of the area, but also included other aspects of late Quaternary history, such as archaeology and Holocene paleoenvironments (e.g., Wendorf 1961; Hester 1962; Hafsten 1964; Oldfield and Schoenwetter 1964, 1975; Wendorf
and Hester 1975). The HPPP, which included work in the draws, playas, and dunes, was and remains one of the few regional studies of late Quaternary history in North America that incorporated archaeology, stratigraphy, geochronology, paleobotany, and paleontology. The principal outcomes of this research included the definition of a sequence of late Quaternary "climatic intervals" (Wendorf 1961) and "pollen-analytical episodes" (Oldfield 1975; Schoenwetter 1975), along with environmental reconstructions for various "intervals" and "episodes" (Oldfield and Schoenwetter 1975; Wendorf 1970, 1975b). Although some investigators criticized some of the interpretations of this work (Holliday 1987, 1995b, 1997a), the project nevertheless provided a model of interdisciplinary research strategies and environmental change, as well as a rich data base for subsequent investigators.

Other geoarchaeological research continued in association with the HPPP studies. F. E. Green (1962a,b, 1963) presented the first comprehensive discussion of the archaeology and geology of Lubbock Lake, and the most substantive discussion of geology, archaeology, and paleoenvironments at Clovis since the work of Howard, Cotter, and Evans. As a specific component of the HPPP and a direct outgrowth of the research at Midland, Green (1961) also summarized stratigraphic and paleoenvironmental research in the Monahans Dunes. His summary was the first comprehensive discussion of this extensive and archaeologically rich dune system. C. V. Haynes became involved in the later stages of the HPPP, which led to a long-term research program at the Clovis site and its environs. Haynes and Agogino (1966), Haynes (1975, 1995), and Stanford et al. (1990), among others, present extensive data on the stratigraphy and geochronology of the valley fill of upper Blackwater Draw in and near the Clovis site, research that is especially significant given the archaeological and paleoenvironmental data that came from the area.

Geoarchaeological research on the Southern High Plains essentially stopped from the middle 1960s to the early 1970s. Beyond some limited work at Clovis (Agogino and Rovner 1969; Stevens 1973; Agogino et al. 1976) and Marks Beach in middle Blackwater Draw (Honea 1980) (map 2.1), researchers carried out no large-scale archaeological investigations involving geoarchaeological studies.

In the 1970s, 1980s, and 1990s there were several new developments in geoarchaeological research on the Southern High Plains. The first began in 1972, with establishment of the Lubbock Lake Project under the auspices of the Museum of Texas Tech University. This was a continuing, interdisciplinary research program at the Lubbock Lake archaeological site, under the direction
of archaeologist and biologist Eileen Johnson and a succession of geoarchaeologists (C. A. Johnson, T. W. Stafford, and V. T. Holliday). Initially the project focused on the record of human adaptation to late Quaternary environmental change at the Lubbock Lake archaeological site (map 2.1). Building on earlier work at the site by Wheat (1974), Evans (1949), Sellards (1952), Green (1962a), and Kelley (1974), the research program included archaeology, geomorphology, pedology, paleontology, and paleobotany (e.g., Black 1974; C. Johnson 1974; Johnson and Holliday 1980, 1981, 1986, 1989; Stafford 1981; Holliday 1985b, c, d, 1988; Holliday and Allen 1987; Johnson 1986, 1987) and yielded the most complete record of late Quaternary human occupation and paleoenvironments in the south-central United States. The research broadened to encompass late Quaternary studies throughout the Llano Estacado (e.g., Johnson 1986; Johnson et al. 1982; Holliday 1985a, e, 1987, 1989b, 1997b; Holliday et al. 1996), including a comprehensive investigation of the stratigraphy and paleoenvironmental record of the fill in the draws (Holliday 1995b) and the Paleoindian geoarchaeology of the region (Holliday 1997a).

Site-specific and regional archaeological and geoarchaeological studies have continued on the Southern High Plains during the past several decades, and the emphasis on Paleoindian sites has continued. In addition to Clovis and Lubbock Lake, investigated sites included Miami (Holliday et al. 1994), Midland (Holliday and Meltzer 1996), Milnesand (Johnson et al. 1986), and Plainview (Holliday 1997a) on the Llano Estacado; Rex Rodgers (Willey et al. 1978) and Lake Theo (Johnson et al. 1982), just off of the Llano Estacado; and Lipscomb in the northern Panhandle (Hofman et al. 1989) (map 2.1) (see also Holliday 1997a). Investigators also addressed some of the non-Paleoindian geoarchaeological records at some of these sites. Paleoenvironments and human adaptations during the Early and Middle Archaic drew special attention at Mustang Springs, on Mustang Draw (Meltzer and Collins 1987; Meltzer 1991) (map 2.1). Regional geoarchaeological studies include work on lower Sulphur Springs Draw (Frederick 1993a, 1994) (map 2.1) and, just north of the Llano Estacado, in Palo Duro Creek (Caran 1991; Frederick 1993b).

The contributions of more than sixty years of geoarchaeology on the Southern High Plains fall into two broad categories: 1) stratigraphy, soils, and paleoenvironments, and 2) Paleoindian chronologies. As will become apparent, the most immediate impact of this research—and by definition the aim of geoarchaeological research—has been on archaeological interpretations. Equally important, however, and usually of equal concern to most geoarchaeologists
on the Southern High Plains, are the contributions of these investigations to the study of late Quaternary paleoenvironments. The studies of human prehistory and the Quaternary period on the Llano Estacado have been intimately linked, as they should be elsewhere.

**STRATIGRAPHY, SOILS, AND PALEOENVIRONMENTS**

Stratigraphic investigations and the reconstruction of paleoenvironments are probably two of the oldest contributions of earth science to archaeology. Certainly they are the first such contributions on the Southern High Plains and continue to be of primary importance in archaeological and broader late Quaternary studies. Most of the archaeological sites in the draws, dunes, and playas are in well-stratified contexts that invite geologic scrutiny. The bulk of the geoarchaeological studies in the region focused on draw localities (Clovis, Lubbock Lake, Midland, and Mustang Springs), but some playa localities (Miami and San Jon) are also worth noting.

An artificial exposure of the well-stratified archaeological record preserved in the draws led to the work at the Clovis site in 1933, heralding the long tradition of geoarchaeology on the Southern High Plains. In November 1932, E. B. Howard was led to the site by local collectors. There he observed "artifacts [including fluted projectile points] . . . as well as mammoth teeth, bison and horse bones . . . weathering out of . . . bluish-gray sands" (Howard 1935:81). These bluish sands contain most of the late Pleistocene and early Holocene archaeological and paleontological record at Clovis. Howard and company also identified similar deposits, which were rich in bone from extinct vertebrates and associated with stone artifacts, locally along Blackwater Draw proper, most notably downstream from the gravel pit in the area called "Anderson Lake" or "Anderson Basin" (Howard 1935; Stock and Bode 1936) (fig. 2.1). They immediately recognized the blue sand as an important geoarchaeological marker.

Howard and his associates focused their attention on the blue sand and underlying lighter (gray) sand—the "caliche" (Howard 1935). The blue sands consisted of several different layers: the lower blue sand included organic-rich, diatomaceous muds and local beds of pure diatomite, whereas the upper blue sand contained organic-rich silt and sand. Most subsequent workers divided the blue sands into two or four lithostrata (e.g., Haynes 1975:table 4-1). The
Fig. 2.1. Stratigraphic correlation chart for the gravel pit at the Clovis site and the Anderson Basin area, prepared by Ernst Antevs (Antevs 1949:186; with very slight modification). His "Blue Gray Silt" is the "Blue Sand" of Howard (1935) and Stock and Bode (1936), which contained most of the Paleoindian archaeology and much of the extinct fauna. Note also the identification of "Altithermal age" eolian sand at both sites.
archaeological investigations focused on the diatomaceous mud, diatomite, and gray sand, all of which produced fossils of extinct vertebrates, as well as stone tools with fluted lanceolate points. These strata indicated substantial changes in depositional environment. To further document these changes, several specialists became involved to study the geology and vertebrate paleontology (Stock and Bode 1936), diatoms (Lohman 1935; Patrick 1938), and mollusks (Howard 1935:89; Clarke 1938). The interpretations from these various lines of evidence were in basic agreement. The lower, pale gray sands were deposited by flowing water, which was fresh to slightly brackish. The blue sands accumulated first in a lake, and then under more marshy conditions. Initially the water was fresh during the deposition of blue sand, but later it became saline. The changing water conditions were interpreted as indicating gradual drying during the Paleoindian occupation, that is, from the Pleistocene into the Holocene period.

Antevs (1949, 186) identified "Altithermal age" eolian sand above the Paleoindian-age deposits at the Clovis site and in Anderson Basin (fig. 2.1) but did not elaborate on his interpretations. Presumably, he believed that the sands resulted from the "Altithermal drought" he proposed earlier (Antevs 1948).

The diatomaceous sediments and gray sands at Clovis were the expressed focus of E. H. Sellards as he directed the next phase of research in the gravel pit. His goal was to further document the association of humans and Pleistocene fauna. Paleoenvironmental data were important, but the archaeological considerations took precedence, in particular, the establishment of a cultural chronology. The TMM work did yield significant post-Paleoindian environmental clues in the discovery of Archaic wells (fig. 2.2). Evans's discussion of these striking features (1951) is an excellent case study in the use of stratigraphic principles for relative dating and, moreover, is a persuasive argument for viewing these features as a human adaptation to drought conditions.

The geoarchaeological significance of the diatomaceous earth and gray sand took on added importance with the discovery of a very similar geocultural record at Lubbock Lake (fig. 2.3). Extinct fauna and stone artifacts were found in diatomaceous mud, pure diatomite, and underlying gray sands (Sellards 1952). Sellards's geoarchaeological interests in Lubbock, as at Clovis, continued to be stratigraphic with the emphasis on building a cultural chronology (fig. 2.4). Sellards exemplifies this emphasis in his last writing on Clovis and Lubbock (Sellards and Evans 1960:643), in which he referred to geologic strata by their artifact content (e.g., the diatomite and diatomaceous muds are the
Fig. 2.2. One of the Archaic age wells (well F) found at the Clovis site by Glen Evans (1951). The well cuts through Units D and C of Haynes (1975, 1995) ("diatomaceous earth" and "gray sand," respectively, of Evans, 1951, and Sellards, 1952). The well was backfilled with a mixture of sediment removed during the Archaic excavation and then buried by Unit G1 of Haynes (1995), the "jointed sand" of Evans (1951), and Sellards (1952). Courtesy of the Texas Memorial Museum.

"Folsom stratum") (fig. 2.4). In this final writing, however, he made some very general interpretations concerning the paleohydrology of the two sites. Deposition of the basal gray sands was related to high spring discharge and runoff resulting in flow that "was greater during deposition of this stratum than at any subsequent time" (641). Based on the extensive lake deposits, climate during the Folsom occupation may have been wetter than today. Sellards also alludes to a dry interval between Clovis and Folsom occupations based on the recovery of Folsom artifacts on top of "older sand dunes" (643) on the uplands. He also invokes the purported dunes to account for the diatomite ponds with the sands choking the draws and impounding water (643). The location or physical characteristics of the "dunes" was never published but may include the sand sheet at the Mitchell Folsom locality at the Clovis site (Stratum II of Boldurian 1990; Stratum C of Holliday 1995b; the locality is also known as "Frank's Folsom site" by Stanford and Broilo 1981) and the pre-Folsom eolian sediments at Midland (Wendorf et al. 1955).
Fig. 2.3. A section of the valley fill in Yellowhouse Draw exposed at Lubbock Lake. The leveling rod at lower right is 3 meters long. The Blanco Formation is Pliocene bedrock. Numbers 1–5 at left are strata 1–5 of Stafford (1981) and Holliday (1985b). Stratum 1 is Clovis-age alluvium. Stratum 2 includes a bedded diatomaceous earth (Folsom) and overlying organic-rich mud (Plainview and Firstview) (lower and upper halves of stratum 2, respectively, in this photo). Stratum 3 (early Archaic) is marl (shown here) with a valley-margin sandy eolian facies. Stratum 4 (Middle Archaic) is primarily an eolian loam. Stratum 5 (Ceramic, Protohistoric, and Historic) includes mud along the valley axis with slope-wash gravel and eolian loam along the valley margin. The mud-loam interface is exposed here. Strata 3, 4, and 5 contain soils. In this section the best-expressed soil is the A-Btk profile in stratum 4 (the Lubbock Lake Soil of Holliday 1985b, c). Courtesy of the Lubbock Lake Landmark, Museum of Texas Tech University.
The TMM work at Plainview (Sellards et al. 1947) yielded a spectacular archaeological feature in well-stratified valley fill. The site was a *Bison antiquus* bone bed with dozens of associated Paleoindian stone artifacts, including the type specimens for the Plainview projectile point. Sellards and Evans (1960) discussed the site in the context of other stratified sites, but the Plainview strata were not incorporated into regional stratigraphic schemes (e.g., fig. 2-4) until several decades after Sellards’s death. This was due to the absence of archaeological features, other than the bone bed with Plainview points, and the absence of distinctive stratigraphic markers such as diatomites and diatomaceous muds.

In the 1930s, Sellards’s field crew at the Miami site found mammoth remains along with Clovis points in sediment filling a very small playa (Sellards 1938). The gray, clayey playa fill was devoid of stratigraphy with the notable exception of a light gray silt immediately below the bone level. Sellards eventually came to believe that the “loess” layer implied “drought and the absence of vegetation” (Sellards 1952:23).

Subsequent research at Miami (Holliday et al. 1994) confirmed a likely eolian origin of the silt layer. The Miami loess layer was one line of evidence used by Haynes (1991) to support his proposal of a “Clovis drought” in the western United States. Stratigraphic data from Clovis also were used to support this hypothesis, but there is no other obvious evidence to support such a drought on the Southern High Plains (Holliday 1995a,b, 1997a, 2000a). Haynes argued that this climatic event was in part responsible for the extinction of late Pleistocene megafauna.

The Miami excavations were followed by archaeological and geological investigations at another playa, the San Jon site (Roberts 1942; Judson 1953). Judson studied the fill in the lake basin and concluded that the San Jon Paleoindian occupation was associated with lake sediments and probably occurred when there was more moisture in the area than there is today. Later occupations at the site were associated with alternating layers of lake sediment, slopewash, and eolian sand, which were interpreted as representing environments alternating between increased moisture (lake sediments) and decreased moisture (slopewash and eolian sediments). Subsequent investigations at the site tend to confirm these conclusions (Hill et al. 1995).

Several years after Sellards’s work at Lubbock Lake, during the final years of his studies at Clovis, stratigraphic studies again proved important in draw and dune contexts as research began at the Midland site (Wendorf et al. 1955;
Fig. 2.4. The geocultural sequence of the Southern High Plains proposed by E. H. Sellards and Glen Evans (Sellards and Evans 1960:fig. 2; with very slight modification), based on geoarchaeological research at the Clovis and Lubbock Lake sites. This is the first geologically oriented cultural chronology for the region.
Wendorf and Krieger 1959). The resulting data were used for environmental reconstructions and to place the well-known human remains within a cultural chronology. The site is located in and next to Monahans Draw (map 2.1) where a small dune field overlaps the drainage. Three strata were identified: White Sand, Gray Sand, and Red Sand (oldest to youngest). The White Sand was interpreted as lacustrine and reflecting “cool, wet . . . pluvial conditions” (Wendorf et al. 1955:68, table 6; Wendorf and Krieger 1959:66). The Gray Sand, which contained the human remains, reflected a drying trend (Wendorf et al. 1955:68, table 6), and the overlying Red Sand represented a period of “extreme aridity” (Wendorf et al. 1955:98). Initial correlations dated all of these events to the Wisconsin glacial period, an interpretation that had substantial archaeological implications.

As an outgrowth of the work at Midland, the High Plains Paleoecology Project (HPPP) yielded environmental data that complemented the known late Quaternary geologic record in the draws. Palynology was a key component of the project, and samples were collected from most stratified archaeological sites (Clovis, Anderson Basin, Lubbock Lake, Plainview, San Jon). The results, combined with some new radiocarbon determinations, were used to define “climatic episodes” (Wendorf 1961, 1970, 1975b) and were a significant refinement of the more generalized environmental record proposed on the basis of geologic data from a few sites such as Midland.

Surprisingly, the HPPP did not incorporate regional stratigraphic investigations. The more localized work of Haynes and Green, however, did yield significant geoaarchaeological results. Green provided the first comprehensive summary of the cultural and geological stratigraphy at Lubbock Lake, as well as additional data on wells at Clovis, and described the origin of dunes at the southern end of the Llano Estacado. Green (1962a) presented his Lubbock Lake record in a paper for a popular audience shortly after Sellards published his final work on the Llano Estacado (Sellards and Evans 1960). The interpretation of the site, based on its geology and paleontology, generally fit the scheme proposed by Antevs (1948) for the Desert West and Great Plains: a cool, humid late Pleistocene and early Holocene; a dry, warm middle Holocene “Altithermal”; and a return to cooler and more moist conditions in the late Holocene represented by today’s environment. Variations in apparent intensity of occupation at the site were linked to these environmental fluctuations. Green’s (1961) dune research expanded the sequence proposed for the Midland site and showed that the dune stratigraphy was more complex than pre-
viously thought. He also demonstrated that much of the record at Midland dated to the very late Pleistocene and most of the Holocene. These data and other work of the HPPP indicated that the Midland finds are younger than the Wisconsin glacial period (Wendorf 1961, 1975b). The dune research by Green (1961) also has proved useful for correlating and dating other archaeological sites associated with eolian sediments in the Midland region (e.g., Blaine 1968; Hofman et al. 1990; Holliday 1997a).

Haynes's studies included the first systematic geologic research at and around Clovis since Stock and Bode (1936), and added substantially to our understanding of the geoarchaeology of upper Blackwater Draw. In particular, Haynes (Haynes and Agogino 1966) documented the location and age of ancient springs along the “north bank” of the site that discharged into the old basin and resulted in deposition of the “gray Sand.” Haynes then argued that the spring-laid deposits were time-transgressive but essentially predated the earliest human occupation. The issue, however, is controversial. Green (1992:336) argues that “the gray sand in the north bank was of Clovis age in its entirety and may have represented the complete span of Clovis cultural activity on the southern High Plains.” This point is significant because no site on the Great Plains is known to contain an in situ record of the “entire span of Clovis cultural activity.” Haynes et al. (1992) point out, however, that most Clovis material comes from the upper gray sand or directly above it and that there is clear evidence for intrusion of Clovis artifacts deep into the gray sand and below it. The issue is likely to remain unresolved because the north bank of the site was destroyed by gravel mining.

Haynes (1968) was the first to correlate the geocultural stratigraphy of the Southern High Plains with other regions of North America. He fit the stratigraphy of the Clovis site into his “alluvial chronology,” which had important implications for regional archaeological chronology, paleoenvironmental reconstructions, and landscape evolution.

Beginning with the work at Lubbock Lake, the resurgence of interdisciplinary archaeological investigations in the Southern High Plains in the 1980s and 1990s significantly expanded our understanding of regional stratigraphy, geochronology, and paleoenvironments. Several examples illustrate this point. The stratigraphic record preserved in the draws has long been used for correlation of archaeological sites and climatic episodes. Between 1988 and 1993, systematic investigations of the fill in the draws showed that the general stratigraphic sequence is remarkably similar along and between most of the draws
Fig. 25. Schematic illustration of depositional chronology, dominated by depositional environments (horizontal scale) and relative dominance of depositional environments (vertical scale). High Plains, from Holiday (1999).
of the Brazos and Colorado systems (Holliday 1995b). The research also shows, however, that the stratigraphic units are time-transgressive (fig. 2.5), generally becoming younger down-draw. One discovery in this research is the very limited extent of sites with diatomite, diatomaceous earth, and muds of Paleoindian age. The presence of these deposits at such widely separated sites as Clovis, Lubbock Lake, and Mustang Springs (Meltzer and Collins 1987; Meltzer 1991) suggested that these sediments would be relatively common. This is not the case.

Correlation of the location of these lacustrine and paludal deposits with locations of historic springs, along with the time-transgressive nature of the valley fill, suggest that much of the stratigraphic record in the draws is related to spring discharge (Holliday 1995b). Stratified, multicomponent archaeological sites also seem to be associated with springs (Holliday 1995b, 1997a). The location of historic springs, therefore, may be a clue to archaeological sites with long, stratified records.

In 1983 renewed archaeological and geological research at the Clovis site resulted in several significant discoveries. Earlier mining of gravel at the site removed substantial quantities of archaeological material (Hester 1972), and the site was considered largely destroyed. Coring and excavation in 1983 and 1984 revealed, however, that a substantial body of archaeologically important late Quaternary valley fill is preserved in the outlet channel that connects the paleobasin with Blackwater Draw (Haynes 1995; Stanford et al. 1990). Stratigraphic mapping and radiocarbon accelerator-mass spectrometer (AMS) dating of this channel fill exposed in the walls of the gravel pit are significant. They document the relationship of lowland and upland facies, which aids in stratigraphic and archaeological correlation. They also show, locally, a major erosional disconformity between strata with Paleoindian debris and later Archaic-age deposits, as well as multiple early, middle, and late Holocene eolian deposits. Both conditions make within-basin stratigraphic and archaeological correlations more difficult but also clarify some long-standing issues of lithostratigraphy and chronostratigraphy at the site (Haynes et al. 1992; Haynes 1995).

Geoarchaeological studies in the 1980s and 1990s also focused on the environment of the early and middle Holocene. Previous investigators correlated Holocene deposits at specific sites with the geologic-climatic sequence proposed by Antevs (1948) for the western United States (Wendorf 1961; Green 1962a; Haynes 1975). Antevs’s "Altithermal" drought was of particular interest. Subsequently, the occurrence of early to middle Holocene eolian sediments in
all dated stratigraphic records from draws, dunes, and playas in the region suggested that the Southern High Plains had, indeed, been subjected to drought between 9000 and 4500 B.P. (Holliday 1989b, 1995a,b). Additional evidence for the Altithermal on the Llano Estacado and human response to it was provided by the artificially excavated wells found first at the Clovis site (Evans 1951; Green 1962b) and later at the Mustang Springs site (Meltzer and Collins 1987; Meltzer 1991). Evans (1951) recognized that the wells were a response to drought, but did not place them in a regional climatic framework. Based on his discovery of additional wells at Clovis and also on stratigraphic data, Green (1962b) was the first to provide clear evidence that the Altithermal affected the southern Great Plains (although Antevs 1949:186, inferred Altithermal conditions for the Clovis site; fig. 2.1). Mustang Springs yielded evidence for an extensive well field (Meltzer and Collins 1987; Meltzer 1991), and Meltzer (1991) used a variety of geologic arguments to support his contention that the pits were not only artificially excavated, but were also related to drought-related drops in the water table. Research on the Altithermal of the Southern High Plains resulted in the development of a model for likely prehistoric responses to such environmental conditions (Meltzer 1995, 1999).

The application of soil science has been an important methodological development in geoarchaeology on the Llano Estacado. Buried “humus zones” (buried A-horizons) were first noted in archaeological contexts in the region during initial excavations at Lubbock Lake (1939 and 1941) (J. B. Wheat, field notes on file, Museum of Texas Tech University; Wheat 1974). They were identified as marking stable land surfaces and utilized as stratigraphic markers. Soils were similarly recognized and used for stratigraphic correlation at San Jon (Judson 1953) and Midland (Wendorf et al. 1955), as well as in and around Clovis (Haynes 1975). Wendorf et al. (1955) and Haynes (1975) also used soils as environmental indicators (i.e., as indicators of more moist conditions following periods of relative aridity and eolian deposition). Systematic and widespread geoarchaeological application of soil science began with the Lubbock Lake Project (C. Johnson 1974; Stafford 1981). Soils have proved very useful for stratigraphic correlations, for age estimations of strata, and for reconstructing paleoenvironments and site formation processes at Lubbock Lake (Holliday 1985b,d, 1988, 1992; Holliday and Allen 1987; Johnson and Holliday 1989) (fig. 2.3) and other localities throughout the region (Holliday 1985a,e, 1989b, 1995a,b, 1997a; Johnson et al. 1982).
Geoarchaeology of the Southern High Plains

Paleoindian Chronology

More than sixty years of geoarchaeological research on the Southern High Plains has contributed substantially to establishing the Paleoindian cultural chronology of the region. This research was also key in sorting out Great Plains cultural chronologies and contributing to a broader perspective of Paleoindian studies in North America.

Chronological differentiation of Clovis and Folsom occupations was first made at the Clovis site based on stratigraphic relationships. Following the initial Folsom discoveries in 1926–1928, Folsom points were recognized immediately as distinctive in technology and type. Formal differentiation between “Folsom” and “Clovis,” however, took well over a decade to resolve. In the years following the Folsom finds, fluted points found in association with mammoth bones at Dent, Colorado (Figgins 1933), Clovis (Cotter 1937), and Miami (Sellards 1938) were differentiated from “True Folsom” by terms such as “Folsom-like,” “Folsomoid,” and “Generalized Folsom” (Wormington 1957:30). By the late 1930s, the typological and chronological distinctions between Clovis and Folsom points were all but formalized (Holliday and Anderson 1993; Holliday 2000a). In 1941, a symposium on Paleoindian terminology was held in Santa Fe (Howard 1943; Wormington 1948, 1957). The group decided to differentiate the various fluted types, thus defining the Folsom and Clovis types so familiar today.

Confirmation of the stratigraphic and relative chronologic relationship between Clovis and Folsom came with renewed excavations at Clovis by Sellards, Evans, and Meade. Folsom artifacts were consistently found in the diatomite and diatomaceous muds whereas Clovis material always came from the underlying sands (Sellards 1952:29–31, 54–58). Both Cotter (1938) and Sellards (1952) noted apparent faunal relationships (Clovis and mammoth, Folsom and bison) that were long considered characteristic of these early Paleoindian occupations. Subsequent work at Clovis and other sites shows this inferred relationship to be more complex than it first seemed (Hester 1972; Johnson 1986).

After the Folsom discoveries, one of the first stylistic differentiations noticed among Paleoindian projectile points was fluted versus unfluted (usually lanceolate) (e.g., Renaud 1931). In the 1940s, various lanceolate styles were found in sites in association with the remains of extinct bison. The Plainview artifact
style, established by Sellards et al. (1947) on the basis of their work at the Plainview site, became the first unfluted Paleoindian point type to be formally described and proposed based on a sizeable collection. The age relationships of Plainview to other Paleoindian styles were unclear, however, because the site contained no archaeological features other than the bone bed with Plainview points and exposed no distinctive stratigraphic marker beds such as diatomites and diatomaceous muds. Sellards et al. (1947) believed that the Plainview style postdated Folsom on the basis of technological and morphological traits. Sellards and Evans (1960) supported this view based on several radiocarbon ages from Plainview and Lubbock Lake. This cultural chronological interpretation was correct, but the radiocarbon ages are questionable (Holliday and Johnson 1981; Holliday 1997a; Holliday et al. 1999).

Dating the Plainview site continues to be a vexing problem. The age of the Plainview occupation of the Southern High Plains has taken on added importance with the dating of the morphologically similar Goshen style to late Clovis or early Folsom time on the Northern Plains (Frison 1991, 1996) and the dating of Plainview-like artifacts to around 9000 B.P. at the Horace Rivers site just north of the Southern High Plains (Mallouf and Mandel 1997). An attempt was made to date bone associated with the Plainview-type collection using the AMS radiocarbon method, but the results are a frustratingly wide array of ages (Holliday et al. 1999). At other sites in the region, however, Plainview is clearly both locally late-Folsom and post-Folsom in age based on stratigraphy and radiocarbon dating (Dibble and Lorraine 1968; Dibble 1972; Harrison and Killen 1978; Johnson and Holliday 1980; Holliday and Johnson 1981). As of this writing, Plainview appears to date to 10,000±500 B.P., but may have continued to as late as 9000 B.P.

Along with determining the stratigraphic relationship of Clovis to Folsom, Sellards's crews at Clovis provided the first documentation of the stratigraphic and relative chronologic relationships of lanceolate styles to fluted forms. Excavations in several bone beds yielded a collection of lanceolate points that Sellards (1952) used to define the "Portales Complex." The points were recovered stratigraphically above Folsom features, establishing the unfluted Paleoindian styles as later than the fluted points (Sellards 1952).

Sellards's work at Clovis and Lubbock coincided with the development of radiocarbon dating. After the discovery of burned bone in the diatomaceous muds at Lubbock Lake in 1950, Sellards decided to submit a sample to Willard Libby, who was in the early stages of applying the radiocarbon method he had
just developed. The bone was interpreted as coming from the same zone that yielded Folsom artifacts elsewhere in the site, and the resulting radiocarbon age (9883±350 B.P., C-558; Libby 1952:82) is one of the first applications of radiocarbon dating to Paleoindian archaeology and is thought to be the first date on the Folsom culture (Roberts 1951; Taylor 1985). Other investigators later questioned the date and the association with Folsom (Holliday and Johnson 1986), but determination and publication of the age were nevertheless landmarks in Paleoindian studies and brought Lubbock Lake into prominence.

CONCLUSIONS

Geoarchaeology has played an important role in archaeological research on the Southern High Plains for over a half century. Historically, researchers used geoarchaeology to establish cultural chronologies (Sellards 1952; Sellards and Evans 1960) and for some environmental reconstructions (Stock and Bode 1936; Sellards and Evans 1960; Green 1962b). More recently, geoarchaeological studies have made significant contributions in all of the traditional roles: stratigraphic correlations, dating, and paleoenvironmental reconstructions. Such research is best exemplified in the draws, where such site-specific geoarchaeological studies as the intensive and extensive work at Clovis (e.g., Haynes 1995) and Lubbock Lake (e.g., Holliday 1985b) were complemented by a regional stratigraphic study (Holliday 1995b). The resulting understanding of facies variations across the draws proved especially useful in placing the well-known human remains from the Midland site in a firmer chronological context (Holliday and Meltzer 1996) and in reconstructing the setting of Paleoindian occupations (Holliday 1997a). At a regional scale, this research provides a better understanding of paleoenvironmental changes in the draws. The depositional environments varied considerably from site to site in the late Pleistocene and early Holocene periods. The resulting lithostratigraphic units are asynchronous along the valleys. As a result, we must make time-stratigraphic correlations between archaeological sites in draws with considerable caution.

Although best known for providing geochronological or paleoenvironmental contexts for Paleoindian occupations, the past and present geoarchaeological investigations in the principal late Quaternary depositional environments (draws, dunes, and playas), integrated with other Quaternary studies, provide a
better understanding of post-Paleoindian environments. Particular attention has focused on aridity during the early Archaic (the Altithermal) (Green 1962b; Meltzer and Collins 1987; Holliday 1989b, 1995b; Meltzer 1991; Quigg et al. 1994) and on environmental fluctuations during the Late Prehistoric and Historic periods (Holliday 1995b; Muhs and Holliday 1995).

Combining site-specific and regional geoscientific studies should provide a better understanding of how humans used the landscape although such studies are relatively rare (Hester 1975; Holliday 1997a, 2000b; Meltzer 1995, 1999). Moreover, geoarchaeological studies, inseparable from Quaternary research, provide a holistic view of the broader physical setting and the landscape and environmental evolution of the Southern High Plains throughout the past twelve thousand years of human occupation.

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