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CONTENTS

ARTICLES

Foreword

Timothy K. Perttula

In recent years, the *Bulletin of the Texas Archeological Society (BTAS)* has published a number of volumes that have been thematically organized. Most of these volumes have focused on the archeology of a specific region of Texas, except for the 1999 BTAS, which had many papers on the Spanish Colonial archeology in the state, and the 1995 *BTAS* provided a one volume summary of the prehistoric archeology of Texas. These papers led to the eventual publication of *The Prehistory of Texas* by Texas A&M University Press (Perttula 2004).

Given the current interest in the archeology of the Paleoindian period in North America generally, and the spate of important archeological research on Paleoindian topics in Texas, it seemed like a good idea for the *BTAS* to join the Paleoindian research effort. That idea, and discussions with various Texas archeologists, has led to the *BTAS* volume now before you.

I thank Michael R. Bever and C. Britt Bousman—the Guest Editors for this volume—and all the other contributors to Volume 78 of the *BTAS* for their willingness to participate in this Texas Archeological Society publication effort. I hope the Texas Archeological Society membership, the general public, as well as other archeologists interested in the Paleoindian period, will find useful—and also challenging—the varied information presented in this volume on Texas Paleoindian archeology.

This volume could not have been completed without the support of the Board of Directors and Executive Committee of the Texas Archeological Society. The fine folks at Morgan Printing, here in Austin, did their usual excellent job in formatting, layout, and publication of the many manuscripts comprising Volume 78 of the *BTAS*. In particular, the efforts of Terry Sherrell and Blake Mitchell were crucial in completing the volume in a timely manner.

REFERENCES CITED

Perttula, T. K. (editor)
2004 *The Prehistory of Texas*. Texas A&M University Press, College Station.

Preface:
Recent Developments in Texas Paleoindian Research

Michael R. Bever

Texas has long held an important role in Paleoindian archeology, both locally and nationally. The state has a rich Paleoindian archeological record and many important sites are found here. Groundbreaking work at classic sites like Miami, Lubbock Lake, Lipscomb, Plainview, and Bonfire Shelter, and more recent work at sites like Gault, Wilson-Leonard, and Aubrey, has helped write, and in some cases rewrite, Clovis, Folsom, and later Paleoindian prehistory. This tradition remains strong, and research in Texas continues to advance our understanding of Paleoindian archeology. The articles collected in this volume report on new directions in Texas Paleoindian research, spanning the full sequence from Clovis—and possibly even pre-Clovis—to late Paleoindian time periods. Using a variety of archeological, geological, and paleontological approaches, the studies are both descriptive and synthetic, and range from the analysis of newly reported sites and collections to the reanalysis and reinterpretation of old sites.

Given these developments in Texas Paleoindian archeology, Timothy K. Perttula, Publications Editor for the Texas Archeological Society, and current editor of the *Bulletin of the Texas Archeological Society*, felt the time was right to devote a special volume of the *Bulletin* to the topic. That was the impetus for the current volume. To initiate the project, Britt Bousman and I organized a symposium on Texas Paleoindian archeology at the 2006 Annual Meeting of the Texas Archeological Society, held in San Angelo. Most of the papers from that session, and one additional paper, have made their way into the current volume. These 10 articles (and one reply) are arranged in roughly chronological order and bring together scholars from a range of disciplines. The collection highlights the diversity of approaches characteristic of Paleoindian research. It is satisfying to see that the strong tradition of Texas Paleoindian scholarship, begun so many decades ago, will continue into the future.

I would like to thank all of the authors for their efforts in bringing this volume to fruition. Without their hard work and productive research, a volume like this would not have been possible. I am especially grateful to Timothy K. Perttula for conceiving of the idea for this volume, as well as his persistence and tireless hard work in polishing the articles and ensuring the smooth and timely flow of the entire publication process.

New Evidence for Mammoth Bone Quarrying on the Inner Gulf Coastal Plain of Texas

*Alston V. Thoms, Eileen Johnson, S. Christopher Caran,
Rolfe D. Mandel, and Thomas Vance*

ABSTRACT

Preliminary evidence is presented for mammoth bone quarrying activities at three Late Pleistocene sites on the inner Gulf Coastal Plain: Richard Beene, San Antonio River, and Munger Branch. These sites resemble the Duewall-Newberry site, also on the inner Gulf Coastal Plain, in that they contain credible evidence—helical fractures, impact marks, and cut marks—for human roles in the breakage of *Mammuthus columbi* bones, presumably as raw material for bone tools. These three sites yielded at most a single chipped stone flake, in marked contrast to other Clovis-era sites in the region, which have an abundance of chipped stone artifacts and, rarely, a few mammoth bones. From an ecological perspective, the widespread abundance of Clovis points throughout Texas is consistent with the contention that human occupation was established well before 11,200 B.P. That Columbian mammoth remains are also abundant and widespread suggests the likelihood of well-developed predator-prey and scavenger relationships during pre-Clovis times.

INTRODUCTION

This article presents preliminary evidence for bone quarrying activities at three new Late Pleistocene mammoth (*Mammuthus columbi*) localities on the inner Gulf Coastal Plain in east-central Texas: Richard Beene, San Antonio River, and Munger Branch (Figure 1). Although each locality is formally designated as an archeological site, they are best considered as *potential* Late Pleistocene occupations that warrant further investigation. To date, field work at these sites and analysis of selected mammoth bones from them has been exploratory in nature. Nonetheless, preliminary findings indicate that the remains from the San Antonio River and Munger Branch sites are in their primary depositional contexts and that long-bone segments from all three sites exhibit helical fractures consistent with human modification (Caran 2001; Johnson 2001, 2007a; Thoms et al. 1997, 2001, 2005). Additional field investigations are planned to further assess the working model that these localities contain significant evidence for mammoth bone quarrying by some of the earliest Texans.

What distinguishes the three sites described herein from most known Paleoindian sites on the inner Gulf Coastal Plain and adjacent physiographic regions is a paucity of chipped stone artifacts and, at two of the sites, a relative abundance of mammoth bones. In marked contrast, chipped stone dominates the assemblages at almost all other archeological sites in the region, regardless of age. Proboscidean remains are sometimes present at Clovis-era sites but usually in low frequencies (Bousman et al. 2004). The Duewall-Newberry site is the notable exception, as it yielded an abundance of mammoth remains and lacked chipped stone altogether (Steele and Carlson 1989).

To establish an ecological context, the geographic and Late Pleistocene paleoenvironmental settings are described, evidence for Paleoindian occupation of the region is summarized, and criteria for evidence of human roles as taphonomic agents in the modification of mammoth bones are reviewed. The primary intent of this article, however, is to describe: (1) the nature of exploratory field work conducted at each site; (2) the stratigraphic position of the mammoth remains; and (3)

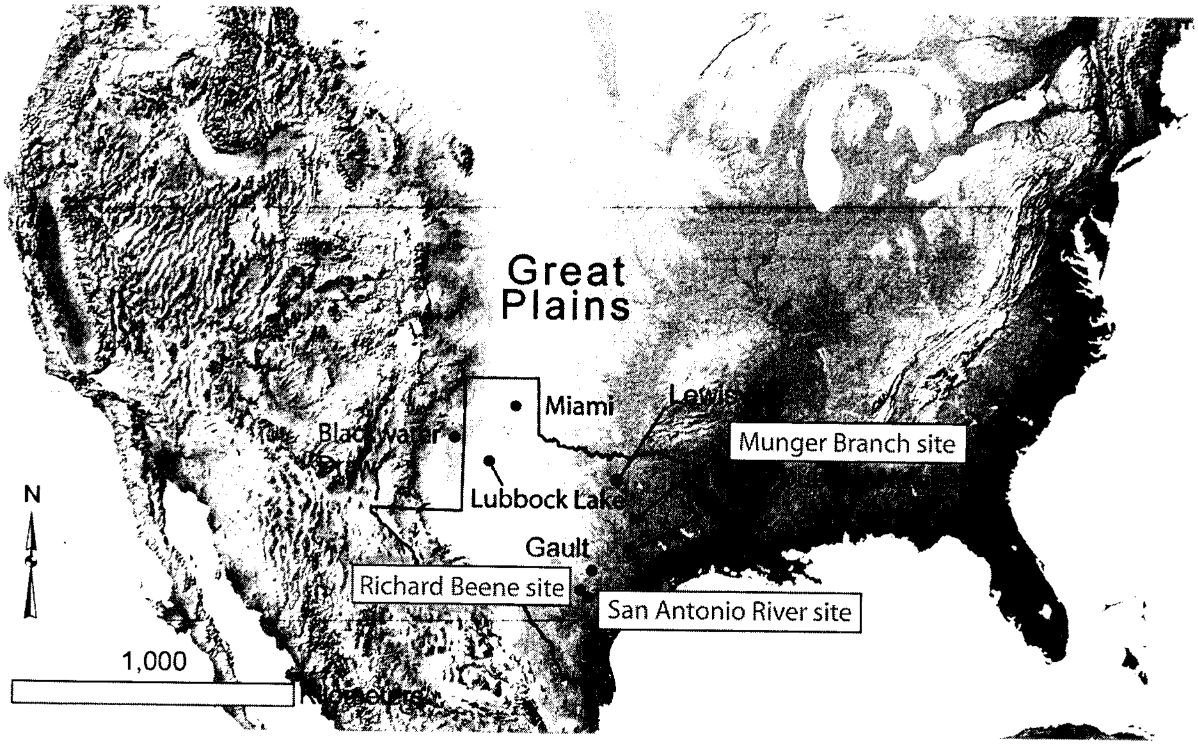


Figure 1. Location of sites and physiographic areas discussed in the text.

the preliminary evidence for human modification of bone segments.

Limb bone segments were selected for analysis because they have thick cortical bone well suited for the production of bone tools and, accordingly, are especially likely to exhibit evidence of human modification (Johnson 1985, 1989). The article concludes with a discussion about the likelihood that fresh remains of mammoths were routinely quarried for portable diaphyseal (i.e., shaft) segments. Such localities are likely to be chipped stone-poor but they may well yield some of the best evidence for pre-Clovis occupation of the region.

GEOGRAPHIC AND ENVIRONMENTAL SETTINGS

The mammoth bone sites discussed herein are located on the inner Gulf Coastal Plain in the Post Oak Savannah and adjacent portions of the Blackland Prairie ecological zones (Figure 2a; Frye et al. 1984). The Richard Beene site is in Bexar County, about 25 km south of San Antonio. It is buried in terrace fill along the left bank of the Medina River. The San Antonio River site is also in Bexar County, along its namesake river, about 1 km below the mouth of the Medina River. It is buried in terrace fill exposed along the right bank of the river.

The area south of San Antonio where these two sites are located marks the southern terminus of the Post Oak Savannah, an ecological zone that defines the southwest corner of the continent's extensive oak, hickory, and pine forests. A few km farther south of San Antonio, thorn brush dominates the landscape and represents a separate ecological zone known as the South Texas Plains (Frye et al. 1984). As such, the San Antonio area is decidedly ecotonal—an area of ecological transition—and different researchers place the boundaries between vegetation and biotic zones in slightly different locations. Blair (1950), for example, places most of Bexar County, including the Richard Beene and San Antonio River sites, within the Tamaulipan biotic province, which encompasses much of the South Texas Plains and is drier and warmer than the Texan biotic province and the Post Oak Savannah ecological zone to the north (Figures 2a and 2b). Distinguished in part by its Neotropical species, the Tamaulipan province contains "a considerable element" of grassland species, along with "some" southeastern forest and Chihuahuan desert species (Blair 1950:103).

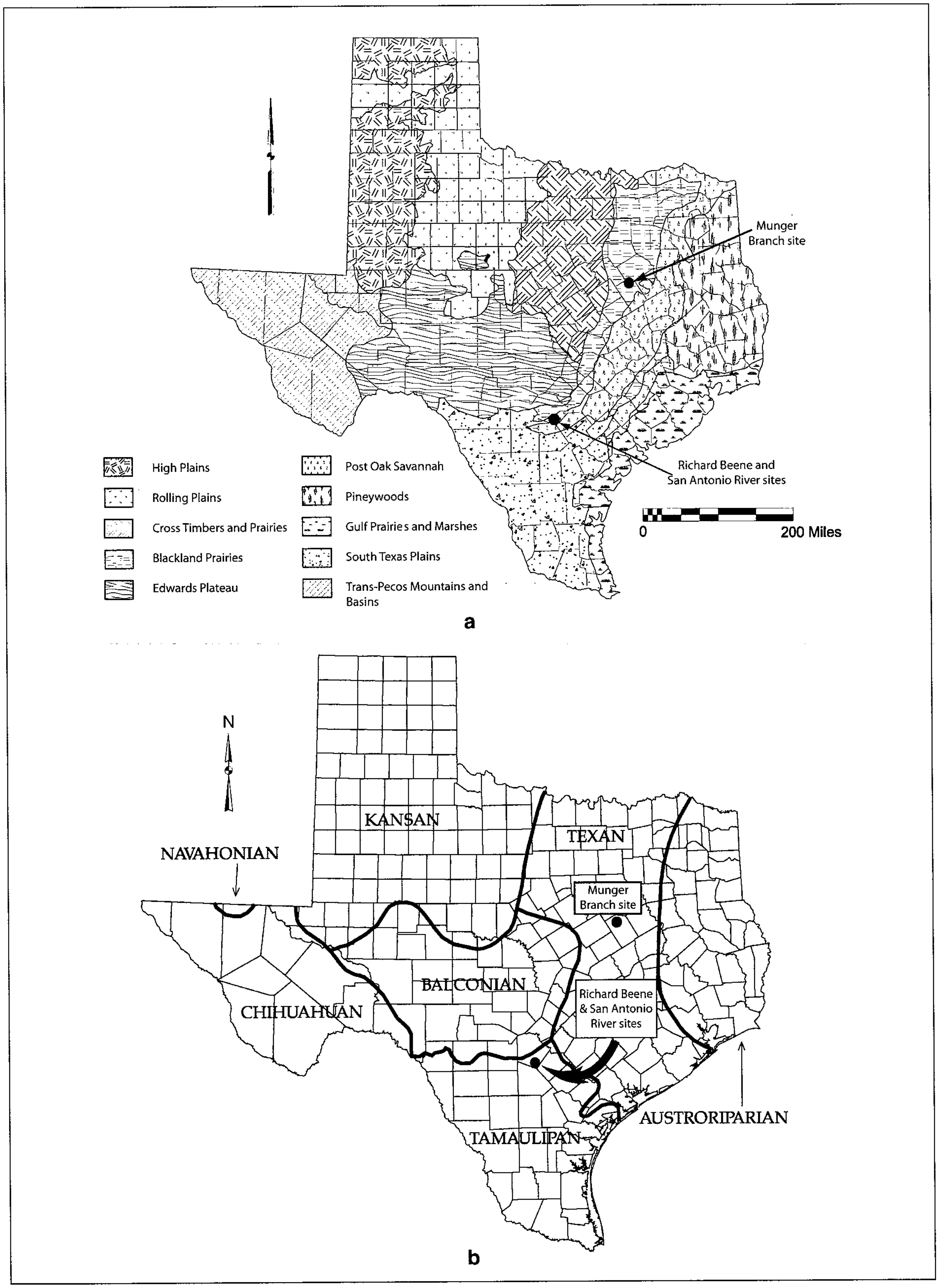


Figure 2. Environmental setting: a, distribution of the vegetation communities mentioned in the text (redrawn from Frye et al. 1984); b, distribution of biotic zones mentioned in the text (redrawn from Blair 1950).

The Post Oak Savannah and the northern tier of the South Texas Plains today, and probably since Late Pleistocene times, visually resemble the mosaic of grasslands and woodlands in south-central Africa where significant numbers of elephants exist today. Considerable information relevant to Paleoindian studies in the Americas has come from observations of African elephants and experiments with their remains (e.g., Backwell and d'Errico 2004; Blumenschine and Selvaggio 1991; Haynes 1991).

Located about 350 km to the north-northeast in northern Limestone County is the Munger Branch site. The Blackland Prairie zone surrounds the Munger Branch site but the Post Oak Savannah is only 10 km to the east (see Figure 2a). The Blackland Prairie is encompassed by the Texan biotic province, which is ecotonal between the forest-dominated Austroriparian province to the east and the grassland-dominated Kansan biotic province to the northwest (see Figure 2b; Blair 1950). The Munger Branch site is deeply buried in very fine-grained terrace fill. Munger Branch is a tributary of Pin Oak Creek, the watercourse for which this mammoth bone locality was first named (Vance 2004). Pin Oak Creek flows into Richland Creek, a major tributary of the Trinity River.

PALEOENVIRONMENTAL CONTEXT

During Late Pleistocene times, the southwest edge of North America's expansive deciduous/coniferous forest extended across most of Texas' inner Coastal Plain. Maps prepared by Delcourt and Delcourt (1981, 1993) and Delcourt (2002) show that, from 18,000 to 10,000 B.P., Bexar and Limestone counties would have been encompassed by an oak, hickory, and southern pine forest that dominated southern North America's Gulf Coastal Plain. By 10,000 B.P. the western fringe of deciduous/coniferous forests in Texas had been replaced by a belt of oak savannah, the precursor of the modern Post Oak Savannah.

Bousman's (1998) reexamination of pollen data from several peat bogs in the Post Oak Savannah yielded similar results showing that woodland (i.e., savannah) vegetation persisted between 17,000 and 10,000 B.P. Arboreal canopy cover ranged from 30–60 percent, except during two periods lasting several centuries and centering on 16,500 and 12,500 B.P. During those times grassland communities dominated but there remained at least 10 percent arboreal cover (Bousman 1998).

Columbian mammoths were living throughout Texas for tens of thousands of years prior to any hint of human habitation in North America, and they continued to occupy the landscape well after the arrival of the first people in Texas and vicinity (Haynes 1991). A growing body of evidence places the arrival of humans well before the Clovis culture developed ca. 11,200–10,800 B.P. (e.g., Bonnichsen et al. 2005; Bousman et al. 2004; Collins 2004; Dillehay 1997; Haynes 1992, 1993, 1995; Meltzer 2004; Waters and Stafford 2007).

A recent overview by Gatlin et al. (2007) reveals that Columbian mammoth remains are reported from 123 of 254 Texas counties (Figure 3). While mammoth bones are known from throughout the state, they are least common in the Edwards Plateau, Trans-Pecos, South Texas Plains, and Pineywoods ecological regions. They are most common on the Southern Plains, Cross Timbers, Blackland Prairie, and the Coastal Plains and Marshes. The sites described herein are from portions of the Post Oak Savannah and Blackland Prairie where mammoth sites are moderately common.

PALEOINDIAN CONTEXT

A surprising abundance of early Paleoindian projectile points in forested regions of southeastern North America, often more than 100 per county (Anderson 1996), indicates that these regions also were well suited for human habitation during the Late Pleistocene. Evidence exists, albeit presently quite limited, for direct associations of mammoth and mastodon (*Mammut americanum*) remains with human activities on the eastern Gulf Coastal Plain (Anderson 1996). It comes primarily from submerged sites in Florida that have yielded proposed proboscidean bone and ivory tools (Dunbar and Webb 1996).

Preservation conditions are such that mammoth remains are more abundant in the grassland regions of south-central North America (Johnson 1989; Holen 2006), even though that habitat may have been less favorable compared to savannah regions to the east. Widespread distribution of Clovis points (Meltzer and Bever 1995; Prewitt 1995) and sites (Bousman et al. 2004) on the southern Plains of Texas (Figure 4), although in significantly lower frequencies than in the southeast part of the continent,

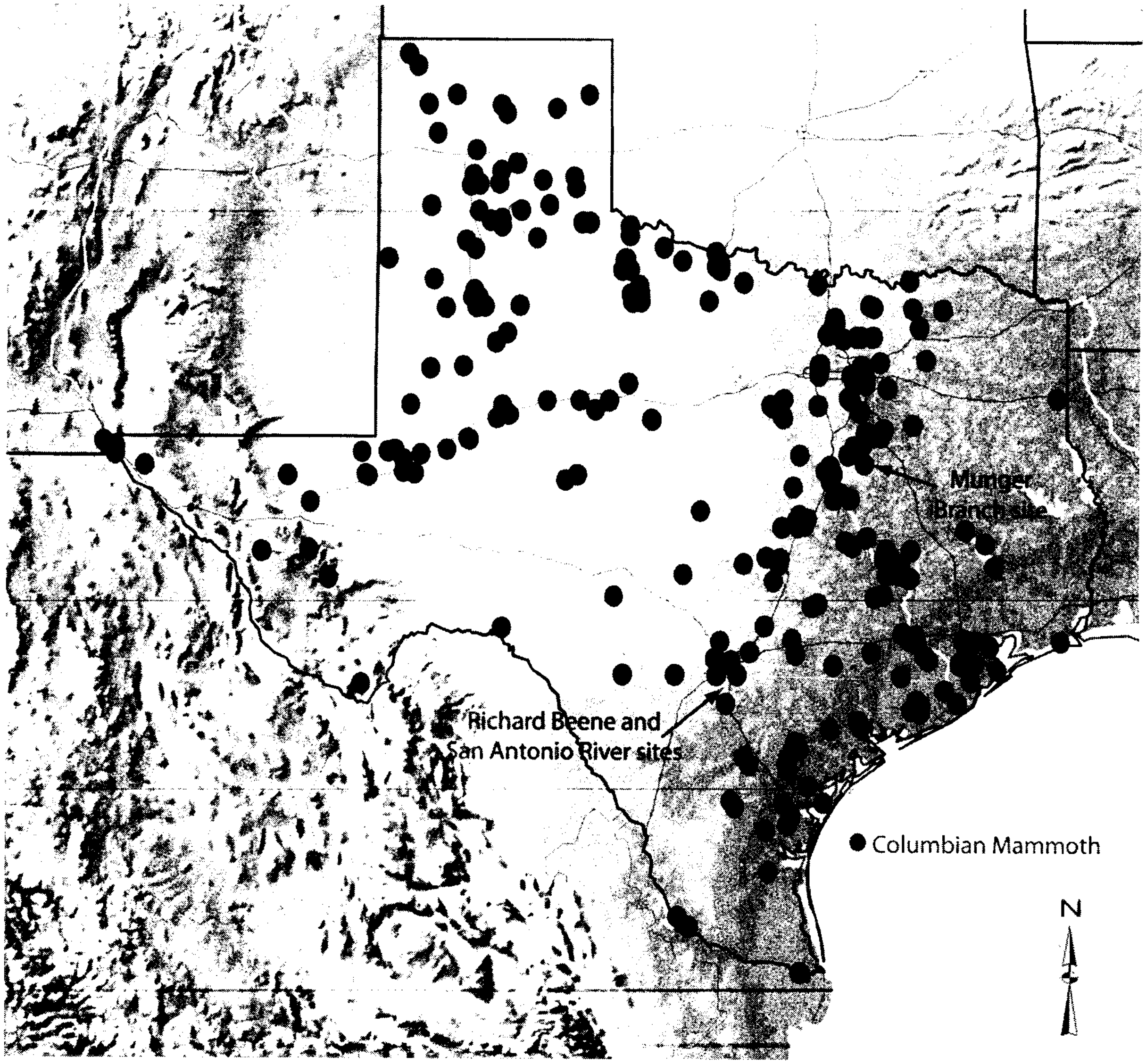


Figure 3. Approximate location of known mammoth localities in Texas (redrawn from Gatlin et al. 2007:Figure 5).

demonstrates that the grasslands of south-central North America and the adjacent woodlands to the east were well-occupied by hunters and gatherers during the Late Pleistocene.

Preliminary results from excavations at the Gault site, located along the westernmost edge of the Coastal Plain about 125 km north-northeast of San Antonio (see Figure 1), adequately attest to a temporal association among mammoth bones, Clovis points, and lithic debitage (Collins 2004). This and other sites in the central part of the continent establish an incontrovertible linkage between proboscideans and hunter-gatherers of the Clovis era (Bousman et al. 2004; Fisher 1984; Johnson 1989, 2005).

From a perspective of human paleoecology, the widespread abundance of Clovis points and sites throughout Texas indicates that human occupation was well-established prior to the Clovis era. Accordingly, long-established populations, as opposed to recently arrived founding populations, were the primary venues for the spread of biface technology that characterizes Clovis culture. This scenario is supported by a recent study showing that all well-dated Clovis sites in North America fall within a time range of 250 calendar years—11,050 to 10,800 B.P.—and, importantly, overlap in age with non-Clovis sites in North and South America (Waters and Stafford 2007). Here, too, the most parsimonious explanation

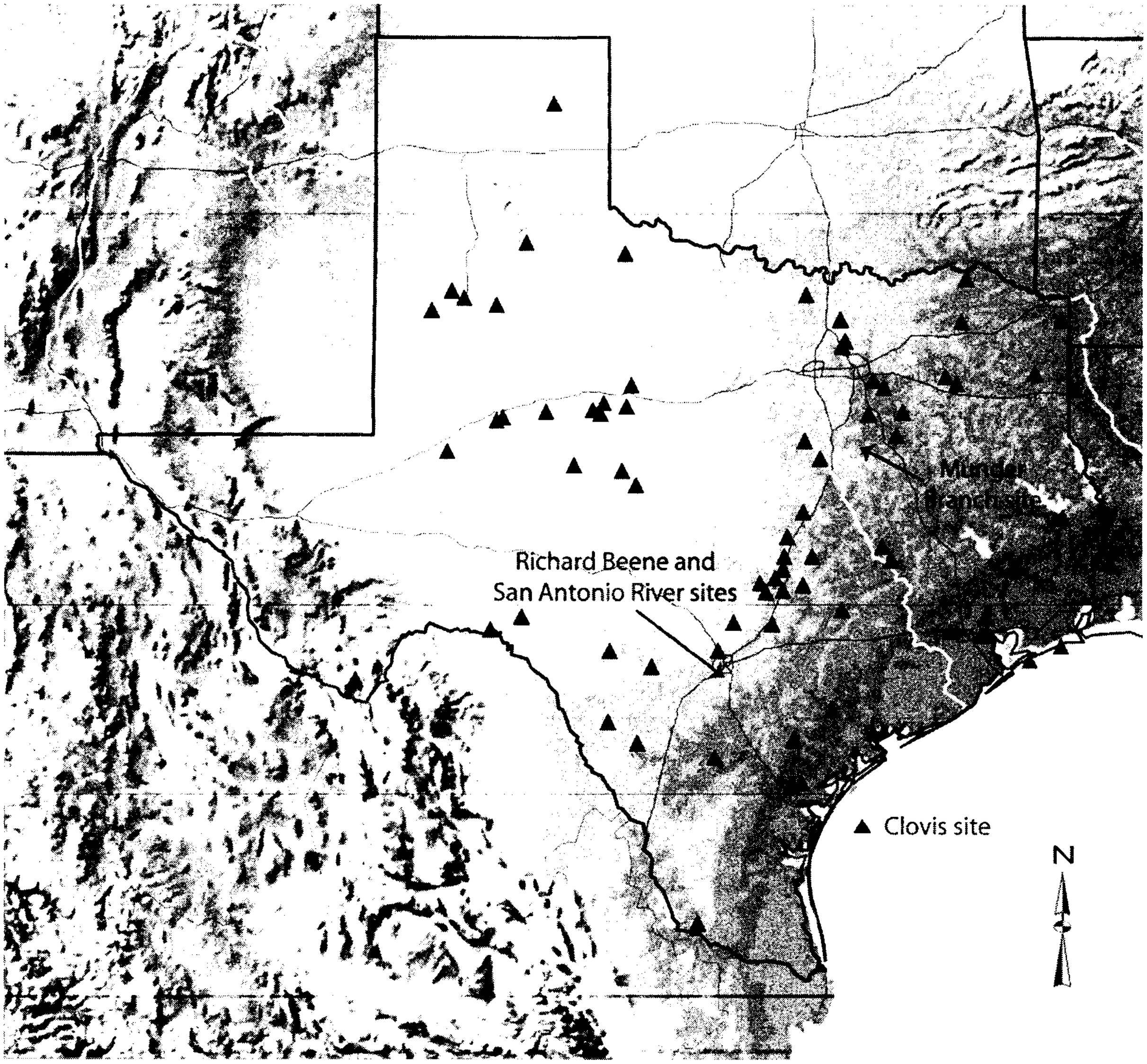


Figure 4. Approximate location of known Clovis sites in Texas (redrawn from Bousman et al. 2004:Figure 2.46b).

for contemporary non-Clovis assemblages, coupled with the brevity of Clovis technology per se, is a continent-wide presence of pre-Clovis cultures.

The widespread and, in some cases, abundant Columbian mammoth remains in many of Texas' ecological zones points to a likelihood of well-developed, pre-Clovis predator-prey and scavenger relationships during the waning stage of the last Glacial Maximum (cf. Collins 2004). In short, it seems likely that the southwestern margin of the continent's expansive oak, hickory, and pine forest, which would become the Post Oak Savannah, afforded ideal human and mammoth habitat prior to and during Clovis times.

TAPHONOMIC CONTEXT

While Late Pleistocene proboscidean remains are fairly common across Texas (Briggs 1987; Evans and Meade 1945; Fox and Smith 1987; Gatlin et al. 2007), their clear association with early peoples is rare (Johnson 1991, 2001). This ostensible rarity results from a traditional stance that the presence of lithic artifacts affords the best, if not the only, acceptable evidence of association, and the small number of adequately analyzed mammoth bone sites. When lacking lithics, proboscidean localities are typically assumed to be paleontological in nature and, hence, recovered bones are unlikely to be examined as carefully for human-caused modification as would be the case if they had been found in the midst of stone tools and debitage. In the past 20 years, however, that stance has been challenged (e.g., Bonnichsen 1979; Bonnichsen and Sorg 1989; Johnson 1985, 2005, 2007b; Morlan 1980; Shipman et al. 1984), and a better understanding of site formation and disturbance processes has developed (e.g., Lyman 1994; Schiffer 1987).

Available evidence indicates that, in general, people broke bones to extract marrow, and obtain raw material for production purposes, including expedient butchering tools and more stylized, formal tools such as awls and needles (Johnson 1985, 2005). The marrow in proboscidean bones, however, is contained in a three dimensional trebecular lattice within the medullary cavity and is not conducive to extraction through bone breakage (Haynes 1991).

The challenge has been in recognizing how people manipulate and modify bone as opposed to the effects of natural (i.e., non-human) processes, and in establishing diagnostic criteria that separate human-induced bone modifications from naturally effected bone damage (e.g., Blumenschine 1988; Capaldo and Blumenschine 1994; Cruz-Uribe 1991; Johnson 1985; Olsen and Shipman 1988). Common types of bone modification are marks on the cortical (outer) surfaces and fractures.

Some of the common causes of natural marks on bone that can be confused with marks produced by people include carnivore gnawing and tooth scoring, root etching, and trampling (Binford 1981; Olsen and Shipman 1988; Shipman 1981; Shipman and Rose 1984). Generally, these types of marks have broad, shallow troughs or narrow troughs that lack microfeatures, can wander and follow the curvature of the bone, and may occur at any location regardless of anatomy. Marks caused by people using lithic tools generally have steep-sided, narrow, V-shaped troughs with microfeatures (Johnson 2007a; Olsen and Shipman 1988; Shipman 1981). This kind of human-induced mark occurs as short, parallel lines (singly or in a series) not oriented toward bone curvature, and placement is related to specific locations on the animal's anatomy (Binford 1981; Johnson 1987, 2007b).

Carnivores may also produce patterns that can be confused with human-induced breakage (Binford 1981; Calpaldo and Blumenschine 1994; Johnson 1985). Bone as a tissue is designed to resist failure (Currey 1984; Evans 1973). When a fresh (i.e., from an animal that just died) long bone is struck with a concentrated force (dynamically-impacted), fracture fronts curve around the bone until the force is dissipated and/or the fronts intersect one another. A fracture front is the leading edge of force and these fronts emanate out from the dynamic loading point in a radial pattern. It is these fronts cutting through the compact bone that produce the helical fracture surfaces. As a front follows its path around the bone diaphysis, it encounters other fracture fronts (Bunn 1989; Johnson 1985:172, 1989).

Bone begins to lose moisture at death. As it dries, its mechanical properties, including tensile and compressive strengths as well as energy absorbing capacity, are altered, such that the bone responds differently to force. Microcracking occurs and this too alters the effect and path of fracture fronts. With drying, the biomechanical response to force (both dynamic and static) changes from a helical to a horizontal tension failure. This type of failure leads to fracture fronts that cut across long bone shafts and produce perpendicular, parallel, or diagonal breaks (Johnson 1985:172).

Carnivores, particularly canids, can break dry bones when they extract the remaining nutrients. In breaking dry bones, they apply static pressure. Dry long bones, whether intact or with one or both ends removed by gnawing, fracture through horizontal tension failure. Whether large canids, particularly hyenas, can fracture intact fresh long bones of elephant-sized mammals through static loading is still an open question (Blumenschine 1988; Blumenschine and Selvaggio 1991; Johnson 1985). Nevertheless, the response of fresh, intact long bones to dynamic impact is that of a helical fracture. Currently, humans are the only known agent to dynamically impact fresh long bones of adult elephant-sized animals (Holen 2006; Johnson 1989, 2005).

Recently, Lucinda Backwell's field school students at the University of the Witwatersrand, South Africa, conducted an actualistic experiment that entailed breaking modern elephant long bones. Eleven bones (Figure 5a) were exposed to the elements for six months while insects removed the flesh (Lucinda Backwell, personal communication 2006). The objective was to compare the broken elephant bones to breakage patterns on fractured bone recovered at Oludvai Gorge from deposits dated 1.8–1 million years ago (Backwell and d'Errico 2004). Students were tasked with breaking the long bones into small pieces using the bones themselves as well as dolomite and quartzite "blocks" as hammers and anvils (Figure 5b). Twenty-seven students, working in

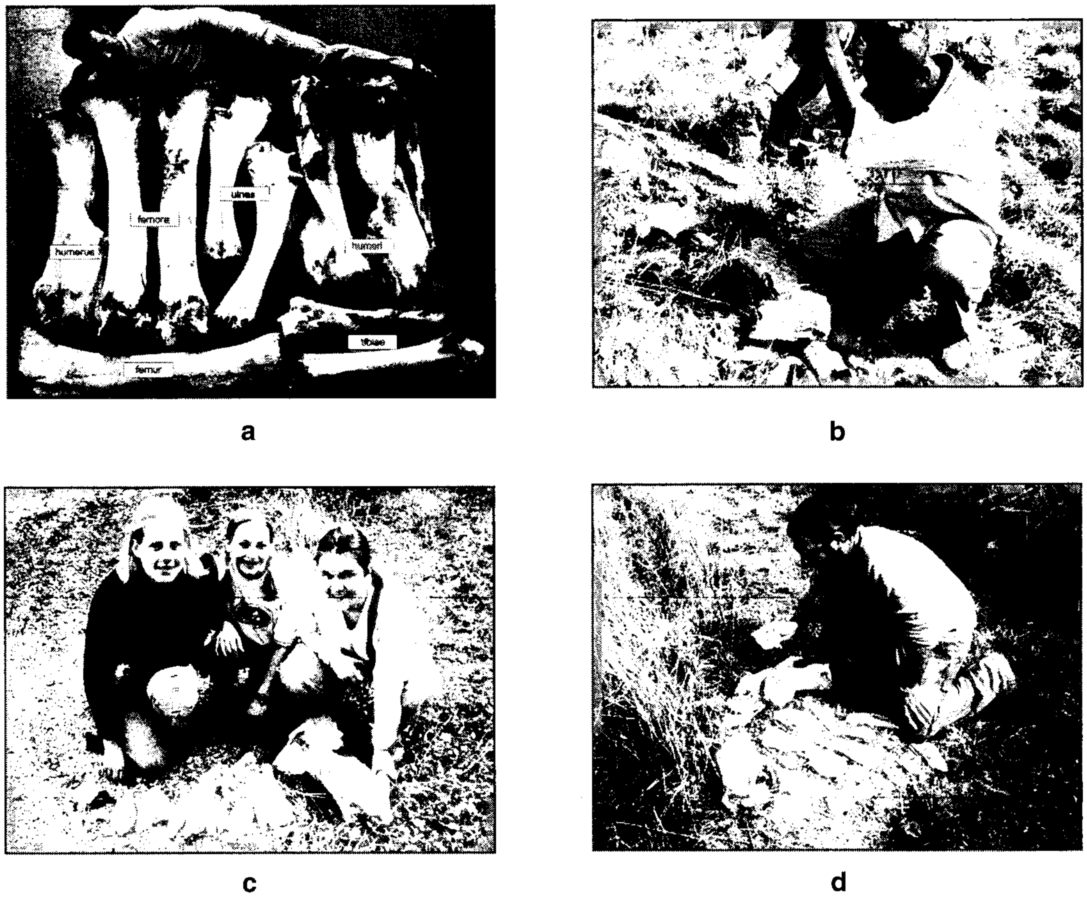


Figure 5. Experiment in South Africa with students breaking elephant long bones within 15 minutes: a, 11 elephant long bones used in the experiment; b, breaking bones with a piece of the local dolomite bedrock; c, bone segments broken by one group of students; d, segments broken by another group of students (photographs courtesy of Lucinda R. Backwell).

groups of three to five, broke the limb bones into small pieces in 15 minutes (Figures 5c-d).

Chemical weathering (or chemical deterioration) also affects bones and occurs in the burial environment. It is a broad category encompassing a number of processes. In general, it is a desiccation and chemical process that leads to changes in the chemical structure and physical properties of the bone. Sediment and soil characteristics and chemistry are important factors. Such deterioration begins on the cortical surface and progresses inward. Cortical surfaces become roughened, irregular spalling may occur, and the bone can become less dense than normal (Johnson 1985, 2006).

In examining the bones for the present study, only those areas of interest were cleaned with distilled water or conservation-grade (technical) acetone. Sand grains were embedded in the bone surfaces and their complete removal proved difficult. Marks, fracture surfaces, and other features on the specimens initially were examined with a Bosch and Lomb stereomicroscope at 3x. More detailed observations were made with a Leica Mz12 stereomicroscope at various settings up to 100x, and photographs were taken. Scanning electron microscopy (SEM) was not practical due to unstable surfaces and embedded sand grains on the specimens.

RICHARD BEENE SITE (41BX831)

The Richard Beene site was first identified in 1989 during a survey of the dam/spillway area of the once-proposed Applewhite Reservoir. Chipped stone artifacts, fire-cracked rocks, and mussel shells were concentrated on the tread of the newly named

Applewhite terrace, the first major terrace above the Medina River (McCulloch et al. 2007). Testing and large-scale excavation carried out intermittently from 1990 through 2005 revealed 20 archeological components buried in 10 m of alluvial fill that spanned the last 10,000 years (Thoms and Mandel 2007). Backhoe trenches and limited testing on the bottom of the spillway trench in 1991 exposed fine-grain sediments (flood-chute fill) dated between 12,500 and 15,500 B.P. and stratified gravel and sand deposits dated between 22,000 and 32,000 B.P. (Mandel et al. 2007).

Fieldwork

Hundreds of well-preserved Late Pleistocene faunal remains, primarily from small animals, were recovered from the flood-chute fill, but none exhibited readily apparent evidence of human modification (Baker and Steele 2007). Small natural pebbles were recovered as well, mostly carbonate nodules, but no chipped stone was found in the excavated Late Pleistocene deposits (Thoms 2007).

The first credible evidence of a potential Late Pleistocene occupation was discovered while inspecting the impacts of the 2002 flood, which is locally considered to have been the "flood-of-record" along that stretch of the Medina River. Ramon Vazquez, Director of American Indians in Texas at Spanish Colonial Missions (AIT-SCM), and fellow members of Tap-Pilam Coahuiltecan Nations were there to assess the flood's impact on archeological deposits at the Richard Beene site and on their nearby ceremonial grounds. While reconnoitering a newly formed gravel bar on the floodplain adjacent to the Richard Beene site, Mr. Vazquez discovered what turned out to be a mid-diaphyseal cylinder portion of a proboscidean long bone. In keeping with a well-established working relationship, Vazquez informed Thoms of his discovery and the mammoth bone was transferred to Texas A&M University for study and curation (Reyes 2006; Thoms 2007; Thoms et al. 2006).

Late Pleistocene Deposits

It is not possible at this time to reliably identify the stratigraphic unit that yielded the mammoth long bone diaphyseal segment found on the gravel bar following the 2002 flood event. Although out of context, it likely eroded from a nearby Late Pleistocene deposit, given the nature of the fine-grained muddy sand adhering to it, its obvious Pleistocene age, and the likelihood of it being broken by humans. Deposits of that age in the excavated portion of the Richard Beene site could not have been the source of the bone segment because they remain buried several m below the surface in the abandoned spillway trench, some 75 m southwest from the gravel bar where the specimen was found (Figure 6).

A plausible source area for the long bone segment is a 5 m high cutbank about 50 m upstream from where the specimen was found (Figure 6b). The cutbank and the eddy pond adjacent to it formed during the 2002 flood when the river removed some of the bank. The new exposure revealed well-stratified fine sandy and silty alluvium that, in color and texture, resembled the palustrine deposit at the San Antonio River site, as discussed below. The elevation (ca. 146–141 m above sea level) of the newly exposed deposit overlaps with the Late Pleistocene flood-chute deposits dated between 12,500 and 15,500 B.P. that are buried beneath the floor of the spillway trench some 100 m to the south.

In this portion of the Medina River basin and extending downstream to the San Antonio River site, floodplain sedimentation between 15,000 and 10,000 years ago was fairly rapid, albeit punctuated by soil development. Soil organic-carbon analysis at the Richard Beene site identified distinct periods of low relative C_4 productivity that occurred between 15,500 and 14,000 B.P. and between 13,000 and 11,000 B.P., which correlates with two well-documented episodes of glacial meltwater discharge via the Mississippi River (Mandel et al. 2007). During those times, cool season trees, shrubs, and grasses dominated the landscape, but with a distinct period of high relative C_4 productivity between ca. 11,000 and 10,500 B.P. (Nordt et al. 2002). Molluscan studies at the site indicate marsh or wet grassland/meadows between 15,300 and 12,500 B.P. and savannah with flooding interludes between 12,500 and 8000 B.P. (Fredlund and Neck 2007; Neck 2007).

Modified Bone

The following is based on Johnson (2007a). The bone specimen recovered from the gravel bar is that of a mid-diaphyseal cylinder portion of a proboscidean long bone (Figure 7). Based on comparative material, it is most likely a tibia, although conformation is not exact. Both mammoth and mastodon are found in Late Pleistocene deposits

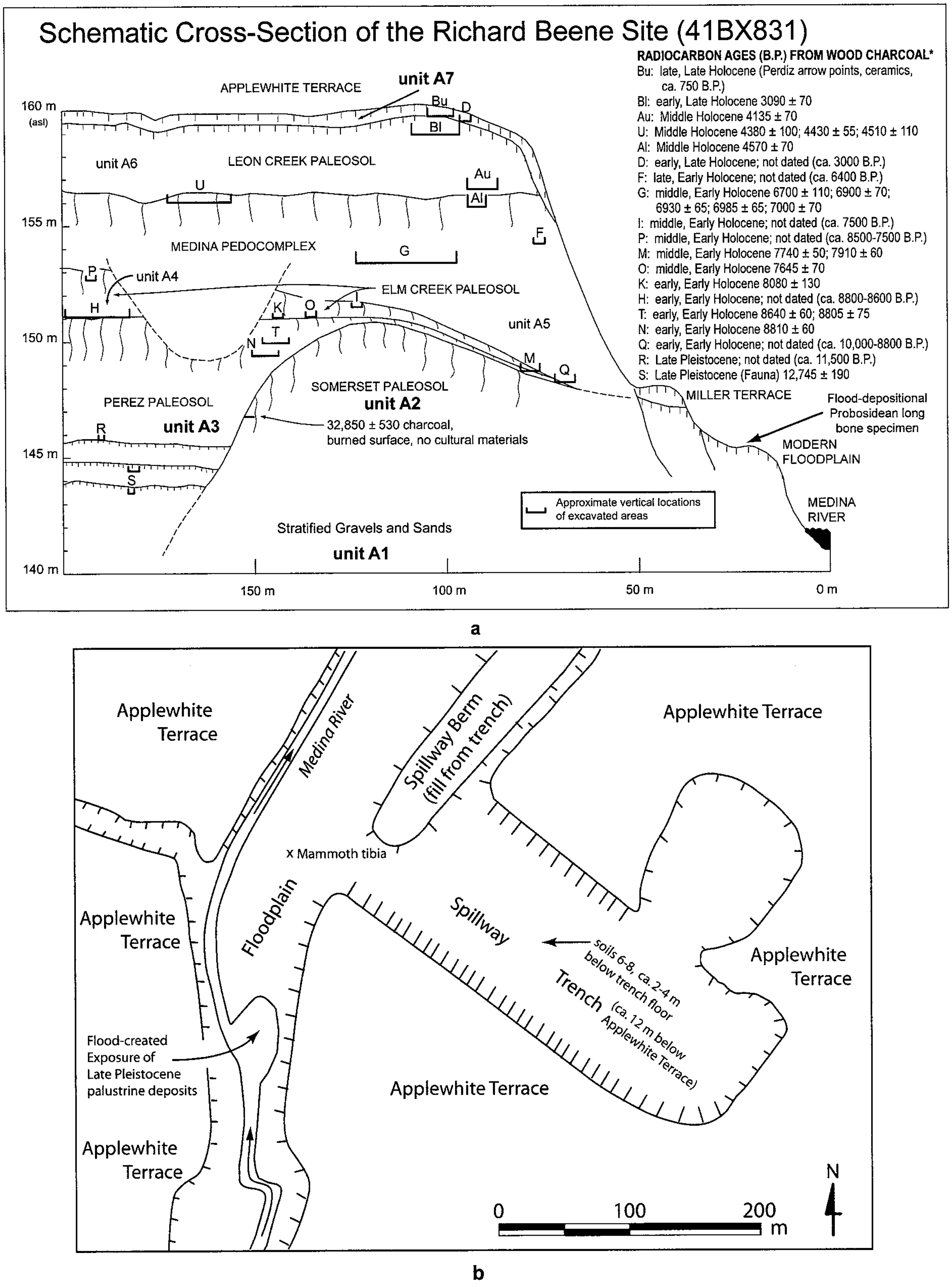


Figure 6. Location of the mammoth tibia segment at the Richard Beene site: a, schematic profile of the site area; b, plan view showing the spatial relationships between the location of the mammoth tibia diaphysis, the flood-caused cutbank and eddy pond, and the Late Pleistocene sediments at the Richard Beene site.

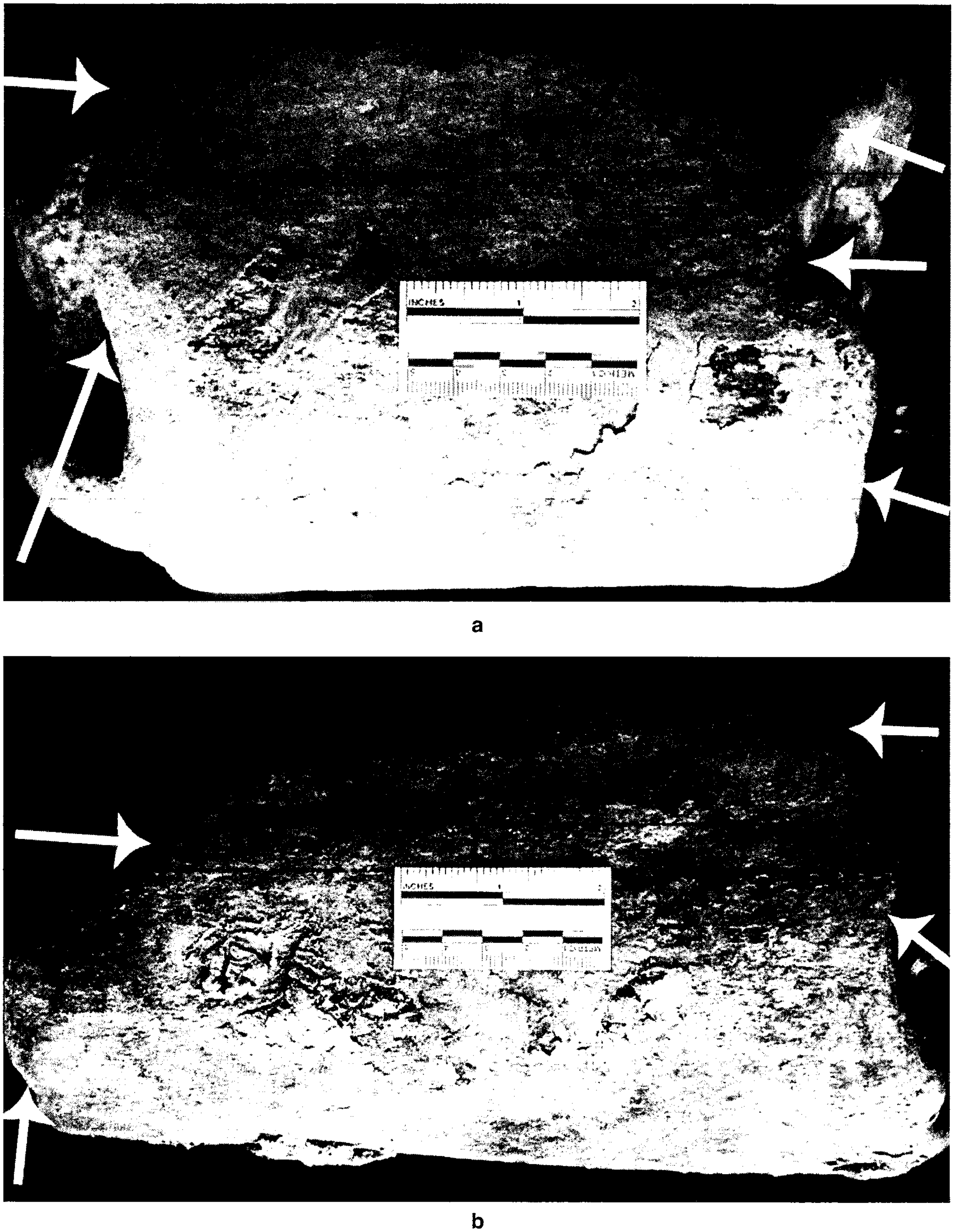


Figure 7. Tibia diaphysis from a *Mammuthus columbi* found on a gravel bed adjacent to the Richard Beene site, showing opposite faces; note the helical fractures at both ends indicated by arrows.

in Texas (Graham and Lundelius 1994). It is difficult to separate these two extinct proboscideans on portions of bones but, in general, mastodon bones are shorter and somewhat stockier than mammoth (Olsen 1972:5). Based on the size of the element portion and cortical thickness, the specimen is referred to as mammoth (cf. *Mammuthus columbi*).

At least three taphonomic processes affected the bone specimen prior to burial. One process is that of subaerial weathering. The cortical surface is checked and desiccation lines parallel to the longitudinal axis of the bone abound on all sides. Most of these are very thin and shallow; a few thicker and deeper ones are present. However, none reach the desiccation crack stage. Root etching is not discernable on the specimen, suggesting that the surface was not heavily vegetated. In general, climatic conditions at the time of deposition would have been subhumid (Johnson 1991). This weathering pattern and associated circumstances suggest that the specimen likely lay exposed to elements for some time prior to burial, perhaps less than five years (Coe 1978; Johnson 2006).

The second process is that of geologic abrasion. The cortical surface of the specimen is worn and there are patches where the cortical surface is no longer present. Edges are rounded and a few pits occur on the bone surface. This type of damage is caused by frictional forces applied to the surface and edges. In general, the major forces leading to abrasion are sedimentary, aeolian, and fluvial (Johnson 1985; Shipman and Rose 1988). The wear pattern is on all surfaces and sides of the specimen. Therefore, the cause is not aeolian, as wind-induced damage generally would be expected on one side only. The specimen is not water worn. It is likely that the rounded character of the fractured ends resulted from sedimentary abrasion.

The third process is that of bone breakage. Bone broken through sediment compaction has a distinctive pattern that does not result in helical fractures (Johnson 1985). For large carnivores, the most common strategy in breaking bones is to break the bone cylinder (produced from chewing off the ends) through static loading. In the Late Pleistocene, the dire wolf (*Canis dirus*) and short faced bear (*Arctodus simus*) were the major large carnivores with powerful jaw muscles and appropriate tooth structure for bone gnawing and crushing. Neither had the masticatory apparatus and facial structure to dynamically or statically fracture intact, wet mammoth limb bones (Johnson 1985, 1991).

This specimen exhibits a helical breakage pattern on both ends and it appears to be either a piece of fracturing debris or a segment intended for further modification. This fracture pattern is associated with breakage of intact wet bone through dynamic loading. Dynamic loading of intact wet bone appears to have been the most common strategy of early inhabitants in breaking open long bones. Experimental work indicates that wet elephant bone is readily broken using at least one large anvil and a large (small boulder size) hammerstone (Johnson 1989, 2005). One of the helical fracture surfaces on this specimen exhibits intersecting fracture fronts. No point of impact, however, is identified for either fracture surface.

A bone cylinder created through dynamic fracture of both ends of a long bone is unusual. The common pattern is to impact the intact element mid-diaphysis and fracture the element into two main portions, the distal and proximal ends (Holen 2006; Johnson 1989, 2005; Steele and Carlson 1989). The cylinder pattern suggests that the element was impacted near both the proximal and distal ends.

SAN ANTONIO RIVER SITE (41BX1239)

The San Antonio River site was identified in 1997 during a water-line survey for the San Antonio Water System (SAWS). Initial inspections revealed a sparse scatter of chipped stone and fire cracked rock on the tread of the first major terrace above the river (Figure 8). Backhoe trenching in search of deeply buried artifacts along the pipeline route resulted in extending the site boundaries northward and down the terrace scarp to encompass a terrace remnant where the mammoth remains were encountered (Thoms 2001). With the discovery of the mammoth bones, SAWS decided to reroute the pipeline to avoid the terrace and thereby precluded a management-related need for further fieldwork. The backhoe trench was carefully refilled with sandy sediment that differed markedly from the terrace fill, the objective being to facilitate relocation at a later date when excavations might be resumed.

Fieldwork

The backhoe trench placed on the terrace remnant revealed mammoth bone buried 1–1.5 m below the surface (see Figure 8), including a tusk,

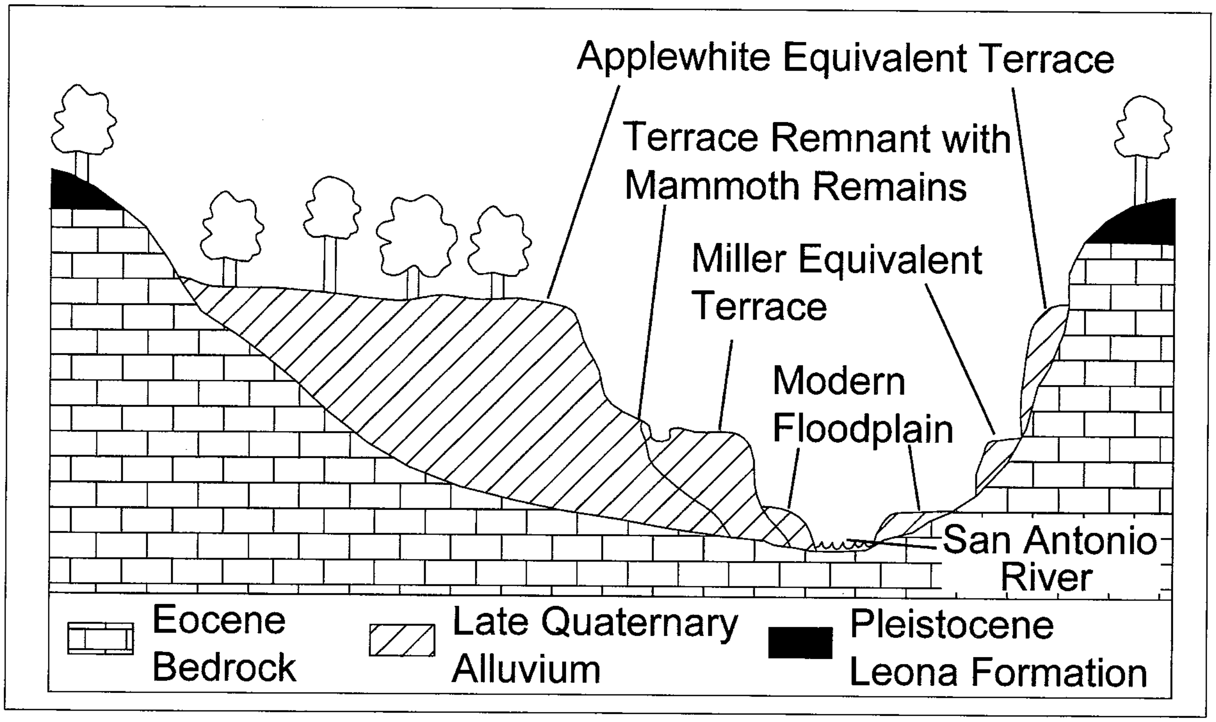


Figure 8. Schematic cross-section of the river valley near the San Antonio River site (redrawn from Thoms et al. 2001:Figure 3)

pieces of the mandible and teeth, and a segment of thick cortical bone with several parallel incisions that appeared to be of human origin (Thoms et al. 2001). Some of the bones appeared to be articulated, including parts of a vertebral column and possibly ribs, but more than 2 m horizontal distance separated the mandible/teeth and tusk pieces. Most of the bones exposed in the trench walls appeared to be relatively complete and fairly well preserved, but they were moist and quite soft, almost sediment-like in texture, such that they could be easily trowelled through. Once dry, however, the bones became hard and rather well consolidated, but all of the surfaces were eroded, probably by chemical weathering (Thoms et al. 2001).

In addition, 10 shovel tests (ca. 30 cm wide by 90 cm deep) were hand excavated in the vicinity of the backhoe trench where the mammoth bones were found. Results revealed that the bone bed extends at least 2.5 m beyond both sides of the trench. Backdirt (ca. 1 m^3) from the bone bed portion of the trench was screened through 1/4-inch hardware cloth as was backdirt from the adjacent shovel tests. Recovered material included 1,667 bone specimens weighing a total of 8,032 g. Only five pieces were greater than 8 cm in maximum dimension and they weighed 1,941.3 g. Twenty-nine pieces were grouped as medium-sized (4–8 cm, for a total of 1,853.6 g) and 1,633 were classed as small (<4 cm, for a total of 4,237.1 g). The fragmentary nature (mostly blocky chunks) of the mammoth bones recovered from the backdirt likely resulted from stress caused during removal of the bones and matrix by the backhoe. The blocky fractures are indicative of post-depositional weathering in a damp, carbonate-rich deposit.

One small (1 cm in diameter), thin, piece of fine-grain quartzite debitage was recovered from the screened sediments (Figure 9). The origin of the

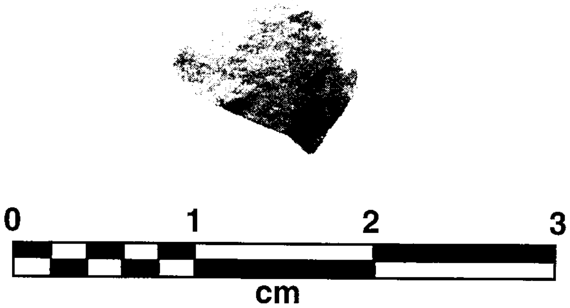


Figure 9. Quartzite flake found with about 1,660 pieces of mammoth bone recovered from back dirt removed from Backhoe trench 7 at the San Antonio River site.

specimen is not certain but it is an obvious flake, as it exhibits a platform and a diffuse bulb of percussion. If this flake had been recovered along with other flakes from a known archeological site, its legitimacy as a human artifact would not be questioned. A few stream-worn pebbles and small cobbles consisting of quartzite, chert, and "cherty" limestone were also recovered from the backdirt (Thoms et al. 2001). Judging from the fine-grained texture of the matrix encompassing the mammoth bones, the pebbles and small cobbles in the backdirt probably came from the sediments underlying the mammoth bones or perhaps from the modern slopewash above the bone bed. It is also possible that slopewash accounts for the presence of the flake in the backdirt, although sediment adhering to the flake resembled the palustrine deposits that encased the mammoth bones.

Stratigraphic Setting

The backhoe trench with mammoth remains was oriented north-northeastward, perpendicular to a smooth, steep, parabolic (concave), north-facing slope at the incised margin of the upper fluvial terrace, probably the Applewhite-equivalent terrace (Mandel et al. 2007). The trench is deepest at its south-southwestern (upslope) end, where it exposes 2.9 m of Quaternary strata in a continuous vertical profile (Figure 10). Stratigraphic relations indicate that some of the bone was fragmented and reworked into an inset fluvial channel fill prior to development of soil types recognized as middle Holocene at the nearby Applewhite site. The inset channel fill truncates the bone-bearing stratum laterally and thickens northwards from the main assemblage of bone (Caran 2001).

The primary stratigraphic context of the bones and teeth (including both tusk and tooth-plate fragments) is the upper half of a thin lensatic bed of palustrine deposits perhaps representing the infilling of a chute channel or oxbow into which shallow ground water discharged and thereby maintained a relatively short-lived but perennial lentic environment. Maximum thickness of this bed is less than 1 m, at the point where the concentration of bone is greatest (see Figure 10). The bed thins both north and south of this point because the depth of the infilled depression decreases; that is, the lower boundary of the bed rises away from the center, defining a channel form (Caran 2001).

The upper boundary of this bed remains nearly level above the southern edge and center of the lens, while to the north it is intersected by an irregular erosional unconformity cutting below the base of the lens, completely truncating the bed.

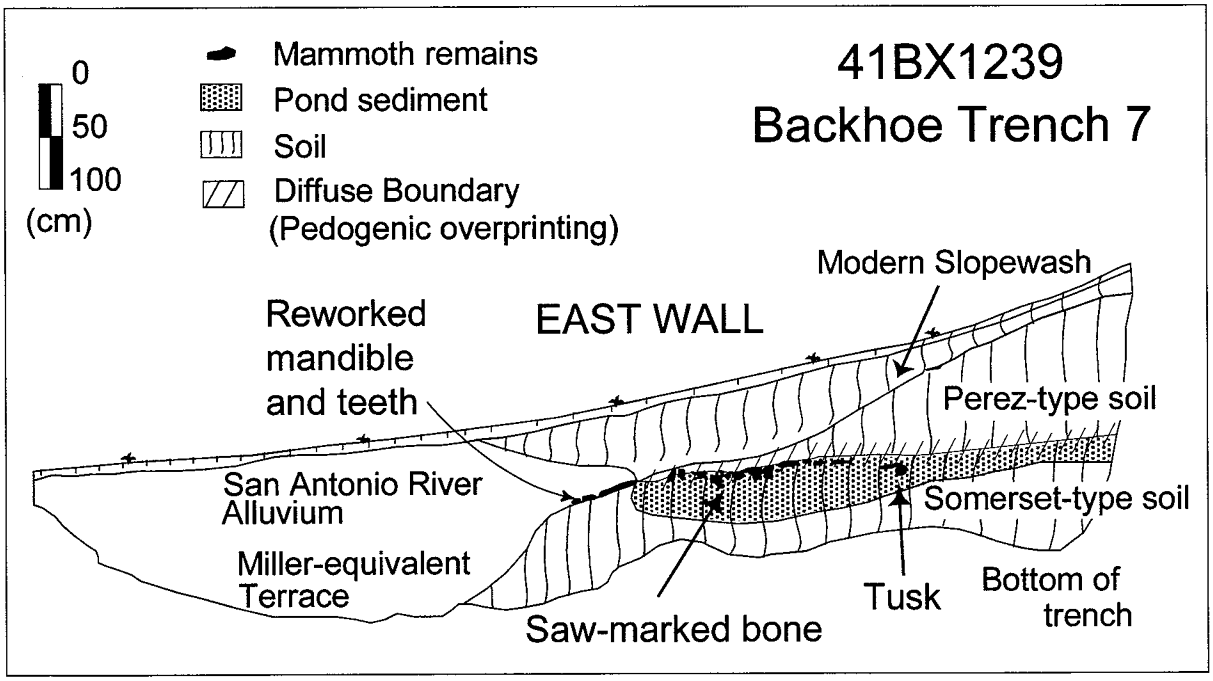


Figure 10. Profile of the east wall of Backhoe trench 7, showing stratigraphic units and paleosols in relation to the bone bed in the palustrine deposit (redrawn from Caran 2001:Figure 14).

Inset fluvial deposits overlie the unconformity. The amount of bone declines southward, and no bone was observed at the southern edge of the exposure (see Figure 10). In the inset fluvial deposits north of the center of the lens, reworked bone is found at and below the elevation of the pond deposits. Bone within the pond deposits is generally well preserved, but that which was reworked is visibly deteriorated (Caran 2001).

The pond deposits consist of highly calcareous silty clay. Near the largest bones, the fine-grain palustrine deposits are replaced by coarser-grained sediment perhaps reflecting hydraulic sorting during flood conditions, prior to bone burial. The bone may represent the remains of two or more mammoths, based on the large number of tusk pieces that are uniform in diameter (i.e., not from different parts of a single tusk, the diameter of which varies along its length). Isolated bones and teeth of microvertebrates also may be present. In addition to bones, the palustrine deposits contain abundant shells (whole and fragmented) of aquatic and terrestrial snails, along with whole ostracod valves (Caran 2001).

These deposits appear to have been gleyed prior to a more recent phase of partial oxidation and concurrent calcification. Gleyed palustrine deposits may contain diatom frustules, phytoliths, and palynomorphs. In most oxidized soils, chemical and/or biological degradation often destroys these microfossils. Yet even when oxidation is extensive, these fossils are often preserved within calcareous pedoconcretions, which are common in these deposits. Fossils representing the aquatic environment of deposition of the soil's parent material must be differentiated from those reflecting stream floodplain or terrace conditions under which pedogenesis subsequently occurred (Caran 2001).

Modified Bones

Three of the more than 1,660 bone pieces were selected by the senior author for detailed analysis as the best candidates for evidence of human modification. The elements from which two of the pieces (catalog numbers 121 and 123) originated could not be identified beyond probable long bone, given cortical thickness. The third (catalog number 122) is a shaft segment of a Columbian mammoth radius.

Impact from backhoe trenching and the burial environment rendered the mammoth bones highly fragile. While buried, the bones underwent chemical weathering that created powdery and eroded surfaces. Within the different categories of marks on these specimens, the marks are similar and only representative examples of those marks judged to be cultural in origin are illustrated. All old marks are highly eroded with embedded sand grains. As the figures illustrate, the effect of these processes is pronounced.

Catalog Number 121

This long bone segment has a series of seven marks along the cortical surface (Figure 11a). These marks are quite deep, wide, and distinctive, with the troughs having smooth bottoms. Six of the marks, the exception being Mark #2, exhibit one steep-sided wall and one shallow sloping wall.

Mark #1 retains striations along the steep-sided wall, visible at various magnifications (see Figure 11a). Mark #2 is shallow, lacks any distinctive features, and loses resolution by 100x (see Figure 11a). Mark #3 has a central line at the base of its V-shaped trough (see Figure 11a). This line is visible at higher power but it is not visible by 100x. However, the steep sloping trough is distinct at 100x, as are embedded sand grains.

Mark #4 exhibits possible striations in its trough that are visible at 100x (Figure 11c). The eroded nature of the cortical surface is well documented at 32x (Figure 11b). Mark #5 appears to lack microfeatures (see Figure 11a). However, the width and plan view of the trough indicate at least two converging marks were not exactly coincident.

Mark #6 has a very steep-sided wall distinctive at both 16x (Figure 11d) and 100x (Figure 11e) and a trough with a very narrow, deep bottom but broader upper reaches. The eroded nature of the mark, embedded sand grains, and eroded cortical surfaces also are clearly discernible. Mark #7 retains only the trough with its steep-side wall, even up to 100x. Other features or microfeatures are not observable.

Catalog Number 122

This shaft segment of a radius is roughly triangular in cross section and has marks on all three cortical surfaces (Figures 12 and 13). Part of the medial end retains a fracture surface (Figure 13a). The fracture surface is along part of the edge of side one and side two. The third side's edge was eroded after breakage. The fracture surface is fairly smooth and even. On side one, however, deep desiccation cracks have invaded the surface while on

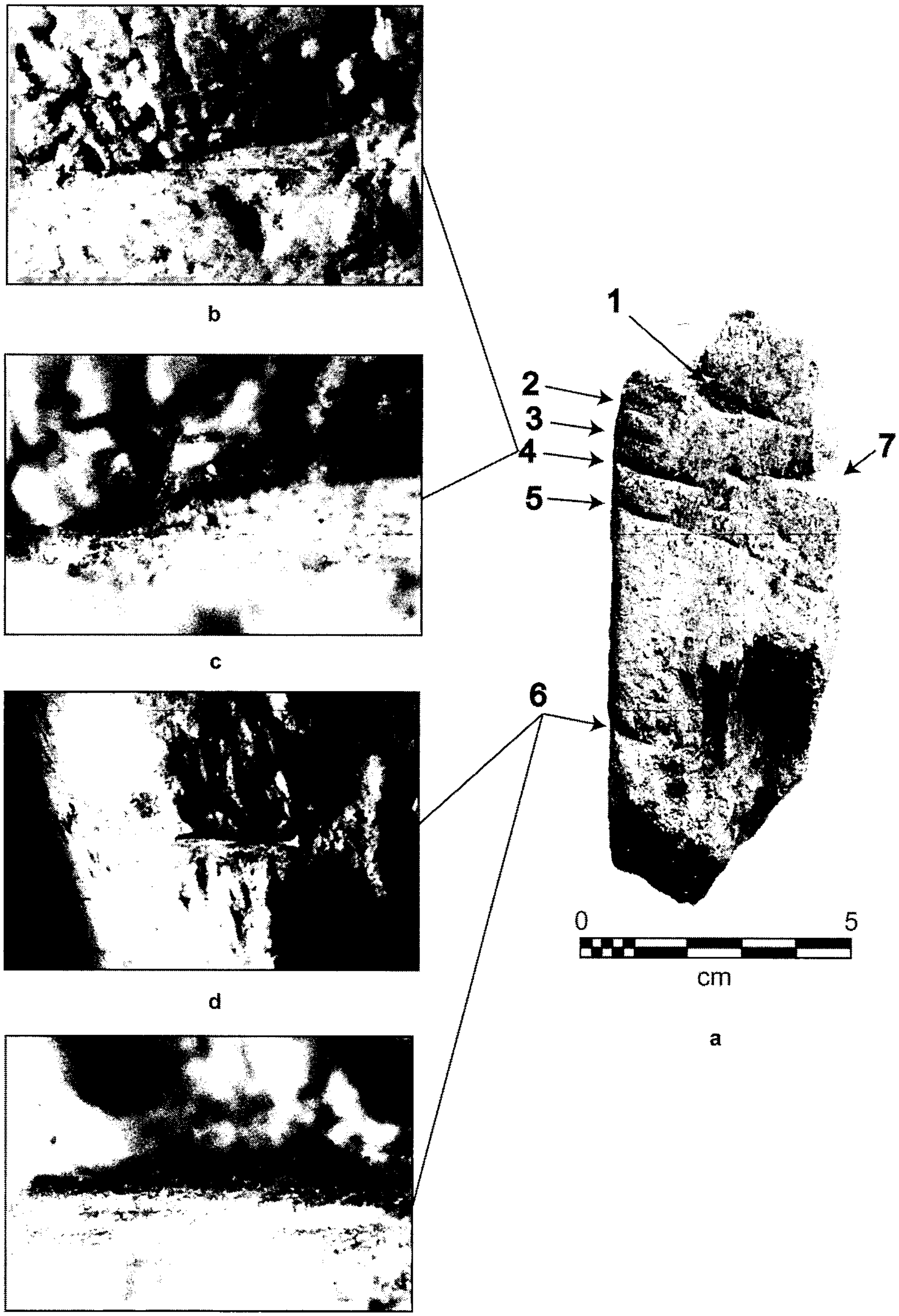


Figure 11. Bone specimen 121 from the San Antonio River site: a, seven marks on cortical surface; b, photomicrograph of Mark #4 at 32x, showing the highly eroded nature of the cortical surface along with the differential exposure of underlying bone structure; c, Mark # 4 at 100x, showing possible striations in the trough; d, Mark #6 at 16x, showing distinctive steep-sided lower wall and a very narrow, deep trough; e, Mark 6 at 100x showing embedded sand grains.

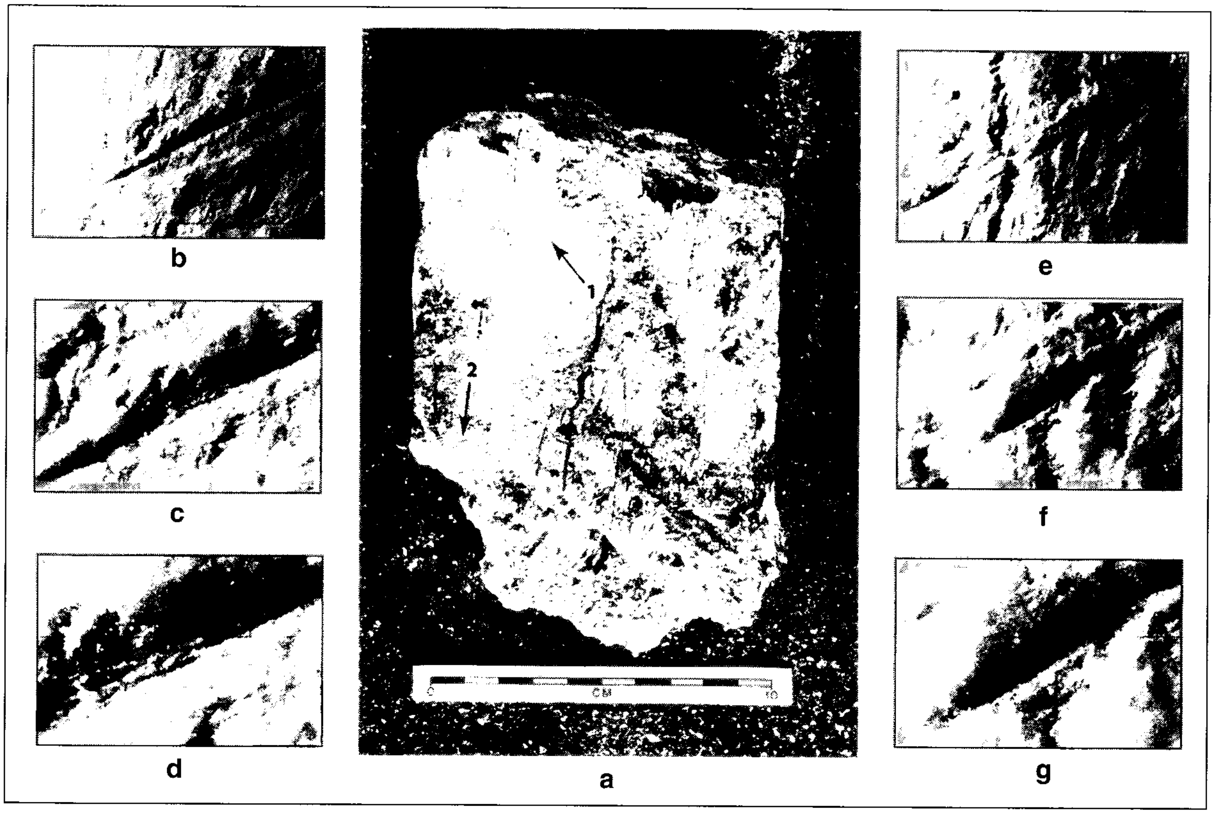


Figure 12. Bone specimen 122 from San Antonio River site: a, overall view of side one; b, Mark #1 at 16x; c, Mark #1 at 50x, focusing on the area of striations; d, Mark #1 at 100x, showing clearly visible striations along the wall and in the trough; e, Mark #2 at 16x, showing two closely spaced incisions; f, Mark #2 at 50x, showing bone laminae exposed along the steep-sided north wall; g, Mark #2 at 100x, showing the wavy appearance of bone laminae.

side two (Figure 12a), a surficial desiccation crack has interfered with the formation of the fracture surface (Figure 13a).

Side one (see Figure 12a) presents a slightly convex surface that bears two short, parallel marks. The cortical surface is unstable and eroded, with marks eroded, worn, and with sand embedded in them. Mark #1 (Figure 12b) exhibits a clear incision with a steep-sided wall and a sloping wall. Striations occur along the steep-sided wall and trough, visible at both 50x (Figure 12c) and 100x (Figure 12d). This microfeature is composed of straight parallel lines superimposed on the bone microstructure, which has laminae that are wavy in appearance. The trough in Mark #1 is very narrow (Figure 12b) and retains that feature even at 100x (Figure 12d). Mark #2 (see Figure 12a) consists of two closely-spaced incisions each with a steep-sided wall, a sloping wall, and a narrow, distinct trough (Figure 12e). The wavy layered effect exposed in the steep-sided wall visible at both 50x (Figure 12f) and 100x (Figure 12g) are laminae rather than striations.

Side two (see Figure 13a) presents a slightly concave surface that bears one mark. The surface is eroded and unstable. Mark #1 is a long fairly straight line that cross-cuts the eroded surface and exposes underlying bone of a different color than the cortical surface. The trough of this line is very shallow and begins to lose resolution by 50x.

Side three (Figure 13b) presents a slightly concave surface that bears five marks. The surface is eroded and unstable. Mark #1 is composed of a number of very broad, shallow lines, some of which are straight and others are curved but all have a straight-sided, flat-bottomed trough and a somewhat straight, very narrow line with sloping walls. This mark cross-cuts the eroded surface and exposes underlying bone of a different color than the cortical surface. Mark #2 is a straight incision with a steep-sided wall and a sloping wall that appears to exhibit a central line in the narrow trough, visible at 50x and 100x. Bone laminae are exposed along the steep-sided wall and their characteristically wavy appearance is visible at 100x. Marks #3, #4, and #5

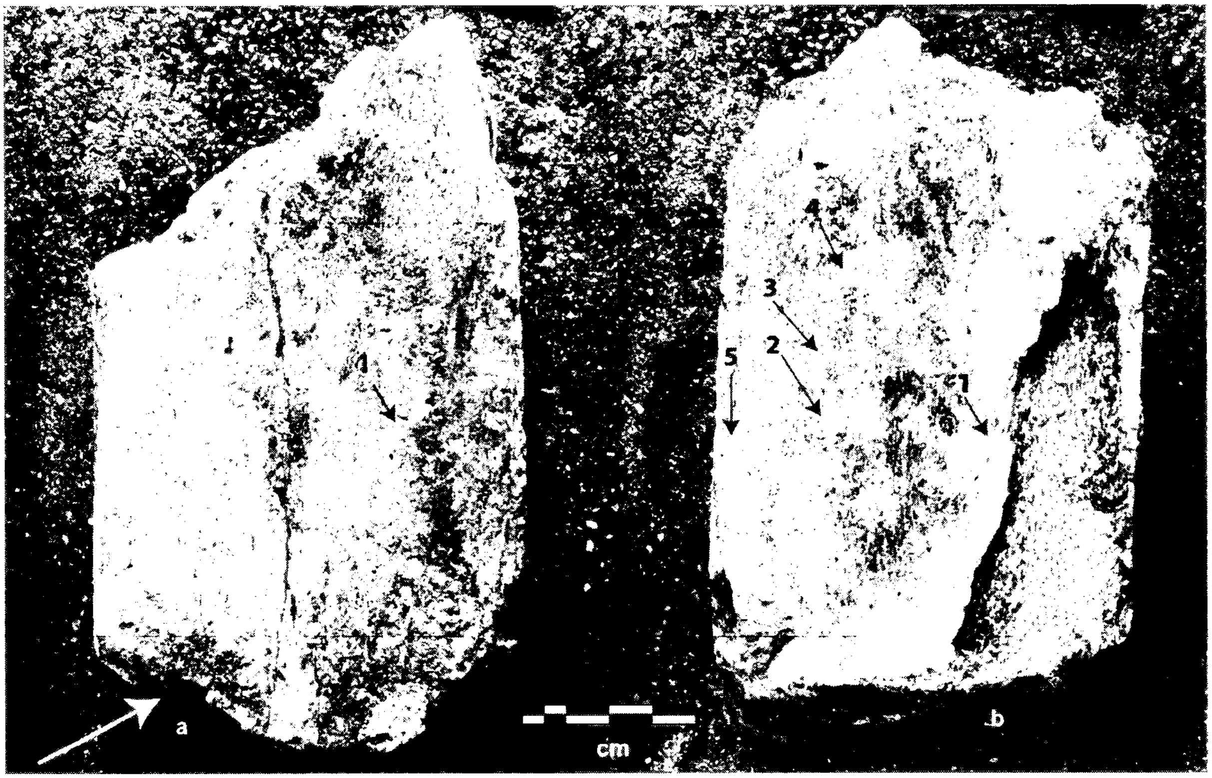


Figure 13. Bone specimen 122 from the San Antonio River site: a, overall view of side two; white arrow points to helical fracture; b, overall view of side three.

are similar and are composed of faint lines having shallow, narrow, to broad troughs with flat bottoms. Bone laminae are exposed in the trough of Mark #4.

Catalog Number 123

While no marks occur on this long bone specimen, it exhibits a fracture feature, which is a restricted area of well-worn and eroded folds along one edge (Figure 14a). The folds on this segment of cortical bone converge at (or radiate from) a central point and the apex of the folds are rounded (Figure 14b), with sloping sides down to rough bottoms (Figure 14c). The configuration formed is that of hills and valleys.

Comments

Observations on the various marks or features exhibited by the three specimens are hampered by the eroded nature of the bones, chemical degradation, unstable cortical surfaces, and lack of SEM confirmation. Nevertheless, the accumulation of observations per specimen, along with an overall perspective, provides some indications for interpretation. In examining the marks in general, those made prior to burial (old marks) could be segregated from those made during exhumation by the backhoe (new marks). For specimen 122, one mark on side two (Mark #1) and one on side three (Mark #1) are scrapes made by equipment. All other marks appear consistent with being contemporary with the bone. This specimen also bears a new scar along side three that is associated with the backhoe work rather than the old fracture surface it exhibits along its shaft.

With regard to the old marks, the majority of them have consistent features of one steep-sided wall with one sloping wall and a deep, narrow trough. Two marks—specimen 121, Mark #3 (see Figure 11) and specimen 122, side one, Mark #2 (see Figure 12)—have two superimposed (although not totally coincident) lines that exhibit these features. Microfeatures are not common but striations appear to be preserved in at least three marks: specimen 121, Marks #1 and #4 (see Figure 11), and specimen 122, side one, Mark #1 (see Figure 12). A central line appears to occur in at least two marks: specimen 121, Mark #3 (see Figure 11) and specimen 122 (see Figure 12), side three, Mark #2.

Of the seven marks on specimen 121 (see Figure 11), six of the marks are related by their consistent features and appear to have been made by the same agency. The cause of Mark #2 could not be determined. Of the eight marks on specimen 122, three of the marks—side one, Marks #1 and #2 (see Figure 12) and side three, Mark #2 (see Figure 13b)—also are related by their consistent features and related to the six marks on specimen 121. For the other five marks, two are new marks and the cause of the other three, side three, Marks #3, #4, and #5, could not be determined (see Figure 12).

The nine related marks, six on specimen 121 (see Figure 11) and three on specimen 122 (see Figure 12), are the ones of interest. The apparent microfeatures of some of these marks indicate their probable creation by lithic tools (Johnson 2007b). The morphology of the six marks on specimen 121 are reminiscent of proposed saw marks identified on mammoth remains from the Miami site (Johnson 1989:452 and Figure 11) and at Blackwater Draw #1 (Saunders and Daeschler 1994). The three marks on specimen 122 are reminiscent of cut marks (cf. Olsen and Shipman 1988; Shipman and Rose 1984).

If these marks are cut and saw marks, this type of damage to bone occurs during carcass butchering and processing operations in the acquisition of meat, nutrients, and other resources. Saunders and Daeschler (1994) relate the saw marks to scavenging activities where drying and rigor mortis has set-in, rather than from a kill-butchering event. Muscle, tendons, and periosteum

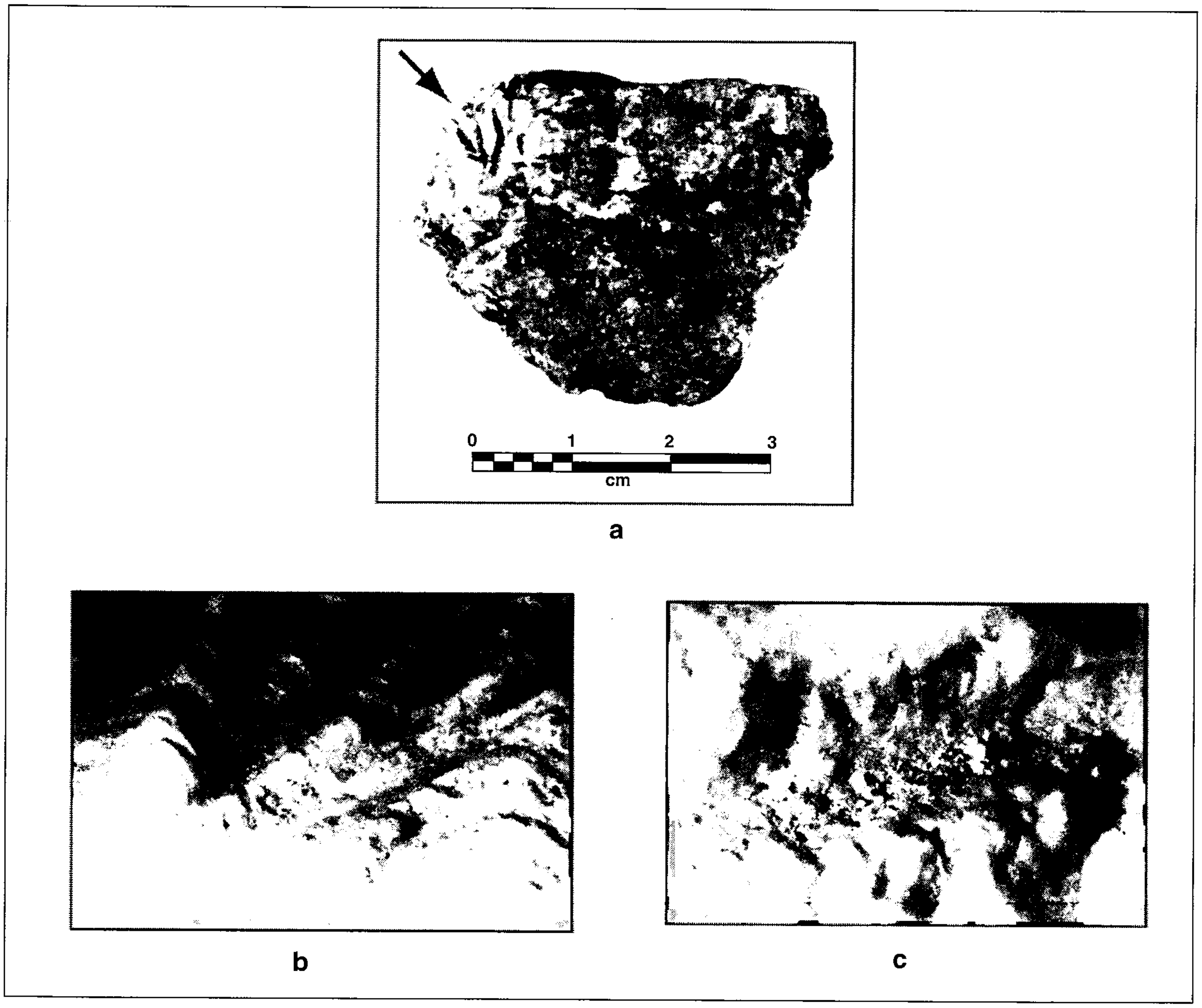


Figure 14. Bone specimen 123 from the San Antonio River site: a, overall view; b, folds at 16x, showing eroded hills and valley that converge to a central point at the lower left; c, a fold at 50x, showing the valley portion with eroded slopes and rough trough; note the embedded sand grains.

would be more difficult to remove from such a carcass and, therefore, the people would have had to work harder with their tools in cutting through resistant areas, increasing the likelihood of damage marks on bones.

Cut marks along a long bone shaft generally are more related to periosteal removal than defleshing (Johnson 1985, 1987). Removing the periosteum is a necessary step in human-induced dynamic fracturing of bone as the periosteum is a protective sheath designed, in part, to help the bone resist failure. The proposed cut marks and apparent helical fracture surface would indicate that specimen 122—the radial shaft—was modified by people. However, the interrupted fracture surface on side two is due to split-line interference (i.e., drying before fracturing occurred) while the desiccation cracks on side one formed after fracturing occurred. The morphology of the fracture surface, then, indicates that the bone had dried for a short period before fracturing occurred and continued to dry after fracturing and before burial. These data are consistent with scavenging activity (Johnson 2007b).

As with specimen 121 (see Figure 11), specimen 123 (see Figure 14) is a portion of long bone segment. The configuration of hills and valleys on specimen 123 is distinctive and consistent with chattering, an impedial feature related to dynamic fracturing of bone (Johnson 1985:194–197, 1989:437). Chattering occurs when the fracture front meets resistance in the bone microstructure or when the morphology of the bone is changing from a rounder to a flatter nature. Peaks and valleys are formed that, in turn, form ridge lines (Johnson 1985:Figure 5.14b, 1989:Figure 6b). Normally, the peaks are steep and straight-sided. The hills on specimen 123 appear to be smoothed-over as a result of erosion (see Figure 14).

Fracturing proboscidean bone is related to using bone as raw material for tools rather than for subsistence purposes. Fracturing the bones is designed to produce portable segments that later can be shaped into tools (Johnson 1985:202–203). This type of scenario appears to be the case at such sites as Lubbock Lake (Johnson 1985, 1987, 1991), Duewall-Newberry (Johnson 1991; Steele and Carlson 1989), Lange/Ferguson (Hannus 1989), and Wasden (Miller 1989). The incomplete helical fracturing of the radial shaft from the San Antonio River site may reflect a failed attempt at quarrying the dried bone.

MUNGER BRANCH SITE (41LT431)

The Munger Branch site, first known as the Pin Oak Creek mammoth, was discovered during the summer of 1997 when two artifact hunters, Robert Davenport and William Pullium, happened upon fragments of an unusually large bone eroding from mud near the bottom of the creek in northern Limestone County (Vance 2004). Munger Branch, an intermittent stream, flows from west to east across a tract of Blackland Prairie and empties into nearby Pin Oak Creek (Figure 15), which follows a northeastward course through the adjacent Post Oak Savannah to its intersection with Richland Creek, a major tributary to the Trinity River.

Davenport and Pullium dug into the muddy sediments covering the bone and removed the distal end of a femur and a partial molar from a Columbian mammoth. Recognizing the potential importance of their discovery, they brought the bone to Navarro College for identification and assessment of its potential significance (Vance 2004).

By the spring of 1998, the property owner had been contacted and had given permission to excavate the site, with an understanding that the skeletal remains would be donated for public display. Plans were soon finalized for the recovery of the Munger Branch mammoth remains. Excavations were carried out intermittently in 1998, 2000, 2002, and 2004 by volunteers from Navarro College, the local community, the Dallas Paleontological Society, and the Texas Archeological Society. Vandals also played a role at the site, destroying the mandible and portions of the skull, possibly in search of a well-preserved molar or section of a tusk.

Fieldwork

As described by Vance (2004), fieldwork was directed primarily toward recovery of what was anticipated to be skeletal material suitable for an interpretive display. Approximately 6 m of fine-grained alluvium was removed by backhoe to create a working surface several cm above the bone bed. A 1 x 1 m grid was laid out over the area. Excavation of the compact silty and clayey sediment that encased the mammoth remains was done with hand tools but the sediments were not screened. Eventually, more than 50 m^2 were hand excavated and dozens of bones were exposed; some were articulated, or nearly so, but most were not. The extent of remaining in situ deposits is not known but

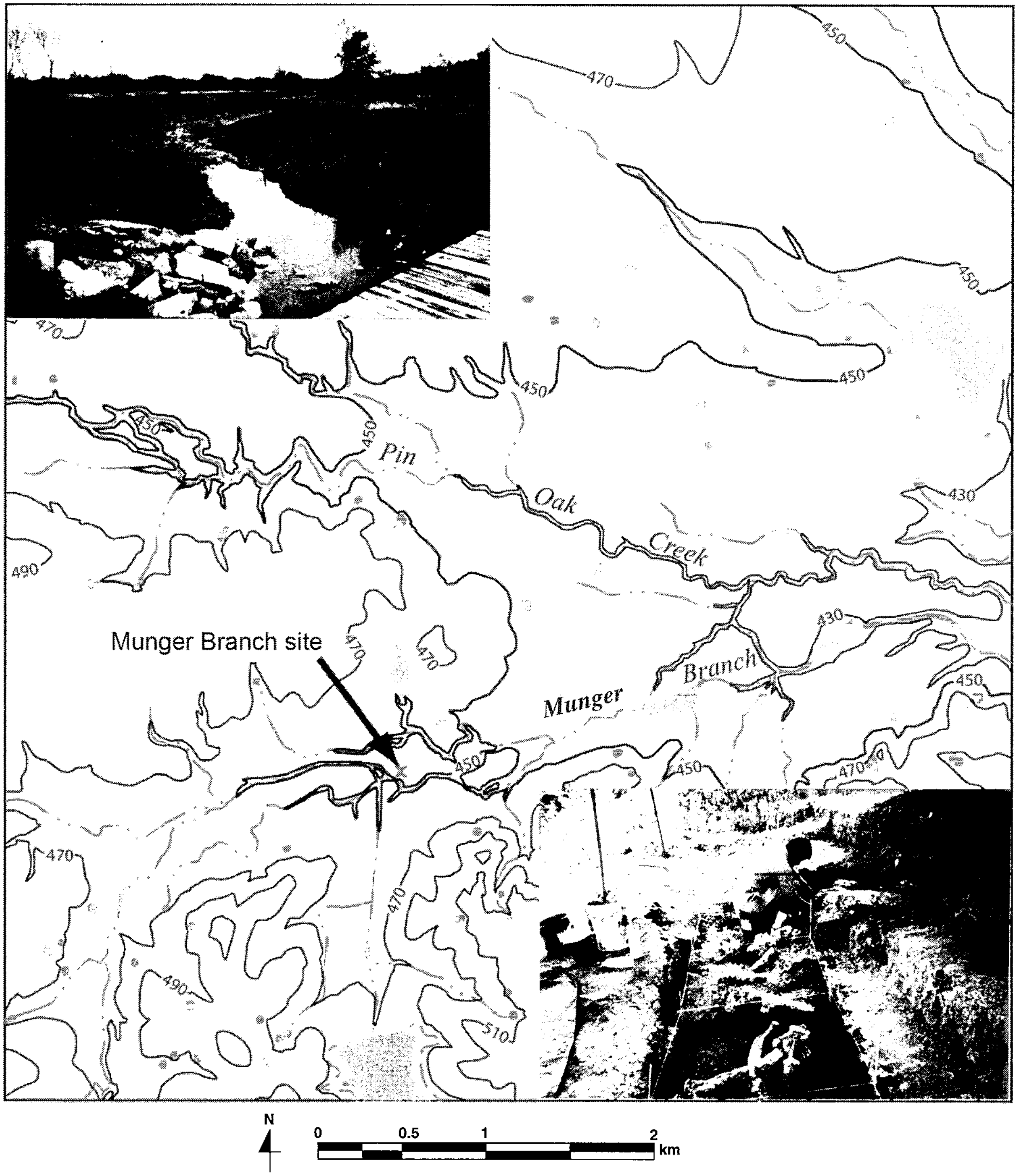


Figure 15. Topographic map showing the location of the Munger Branch site in northern Limestone County; photo inset in the upper left corner shows the tarp-shaded excavation area and the lower right inset shows excavations in progress.

it seems likely that portions of the site remain intact for future excavations.

Upon exposure from the damp compact sediment, the mammoth bones, whether large or small segments, were "as fragile as a soft sponge" but, once dry, were as friable as "dry bread" (Vance 2004:16). Limb bones, ribs, and vertebrae were mapped in place (Figure 16) along with the mandible, tusk, pelvis, scapula, partially articulated bones of one foot, and several large segments of unidentified

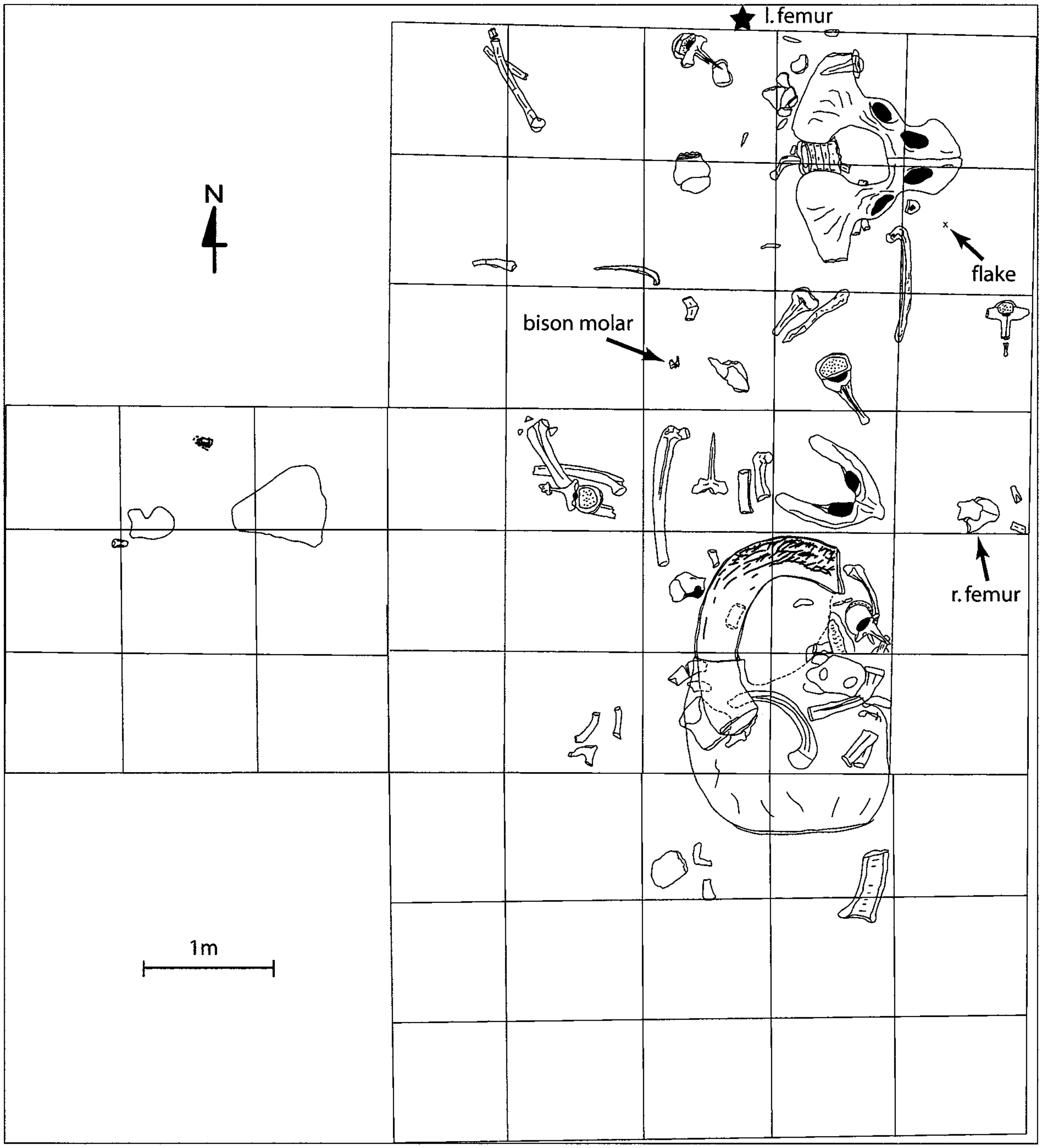


Figure 16. Plan view map of the mammoth bone bed at the Munger Branch site (redrawn and updated from Vance 2004:Figure 38), showing the location of the femora, the single flake, and the bison molar fragment.

bones. To stabilize the bones for removal, a solution of polyvinyl acetate and acetone was dripped onto the bones as they were exposed. Prior to removal, several dozen of the larger pieces were covered with paper towels and jacketed with burlap strips soaked in wet plaster-of-Paris (Vance 2004).

Excavators concluded that the mammoth died in a shallow body of calm water or perhaps a muddy depression underlain by a deposit of finely stratified silt. One tusk, the intact portion of which was about 1.5 m long, was still embedded in its cranial opening and lay adjacent to the mandible; the pelvis and several vertebrae lay 2–3 m to the north (see Figure 16). The positions of these bones suggested to the excavators that the mammoth may have floated on its back after the legs became detached by wave action that also "bent the carcass into a position where the pelvis and head were in close contact" (Vance 2004:22).

In the absence of readily apparent butchering marks or chipped stone tools, little evidence suggested that humans might have been among the taphonomic agents. The only hint of a human role was the presence of a chert flake made from the type of opaque yellowish-brown Edwards Formation chert that occurs in cobble form in stream beds throughout the Blackland Prairie and Post Oak Savannah. The small, complete flake exhibits sharp edges, a patch of cobble cortex, and a clear bulb of percussion (Figure 17). It was found near and just below the pelvis, which rested on the finely stratified silty deposit that underlay the bone bed (Vance 2004).

Also present in the vicinity of the pelvis were several iron concretions that resembled red ocher. The silty clay sediments encasing the mammoth remains contained various aquatic and terrestrial snail shells along with mussel shells. In addition, a partial molar from a bison (*Bison* spp.) was recovered from what was otherwise a mammoth bone bed (Vance 2004).

Figure 17. Chert flake, showing both faces, recovered from mammoth bone bed at the Munger Branch site.

Stratigraphic Setting

The site is located along Munger Branch near the point where it enters an expansive floodplain formed by Pin Oak Creek (see Figure 15). The silty clay unit that encases the bone bed lies near the base of the 7 m thick fill of the first major terrace (Figure 18). In the immediate site area, Munger Branch flows over limestone gravel and marl bedrock of the Taylor Formation, which is Late Cretaceous in age. It remains unclear whether the thick fine-grain alluvial deposit caps a channel gravel deposit or bedrock. Two thick (2–3.7 m) units of clayey alluvium, separated by a 20 cm thick deposit of silty sand with some pea-size gravel, overlay the bone bed. The alluvial unit sandwiched between the bone bed and the thin deposit of coarse-grained alluvium contained the remains of an earth oven, of undetermined age, with fist-size, fire-cracked quartzite and chert cobbles underlain by charcoal (Vance 2004).

The lowermost deposit exposed during excavation was thinly bedded black silt that underlay the bone bed and appeared to have accumulated in a shallow pond or perhaps a flood chute. Mammoth bones were encased in a yellowish-grey clay-rich deposit, apparently massive in nature, which contained various terrestrial and aquatic snails as well as mussel shells, none of which has been examined in detail. The presence of a substantial carbonate coating on the bones, along with the remains of aquatic fauna, was suggestive of water-logged conditions (Vance 2004). That the mammoth bones had the consistency of a "soft sponge" when first exposed but soon dried to a fragile, brittle condition implies that both bone mechanical strength and chemical constituency had been impacted. This condition is typical of bone that remained in damp to water-saturated sediments over an extended period of time.

Thumbnail-sized pieces of exfoliated mammoth bone were associated with the larger bone segments and likely resulted from root action, seasonal drying, and related shrinking and swelling of the clay-rich deposit. Both the skull and pelvis were lying upside down, which indicated to the field team that these portions of the mammoth carcass may have

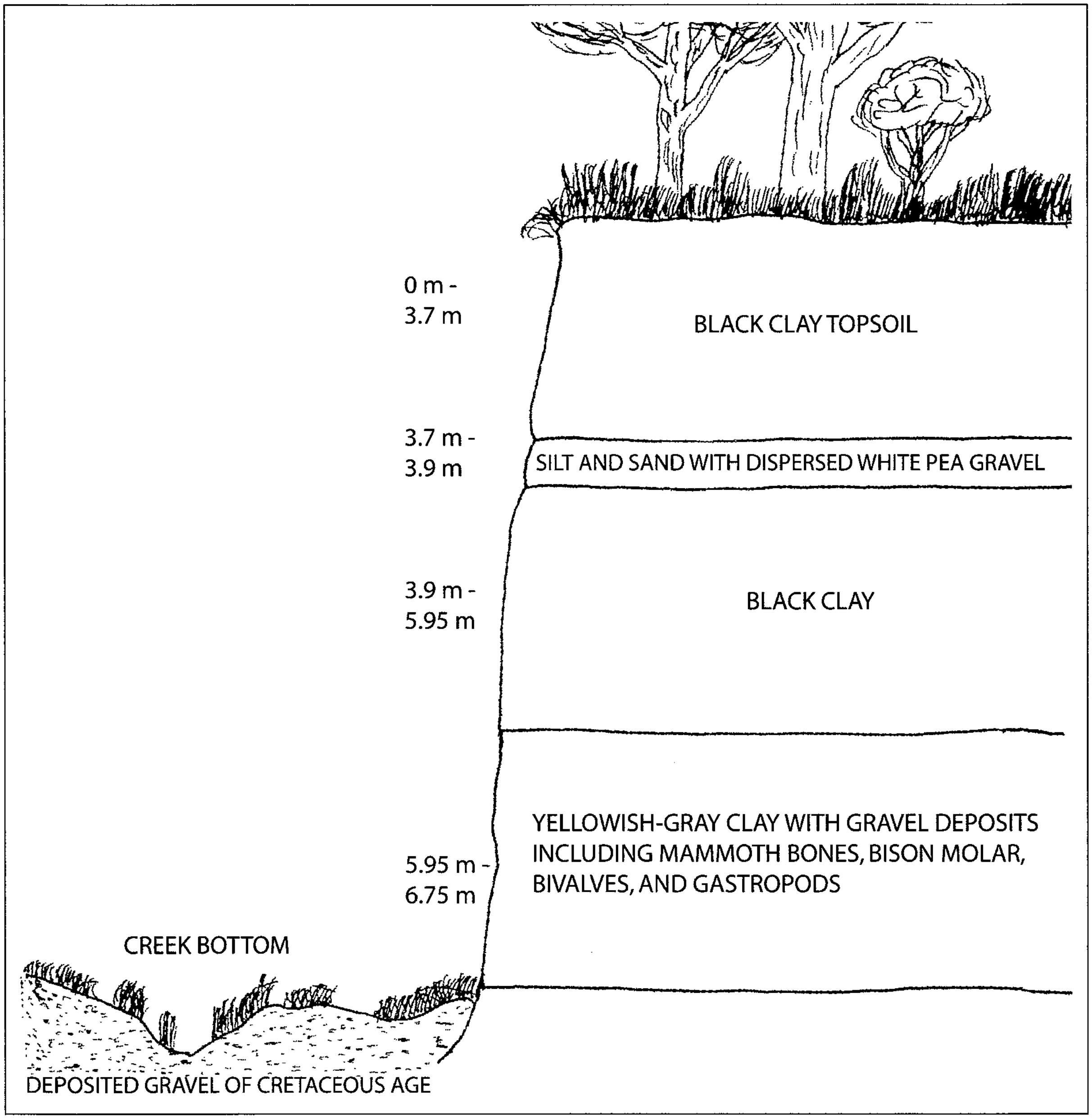


Figure 18. Schematic profile of the cutbank at the Munger Branch site, showing the location of the bone bed near the base of the 7 m thick alluvial deposit (revised from Vance 2004:Figure 20).

floated in calm water for some period. Some of the bones, including the pelvis, were in direct contact with the thinly bedded silty deposit. Bottom elevation of the mammoth bones varied by as much as 30 cm; in a few places, two or three bones were superimposed (Vance 2004). The only appreciable quantity of pea gravel found in the bone bed was immediately beneath the pelvis. The presence of gravel in the otherwise fine-grain matrix suggests proximity to a channel, perhaps a flood chute, with water velocity temporarily in excess of that needed to transport the underlying well-stratified silty unit.

Modified Bones

A complete list of recovered elements is not yet available. Among those identified to date are the distal ends of the femora, numerous ribs and vertebrae, sections of a tibia, a fibula, a clavicle, and a scapula. Also present are the almost-complete pelvis, the poorly preserved skull, the mandible, a

1.5 m section of one tusk, and a partial molar. The broken ends of the femora exhibit fracture patterns typical of human modification, as shown at Duewall-Newberry (Steele and Carlson 1989) and Lubbock Lake (Johnson 1985). To date, only the femora from the Munger Branch site have been examined and preliminarily described.

The proximal femora are similarly weathered and exhibit both carnivore and cultural modifications. Those modifications, however, are segregated and concentrated on different parts of the element. Tooth pitting, scoring, and furrowing occur around and across the femoral heads (Figure 19). These morphologies represent a continuum of damage within a carnivore's activities to break through the softer ends of long bones and consume the nutrients contained within. Isotope studies show that both the short-faced bear and gray wolf scavenged mammoth carcasses for meat (Matheus et al. 2003). Based on furrow size, the large carnivore modifying the Munger Branch mammoth remains was a canid, most likely the dire wolf (Haynes 1982; Johnson 2006).

Both femora exhibit characteristics of dynamic impact of intact fresh bone that indicate bone breakage by people (Johnson 1985). The modifications are centered on the diaphyses. Helical fractures occur along the diaphyses with intersecting fracture fronts on both femora (Figures 20-21). The right femur (#52) also has two impact points, one on either side of the upper end of the diaphysis (Figures 21 and 22).

Dynamic impact employs a percussion method of a focused, quick impact to the diaphysis to fracture it. That impact creates an impact point (or loading point). Using this high velocity technique, breaking intact fresh long bones can be done through either a single or double anvil mode. Opposing impact points on alternate sides is the hallmark of the use of a hammerstone and single anvil (Johnson 1985). The impact caused by the hammerstone produces a large impact area that can undergo bone loss due to crushing and flaking. The preserved impact area, then, is a remnant of the impact point. The opposing impact point is caused by the redirection of force from the anvil back to the diaphysis that causes a rebound impact. The rebound impact point is smaller and generally exhibits greater integrity (Johnson 1985).

The right femur from the Munger Branch mammoth was probably placed on a single anvil in cantilever fashion with the upper diaphysis resting on the anvil. The remnant impact point produced by the hammerstone occurs on one side of the bone (Figure 22a) and the smaller, more intact impact point occurs on the opposite side and represents the rebound and anvil side of the bone (Figure 22b).

Discussion

Climatic conditions during Paleoindian times on the inner Gulf Coastal Plain in Texas tended to

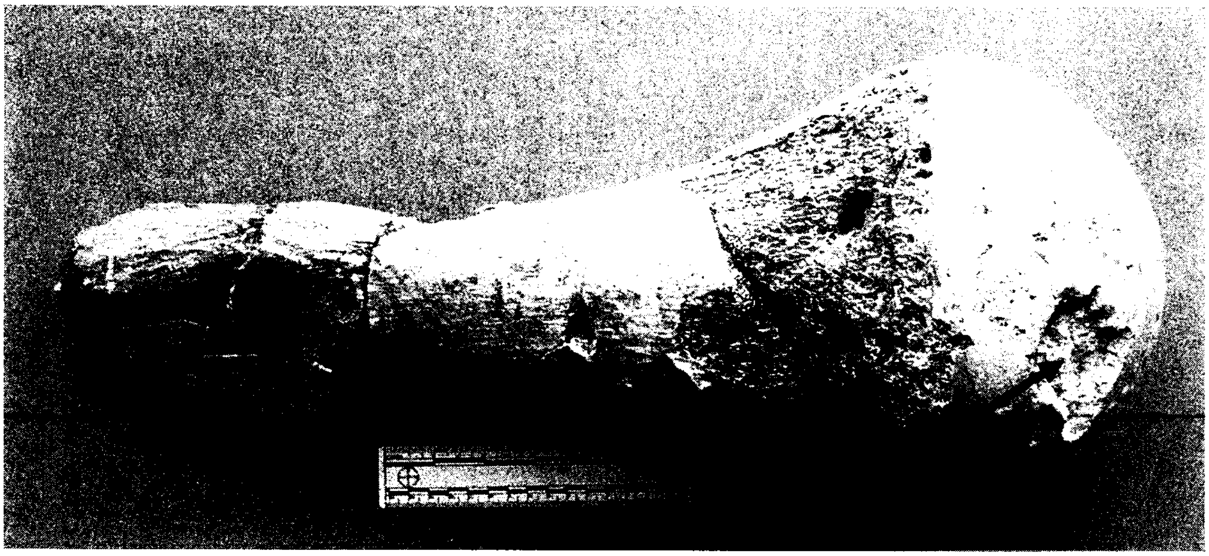
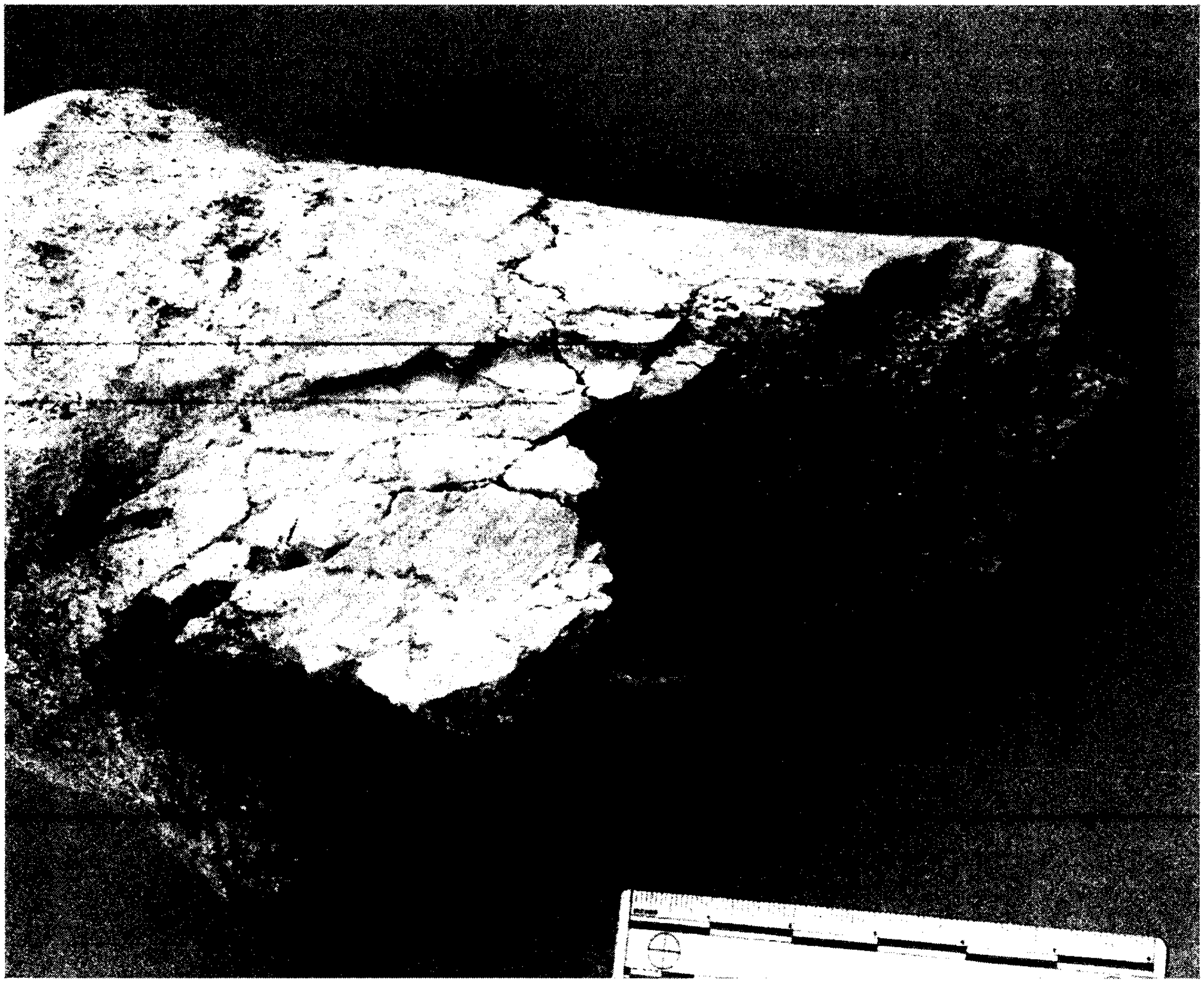


Figure 19. Proximal end of the left femur of the Munger Branch mammoth, showing tooth pitting, scoring, and furrowing around and across the femoral head.

Figure 20. Helical fractures along the diaphysis of the proximal end of the left femur of the Munger Branch mammoth, with intersecting fracture fronts.



Figures 21. Helical fracture along the diaphysis of the proximal end of the right femur of the Munger Branch mammoth.

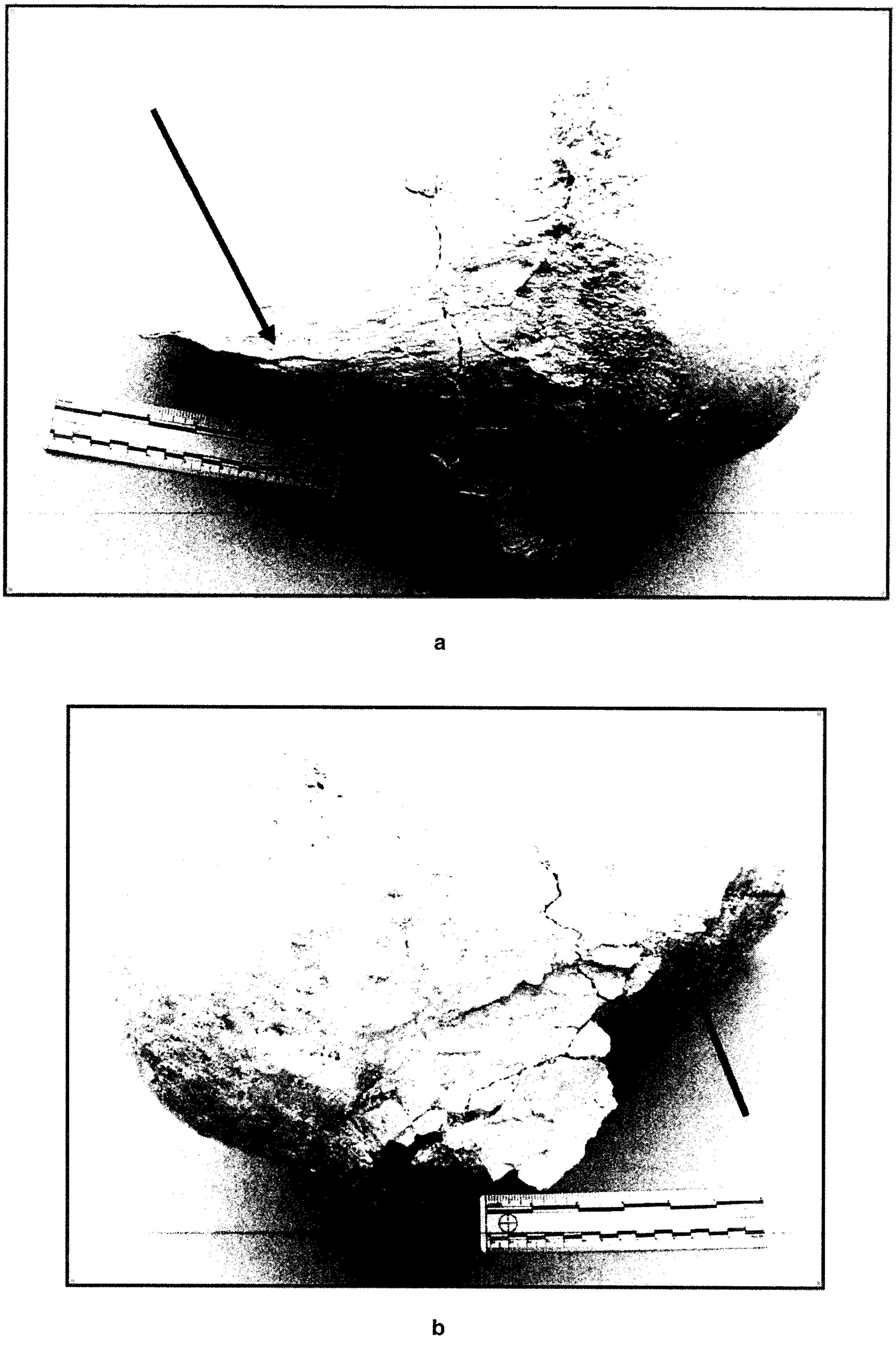


Figure 22. Preserved impact points on opposite sides of the upper proximal end of the right femur diaphysis of the Munger Branch mammoth: a, remnant of the original impact point; b, rebound impact point on the opposing side.

be cooler and wetter than those of today, and fostered vegetation communities that differed significantly from those of the modern era (Bousman 1998; Bryant and Holloway 1985). It is unlikely, however, that the magnitude of arboreal canopy cover or the expansiveness of grasslands during the Late Pleistocene differed substantially, except for the boreal elements, from what one encounters within 200 km of the Post Oak Savannah today. In short, what is present collectively over this vast area today in terms of potential grassland, savannah, and forest probably resembles what the first Texans saw on the inner Gulf Coastal Plain, albeit composed of different plant communities.

The rather limited distribution of well-documented Late Pleistocene archeological sites on the Texas Gulf Coastal Plain belies the appreciable spatial overlap between Columbian mammoths and Clovis-era sites (Figure 23). One also would expect considerable spatial overlap if the plot of Columbian mammoths was limited to those dated between 25,000 and 11,000 years ago as well as if Clovis points were plotted instead of Clovis sites. Said differently, the known distribution of Clovis-era sites and projectile points provides strong inference

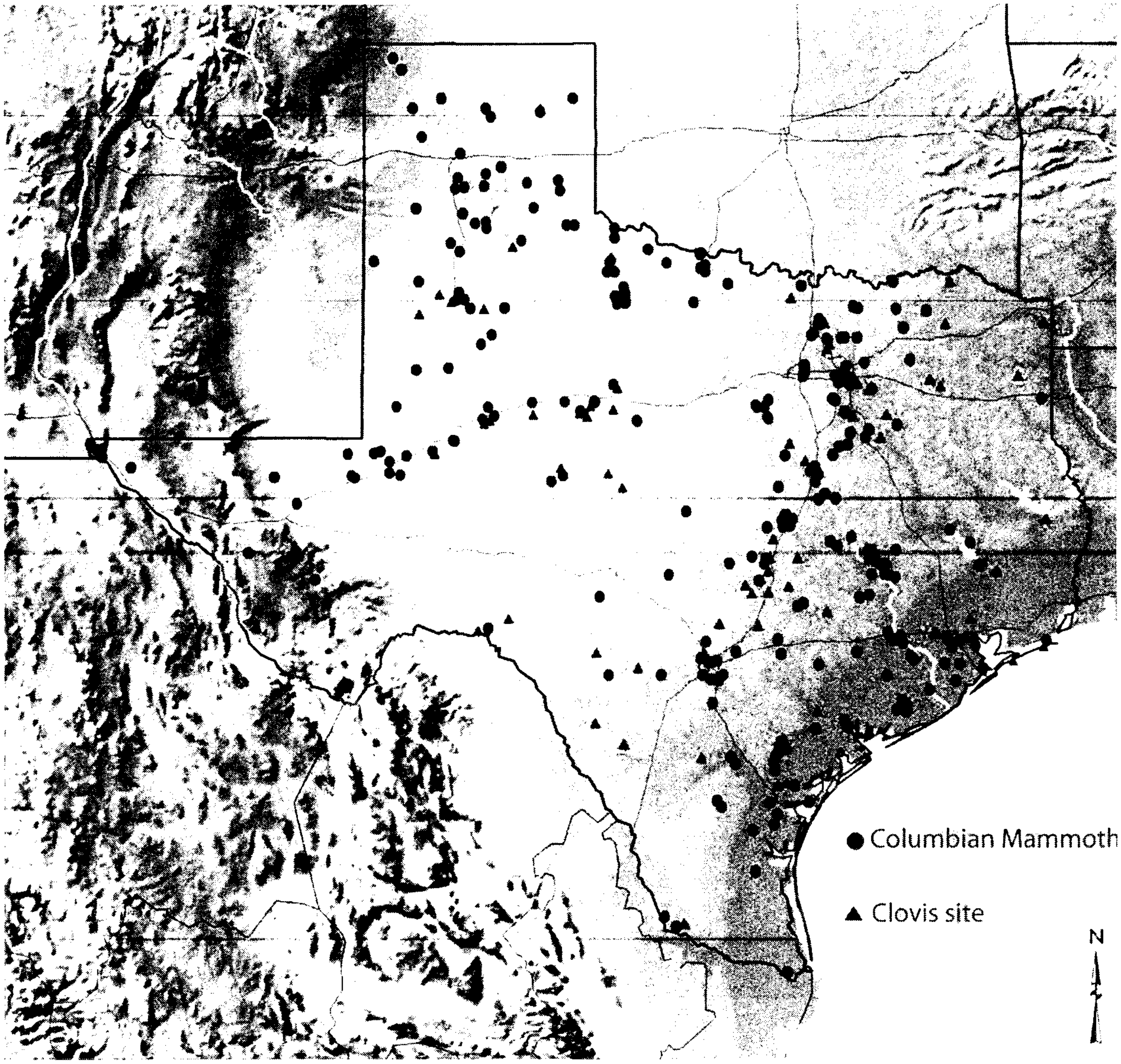


Figure 23. Distribution of Columbian mammoth localities (adapted from Gatlin et al. 2007) and Clovis-era sites (adapted from Bousman et al. 2004) in Texas.

for substantial human populations during the Late Pleistocene when mammoths and mastodons were seemingly abundant in the Coastal Plain.

Long ago, archeologists established the presence of predator-prey relationships between humans and proboscideans throughout North America. It has since become clear that proboscidean carcasses were also routinely exploited for their thick cortical bone that was used to manufacture a variety of tools (Bonnichsen and Sorg 1989; Holen 2006; Johnson 1985, 1989, 2005). As with African elephants today, dying/dead proboscideans throughout North America probably attracted considerable attention from various scavengers, including vultures and canids, some of which were undoubtedly monitored by local hunter-gatherers who may have relished an opportunity to obtain raw material from these carcasses.

A growing body of evidence attests to the importance of bone tools on the eastern Gulf Coastal Plain (Anderson and Sassaman 1996) and ample evidence now exists on the Great Plains for the use of mammoth bones as expedient tools and in the manufacture of complex, multi-component tools (Hannus 1989; Holen 2006; Johnson 1985, 1989, 2005). The La Sena and Lovewell sites in Kansas are in the heartland of the North American Great Plains, hundreds of km northeast of the Post Oak Savannah, but they too exhibit convincing evidence of mammoth bone quarry activities at loci lacking chipped stone artifacts (Holen 2006). Fractured mammoth long bones and bone flakes are present at Lubbock Lake where chipped stone artifacts are minimal for this Clovis-era processing area (Johnson 1987, 1989).

The Duewall-Newberry site, which yielded some of the best examples in North America of human-fractured mammoth bones at a Late Pleistocene site lacking stone tools, is located on the banks of the Brazos River (Steele and Carlson 1989). It lies in the midst of the Post Oak Savannah, roughly midway between the Pin Oak Creek and San Antonio River sites (see Figure 1). The carefully excavated site yielded broken mammoth bones, bone flakes, and a bone pile. Several long bones exhibited distinctive helical and impact fractures (Steele and Carlson 1989). That mammoth bone quarrying was more widespread and common than the available data suggest is further indicated by the nature of modified mammoth bones from the Richard Beene, San Antonio River, and Munger Branch sites.

Backwell and d'Errico's (2004) studies in South Africa have shown that a few people can break elephant long bones into small pieces without the aid of chipped stone. A central tenant of the present article is that overdependence on chipped stone as *the only credible evidence* of human occupation arguably hampers the ability to see other potentially credible evidence for pre-Clovis occupations, especially mammoth bone quarrying activities. An important component of the working model used herein is that mammoth bone quarrying was commonplace during the Late Pleistocene in North America. Moreover, recent studies (e.g., Holen 2006; Johnson 2005) suggest that bone-working technology may have been in full swing several millennia prior to the well-documented Clovis era and widespread use of bifacially flaked tools.

CONCLUSIONS

The preliminary findings at the three sites described herein are compatible with evidence for mammoth bone quarrying activities at better documented sites in Texas, notably Duewall-Newberry (Steele and Carlson 1989), which lacked chipped stone altogether, and Lubbock Lake (Johnson 1985, 1989, 2005), where chipped-stone tools and debitage are minimal compared to other Late Pleistocene sites with mammoth bones (Bousman et al. 2004). Holen (2006) has presented evidence for mammoth bone quarrying at two pre-Clovis sites in the central Plains that lacked chipped stone tools. That pre-Clovis mammoth bone quarrying should also be well represented in the Post Oak Savannah region and vicinity is demonstrated by the widespread occurrence of Late Pleistocene proboscidean remains, Clovis-era sites, and Clovis projectile points throughout Texas.

Two long bone segments from the San Antonio River site have features and microfeatures that appear to represent cut and saw marks made by lithic tools. The third bone from the site, a piece of thick cortical bone, as well as the radius segment with cut marks, exhibit helical breaks and chattering indicative of dynamic fracturing of the bone, an activity associated with human bone processing. Collectively, these bone-modifying activities appear to have been for subsistence and tool making purposes.

Both femora from the Munger Branch site as well as the tibia from the Richard Beene site exhibit characteristics of dynamic impact of intact fresh bone that indicate bone breakage by people. Modifications on these three segments are centered on the diaphyses and consist of helical fractures along the diaphyses with intersecting fracture fronts. The tibia exhibits a helical breakage pattern on both ends. At least one anvil and a large (small boulder size) hammerstone were probably involved in fracturing these bones. Particularly for mammoth bones, this pattern is consistent with quarrying to obtain raw material for bone tools (Figure 24).

Mammoth bones from the San Antonio River, Richard Beene, and Munger Branch sites afford credible evidence of what arguably must have been widespread and common bone-quarrying activities. While the ages of mammoth bones from these sites are not known, it is reasonable to conclude that they are Late Pleistocene in age. Any one of the sites may well date prior to 11,500 B.P. and thus shed additional light on pre-Clovis lifeways in Texas. These sites attest to the potential of Late Pleistocene fine-grained alluvial deposits on the Gulf Coastal Plain of Texas to yield new evidence of Paleoindian behavior and thereby significant information on the early peopling of North America. Given the region's favorable habitat during the Late Pleistocene for mammoths and hunter-gatherers, an over-dependence on chipped stone as *the* primary evidence of human occupation hampers the ability to see other primary evidence for Paleoindian activities, including pre-Clovis occupations and especially mammoth bone quarrying.

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Figure 24. Artist depiction, from a mural at the Lubbock Lake Landmark, of a Clovis-age group butchering a mammoth and fracturing one of the femora to obtain cortical bone for manufacturing bone tools (painting courtesy of the Lubbock Lake Landmark).

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REFERENCES CITED

Anderson, D. G.
1996 Models of Paleoindian and Early Archaic Settlement in the Lower Southeast. In *The Paleoindian and Early Archaic Southeast*, edited by D. G. Anderson and K. E. Sassaman, pp. 29–57. University of Alabama Press, Tuscaloosa.

Anderson, D. G. and K. E. Sassaman (editors).
1996 *The Paleoindian and Early Archaic Southeast.* University of Alabama Press, Tuscaloosa.

Backwell, L. R. and F. d'Errico
2004 The First Use of Bone Tools: A Reappraisal of the Evidence from Olduvai Gorge, Tanzania. *Palaeontologia Africana* 40:95–158.

Baker, B. W. and D. G. Steele
2007 The Late Pleistocene through Late Holocene Faunal Assemblage from the Richard Beene Site. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A. V. Thoms and R. D. Mandel, pp. 229–240. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Binford, L. R.
1981 *Bones: Ancient Men and Modern Myths.* Academic Press, New York.

Blair, W. F.
1950 The Biotic Provinces of Texas. *The Texas Journal of Science* 2:93–117.

Blumenschine, R. J.
1988 An Experimental Model of the Timing of Hominid and Carnivore Influence on Archaeological Bone Assemblages. *Journal of Archaeological Science* 15:483–502.

Blumenschine, R. J. and M. M. Selvaggio
1991 On the Marks of Marrow Bone Processing by Hammerstones and Hyaenas: Their Anatomical patterning and Archaeological Implications. In *Cultural Beginnings: Approaches to Understanding Early Hominid Life-ways in the African Savanna*, edited by J. D. Clark. Union Internationale des Sciences Préhistoriques et Protohistoriques, Monographien Band 19:17–32.

Bonnichsen, R.
1979 *Pleistocene Bone Technology in the Beringian Refugium.* Mercury Series, Archaeological Survey of Canada Paper 89:1–280. National Museum of Man, Ottawa.

Bonnichsen, R., B. T. Lepper, D. Stanford, and M. R. Waters
2005 *Paleoamerican Origins: Beyond Clovis.* Center for the Study of the First Americans, Texas A&M University, College Station.

Bonnichsen, R. and M. H. Sorg (editors)
1989 *Bone Modification.* Center for the Study of the First Americans, University of Maine, Orono.

Bousman, C. B.
1998 Paleoenvironmental Change in Central Texas: The Palynological Evidence. *Plains Anthropologists* 43(164):201–219.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian Archaeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15–97. Texas A&M University Press, College Station.

Briggs, A.
1987 Mammoths and mastodons and the Congress Avenue Site, Austin. Paper presented at the Mammoth, Mastodons, and Human Interaction Symposium, Waco, Texas.

Bryant, V. M., Jr. and R. G. Holloway

1985 A Late-Quaternary Paleoenvironmental Record of Texas: An Overview of the Pollen Evidence. In *Pollen Records of Late-Quaternary North American Sediments*, edited by V. M. Bryant, Jr. and R. G. Holloway, pp. 39–70. American Association of Stratigraphic Palynologists Foundation, Dallas.

Bunn, H. T.

1989 Diagnosing Plio-Pleistocene Hominid Activity with Bone Fracture Evidence. In *Bone Modification*, edited by R. Bonnichsen and M. H. Sorg, pp. 229, 315. Center for the Study of the First Americans, University of Maine, Orono.

Capaldo, S. D. and R. J. Blumenschine

1994 A Quantitative Diagnosis of Notches Made by Hammerstone Percussion and Carnivore Gnawing on Long Bone. *American Antiquity* 59(4):724–728.

Caran, S. C.

2001 Field Observations on the Stratigraphic Context of Mammoth Remains at 41BX1239. In *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar County, Texas*, edited by A. V. Thoms, pp. 25–28. Technical Report No. 3. Center for Ecological Archaeology, Texas A&M University, College Station.

Coe, M.

1978 The Decomposition of Elephant Carcasses in the Tsavo (East) National Park, Kenya. *Journal of Arid Environments* 1(1):71–86.

Collins, M. B.

2004 The Gault Site, Texas, and Clovis Research. *Athena Review* (3)2: *Peopling of the Americas*. Electronic document, http://athenapub.com/10gault.htm, accessed December 29, 2004.

Cruz-Uribe, K.

1991 Distinguishing Hyena from Hominid Bone Accumulations. *Journal of Field Archaeology* 18:467–486.

Currey, J. D.

1984 *The Mechanical Adaptations of Bones*. Princeton University Press, Princeton.

Delcourt, P. A. and H. R. Delcourt

1981 Vegetation Maps for Eastern North America: 40,000 Years B.P. to Present. In *Geobotany: An Integrating Experience*, edited by R. Romans, pp. 123–166. Plenum, New York.

1983 Late-Quaternary Vegetational Dynamics and Community Stability Reconsidered. *Quaternary Research* 19:265–271.

Delcourt, H. R.

2002 *Forest in Peril: Tracking Deciduous Trees from Ice-Age Refuges into the Greenhouse World*. McDonal & Woodward, Blacksburg, Virginia.

Dillehay, T. D.

1997 *Monte Verde, A Late Pleistocene Settlement in Chile. Volume 2: The Archaeological Context and Interpretation*. Smithsonian Institution Press, Washington, D.C.

Dunbar, J. S. and S. D. Webb

1996 Bone and Ivory Tools from Submerged Paleoindian Sites in Florida. In *The Paleoindian and Early Archaic Southeast*, edited by D. G. Anderson and K. E. Sassaman, pp. 311–353. University of Alabama Press, Tuscaloosa.

Evans, G. F.

1973 *Mechanical Properties of Bone*. Charles C. Thomas, Springfield, Illinois.

Evans, G. L. and G. E. Meade

1945 Quaternary of the Texas High Plains. *University of Texas Publication, Contributions to Geology* 4401:487–507.

Fisher, D. C.

1984 Taphonomic Analysis of Late Pleistocene Mastodon Occurrences: Evidence of Butchery by North American Paleo-Indians. *Paleobiology* 10(3):338–357.

Fox, J. W. and C. B. Smith

1987 Herd Bunching of *Mammuthus columbi* at the Waco mammoth Site. Paper presented at the Mammoths, Mastodons, and Human Interaction Symposium, Waco, Texas.

Fredlund, G. G. and R. W. Neck

2007 Stable Isotope Analysis of Land-Snail Shell Carbonate, the Richard Beene Site. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A. V. Thoms and R. D. Mandel, pp. 111–120. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Frye, R. G., K. L. Brown, and C. A. McMahon

1984 *The Vegetation of Texas* (map only). Bureau of Economic Geology, The University of Texas at Austin.

Gatlin, G., E. Glass, and T. Vance.

2007 *The Mammoths of Texas*. Occasional Papers of the Dallas Paleontological Society 8, in press.

Graham, R. and E. L. Lundelius, Jr.

1994 *Faunmap: A Database Documenting Late Quaternary Distributions of Mammal Species in the United States*. Scientific Papers 25(2). Illinois State Museum, Springfield.

Haynes, G.

1982 Utilization and Skeletal Disturbances of North American Prey Carcasses. *Arctic* 35(2):226–281.

1991 *Mammoths, Mastodons, & Elephants: Biology, Behavior, and the Fossil Record.* Cambridge University Press, Cambridge.

Hannus, L. A.

1989 Flaked Mammoth Bone from the Lange/Ferguson Site, White River Badlands Area, South Dakota. In *Bone Modification*, edited by R. Bonnichsen and M. H. Sorg, pp. 395–412. Center for the Study of the First Americans, University of Maine, Orono.

Haynes, C. V., Jr.

1992 Contributions of Radiocarbon Dating to the Geochronology of the Peopling of the New World. In *Radiocarbon After Four Decades*, edited by R. E. Taylor, A. Long, and R. S. Kra, pp. 355–374. Springer-Verlag, New York.

1993 Clovis-Folsom Geochronology and Climatic Change. In *From Kostenki to Clovis: Upper Paleolithic—Paleo-Indian Adaptations*, edited by O. Soffer and N. D. Praslov, pp. 219–236. Plenum, New York.

1995 Geochronology of Paleoenvironmental Change, Clovis Type Site, Blackwater Draw, New Mexico. *Geoarchaeology* 10:317–388.

Holen, S. R.

2006 Taphonomy of Two Last Glacial Maximum Mammoth Sites in the Central Great Plains of North America: A Preliminary Report on La Sena and Lovewell. *Quaternary International* 142–143:30-43.

Johnson, E.

1985 Current Developments in Bone Technology. In *Advances in Archaeological Method and Theory,* Volume 8, edited by M. B. Schiffer, pp. 157–235. Academic Press, New York.

1987 Cultural Activities and Interactions. In *Lubbock Lake: Late Quaternary Studies on the Southern High Plains*, edited by E. Johnson, pp. 120–158. Texas A&M University Press, College Station.

1989 Human Modified Bones from Early Southern Plains Sites. In *Bone Modification*, edited by R. Bonnichsen and M. Sorg, pp. 431–471. Center for the Study of the First Americans, University of Maine, Orono.

1991 Late Pleistocene Cultural Occupation on the Southern Plains. In *Clovis: Origins and Adaptations*, edited by R. Bonnichsen and K. L. Turnmire, pp. 215–236. Center for the Study of the First Americans, Oregon State University, Corvallis.

2001 Observations on Mammoth Remains from 41BX1239. In *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar County, Texas*, edited by A. V. Thoms, pp. 29–42. Technical Report No. 3. Center for Ecological Archaeology, Texas A&M University, College Station.

2005 Late Wisconsinan Mammoth Procurement in North American Grasslands. In *Paleoamerican Origins: Beyond Clovis*, edited by R. Bonnichsen, B. T. Lepper, D. Stanford, and M. R. Waters, pp. 161–182. Center for the Study of the First Americans, Texas A&M University, College Station.

2006 The Taphonomy of Mammoth Localities in Southeastern Wisconsin (USA). *Quaternary International,* 142–143(1):58–78.

2007a A Description of a Proboscidean Bone Specimen from 41BX831. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A.V. Thoms and R. D. Mandel, pp. A1–A4. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

2007b Along the Ice Margin—the Cultural Taphonomy of Late Pleistocene Mammoth in Southeastern Wisconsin (USA). *Quaternary International*, 169–170:64–83.

Lyman, L. R.

1994 *Vertebrate Taphonomy.* Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Mandel, R. D., J. S. Jacob, and L. C. Nordt

2007 Geoarchaeology of the Richard Beene Site. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A. V. Thoms and R. D. Mandel, pp. 27–60. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Matheus, P., R. D. Guthrie, and M. L. Kunz

2003 Predator-Prey Links in Pleistocene East Beringia: Evidence from Stable Isotopes. 3rd International Mammoth Conference, 2003: Program and Abstracts. *Occasional Papers in Earth Sciences* 5:80. Paleontology Program, Government of the Yukon, Dawson

McCulloch, S., J. W. Saunders, G. D. Hall, R. D. Mandel, J. Miller, and C. Freuden

2007 Testing. In *Prehistoric Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas*, edited by D. L. Carlson, pp. 7.1–7.98. Reports of Investigations No. 7. Center for Ecological Archaeology, Texas A&M University, College Station.

Meltzer, D. J.

2004 Peopling of North America. In *The Quaternary Period in the United States*, edited by A. Gillespie, S. C. Porter, and B. Atwater, pp. 539-563. Elsevier Science, New York.

Meltzer, D. J. and M. R. Bever

1995 Paleoindians of Texas: An Update on the Texas Clovis Fluted Point Survey. *Bulletin of the Texas Archeological Society* 66:47–81.

Miller, S. J.
1989 Characteristics of Mammoth Bone Reduction at Owl Cave, The Wasden Site, Idaho. In *Bone Modification*, edited by R. Bonnichsen and M. H. Sorg, pp. 381–394. Center for the Study of the First Americans, University of Maine, Orono.

Morlan, R. E.
1980 *Taphonomy and Archaeology in the Upper Pleistocene of the Northern Yukon Territory: A Glimpse of the Peopling of the New World.* Mercury Series, Archaeological Survey of Canada Paper 94:1–398. National Museum of Man, Ottawa.

Neck, R. W.
2007 Late Pleistocene and Holocene Environments in the Medina Valley of Texas as Revealed by Nonmarine Mollusks. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A. V. Thoms and R. D. Mandel, pp. 83–98. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Nordt, L. C., T. W. Boutton, J. S. Jacob, and R. D. Mandel
2002 C_4 Plant Productivity and Climate-CO_2 Variations in South-Central Texas during the Late Quaternary. *Quaternary Research* 58:182–188.

Olsen, S. L. and P. Shipman
1988 Surface Modification on Bone: Trampling versus Butchery. *Journal of Archaeological Science* 15:535–553.

Olsen, S. J.
1972 *Osteology for the Archaeologist: The American Mastodon and the Woolly Mammoth.* Papers of the Peabody Museum of Archaeology and Ethnology, Vol. 56, No. 3. Harvard University, Cambridge, Massachusetts.

Prewitt, E. R.
1995 Distributions of Typed Projectile Points in Texas. *Bulletin of the Texas Archeological Society* 66:83–173.

Reyes, J. J., Jr.
2006 A Personal Native American Perspective on the Richard Beene Archaeological Survey and Monitoring Project. In *Archaeological Survey and Monitoring in 2005 at the Richard Beene Site, South-Central Texas*, by A. V. Thoms, P. A. Clabaugh, S. Thomas, and M. Kamiya, pp. 29–30. Technical Report No. 7. Center for Ecological Archaeology, Texas A&M University, College Station.

Saunders, J. J. and E. B. Daeschler
1994 Descriptive Analyses and Taphonomical Observations of Culturally-Modified Mammoths Excavated at "The Gravel Pit," near Clovis, New Mexico in 1936. *Proceedings of the Academy of Natural Sciences of Philadelphia* 145:1–28.

Schiffer, M. B.
1987 *Formation Processes of the Archaeological Record.* University of New Mexico Press, Albuquerque.

Shipman, P.
1981 *Life History of a Fossil: An Introduction to Taphonomy and Paleoecology.* Harvard University Press, Cambridge.

Shipman, P. and J. J. Rose
1984 Cutmark Mimics on Modern and Fossil Bovid Bones. *Current Anthropology* 25:116–117.
1988 Bone Tools: An Experimental Approach. In *Scanning Electron Microscopy in Archaeology*, edited by S. L. Olsen, pp. 303–335. British Archaeological Reports International Series 452.

Shipman, P., D. C. Fisher, and J. J. Rose
1984 Mastodon Butchery: Microscopic Evidence of Carcass Processing and Bone Tool Use. *Paleobiology* 10:358–365.

Steele, D. G. and D. L. Carlson
1989 Excavation and Taphonomy of Mammoth Remains from the Duewall-Newberry Site, Brazos County, Texas. In *Bone Modification* edited by R. Bonnichsen and M. H. Sorg, pp. 413–430. Center for the Study of the First Americans, Institute for Quaternary Studies, University of Maine, Orono.

Thoms, A. V.
2007 Archaeological Records at the Richard Beene Site: Summary and Synthesis. In *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas*, edited by A. V. Thoms and R. D. Mandel, pp. 337–380. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V. (editor)
2001 *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar County, Texas.* Technical Report No. 3. Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V., S. W. Ahr, D. D. Kuhen, and R. D. Mandel
2001 Archaeological Survey Methods and Results. In *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar County, Texas*, edited by A. V. Thoms, pp 11–24. Technical Report No. 3. Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V., E. Johnson, S. C. Caran, and R. D. Mandel
2005 Glimpses of Mammoth Bone Quarrying on North

America's Western Gulf Coastal Plain: Two New Localities near San Antonio, Texas. *Mammoth Site Scientific Papers* 4:183–185.

2006 Mammoth Bone Quarrying in the Post Oak Savannah and Vicinity: An Ecological Perspective. Abstracts of the 77th Annual Meeting of the Texas Archeological Society, p. 37, San Angelo.

Thoms, A. V., D. D. Kuehn, and R. D. Mandel
1997 Mammoth Remains Discovered at 41BX1239. *Cultural Resource Management News & Views* 9(2):13–16.

Thoms, A. V. and R. D. Mandel (editors)
2007 *Archaeological and Paleoecological Investigations at the Richard Beene Site—41BX831—South-Central Texas.* Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Vance, T.
2004 *Brief Introduction to the Ice Age Mastodons and Mammoths of Texas with Special Reference to the Recovery of the Pin Oak Creek Mammoth.* Distinguished Faculty Lecture Series 3. Navarro College, Corsicana, Texas.

Waters, M. R. and T. W. Stafford, Jr.
2007 Redefining the Age of Clovis: Implications for the Peopling of the Americas. *Science* 315:1122-1126.

The Search for Late Pleistocene pre-Clovis Archeology in Texas: Problems and Potentials

C. Britt Bousman and S. Alan Skinner

ABSTRACT

Geoarcheological research in the North Sulphur River valley demonstrates the presence of an alluvial sequence that spans 17,000 years and provides the first radiocarbon dates for the Lower Sulphur River Formation. Stone artifacts and a single bone were discovered on the eroded surface of the Lower Sulphur River Formation and might represent a pre-Clovis occupation. Before such a claim can be made, in situ artifacts must be documented in these Late Pleistocene sediments. If pre-Clovis occupations exist anywhere in Texas, systematic geoarcheological investigations must target and identify Late Pleistocene deposits older than 11,050 B.P., then careful archeological searches must focus on these sediments.

INTRODUCTION

Clovis Paleoindian artifacts are the oldest well-dated evidence for human occupation within the Pleistocene period in Texas (Bousman et al 2004; Waters and Stafford 2007). Occasionally a claim for Late Pleistocene pre-Clovis occupation is made for a Texas site (e.g., Collins 1976); however, even as some of the original authors have come to realize, none of these claims have been substantiated with credible evidence (Collins 1994). The reasons for this situation are convoluted, complex, and somewhat unique to each site, but it is widely recognized that much of the problem lies with an absence of geological deposits that date to this highly important time span. Various geoarcheological and Quaternary geology studies have demonstrated that alluvial, colluvial, and eolian deposits dating between 18-12,000 years ago (18-12 kya) are rarely preserved in Texas (Abbott 2001; Blum and Valastro 1994; Ferring 1993; Holliday 1997). The reasons for this absence are not fully known, but Bousman (1998) argued that a cold glacial melt water spike surging down the Mississippi River into the diminutive Gulf of Mexico between 13-12 kya caused a marked drought and stimulated widespread erosion that removed these Late Pleistocene deposits across a wide region of the American South. Whatever the reason(s), the absence of Late Pleistocene sediments is common. Any evidence of ancient Native Americans that might have been contained within these sediments would also be missing. This article presents new evidence for Late Pleistocene sediments in the North Sulphur River valley and a possible, but not necessarily probable, claim for a pre-Clovis occupation in Northeast Texas.

In the spring and summer of 2005, AR Consultants surveyed a tract on the North Sulphur River that was the proposed future site for Lake Ralph Hall in Fannin County (Skinner et al. 2006). As part of this project, a preliminary geoarcheological reconnaissance of the basin was undertaken. This was an area that had not been investigated in a number of years, but previous work in the 1960s and 1970s by geologists from Southern Methodist University discovered and documented what is still the oldest in situ archeological site in Northeast Texas. For years the Sulphur River basin has been known to collectors for its abundant Cretaceous and Pleistocene fossils, and prehistoric artifacts (McKinzie et al. 2001). Plus geoarcheological studies in the South and Middle Sulphur River valleys had shown that great potential existed for buried sites and long depositional sequences (Bousman 1990; Bousman et al. 1988; Darwin et al. 1990; Fields et al. 1993a; Gadus et al. 1991). However, Pleistocene-aged archeological materials have only been found in situ in the North Sulphur River valley (Slaughter and Hoover 1965).

QUATERNARY GEOLOGY AND PALEOINDIAN ARCHEOLOGY IN THE NORTH SULPHUR RIVER VALLEY

Frye and Leonard (1963) conducted the first study of sediments in the Sulphur River drainage. They identified the "Sulphur River Alluvial Terrace" with three depositional units that they believed dated to the Kansan and early Wisconsin glacial periods. They based their temporal assignments on the recovery of molluscan fauna. Shortly after, Slaughter and Hoover (1963) revised the Frye and Leonard study with a more detailed scheme. At many locations in the North, Middle, and South Sulphur river basins, they identified two stratigraphic units in the alluvium. Using vertebrate fauna, Slaughter and Hoover (1963) defined the oldest deposit as the Sulphur River Formation producing a characteristic Late Wisconsin fauna named the Ben Franklin Local Fauna. The Ben Franklin Local Fauna consisted of shrews, armadillos, ground squirrels, gophers, giant beavers, cotton rats, mice, wood rats, muskrats, voles, lemmings, coyotes, mammoths, mastodons, cottontail rabbits, peccaries, antelopes, deer, bison, and horses. Slaughter and Hoover (1963) also submitted materials for radiocarbon assays. From the base of the Sulphur River Formation, articulated *Amblema plicata* mussel shell produced a radiocarbon age estimate of 11,135 ± 450 B.P. (SM-533) and charcoal from a hearth was assayed at 9550 ± 375 B.P. (SM-532). This hearth was adjacent to a pond deposit 4 ft. above bedrock. Near the hearth, Slaughter and Hoover (1965) reported the discovery of a bipointed deer antler pick with a drilled hole through the middle and a few quartzite flakes. Based on an absence of extinct Pleistocene taxa, the younger deposit was suggested to date to the Holocene. Supplemental studies of mollusks, amphibians, reptiles, charophytes (freshwater green algae), and fish remains from these deposits by Cheatham and Allen (1963), Holman (1963), Schlichtling (1963), and Ueyeno (1963) supported the conclusions of Slaughter and Hoover (1963).

In 1974, Mary Rainey, under the supervision of Vance Haynes, finished a Master's Thesis on the Quaternary sediments in the North Sulphur drainage. Rainey (1974) provides descriptions for 12 profiles in the main North Sulphur River channel and Ghost Creek, a tributary on the north side of the river near Ben Franklin. Based on these descriptions, she clarified the stratigraphic relationship between the Sulphur River Formation and the overlying Holocene deposits, which she named the Ben Franklin Formation. This term causes serious confusion as Slaughter and Hoover (1963) called the fauna from the older Sulphur River Formation the Ben Franklin Local Fauna.

Rainey provided five new radiocarbon assays on charcoal, mussel shells, and clam shells from the Ben Franklin Formation. These were 660 ± 70 B.P. (SMU-70; hearth charcoal), 1123 ± 366 B.P. (SM-598; gravel charcoal), 1790 ± 50 B.P. (SMU-71; gravel charcoal), 1833 ± 144 B.P. (SM-599; clam shells), and 2840 ± 60 B.P. (SMU-62; mussel shells). The assays on mollusks are probably too old, and based on the remaining assays Rainey suggested that the Ben Franklin Formation is at least 1800 years old.

Rainey (1974) also provided a map of geomorphic terraces and presented a model of Pleistocene and Holocene depositional history for the North Sulphur drainage. She divided the Sulphur River Formation into Lower (Qsr1 and Qsr2) and Upper (Qsr3 and Qsr4) units. The top of the Upper Sulphur River Formation (Qsr4) was capped by a soil (S1). The Ben Franklin Formation was divided into multiple units (Qbf1, Qbf2, and Qbf3) and the upper surface was weathered into a soil (S2). Rainey depicted the unnamed surface sedimentary unit as Qal and it was weathered to form two soils (S3 and S4); S4 overlaid S3 within the Qal sedimentary unit.

In the 1980s, 1990s, and later, a number of archeologists and geoarcheologists visited and inspected Quaternary sediments in the North Sulphur River valley, but no substantive evidence for Paleoindian occupations dating to the Pleistocene had been found. This current study begins to redress this lack of research in one of the most promising areas in Texas for Pleistocene archeology.

CURRENT STUDY

In May and August 2005, 10 cutbank and backhoe trench profiles (Figure 1) were described on the North Sulphur River near the community of Ladonia, Texas, in eastern Fannin County. This area is upstream of the area where Slaughter and Rainey had worked, and the work was undertaken

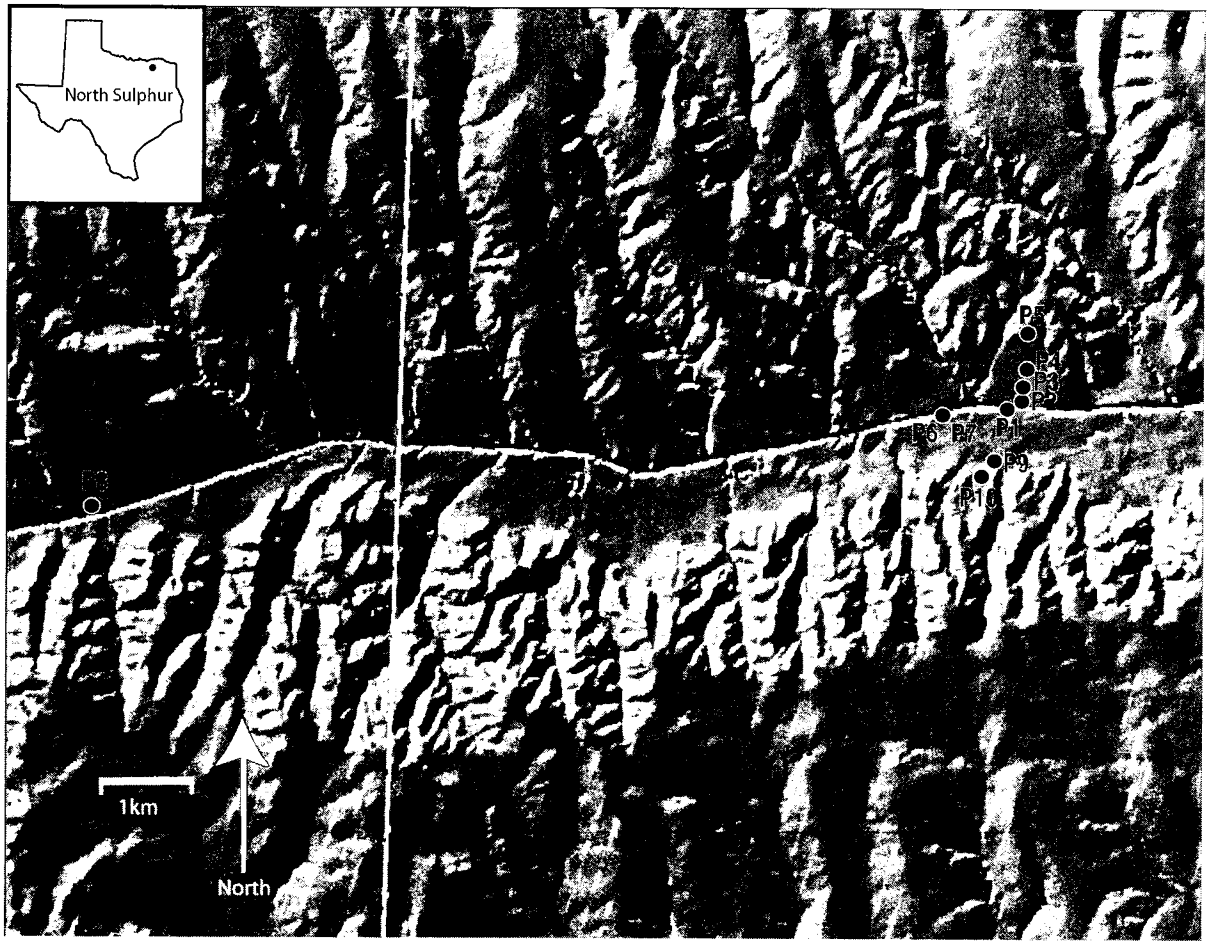


Figure 1. Three-dimensional map showing location of profiles in the North Sulphur River valley.

to evaluate the nature of Quaternary deposition, history of soil formation, and landscape evolution in the proposed Lake Ralph Hall. All the profiles except Profile 8 were placed near the dam axis on the downstream end of the reservoir, and these provide a cross-section of the valley (Figure 2). Artifacts were observed in or adjacent to three profiles (Profiles 1, 3, and 8).

During an initial field reconnaissance we identified eroded cutbank profiles and landscape features with the potential to provide geological information. In addition, we selected profiles for description that would provide a comprehensive valley topographic cross-section of alluvial deposits. We described selected cutbanks, but if selected landscape features did not have good natural exposures, then a backhoe was used to excavate small trenches on landscape surfaces in order to expose vertical profiles.

In the field, we described profiles by sediment zones. A zone is a distinctive and homogeneous sedimentary unit with a recognizable top and bottom boundary. Sediment color was estimated by comparison to a Munsell chart. For each zone texture, soil structure, mottling, calcium carbonate and manganese accumulations, natural or cultural inclusions of all sorts, evidence for disturbance, and zone boundaries were systematically described. We assigned soil horizon designations to sediment zones in the field or later in the lab. Soil horizon and depositional unit designations follow the Soil Survey Division Staff classifications (1993) and Reineck and Singh (1975). Additionally, we collected sediment and charcoal samples from selected trenches for radiocarbon dating.

GEOMORPHIC SETTING

The Sulphur River drains from west and northwest to east and southeast across the northeastern

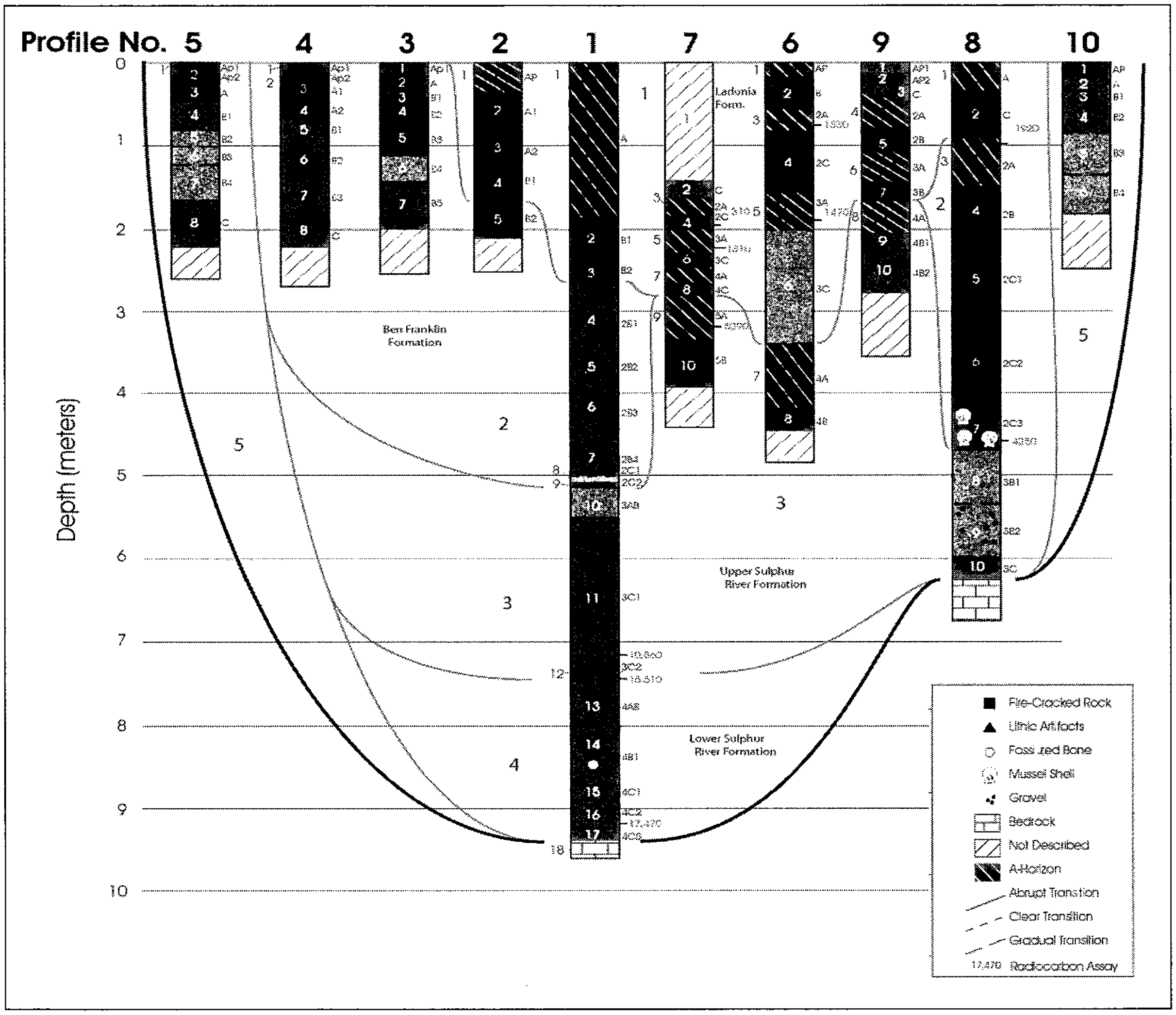


Figure 2. Cross-section of the North Sulphur River valley with geological units illustrated in Profiles 1-10.

portion of Texas south of the Red River. This is a gentle rolling hill-and-valley landscape that supports the northeastern tip of the Blackland Prairie and various woodlands. In 1929, the Texas Reclamation Department channelized the North Sulphur River in order to improve drainage for farming purposes. They straightened the original channel, which increased the speed of stream flow and stimulated rapid erosion of the river channel. The initial excavated channel was only 30 ft. wide and 12 ft. deep, but since 1929 dramatic erosion has expanded the channel to 30-40 ft. deep and 200 ft. wide (Figure 3). Today this is a remarkably straight and wide channel that is deeply eroded into bedrock, and exposes all the Quaternary deposits adjacent to the modern channel. The original stream meanders are visible on aerial photographs and topographic maps.

In Northeast Texas surface bedrock geology consists of southeast-dipping beds. This allows streams to erode laterally to form slip-off slopes and create asymmetrical valley profiles (Bousman et al. 1988: Figure 2). The surface expression of this erosional pattern results in long, gently sloping tributaries that drain into the North Sulphur from the northwest, and very short and steep tributaries that drain from the south (see Figure 1). The North Sulphur River floodplain is mapped as Quaternary alluvium (Qal) and this deposit is flanked by patches of Quaternary Terrace (Qt) deposits forming the valley walls (Shelby et al. 1966). The Ozan Formation is on both sides and underneath the Quaternary sediments. The Ozan Formation, consisting of easily eroded shales and marls, is an Upper Cretaceous deposit that dates to approximately 75-80 million years ago (McKinzie et al. 2001).

Figure 3. Photograph of North Sulphur River channel at Profile 1 looking upstream, May 2005.

These deposits have weathered to form a series of soils in the floodplain and valley walls (Goerdel 2002). On the surface of the floodplain and corresponding to the Qal deposits are dark clayey Tinn and Hopco soils. Wilson silt loam soils cap T1 and T2 terrace deposits on the north side and Benklin silt loam soils are found on T1 and T2 terraces on the south side of the channel. Normangee clay loam is found on older, more weathered, eroded terrace deposits, and can be used to identify the boundary between the T1 and T2 terraces. Upland soils on Cretaceous bedrock formations are mapped as Crockett loam and Ferris clay.

QUATERNARY SEDIMENTS AND SOIL STRATIGRAPHY

We identified five depositional units (numbered 1-5 from youngest to oldest) in the floodplain and terrace deposits on the North Sulphur River (Skinner et al. 2006). A schematic profile illustrates the stratigraphic relations between these units (see Figure 2). Correlations between profiles used the color and texture of sediment zones, the degree of soil development in the zones as indicated by structure, mottling, calcium carbonate accumulation and manganese formation, and the age of radiocarbon assays.

Unit 1

Unit 1 is mapped as the Qal deposit on the Bureau of Economic Geology Texarkana Sheet (Shelby et al. 1966) and it formed the pre-1929 T0 floodplain. Unit 1 sediments are found in Profiles 1-2, 6-8, and 9. These sediments are characterized by black to very dark grayish-brown clay loams, and a lack of evidence of advanced pedogenic development on the surface. Immediately west of Profile 1 these sediments grade into well-stratified channel fills that sit unconformably on eroded older sediments.

Two buried soils from this unit at Profile 6 (Zones 3 and 5) were dated. These produced radiocarbon assays of 1330 ± 80 B.P. (Beta-205704) in Zone 3 and 1470 ± 40 B.P. (Beta-206952) in Zone 5. The soils in Profile 6 are correlated to similar soils in Profile 9. In Profile 7, a single large piece of charcoal in the bottom of Zone 4 was dated to

310 ± 30 B.P. (Beta-205702) and a buried soil in Zone 5 was dated to 1310 ± 40 B.P. (Beta-206951). Based on the stratigraphic correlations, the assay in Zone 4 of Profile 7 is probably erroneous. It is possible that this is a root or somehow represents a too recent piece of charcoal, although no evidence of bioturbation was observed.

A comparison to previous radiocarbon dates from the Ben Franklin Formation (Rainey 1974) can be used to suggest that these current assays are contemporary in age. However, all but one of the previous samples used either mollusk shells or charcoal in gravels. These assays can be discounted because mollusk shells produce notoriously inaccurate radiocarbon assays and gravel deposits are not reliable stratigraphic contexts for radiocarbon dating. This leaves a single assay, 660 ± 70 B.P., providing an age estimate for the Ben Franklin Formation from Rainey's (1974) study, and this is younger than all but one of the assays from this current project in Depositional Unit 1.

Unit 2

Depositional Unit 2 sediments are present in Profiles 1-4, 8, and 9. These sediments reflect a series of surface soils, buried soils, overbank alluvium, pond or channel deposits, and gravel layers. The high amount of calcium carbonate in Zones 4 and 5 of Profile 1 indicates that this pedon is truncated by erosion. The bottom of this depositional unit is marked by gravel in Profile 1, Zone 9. The upper surface of Unit 2 forms the top of the T1 terrace. At Profile 3 this is only a few tens of centimeters higher than the T0 terrace surface.

Chronology is fixed by two radiocarbon assays in Profile 8. The youngest age estimate comes from a buried soil sample from Zone 3 in Profile 8. This sample produced an age estimate of 1920 ± 40 B.P. (Beta-206954). At the bottom of Unit 2, sediments in Profile 8 consist of a series of pond or channel deposits. The lowest zone contains a concentration of freshwater mussel shells and a few lithic artifacts which were recorded as site 41FN66. Organic-rich sediments from this zone were dated to 4250 ± 90 B.P. (Beta-205705). This is one of the oldest in situ sites recorded in Northeast Texas (Fields et al. 1993b; Bousman et al. 2004).

It is suggested here that the Unit 2 sediments correlate to the Ben Franklin Formation of Slaughter and Hoover (1963) and Rainey (1974). These are restricted to the T1 terrace deposits. We also suggest that our Unit 1 sediments, which comprise the T0 terrace deposits of the modern floodplain, be called the Ladonia Formation. These younger deposits date to the last 1500 years B.P. and are inset into the Unit 2 sediments.

Unit 3

These sediments are found in Profiles 1, 6-7, and 8. Buried soils cap this unit composed of overbank alluvium, and channel or pond sediments. The bottom of this unit in Profile 1, Zone 12, consists of gravel deposits. Two radiocarbon dates were obtained from this unit. A soil capping the top of Depositional Unit 3 in Zone 9 of Profile 7 was dated to 5290 ± 70 B.P. (Beta-205703), and the bottom of the deposition unit in Profile 1 was dated to 10,860 ± 140 B.P. (Beta-206953). These deposits can be correlated to the Upper Sulphur River Formation of Slaughter and Hoover (1963) and Rainey (1974). The lower radiocarbon dates reported by Slaughter and Hoover (1963) for the bottom of the Sulphur River Formation are similar to the older dates reported here. No surface exposures of this unit have been found in the valley.

Unit 4

Zones 13 through 17 in Profile 1 were the only recorded zones with sediments correlated to this unit (Figure 4). No surface exposures of this unit were discovered. These zones represent a truncated AB soil horizon with fine-grained loamy channel, pond, and gravel beds stratified below. All the deposits are well mottled and the degree of mottling helps distinguish Unit 4 from Unit 3. The top of this unit in the truncated soil was dated to 15,510 ± 120 B.P. (Beta-205701), and near the bottom this unit was dated to 17,470 ± 330 B.P. (Beta-205700). This unit can be correlated to the Lower Sulphur River Formation and these are the first radiocarbon dates for this formation.

Unit 5

Only Profile 5 and Profile 10 have sediments correlated to Unit 5. Both profiles were described from backhoe trenches excavated into the T2 terrace surfaces. Profile 5 is on the north side of the Sulphur River floodplain and Profile 10 is on the south side. Sediments in these profiles are highly weathered, very firm clays and are truncated by erosion.

Figure 4. Photo of Profile 1 showing Depositional Unit 3 and 4. Bottom of scale and trowel (910-925 cm bs) mark the location of Beta-205700, lowest radiocarbon sample, extracted from Zone 16. Gravels in Zone 17 are below the scale. Above the trowel at 733-753 cm bs is a visible rectangular radiocarbon sample location where Beta-205701 was extracted from the top of Depositional Unit 4 (Zone 11). Between 711-721 cm bs, Beta-206953 was collected from the bottom of Depositional Unit 3.

ASSOCIATED ARCHEOLOGICAL MATERIALS

Adjacent to Profile 1 and on the eroded sloping surface of Unit 4 sediments, a quartzite core/chopper was collected a few m east on the eroded profile face at 758 cm below the upper surface of the terrace deposit (bs) (Figure 5). West of the profile and on the eroded profile face of the sedimentary unit, we recovered a broken flake at 854 cm bs (Figure 6) and nearby we collected a fossilized bone with visible linear striations that we believed might be cut marks at 847 cm bs (Figure 7). The depths of artifacts were measured at the same time as the profile sedimentary/soil zone boundaries with a total station electronic transit. These materials were recorded as site 41FN73. We found no artifacts in situ, but we did not see any artifacts above Depositional Unit 4 on or adjacent to the profile.

These materials might, and we underline might, represent a Late Pleistocene pre-Clovis occupation, but recovery of in situ artifacts and features within an uncontestable geological context is necessary before an occupation of this age could be confirmed. This material does not present that type of evidence. The lithic artifacts are completely non-diagnostic in terms of technology and style, and could have been produced by any prehistoric knappers. In regards to the fossil bone, Dr. Eileen Johnson graciously inspected the fossil bone and on February 21, 2007 said: "I was able to look at the modifications using the SEM [scanning electron microscope]. The modifications are natural. The bone is very weathered and eroded. Several carnivore tooth pits occur on both sides. The distinct lines on both sides are trample marks. No cultural marks occur." Thus, no clear cultural modifications are visible on the surface of the bone. Even though this does not exclude humans as the agents of discard, it does not provide any form of viable evidence of human involvement either.

DISCUSSION AND CONCLUSIONS

Geoarcheological research has provided a better chronological scheme for Quaternary alluvial deposits in the upper reaches of the North Sulphur

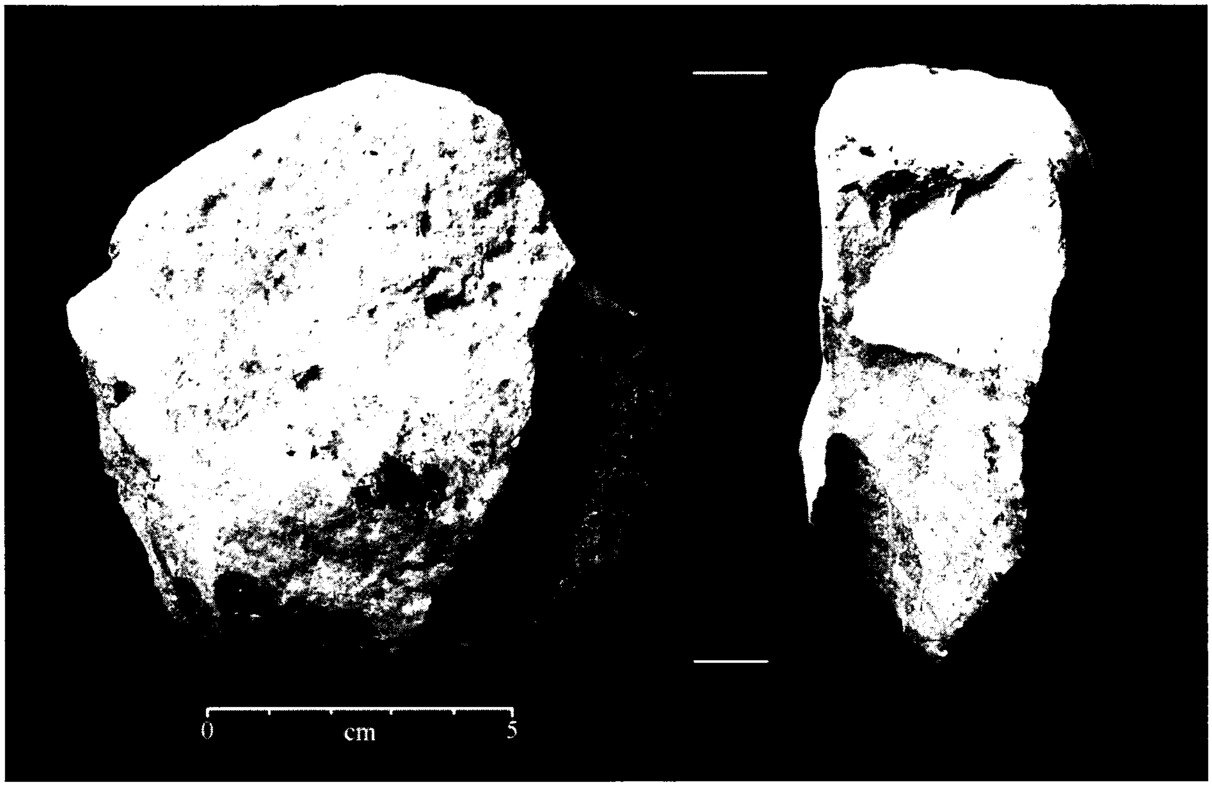


Figure 5. Quartzite core collected from the Profile 1 surface.

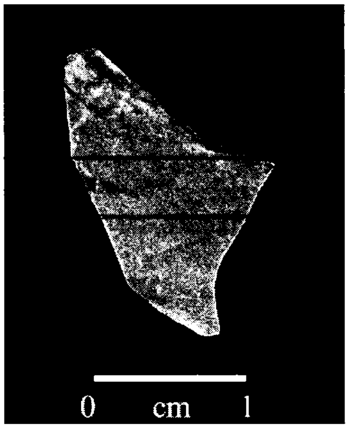


Figure 6. Small quartzite flake collected from the Profile 1 surface.

River valley. This work can be reasonably correlated to the Upper Sulphur River and Ben Franklin formations identified by earlier research down stream and can be shown to span much of the last 17,000 years. Five depositional units were defined (see Figure 2) and archeological materials were discovered in situ in mid Holocene-aged deposits and on the eroded surfaces of Late Pleistocene-aged deposits.

Depositional Unit 4 is documented only in Profile 1 and preliminary observations indicate that this unit is limited to the downstream portion of the proposed reservoir. This depositional unit is correlated to the Lower Sulphur River Formation as originally defined by Slaughter and Hoover (1963) and more fully characterized by Rainey (1974). We obtained radiocarbon dates ranging between about 17.5-15.5 kya. These are the first published radiocarbon dates for the Lower Sulphur River Formation and these assays demonstrate that these deposits date to the period immediately following the Last Glacial Maximum of the Wisconsin glacial period. Upper Sulphur River Formation sediments were dated to the time span between 10.8 kya and 5.3 kya and are mostly of Holocene age.

Lithic artifacts and a fossilized bone were found on the eroded surface of the Lower Sulphur River Formation deposits and might represent an early human occupation in the valley. Recent research at Clovis sites in Texas clearly illustrates the technological approaches of Clovis knappers (Collins 1999) and it is obvious that the very limited number of artifacts recovered on the surface of 41FN73

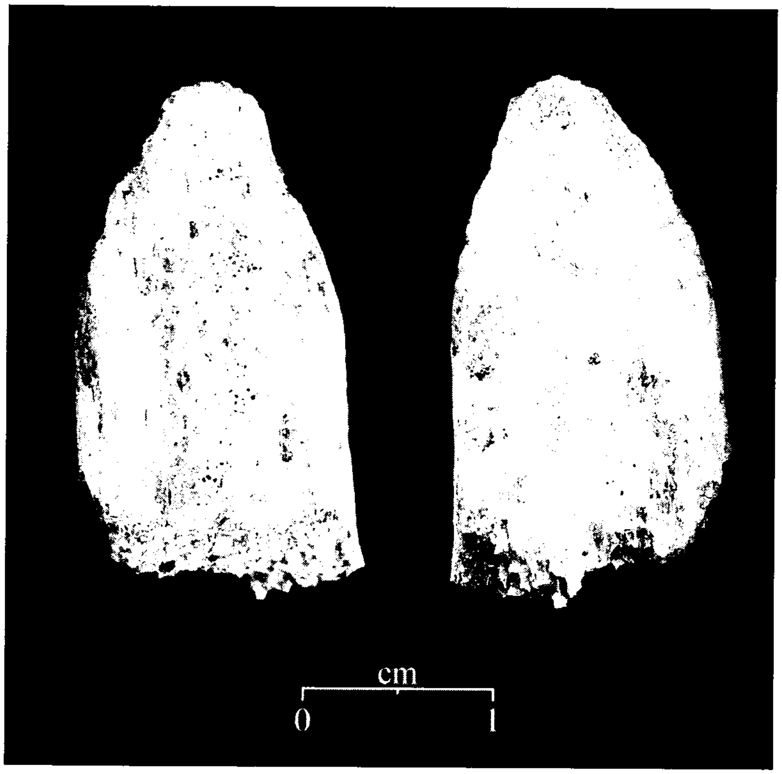


Figure 7. Fossilized bone collected from the Profile 1 surface.

are not particularly diagnostic of the Clovis method(s) of stone tool manufacture. No tools were found that would have further aided in the chronological placement of these artifacts. This lack of diagnostic evidence, in and of itself, does not indicate a pre-Clovis age for these materials, however. Artifacts recovered from uncontestable in situ and well-dated geological contexts are needed before a pre-Clovis occupation can be convincingly demonstrated. At present we do not have this evidence. More research is needed to further characterize and fully date the accumulation of sediments in the Sulphur River Valley, and search for in situ artifacts and features.

If pre-Clovis sites are present in Texas and surrounding areas then geoarcheological methods which target Late Pleistocene deposits older than 11,050 B.P. (Waters and Stafford 2007) should be integrated with archeological surveys in a systematic fashion. Careful inspection of these deposits has the potential to provide the evidence needed to confirm or reject the notion of preserved human habitations before the Clovis period in and peripheral to the Southern Plains.

REFERENCES CITED

Abbott, J.
2001 *Houston area geoarcheology, a framework for archeological investigation, interpretation, and culture resource management in the Houston Highway District.* Archeological Studies Program Report 27. Environmental Affairs Division, Texas Department of Transportation, Austin.

Blum, M. D. and S. Valastro, Jr.
1994 Late Quaternary sedimentation, lower Colorado River, Gulf Coastal Plain of Texas. *Geological Society of America Bulletin* 106:1002-1016.

Bousman, C. B.
1990 Geomorphic investigations. In *Excavations at the Finley Fan Site, 41HP159, Hopkins County, Texas,* by E. F. Gadus, R. C. Fields, C. B. Bousman, S. A. Tomka, and M. A. Howard, pp. 25-35. Reports of Investigations No. 78. Prewitt and Associates, Inc., Austin.

1998 Paleoenvironmental change in Central Texas: the palynological evidence. *Plains Anthropologist* 43:201-219.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian archeology in Texas. In: *The Prehistory of Texas*, edited by T. K. Perttula, pp 15-97. Texas A&M University Press, College Station.

Bousman, C. B., M. B. Collins, and T. K Perttula
1988 *Quaternary geomorphology at Cooper Basin: a framework for archeological inquiry, Delta and Hopkins counties, Texas.* Reports of Investigations No. 55. Prewitt and Associates, Inc., Austin.

Cheatum, E. P. and D. Allen
1963 An ecological comparison of the Ben Franklin and Clear Creek local molluscan faunas in Texas. *Journal of Graduate Research Center* 31(3):174-179.

Collins, M. B.

1976 Terminal Pleistocene Cultural Adaptations in Southern Texas. In *Pretirage, Colloque XVII, Habitats Humains Anterieurs a L'Holocene en Amerique*, edited by J. B. Griffen. Union Internationale des Sciences Prehistoriques et Protohistoriques, IXe Congres, Nice, France.

1994 Cueva Quebrada Shelter, Texas. *Current Research in the Pleistocene* 11:26-28.

1999 *Clovis blade technology*. University of Texas Press, Austin.

Darwin, R. L., C. R. Ferring, and B. B. Ellwood

1990 Geoelectric Stratigraphy and Subsurface Evaluation of Quaternary Stream Sediments at the the Cooper Basin, NE Texas. *Geoarchaeology* 5(1):53-79.

Doering, J. A.

1963 Correlations of the Sulphur River Formation. *Journal of Graduate Research Center* 31(3):149-157.

Ferring, C.R.

1993 Late Quaternary Geology of the Upper Trinity River Basin, Texas. Ph.D. Dissertation, University of Texas at Dallas.

Fields, R. C., E. F. Gadus, L. W. Klement, C. B. Bousman, and J. B. McLerran

1993a *Excavations at the Tick, Spike, Johns Creek and Peerless Bottoms sites, Cooper Lake project, Delta and Hopkins counties, Texas*. Reports of Investigations No. 91. Prewitt and Associates, Inc., Austin.

Fields, R. C., S.A. Tomka and T. K. Perttula

1993b Hunter-gatherer mobility in Northeast Texas, 10,000-200 B.C. In *Archeology in the Eastern Planning Region, Texas: a Planning Document*, edited by N. A. Kenmotsu and T. K. Perttula, pp. 69-95. Cultural Resource Management Report 3. Department of Antiquities Protection, Texas Historical Commission, Austin.

Frye, J. C. and A. B. Leonard

1963 *Pleistocene geology of the Red River basin in Texas*. Report of Investigations 49. Bureau of Economic Geology, The University of Texas at Austin.

Gadus, E. F., R. C. Fields, L. W. Klement, C. B. Bousman, M. A. Howard, and K. M. Gardner

1991 *Testing, revisitation, and evaluation of selected sites at Cooper Lake, Delta and Hopkins counties, Texas. Texas*. Reports of Investigations No. 81. Prewitt and Associates, Inc., Austin.

Goerdel, A. R.

2002 *Soil survey of Fannin County, Texas*. Natural Resources Conservation Service, United States Department of Agriculture, Washington, D.C.

Holliday, V. T.

1997 *Paleoindian Geoarchaeology of the Southern High Plains*. University of Texas Press, Austin

Holman, J. A.

1963 Late Pleistocene amphibians and reptiles of the Clear Creek and Ben Franklin local faunas of Texas. *Journal of Graduate Research Center* 31(3):152-167.

McKinzie, M. G., R. Morin, and E. Swiatovy

2001 *Fossil collector's guide to the North Sulphur River*. Occasional Papers Volume 4. Dallas Paleontological Society, Dallas.

Rainey, M.

1974 The Quaternary stratigraphy of the North Sulphur River. Master's Thesis. Southern Methodist University, Dallas.

Reineck, H.-E. and I. B. Singh

1975 *Depositional sedimentary environments*. Springer-Verlag, Berlin.

Schlichtling, H. E.

1963 Charophytes of Pleistocene age from Delta and Denton counties, Texas. *Journal of Graduate Research Center* 31(3):180-181.

Shelby, C. A., M. K. Pieper, D. E. Owen, T. J. Freeman, A. C. Wright, and V. E. Barnes.

1966 *Geological Atlas of Texas, Texarkana Sheet*. Bureau of Economic Geology, The University of Texas at Austin.

Skinner, S. A., C. B. Bousman, N. Plumb, A. P. Wilson, J. Todd, and T. Jennings

2006 *Archaeology and Quaternary Geology at Lake Ralph Hall, Fannin County, Texas*. Cultural Resources Report 2005-31. AR Consultants, Inc., Dallas.

Slaughter, R. and R. Hoover

1963 Sulphur River Formation and the Pleistocene mammals of the Ben Franklin Local Fauna. *Journal of Graduate Research Center* 31(3):132-148.

1965 An antler artifact from the Late Pleistocene of northeastern Texas. *American Antiquity* 30:351-352.

Soil Survey Staff

1993 *Soil Survey Manual*. U. S. Department of Agriculture Handbook Number 18. U.S. Government Printing Press, Washington, D.C.

Ueyeno, T.

1963 Late Pleistocene fishes of the Clear Creek and Ben Franklin local faunas of Texas. *Journal of Graduate Research Center* 31(3):168-173.

Waters, M. R. and T. W. Stafford, Jr.

2007 Redefining the age of Clovis: implications for the peopling of the Americas. *Science* 315:1122-1126.

The Geoarcheology of the McNeill Ranch Site: Implications for Paleoindian Studies of the Gulf Coastal Plain of Texas

Michael J. Aiuvalasit

ABSTRACT

Excavations at the McNeill Ranch site (41VT141) found prehistoric artifacts, including Late Paleoindian components, preserved in a Deweyville terrace. Deweyville terraces date to the Late Pleistocene, yet archeological materials are being recovered from the upper portions of these terraces across the Gulf Coastal Plain of Texas. Detailed stratigraphic studies at the McNeill Ranch site, combined with data from other localities, indicate there is the potential for the preservation of archeological deposits in Deweyville terraces. These archeological deposits were buried during the Holocene by localized eolian and colluvial deposition. The results of this study demonstrate that Deweyville terraces provide opportunities to investigate Paleoindian occupations in a region where Paleoindian sites are not readily preserved or are hard to access due to submersion by sea level change during the Holocene, exposure on stable upland settings, and burial by deep Holocene alluvial sequences.

INTRODUCTION

This study uses geoarcheological methods to understand the stratigraphy and site formation processes at the McNeill Ranch site (41VT141). The site is located on a Deweyville terrace of the Guadalupe River in the Gulf Coastal Plain of Texas. Two research problems are addressed in this geoarcheological investigation. First, archeological materials are being recovered in the upper portions of Deweyville terraces, which are widely understood to be middle Late Pleistocene in age and therefore should not contain archeological materials. In his geoarcheological study of the Houston area, Abbott (2001) addresses the archeological potential of Deweyville terraces. His study of the regional geoarcheology found that although these terraces are too old to contain archeological deposits, there are examples of Holocene deposits mantling the older core of Deweyville terraces; however, his work does not present a model for the depositional processes acting on these terraces. The second research problem pertaining to the site concerns the recovery of Late Paleoindian components in a region where few studies of site formation processes of early archeological components exist. The latest synthesis of Paleoindian archeology in Texas found no comprehensively excavated or systematically reported Paleoindian sites on the Coastal Plain (Bousman et al. 2004:34). The Paleoindian artifacts that have been found on the Coastal Plain typically come from surficial finds or disturbed contexts. The lack of Paleoindian archeological sites is largely due to the submersion of coastal occupations by post-glacial sea level rise and the limited potential for site preservation across the older stable surfaces of the uplands (Ricklis and Blum 1995; Ricklis and Weinstein 2005).

The McNeill Ranch site proved to be a good locality to study depositional processes of Deweyville terraces and site formation processes of Late Paleoindian components because the investigation had access to the entire terrace, the uplands, and the Holocene floodplain adjacent to the site. This allowed for the reconstruction of cross sections through the site and the terrace. These cross sections, combined with granulometric studies and optically stimulated luminescence dating (OSL), facilitated a reconstruction of site stratigraphy. The results found that there is potential for burial and preservation of archeological components in Holocene deposits that mantle the older Deweyville terraces. A model of site formation by localized eolian deposition developed by researchers for terraces in the northeastern United States is applied to the McNeill Ranch site. The findings suggest that the site formed through localized eolian deposition and colluvial reworking of the Holocene mantle and Deweyville terrace deposits. This article concludes with an evaluation of the archeological potential of Deweyville terraces and the implications for this research for regional Paleoindian studies.

SITE SETTING

The McNeill Ranch site is located approximately 15 km to the northwest of the city of Victoria on the slope (scarp) and surface (tread) of a Deweyville terrace on the Guadalupe River (Figure 1). Deweyville terraces are a generalized geologic name for terrace deposits on the Gulf Coastal Plain that occupy positions in a valley cross-section between Early to Middle Pleistocene uplands and Holocene alluvial deposits. These terraces are typically found within 100 km of the modern coastline and are easily identified by their large arcuate relict meanders cut into older valley margins. Deweyville terraces were deposited during the middle Late Pleistocene (Isotope Stage 3) (Figure 2) (Blum et al. 1995). Paleoclimate models of this glacial period indicate there were frequent but moderate storms that led to discharges into fluvial systems greater than current levels. This caused the large arcuate meander scars on the margins of the valleys that define Deweyville terraces. Sediments are thick channel belt sands with few overbank mud deposits that commonly have a paleosol bounding the top of the deposits (Blum et al. 1995). In a study of the lower Nueces River, Durbin et al. (1997:122) dated the three periods of Deweyville terrace aggradation, classified as: High Deweyville 60–47 ka, Middle Deweyville 43–40 ka, and Low Deweyville 35–31 ka.

The Last Glacial Maximum (LGM) of the Late Pleistocene occurred at approximately 20,000 years ago, and had a tremendous impact on the landscape and environment. Moisture was sequestered by glaciers on a global scale, which caused sea level to be dramatically lower than the current level. Along the Gulf of Mexico, shorelines dropped to the mid-shelf and edge of the continental shelf, approximately 200 to 300 km from the modern shoreline (Blum and Tornqvist 2000). This drop in sea level caused the base level of drainage basins to drop, and rivers responded by downcutting their valleys. This created the Deweyville terraces. Localized erosion would have occurred on the terraces as well, which would have gullied the surfaces. These erosive actions are evidenced at the McNeill Ranch site by an infilled paleo-gully and stripped paleosols.

Following the end of the Pleistocene, the Holocene interglacial period has been marked by a transgression of sea level, warmer temperatures, and a change to precipitation influenced by tropical moisture from the Gulf of Mexico. The rising sea level lowered stream gradients, which caused the drainages to accommodate or "back up" sediments as muddy overbank deposits in the floodplain during the Late Pleistocene, reversing the processes of valley incision that occurred during the LGM. However, the increase in tropical moisture has caused flashy stream discharge with some channel incision (Blum and Tornqvist 2000:33; Abbott 2001:99; Brown 2006). Aggradation of alluvium has led to the burial of Low Deweyville terraces by the Holocene floodplain. This is particularly evident in the lower reaches of the drainages, and the Johnson-Heller (Birmingham and Hester 1976) and Berger Bluff sites (Brown 2006) are examples of archeological locales found in deep Holocene alluvium.

The McNeill Ranch site is located on an unpaired Deweyville terrace of the Guadalupe River (Figure 3). The surface of the terrace is between 26 and 34 m above sea level on the northern margin of the valley, 5 m below the middle Pleistocene uplands of the Lissie and Beaumont Formation, and approximately 7 m above the modern floodplain. The area of the terrace is 0.5 km^2 and it exhibits the arcuate valley margin incision typical of other Deweyville localities. The site is found along the terrace margin with archeological materials present on both the tread and scarp of the terrace (Figure 4). The terrace tread is a relatively level and open field with gentle, low mound topography that never rises more than 0.5 m above the present ground surface. Very few artifacts were observed on the tread; archeological materials are concentrated on the southeastern portion of the terrace. The terrace scarp is variable in shape and slope across the terrace. At the western side of the site, the terrace slope is convex and steep; in the southeastern portion of the site, the slope is concave and gradual.

Archeological investigations at the site consisted of salvage and test excavations by Texas Historical Commission (THC) Stewards, bioarcheological investigations (Taylor 2005), a university field school, and a geoarcheological investigation (Aiuvalasit 2006). Braun (2006) reports the background of the site's discovery in 2003,

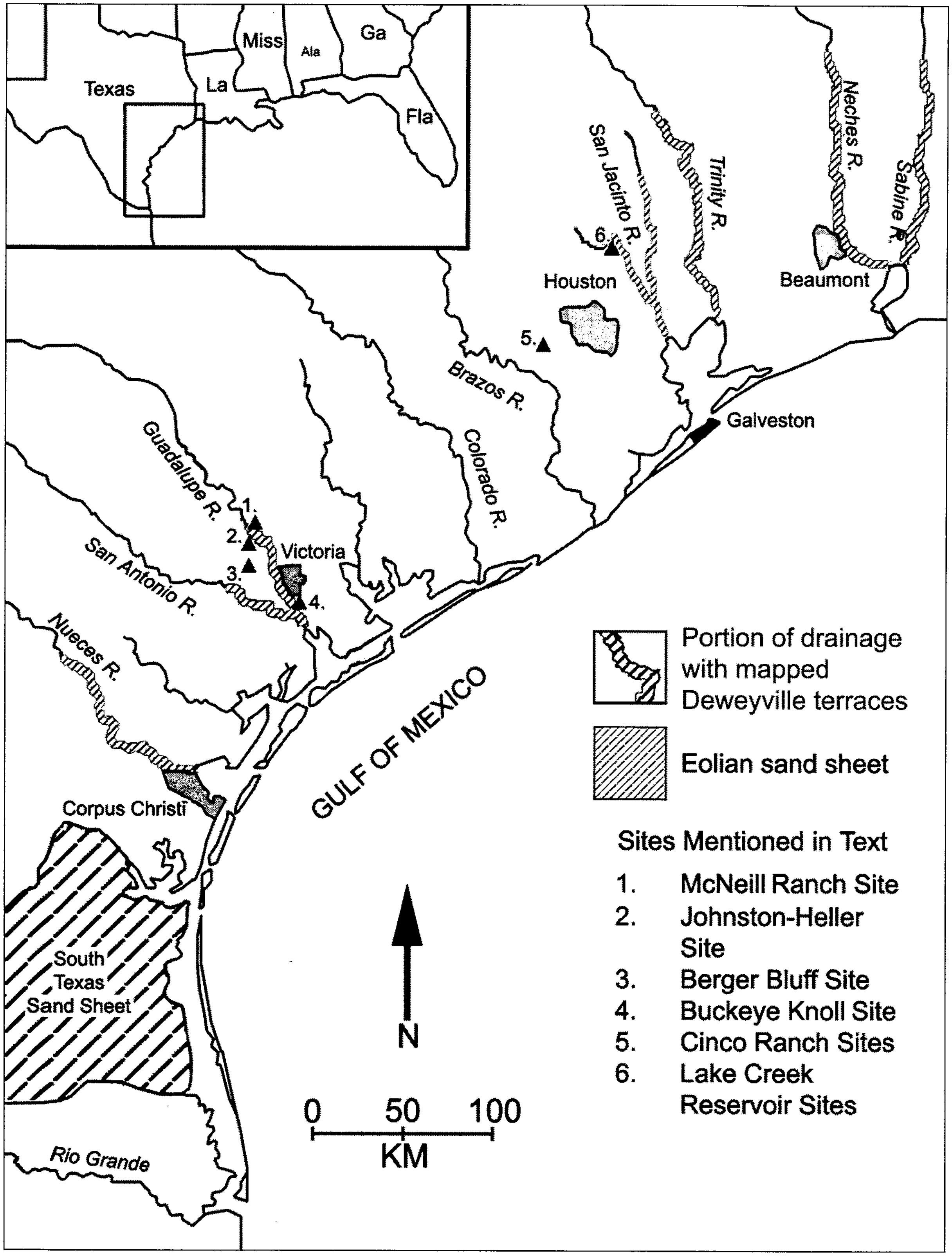


Figure 1. Sites and geologic features mentioned in text, based on Ricklis (2004) and Barnes (1992).

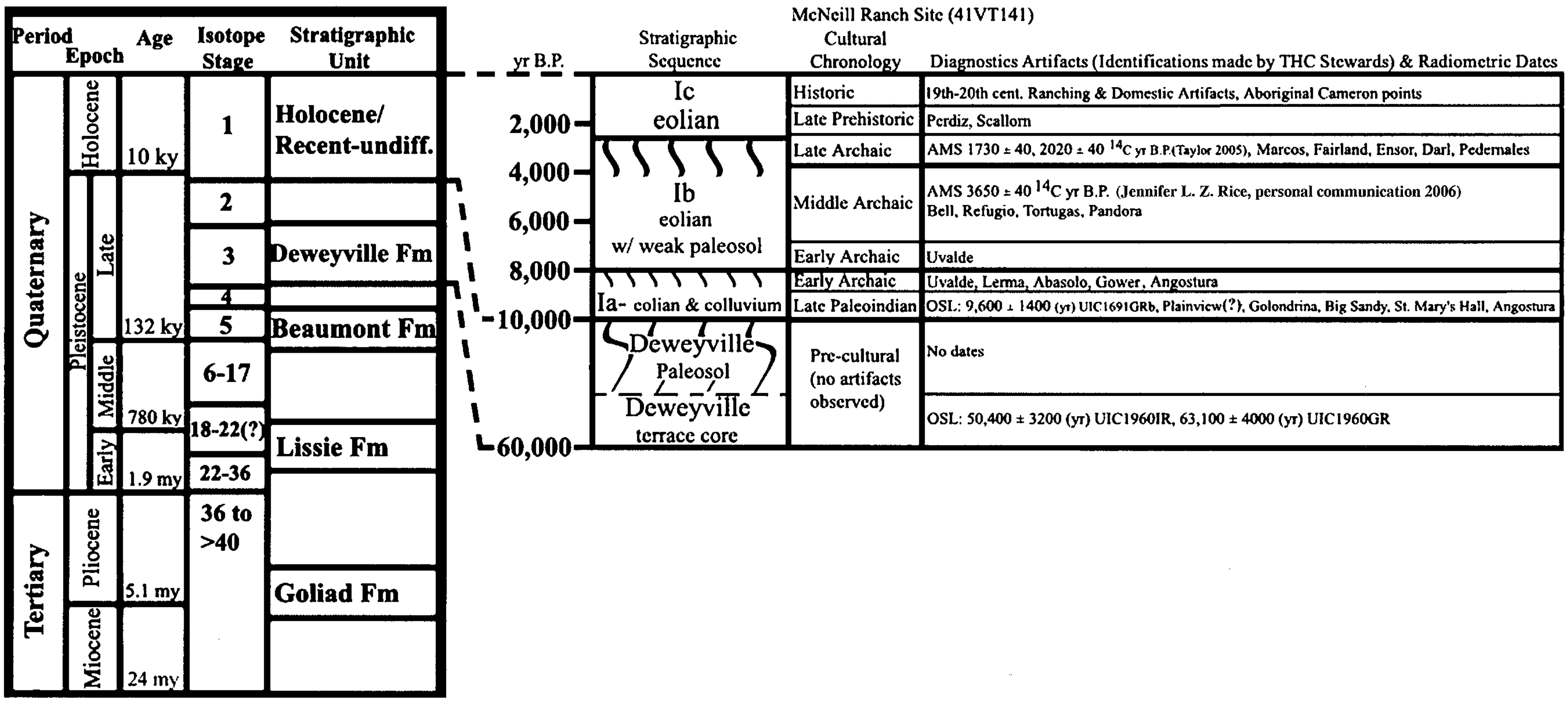


Figure 2. Geologic and archeological timescale (based on Durbin et al. 1997:Figure 1; Perttula 2004; Turner and Hester 1993).

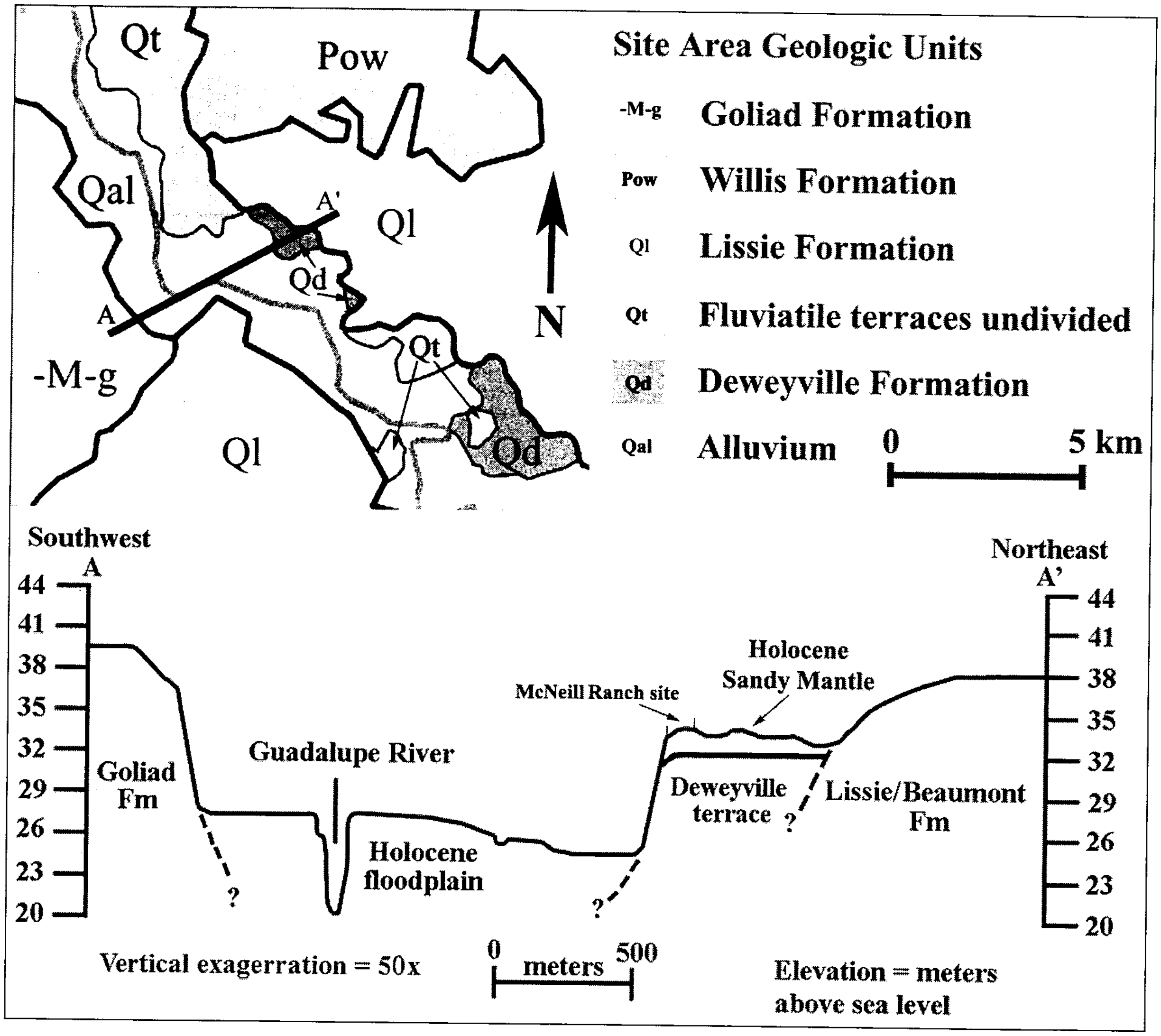


Figure 3. Guadalupe valley cross section.

subsequent salvage excavations, and educational presentations by THC Stewards and volunteers. Geoarcheological field investigations consisted of the following: profile descriptions of test units excavated by THC Stewards and borrow pit exposures; 10 cores with the assistance of local NRCS soil scientists Wesley Miller and Amanda Bragg; 50 hand augers to a depth of up to 3 m each; and 4 test pits excavated by backhoe. The fieldwork was complimented by granulometric studies of the particle size distribution of sediments and soils processed in the Soils Characterization Lab at Texas A&M University, College Station, as well as OSL dating of sediments by Steve Forman of the University of Illinois at Chicago (Aiuvalasit 2006). The artifact typology used in this article derives from identifications made by the THC Stewards.

STRATIGRAPHY

The generalized stratigraphy of the site consists of three deposits. The first are Pleistocene fluvial deposits of the Deweyville terrace core, followed by a truncated, variously present paleosol capping the fluvial deposits here named the *Deweyville Paleosol*, and three Holocene units (Ia-Ic) containing archeological materials mantling either the Deweyville Paleosol or exposed portions of the terrace core (Figure 5).

Deweyville terrace core

The deposits of the terrace core are bedded light yellowish-brown sands to gravelly sands of a fluvial origin. Particle size analysis of six samples

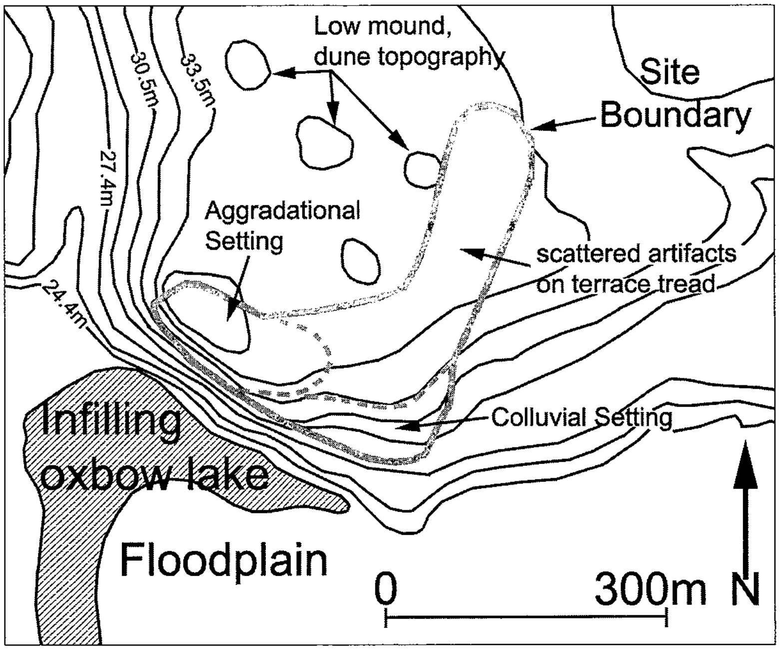


Figure 4. McNeill Ranch site map.

of the terrace core sediments from three exposures averaged to a slightly gravelly (1.3%) sand with 91.3% of the fraction consisting of sand. Observed gravels range from small pebbles to medium cobbles, and the sand size fraction (0.0625-2.0 mm) is moderately sorted fine skewed medium sand. Because the deposits lacked organics suitable for radiocarbon dating the sediments were dated directly using OSL (Table 1). Two splits from one sample from the terrace core were analyzed using multiple aliquots and both infrared and green light excitation methods. The two multiple aliquot samples produced finite ages with errors reported to 1 sigma. The infrared excited sample dated to 50,400 ± 3200 years ago (UIC1960IR), and the green light excited sample dated to 63,100 ± 4000 years ago (UIC1960GR). Although finite ages from the same sample are over 12,000 years apart, they do overlap at the 2 sigma range. These dates provide a generalized age of the terrace core, which correlates to the Durbin et al. (1997) "High Deweyville" dates of 60-47 ka for a Pleistocene deposition of Deweyville terraces.

Deweyville Paleosol

The Deweyville Paleosol caps the core of the Deweyville terrace. The polygenetic paleosol varies in thickness from 0.75 to 1.75 m and has been truncated with no associated epipedon. The paleosol has been completely eroded in some portions of the site, particularly in the southeastern portion of the terrace and in a small area of the central portion of the terrace that may represent a paleo-gully. In locations where the paleosol has been eroded, Holocene sediments lie unconformably atop the

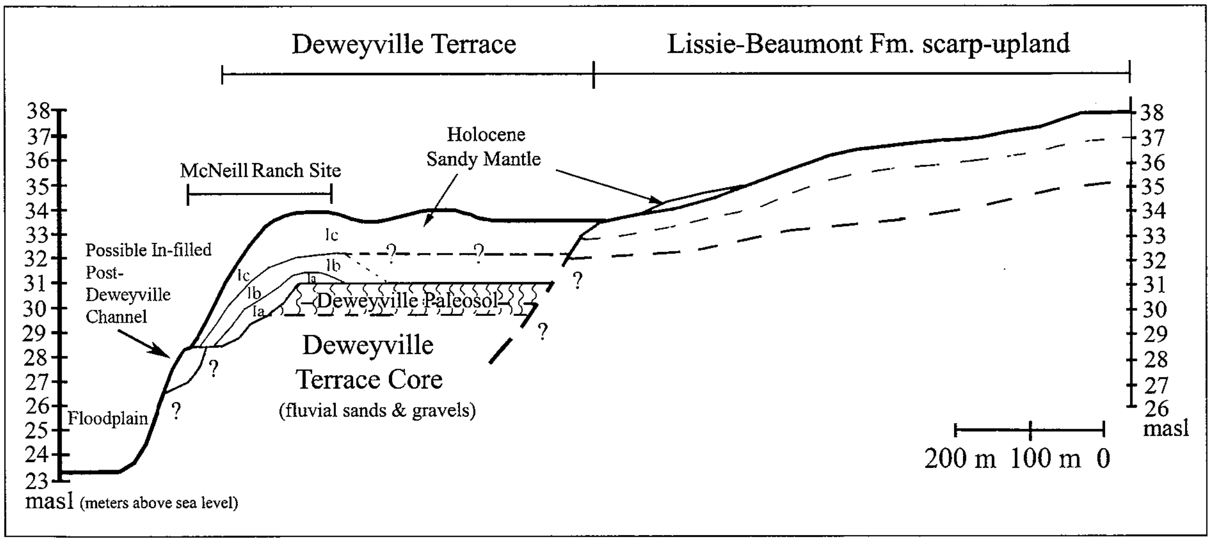


Figure 5. Generalized profile of Deweyville terrace.

Table 1. OSL dates.

Laboratory Number	Fraction (µm)	Equivalent dose (Gray)	U (ppm)[d]	Th (%)[d]	$K_2$0 (%)[d]	Cosmic dose (mGray/yr)[e]	Moisture content (%)	Dose rate (mGray/yr)	OSL age (yr)[f]
UIC1690IR[a]	150-250	88.43±0.51	1.3±0.1	3.7±0.1	1.12±0.01	0.14±0.014	5±2	1.72±0.07	50,400±3200
UIC1690GR[b]	150-250	110.66±0.42	1.3±0.1	3.7±0.1	1.12±0.01	0.14±0.014	5±2	1.72±0.07	63,100±4000
UIC1691GRb[c]	150-250	14.35±1.87	1.3±0.1	3.7±0.1	0.95±0.01	0.18±0.018	5±2	1.48±0.06	9600±1400

[a] Equivalent dose and associated OSL age determined by the multiple aliquot regeneration protocols under infrared excitation (880 nm) (Jain et al. 2003).

[b] Equivalent dose and associated OSL age determined by the multiple aliquot regeneration protocols under green excitation (470 nm) (Jain et al. 2003).

[c] Equivalent dose and associated OSL age determined by the multiple aliquot regeneration protocols under green excitation (470 nm) (Jain et al. 2003). with a residual correction for partial solar resetting (Pierson and Forman, unpublished data).

[d] U, Th, and K20 content analyzed by inductively coupled plasma-mass spectrometry analyzed by Activation Laboratory LTD, Ontario, Canada.

[e] From Prescott and Hutton (1994).

[f] All errors are at 1 sigma and are finite analyses. Analyses by Luminescence Dating Research Laboratory, Dept. of Earth and Environmental Sciences, University of Illinois at Chicago (http://www.uic.edu/labs/ldrl).

fluvial deposits of the Deweyville terrace core (Figure 6). The upper meter of the paleosol is an argillic dark gray sandy clay loam to clay loam with distinct common red iron (Fe) redox mottles and a strong coarse blocky subangular structure. The iron redox mottles are associated with seasonal wetting and drying, which is actively occurring as water flows through the mantle of well-drained fine sands until it reaches the impediment of the argillic paleosol. The average particle size distribution of the paleosol is 60.6% sand, 12.5% silt, and 26.9% clay. In four exposures below the upper argillic portion of the soil there is a lower calcic horizon of dark gray sandy clay loam with common, distinct calcium carbonate nodules. One exposure lacked the calcic horizon, and instead strong, well developed wavy clay lamellae formed up to a depth of 1.4 m into the fluvial deposits of the Deweyville terrace core. The thickness of the paleosol, lack of artifacts, well-developed redox features, calcic horizon, and the age of the sandy parent material indicate that the Deweyville Paleosol is a buried soil and not a soil formed solely by illuvial processes during the Holocene.

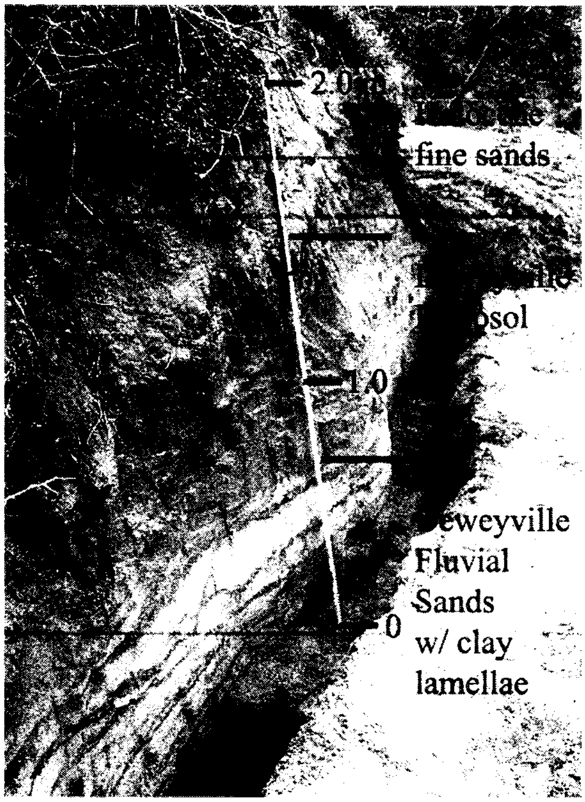


Figure 6. Basic stratigraphic sequence.

Holocene Units

There are three Holocene units (named Ia-Ic) mantling the Deweyville terrace. These sediments were deposited by colluvial and eolian mechanisms and have since undergone post-depositional processes such as pedogenesis, erosion, and bioturbation. Evidence of bioturbation in the form of root stains and infilled rodent burrows are found throughout the Holocene deposits. These features contributed to the obliteration of bedding structures; however, intact human burials, small hearth features, and diagnostic artifacts in stratigraphic sequence indicate that bioturbation has not completely compromised the integrity of the Holocene deposits. Although this suite of post-depositional processes created a complex stratigraphy, it was possible to correlate the deposits across the site. The intra-site stratigraphy can be divided into two settings: a primarily aggradational setting with limited soil development on the western edge of the site, and a colluvial setting with stronger soil development on the southeastern portion of the site (see Figure 4).

Aggradational Setting

Atop the terrace tread three Holocene deposits (Ia-c) of fine sands mantle the Deweyville Paleosol (Figure 7). The deposits are up to 2 m thick and contain a sequence of buried A horizons and a weak illuvial horizon formed in the basal portion of the deposits.

Unit Ia is an approximately 80 cm thick deposit immediately above the Deweyville Paleosol and it is only found in this area where it fills a low depression near the terrace edge. There is a weak remnant buried A-horizon of dark grayish-brown loamy fine sand at the top of Ia that is underlain by a weak illuvial sequence that welds with the underlying Deweyville Paleosol. Artifact concentrations are the highest in the 3Ab and 3AB horizons and then decrease significantly with depth. Diagnostic artifacts from Ia include Angostura, Golondrina, Big Sandy, Lerma, Hoxie, and Abasolo dart points, all of which date the deposits to the Late Paleoindian/Early Archaic.

Unit Ib is an approximately 60 cm thick buried cumulic 2Ab horizon that continues filling the terrace edge depression and mantles a greater portion of the terrace tread. The horizon is dark gray fine sand with a weak coarse blocky subangular structure. Diagnostic artifacts include Clear Fork gouge tools, and

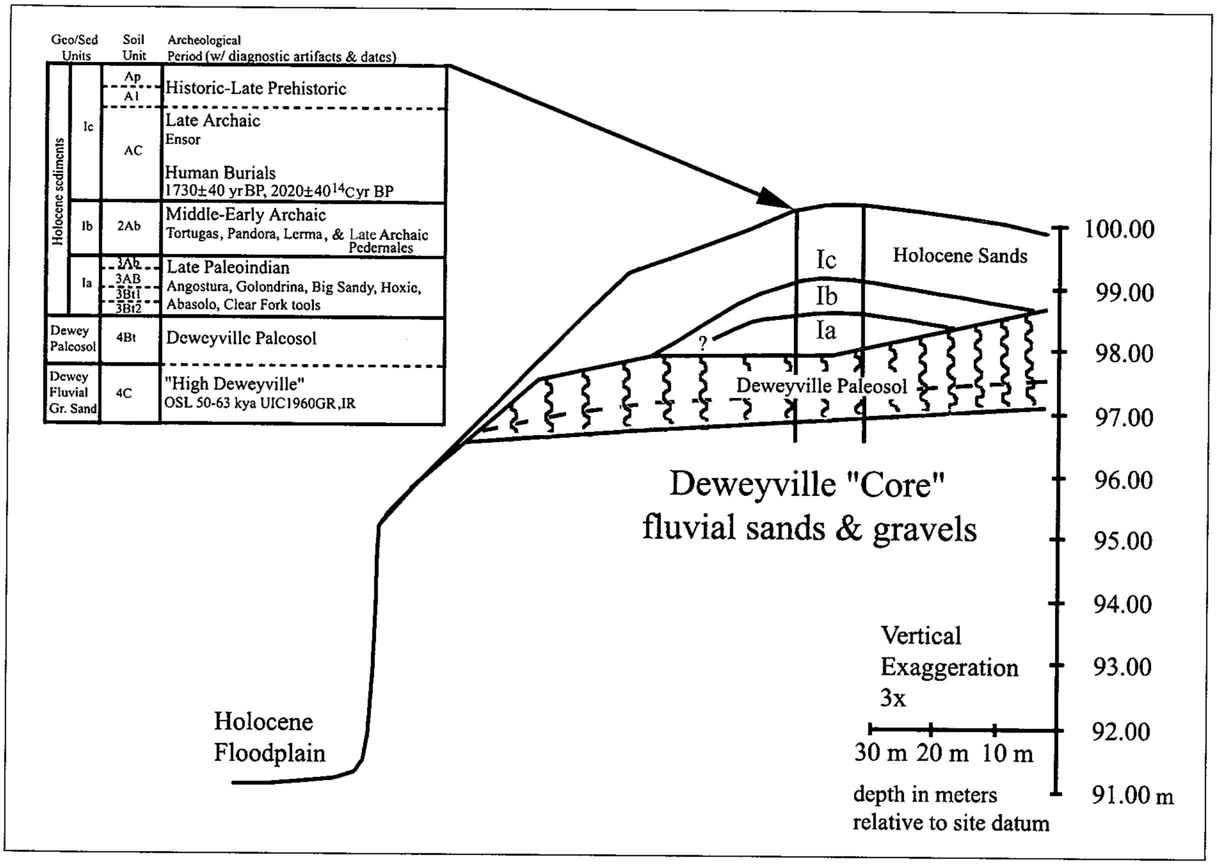


Figure 7. Aggradational area profile.

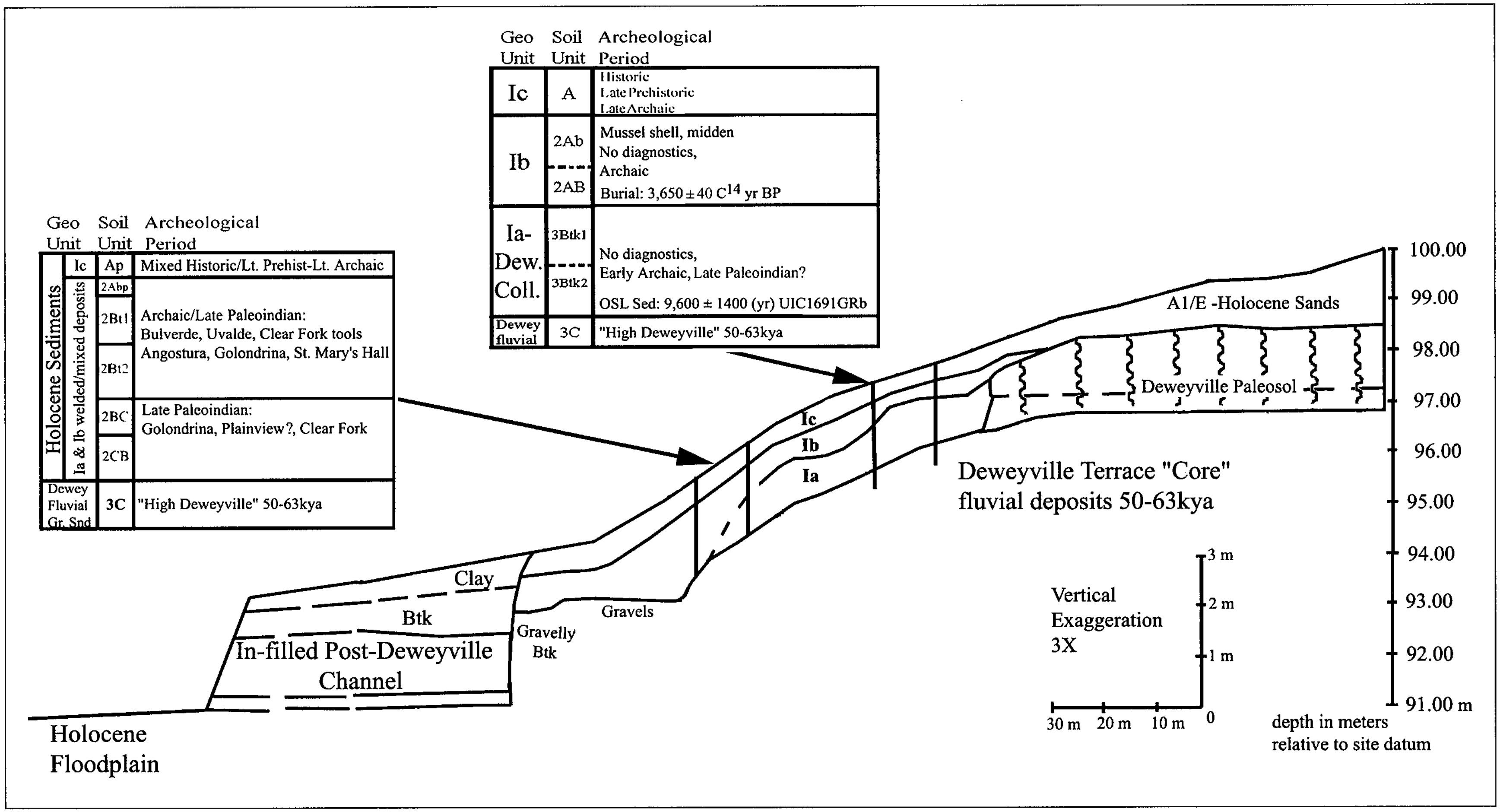
Pandora, Tortugas, and Pedernales dart points. These artifacts date the deposits to the Middle to Late Archaic. Late Archaic burials intrude into the top of these deposits, presumably from Ic components.

Holocene Unit Ic is approximately 110 cm thick and is a mollic epipedon. The soil stratigraphy of the unit is an Ap-A1-AC sequence. The sediments within the site are very dark gray loamy fine sand. These deposits appear to mantle the entire terrace tread, but compared to the sediments within the site along the terrace scarp, the sediments across the terrace tread are lighter colored brown fine sands with distinct E/Bt horizon clay lamellae, and the artifact content decreases dramatically. The archeological materials within Unit Ic contain Historic, Late Prehistoric, and Late Archaic diagnostic artifacts. Historic and Late Prehistoric artifacts are found in the upper 60 cm, while Late Archaic artifacts extend from 60 cm below surface to the base of the unit. There is greater preservation of bone and charcoal in this horizon. Prehistoric human remains were recovered in this unit and in burials excavated into the lower Ib horizon.

Colluvial Setting

The southeastern portion of the terrace shows the same general Holocene sequence described above, but in this area of the terrace the argillic portion of the Deweyville Paleosol is completely eroded away, creating an unconformable contact between Holocene deposits and fluvial sands of the Deweyville terrace core down the slope of the terrace (Figure 8). The surface of the terrace is approximately 2-3 m lower in elevation than the aggradational setting to the west. The Holocene deposits are up to 1.75 m thick upslope thinning to approximately 1 m thick downslope.

Unit Ia shows variation in depositional history and soil development between upslope and down slope portions. On the upslope portion of the site, Unit Ia is a distinct unit of colluvium that experienced calcic and argillic soil formation, although the calcic attributes may be inherited from the eroded calcic portion of the Deweyville Paleosol. The soil formation gradually decreases with depth and there is an indistinct boundary with the sands of the Deweyville core. There are occasional lithic



Geo Unit		Soil Unit	Archeological Period
Holocene Sediments	Ic	Ap	Mixed Historic/Lt. Prehist-Lt. Archaic
	Ia & Ib welded/mixed deposits	2Abp 2Bt1 2Bt2	Archaic/Late Paleoindian: Bulverde, Uvalde, Clear Fork tools Angostura, Golondrina, St. Mary's Hall
		2BC 2CB	Late Paleoindian: Golondrina, Plainview?, Clear Fork
Dewey Fluvial Gr. Snd		3C	"High Deweyville" 50-63kya

Geo Unit	Soil Unit	Archeological Period
Ic	A	Historic Late Prehistoric Late Archaic
Ib	2Ab 2AB	Mussel shell, midden No diagnostics, Archaic Burial: 3,650 ± 40 C^{14} yr BP
Ia-Dew. Coll.	3Btk1 3Btk2	No diagnostics, Early Archaic, Late Paleoindian? OSL Sed: 9,600 ± 1400 (yr) UIC1691GRb
Dewey fluvial	3C	"High Deweyville" 50-63kya

Figure 8. Colluvial area profile.

artifacts, including one Clear Fork gouge tool, but no diagnostic artifacts were observed in the profile exposure. The lithic artifacts had a white to grayish patina, and numerous unidentified snail and freshwater mussel shells were observed towards the top of the unit. These deposits dated to 9,600 ± 1400 years ago (UIC1691GRb) using OSL dating. The sample was dated using green light excitation, with a residual correction for partial solar resetting. Considering the additional steps necessary to obtain this date, as well as the rather large error of 1400 years at the 1 sigma range, it should be viewed as a generalized age for these deposits until additional dating and excavation are undertaken. The down slope portion of Unit Ia is welded with Unit Ib and has experienced argillic soil formation. Excavations by THC Stewards at this downslope location recovered numerous Late Paleoindian and Early Archaic artifacts, including Angostura, Golondrina, St. Mary's Hall, and a dart point with some characteristics of Plainview. However, considering the poorly understood nature of Plainview (Bousman et al. 2004) a final designation has yet to be assigned to this one point. Observations of displaced and upturned artifacts, Late Paleoindian and Archaic artifacts mixed together at the Ia/Ib contact, and the lack of identifiable features suggest a lack of integrity in these downslope components.

Holocene Unit Ib is a buried paleosol of fine sandy loam that is found across the site. This unit mantles Holocene Unit Ia on the upslope portion of the colluvial slope. The unit is texturally similar to other deposits across the site, except from the down slope portion that has welded with Unit Ia. Prehistoric lithic artifacts are very common in this horizon, as are broken snail and freshwater mussel shells. No diagnostic artifacts were observed in the upslope profile, but Uvalde and Bulverde dart points found downslope in Unit Ib facilitate the broad correlation of this deposit to the Early to Middle Archaic.

Holocene Unit Ic is very dark grayish-brown loamy fine sand that thickens towards the terrace tread. Few prehistoric artifacts were observed in this unit, which is quite notable given that abundant prehistoric artifacts were found in this unit at other parts of the site. No diagnostics were observed, but similarities in sediment characteristics and the orientation of the deposit on the terrace tread and slope allow correlations to the better dated Late Archaic-Historic deposits of the western portions of the site.

SITE FORMATION MODEL

Evidence from site stratigraphy, site context, and the application of a site formation model suggest that the McNeill Ranch site formed primarily through eolian sedimentation through the Holocene. The site setting matches a model for eolian deposition on bluff tops presented by Thorson and Tryon (2003). Their model explains settings where sands containing stratified archeological deposits mantle high Pleistocene terraces in the northeastern United States. In this model, under certain conditions terraces become both sources of eolian material and places where eolian sands are deposited (Table 2). Their model uses hydraulic modeling of wind patterns to show that eolian sediments derived from floodplain exposures of sand and entrained or saltating sediments derived from exposures along the terrace scarp can be deposited on the terrace tread. Wind flow velocity increases when wind encounters the obstacles of the terrace. Due to

Table 2. Criteria for Thorson and Tryon's (2003) model of terrace edge retreat and burial of archeological components by windblown sediments.

1. Site is located on a terrace facing the dominant wind direction, and is above the flood level of a major river.
2. The bluff face fronting the site could have been destabilized by episodes of fluvial bank erosion.
3. Fine-grained sediment suitable for entrainment is widely available.
4. Holocene eolian deposits are widespread in the area.
5. Sediment texture and structures are consistent with eolian origin and the alternative of colluvial transport is precluded by low slope of the terrace tread.

turbulence caused by vegetation atop the terrace the velocity rapidly drops as it crosses the terrace (Figure 9). The eolian deposits drop to the terrace tread, burying archeological materials and mantling older surfaces. This process also leads to the erosion of the terrace scarp, which in turn leads to the retreat of the bluff face, potentially damaging archeological components along the slope.

The McNeill Ranch site compares favorably to the model of eolian bluff top site formation. The site is on a terrace at the northern end of the valley, which is 3 km wide from north to south. The setting gives the dominantly south to southeastern winds (TCEQ 2006) the longest fetch across the valley to increase velocity and entrain sediments before encountering the "obstacle" of the Deweyville terrace. The dominance of south to southeastern winds is primarily due to diurnal "sea breeze" patterns associated with the coastline. Although it is not possible to project wind conditions back through the Holocene, shoreline progradation (Ricklis and Blum 1995), and the establishment of warm waters responsible for tropical weather systems in the Gulf during the Early to Middle Holocene (Aharon 2003; Brown 2006), suggest that weather patterns similar to modern conditions would have been present by the Middle Holocene. Another consideration of the site setting is the elevation of the terrace relative to flood levels. According to the McNeill family, the terrace is above the flood level as observed in the summer of 1998 during the flood of record. There is currently no active bluff face destabilization by fluvial erosion, but the topographic expression of the relict oxbow on the floodplain adjacent to the site indicates that the channel of the Guadalupe River was once adjacent to the terrace. This would have eroded the terrace scarp, exposing sands of the Deweyville terrace core that could be entrained by eolian processes and deposited on the terrace tread. The sandy point bars and levees of a nearby channel could also have served as additional sand sources entrained by eolian processes.

Eolian deposits on the Coastal Plain are typically localized occurrences, but are found across the region. Eolian deposits of the South Texas Sand Sheet and prairie mounds across the Coastal Plain in Southeast Texas indicate that conditions in the past and the present are conducive to localized eolian transport. Otvos (2004) applied the luminescence dating method to a series of prairie mound dunes across the Texas Coastal Plain and found that the majority date to the Late Holocene. Archeological sites found buried in prairie mounds include the Cinco Ranch sites in Fort Bend County (Ensor 1987). Pedological and geoarcheological investigations of the depositional context of these prairie mound sites suggest that these features formed through eolian sedimentation (Holliday 1987). None of these deposits mantle Deweyville terraces as at the McNeill Ranch site, but the results show that during at least the Late Holocene conditions were suitable for eolian deposition across the region.

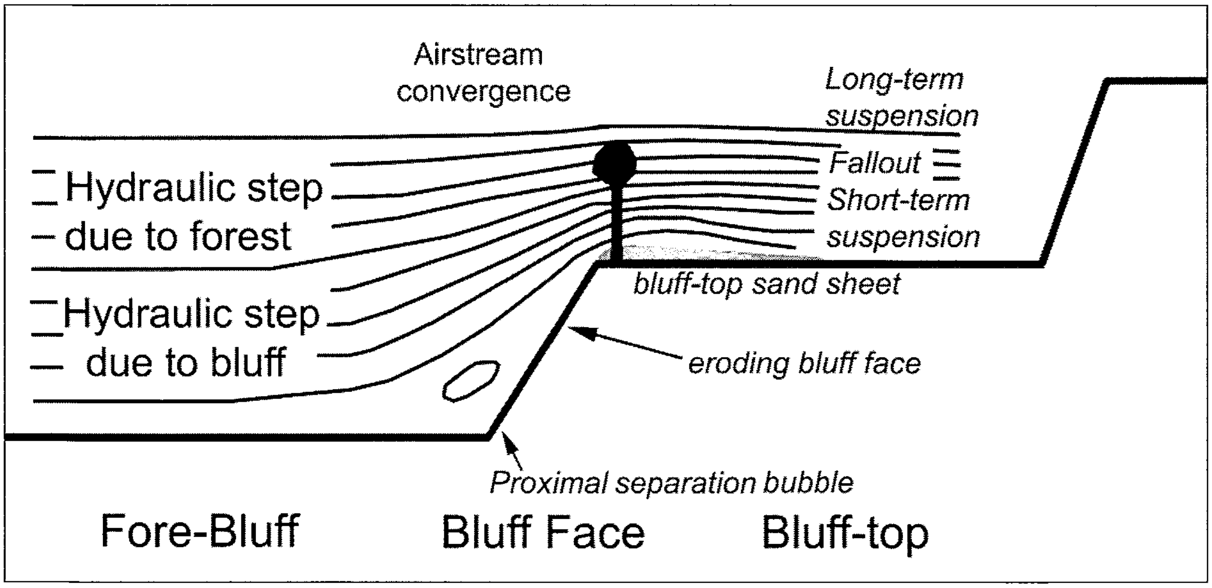


Figure 9. Depositional model of bluff-top sand sheets, based on Thorson and Tryon (2003:Figures 5.2 and 5.3).

Examples of eolian sands mantling Deweyville terraces were noted by Durbin and Sanders (2001) in their study of the Holocene stratigraphy of the lower Nueces River, and by Mandel (1987) in his study of the West Branch of the San Jacinto River in Montgomery County. Durbin and Sanders (2001) found limited eolian deposits that dated to 960 yrs B.P. above older Deweyville terraces while Mandel (1987) recorded numerous instances of eolian sands mantling Deweyville terraces. In microscopic studies of grain characteristics, Mandel found features of the sand grains that, along with field observations, suggested that eolian deposits mantled Deweyville terraces. The Buckeye Knoll site is an example of a site with probable eolian origins mantling a Deweyville terrace. Preliminary geoarcheological results have found Holocene sandy deposits unconformably mantling older Deweyville deposits, with stratigraphy and archeological components similar to the McNeill Ranch site (Frederick and Bateman 2004).

Another line of evidence for an eolian depositional mechanism at the McNeill Ranch site comes from attributes of the sediments mantling the Deweyville terrace. The sediment particle size of the sandy mantle is distinctly different from the known fluvial deposits of the underlying Deweyville sediments and modern overbank deposits of the Guadalupe River. A comparison of fine to coarse sand fractions shows that the samples from the sandy mantle are better sorted, finer in texture size, and are uniform in their sand fraction distribution. Samples from the Deweyville sands and the Guadalupe River overbank deposits are not as well sorted, and are slightly coarser textured (Figure 10). The terrace top deposits also meet attributes common for eolian sands presented by Leigh (2001) in his study of site formation in sandy sediments. Sediments commonly considered to be deposited by eolian processes are approximately 90% sand, lack any coarse (>2 mm) fragments or coarse sands (1-2 mm), and have a Phi coefficient of variance of the sand fraction less than 55%. Three samples of the sandy mantle all meet the criteria for eolian sands, except for a total percentage of sands just below 90% in two samples (Table 3). The final line of evidence suggesting an eolian origin is the uniform character of the sandy mantle deposits. A cumulative profile of the Holocene deposits shows that the only

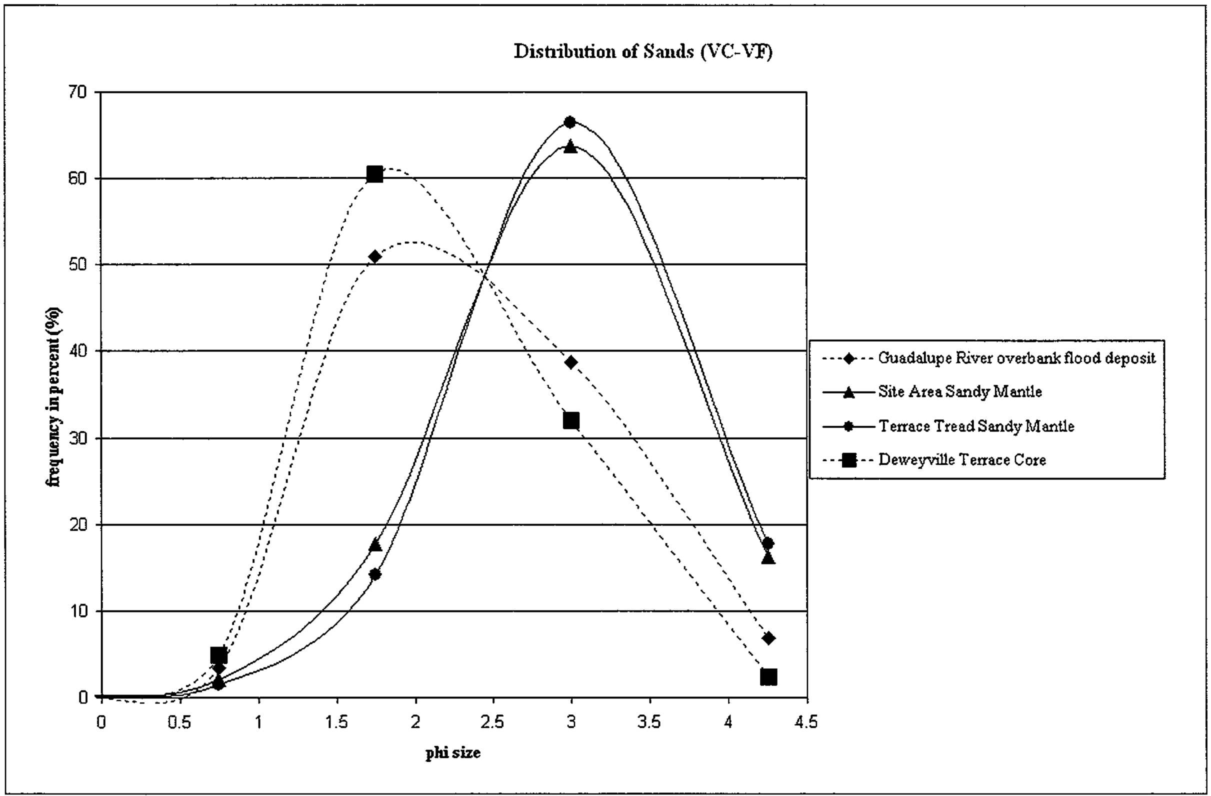


Figure 10. Comparison of sand fraction particle size distributions between sandy mantle deposits and known fluvial deposits.

Table 3. Particle size distribution of sandy mantle deposits.

		Particle Size Distribution (mm)									
		Sand						Silt		Clay	
Location	Coarse Fragments %	Very Coarse (2.0-1.0)	Coarse (1.0- 0.5)	Medium (0.5- 0.25)	Fine (0.25- 0.10)	Very Fine (0.10-0.05)	Total (2.0- 0.05)	Fine ·(0.02- 0.002)	Total (0.05- 0.002)	Fine (<0.0002)	Total (<0.002)
Terrace tread	0	0.1	1.2	12.8	62.3	16.6	93.0	total silt & clay = 7			
Southeast colluvial slope	0	0.4	3.3	22.0	45.0	12.6	83.3	total silt & clay = 16.7			
Western edge of site/ aggradational	0	0.2	1.9	17.0	56.6	12.7	88.4	2.5	5.0	3.9	6.6

variation in sediment texture down profile is the illuvial horizon that forms at the bottom of Holocene Unit Ia (Figure 11). This trend was mirrored in exposures across the terrace, and when combined with the other evidence, suggests an eolian origin as opposed to fluvial deposition. The reason is that fluvial deposits typically have greater variability in sorting and grain size associated with the more complex and changing depositional environments of fluvial systems. Unfortunately, bioturbation has obliterated any bedding structures in the Holocene sediments that would help determine the depositional origins.

The results of the geoarcheological investigations coupled with the application of the bluff-top site formation model allows for a scenario of site formation at the McNeill Ranch site. The Deweyville terrace stopped aggrading and began to develop a soil shortly after 60,000 years ago. The change in base level associated with sea level drop of the Late Glacial led to downcutting and erosion of the Deweyville surface, which created the terrace. Surficial erosion also impacted the Deweyville surface. These actions, which occurred before the Holocene, truncated the surface of the terrace and created topographic depressions and gullies that exposed the calcic portion of the Deweyville Paleosol and the underlying sandy fluvial deposits. This would have eroded archeological components from the Late Pleistocene and potentially explains the lack of Folsom, Clovis and potentially pre-Clovis archeological materials at the site.

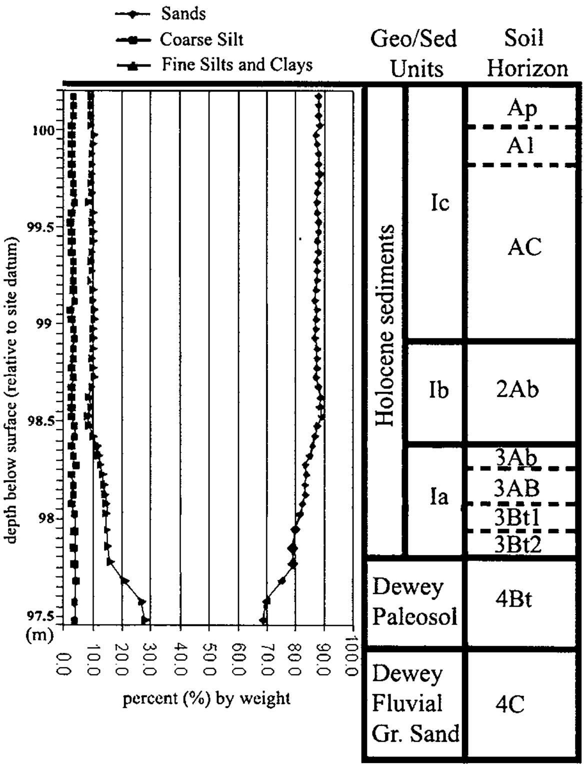


Figure 11. Cumulative particle size distribution profile.

The truncated Deweyville Paleosol became the occupation surface for prehistoric peoples between approximately 10,000-8,000 B.P. People using Late Paleoindian and Early Archaic projectile points occupied the slopes of the Deweyville terrace, primarily on the southeastern portion atop the colluvial slope of the exposed calcic paleosol, and atop the relatively minimally eroded paleosol further upslope on the central portion of the terrace. Numerous gouge tools in these early portions of the site suggest woodworking activities, likely using local riparian wood sources.

During this occupation of the colluvial slope on the southeast portion of the terrace, an eolian sandy mantle began aggrading on the terrace tread (Unit Ia), filling low surfaces along the margins of the terrace with fine sand. It is uncertain how much sand was deposited across the terrace tread because diagnostic artifacts and OSL samples only came from along the terrace edge, although initial deposits would be found first along the terrace edge in accordance with the model of eolian deposition. Late Paleoindian and Early Archaic peoples occupied this portion of the terrace as well. A weak paleosol (3Ab) developed atop the fine sands of these deposits on the central portion of the terrace. The Holocene soil formation of Unit Ia did not form on the southeastern side of the terrace, but instead the sedimentation continued into the Archaic where Uvalde and Bulverde dart points are found mixed with the earlier Late Paleoindian/ Early Archaic dart points.

A thicker eolian sand deposit of Unit Ib continued filling low-lying portions along the terrace edge and possibly mantled the entire tread of the Deweyville terrace. This thicker sand deposit contains artifacts from the Early Archaic to the very beginning of the Late Archaic. During the period from ca. 5,000 to 2,500 B.P., the region experienced conditions drier than modern, which may have facilitated eolian deposition atop the terrace tread (Toomey et al. 1993). Fine sands on the southeastern edge of the terrace continued aggrading with the continuation of prehistoric occupation. The earliest dated aboriginal burial is found in this deposit. Freshwater mussel and snail shells appear in the site matrix, which suggests close proximity to a channel that could support beds of mussels. The interpretation of a nearby channel also implies that fluvial sands were adjacent to the terrace. These could have served as source material for eolian deposits atop the terrace. There are fewer mussel shells in the western portion of the site, and by this time the paleo-gully at the central portion of the aggradational area of the site had nearly completely filled to the level of the terrace tread.

At the end of the Middle Archaic a paleosol formed at the top of the fine sand deposits of Unit Ib across the aggradational portion of the site, as well as in colluvial areas on the southeastern edge of the site. This paleosol is mollic and has a more strongly developed soil structure. There was enough stability on the southeastern edge of the site for a weak illuvial horizon to form in the lower portions of the Early Archaic/Late Paleoindian deposits.

From ca. 3,000 B.P. to the present, sedimentation continued across the tread and the scarp. During this period of aggradation Unit Ic covered the entire surface of the terrace with thick sand deposits aggrading atop the terrace, but only a relatively thin deposit of sand mantling the southeastern portion of the terrace. In the thicker portions of the sand deposit pedogenic clay lamellae developed that can be traced from the edge of the terrace onto the terrace tread. This depositional unit has the greatest concentration of prehistoric artifacts, prehistoric human remains, and a distinct anthropogenic midden of darker sediments, although their highest concentrations are in the western portions of the site.

IMPLICATIONS FOR PALEOINDIAN STUDIES

The results of this geoarcheological study have implications for Paleoindian studies in Texas. The work at the McNeill Ranch site shows that it is possible to identify Late Paleoindian archeological deposits and materials in sediments mantling Deweyville terraces. However, the contextual setting of the terrace has a significant impact on the potential for the preservation and integrity of these archeological materials. Eolian sedimentation as seen at the McNeill Ranch site, the Buckeye Knoll site, and in regional geomorphic studies has the potential to preserve archeological materials, including Late Pleistocene/Early Holocene components and deposits. Colluvial slopes of Deweyville terraces can preserve Paleoindian components as well, but with a greater likelihood for mixed components. Alluvial deposits atop these terraces have a greater potential to preserve archeological materials through rapid burial, but it appears that the mapped Deweyville terraces are too high for extensive flooding. Closer to the modern coastline, named terraces and buried low Deweyville terraces mapped as Holocene alluvium have the potential for buried archeological sites. The processes of embayment and marsh formation, however, complicate the testing and preservation of some archeological components.

Deweyville terraces should also be considered for their position in the landscape relative to resources critical to hunter-gatherers. These terraces provide an intermediate position on the landscape between upland resources and floodplain resources. These intermediate locations on the Deweyville terrace would have been optimal locations for base camps, as seen at the McNeill Ranch site. The diverse tool assemblages found in all prehistoric components at the site suggest repeated occupations over at least nine millennia.

While these terraces do provide opportunities to explore Paleoindian archeological components, this research shows there is the potential for post-depositional processes to impact site integrity. In cases where the rate of deposition does not exceed the effects of post-depositional processes, the archeological record will be impacted. Compressed archeological sequences, bioturbation, and mixed colluvial deposits on erosional slopes are all problems associated with sandy mantle deposits, and there is evidence for these processes impacting the archeology of the McNeill Ranch site. Although sites on Deweyville terraces may be easier to locate and contain greater numbers of archeological materials than deeply buried, short-term Paleoindian components in Holocene floodplains, the setting has the potential to hinder the interpretative value of sites in these settings. Future researchers will have to rigorously evaluate the context of sites situated on Deweyville terraces, and apply innovative techniques, such as subsurface imaging and chemical and micromorphological studies, to these sites. Efforts such as these may increase the interpretative potential of archeological materials, and in particular Paleoindian components, in a region with few well excavated Paleoindian sites.

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REFERENCES CITED

Abbott, J. T.
2001 *Houston Area Geoarcheology.* Archeological Studies Program Report No. 27. Environmental Affairs Division, Texas Department of Transportation, Austin.

Aharon, P.
2003 Meltwater Flooding Events in the Gulf of Mexico Revisited: Implications for Rapid Climate Changes During the Last Deglaciation. *Paleoceanography* 18(4): 3-1 to 3-13.

Aiuvalasit, M. J.
2006 Geoarchaeological Investigations at the McNeill-Gonzales Site (41VT141), Victoria County, Texas. Masters Thesis, Department of Anthropology, Texas A&M University, College Station.

Barnes, V. R.
1992 *Geologic Map of Texas.* Bureau of Economic Geology, The University of Texas at Austin.

Birmingham, W. W. and T. R. Hester
1976 Late Pleistocene Archaeological Remains from the Johnston-Heller Site, Texas Coastal Plain. In *Papers on Paleo-Indian Archaeology in Texas,* edited by T. R. Hester, pp. 15-33. Special Report No. 3. Center for Archaeological Research, The University of Texas at San Antonio.

Blum, M. A., R. A. Morton, and J. M. Durbin
2000 'Deweyville' Terraces and Deposits of the Texas Gulf Coastal Plain. *Transactions of the Gulf Coast Association of Geological Societies* 45:53-60.

Blum, M. A. and T. E. Tornqvist
2000 Fluvial Responses to Climate and Sea-level Change: A Review and Look Forward. *Sedimentology* 47 (Supplement 1):2-48.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas,* edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Braun, P.
2006 Turning the 41VT141 Salvage Site into a Unique Research and Educational Resource. *Current Archeology in Texas* 8(1):17-19.

Brown, K. M.
2006 The Bench Deposits at Berger Bluff: Early Holocene-Late Pleistocene Depositional and Climatic History. Ph.D. dissertation, Department of Anthropology, The University of Texas at Austin.

Durbin, J. M.
1999 Geomorphic Responses to Late Quaternary Climate and Sea-Level Change, Lower Nueces River, Texas. Ph.D. dissertation, Department of Geosciences, University of Nebraska, Lincoln.

Durbin, J. M., M. D. Blum, and D. M. Price
1997 Late Pleistocene Stratigraphy of the Lower Nueces River, Corpus Christi, Texas: Glacio-eustatic Influences on Valley-fill Architecture. *Transactions of the Gulf Coast Association of Geological Societies* 47:119–127.

Durbin, J. M. and K. Sanders
2001 Holocene Stratigraphy and Geomorphology of the Lower Nueces River Valley. *Geological Society of America North-Central Meeting, Abstracts* (35): 23.

Ensor, H. B.
1987 *The Cinco Ranch Sites, Barker Reservoir, Fort Bend County, Texas.* Reports of Investigations No. 3. Archeological Research Laboratory, Texas A&M University, College Station.

Frederick, C. D. and M. D. Bateman
2004 Geoarchaeological Investigations at 41VT98, Part 1. Report submitted by Sheffield Centre for International Drylands Research to Coastal Environmental Resources, Inc., Corpus Christi, Texas.

Holliday, V. T.
1987 Observations on the stratigraphy and origin of the Cinco Ranch Mounds. In *The Cinco Ranch Sites, Barker Reservoir, Fort Bend County, Texas,* by H. B. Ensor, pp. 275-280. Reports of Investigations No. 3. Archeological Research Laboratory, Texas A&M University, College Station.

Jain, M., L. Botter-Jensen, and A. K. Singhvi
2003 Dose Evaluation Using Multiple-aliquot Quartz OSL: A Test of Methods and a New Protocol for Improved Accuracy and Precision. *Radiation Measurements* 37:67-80.

Leigh, D. S.
2001 Artifacts in Sandy Soils. In *Earth Sciences and Archaeology,* edited by P. Goldberg, V. T. Holliday,

and C. R. Ferring, pp. 269-296. Kluwer Academic/Plenum, New York.

Mandel, R. D.
1987 Geomorphological Investigations. In *Buried in the Bottoms: The Archeology of Lake Creek Reservoir, Montgomery County, Texas,* by L. C. Bement, R. D. Mandel, J. F. De le Teja, D. K. Utley, and S. A. Turpin, pp. 4-1 to 4-41. Research Report 97. Texas Archeological Survey, The University of Texas at Austin.

Otvos, E. G.
2004 Prospects for Interregional Correlations Using Wisconsonian and Holocene Aridity Episodes, Northern Gulf of Mexico Coastal Plain. *Quaternary Research* 61:105-118.

2005 Numerical Chronology of Pleistocene Coastal Plain and Valley Development; Extensive Aggradation during Glacial Low Sea-Levels. *Quaternary International* 135:91–113.

Prescott, J. R. and J. T. Hutton
1994 Cosmic Ray Contributions to Dose Rates for Luminescence and ESR Dating: Large Depths and Long-term Time Variations. *Radiation Measurements* 23:497-500.

Perttula, T. K.
2004 An Introduction to Texas Prehistoric Archeology. In *The Prehistory of Texas*, edited by T.K. Perttula, pp. 5-14. Texas A&M University Press, College Station.

Ricklis, R. A.
2004 Prehistoric Occupation of the Central and Lower Texas Coast. In *The Prehistory of Texas,* edited by T. K. Perttula, pp. 155-180. Texas A&M University Press, College Station.

Ricklis, R. A. and M. D. Blum
1995 The Geoarchaeological Record of Holocene Sea Level Change and Human Occupation of the Texas Gulf Coast. *Geoarchaeology* 12(4):287–314.

Ricklis, R. A. and R. Weinstein
2005 Sea-Level Rise and Fluctuation on the Central Texas Coast. In *Gulf Coast Archaeology,* edited by N. M. White, pp. 108-154. University Press of Florida, Gainsville.

Taylor, M. S.
2005 Results of AMS Dating from the Cemetery Portion of the McNeil-Gonzales Site (41VT141). *Newsletter of the Texas Archeological Society* 49(1):23.

TCEQ
2006 Texas Commission for Environmental Quality, Wind Roses 1984-1992. Electronic Document. http://www.tceq.state.tx.us/compliance/monitoring/air/monops/windroses.html accessed July 21, 2006.

Thorson, R. M. and C. A. Tryon
2003 Bluff Top Sand Sheets in Northeastern Archaeology: A Physical Transport Model and Application to the Neville Site, Amoskeag Falls, New Hampshire. In *Geoarchaeology of Landscapes in the Glaciated Northeast,* edited by D. L. Cremeens and J. P. Hart, pp. 61-74. New York State Museum, Albany.

Toomey, R. S., M. D. Blum, and S. Valastro Jr.
1993 Late Quaternary Climates and Environments of the Edwards Plateau, Texas. *Global and Planetary Changes* 7:299–320.

Turner, E. S. and T. R. Hester
1993 *A Field Guide to Stone Artifacts of Texas Indians.* 2nd edition. Gulf Publishing Company, Houston.

Exploring Variation in Paleoindian Life Ways: The Third Revised Edition of the Texas Clovis Fluted Point Survey

Michael R. Bever and David J. Meltzer

ABSTRACT

Over 20 years have passed since the Texas Clovis Fluted Point Survey (TCFPS) was initiated. The database has now grown to 544 points, representing 149 of Texas' 254 counties. The database by now contains a demonstrably representative sample of the known Clovis point record in Texas, and has developed into a productive research tool for addressing questions of Clovis adaptations and lifeways. Some regions of the state show an abundant record of Clovis points while others are quite poorly represented. We argue that in certain regions the scarcity of points results from poor preservation or archeological exposure, while in others it may be due to a sparse Clovis occupation. In this regard, the distribution of Clovis sites provides an informative counterpoint to the distribution of Clovis points. Raw material distributions continue to provide insight into variation in Clovis technology and land use, but concerns about the accurate identification of raw materials found outside Central Texas limit the analytical potential of this line of evidence. Although there is significant variation in the size and use histories of Clovis points, the latter evidenced by reworking and breakage, we find little indication of morphological variation in Texas Clovis points not related to technological or raw material constraints. We conclude by identifying several gaps in our knowledge of Texas Clovis archeology that, if pursued as future research topics, would make the TCFPS an even more productive tool, and would advance Texas Clovis scholarship generally.

INTRODUCTION

Over ten years have passed since the last report on the Texas Clovis Fluted Point Survey (hereafter TCFPS) (Meltzer and Bever 1995). Since then, the database has grown by over 30%. The number of counties reporting Clovis points has increased, patterns once vague are now stronger, and conclusions once qualified are now more secure. Despite this, there have not been many significant changes in the TCFPS since the last update: few new patterns have emerged and the increase in points largely confirms previously reported findings. We are comforted by this; it indicates that the TCFPS provides (in general) a remarkably representative picture of Clovis point distributions and characteristics across the state. However, as we discuss below, that is not equivalent to saying that it fully represents the distribution of Clovis groups on the landscape of Late Pleistocene Texas.

So why update the TCFPS? Most importantly, much has changed in Clovis archeology in the last decade. Long held ideas about Clovis and its place in the earliest prehistory of North America—including Texas—have changed dramatically. Most archeologists now acknowledge Clovis does not represent the initial colonizing population of the western hemisphere (e.g., papers in Bonnichsen et al. 2006; Jablonski 2002; Madsen 2004; Waters and Stafford 2007). The stereotype of Clovis as pan-continental big game hunter has all but disappeared, and we now see substantial diversity in Clovis adaptations across the country (Byers and Ugan 2005; Cannon and Meltzer 2004; Grayson and Meltzer 2002; cf. Waguespack and Surovell 2003). Newly reported Clovis sites, like Gault in Central Texas (Collins 1999, 2002), have contributed to a much richer view of Clovis adaptations. Where once it was argued that Clovis—and especially the diagnostic Clovis fluted point—was rather homogenous from coast to coast (e.g. Haynes 1982), most now believe that Clovis can no longer be viewed as a monolithic cultural phenomenon. Adopting this perspective, we might expect evidence of this variation will be discernible in the Texas Clovis point database.

As our understanding of Clovis has changed, so too have the questions we should ask of point databases such as the TCFPS. Here is where this iteration of the TCFPS departs slightly from earlier versions. Although we provide an update of previously discussed themes and patterns, we also undertake a more directed analysis of the database in light of these new ideas about Clovis. We refer the reader to previous publications on the TCFPS (Meltzer 1986a, 1986b, 1989; Meltzer and Bever 1995) for an overview of the database and its history, and a detailed discussion of its biases and limitations. This article begins by broadly examining the distribution of Clovis points across the state. We ask whether these spatial patterns are more reflective of: (1) past human behavior or (2) the vagaries of archeological preservation and discovery. We then use this spatial framework to narrow in on specific areas of the state and structure an examination of variation in raw material use, point morphology, and point life histories. Our overarching goal is to identify meaningful variation in the TCFPS data that might reflect differences in Clovis land use and life ways across the state.

THE SPATIAL DISTRIBUTION OF TEXAS CLOVIS POINTS

The total number of points in the TCFPS now stands at 544, a substantial increase over the 205 reported in the initial publication (Meltzer 1986b), and the 406 reported in the last update (Meltzer and Bever 1995). In the current sample, 149 (or 58.7%) of the state's 254 counties now have recorded Clovis points (Table 1 and Figure 1).

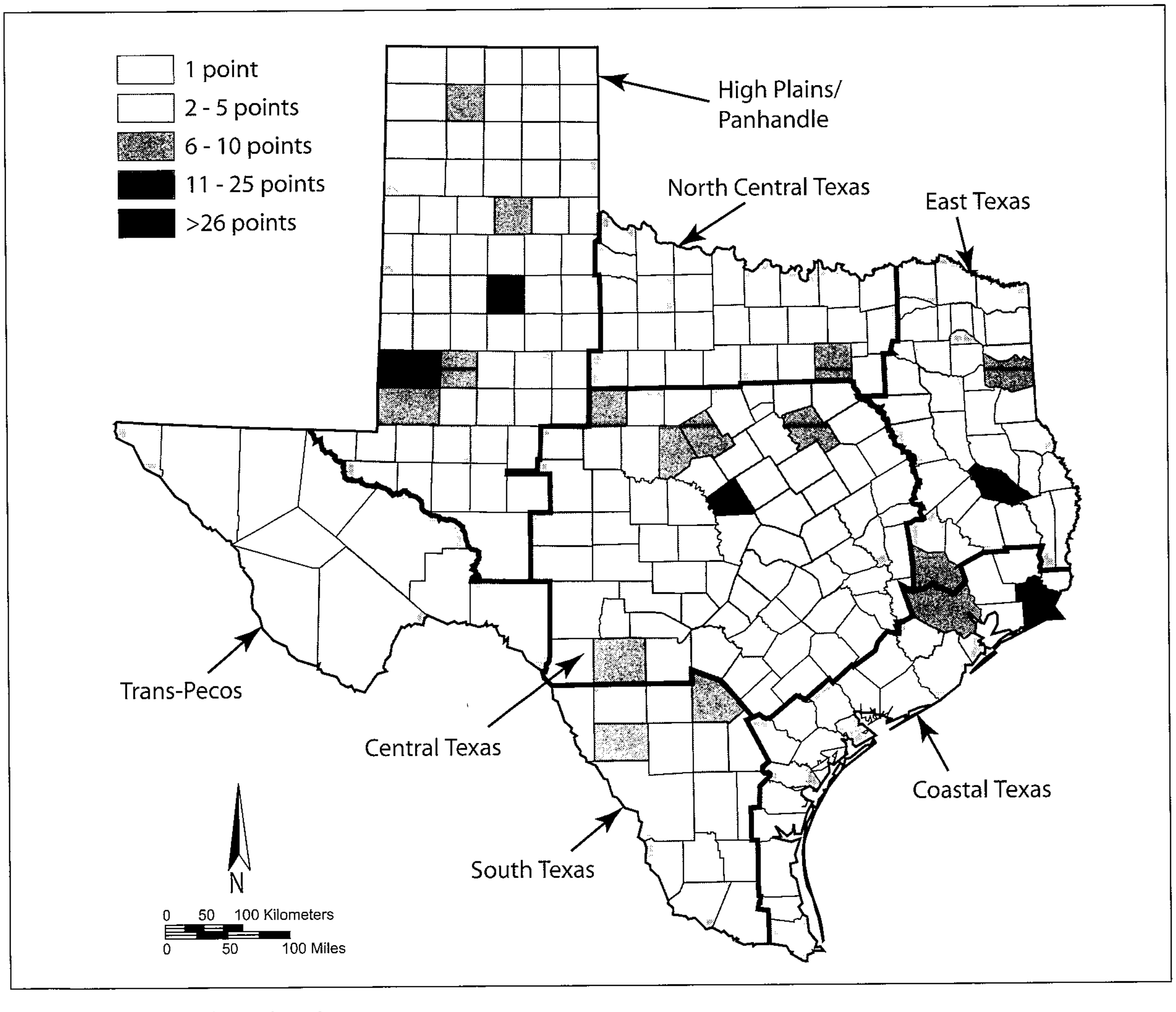

Figure 1. Number of Clovis points per county.

Table 1. Current and previous tallies of Texas Clovis points by county.

County	1986 tally	1995 tally	Current tally	Reference
Anderson	0	1	1	TCFPS
Andrews	2	3	6	TCFPS
Angelina	1	7	16	Brown 1994; TCFPS
Aransas	0	0	1	TCFPS
Armstrong	1	1	1	TCFPS
Atascosa	1	8	8	Hester 1974:Figure 1j; TCFPS
Bailey	1	1	3	TCFPS
Bandera	1	1	1	TCFPS
Bastrop	0	0	1	TCFPS
Baylor	0	0	1	TCFPS
Bee	1	1	1	Sellards 1940
Bell	1	3	5	Collins et al. 1991, 1992; TCFPS
Bexar	2	3	4	Henderson and Goode 1991; TCFPS
Blanco	1	1	1	Orchard and Campbell 1954; TCFPS
Borden	1	1	1	TCFPS
Bosque	1	1	1	TCFPS
Bowie	0	1	1	Story 1990:Table 44:8
Brazoria	0	1	1	Chandler and Rogers 1995
Brazos	1	2	2	TCFPS
Brewster	2	3	5	Enlow and Campbell 1955; Hester n.d.; TCFPS
Briscoe	0	8	8	TCFPS
Brown	4	5	6	TCFPS
Burnet	0	1	1	TCFPS
Calhoun	2	3	3	Suhm and Jelks 1962:Plate 89A, G; Hester 1988
Callahan	1	1	1	TCFPS
Cameron	1	1	1	Hester n.d.
Camp	1	1	3	TCFPS
Cass	0	1	2	TCFPS
Cherokee	1	1	1	Hester n.d.; TCFPS
Childress	0	0	1	TCFPS
Coke	2	4	4	TCFPS
Collingsworth	0	0	1	TCFPS
Comal	0	1	1	TCFPS
Comanche	2	7	9	TCFPS
Concho	1	1	1	Espey, Huston and Associates, Inc. 1981
Cooke	1	1	1	Jensen 1968
Coryell	0	4	4	TCFPS
Crosby	12	12	12	TCFPS
Dallam	3	3	4	TCFPS
Dallas	3	6	6	Crook and Harris 1955; Suhm and Jelks 1962:Plate 89C; TCFPS

Table 1. *(Continued)*

County	1986 tally	1995 tally	Current tally	Reference
Dawson	0	6	8	TCFPS
Deaf Smith	1	1	1	Suhm and Jelks 1962:Plate 89C
Denton	1	4	4	Crook and Harris 1957; Ferring 1990; TCFPS
DeWitt	1	1	1	Prewitt, unpublished
Dimmit	6	6	6	Hester n.d., 1974:Figure 1a, c, f-g
Donley	0	1	1	TCFPS
Duval	1	1	1	Hester n.d., 1974:Figure 1b
Ellis	2	3	3	TCFPS
El Paso	0	1	1	TCFPS
Erath	3	5	5	TCFPS
Falls	0	2	2	TCFPS
Fannin	0	0	1	TCFPS
Fayette	3	3	3	Meier and Hester 1972, 1976; Wilson 1979
Floyd	1	1	1	TCFPS
Foard	1	1	1	Etchieson et al. 1979
Fort Bend	0	0	2	Patterson 1997a, 1997b
Frio	0	0	1	TCFPS
Gaines	16	23	28	TCFPS
Galveston	0	1	1	TCFPS
Garza	1	1	1	TCFPS
Gillespie	0	0	1	TCFPS
Gonzales	1	1	1	Hester n.d.
Gray	2	2	2	TCFPS
Grayson	1	1	1	TCFPS
Hall	0	1	2	TCFPS
Hamilton	1	3	3	TCFPS
Hardeman	0	0	3	TCFPS
Harris	2	6	9	Hester 1980; Patterson 1986; Patterson et al. 1992a, 1992b; Suhm and Jelks 1962:Plate 89B; Wheat 1953; TCFPS
Harrison	5	6	8	Hayner 1955, Hester n.d.; TCFPS
Hartley	0	1	1	TCFPS
Hays	4	5	5	Hester n.d.; Takac 1991; TCFPS
Henderson	1	4	4	Story 1990:Table 44:29; TCFPS
Hill	2	6	6	TCFPS
Hockley	1	2	2	Walter 1990; TCFPS
Hood	1	1	1	Skinner and Rash 1969
Howard	3	4	5	TCFPS
Hunt	0	1	3	TCFPS
Jasper	2	2	3	TCFPS
Jefferson	10	70	97	Long 1977; Turner and Tanner 1994; TCFPS
Johnson	2	2	2	TCFPS
Jones	1	1	1	TCFPS

Table 1. *(Continued)*

County	1986 tally	1995 tally	Current tally	Reference
Kaufman	0	1	1	TCFPS
Kendall	1	3	4	Chandler 1983; TCFPS
Kerr	1	2	2	Saner 1995; TCFPS
Kimble	0	1	1	TCFPS
Lamar	2	4	4	TCFPS
Lamb	0	0	5	TCFPS
Lampasas	0	1	18	TCFPS
Lee	0	0	3	TCFPS
Limestone	0	0	1	TCFPS
Live Oak	0	1	1	House 1974
Llano	0	0	1	TCFPS
Lubbock	1	2	3	Johnson 1983; TCFPS
Marion	4	4	4	Hayner 1955; Story 1990:Table 44:20; TCFPS
Martin	2	2	2	TCFPS
McLennan	3	3	3	TCFPS
McMullen	2	3	3	Cooper 1974; Kelly 1983; TCFPS
Medina	1	3	3	TCFPS
Midland	5	5	5	TCFPS
Milam	0	1	2	TCFPS
Mills	0	1	1	TCFPS
Montague	1	1	1	TCFPS
Montgomery	0	4	8	Chandler and Rogers 1995; TCFPS
Moore	6	6	6	TCFPS
Navarro	1	3	3	Story 1990:Table 44:33;TCFPS
Nolan	2	2	2	TCFPS
Oldham	2	2	2	TCFPS
Panola	1	1	1	Scurlock and Davis 1962
Parker	1	1	1	TCFPS
Pecos	1	1	1	Hester n.d.
Polk	0	1	2	TCFPS
Potter	0	3	3	TCFPS
Real	0	0	1	Saner 2005
Red River	0	1	2	Skinner and Rash 1969; TCFPS
Roberts	3	3	3	Holliday et al. 1994; Sellards 1952
Robertson	1	1	1	TCFPS
Runnels	2	3	3	Espey, Huston and Associates, Inc. 1981; TCFPS
San Augustine	1	2	2	Brown 1994; TCFPS
San Patricio	2	2	2	Chandler 1982; Hester 1980
San Saba	0	1	1	TCFPS
Schleicher	2	2	2	TCFPS
Scurry	0	0	1	TCFPS

Table 1. *(Continued)*

County	1986 tally	1995 tally	Current tally	Reference
Shackleford	1	1	1	TCFPS
Shelby	0	0	1	TCFPS
Smith	0	0	1	TCFPS
Starr	1	1	2	Weir 1956; TCFPS
Sutton	0	0	1	TCFPS
Swisher	1	1	2	TCFPS
Taylor	5	6	6	Mallouf 1989; Ray 1930; Sellards 1952; TCFPS
Terry	0	4	4	TCFPS
Titus	0	2	3	Story 1990:Table 44:9-11; TCFPS
Tom Green	0	1	2	TCFPS
Travis	4	4	5	Alexander 1963; Hester n.d.; TCFPS
Tyler	1	1	1	Suhm and Jelks 1962:Plate 89E
Uvalde	1	7	7	Collins et al. 1989; Hester n.d.
Val Verde	1	1	1	Greer 1968
Van Zandt	2	2	2	Johnson 1961
Victoria	1	1	1	Hester 1974:Figure 1i
Walker	0	0	1	TCFPS
Ward	3	3	4	TCFPS
Webb	0	1	1	Mitchell and Winsch 1974
Williamson	2	2	2	Collins et al. 1993; Hays 1982; TCFPS
Wilson	0	1	1	TCFPS
Winkler	2	2	2	TCFPS
Wise	0	1	1	TCFPS
Wood	0	2	2	Story 1990:Table 44:19
Yoakum	1	2	2	TCFPS
Zapata	0	0	1	TCFPS
Zavala	1	2	2	Hester 1974: Figure 1d, e
Unknown	1	1	7	TCFPS
Totals	205	406	544	

Given the number of Clovis-point bearing counties added between the 1986 to 1995 surveys (33 counties), compared to the smaller number added between the 1995 survey and the present one (21 counties), a statistical trend seems clear: much of the Texas Clovis-by-county map has been filled in. Additional records will surely add more counties to the list, but the trend would suggest that number will not be large (and probably significantly less than 21 counties, at least over the next five or 10 years, were we to venture a prediction).

Although this county-by-county examination broadens the spatial extent of Clovis points across the state, as before the majority of the counties that have produced Clovis points contain just one point (in the current sample, that is 64 counties, or 43% of the counties that have produced points); counties with three or fewer points account for 73.8% of the total. Only five counties have produced 10 or more points (Table 2). Stated another way, roughly two-thirds of the state has no apparent Clovis presence, or at most a light scatter. Conversely, pronounced concentrations of Clovis evidence are restricted to a few areas. Figure 1, a plot of the number of points per county, shows this uneven distribution.

All of the physiographic regions of the state[1] have likewise seen an increase in Clovis points since the 1995 update (Table 3). With two notable exceptions, each region experienced a similar rate of growth: from 25.7% to 38.4%, which generally matches the overall increase in the database of 34%. This means that over the last decade new points have been reported from each region at roughly the same rate. As one might expect, regions with many points in 1995 showed a larger increase in absolute numbers, while regions with fewer points showed a correspondingly smaller increase. This proportional growth suggests to us that the database has statistically stabilized, and that the current tally probably provides a fairly accurate representation of the relative frequency of Clovis points in each region. Of course, we expect that the overall numbers of points in all regions will continue to increase, including examples from counties now lacking points. However, with such a large sample, derived from a variety of sources and over such a long span of time, the TCFPS probably has reached the point where the basic patterning in regional abundance and scarcity—like that of the county tallies—will not change appreciably in future versions.

To explore the distribution of points in greater detail, Table 4 shows the observed and expected

Table 2. Modal distribution of Clovis fluted points by county (total number of counties with occurrences = 149)

	Number of occurrences									
	1	2	3	4	5	6	7	8	9	≥10
Number of counties	64	27	19	11	8	7	1	5	2	5

Table 3. Tally of Texas Clovis fluted points by region, 1995 and current.

	Number of Clovis points		
Region	1995 tally	Current tally	Percent increase
1 Plains/Panhandle	109	137	25.7%
2 North Central	20	27	35.0%
3 East	48	74	54.2%
4 Coast	86	119	38.4%
5 South	23	26	13.0%
6 Trans-Pecos	6	8	33.3%
7 Central	113	151	33.6%
Unknown[a]	1	2	100.0%
Total	406	544	34.0%

a. The count of "Unknown" differs between Table 1 and this table because, while seven points are unassigned to a county, all but two can be assigned to a region.

Table 4. Distribution and density of Clovis fluted points by region against expected point frequency.

Region	Number of points	Area in square miles[a]	Density (points/ 10,000 mi^2)	Percent of total area	Expected number of points[b]	Standardized residual
1 Plains/Panhandle	137	65,388	21.0	24.9	135.0	0.17
2 North Central	27	24,719	10.9	9.4	50.9	-3.35
3 East	74	26,765	27.6	10.2	55.3	2.51
4 Coast	119/22[c]	21,527	55.3/10.2[c]	8.2	44.4	11.31/-3.36[c]
5 South	26	21,683	12.0	8.3	45.0	-2.83
6 Trans-Pecos	8	34,797	2.3	13.3	72.1	-7.55
7 Central	151	67,235	22.5	25.7	139.3	0.99
Total	542	262,114	20.7	100.0	542.0	

Chi square = 208.91, df = 6, $p < 0.001$; significant residuals are underlined.

a. Data on area from Arbingast et al. (1976:78-79).

b. Obtained by multiplying the regional percent of the total area by the number of points (542) from all regions.

c. Indicates values with/without the points from McFaddin Beach. The chi square statistic is significant either way, and here the result *with* the McFaddin Beach points is shown.

numbers of Clovis points by region when the varying size of the regions is taken into account. Figure 2 portrays this graphically by showing the density of Clovis points across the state by county (in points per 1,000 km^2). The difference between regions is significant, as it was in 1995. The standardized residuals in Table 4 express the difference between observed and expected frequencies in standard deviations. Residuals greater than 1.96 (or less than -1.96) indicate significant deviations from expected frequencies. Regions with significantly greater than expected numbers of Clovis points include the Gulf Coast and East Texas. Central Texas and the Plains/Panhandle also have relatively high point densities, although they are not significantly higher than expected. These patterns can be seen quite clearly in Figure 2, where the Southern High Plains and portions of Central and East Texas show the greatest density of Clovis points. Areas with lower than expected frequencies include Southwest Texas, North Central Texas, and the Trans-Pecos. Each of these regions will be summarized in turn, noting especially differences between this and previous versions of the TCFPS.

Clovis Point Frequencies by Region

The Gulf Coast

The Gulf Coast has the highest density of Clovis points of any region in Texas (see Table 4). Taken at face value, however, this figure is misleading. Over 81% of the 119 points on the coast come from a single locale: McFaddin Beach in Jefferson County (this includes 27 of the 33 points reported from coastal counties since 1995). Though McFaddin Beach has produced Clovis points for several decades, it remains an enigma. Of course, the present location of McFaddin Beach would have been well inland (ca. 80 km) in Pleistocene times owing to lower sea levels, and the points are not in primary context but were collected from a 35 km stretch of beach. Almost certainly they were redeposited from one or more sites now submerged offshore, and the lack of wear and abrasion from stream or shoreline tumbling suggests they have not been transported far from their original location. Since the current collection contains primarily finished points and lacks associated habitation

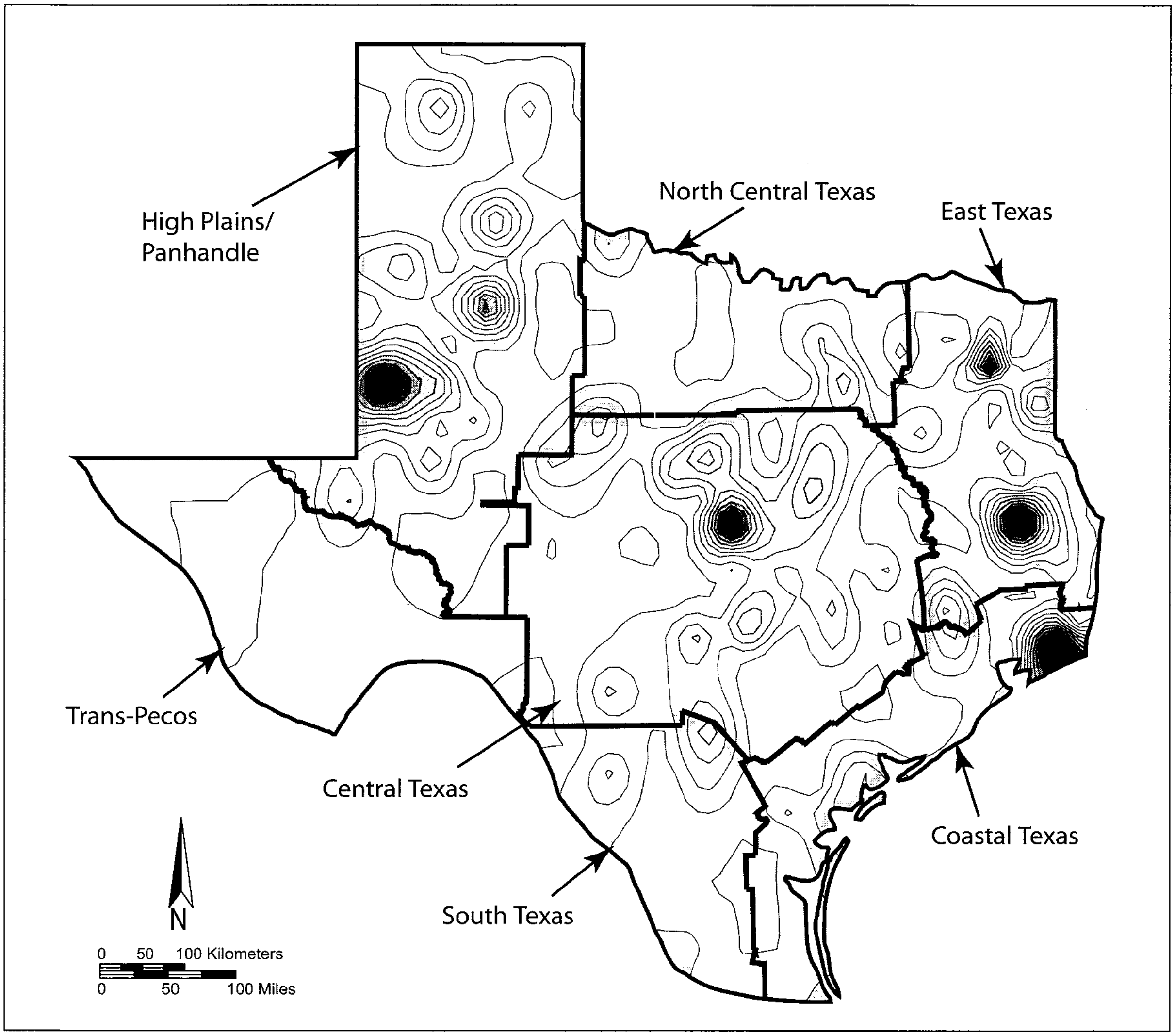

Figure 2. Contour map of Clovis point density (points per 1,000 km^2), plotted to the centroid of each county. Because of the large number of points, the density for Jefferson County was arbitrarily set at eight points per 1,000 km^2, placing it just above the next highest values in the state, Gaines and Angelina counties.

debris or other tools, it is not clear what type of site or sites account for the points washed up on McFaddin Beach (Hall 1998; Long 1977; Stright 1999; Turner and Tanner 1994).

Aside from McFaddin Beach, the coastal prairies and marshes of Texas actually have produced very few Clovis points. In fact, when the McFaddin Beach points are removed from the calculation, the coastal region has one of the lowest densities of Clovis points in the state (see Table 4). Figure 2 shows this quite clearly. Aside from Jefferson and Harris counties in the southeasternmost portion of the state, and a handful of counties from the central Texas coast, the remaining counties along the coast show a near absence of points. This absence of points extends across a broad swath of the Texas Coastal Plain, stretching from the Gulf Coast to the Balcones Escarpment, some 200 km inland to the northwest. Though this scarcity of Clovis points could indicate that the Coastal Plain was sparsely inhabited during Clovis times, there are clues to the contrary. McFaddin Beach and other instances where Clovis points have been washed ashore on modern beaches hint at a rich offshore record of Clovis habitation. Further, though rare, sites like Johnston-Heller (Birmingham and Hester 1976; Hester 2004) in Victoria County contain Clovis components that are deeply buried in fluvial terraces. Dissected by numerous drainages, post-glacial sea level rise would have caused rapid alluvial deposition across large areas of the Coastal Plain. Rather than an absence of habitation, then, the scarcity of Clovis points (and sites) from the Coastal Plain might indicate that the Clovis record in this area of the state remains deeply buried beneath Holocene alluvial fill. This is dramatically illustrated at a site like Richard Beene, which is located on the Coastal Plain just south of the Balcones Escarpment and contains 20 m of stratified Holocene deposits (Thoms and Mandel 2007). Of course, it is also possible that just the opposite has occurred in some areas, and that actively meandering river systems have washed away the Clovis-aged deposits (Waters and Nordt 1995).

East Texas

The Gulf Coast aside, East Texas actually has the greatest density of Clovis points of any region in Texas (see Table 4). Furthermore, between 1995 and 2006, East Texas showed the highest rate of increase in Clovis points, well above the range of the other regions (see Table 3). A similar increase was seen from 1986 to 1995 (see Meltzer and Bever 1995:Table 3). For whatever reason, East Texas was not accurately represented in earlier versions of the TCFPS, and the surge in the number of points in the region represents one of the greatest changes in the data base. Consequently, East Texas now exhibits one of the richest Clovis point records in the state, which is all the more reason to lament the fact that no large scale investigation of a Clovis site has been undertaken there. The high incidence of Clovis points from East Texas should not be surprising in light of the larger continental distribution of Clovis points (e.g., Anderson and Faught 2000; Buchanan 2003). In general, the woodlands of the eastern United States show a much greater density of Clovis points than the central and western portions of the country. As the westernmost extension of the eastern Woodlands, East Texas might be expected to contain a similarly extensive Clovis record. Gauging from the continental pattern (Cannon and Meltzer 2004; Meltzer 1993), we might expect that the adaptations of these East Texas Clovis groups differed from more westerly groups as well.

Figure 2 shows that the distribution of Clovis points in East Texas is uneven. In the northeast, numerous points have been found as isolated occurrences along the North Sulphur River (see article by Bousman and Skinner, this volume), eroding from deeply buried alluvial contexts. Others have been exposed by erosion resulting from modern reservoir construction. In Angelina County, which has the greatest density of points in the state after Jefferson County (McFaddin Beach), over half of the 17 points were reported by a single avocational archeologist working in a restricted area. In general, where there has been good exposure of deposits of the proper age, large quantities of Clovis points have been found. Other such hot spots almost certainly exist in East Texas, and the region probably holds an even more robust record of Clovis occupation than that identified here.

Central Texas

Central Texas has produced the greatest number of points of any region in the state (see Table 4). However, Central Texas is also one of the largest regions in the state, at least as partitioned here; that noted, the frequency of Clovis points in the region does not diverge significantly from expected values. It is the case, however, that the distribution of points across this region is not continuous; there are portions with distinct concentrations and others with a virtual absence of points (see Figure 2). In general, Clovis points are distributed in an arc-like pattern, beginning near Abilene in the north and swinging clockwise through Austin, San Antonio, and ending in Uvalde County. A short spur also extends to the northeast toward the Dallas-Forth Worth area in North Central Texas (see Figure 2). In contrast, the area within this arc, and the entire western half of the Edwards Plateau southward to the lower Pecos, is nearly devoid of points.

As noted in previous versions of the TCFPS, the curvilinear distribution of points corresponds closely to the Balcones Escarpment (Meltzer 1986b; Meltzer and Bever 1995), at least on the eastern and southern portions of the arc. Marked by permanent freshwater springs and outcrops of high quality Edwards Formation chert, the Balcones Escarpment forms an ecotone between the uplifted Edwards Plateau to the west and the rolling prairies to the east and south (Ellis et al. 1995). A combination of factors, including reliable fresh water, ready access to the subsistence resources of two ecological zones, and a reliable source of lithic raw material, likely drew Clovis inhabitants to the area. It is surely no coincidence that the largest Clovis site ever recorded—the Gault site—is situated in this region at the head of a creek next to a high quality Edwards outcrop (Collins 2002). The northern periphery of the Edwards Plateau also contains outcrops of high quality chert, from Abilene eastward, which probably accounts for the concentration of points there. These sources of chert might have been particularly valuable to groups inhabiting the raw material-poor Southern High Plains.

Although we believe this pattern is meaningful in terms of Clovis land use, we acknowledge that other factors complicate this simple picture. Two major interstate highways—I-35 on the eastern boundary and I-20 on the northern—pass through the area, and some of the largest urban areas in the state can be found there (originally settled in part for the same reason Clovis groups settled here: water and the escarpment boundary—though we hasten to add, not because of the lithic outcrops). The concentration of points through San Antonio, Austin, Waco, and Dallas corresponds precisely to the I-35 corridor, which cannot be mere coincidence.

Also, as noted in previous versions of the TCFPS (Meltzer 1986b), the fact that points are concentrated in raw material-rich areas does not necessarily mean that those areas saw more intense habitation. Instead, an abundance of high quality raw material might have had a strong effect on patterns of point discard and accumulation in the archeological record. For example, discard rates would have been high for groups visiting these sources to rejuvenate their tool kit. Further, groups inhabiting the area would not have needed to conserve their tools to the same degree as groups living in raw material-poor areas. Both of these factors would create a greater accumulation of points regardless of how many people exploited the area or how intensively they did so (Meltzer and Bever 1995; cf. Shiner 1983). This does not mean, of course, that these raw material-rich zones of Central Texas were unimportant to Clovis groups, or that they were not used differently than other areas. It simply highlights the difficulty in using point distributional data to address questions of prehistoric land use.

Plains/Panhandle

The Plains/Panhandle region also exhibits a high density of Clovis points, though not significantly higher than would be expected for a region of its size (see Table 4). Within the region, points are far more common on the Southern High Plains than the adjacent rolling plains to the east. This marks the Southern High Plains as one of the densest records of Clovis points in the state. The Southern High Plains has seen decades of continuous research by Paleoindian specialists (e.g., Holliday 1997) and its rich record of classic Clovis sites, like Miami, Blackwater Draw and Lubbock Lake, is well known. Perhaps because it has been systematically studied for so long, the Southern High Plains experienced a lower than average increase in the point tally since the last update (see Table 3). Despite this, it remains one of the better represented regions of the state, and for good reason. The Southern High Plains is sparsely vegetated, large areas are subject to repeated plowing, and it is crossed by numerous deeply incised intermittent streams (Holliday 1995). These factors have ensured good archeological exposure of Clovis-age deposits. During the latest Pleistocene the Southern High Plains was well watered, with permanently flowing streams and water-filled playas (Sabin and Holliday 1995). These would have served as magnets for the abundant game animals that wandered the Plains, and would have attracted Clovis hunters as well. Most Clovis sites from the region are associated with these water sources and evidence for the exploitation of these animals is well documented (Grayson and Meltzer 2002; Haynes 1995; Hester 1972; Holliday et al. 1994; Johnson 1987).

Trans-Pecos

In contrast to the preceding regions, the Trans-Pecos has by far the lowest number and density of Clovis points of any region in the state (see Table 4). We noted previously that the lack of points in the Trans-Pecos might be due to a lack of archeological scrutiny (Meltzer 1986b; Meltzer and Bever 1995). This conclusion probably remains true for portions of the Trans-Pecos. With few major highways, limited urban development, and a small population scattered across large tracts of private ranch land, the potential for discovering Clovis points is quite low. There are exceptions to this generalization, however, and the exceptions are informative. Numerous archeological surveys, including large scale projects on Fort Bliss and in the national and state parks in the Big Bend region, have produced very few Clovis points (Miller and Kenmotsu 2004). If Clovis points existed in these areas in any numbers, it seems likely that more would have been found by now. Perhaps even more telling is the presence of only one Clovis point from El Paso County. In the past few decades, the densely populated city of El Paso has seen extensive archeological survey and excavation related to cultural resource management (CRM) projects. Indeed, more archeological sites are recorded in El Paso County than in any other county in Texas, despite its small size. That only one Clovis point has been found there, and none in the decade since the 1995 update, is quite telling. Finally, while Clovis materials are rare, Folsom and later Paleoindian materials are not at all uncommon in the Trans-Pecos region (such as Bonfire Shelter [Dibble and Lorrain 1968; Byerly et al. 2005; Byerly et al., this volume] and Chispa Creek [Amick and Hofman 1999]). The accumulation of evidence, then, seems to indicate that the low density of Clovis points in the Trans-Pecos may very well reflect a sparse Clovis occupation.

North Central Texas

In earlier versions of the TCFPS, we suggested that the absence of Clovis points from North Central Texas might be due to geological processes that deeply buried deposits of Clovis age. Surrounded by regions with abundant Clovis points—the Edwards Plateau to the south, the Southern High Plains to the west, and East Texas to the east (see Figure 2)—there seems to be little else that would explain the scarcity of points in this area of the state, particularly since it has seen an intensity of CRM projects that is equal to or greater than any other region of the state. We know Clovis groups inhabited North Central Texas, as indicated by a scatter of isolated points, and sites like Aubrey (Ferring 2001) and Lewisville (Crook and Harris 1957). Indeed, Aubrey provides a case in point. The site was deeply buried beneath 8 m of Holocene alluvium and would not have been found were it not for the construction and subsequent erosion of an artificial outlet channel below the Lake Ray Roberts dam (Ferring 2001). Corroborating evidence can be found in the single concentration of Clovis points in North Central Texas, seen in the eastern end of the region in the vicinity of the Dallas metropolitan area (see Figure 2). This is precisely the type of setting that has seen the degree of modern development (and accompanying archeological work) necessary to expose large tracts of deeply buried Clovis-aged deposits. As with the Gulf Coast, we conclude again that Clovis points in North Central Texas are otherwise underrepresented in the TCFPS because deposits of the proper age remain only sporadically accessible to archeologists.

South Texas

South Texas also displays a significantly lower than expected frequency of Clovis points (see Table 4). Predictably, most of the points in the region are found in counties skirting the Balcones Escarpment, indicating that Clovis points are even scarcer in the far south, approaching the Rio Grande. South Texas also showed the lowest increase in points over the 1995 version of the database, indicating that the initial and active recording of Clovis points in this area several decades ago—primarily by Thomas Hester, C. K. Chandler, and other members of the Southern Texas Archaeological Association—was quite thorough (Hester 1974, 2004). As with the Trans-Pecos, large areas of South Texas are covered by private ranch land and have seen minimal archeological scrutiny. However, even in those areas where archeologists have looked, Clovis points are rare, despite the fact that most of the region has minimal vegetation cover, and ancient deflated surfaces, largely unaffected by fluvial erosion or burial, cover large expanses of the region (Black 1989; Hester 2004). This scarcity of deeply stratified sites has long confounded attempts to develop a reliable culture-historical chronology for the area (Hester 2004). However, shallow deposits and good surface visibility seem to be precisely the characteristics that should ensure the discovery of *more* Clovis points, though not necessarily from secure contexts. Why the South Texas Clovis record remains sparse is unclear, but it appears that it might be a real phenomenon and not entirely a product of limited archeological scrutiny or geological processes that have obscured the Clovis record.

Clues from the Distribution of Clovis Sites

The patterning in the distribution of Texas Clovis points is intriguing. However, while we can make inferences about the meaning of the *presence* of Clovis points in a region, any inference about the *absence* of points from a particular region must be tempered with the fact that a good part of the patterning may have more to do with modern circumstance than variation in Clovis land use (Buchanan 2003; LaBelle 2005). Put another way: is the record of Clovis points representative of what was left behind by Clovis groups? This concern should be abundantly clear from the previous discussion. A lack of points may be variously attributed to limited archeological investigation, erosion, or burial. Even if these concerns could be ruled out, a scarcity of points from a region need not necessarily indicate a low level of Clovis habitation. It might simply indicate an absence of the types of activities that led to the creation, use, and discard of Clovis points. Unfortunately, these issues are difficult, if not impossible, to resolve with simple distributional data.

There are, however, a couple of ways to come at this question. The first makes use of two independent but similar sets of data: the distribution of Clovis sites in Texas and the archeological context of the points in the TCFPS. The second makes use of variability inherent in the points themselves. We explore these themes in greater detail as both provide evidence for variation in Clovis land use.

To examine patterning in the distribution of sites, we compiled a comprehensive list of Clovis sites recorded in the Texas state files. We used two sources. The first is Bousman et al. (2004), which presents the results of a tabulation of all recorded Paleoindian sites on file at the Texas Archeological Research Laboratory of The University of Texas at Austin, one of the main repositories for archeological site records in the state. Conducted in 1994, the search found 81 Clovis sites (Bousman et al. 2004). To supplement this information, we conducted an online search of the more than 60,000 site records in the State of Texas Archeological Site Atlas, maintained by the Texas Historical Commission.[2] While most of the site records found in this search were redundant with those contained in Bousman et al. (2004), we did locate an additional 34 Clovis sites, producing an overall total of 115 sites.

A few words of explanation are in order concerning these data. Isolated points recorded as sites were not included in the site tally. Also, in compiling the list of sites, we erred on the side of caution. If the identification of a Clovis component at a site was suspect (usually meaning that the identification of a projectile point as a Clovis point was suspect), we did not include it in the final tally. We should also note that since we were not able to link all of the points in the TCFPS that came from archeological sites to specific recorded Clovis sites, we treat the two databases as independent sources. Finally, while neither the number of Clovis points nor Clovis point density by county correlates with county population or population density, respectively, this is not the case for Clovis sites. Where more people live, more Clovis sites have been found (Pearson correlation coefficient = .350, $p<.001$). This is not surprising. Many Clovis sites recorded in recent decades were found as a result of CRM work stemming from urban development, which is most prevalent in the heavily populated areas of the state. This bias must be kept in mind in the discussion that follows.

The 115 Clovis sites included in the database are plotted in Figure 3, superimposed over the density of Clovis points in the TCFPS. Visually, there is a strong correspondence between the distribution of Clovis points and sites.[3] This provides support for the patterns discussed previously: whether based on Clovis points or recorded Clovis sites, some areas of the state have a richer record of Clovis occupation than others. Table 5 shows the frequency and density of Clovis sites by region. The differences between regions are significant and the adjusted standardized residuals indicate which regions deviate most strongly from expected frequencies. The Trans-Pecos and Plains/Panhandle show significantly lower than expected frequencies, while East and Central Texas shows higher than expected frequencies.

Despite the similarity between the two records, the overall relationship between the number of Clovis points and the number of Clovis sites by county is not significant,[4] primarily because in some regions the two do not correspond. Most informative in this regard are the cases where there is a disjunction between points and sites. North Central Texas and the Coast, which have fewer points than expected, do not deviate significantly from expected frequencies in terms of sites. In other words, there are fewer points than expected, but about as many sites as expected. On the surface, this might indicate that sites in these regions contain relatively few points, a pattern that might have implications for Clovis adaptations. However, it might also be a function of poor archeological visibility, a factor argued above to have played a role in the low point density from these particular areas. Isolated points, presumably deeply buried in most instances, would not be as readily found upon exposure (though we are aware that the Aubrey site [Ferring 2001] is an exception to that rule: Ferring found the point first, which in turn led him to the site). Archeological sites, however, with their relatively greater visibility, might be more easily recognized—though not necessarily recognized immediately as Clovis sites. In any case, the result would be a bias toward an

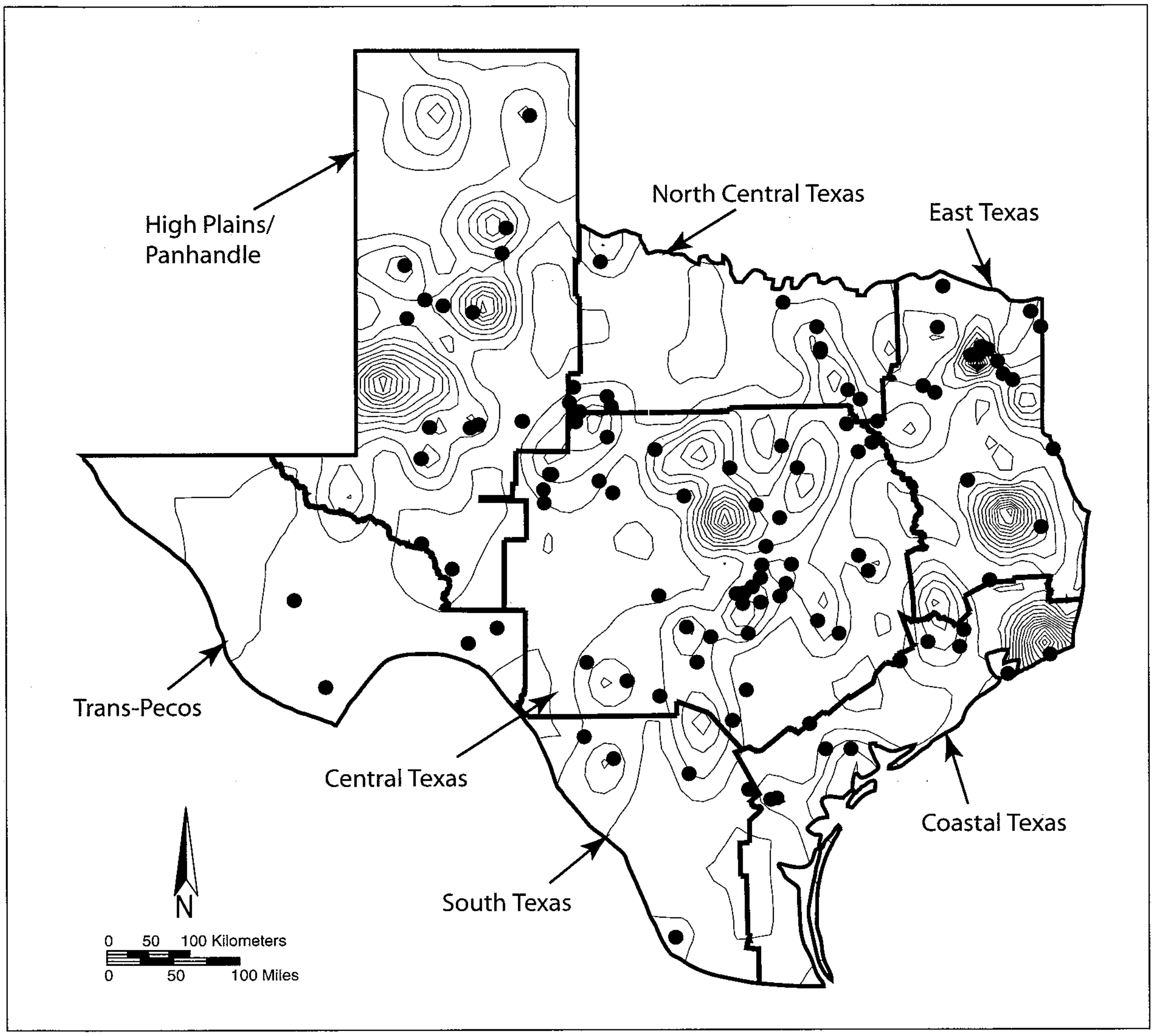

Figure 3. Clovis sites on file with the Texas Archeological Research Laboratory and the Texas Historical Commission, superimposed over Clovis point density by county.

archeological record consisting primarily of Clovis sites, and points derived from those site contexts. At present, however, and with such a small sample of both points and sites, the meaning of this pattern in North Central Texas and the Coastal region is not clear.

Stronger and probably more meaningful discrepancies between the site and individual point records occur in the Plains/Panhandle and Central Texas regions. Both of these regions have abundant point records, but have opposing site frequencies. The Plains/Panhandle, and particularly the Southern High Plains, has fewer sites than expected for a region of this size. Given the rich record of Clovis points, and the well known sites that occur here (and just across the border on the Southern High Plains of New Mexico), it is rather surprising to note that the region actually has one of the lowest densities of Clovis sites anywhere in the state, approaching those of South Texas and the Trans-Pecos. This pattern indicates that either there are many more points per site in the Plains/Panhandle (the opposite of the situation in North Central Texas), or that substantially more points do not come from site contexts.

To explore this in greater detail we can make use of another line of evidence, which is the archeological context of the points in the TCFPS. Each point in the TCFPS is coded according to one of four possible contexts (see Meltzer and Bever

Table 5. Distribution and density of Clovis sites by region against expected site frequency.

Region	Number of sites	Area in square miles[a]	Density (sites/ 10,000 mi^2)	Percent of total area	Expected number of sites[b]	Standardized residual
1 Plains/Panhandle	16	65,388	2.45	24.9	28.6	-2.36
2 North Central	11	24,719	4.45	9.4	10.8	0.06
3 East	20	26,765	7.47	10.2	11.7	2.43
4 Coast	10	21,527	4.65	8.2	9.4	0.20
5 South	5	21,683	2.31	8.3	9.5	-1.46
6 Trans-Pecos	5	34,797	1.44	13.3	15.3	-2.63
7 Central	48	67,235	7.14	25.7	29.6	3.38
Total	115	262,114	4.39	100.0	115.0	

Chi square = 31.98, df = 6, $p < 0.001$; significant residuals are underlined.

a. Data on area from Arbingast et al. (1976:78-79).

b. Obtained by multiplying the regional percent of the total area by the number of sites (115) from all regions.

1995 for a more detailed discussion): as isolated occurrences (*isolates*), in well defined Clovis site contexts (*Clovis site*), as part of a mixed surface scatter of artifacts of various ages (*surface scatter*), or in an unreported or ambiguously reported context (*unknown*).The category 'surface scatter' likely includes mostly disturbed site contexts, but could also represent a Clovis isolate in the midst of later archeological materials. To err on the safe side, we tallied only those Clovis points from clear—generally meaning stratigraphically sound—contexts as Clovis sites. Table 6 shows the frequency of points from the different contexts by region. Points from unknown contexts, which account for 39% of the points in the TCFPS, are not included in the chi square statistic and are tabulated separately.

While variation in the context of Clovis points by region is significant, Table 6 shows that the significance is driven primarily by opposing deviations in Central Texas and the Plains/Panhandle. As noted above, the Clovis point record from the Plains/Panhandle is dominated by Clovis isolates. This agrees with the Clovis site database, which shows that recorded Clovis sites are rare from the region. Taken together, this pattern places the Southern High Plains in strong contrast with other areas of the state, and indicates that the Clovis record from the Southern High Plains is made up of a very ephemeral record of Clovis isolates. This pattern could mean that Clovis groups on the Southern High Plains did not engage in the types of redundant or repetitive activities that would have left a distinct record of sites. While it is generally recognized that the Clovis archeological record is ephemeral, a point noted in previous versions of the TCFPS (Meltzer 1986b; Meltzer and Bever 1995), this seems to be especially true of the Southern High Plains. If this pattern is real—and we make no guarantees—it is interesting to note that it mirrors a finding emerging in recent studies of Folsom and later Paleoindian period land use (LaBelle 2005): namely, that the Plains may have more than its share of kill sites, relatively speaking, but that Paleoindian groups at this time may have spent much of their time in sites off the Plains, which provide a greater variety of food resources than the Plains proper. Assuming, that is, that the pattern is real.

Of course, a bias in site reporting from the Southern High Plains could also contribute to the pattern. For example, Gaines County, which produced 28 points (20.4% of the total from the Plains/ Panhandle), does not have a single recorded site. It seems that at least some of these points must derive from unreported sites.[5] Perhaps a lack of site recording (but not Clovis point reporting) has created the high point:site ratio, though why this would

Table 6. Archeological context of Clovis points in the TCFPS by region.

Region		Clovis site	Mixed scatter	Isolate	Unknown[a]	Total
1 Plains/Panhandle	count	6	29	29	73	137
	adj. residual	-2.1	-1.8	3.8		
2 North Central	count	5	5	6	11	27
	adj. residual	1.4	-1.9	1.0		
3 East	count	6	22	11	35	74
	adj. residual	-.5	.2	.2		
4 Coast	count	0	6	1	15	22
	adj. residual	-1.3	1.7	-.8		
5 South	count	1	5	6	14	26
	adj. residual	-.9	-.9	1.8		
6 Trans-Pecos	count	0	1	2	5	8
	adj. residual	-.8	-.7	1.6		
7 Central	count	25	61	9	56	151
	adj. residual	2.6	2.4	-5.0		
Total		43	129	64	209	445[b]

Chi square = 40.23, df = 12, $p < 0.001$; significant residuals are underlined.

a. Not included in the chi square calculation.

b. This number is smaller than other totals because the 97 points from McFaddin Beach are not included in the tabulation.

affect the Southern High Plains more than other regions of the state is not clear.

In contrast to the Plains/Panhandle, Central Texas shows the opposite pattern: isolates are rare while Clovis sites are more common than expected (see Table 5). This, too, diverges from the more typical view of Clovis. We mentioned above the types of resources that would have attracted Clovis groups to Central Texas, and particularly its abundance of accessible chert in areas where both Clovis points and sites are concentrated. This pattern fits with the notion that, for Clovis groups visiting or residing in these areas of Central Texas, there would have been repeated use of specific spots on the landscape favorable for acquiring raw material and other resources. Discard rates of points would have been high, as new tools were manufactured from abundant raw material, and the result of this more structured use of the landscape would have been a robust, site-dominated Clovis record. The contrast between the Southern High Plains and Central Texas is strong and will be explored in greater detail in the following sections.

This brief examination of the distribution of Clovis sites and points clearly provides clues for exploring variation in Clovis adaptations, particularly when comparing those areas displaying rich records of individual points, like the Southern High Plains and the chert-rich areas of Central Texas. Despite these provocative patterns, however, biases in preservation and discovery must remain a concern, and little can be said about those regions lacking abundant points, like North Central Texas and the Coast.

One of the strengths of the TCFPS, however, is that it contains more than simple provenience data. It also contains data on characteristics inherent to the points themselves that are not directly affected by biases affecting point recovery (see LaBelle 2005). Patterning in these aspects of the point record—raw material, point morphology, and patterns of breakage, for example—holds further clues for understanding variation in Clovis land sue.

FORM, FUNCTION, AND TECHNOLOGY OF TEXAS CLOVIS POINTS

Raw Material Variation in Texas Clovis Points

Texas Clovis points are made on a variety of raw materials, although fewer than half (42%) can be positively identified to a specific source or type of material (Table 7). In this context, the term 'type' indicates that a material can be classified to a kind of stone (e.g., quartzite or petrified wood) but the precise geological source or formation is unknown. This contrasts with materials that can be assigned to a known source (e.g., Edwards chert, Alibates Agate, and Manning Fused Glass). Although the raw material for over half of the points in the TCFPS is recorded as *unknown*, this does not necessarily mean they are made on unknown materials or even materials different from those listed in Table 7. In most cases, a designation of unknown simply indicates that either the information was not provided by the TCFPS contributor or the material was described but not identified to a particular type. Accordingly, if raw material descriptions were imprecise, we coded those points as unknown. That said, there are points in the TCFPS that truly are made from unknown materials. This is particularly apparent in East Texas and the Trans-Pecos, regions distant from the major Texas stone sources. We suspect that a good number of these points are made from materials derived from geological sources outside Texas.

Of the 229 points identifiable to source or type, Edwards chert accounts for 76%. Based on descriptions provided by contributors to the TCFPS, many of the points listed as unknown in Table 7 probably are Edwards chert as well. The dominance of Edwards chert is not unexpected. The chert-bearing formations of the Edwards uplift cover a substantial portion of Central Texas, with primary outcrops discontinuously scattered over an area covering well over 160,000 square kilometers. Though usually readily recognizable and quite common throughout Texas, Edwards chert is diverse in appearance and chemistry. Importantly, since it outcrops over such a large area, it should not be treated as a single point source. While variations in color, ultraviolet fluorescence (Hofman et al. 1991), isotope chemistry (Roberson 2005), and trace elements (Frederick et al. 1994) offer promise for identifying specific outcrops or variants within the larger formations, this fine-grained resolution is not available for points in the TCFPS. While it can be said that the majority of Clovis points in the TCFPS

Table 7. Count of raw material types by region.

	Region[a]								
Source/type	1	2	3	4	5	6	7	Unknown	Total
Edwards	54	11	11	17	4	0	77	1	175
Alibates	22	2	0	1	0	0	4	1	30
Tecovas	6	1	0	0	0	0	0	0	7
Alibates or Tecovas	2	0	0	1	0	0	0	0	3
Quartzite	4	1	1	1	0	0	0	0	7
Petrified Wood	0	0	2	1	0	1	0	0	4
Obsidian	0	0	0	1	0	0	1	0	2
Manning Fused Glass	0	0	1	0	0	0	0	0	1
Unknown	49	12	59	97	22	7	69	0	315
Total	137	27	74	119	26	8	151	2	544

a. Region designations follow Table 3.

are made from a single material, Edwards chert, in reality these points potentially derive from countless outcrops and secondary deposits scattered across a broad swath of Central Texas.

Other identified raw materials are much less common in the TCFPS. Alibates agatized dolomite, which outcrops in the vicinity of the Canadian River in the northern Panhandle, accounts for 30 Clovis points, or 13% of those identified to type. The remaining raw materials occur in lesser frequencies and include Tecovas jasper, another Southern High Plains source, various types of quartzite and petrified wood, obsidian (including one point base from Kincaid Shelter in Uvalde County linked to a source in central Mexico [Hester 1988]), and Manning Fused Glass from East Texas (Brown 1976).

Despite the limitations in the data on raw material in the TCFPS, some intriguing patterns emerge, particularly for those regions and raw materials with robust samples. For the following analyses, we have collapsed the raw material information into four categories: Edwards chert, Alibates agatized dolomite and Tecovas jasper combined (representing High Plains sources), all other identifiable materials, and unknown or unidentified materials. Table 8 presents a chi square of these revised raw material categories by region, a relationship which is significant. The Trans-Pecos is not included because the low number of points would compromise the validity of the chi square statistic. In any case, seven of the eight points from the region are made from unidentified materials. The McFaddin Beach points also are not included since most are unidentified to raw material and others may be incorrectly identified (Turner and Tanner 1994).

Table 8 shows quite clearly that Edwards chert dominates in Central Texas. It is also common (though not at greater than expected amounts) in the Plains/Panhandle, which is otherwise dominated by points made of Alibates/Tecovas. East Texas, South Texas, and the Coast, in contrast, are significantly under-represented in Edwards and Alibates/Tecovas points, and instead are dominated by a variety of unknown materials. Two possibilities might account for this. First, it seems sensible that

Table 8. Combined raw material groups by region.

Region[a]		Edwards	Alibates/ Tecovas	Other identified	Unknown	Total
1 Plains/Panhandle	count	54	30	4	49	137
	adj. residual	1.0	6.8	.2	-4.8	
2 North Central	count	11	3	1	12	27
	adj. residual	.5	.5	.3	-.9	
3 East	count	11	0	4	59	74
	adj. residual	-4.2	-2.9	1.5	5.1	
4 Coast[b]	count	1	0	2	19	22
	adj. residual	-3.2	-1.5	1.9	3.3	
5 South	count	4	0	0	22	26
	adj. residual	-2.3	-1.6	-.9	3.4	
7 Central	count	77	4	1	69	151
	adj. residual	4.7	-3.2	-1.9	-2.1	
Total		158	37	12	230	437

Chi square = 111.59, df = 15, $p < 0.001$; significant residuals are underlined.

a. The Trans-Pecos has been omitted because of its low point frequency (n=8).

b. Does not include the 97 McFaddin Beach points.

as distance to the Edwards source area increases, Edwards-manufactured points decrease in frequency. A simple distance-decay phenomenon is not unexpected in this sort of situation. Second, it might also be the case that archeologists are less apt to conclude that a point is made from Edwards chert in those areas of Texas distant from the Edwards Plateau, particularly if the archeologists involved are not that familiar with the many varieties of Edwards chert. The opposite likely would occur were the point found in Central Texas: the assumption would be that a point on a questionable material probably is Edwards unless satisfactorily demonstrated otherwise. These factors probably account for the low frequency of Edwards chert points and correspondingly high frequency of unknown materials in South, East, and Coastal Texas (and the Trans-Pecos as well, though it is not included in Table 8).

This is not true in the Plains/Panhandle, however, where points on unknown materials are relatively (and to a statistically significant degree) uncommon. Exposures of high quality raw material of any type are rare on the Southern High Plains, and those that do occur there, like Edwards chert and Alibates agate, are usually readily recognizable (Holliday and Welty 1981). Indeed, these materials account for the majority of Clovis points from the region.

The relative frequency of Edwards and Alibates/Tecovas on the Southern High Plains versus Central Texas is of particular interest, given they are essentially somewhat asymmetrical. On the one hand, both Alibates/Tecovas and Edwards chert occur in greater than expected frequencies on the Southern High Plains and Central Texas, respectively. On the other hand, Alibates/Tecovas is significantly under-represented in Clovis points in Central Texas, while Edwards chert occurs in the statistically expected amounts (that is, it is neither significantly under- nor over-represented) on the Southern High Plains.

A common interpretation of Clovis raw material use on the Southern High Plains is that Clovis groups tracked between high quality sources, in particular the Alibates/Tecovas source areas while in the Panhandle, and the Edwards sources while on the southern fringe of the Plains. This would have supplied them with high quality material as they made their rounds through the extensive areas of the Southern Plains that lack knappable stone. The data in the TCFPS do not support this interpretation, however. Were this the case, we would expect high frequencies of worn and discarded Edwards tools at the Alibates and Tecovas sources, or at least in the northern portion of the Panhandle approaching these source, and a corresponding peak in worn Alibates/Tecovas tools at Edwards sources to the south. A map of the distribution of Clovis points by raw material, however, shows this is not the case (Figure 4).

If these patterns are genuine indications of technological organization among Texas Clovis groups, they reveal that Clovis groups commonly transported Edwards points to the north and northwest onto the High Plains, but they did not bring Alibates/Tecovas to the south and southeast into Central Texas (or other parts of the state) with comparable regularity. The upper map in Figure 4 (Figure 4a) shows the distribution of Clovis points made from Edwards chert by county. Though concentrated in Central Texas and the southern portion of the Southern High Plains—in counties at or near source outcrops—Edwards chert shows up everywhere in the state with the exception of the Trans-Pecos. The abundance and widespread distribution of Edwards chert is not surprising. This high quality material was heavily exploited throughout prehistory and, especially during the Paleoindian period, was commonly transported hundreds of kilometers from Central Texas (Banks 1990).

In contrast, the lower map in Figure 4 (Figure 4b) shows that the combined distribution of High Plains sources—Alibates and Tecovas—is much more restricted than that of Edwards chert. Aside from a light scatter of points across North Central Texas and a few possible Alibates points from McFaddin Beach, they do not show up outside the Southern High Plains, at least in Texas.[6] Furthermore, some of those occurrences south and east of the primary outcrops shown on the map possibly reflect the use of Alibates cobbles carried eastward by the Canadian River. Both Tecovas and Alibates occur as secondary deposits, and possibly even in primary exposures, hundreds of kilometers away from the better described source areas depicted in Figure 4b (e.g., Kraft 1997; Wyckoff 1993).

What is particularly interesting about the distribution of Edwards chert in Figure 4a, however, is that, while common on the Southern High Plains, points made from Edwards chert are restricted to the southern half of the region. In contrast, Alibates/Tecovas is primarily restricted to the northern half. This shows that for the most part points were not transported nearly as far on the Southern High Plains

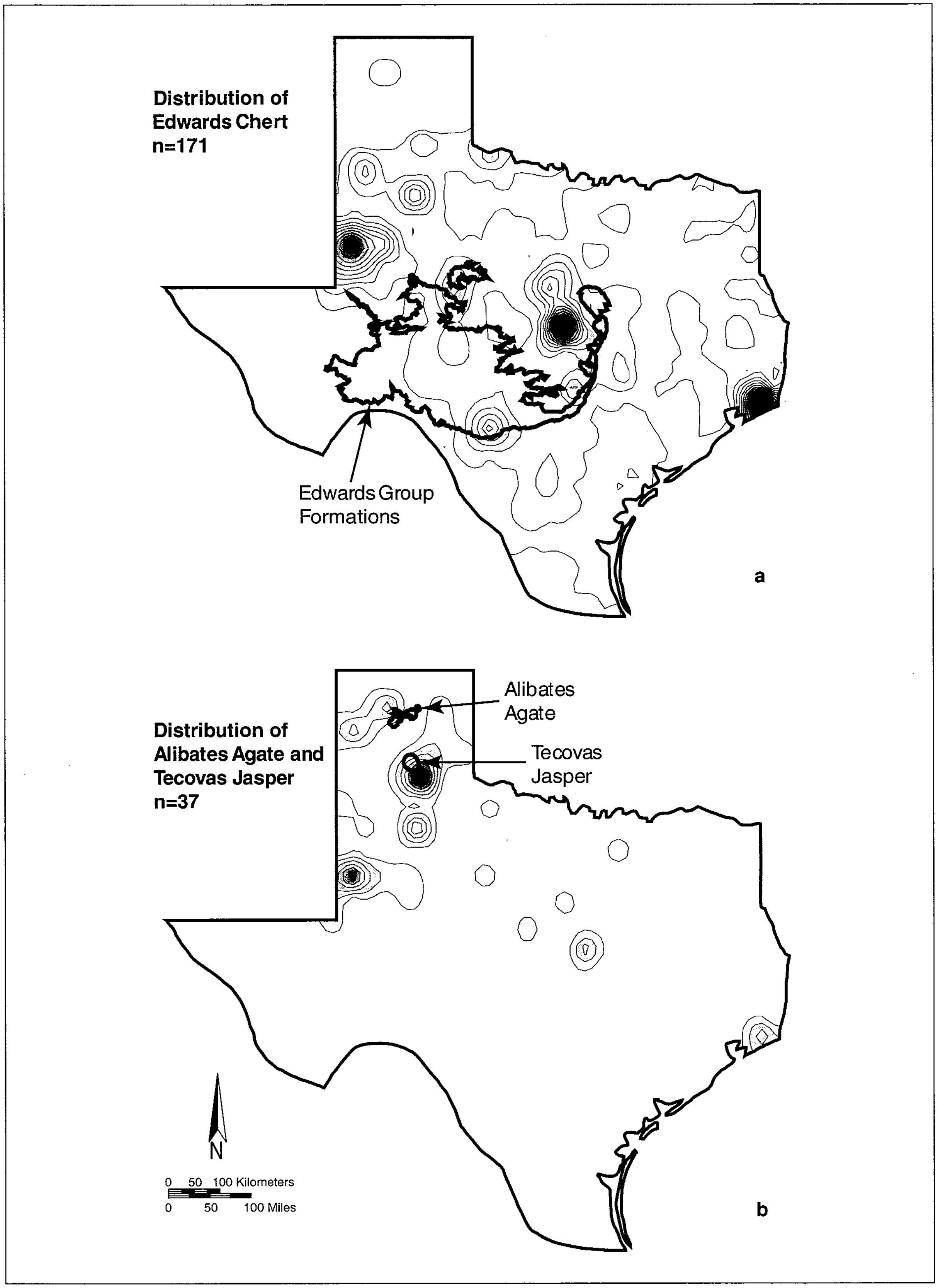

Figure 4. Distribution of Clovis points made on Edwards chert, derived from Central Texas sources (upper figure), and Alibates agate and Tecovas jasper combined, derived from High Plains sources (lower figure).

as is often presumed, a pattern which is masked by the summary data in Table 8. More importantly, the distributions shown in Figure 4 definitely do not support the expectation outlined above of Clovis groups in the Panhandle tracking between the Edwards and Alibates/Tecovas sources. Instead, the minimal overlap between the two distributions suggests that those groups using Alibates/Tecovas restricted their movement to the northernmost portion of the Panhandle and points further north, while those making use of Edwards chert did not move beyond the southernmost portion of the Plains, within 200 km of the Edwards Plateau.

It is not clear that there was strong territoriality during this time in prehistory; indeed, given how relatively few people were likely on the landscape, a strongly territorial posture would have been decidedly disadvantageous. However, given the two apparent spheres of raw material use on the High Plains of Texas (one in the north and one in the south), these groups were clearly starting to form geographic habits and possibly establishing 'home' ranges (similar to processes occurring elsewhere about this time, e.g., Jones et al. 2003). This distinction between a northern and southern sphere on the Southern High Plains manifests itself in other aspects of the TCFPS as well, and will be discussed in more detail in the next section.

Doubtless, other similar pattern in raw material distribution exist in the Texas Clovis point record, but given the coarse level of material identification of many of the points in the TCFPS, these patterns remain hidden. Particularly informative would be a detailed, first-hand examination of raw material characteristics of Clovis points from East Texas. In the absence of more such data, however, we turn to a discussion of Clovis point morphology and the further light it might shed on variation in the Texas Clovis record.

Morphology and Patterns of Breakage in Texas Clovis Points

As mentioned at the outset, one of the more notable developments in Clovis studies in recent years has been the widespread acceptance that Clovis groups were doing different things—adaptively speaking—in different areas of the continent. These differences are reflected in various aspects of the Clovis archeological record writ large: site size, assemblage composition, tool types, and faunal remains (e.g., Cannon and Meltzer 2004; Collins 1999; Ellis and Deller 1997; Meltzer 1993; for a discussion of how this plays out in later Paleoindian times, see Bamforth [2002]). We can see aspects of this adaptive variation within the smaller microcosm of Texas as well. Classic Southern High Plains sites like Miami (Holliday et al. 1994; Sellards 1952), Lubbock Lake (Johnson 1987), and (though technically just beyond Texas' borders) the Clovis type site at Blackwater Draw (Hester 1972) are primarily kill, processing, or scavenging sites. They provide evidence of rather brief, specialized use by Clovis groups. They differ markedly from Clovis sites along the Balcones Escarpment, like Gault (Collins 2002) and Kincaid Shelter (Collins 1990), which were long term or repeat-occupation habitation sites. Evidence of these differences can be seen in the patterns in raw material use and distribution discussed above.

As argued in previous publications on the TCFPS (Meltzer 1986b; Meltzer and Bever 1995), we might expect regional differences like these to show up in point morphology and life histories as well. If Clovis points were an important component of the Clovis toolkit—and there is no reason to think that they were not—it follows that they may have been created and used differently depending on the types of tasks undertaken. As such, variation in Clovis point use, rejuvenation, and breakage might be expected to correspond with regional variation in adaptation. We might also expect point form to display regional variation as a function of stylistic variability corresponding to interaction spheres, ranges, or regions of shared life ways. We explore these issues here, although our discussion is brief since few of our conclusions have changed since the last update.

As with raw material, approximately half of the points in the TCFPS contain a complete or nearly complete set of morphological data, although the counts range widely depending on the variable (Figure 5). Table 9 provides summary statistics for metric and categorical variables recorded in the TCFPS. By all accounts, Texas Clovis points are quite variable in their morphology. However, as shown by the coefficients of variation in Table 9, several attributes vary much more than most, while others show very little variation. Length, of course, is one of the most widely varying measures, due primarily to the effects of breakage and reworking. The distance from the point of maximum width to the base also varies widely; like length, this dimension can be affected by tip reworking, particularly

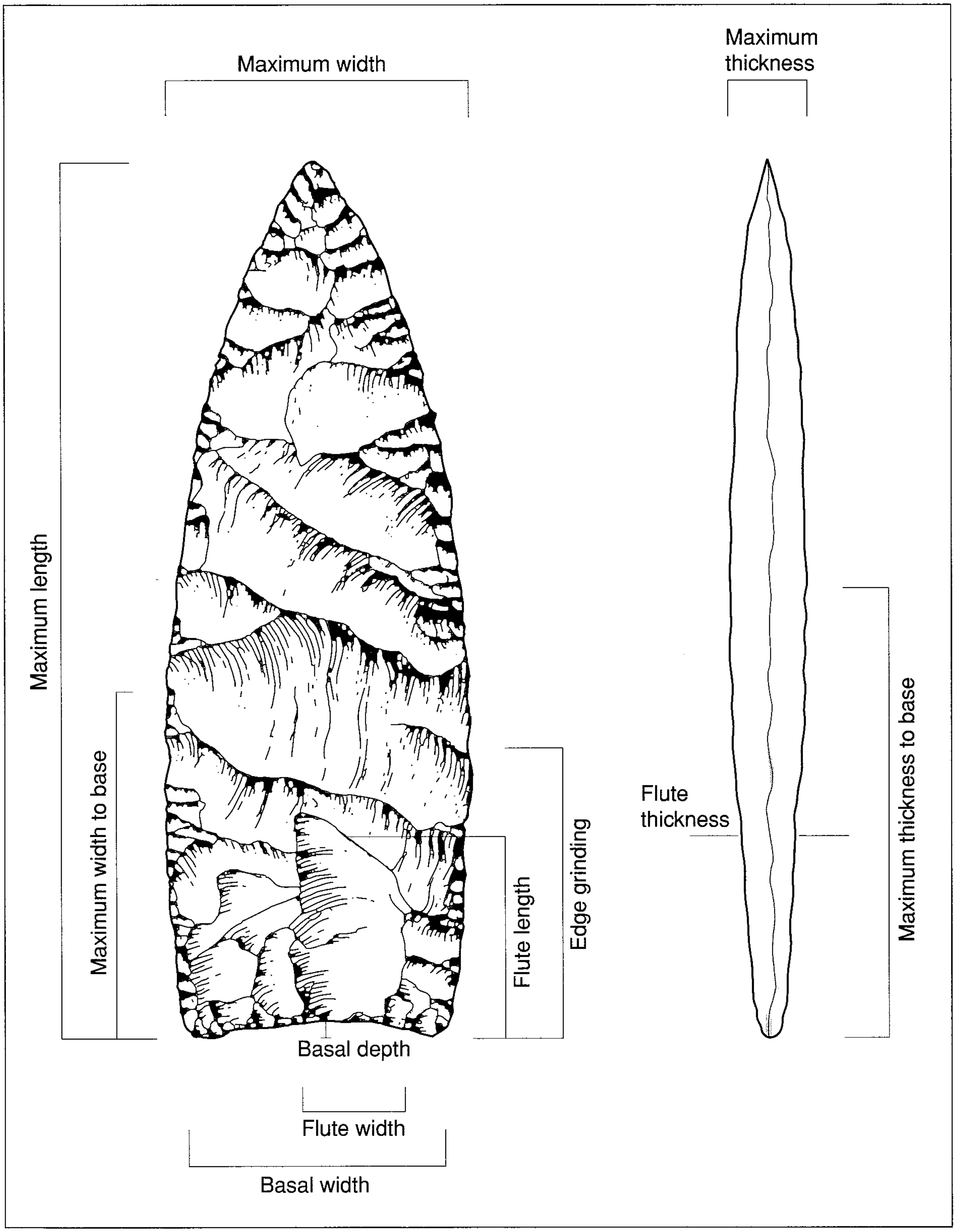

Figure 5. Schematic diagram showing metric attributes recorded on Texas Clovis fluted points.

Table 9. Morphological data for Texas Clovis points.

Variable	No. in database	Mean (cm)	Minimum (cm)	Maximum (cm)	Standard Deviation	Kurtosis	Coefficient of Variation
Maximum length	408	6.50	1.10	16.40	2.69	-.05	41.43
Length (whole points only)[a]	257	7.33	1.64	16.4	2.32	.52	31.69
Maximum width	413	2.80	1.71	6.30	.54	5.11	19.14
Base width	381	2.39	1.38	4.50	.46	1.28	19.14
Maximum width to base	329	3.05	.00	8.13	1.39	.79	45.61
Maximum thickness	397	.74	.30	1.40	.15	1.01	20.20
Flute thickness	92	.57	.16	.94	.13	1.28	23.75
Maximum thickness to base	106	3.76	1.10	7.30	1.15	.30	30.66
Basal concavity	289	.31	.00	.95	.17	.51	54.47
Average length of edge grinding	229	2.62	.65	5.72	.78	1.35	29.57
Average flute length	222	2.52	.27	6.89	.83	2.91	32.99
Average flute width	236	1.35	.57	2.39	.35	.02	25.97

a. While all variables show a difference between the full database and the subsample of whole points, only length has a difference of more than 1-2 mm.

when the point of maximum width is found forward of the hafting elements, as is the case with many Texas Clovis points. For reasons which are unclear, the depth of the basal concavity shows the greatest variation (see Taylor-Montoya, this volume for a similar conclusion regarding later Paleoindian points in Texas). In contrast, width, base width, thickness, and fluting thickness show the least amount of variation (see Table 9). As discussed in previous versions of the TCFPS, most of these attributes pertain to the hafting element of the point. The low degree of variation is probably due to hafting constraints, and specifically the need to manufacture points to fit pre-existing hafts of a specific dimension (an observation first made by Judge [1973]). This implies that the hafting material (perhaps bone or wood) may have been harder to come by than stone, or perhaps the hafts were more difficult to make—relative to fashioning a point, and flaking or grinding it to tight tolerances. As the portion contained within a haft, the suite of basal attributes comprising the haft element are also the least affected by expedient, in-the-haft reworking (see Meltzer and Bever [1995] for a full treatment of this topic). Why basal concavity—seemingly a hafting element as well—is the most variable of attributes is unclear. Perhaps it has little effect on the mechanics of hafting and other aspects of functionality.

Clearly there is substantial variation in the metric dimensions of Clovis points. This comes as no surprise, however: a casual glance at any collection of more than a few Clovis points will confirm the truth of this. Clovis sites that have produced multiple points (e.g., Miami [Sellards 1952], Blackwater Draw [Hester 1972], and Gault [Collins 2002]), including those reflecting a single event (like Naco in Arizona [Haury et al. 1953]), show appreciable variation in raw material, degree of reworking, and overall size. A more appropriate question to ask of the TCFPS, then, is whether co-variation in certain attributes are patterned in such a way that discrete sub-groups can be identified. In exploring the correlation between different metric variables in the TCFPS, it quickly becomes apparent that the overall shape of Clovis points actually is quite homogenous. With the exception of basal concavity, all

Table 10. Point breakage by region.

Region		Whole (including reworked)	Basal portion	Tip or midsection	Preform	Total
1 Plains/Panhandle	count	92	27	5	0	124
	adj. residual	.5	.8	-1.2	-1.8	
2 North Central	count	17	5	3	1	26
	adj. residual	-.8	.0	1.1	.8	
3 East	count	36	14	6	0	56
	adj. residual	-1.5	1.1	1.4	-1.1	
4 Coast	count	56	5	7	0	68
	adj. residual	2.0	-2.7	1.5	-1.2	
5 South	count	19	5	0	0	24
	adj. residual	.8	.2	-1.3	-.7	
6 Trans-Pecos	count	4	2	0	0	6
	adj. residual	-.3	.9	-.6	-.3	
7 Central	count	97	28	7	7	139
	adj. residual	-.9	.3	-.8	3.5	
Total		321	86	28	8	443

Chi square = 30.46, df = 18, p = 0.033; significant residuals are underlined.

metric measures in the TCFPS correlate significantly with each other. Rather than true variation in form, the dominant pattern seems to reflect a single size-scaled trajectory. Further, the range of variation along this trajectory is continuous, with no discernable breaks or gaps. Longer points tend to be wider, thicker, and have wider bases, longer and wider flutes, and longer ground edges. Points with wider bases also tend to have more flutes on average, and deeper basal concavities, although basal concavity and flute form are some of the more freely varying attributes in Texas Clovis points. Similarly, shorter (or narrower or thinner) points are proportionally smaller in all attributes. In this regard, little has changed in the current version of the TCFPS and we refer readers to the previous report (Meltzer and Bever 1995) for a more detailed discussion of the fine-grained variation in Texas Clovis points.

What we wish to convey here is that this variation in size is neither unusual nor unexpected, and despite our efforts (here and in earlier articles) to explore the data using various quantitative clustering, data reduction and classification techniques, and to partition the database in different ways (e.g., by region or raw material), we have been unable to discern meaningful morphological variation in the TCFPS. At most, there is minor variation in point size between some regions. For example, in South Texas, points tend to be shorter and narrower, which is not surprising given the scarcity of large nodules of good quality raw material in the region. In contrast, points from Central Texas, East Texas, and the coast (primarily McFaddin Beach) tend to be slightly larger, as do points manufactured from Edwards chert regardless of where they are found. Again, much of this likely has to do with the quality and size of available raw material. In any case, none of this variation is statistically significant. While regional (and possibly temporal) variation might be present in variables not recorded in the TCFPS, like the presence of basal "ears," for example, or flaking and fluting technology (see Collins 1999; Collins et al., this volume), we suspect these differences will be expressed in degree rather than kind. But perhaps this is not surprising: viewed on a continental scale, there are clear differences in the morphology of Clovis and related forms (as, for example, Colby and Gainey fluted points). That variation likely bespeaks alterations in form due in part to the effects of use and re-sharpening of the points, but also to the divergence of populations and knapping styles and techniques over time and space. Think of it as a kind of cultural "drift," as kin and descendants experimented with and introduced their own variations on the Clovis theme (Meltzer, in press). But that is on a continental scale: on a smaller scale, the variation is less apparent.

While we find little evidence of morphological patterning in the TCFPS database, there is more insight to be had from an examination of point life histories as identified by breakage and reworking. Table 10 shows breakage categories by region. Although the chi square statistic is significant at the .05 level, this significance must be viewed with caution since over half the cells in the table have expected frequencies less than five. The adjusted residuals are most informative here and show that, in general, breakage does not vary significantly between most regions. For reasons that may have to do with collector preferences along McFaddin Beach, whole points are more common and basal portions less common than expected along the coast. More readily meaningful is the higher than expected frequency of preforms in Central Texas. In one regard this is to be expected. Given the abundance of high quality Edwards chert in the area, many of the sites found there are quarries and workshops (e.g., Pavo Real [Collins et al. 2003], Gault [Collins 2002], and Yellowhawk [Mallouf 1989]). It is also worth noting that the TCFPS only contains preforms that have been fluted, for obvious reasons having to do with identification. The pattern nevertheless provides further confirmation that Clovis habitation of the Central Texas region differed in a number of ways from other areas of Texas.

Aside from these few deviations, however, the basic picture in Table 10 shows that most of the points in the TCFPS are complete or nearly complete specimens. Considering the source of the majority of the sample—private collections—the high frequency of whole points is not unexpected. Also, the low frequency of tips and midsections (see Table 10) can be explained by the fact that only whole or basal portions retaining flute scars are typically identified as Clovis points. While flaking pattern may be an equally valuable criterion for identifying Clovis bifacial technology (see Collins et al., this volume), it does not factor into the identification of Clovis points in the TCFPS.

One final pattern of note is the incidence of reworking and impact fractures in the TCFPS. Table 11 shows that reworked points are present on the Southern High Plains in greater than expected frequencies, while unreworked whole points are less common than expected. This fits well with the notion that groups on the Southern High Plains conserved raw material as they ranged across areas devoid of tool stone. In contrast, Central Texas shows a lower than expected frequency of reworking, due no doubt to the abundance of high quality raw material in the area and the correspondingly less pressing need to conserve material. Both of these patterns fit with the interpretation offered in the preceding section whereby two distinctly different patterns of raw material and probably landscape use were identified on the Southern High Plains and in Central Texas.

Also apparent in Table 11 is the fact that impact fractures are extremely rare in the database–and, for that matter, in Clovis points across North America–and are almost entirely restricted to the Southern High Plains and Central Texas. Impact fractures occur when stone meets bone at high velocity. Their scarcity in most areas, and presence in others, are further hints to differences in the use of this technology.

Focusing further on the Southern High Plains, there are also interesting differences in reworking by raw material. Although a chi square statistic of the overall relationship between reworking and raw material is not significant, adjusted residuals show that several deviations are significant. Specifically, on the Southern High Plains, Alibates/Tecovas points show a significantly higher incidence of reworking than expected, while points on Edwards chert in the same region show a lower than expected frequency of reworking. In the preceding section on raw material distributions, it was noted that Alibates/Tecovas Clovis points are largely restricted to the northern portion of the Panhandle while Edwards Clovis points are restricted to the southern portion. Two zones of raw material use (reflective of Clovis group mobility and organization?) were identified on the Southern High Plains. It now appears that those groups in the northern sphere, relying heavily on Alibates agate, Tecovas

Table 11. Reworking and impact fractures by region.

Region		Whole	Reworked	Impact fractured[a]	Total
1 Plains/Panhandle	count	61	31	6	98
	adj. residual	-2.9	2.8	.6	
2 North Central	count	12	5	0	17
	adj. residual	-.2	.8	-1.0	
3 East	count	24	12	1	37
	adj. residual	-1.2	1.6	-.7	
4 Coast	count	52	4	1	57
	adj. residual	3.4	-3.0	-1.2	
5 South	count	12	7	0	19
	adj. residual	-1.0	1.6	-1.0	
6 Trans-Pecos	count	4	0	1	5
	adj. residual	.4	-1.2	1.5	
7 Central	count	82	15	8	105
	adj. residual	1.4	-2.3	1.5	
Total		247	74	17	338

Chi square = 30.57, df = 12, p = 0.002; significant residuals are underlined.

a. All impact fractured points in the database are also reworked. In most instances, combining the two categories of reworked points has the effect of amplifying significant deviations.

jasper, and as yet unidentified materials, ranged more widely into raw material-poor areas, relying on conservation and heavy reuse of projectile points. Groups occupying the southern sphere, by contrast, appear to have been less concerned with raw material conservation, and may have had more ready access to Edwards chert sources along the southern periphery of the Plains. Though also occupying an area devoid of raw material, the pattern in the southern portion of the Plains differs appreciably from that in the northern portion, and both are distinct from the patterns seen in the raw material-rich zones of Central Texas. Importantly, these fine distinctions in raw material and landscape use between Central Texas and the northern and southern portions of the South High Plains—whatever they might ultimately represent—are not manifest in 'stylistic' aspects of point form. Rather, they only become apparent through a close examination of several lines of evidence. Unfortunately, the TCFPS currently lacks the quality of data needed to search for similar patterns of variation in other areas of the state, though it seems they likely exist.

SUMMARY AND CONCLUSIONS

Briefly, conclusions of note in this latest version of the TCFPS include the following:

1) The TCFPS currently contains 544 points, reflecting an increase of 138 points since 1995, and 339 points since 1986. Thirty-three new counties have been added to the database, and 149 of Texas' 254 counties have produced at least one point. Now over 20 years old, growth in the TCFPS appears to have reached a plateau, indicating that the database probably provides a fairly representative sample of the known Clovis point record. The relative frequencies of points by region have changed little since the last version, and patterns in raw material and morphological variation remain virtually unaffected. We suspect that future growth in the database will not significantly alter the general patterns identified here. That said, the continued addition of new points can only

help to fine tune and strengthen these patterns, and is a worthwhile goal.

2) Three regions of the state—the Southern High Plains; East Texas; and the northern, eastern and southeastern periphery of the Edwards Plateau in Central Texas—show the greatest frequency (and density) of Clovis points in the state. The prairies and savannahs of North Central Texas and the Coastal Plain have relatively fewer points, but we suspect that, as predominantly fluvial environments, Clovis-aged deposits in these areas are either deeply buried or entirely eroded. In contrast, the absence of points from the Trans-Pecos and South Texas may be a real phenomenon, meaning that these areas experienced relatively sparse habitation by Clovis groups. McFaddin Beach remains an enigma, and will likely stay that way until the source (sources?) of these points is found.

3) The statewide distribution of Clovis sites generally mirrors that of Clovis points. However, determining whether concentrations of Clovis materials—whether sites, isolated points, or points found in sites—indicate that these areas were attractive to Clovis groups, or that they simply are areas with preserved (and exposed) Clovis-aged deposits, is a difficult issue to resolve. Regardless, two lines of Clovis site evidence—the context of points in the TCFPS and an independent database of officially recorded Clovis sites—show that the structure of the Clovis record differs regionally. Most notably, the Southern High Plains has a record dominated by isolated Clovis points, while Central Texas has a site-dominated record. North Central Texas and the Coast also show interesting deviations that seem to indicate that, although site-dominated like Central Texas, Clovis sites in these areas generally contain very few points. These patterns have clear implications for variation in Clovis land use. Contrary to the general belief that the Clovis way of life consisted of small groups of highly-mobile hunter-foragers leaving behind an ephemeral archeological record (perhaps as exemplified by the Clovis record on the Southern High Plains), it appears that in certain places, like Central Texas and maybe East Texas, Clovis groups engaged in the types of activities that left a structured, site-based archeological record.

4) Fully 76% of the points in the TCFPS that can be identified to raw material are made from Edwards chert. Alibates agate comes in a distant second. However, since fewer than half of the points in the TCFPS can actually be identified to raw material, it probably is premature to conclude that Edwards chert dominates the Texas Clovis point record, at least in all areas of the state. Furthermore, the certainty with which Edwards chert can be identified seems to decline as one moves away from Central Texas. This severely limits the information that can be gained from an examination of raw material in those areas outside Central Texas (and the Southern High Plains to a lesser degree).

5) Given these limitations, detailed observations of raw material use are restricted to Central Texas and the Southern High Plains. The patterns that emerge are suggestive, however. It appears there were two spheres of raw material use on the Southern High Plains: one in the northern portion of the Panhandle focused on the use of Alibates agate, and one in the south making use of Edwards chert (presumably derived from outcrops along the northern fringe of the Edwards Plateau). There is little overlap between the two raw material distributions, and there is no support for the notion that Clovis groups tracked between these two source areas as they ranged across the Southern Plains.

6) Only in the northern portion of the Southern High Plains is there evidence for pronounced conservation of raw material as reflected by a high incidence of point reworking. Groups to the south seem to have had more reliable access to Edwards source areas. Finally, in Central Texas, with its abundant sources of raw material, the incidence of reworking is significantly lower than elsewhere in the state and, not surprisingly, direct evidence of point production—in the form of preforms—is most common.

7) Despite substantial variation in the size of Clovis points (some of which is no doubt due to reworking), variation in virtually all metric attributes is scaled and continuous, and we find no clear evidence of morphological subgroups within the TCFPS. The variation that

is present seems to relate primarily to the nature and availability of tool stone. Even variation in size shows only subtle and statistically insignificant patterning by region. Indeed, both small and large points are found in all regions. Of course, it is possible that meaningful variation might exist in attributes not recorded in the TCFPS, or that 'stylistic' variants, if such exist, do not correspond to the environmental regions used here (as, indeed, they might not). Ultimately, getting a better handle on Clovis adaptive variation requires that we go beyond the projectile points themselves, and look more broadly at tool kits, particularly as they might occur in habitation sites like Gault where—by virtue of longer periods of occupation and greater numbers of activities—a wider range of tool classes would be expected. But for that, we need more sites.

Indeed, this exploration of the TCFPS highlights several gaps in our knowledge of the Texas Clovis record that beg for focused research and data collection. These concern topics that, had we more knowledge of them, would make the TCFPS a more robust tool for asking meaningful questions. Though the list could be nearly endless, we limit ourselves to a few areas of research that spring most directly from the themes explored in this article:

1) More work could be done with raw material identification and sourcing. As seen, one of the more fruitful lines of evidence in the TCFPS relates to the raw material characteristics of Clovis points. In Central Texas and the Southern High Plains, areas where raw materials are rather more reliably identifiable, we were able to identify detailed and behaviorally meaningful patterns. A better understanding of raw materials outside of Central Texas would go a long way toward identifying similar variation in Clovis land use across the state. This is particularly true for East Texas, which has a robust sample of Clovis points but where so many points in the TCFPS are tabulated as raw material 'unknown.' Even knowing with confidence which points are made from Edwards chert and which are not would be quite valuable. The work would, of course, require exploration of raw material sources outside the state. It is also worth stressing that more could be learned about Central Texas raw material sources as well, including a better understanding of chemical, visual, and fluoroscopic variation within the quite complex chert-bearing formations of the Edwards Plateau.
2) It would be worthwhile examining more closely those regions in Texas with a scarcity of Clovis points (and sites). Specifically, it would be useful to know whether the lack of points in these areas is due to issues of preservation and discovery, or to an actual scarcity of Clovis habitation. Is it true that Clovis-aged deposits are deeply buried in North Central Texas and along the coastal prairie? If so, how might we efficiently explore those deposits for evidence of Clovis occupation? Along the same lines, if the absence of points in South Texas and the Trans-Pecos truly does reflect an absence of Clovis habitation, then what was it about these areas that was unattractive to humans at the close of the Pleistocene?
3) It has become increasingly clear in recent years that the Southeastern Woodlands of the United States hold a rich record of Clovis habitation. Despite this, little is known of Clovis adaptations in this vast area. The current version of the TCFPS demonstrates that the Texas portion of the Southeastern Woodlands has a rich Clovis record as well. However, while Clovis points have been found in site contexts, not a single Clovis site has been thoroughly excavated and documented in East Texas (Fields 2004; Perttula 2004; Story 1990). While we continue to refine our understanding of Clovis in the better studied areas of the Southern High Plains and Central Texas, our understanding of Clovis lifeways in the east remains woefully underdeveloped. While it is all too easy to call for the discovery and excavation of more Clovis sites in good context, it is true that concerted efforts in East Texas, resulting in even a modicum of success, would go a long way towards rectifying a major deficiency in our understanding of Clovis archeology.

Point databases such as the TCFPS provide valuable insight into Clovis prehistory. We undertook this revision on the TCFPS partly in response to the many changes that have taken place in Clovis archeology over the past decade. As the TCFPS has continued to grow and develop into a robust source of information, we have found that its greatest value is as a tool for asking pointed questions about the technology, adaptive strategies, and life ways of Clovis hunter-gatherers. Future developments in the field of Clovis archeology will no doubt point to new questions that can be asked of the TCFPS, and new ways to use it more productively.

Although we do not expect the basic patterns in the TCFPS to change substantially in future versions, we do intend to continue adding points to the database and to refine the quality of the data it contains. At the end of this article is the standard TCFPS recording form (metric variables correspond to those shown in Figure 5). A digital version of the form can also be obtained by contacting either of the authors. To facilitate its use as a research tool, we have made the TCFPS database available online at http://www.smu.edu/anthro/faculty/dmeltzer/research.htm. We encourage the members of the Texas archeological community to continue to submit information on Clovis points, and we encourage other researchers to continue to explore, in new and productive ways, the Clovis Paleoindian occupation of Texas.

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END NOTES

1. Region divisions are the same as those used in previous versions of the TCFPS and follow Suhm et al. (1954), with modifications from Arbingast et al. (1976) and Brown et al. (1982). The seven regions are shown in Figure 1.

2. We conducted multiple keywords searches of the online database, the most productive being those using "Clovis" and "Fluted."

3. The slight mismatch between peaks in point density and Clovis site locations in Figure 3 results from the way in which provenience was recorded in the two databases. Clovis points in the TCFPS are recorded by county, and the contour map uses the centroid of the county as the coordinate for each tally. In contrast, Clovis sites are precisely plotted by latitude and longitude.

4. The same holds true for point and site density by county.

5. It has also been suggested that some of the points from Gaines County may be well-made, modern forgeries, thereby accounting for the unusually high frequency of points from that county. Since we have not examined all of the points firsthand, we cannot evaluate the veracity of this claim. We do acknowledge that a small number of points in the TCFPS may very well be forgeries.

6. While Alibates Paleoindian points are rare south of the Southern High Plains, their occurrence to the north of Texas in the central Plains is well documented, as, for example, in the Drake Clovis cache, which occurs more than 400 km north of the Alibates source (Stanford 1999).

REFERENCES CITED

Alexander, H. J.
1963 The Levi Site: A Paleo-Indian Campsite in Central Texas. *American Antiquity* 28:510-528.

Amick, D. S. and J. L. Hofman
1999 Joe Ben Wheat's Investigations at Chispa Creek in Trans-Pecos, Texas. *Current Research in the Pleistocene* 16:3-5.

Anderson, D. G. and M. Faught

2000 Palaeoindian Artifact Distribution: Evidence and Implications. *Antiquity* 74:507-513.

Arbingast, S. A., L. G. Kennamer, R. H. Ryan, J. R. Richardson, W. L. Hezlep, L. T. Ellis, T. G. Jordan, C. T. Cranger, and C. P. Zlatkovich

1976 *Atlas of Texas*. Bureau of Business Research, The University of Texas at Austin.

Bamforth, D.

2002 High-tech Foragers? Folsom and Later Paleoindian Technology on the Great Plains. *Journal of World Prehistory* 16:55-98.

Banks, L. D.

1990 *From Mountain Peaks to Alligator Stomachs: A Review of Lithic Sources in the Trans-Mississippi South, the Southern Plains, and Adjacent Southwest.* Memoir No. 4. Oklahoma Anthropological Society, Oklahoma City.

Birmingham, W. W. and T. R. Hester

1976 Late Pleistocene Archaeological Remains from the Johnston-Heller Site, Texas Coastal Plain. In *Papers on Paleo-Indian Archaeology in Texas*, edited by T. R. Hester, pp. 15-33. Special Report 3. Center for Archaeological Research, University of Texas at San Antonio.

Black, S. L.

1989 South Texas Plains. In *From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos, Texas*, by T. R. Hester, S. L. Black, D. G. Steele, B. W. Olive, A. A. Fox, K. J. Reinhard, and L. C. Bement, pp. 39-62. Research Series No. 33. Arkansas Archeological Survey, Fayetteville.

Bonnichsen, R., B. T. Lepper, D. Stanford, and M. Waters (editors)

2006 *Paleoamerican Origins: Beyond Clovis.* Center for the Study of the First Americans, Texas A&M University Press, College Station.

Bousman, C. B., B. W. Baker, and A. C. Kerr

2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Brown, K.M.

1976 Fused Volcanic Glass from the Manning Formation. *Bulletin of the Texas Archeological Society* 47:189-207.

1994 Four Clovis points from San Augustine County, Texas. *La Tierra* 21:24-39.

Brown, T., K. Killen, H. Simons, and V. Wulfkuhle

1982 *Resource Protection Planning Process for Texas.* Texas Historical Commission, Austin.

Buchanan, B.

2003 The Effects of Sample Bias on Paleoindian Fluted Point Recovery in the United States. *North American Archaeologist* 24:311-338.

Byerly, R. M., J. R. Cooper, D. J. Meltzer, M. E. Hill, and J. M. LaBelle

2005 On Bonfire Shelter (Texas) as a Paleoindian Bison Jump: An Assessment Using GIS and Zooarchaeology. *American Antiquity* 70:595-629.

Byers, D. A. and A. Ugan

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.

Cannon, M. D. and D. J. Meltzer

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.

Chandler, C.K.

1982 Paleo-Indian Projectile Points from San Patricio County, Texas. *La Tierra* 9(3): 26-28.

1983 Paleo-Indian Projectile Points from Kendall County, Texas. *La Tierra* 10(4):36-37.

Chandler, C.K. and D. Rogers

1995 Clovis Points from Montgomery and Brazoria Counties in Southeast Texas. *La Tierra* 22(4):12-14.

Collins, M. B.

1990 The Archaeological Sequence at Kincaid Rockshelter, Uvalde County, Texas. *Transactions of the 25th Regional Archeological Symposium for Southeastern New Mexico and Western Texas*, edited by P. Brothers, pp. 25-33. Midland Archeological Society, Midland.

1999 *Clovis Blade Technology*. The University of Texas Press, Austin.

2002 The Gault site, Texas, and Clovis Research. *Athena Review* 3:31-41.

Collins, M. B., C. B. Bousman, P. Goldberg, P. Takac, J. Guy, J. L. Lanata, T. W. Stafford, and V. T. Holliday

1993 The Paleoindian Sequence at the Wilson-Leonard Site, Texas. *Current Research in the Pleistocene* 10:10-12.

Collins, M. B., G. E. Evans, T. N. Campbell, M. C. Winans, and C. E. Mear

1989 Clovis Occupation at Kincaid Shelter, Texas. *Current Research in the Pleistocene* 6:3-4.

Collins, M. B., T. R. Hester, and P. Headrick

1992 Engraved Cobbles from the Gault Site, Central Texas. *Current Research in the Pleistocene* 9:3-4.

Collins, M. B., T. R. Hester, D. Olmstead, and P. Headrick
1991 Engraved Cobbles from Early Archaeological Contexts in Central Texas. *Current Research in the Pleistocene* 8:13-15.

Collins, M. B., D. B. Hudler, and S. L. Black
2003 *Pavo Real (41BX52): A Paleoindian and Archaic Camp and Workshop on the Balcones Escarpment, South-Central Texas.* Studies in Archeology 41, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeological Studies Program, Report 50, Environmental Affairs Division, Texas Department of Transportation, Austin.

Cooper, B.
1974 A Fluted Point from McMullen County, Texas. *La Tierra* 1(3):18.

Crook, W. W. and R. K. Harris
1955 Scottsbluff Points in the Obshner Site near Dallas, Texas. *Bulletin of the Texas Archeological Society* 26:75-100.
1957 Hearths and Artifacts of Early Man near Lewisville, Texas, and Associated Faunal Material. *Bulletin of the Texas Archeological Society* 28:7-97.

Dibble, D. and D. Lorrain
1968 *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas.* Miscellaneous Papers 1. Texas Memorial Museum, The University of Texas at Austin.

Espey, Huston and Associates, Inc.
1981 *A Cultural Resource Inventory and Assessment of the Proposed Stacy Reservoir, Concho, Coleman, and Runnels Counties, Texas.* 3 Vols. Espey, Huston and Associates, Inc., Austin.

Ellis, C. J. and D. B. Deller
1997 Variability in the Archaeological Record of Northeastern Early Paleoindians: A View from Southern Ontario. *Archaeology of Eastern North America* 25:1-30.

Ellis, L., G. L. Ellis, and C. Frederick
1995 Implications of Environmental Diversity in the Central Texas Archeological Region. *Bulletin of the Texas Archeological Society* 66:401-426.

Enlow, D. and T. N. Campbell
1955 Some Paleo-Indian Projectile Points from the Southeastern Periphery of the Great Plains. *The Panhandle-Plains Historical Review* 28:29-38.

Etchieson, G., R. Speer, and J. Hughes
1979 *Archaeological Investigations in the Crowell Reservoir Area, Cottle, Foard, King, and Knox Counties, Texas.* Report submitted to the U.S. Army Corps of Engineers, by the Archaeological Research Laboratory, Killgore Research Center, West Texas State University, Canyon, Texas.

Ferring, C. R.
1990 The 1989 Investigations at the Aubrey Clovis Site, Texas. *Current Research in the Pleistocene* 10:10-12.
2001 *The Archaeology and Paleoecology of the Aubrey Clovis Site (41DN479), Denton County, Texas.* Center for Environmental Archaeology, University of North Texas, Denton.

Fields, R. C.
2004 The Archeology of the Post Oak Savanna of East-Central Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 347-369. Texas A&M University Press, College Station.

Frederick, C., M. D. Glascock, H. Neff, and C. M. Stevenson
1994 *Evaluation of Chert Patination as a Dating Technique: A Case Study from Fort Hood, Texas.* Research Report No. 32. Archeological Resource Management Series. U.S. Army, Fort Hood.

Grayson, D. K. and D. J. Meltzer
2002 Clovis Hunting and Large Mammal Extinction: A Critical Review of the Evidence. *Journal of World Prehistory* 16:313-359.

Greer, J. W.
1968 Some Unusual Artifacts from Val Verde County, Texas. *Texas Journal of Science* 20:183-192.

Hall, D.
1998 Clovis Site on Gulf Coast Yields Booty Only to Waves: Highway Project Focuses New Interest on McFadden Beach. *Mammoth Trumpet* 13(4):7-12.

Haury, E. W., E. Antevs, and J. Lance
1953 Artifacts with Mammoth Remains, Naco, Arizona. *American Antiquity* 19:1-24.

Hayner, E. W.
1955 Research in East Texas Projectile Points. *Bulletin of the Texas Archeological Society* 26:235-243.

Haynes, C. V.
1982 Were Clovis Progenitors in Beringia? In *Paleoecology of Beringia*, edited by D. M. Hopkins, J. Matthews, C. Schweger, and S. Young, pp. 383-398. Academic Press, New York.
1995 Geochronology of Paleoenvironmental Change, Clovis Type Site, Blackwater Draw, New Mexico. *Geoarchaeology* 10:317-388.

Hays, T.
1982 *Archaeological Investigations of the San Gabriel Reservoir Districts, Central Texas.* Volume 1. Institute of Applied Sciences, North Texas State University, Denton.

Henderson, J. and G. Goode
1991 Pavo Real: An Early Paleoindian Site in South-Central, Texas. *Current Research in the Pleistocene* 8:26-28.

Hester, J.

1972 *Blackwater Locality No. 1: A Stratified Early Man Site in Eastern New Mexico.* Fort Burgwin Research Center, Dallas.

Hester, T. R.

n.d A Distributional Study of Paleo-Indian Projectile Point Types in Texas. Unpublished paper, on file with the author (prepared 1967).

1974 On Fluted Points and South Texas Archaeology. *Texas Archaeology* (The Newsletter of the Texas Archeological Society) 18(2):11-14.

1980 A Survey of Paleo-Indian Archaeological Remains along the Texas Coast. In *Papers on the Archaeology of the Texas Coast*, edited by L. Highly and T. R. Hester, pp. 1-12. Special Report No. 11. Center for Archaeological Research, The University of Texas at San Antonio.

1988 Paleoindian Obsidian Artifacts from Texas: A Review. *Current Research in the Pleistocene* 5:27-29.

2004 The Prehistory of South Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 127-151. Texas A&M University Press, College Station.

Hofman, J. L., L. W. Todd, and M. B. Collins

1991 Identification of Central Texas Edwards Chert at the Folsom and Lindenmeier Sites. *Plains Anthropologist* 36:297-308.

Holliday, V. T.

1995 *Stratigraphy and Paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains.* Memoir 186. Geological Society of America, Boulder.

1997 *Paleoindian Geoarchaeology of the Southern High Plains.* University of Texas Press, Austin.

Holliday, V. T., C. V. Haynes, J. L. Hofman, and D. J. Meltzer

1994 Geoarchaeology and Geochronology of the Miami (Clovis) Site, Southern High Plains of Texas *Quaternary Research* 41:234-244.

Holliday, V. T. and C. Welty

1981 Lithic Tool Resources of the Eastern Llano Estacado. *Bulletin of the Texas Archeological Society* 52:201-214.

House, K.

1974 A Paleo-Indian Fluted Point from Live Oak County, Texas. *The Texas Archeological Society Newsletter* 18(1):17-19.

Jablonski, N. (editor)

2002 *The First Americans: The Pleistocene Colonization of the New World.* Memoir No. 27. California Academy of Sciences, San Francisco.

Jensen, H.

1968 Report on Excavations at the Field Ranch Site (X41CO-10), Cooke County, Texas. *Bulletin of the Texas Archeological Society* 39:133-146.

Johnson, E.

1983 The Lubbock Lake Paleoindian Record. In *Guidebook to the Central Llano Estacado*, edited by V.T. Holliday. Center for Arid Land Studies, Lubbock.

Johnson, E. (editor)

1987 *Lubbock Lake: Late Quaternary Studies on the Southern High Plains.* Texas A&M University Press, College Station.

Johnson, L.

1961 The Yarbrough and Miller Sites of Northeastern Texas, with a Preliminary Definition of the La Harpe Aspect. *Bulletin of the Texas Archeological Society* 32:141-284.

Jones, G. T., C. Beck, E. Jones, and R. Hughes

2003 Lithic Source Use and Paleoarchaic Foraging Territories in the Great Basin. *American Antiquity* 68:5-38.

Judge, W. J.

1973 *Paleoindian Occupation of the Central Rio Grande Valley in New Mexico.* University of New Mexico Press, Albuquerque.

Kelly, T. C.

1983 The Brom Cooper Paleo-Indian Collection from McMullen County, Texas. *La Tierra* 10(3):17-40.

Kraft, K. C.

1997 The Distribution of Alibates Silicified Dolomite Clasts along the Canadian River. *Current Research in the Pleistocene* 14:106-109.

LaBelle, J. M.

2005 Hunter-Gatherer Foraging Variability During the Early Holocene on the Central Plains of North America. Ph.D. dissertation, Department of Anthropology, Southern Methodist University, Dallas.

Long, R. J.

1977 *McFaddin Beach.* The Patillo Higgins Series of Natural History and Anthropology, Number 1. Spindletop Museum, Lamar University, Beaumont.

Madsen, D. (editor)

2004 *Entering America: Northeast Asia and Beringia before the Last Glacial Maximum.* University of Utah Press, Salt Lake City.

Mallouf, R. J.

1989 A Clovis Quarry Workshop in the Callahan Divide: the Yellow Hawk Site, Taylor County, Texas. *Plains Anthropologist* 34:81-103.

Meier, C. J. and T. R. Hester

1972 Notes on the Meier Site, Fayette County, Texas. *Bulletin of the Lower Plains Archeological Society* 3:69-72.

1976 Paleo-Indian Artifacts from the Meier Site, Southeast Texas. *La Tierra* 3(1):16-19.

Meltzer, D. J.

1986a A Study of Texas Clovis Points. *Current Research in the Pleistocene* 3:33-36.

1986b The Clovis Paleoindian Occupation of Texas: Results of the Texas Clovis Fluted Point Survey. *Bulletin of the Texas Archeological Society* 57:27-68.

1989 An Update on the Texas Clovis Fluted Point Survey. *Current Research in the Pleistocene* 6:31-33.

1993 Is There *a* Clovis Adaptation? In *From Kostenki to Clovis: Upper Paleolithic—Paleo-Indian Adaptations*, edited by O. Soffer and N. Praslov, pp. 293-310. Plenum Press, New York

In press *American Origins: Colonizing the Ice Age Continent.* University of California Press, Berkeley.

Meltzer, D. J. and M. R. Bever

1995 Paleoindians of Texas: An Update on the Texas Clovis Fluted Point Survey. *Bulletin of the Texas Archeological Society* 66:17-51.

Miller, M. R. and N. A. Kenmotsu

2004 Prehistory of the Jornada Mogollon and Eastern Trans-Pecos Regions of West Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 205-265. Texas A&M University Press, College Station.

Mitchell, J. B. and J. Winsch

1973 A Paleo-Indian Point from South Texas. *Ohio Archeologist* 23(2):9.

Orchard, C. and T. Campbell

1954 Evidences of Early Man from the Vicinity of San Antonio, Texas. *Texas Journal of Science* 4:454-465.

Patterson, L. W.

1986 Site 41HR571, a Long Prehistoric sequence in Harris County, Texas. *Journal of the Houston Archeological Society* 88:15-18.

1997a *The Wheeless Archeological Collections, Fort Bend County, Texas.* Report No. 4. Fort Bend Archaeological Society, Richmond, Texas.

1997b *The Meitzen Collection, 41FB249, Fort Bend County, Texas.* Report No. 6. Fort Bend Archaeological Society, Richmond, Texas.

Patterson, L. W., J. D. Lockwood, R. L. Gregg, and S. M. Kindall

1992a The Lockwood Collection (41HR343), Harris County, Texas. *Journal of the Houston Archeological Society* 104:16-24.

1992b Prehistoric Sites 41HR354, 730, 731, 732, Harris County, Texas. *Journal of the Houston Archeological Society* 104:25-30.

Perttula, T. K.

2004 The Prehistoric and Caddoan Archeology of the Northeastern Texas Pineywoods. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 370-407. Texas A&M University Press, College Station.

Ray, C. N.

1930 Report on Some Recent Archaeological Researches in the Abilene Section. *Bulletin of the Texas Archeological and Paleontological Society* 2:45-58.

Roberson, J.

2005 Stable Isotope Analysis of Some Texas Cherts. Paper presented at the 76th Annual Meeting of the Texas Archeological Society, Austin, Texas.

Sabin, T. J. and V. T. Holliday

1995 Playas and Lunettes on the Southern High Plains: Morphometric and Spatial Relationships. *Annals of the Association of American Geographers* 85:286-305.

Saner, B., Jr.

1995 An in situ Clovis Point Find from Kerr County. *La Tierra* 22(3):20-23.

2005 Clovis Manufacture Failure from Real County, Texas. *La Tierra* 32(2):29-31.

Scurlock, J. and W. Davis

1962 Appraisal of the Archeological Resources of Toledo Bend Reservoir, Panola, Newton, Sabine, and Shelby Counties, Texas; Sabine and De Soto Parishes, Louisiana. Report submitted to the National Park Service by the Texas Archeological Salvage Project, The University of Texas at Austin.

Sellards, E. H.

1940 Pleistocene Artifacts and Associated fossils from Bee County, Texas. *Bulletin of the Geological Society of America* 51:1627- 1658.

1952 *Early Man in America.* University of Texas Press, Austin.

Shiner, J. L.

1983 Large Springs and Early American Indians. *Plains Anthropologist* 28:1-7.

Skinner, S. A. and R. Rash

1969 A Clovis Fluted Point from Hood County, Texas. *Bulletin of the Texas Archeological Society* 40:1-2.

Stanford, D.

1999 Paleoindian Archaeology and Late Pleistocene Environments in the Plains and Southwestern United States. In *Ice Age People of North America:*

Environments, Origins, and Adaptations, edited by. R. Bonnichsen and K. L. Turnmire, pp. 281-339. Center for the Study of the First Americans, Corvallis.

Story, D. A.
1990 Culture History of the Native Americans. In *The Archeology and Bioarcheology of the Gulf Coastal Plain*, by D. A. Story, J. A. Guy, B. A. Burnett, M. D. Freeman, J. C. Rose, D. G. Steele, B. W. Olive, and K. J. Reinhard, pp. 163-366. Research Series No. 38. 2 Vols. Arkansas Archeological Survey, Fayetteville.

Stright, M. J.
1999 Spatial Data Analysis of Artifacts Redeposited by Coastal Erosion: A Case Study of McFaddin Beach, Texas. Ph.D. dissertation, Department of Anthropology, American University, Washington, D.C.

Suhm, D. A. and E. B. Jelks (editors)
1962 *Handbook of Texas Archeology: Type Descriptions.* Special Publication 1, Texas Archeological Society, and Bulletin 4, Texas Memorial Museum, Austin.

Suhm, D. A., A. D. Krieger, and E. B. Jelks
1954 An Introductory Handbook of Texas Archaeology. *Bulletin of the Texas Archeological Society* 25:1-562.

Takac, P.
1991 Underwater Excavations at Spring Lake: A Paleoindian Site in Hays County, Texas. *Current Research in the Pleistocene* 8:46-48.

Thoms, A. V. and R. D. Mandel (editors)
2007 *Archaeological and Paleoecological Investigations at the Richard Beene Site, 41BX831, South-Central Texas.* Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station.

Turner, E. S. and P. Tanner
1994 The McFaddin Beach Site on the Upper Texas Coast. *Bulletin of the Texas Archeological Society* 65:319-336.

Waguespack, N. and T. Surovell
2003 Clovis Hunting Strategies, or How to Make Out on Plentiful Resources. *American Antiquity* 68:333-352.

Walter, R. W.
1990 Similarities Between Two Texas Clovis Fluted Points Found on the South Plains. *The South Plains Archeological Society Newsletter* 99.

Waters, M. R. and L. C. Nordt
1995 Late Quaternary Floodplain History of the Brazos River, Texas. *Quaternary Research* 43:311-319.

Waters, M. R. and T. W. Stafford, Jr.
2007 Redefining the Age of Clovis: Implications for the Peopling of the Americas. *Science* 315:1122-1126.

Weir, F.
1956 Surface Artifacts from La Perdida, Starr County, Texas. *Bulletin of the Texas Archeological Society* 27:59-78.

Wheat, J. B.
1953 *An Archaeological Survey of the Addicks Dam Basin, Southeast Texas.* River Basin Surveys Papers 4, Bulletin 154:143-252. Bureau of American Ethnology, Smithsonian Institution, Washington D.C.

Wilson, J.
1979 A Preliminary Report on the Little Pin Oak Creek Site (41FY53): A Campsite with Clovis, Plainview, and Subsequent Artifacts in Fayette County, Texas. *Bulletin of the Texas Archeological Society* 50:135-140.

Wyckoff, D. G.
1993 Gravel Sources of Knappable Alibates Silicified Dolomite. *Geoarchaeology* 8:35-58.

Sequence _____________ County ___________________

TEXAS CLOVIS FLUTED POINT SURVEY FORM

Please attach a tracing of the outline (or a photocopy) of both faces of the fluted point. Be sure to show the outline of the flute(s), broken areas, and the extent of edge grinding. If possible, please take measurements in centimeters.

1. Maximum length		2. Maximum width	
3. Width of base		4. Distance from maximum width to base	
5. Maximum thickness		6. Distance from maximum thickness to base	
7. Maximum flute thickness		8. Basal concavity depth	
9. Obverse flute length		10. Obverse flute width	
11. Reverse flute length		12. Reverse flute width	
13. Number of flutes obverse		14. Number of flutes reverse	
15. Length of grinding left edge		16. Length of grinding right edge	
17. Basal grinding	Yes No	18. Measurements in	cm in

19. Location where point was discovered: ______________________________

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(Please be as specific as possible, and include county name)

20. Artifacts or features found with the point: ______________________________

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21. Color and type of stone material: ______________________________

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22. Please print name and address:

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Please return the completed form to:
David J. Meltzer
Department of Anthropology
Southern Methodist University
Dallas, Texas 75275-0336

The de Graffenried Collection: A Clovis Biface Cache from the Gault Site, Central Texas

Michael B. Collins, Jon C. Lohse, and Marilyn B. Shoberg

ABSTRACT

A collection of chipped stone bifaces bearing technological traits indicating Clovis-period manufacture was shown to the senior author at the *Clovis and Beyond* conference in Santa Fe, New Mexico, in the fall of 1999. Based on the oral history of the collection, it is probable that the five pieces were recovered together in archeological association from Bell County, Texas, and may have even come from the Gault site. This article traces the probable origin of the cache, presents technological and microscopic analyses of the collection, and discusses some implications of flaking technology represented for Clovis reduction sequences.

INTRODUCTION

In the Fall of 1999, while at the *Clovis and Beyond* conference in Santa Fe, New Mexico, the senior author was approached by a private collector and shown a collection of five chipped stone bifaces of distinctively Clovis-period manufacture. According to information provided by the collector, and by tracing the history of the collection, it is possible that these artifacts were recovered between the 1930s and 1940s from Central Texas, and that they may have come from the Gault site (41BL323), a major Clovis locality in Bell County (Collins 2002). Named after Gaines de Graffenried, an early owner of the artifacts, this collection represents a single cache of artifacts dating to the Clovis period, ca. 11,500-10,800 radiocarbon years ago (Stanford 1999). In this article we trace the oral history of the cache, present the results of our technological analyses and microscopic examination, and explore larger implications for Clovis lithic technology.

While some caches (e.g., Anzick [Wilke et al. 1991] and Simon [Woods and Titmus 1985]) have been examined for the clues they contain about Clovis knapping strategies and biface reduction behavior, the de Graffenried collection affords the singular opportunity to supplement information from cache pieces by comparing them with other artifacts made of the same raw material recovered from the same site. We argue that examining ratios of length, width, and thickness, together with absolute measurements, flaking styles, and artifact form allows archeologists to more accurately recognize prehistoric decisions for designing and achieving different tool forms from morphologically similar progenitors than is possible by comparing artifact form and size alone.

BACKGROUND OF THE CACHE

Two kinds of evidence suggest that the five specimens we report came from the Gault site or from somewhere very close by. The first line of evidence is the oral history of the collection, and the second is the physical character of the specimens.

Oral History of the Cache

A private collector, Michael Speer, brought the de Graffenried cache to the attention of the senior author during the 1999 *Clovis and Beyond* conference. According to Speer's account, two separate biface caches were auctioned in 1991 as part of the estate of Gaines de Graffenried, a well-known resident of Waco, Texas. One collection included a sizeable number of large, thick pieces closely resembling those seen in caches of Archaic age (Miller 1993). The other cache included the five Clovis specimens that are described here.

Gaines de Graffenried was a businessman in Waco who, beginning around 1930, collected guns and other historical items relevant to Texas history. De Graffenried served as curator of exhibits for the Texas Ranger Hall of Fame Museum from 1975 until his death in 1991 (Conger 1987, 1996). Much of his personal collection formed the basis of many of the exhibits in the Texas Ranger Museum, including the large Archaic cache mentioned above. So far as we have been able to ascertain, the five piece cache was never displayed in the museum.

Speer reports that, beginning in the late 1930s or early 1940s, a collector named Erich Pohl conducted extensive excavations at the Gault site, then known as the Gault Farm, sometimes using up to a dozen local laborers. Upon Pohl's death in 1960, half of his collection went to the Indian and Trapper's Museum, a private enterprise in Missouri. When the Missouri museum closed in the early 1990s, Speer bought all of the Texas artifacts in its collection, including an 8 mm film of Pohl and his laborers working at Gault. While the film is no longer available, Speer recounts that it clearly showed Pohl and his crew at work at the Gault Farm. Speer had visited the Gault site and recognized the locality depicted in the film. According to Speer, de Graffenried obtained the five piece cache from Pohl in a trade.

Since many of the principals of this sequence of events are deceased, some elements of this history may be difficult to confirm. Nevertheless, these oral accounts, partly substantiated by newspaper accounts describing Pohl's work at the Gault Farm (Yates 1941:9), provide some evidence that the collection was indeed recovered from somewhere in Bell County, and may even have come from the Gault Farm in the 1930s or 1940s. The cache eventually made its way into the possession of Gaines de Graffenried, and was sold at auction to Mike Speer upon de Graffenried's death.

Description of Cache Lithology

When the senior author first saw the five pieces in Santa Fe, their form and technological attributes were immediately recognizable as Clovis. More surprising, the raw material and its patterns of discoloration and weathering were identical to the variety of Edwards chert found in lower levels at Gault.

Edwards Limestone (Lower Cretaceous) forms the caprock around the valley head where Gault is located (Barnes 1981). Large nodules of chert are present in at least two beds of this limestone, and clasts of this chert occur as dislodged nodules in colluvial slopes and as cobbles in the fluvial gravels on the valley floor. It typically has a soft, white cortex in the nodule form and a hard, white to yellowish-brown cortex in the cobble form. Fresh interior colors are shades of gray (near Munsell color 5YR 5/1 and 10YR 6/1) with sparse, small spots and streaks of light gray (near 2.5Y 7/0). In some pieces, there is faint banding of shades of gray. Flaked surfaces of this chert recovered by archeologists are often stained by limonite-rich ground water up to 2 mm into the stone. The stained surfaces are yellowish and exhibit such colors as pale yellow (near 2.5Y 7/4), olive yellow (near 2.5Y 6/6), reddish-yellow (near 7.5YR 6/8), and strong brown (near 7.5YR 5/8). Many, although not all, of the artifacts recovered from lower levels at Gault have calcium carbonate encrustations on their faces. In most cases, greater calcium carbonate buildup occurs on an artifact's downward face, telling archeologists something about how artifacts were deposited at the site.

The five pieces described here are all of gray chert with small spots and streaks of light gray; banding is very faint on a few of the pieces. No calcium carbonate is present on any of the artifacts, although the specimens could have been cleaned with a light acid solution at some point. All five have at least some staining on both faces, but in general each has most of one face extensively stained and the opposite face much less stained. Each stained face shows a light "shadowing" effect, where a small part of the face is stained much less deeply than the rest. This patterning possibly indicates something about the way the artifacts were stacked atop each other when they were originally deposited. Colors of the staining are predominantly olive yellow with lesser areas of pale yellow, reddish-brown, and strong brown.

INTRODUCTION TO THE GAULT SITE

Gault is an extensive, multi-component open site in Central Texas. The site has been the object of unrelenting destruction by looters and collectors over much of the last 80 years until 1998. Artifacts from the site represent nearly all of the Holocene-era archeological style intervals (described in Collins 2004:102) of Central Texas from ca. 9,000 to 500 years ago. Almost no deposits from these intervals remain intact (Collins 2002). Deeper deposits, though, are largely undisturbed and contain archeological materials from the earliest Archaic as well as the Early and Late Paleoindian intervals. At the site locality, several springs give rise to a small stream that flows eastward some 15 km where it reaches the Gulf Coastal Plain and coalesces with other streams before reaching the Brazos River. The fine gray, spotted variety of Edwards chert that crops out at the site, together with these springs, undoubtedly were important factors in the site's long history of occupation.

Excavations under the direction of the senior author and associates in 1991 and 1998-2002 primarily targeted Early Paleoindian (Clovis and Folsom) deposits. Clovis materials comprise multiple components and are far more abundant at Gault than are any other kinds of Paleoindian materials. Several hundred thousand Clovis stone and bone objects have so far been recovered, including knapping debris, points, bifaces, unifaces, adzes, choppers, flake cores, blade cores, tools on blades, a pointed bone rod, and associated bones of large and small vertebrate fauna. Analyses of this material are ongoing.

DESCRIPTION OF CLOVIS LITHIC TECHNOLOGY

A comparative overview of Clovis stone tool forms and their production reinforces our assertion that the five artifacts in the de Graffenried cache are of Clovis-period manufacture. Clovis knappers produced large bifacial preforms that became knives and distinctive fluted points, as well as a variety of flake tools on normal flakes and on bifacial thinning flakes. In some Clovis sites, polyhedral blade cores, prismatic blades, and various tools on blades comprise part of the lithic assemblage (Boldurian and Cotter 1999; Bradley 1991; Collins 1999a; Stanford 1999). Of these artifacts, points and large bifaces are relevant to our discussion of Clovis lithic technology.

Clovis knappers made a number of bifacial forms, but the majority are large, roughly lanceolate pieces that were evidently Clovis point preforms. These were produced from cores or from very large, straight flakes. Excellent quality and often aesthetically dramatic raw materials (such as Alibates agatized dolomite, Edwards chert, Niobrara chert, various obsidians and agates, and quartz crystal) were used in the manufacture of most of these bifaces. Clovis points have been found in kill and habitation sites, in quarries and workshops, in caches, and as isolated surface finds.

Direct soft hammer percussion is evident for all but the final pressure-flake edge trimming in the production of Clovis bifaces and points. Early stage bifaces were fashioned by the removal of relatively few, large flakes. Platforms were often isolated and ground or fully trimmed by removal of multiple small flakes. In some cases, a more expedient approach involved the beveling of an entire edge. As bifacial preforms took shape, broad flakes extending completely (called overshot flakes) or nearly across the width of the biface were removed (Figure 1b-c). Each face of large Clovis bifaces and preforms is often dominated by only three or four broad flake scars (Figures 1a, d-e, and 2a-c). Relatively minor trimming scars are found along the margins of finished pieces (Figure 2d-f). Remnants of two or more of the larger flake scars sometimes remain on the faces of finished Clovis points (Figure 2e). Overshot flaking (see Figure 1b-c, e) by Clovis knappers was highly controlled and intentional, in distinct contrast to the widespread occurrence of accidental overshots that often ruined bifaces from other cultures and time periods. Controlled overshot flaking was used to remove irregularities along bifacial edges by reaching across the piece with a flake rather than nibbling away at the irregularities on the edge itself.

Early in the shaping of bifacial preforms, the Clovis point outline with its straight base, convergent tip, and straight to slightly convex edges (see Figure 2c) was established and then maintained throughout the reduction. Also early in the production of these preforms, the basal edge was given a strong bevel which served as the platform for flute-like removals (see Figures 1a and 2a-b). This beveling was renewed on alternating faces as flutes were removed multiple times during the reduction of the preform. Earlier flutes were obliterated as the preform was thinned. As the preform neared completion, a bevel was established on one face for removal of the flute that would remain on the finished point, the flute was removed, and the final bevel was set up to remove the flute from the opposite face. Direct percussion is indicated for these flute removals. Final trimming by direct percussion and pressure flaking brought the finished point into symmetry around the flutes; some trimming flakes

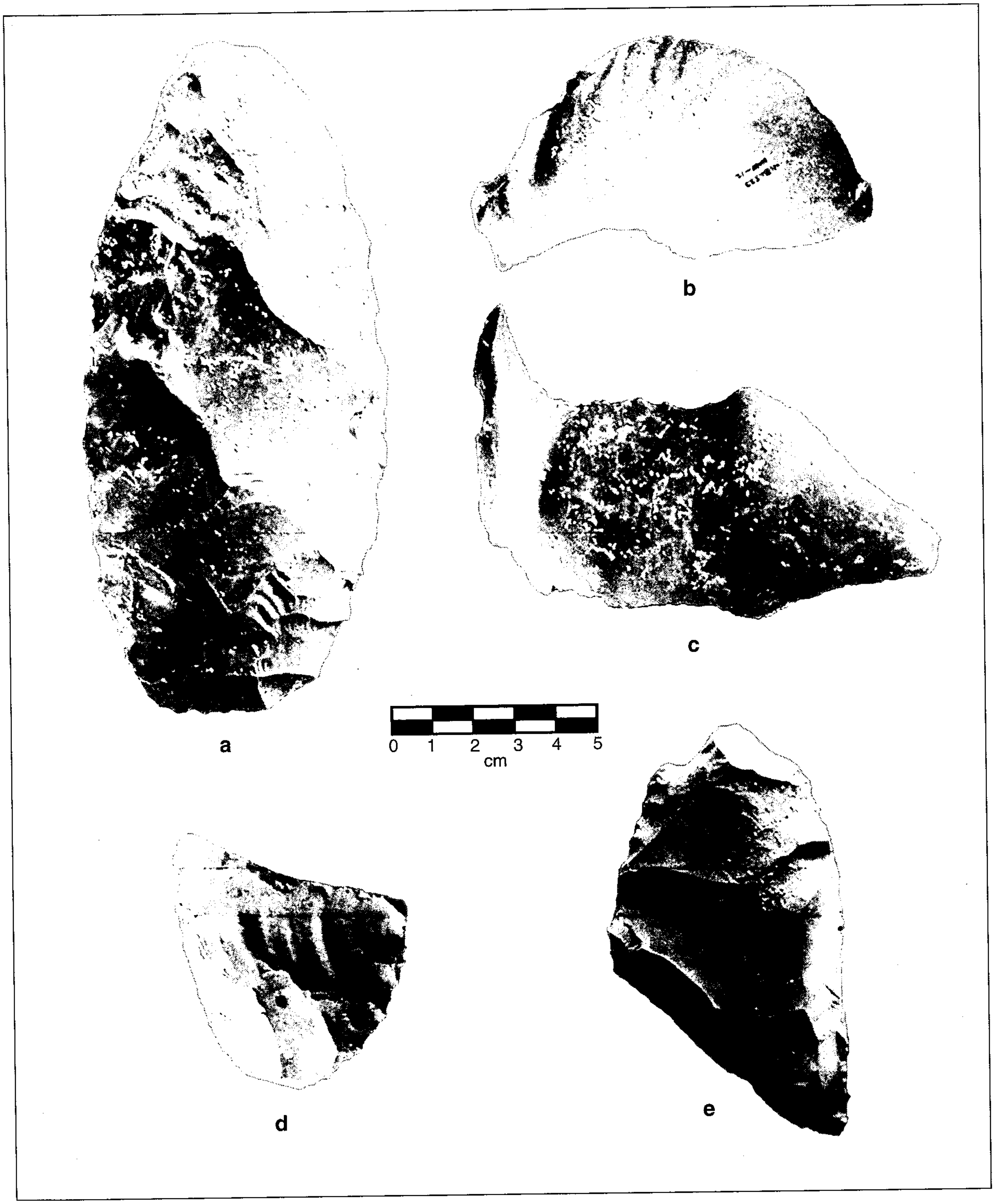


Figure 1. Clovis bifaces and overshot flakes recovered from the Gault site: a (1040-103): large ovoid biface with square edge on upper left margin, large central flake scar that carries almost across the entire face, beveled base, and greater thickness than the de Graffenried bifaces; b (1040-112): interior view of broad, thin overshot flake removed from a biface ca. 95 mm wide with small, isolated platform and remnant of irregular opposite edge of the biface; c (1058-10): interior view of very large overshot flake removed from a biface ca. 130 mm wide with small isolated platform and remnant of opposite edge of biface; d (4469-43): fragment of typical Clovis biface illustrating broad flake scar extending across most of the width of the biface and remnant of square cortical edge at the base; e (3292-1): fragment of biface, ruined by perverse fracture, with broad flake scars, and remnant scar of overshot flake.

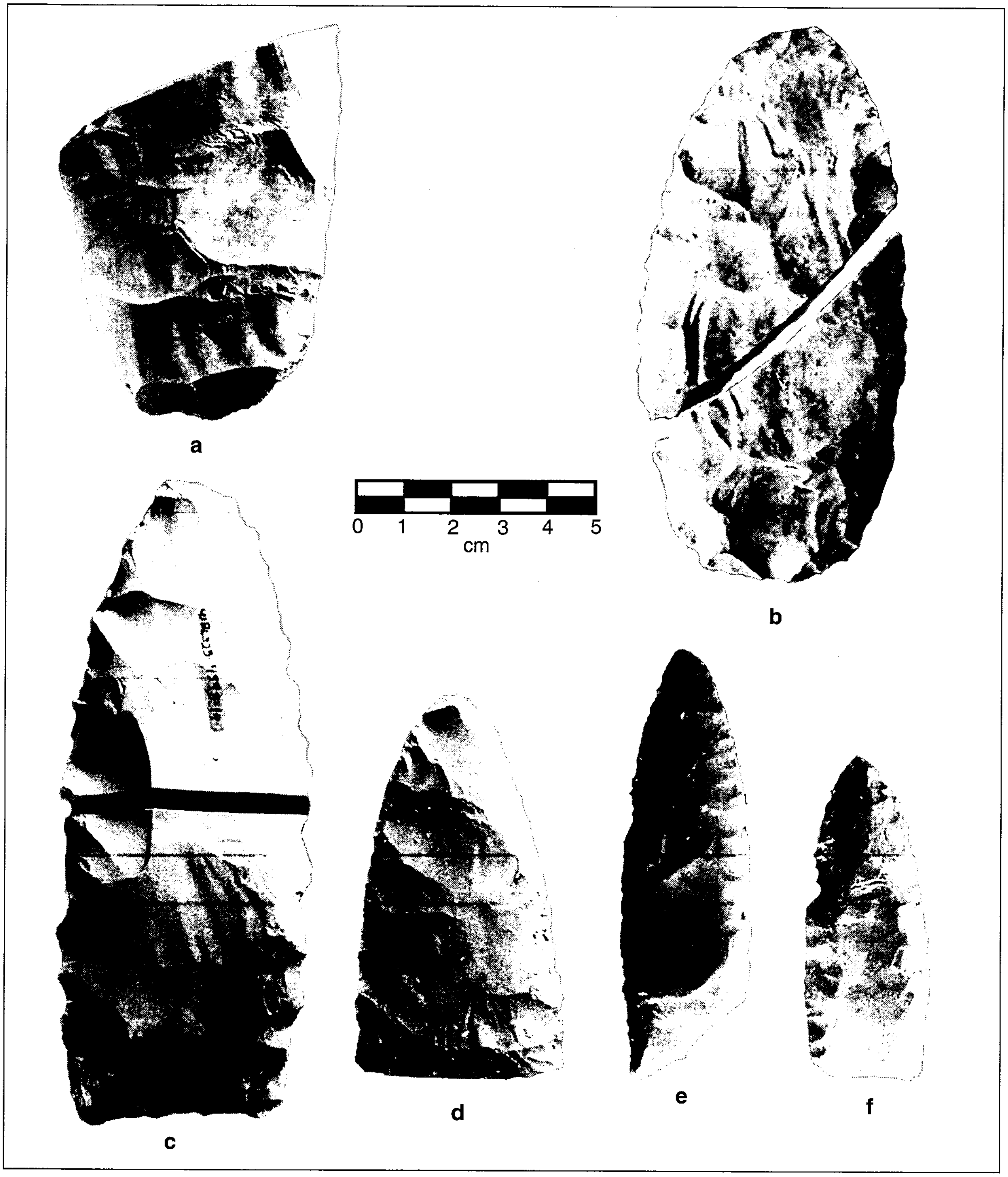


Figure 2. Clovis bifaces, preforms, and points recovered from the Gault site: a (2996-7): biface fragment with three broad thinning flake scars—one of which is overshot—and a basal bevel from which a small flute-like flake was detached from the opposite face; b (2765-13, upper, 2765-14, lower): conjoined fragments of a biface—ruined by perverse fracture—that exhibits basal bevel and basal thinning flake and is smaller than, but similar to, the de Graffenried bifaces in its pattern of flake scars; c (4348-14, upper, 4256-13, lower): conjoined fragments of large Clovis point preform exhibiting typical size and flaking pattern that was snapped in two, probably by end shock, at a stage of reduction closely similar to that of the point in the de Graffenried cache; d (4104-21): snapped fragment of Clovis point with remnants of broad thinning flake scars and edge trimming, broken by bending; e (1040-113): resharpened and then broken Clovis point with typical remnants of broad thinning flake scars with invasive edge trimming scars; f (36-42): resharpened Clovis point exhibiting typical symmetry and edge trimming flake scars invading the flute scar.

intrude into the flutes (Figure 2f). The basal edge and proximal segments of the lateral edges were ground as the final production step.

CLOVIS CACHING BEHAVIOR

A handful of caches of Clovis artifacts have been reported across North America over the past several decades, including Anzick (Wilke et al. 1991), Busse (Hofman 1995), Crook County (Tankersley 1998, 2002), Blackwater Draw 1 and 2 (Green 1963; Montgomery and Dickenson 1992), Drake (Stanford and Jodry 1988), East Wenatchee (Gramly 1993; Mehringer 1988), Fenn (Frison and Bradley 1999), Keven Davis (Collins 1999a), Sailor-Helton (Mallouf 1994), Simon (Butler 1963; Butler and Fitzwater 1965; Woods and Titmus 1985), and Watts (Bob Patten, personal communication 2003). In addition to these caches, we have recently seen two others, called Hogeye and Wall, from near Bastrop, Texas, that await publication. Even this listing is probably incomplete, and is sure to grow as more caches come to light. Frison (1991b:41) has suggested that caching behavior may have been an "institutionalized" component of Clovis lifeways. These caches often occur as isolated deposits; are frequently uncovered inadvertently by farmers, ranchers, land surveyors, or collectors; come mostly from the Great Plains and Western United States; and all include pieces made of very high quality stone. Frequently, traces of red ocher are found on cache specimens, although the reason(s) why this substance was sometimes used remains unknown.

Based on known assemblages and their contexts, caches were deposited for any of several reasons, and important distinctions should be drawn between the different types of behaviors that can be inferred. Some assemblages such as Keven Davis, Sailor-Helton, and both examples from Blackwater Draw, contain an abundance of blades that appear to represent utilitarian behaviors such as processing game animals. Anzick is perhaps singular in that it contained large amounts of red ocher and the remains of a human interment (see discussion of caching behavior by Frison 1991b:351-357). Some caches, such as Drake, contain only finished or nearly finished projectile points, and appear to represent hunters' tool kits that have been stored for later retrieval. Caches such as Fenn and Simon, as well as Anzick, have been used by archeologists to support generalizations about continent-wide Clovis lithic technology. Unfortunately, detailed summaries of caches and the significance they hold for understanding Clovis culture and flintkapping behavior are impeded by a number of factors. Illustrations often are not provided or are inadequate for showing important technical attributes. Complete metric dimensions are frequently absent, are available only for projectile points, or are presented only for the largest and smallest specimens to indicate size ranges. Additionally, very few artifacts are microscopically examined, undermining statements about the use-life of individual specimens. Finally, considering the history of discovery and ownership of some of these caches, it is apparent that not all specimens are equally available to scientists for study. This is the case for Anzick.

While the caches listed above are all variable in that they contain multiple tool forms in different stages of manufacture or reduction, none to date has been recovered from a site that contains the amount of habitation and other archeological deposits present at Gault (the closest comparisons in this regard are the two caches at Blackwater Draw). The de Graffenried collection is therefore both unusual and significant in this respect. This collection invites consideration not only of the complexities of Clovis period caching behavior, but allows broader comparisons with excavated artifacts for deducing Clovis tool reduction trajectories.

DESCRIPTION OF THE DE GRAFFENRIED CACHE

The de Graffenried collection includes four large oval bifaces and a fluted lanceolate biface that we view as a projectile point perform. Each biface was shaped by soft hammer direct percussion, and is made of the same iron-stained yellow-brown chert that is found in abundance at Gault and described above. Metric dimensions and weight of each specimen are presented in Table 1.

Specimen 264

This biface (Figure 3) was produced by removing large, relatively flat flakes from each face, many of which carry across almost to the opposing edge. A faint remnant of cortex is at each end, and very small remnants of square edges are found in two places. Side A retains three primary flake scars that run nearly parallel from right to left and that overlie

Table 1. Metric dimensions of de Graffenried specimens.

Specimen Number	Form	Length	Width (midpoint)	Thickness (maximum)	Weight (g)
264	Oval	211.2	102.5	11.3	320.4
265	Oval	175.5	108.4	12.3	315.3
266	Oval	176.8	108.5	11.2	306.0
267	Oval	170.0	94.9	11.0	208.2
439	Lanceolate	172.2	47.1	13.4	136.3

Length, width, and thickness are in mm.

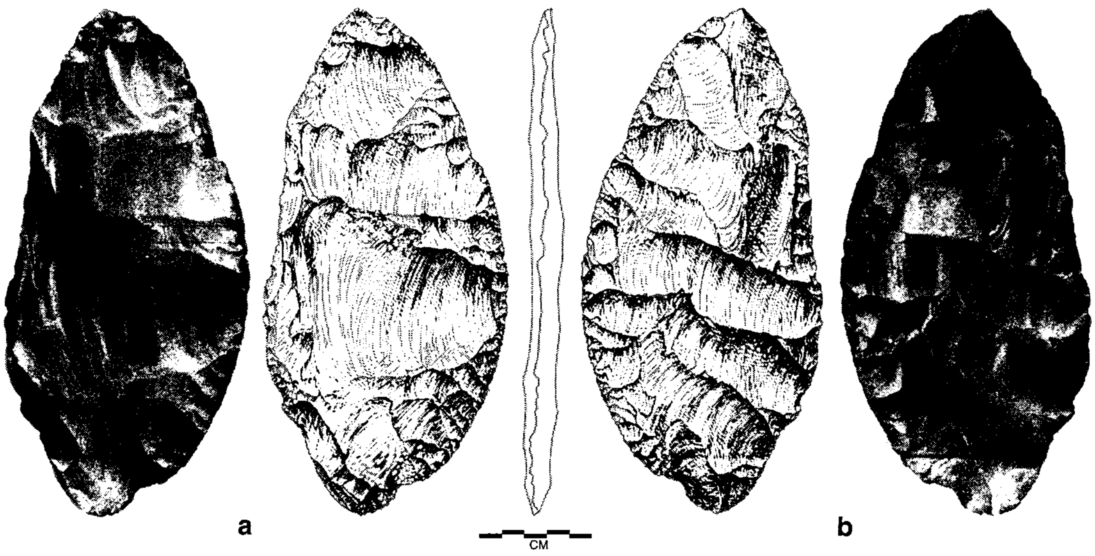


Figure 3. Line drawing and digital image of Specimen 264 showing flaking patterns on Side A (left) and Side B (right).

earlier scars also running in the same direction. These three large scars originated beyond the artifact's current lateral edge, indicating that they were removed when the piece was larger than at present. Several smaller, subsequent flakes achieve the oval shape; these flakes rarely approach the artifact's midline. Side B was shaped by two series of large flakes originating from opposing edges. One series runs from lower right toward upper left and the other series runs from upper left toward lower right. As with Side A, the directions of these scars are nearly parallel, and many remnant scars from prior flake removals are visible. Evidence of more delicate percussion and perhaps even pressure flaking remains around most of the margins on both sides, although it is particularly visible along the lower right margin of Side A and the lower left margin of Side B.

Specimen 265

This oval-shaped biface (Figure 4) was shaped by removing two to four nearly parallel flakes from each face. Flake scars are large, broad, and flat. Side A shows four flake scars, each running left to right, including one possible overshot scar. It is likely that other flakes also extended completely across this side of the biface, although shorter flakes from the right

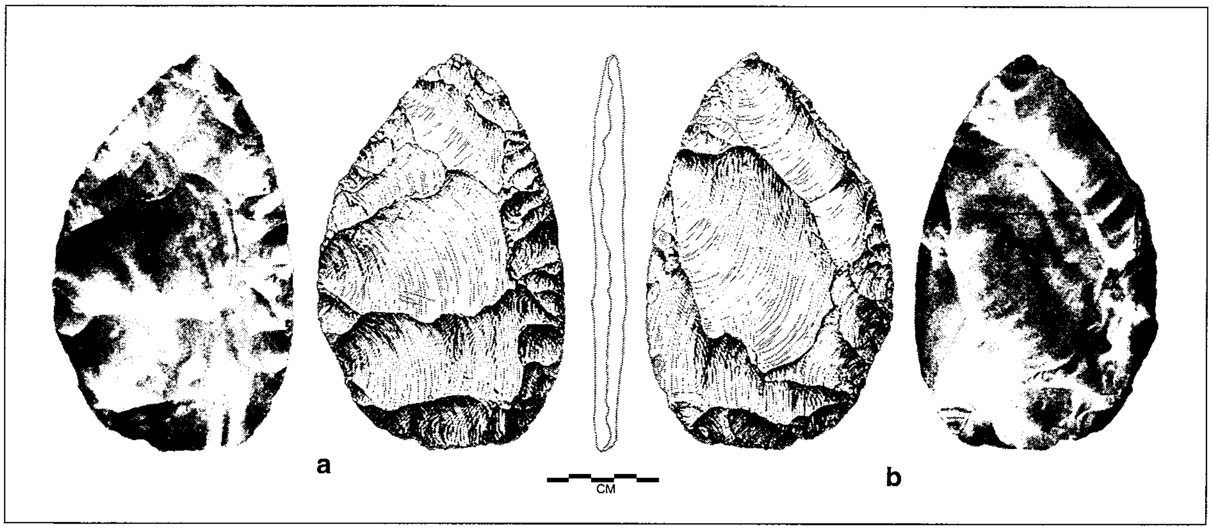


Figure 4. Line drawing and digital image of Specimen 265 showing flaking patterns on Side A (left) and Side B (right).

margin obscure these terminations. A fifth flake scar originates at the upper left and runs toward the lower right (remnants of earlier flake scars can be seen). Side B retains three primary flake scars, with two running from the upper left toward the lower right and the third from the right to left, a pattern also evident on Side B of Specimen 264. The lowest flake on Side B is an overshot, and forms much of the artifact's oval-shaped margin at its termination. Faintly banded coloring indicates that this face was near the cortex of the original nodule. One small, older remnant flake scar is visible on this face. The oval form of this specimen was achieved by the removal of a number of smaller percussion flakes, although this artifact shows only very light retouch around the edges.

Specimen 266

Specimen 266 (Figure 5) shows the same pattern of flaking seen in the previous specimens, with a series of four nearly parallel flake scars running from left to right on Side A and four similar scars running from right to left on Side B. One flake scar on Side A is an overshot (terminations of all other flake scars have been obscured by retouch; some of these, too, could originally have been overshots). Remnants of prior flake scars are seen in elevated surfaces on Side B, suggesting that this artifact was originally larger than its present size. While the larger flake scars carry well past the artifact's midline, secondary flaking

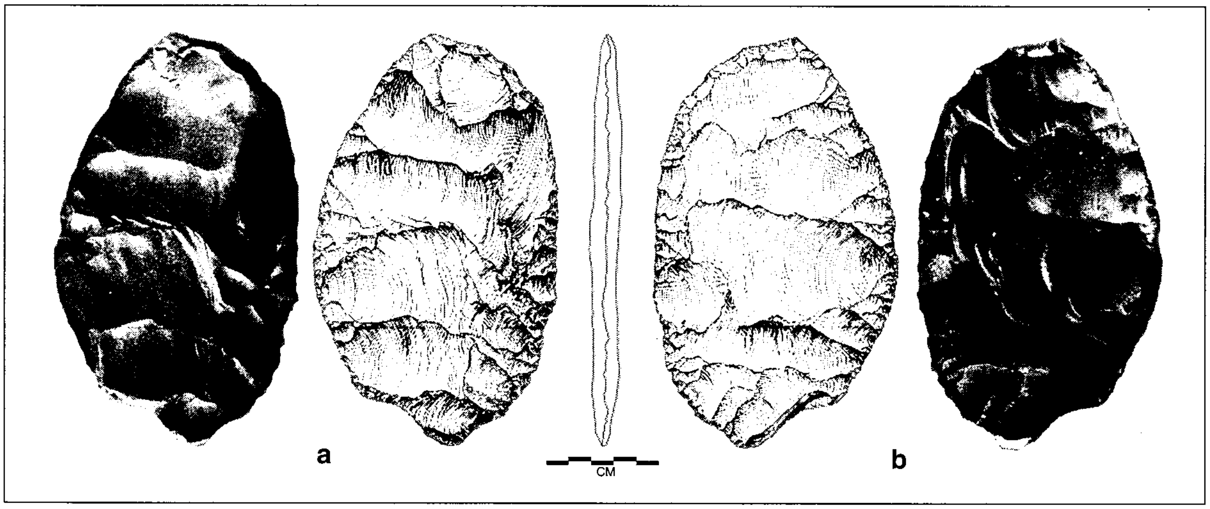


Figure 5. Line drawing and digital image of Specimen 266 showing flaking patterns on Side A (left) and Side B (right).

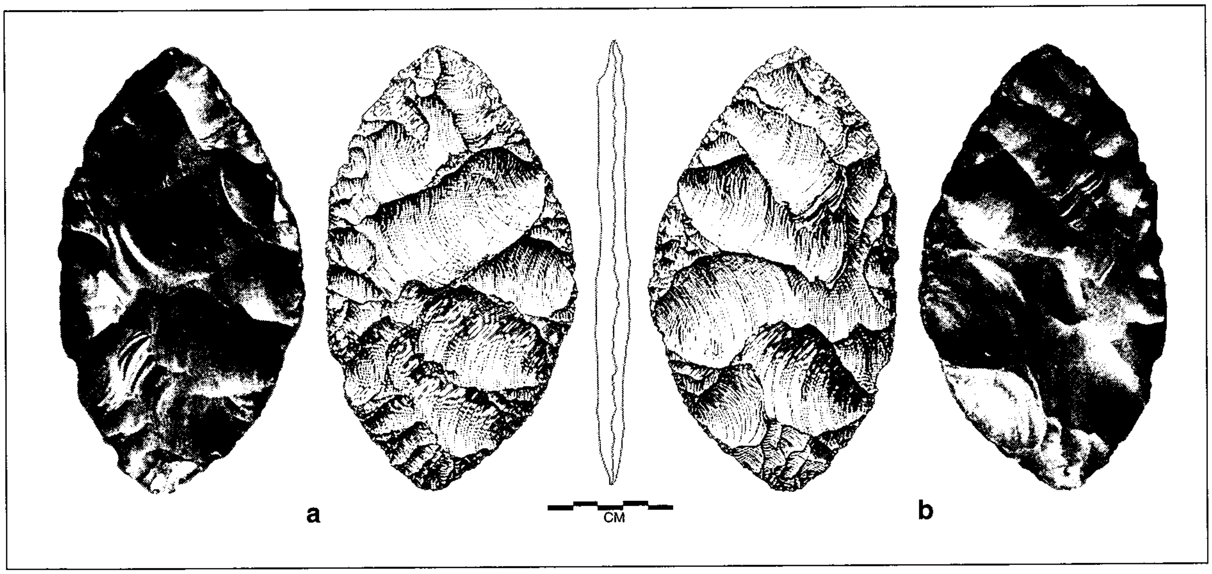


Figure 6. Line drawing and digital image of Specimen 267 showing flaking patterns on Side A (left) and Side B (right).

rarely extends this far. The result of this pattern is that the biface is rather asymmetrical in plan. Light retouch, perhaps by pressure flaking, is evident around the lateral margins on Side A, and to a lesser extent on Side B. This specimen has small areas of cortex on both ends.

Specimen 267

Specimen 267 (Figure 6) is the smallest of the four oval-shaped bifaces, but it retains the same pattern of flaking that characterizes the other three specimens. A small remnant of a square edge is found on one margin. Side A has five large flake scars. Three run nearly parallel from the lower right toward the left or upper left, while the fourth and fifth ones (numbered from the bottom up) initiate in the upper right and run toward the lower left, obscuring portions of two earlier large flake scars. A remnant of yet another flake scar is visible near one end (top in Figure 6), obscuring the point of origin for the final right-to-left running scar. As with other bifaces in this collection, the terminations of these large flakes are obscured by smaller percussion flakes removed from the opposing (left) edge. At least three elevated surfaces from earlier stages of reduction are visible between flake scars. Side B is dominated by four large, nearly parallel flake scars that run from left to right, and a fifth scar originating in the lower right and running to the left. This artifact shows little evidence of edge retouch.

Specimen 439

Specimen 439 is a lanceolate form with near-parallel lateral edges and asymmetrical basal fluting on both sides (Figure 7). It is similar in form and size to large preforms noted in the Fenn, Simon, East Wenatchee, and Anzick caches, and an examination of point performs at Gault indicates this to be a normal size range, at least for points manufactured at this site. This artifact was shaped by percussion flakes from both sides, many of which extend far beyond the artifact midline. Its proximal and distal ends have been roughly finished with fine percussion or pressure flaking. Its lateral edges were left unground, and a square edge remnant is found on one margin. Evidence of a beveled base remains (Side B), a trait characteristic of many late-stage Clovis preforms. No lateral invasive flake scars extend into either flute. Side A was fluted first, followed by the shorter flute on Side B. Three elevated surfaces on Side A are remnants of earlier flake removals. No fewer than four such remnants are visible on Side B. The first flute was modified from the base in setting up the bevel for the second flute, which has slight invasive flaking from the base.

General Discussion of the de Graffenried Collection

The four oval de Graffenried bifaces show flaking patterns highly diagnostic of Clovis lithic assemblages. Broad, thin flakes, analogous to the scars

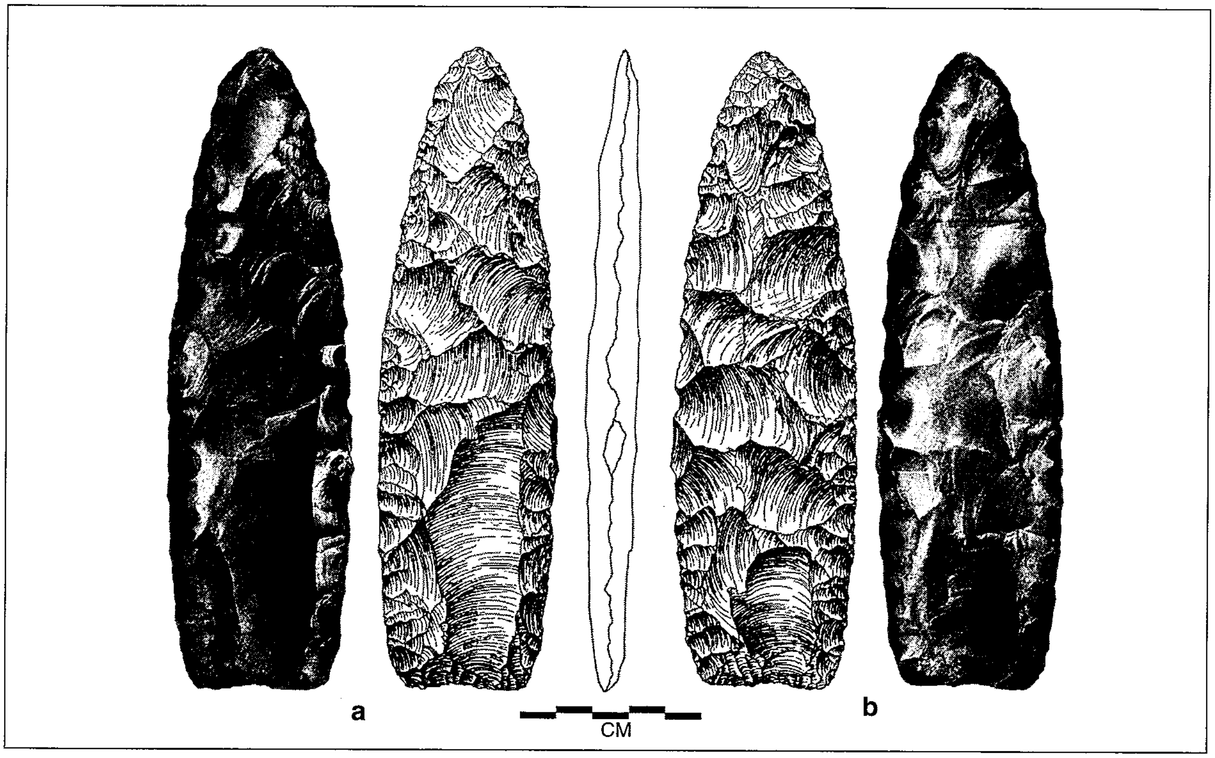


Figure 7. Line drawing and digital image of Specimen 439 showing flaking patterns on Side A (left) and Side B (right).

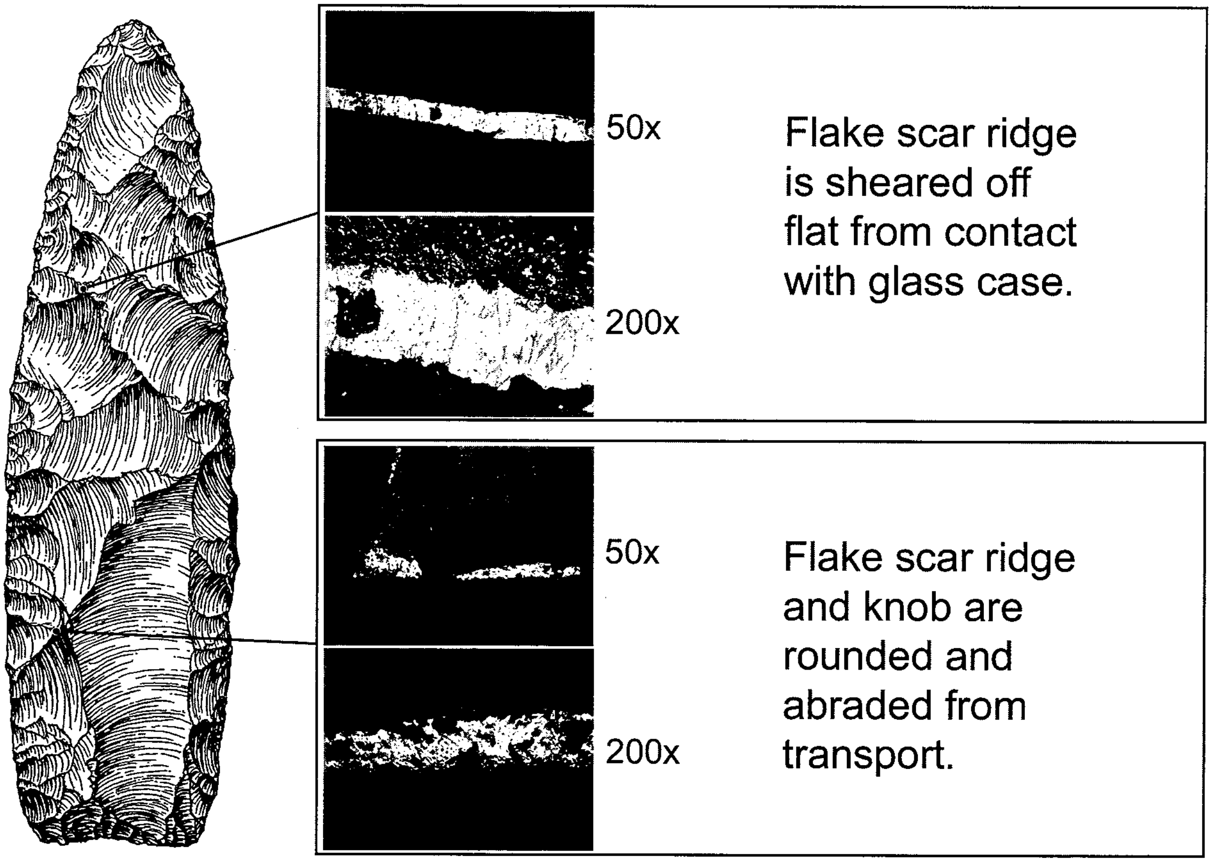
seen extending most or all of the way across the face of each parallel-flaked oval biface, have been recovered from Clovis contexts at Gault. Such flaking is common in many Clovis assemblages (Collins 1999b), with the end result often being overshot flakes that remove opposing tabular or bifacial edges. All five de Graffenried bifaces show relatively little longitudinal curvature. The result is that when viewed from the edge, each side is nearly parallel and the artifacts assume an almost tabular form.

Clovis projectile point preforms exhibit a generalized lanceolate outline beginning early in the manufacturing process (Collins 1999a). More oval to almost bipointed bifaces with broad flake scars and overshot flaking like the four in this cache occur less frequently in Clovis contexts, but are seen in the Fenn, Crook County, Anzick, and Simon caches, although the De Graffenried pieces are proportionately somewhat thinner.

Importantly, not only do all specimens show distinctive traits of Clovis knapping, but the four oval forms are highly comparable to one another in terms of general size, shape, and flaking patterns and sequences. They do, however, vary in terms of the sequences in which these large flakes were removed, with some specimens having all predominating flakes removed from one edge while others have series of flakes removed from opposing edges. It therefore seems that a single sequence of flake removal cannot be used to model all Clovis biface reduction (e.g., Bradley 1982).

In our examination, we scanned each specimen with a binocular microscope at magnification of 10x, and analyzed each in greater detail at magnifications between 50x and 200x with an optical microscope using incident light and Nomarski optics. The specimens all have smooth, reflective surfaces, and none appears to have been used. A weakly formed polish is present on all surfaces, although not to the extent expected on the edges of artifacts used as tools. Moreover, there are no striations that are specifically associated with edge wear.

Promient flake scar ridges and knobs on both faces of each biface are rounded and smoothed. At 200x magnification, this ridge polish has a coarse, grainy surface, irregular edges, and contains groups of overlapping subparallel striations. Abrasive wear is also found on compression rings or ripples in the lower topography of the large flake scars. The alignment of irregular patches of coarse, grainy polish across the tops of concentric ripples in flake scar depressions is consistent with the bifaces having been carried together with the ridge of one biface rubbing against the topographically lower flake scar



Flake scar ridge is sheared off flat from contact with glass case.

Flake scar ridge and knob are rounded and abraded from transport.

Figure 8. Examples of ridge wear and polish on Specimen 439.

of another biface during transport. High point abrasive polish is also found on biface edges. The abrasive wear found on both high and low areas of the de Graffenried bifaces conforms to experimentally produced transport wear (Huckell et al. 2002).

Some of the most prominent ridges appear to have been sheared off, leaving a long and broad, bright, flat surface in contrast to the rounded morphology of other ridges and knobs (Figure 8). The "sheared" ridges correspond to the highest points on the bifaces, and in some instances it is clear that the ridges have been in contact with the glass cover on the case in which the collection has been stored for an unknown period of time. Traces of metal were found in four places on the edges of Specimen 266, and on a flake scar interior to the edge of Specimen 265. Metal contact could have happened during excavation, or perhaps as a result of how the collection was displayed after excavation.

A final observation from microscopic analyses that deserves mention is the extensive presence of red staining on all five specimens. While difficult to identify, this material resembles ocher, and it is embedded in micro-fissures at the terminations of flake scars and in pits on flake scar ridges and also in the rough microtopography along the edges of flake scars. As discussed earlier, the use of ocher in Clovis times is well-known, and has been associated with cached artifacts.

IMPLICATIONS OF THE DE GRAFFENRIED COLLECTION FOR CLOVIS LITHIC TECHNOLOGY

Artifact Size

At first glance, the oval de Graffenried bifaces appear to represent intermediate stages of biface reduction between initial raw nodule and final tool form, and so hold important implications for understanding Clovis lithic technology and tool manufacturing trajectories. Two traits immediately apparent in the metric data in Table 1 are (1) that all five specimens are comparable in terms of both thickness and length, and (2) that the four oval-shaped specimens are similar in overall size. These similarities become readily apparent when the artifacts are plotted according to both thickness-to-width and width-to-length values (Figure 9). These data suggest that the de Graffenried knapper(s) targeted a certain size range when producing bifaces, particularly in length and thickness dimensions.

Relationships expressed between size (particularly along the thickness dimension for all specimens) and certain shapes (with the greater width of the oval forms) reflect additional decisions made in Clovis biface reduction sequences. Data depicted in Table 1 and Figure 9 suggest that, because some Clovis flaking involves the removal of broad thinning flakes that extend nearly or completely across the face of an artifact (making an artifact both thinner and more narrow), knappers made a choice between pursuing the oval or the lanceolate form at some earlier point in a reduction sequence. The presence of these two forms in the de Graffenried collection reflects this divergence of knapping strategies. Given this flaking behavior and the fact that the lanceolate form is absolutely thicker than the oval bifaces, we suggest that the lanceolate form almost certainly did not originate from a biface comparable in dimension with the oval specimens. If the lanceolate biface was originally comparable in dimension to the four oval forms in this collection, its thickness value would be considerably less, not greater, than the oval bifaces, even while the present width and length values might have been attained.

To address the relationship between the five de Graffenried bifaces and an earlier reduction stage that the two forms may have shared in common, we compared them with five additional bifaces that have been recovered from our excavations at Gault and that are in different stages of reduction (Figure 10). Flaking patterns vary, with the largest specimen (3181-1) having extraordinarily large, broad, and flat flake scars that extend well past the midline of the artifact (one intact scar measures 73 mm wide by 130 mm long). The smaller three all retain smaller and steeper scars that terminate at or before their midlines. In many cases these smaller scars overlie and obscure earlier, larger scars. Flakes originate from all directions on the smaller four artifacts, while the largest specimen is flaked from its opposing ends; its lateral edges retain strong tabular morphology.

In terms of metric dimensions (Table 2), these five bifaces tend on average to be much thicker (mean=27.6 mm vs. 11.4 mm) and a little shorter (mean=149.4 mm vs. 181 mm) than the de Graffenried specimens, although there is some overlap in length between the two groups. There are also only slight differences in width (mean=113 mm vs. 103.6 mm) between these artifacts and the oval de Graffenried bifaces, although the lanceolate form (47.1 mm) is significantly narrower. The length values for all of the de Graffenried specimens, which are greater than all but one of the five bifaces in Figure 10 (Specimen 3181-1), suggests that neither the lanceolate nor the oval bifaces maintain these types of bifaces as an antecedant. It is probable that large, sometimes tabular, flake cores in early stages of reduction,

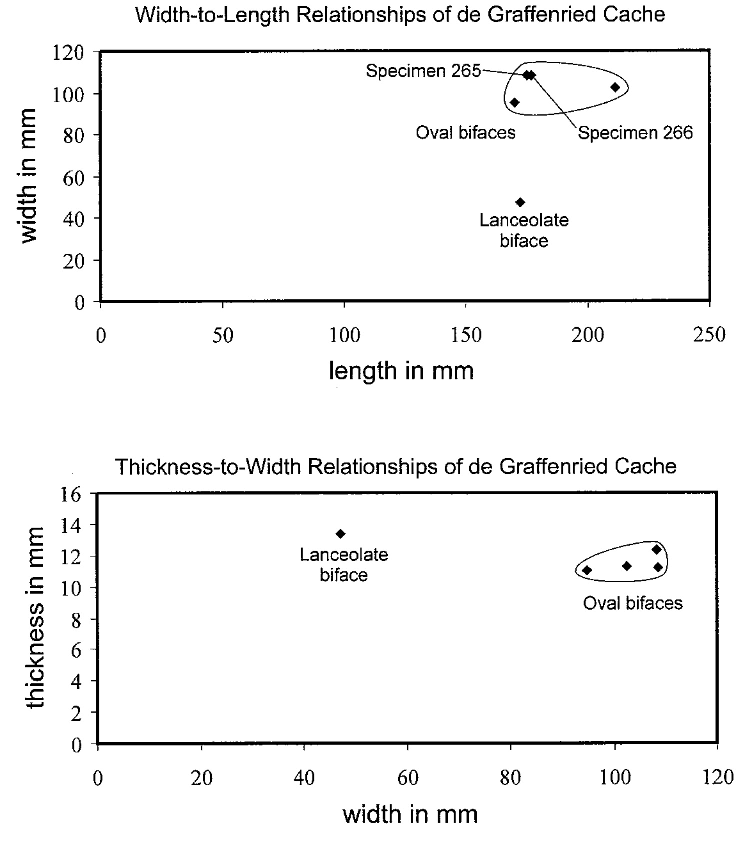


Figure 9. Bivariate graphs of metric properties of de Graffenried bifaces.

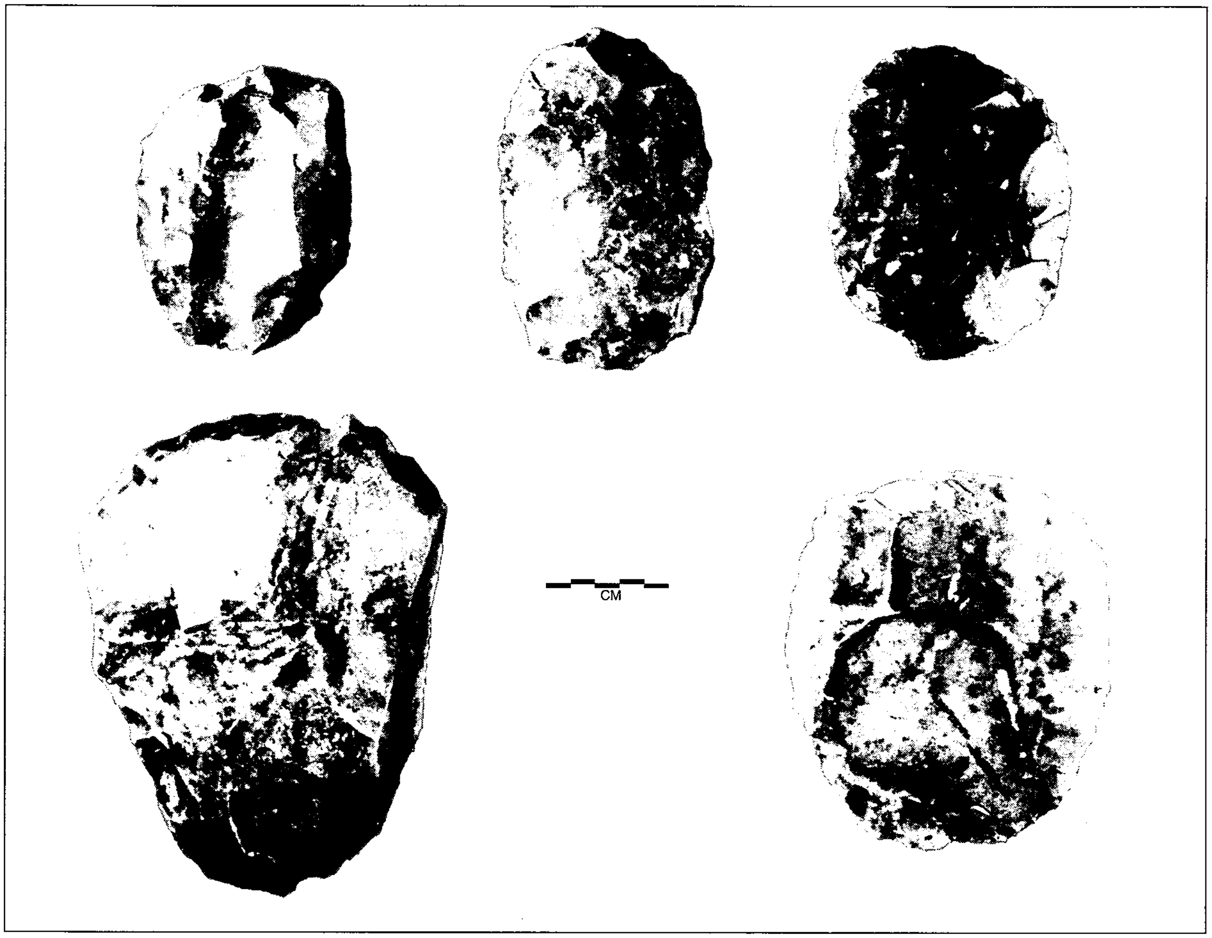


Figure 10. Large bifaces from Gault. Top row (L to R): 1001-28, 1001-27, 2434-1. Bottom row (L to R): 3181-1, 4328-1.

Table 2. Metric dimensions of five bifaces, perhaps flake cores, recovered from Gault.

Specimen Number	Length	Width (maximum)	Thickness (maximum)
1001-28	117	90	27
1001-27	143	88	25
2434-1	137	103	21
3181-1	195	151	38
4328-1	155	133	27

Length, width, and thickness are in mm.

such as Specimen 3181-1, could have been reduced into the forms represented in the de Graffenried collection. Moreover, the other four specimens are likely to represent not just later stages of biface reduction, but also a separate trajectory of tool design altogether, perhaps as flake cores (we return to this issue below). Likely derivatives from this type of core include any of an array of ad hoc flake tools (Figure 11) as well as smaller bifaces.

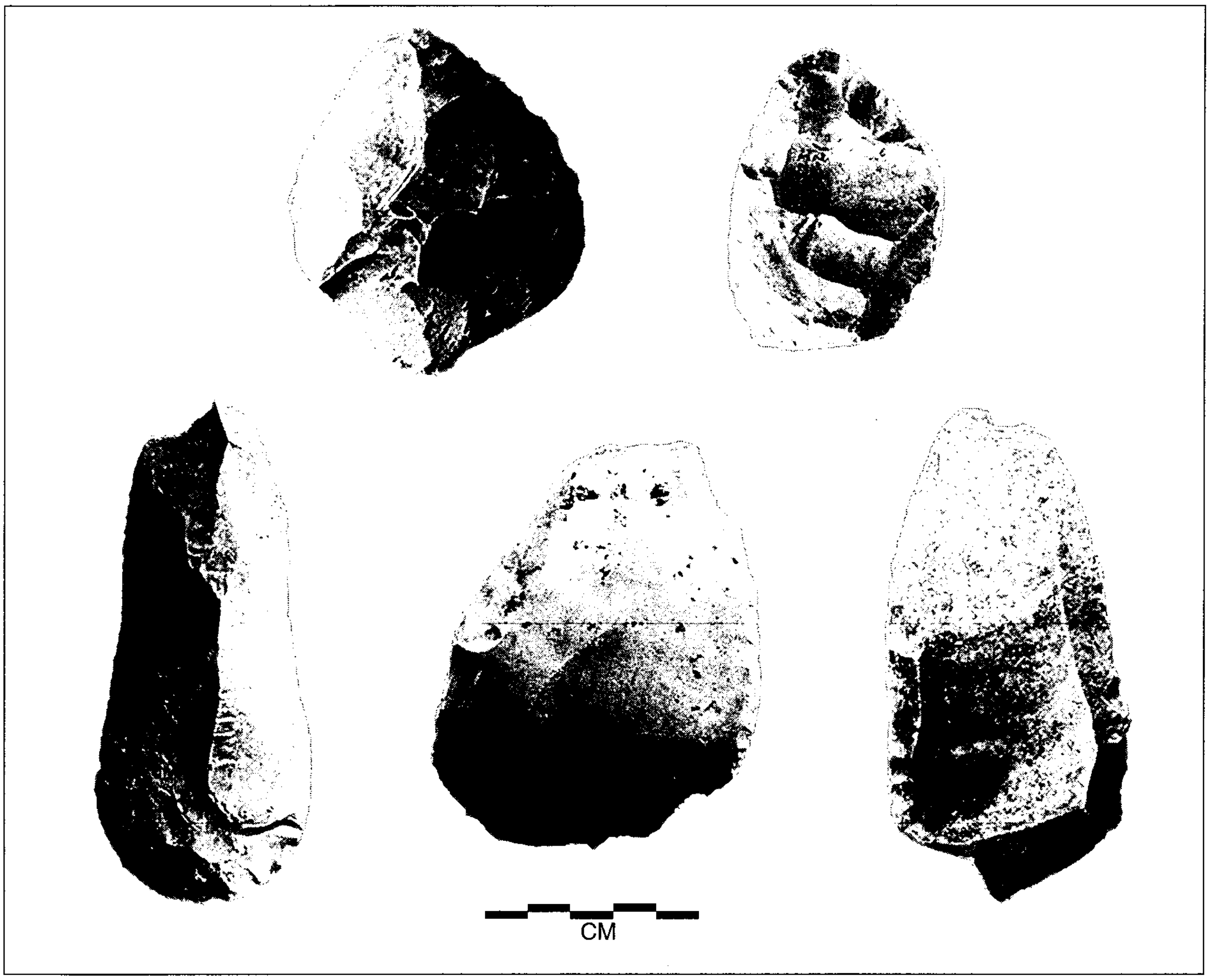


Figure 11. Examples of laterally trimmed Clovis flake tools recovered from Gault. Top row (L to R): 4350-17, 4292-2. Bottom row (L to R): 4543-12, 3055-1, 2897-1.

Artifact Morphology and Proportion

The divergence in biface reduction trajectories suggested by metric values of the five de Graffenried specimens when compared with large bifacial flake cores from Gault raises questions concerning the status of certain types of bifaces as distinct manufacturing stages for some tools. For instance, do the two forms in the de Graffenried collection correspond with discernable and non-overlapping end products in Clovis assemblages? Or are they simply different means to the same end, such as the manufacture of specific tool types (fluted points, for example) or general lithic reduction trending into a number of objectives? We address these questions by (1) evaluating the proportions or ratios of each metric dimension (length, width, and thickness) for the de Graffenried specimens, and (2) comparing these against other Clovis bifaces recovered from Gault.

We converted the metric data (length, width, and thickness) shown in Tables 1 and 2 into ratios by dividing each value of length, width, and thickness by the sum of all three. This formula yields a number, expressed as a decimal proportion (rounded up to the nearest hundredth), indicating the percentage that any particular dimension contributes to an artifact's overall morphology. Next, we plotted each artifact on a triangular coordinate graph (Figure 12), useful for depicting similarities between artifacts by shape without the potentially deranging effects of size difference. Toward the apex of such a graph would plot items that are proportionately long and slender (such as a pencil or flag pole), toward the bottom left would fall items that are hemispherically round but flat (such as a coin), and to the bottom right can be found more perfectly spherical objects. This method of measuring artifact dimensions as ratios without regard to size can

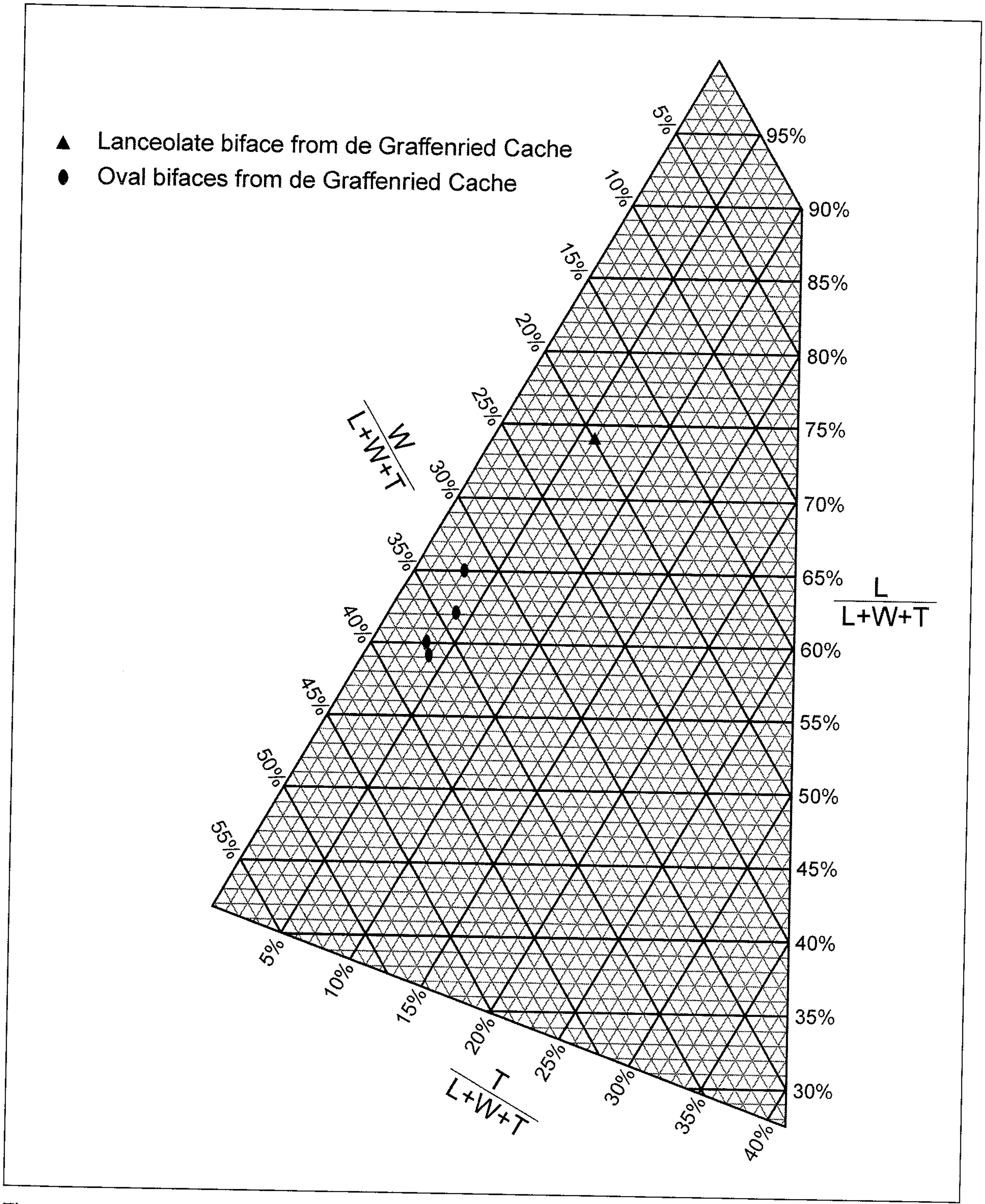


Figure 12. Triangular coordinate graph showing the proportions of length, width, and thickness as percentages of total artifact morphology for the de Graffenried specimens.

be useful in discerning behaviors that produce important though hard to document variation noted within some artifact assemblages (see Collins 1999a:104; Collins and Lohse 2004).

The similarities in thickness noted in Table 1 are shown in Figure 12, where thickness contributes between only 3% and 6% (mean=4%) to each artifact's morphology. Closeness in length and width among the oval forms is also evident, where length contributes between 59% and 65% (mean=62%) and width contributes between 32% and 37% (mean=35%) to each specimen's morphology. Distinctions evident between the oval forms and the lanceolate form emerge primarily between length and width values, where width contributes only 20% but length represents 74% of the lanceolate form.

When compared with similar ratios calculated for a sample of 10 Clovis points and one very late stage preform from Gault (Figure 13), significant patterns emerge (Figure 14). Several points were resharpened or have missing distal tips (no specimen was included if more than an estimated 1 cm was missing). While both the absolute length (Table 3) and relative length ratios are likely to have diminished throughout the life histories of these artifacts as they were continually resharpened, their current proportions are still informative for the present study.

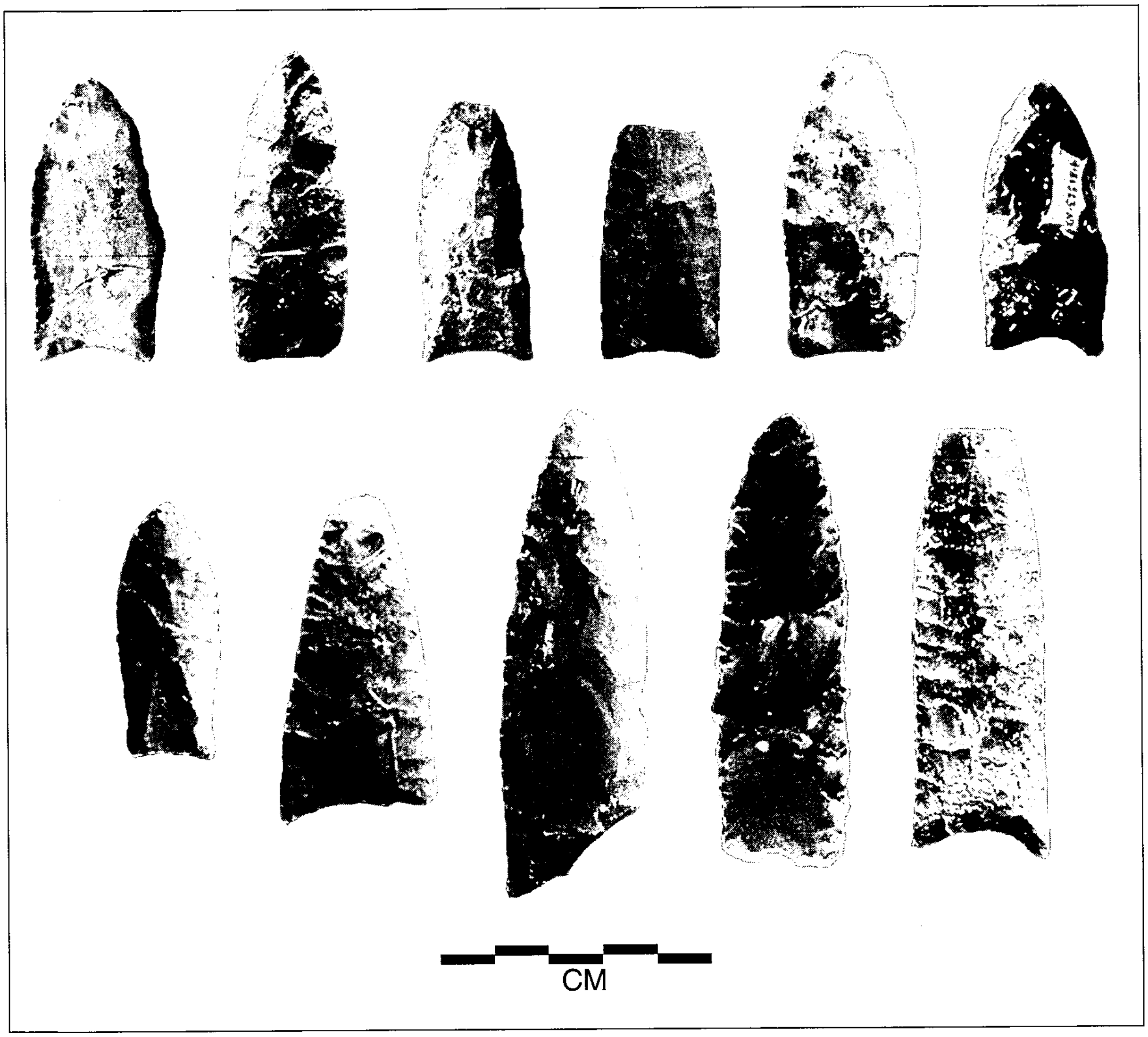


Figure 13. Clovis points and a preform recovered through excavations at Gault. Top row (L to R): 3103-1, 36-42, 3559-1, 2037-1, 2621-1, NH-1323-1. Bottom row (L to R): 2643-15, 2537-1, 1040-113, 1007-1, 2624-1.

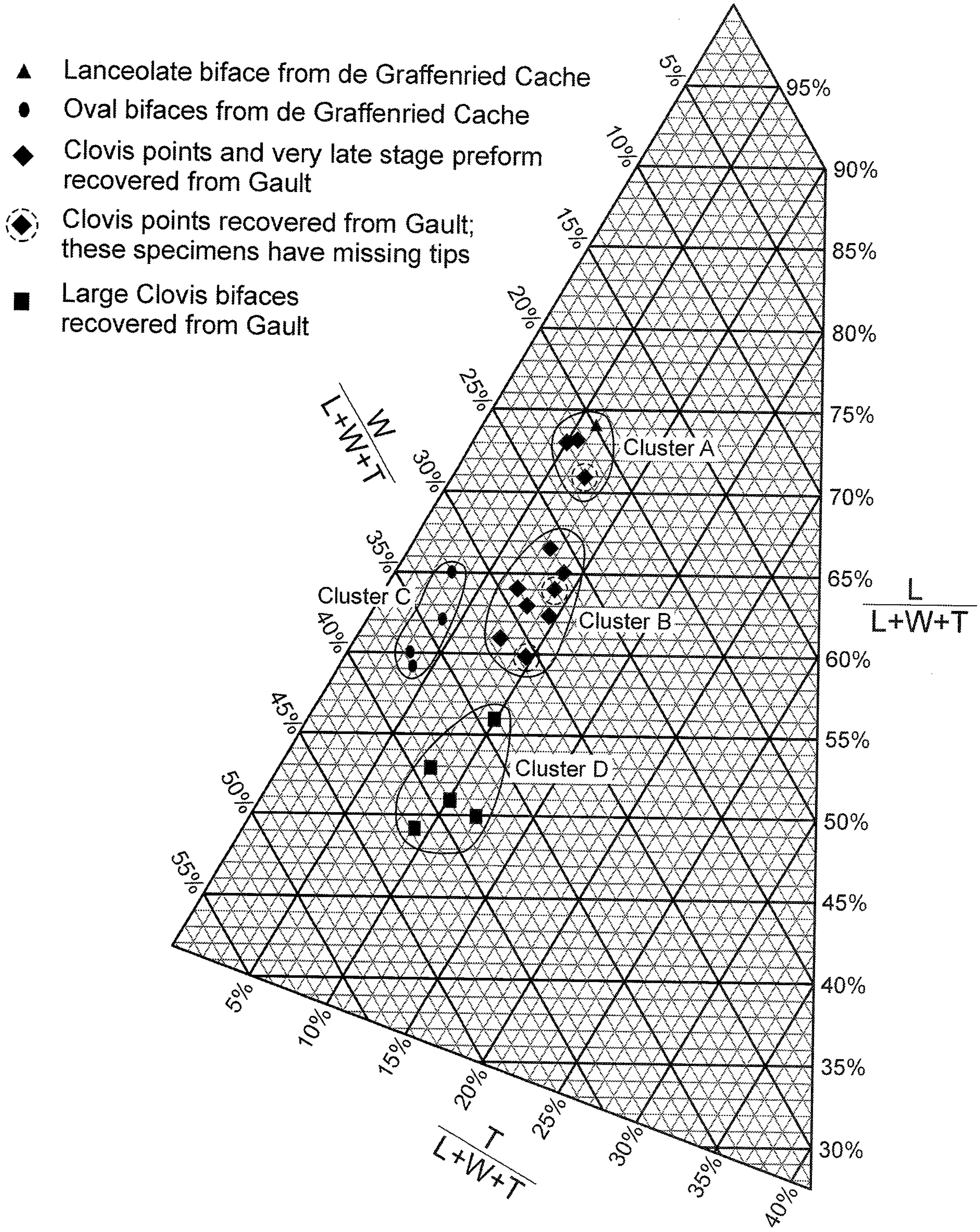


Figure 14. Triangular coordinate graph showing the five de Graffenried specimens together with bifacial flake cores and projectile points recovered from Gault.

Table 3. Metric dimensions of 10 Gault Clovis points and a very late stage preform (Specimen 1007-1).

Specimen Number	Length	Width (maximum)	Thickness (maximum)
36-42	66.3	25.6	7.7
3559-1	(51.3)	21.3	7.2
3103-1	65.6	30.0	9.8
1007-1	93.5	27.9	6.6
2621-1	61.1	27.7	6.6
1040-113	98.2	29.5	7.2
NH1323-1	52.9	24.5	6.7
2037-1	(49.1)	25.3	8.1
2624-1	(86.3)	27.1	8.7
2643-15	53.5	21.4	7.1
2537	64.4	32.5	8.0

Length, width, and thickness are in mm; parentheses indicate incomplete measurement due to missing distal tips.

By plotting the morphological ratios of these artifacts, three of the Gault Clovis points group with the lanceolate de Graffenried biface to form a relatively tight cluster (Cluster A in Figure 14). One nearly intact point (Specimen 1040-113) shows little evidence of having been resharpened, although one of its basal corners was broken off. Another specimen (2624-1) also shows no reworking but its distal tip is absent. These specimens and the late stage preform (1007-1) consist of nearly identical ratios of length (73%, 71%, and 73%, respectively), width (22%, 22%, and 21%, respectively), and thickness (5%, 7%, and 5%, respectively). The slight "drift" of Specimen 2624-1 towards the bottom of the graph and away from Specimens 1040-113 and 1007-1 and the lanceolate biface is explained by its missing distal end; if the end were present, this artifact would be nearly indistinguishable from the other three artifacts in Cluster A.

The remaining eight Clovis points aggregate in a loose cluster (Cluster B) somewhat below and left of Cluster A. As with Specimen 2624-1, the two with missing tips (Specimens 3559-1 and 2037-1) contribute to the looseness of this cluster; if those specimens were complete they would move up the graph (proportionately longer) and slightly to the right (proportionately more narrow). Another, probably more predominating, factor in the looseness of Cluster B are the current lengths of these points, reflecting both different degrees of resharpening and original size. However, the ratios of the thickness (between 7% and 10%) and width (between 26% and 31%) dimensions of these eight artifacts still fall within well-defined ranges. This pattern is true even for two specimens (2643-15 and 2537) that may represent sub-types of Clovis points.

Regarding the relationship between the eight Clovis points (Cluster B) and the four oval de Graffenried bifaces (Cluster C), it is noteworthy that the range of variation for length, width, and thickness ratios remains constant between the two clusters. Though the exact percentages are different, with the points being on average somewhat thicker, longer, and narrower by proportion, both clusters fall within a range of 7% variation for length, 5% variation for width, and 2% or 3% variation for thickness. It is impossible at present to know if the oval de Graffenried bifaces were blanks for a style of Clovis point represented by the eight specimens in Cluster B and different from Cluster A; if through gradual and dramatic resharpening the points in Cluster B drifted down the graph away from Cluster A towards proportionately shorter and wider, but only slightly thinner, artifacts; or if some combination of these explanations should be considered before manufacturing trajectories for all Clovis points can be understood.

The relationships between Cluster C and the large bifaces (Cluster D) are also less than clear, although we are confident for three reasons that these two groups represent distinct artifact categories. First, the pattern of flaking on the oval bifaces is easily distinguished from that of the bifacial flake cores. The de Graffenried specimens are all characterized by the regular and consistent removal of broad, near-parallel thinning flakes extending most or all the way across the artifact. In contrast, extant flake scars on the smaller three of the five bifaces rarely exceed the artifacts' midpoints, are more commonly short and relatively steep, and originate from nearly all directions.

Second, the morphological variation evident between the two clusters, particularly in thickness, is extreme enough to warrant separation into different categories, even though the general forms of the tools are comparable (i.e., generally oval in shape). Artifacts in Cluster C, as noted above, are characterized by a mean thickness ratio of 3.5% (range of 3% to 4%) for the tools' overall morphologies. In contrast, the artifacts in Cluster D maintain much higher variations in proportional thickness, with ranges from 8% to 12% (mean=9.8%). These data mean that, on average, the thickness ratios of the large bifaces are between three and four times greater than the de Graffenried specimens.

Finally, given the greater overall values in every dimension except for thickness for the de Graffenried specimens, the oval forms cannot be placed either before or after the smaller four of the large bifaces in a linear reduction sequence in which one form derives from the other. In other words, it would not be possible to achieve the oval de Graffenried forms, with greater overall width but less thickness, from the thicker but more narrow large bifaces, and vice versa. Clearly, ancient Clovis knappers faced a decision about whether to pursue oval bifaces such as those in the de Graffenried collection or other types such as the four from Gault (excluding Specimen 3181-1) at an early stage in the reduction process. In the larger context of Clovis biface production, these differences indicate divergences in knapping strategies, with the objective of different production trajectories that were generally (although perhaps not always) distinguished at an early stage of the reduction process. Our ongoing analyses of preforms from Gault has corroborated this observation by revealing the different orders in which certain tasks were performed in the process of manufacturing points. For example, bases were eventually squared and beveled for fluting before points were finished, while this step is seen to occur at different stages of reduction. Some preforms show early flute removal from square bases; these were fluted again as they were further reduced. In contrast, other preforms were fluted only once as one of the final steps of point production. Variations in the sequences in which these tasks were performed indicate the role of individual knapper decision-making in preform reduction and point production.

CONCLUSIONS

Our data strongly indicate that at least one strategy selected by Clovis knappers for achieving completed points involved producing lanceolate preforms, and that decisions were made at a yet-earlier stage of reduction, probably that represented by the large flake core (such as Specimen 3181-1), about whether to pursue lanceolate preforms or parallel-flaked oval bifaces as intermediate stages. This leaves the relationships between Clovis points and the parallel-flaked oval bifaces unclear. This is not to argue that projectile points were not ultimately derived from parallel-flaked oval bifaces, only that our current sample is not robust enough to resolve this question. We show our interpretation of the relationships between these artifact categories in Figure 15, based on the current analysis of the de Graffenried collection and a limited number of additional specimens recovered from Gault.

Comparisons between the parallel-flaked oval bifaces and other bifaces from Gault reveal additional divergences in Clovis knapping strategies. Differences expressed both in overall sizes and important dimension ratios, especially thickness, as well as flaking patterns, distinguish the de Graffenried bifaces from the more common forms shown in Figure 10 and represented in Figure 14's Cluster D. These traits suggest that the smaller Gault bifaces are yet another derivative of the large bifacial flake core in Clovis lithic reduction sequences. However, that such by-products as flake tools, small bifaces, and perhaps even Clovis points can be achieved from different stages in reduction sequences should serve as a caution to scholars that at least some Clovis tool manufacturing trajectories were non-linear in nature, and that

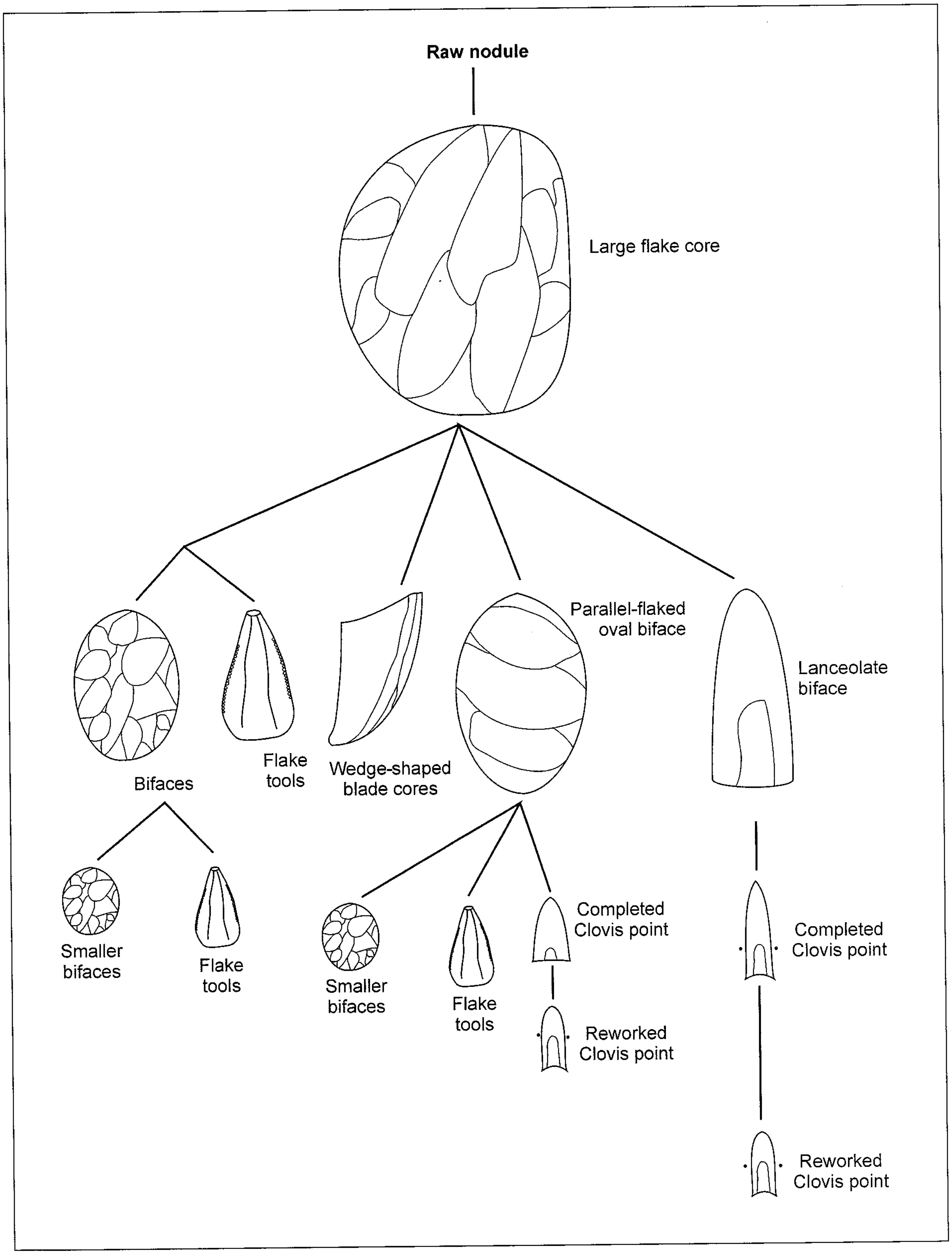


Figure 15. Postulated Clovis lithic reduction sequence based on metric and proportional analyses of de Graffenried specimens and including other bifaces and flake tools recovered from Gault. Some wedge-shaped blade cores, as well as conical cores, probably do not come from large flake cores. We have different point styles from Gault, but have not yet recognized the preforms that go with them.

knappers were able to attain the same results through different processes. This means that, while it is possible for archeologists to know at least some of the earlier stages an artifact went through before achieving its final form, it would be impossible in most cases to know the form in which certain early-stage tools might ultimately end up.

As analyses of excavated Gault materials continue, we are recognizing more and more complexity in the Clovis evidence. The presence of the de Graffenried biface cache, which historical information identifies as likely having come from Gault, contributes to this complexity while also providing important information that improves our understanding of Clovis lifeways at a number of levels. This collection adds questions of caching behavior to a range of others asked at Gault, and in Early American studies in general, that include subsistence adaptation, lithic tool manufacture, variation in tool morphology and use, occupational history and seasonality, and regional settlement patterning. Our analyses of this cache provide clues that will, hopefully, help researchers address these issues both at Gault and elsewhere.

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REFERENCES CITED

Barnes, V. E.
1981 *Geologic Atlas of Texas: Austin Sheet.* Bureau of Economic Geology, The University of Texas at Austin.

Boldurian, A. T. and J. L. Cotter
1999 *Clovis Revisited: New Perspectives on Paleoindian Adaptations from Blackwater Draw, New Mexico.* The University Museum, University of Pennsylvania, Philadelphia.

Bradley, B. A.
1982 Flaked Stone Technology and Typology. In *The Agate Basin Site: A Record of Paleoindian Occupation of the Northwestern High Plains*, edited by G. C. Frison and D. J. Stanford, pp. 181-208. Academic Press, New York.
1991 Flaked Stone Technology in the Northern High Plains. In *Prehistoric Hunters of the High Plains*, edited by G. C. Frison, pp. 369-395. Second Edition. Academic Press, New York.
1993 Paleo-Indian Flaked Stone Technology in the North American High Plains. In *From Kostenki to Clovis: Upper Paelolithic-Paleoindian Adaptations,* edited by O. Soffer and N. D. Praslov, pp. 251-262. Plenum Press, New York.

Butler, B. R.
1963 An Early Man Site at Big Camas Prairie, South-Central Idaho. *Tebiwa* 6(1):22-33.

Butler, B. R. and R. J. Fitzwater
1965 A Further Note on the Clovis Site at Big Camas Prairie, South-Central Idaho. *Tebiwa* 8(1):38-40.

Collins, M. B.
1995 Forty Years of Archeology in Central Texas. *Bulletin of the Texas Archeological Society* 66:361-400.
1999a *Clovis Blade Technology.* University of Texas Press, Austin.
1999b Clovis and Folsom Lithic Technology On and Near the Southern Plains: Similar Ends, Different Means. In *Folsom Lithic Technology: Explorations in Structure and Variation*, edited by D. S. Amick, pp. 12-38. Archaeological Series 12. International Monographs in Prehistory, Ann Arbor.
2001 Clovis Lithic Technology. Paper presented at the 66th Annual Meeting of the Society for American Archaeology, New Orleans.
2002 The Gault Site, Texas, and Clovis Research. *Athena Review* 3(2):31-41, 100-101.
2004 Archeology in Central Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 101-126. Texas A&M University Press, College Station.

Collins, M. B. and J. C. Lohse
2004 The Nature of Clovis Blades and Blade Cores. In *Entering America: Northeast Asia and Beringia Before the Last Glacial Maximum*, edited by D. B. Madsen, pp. 159-183. University of Utah Press, Salt Lake City.

Conger, R. N.
1987 *Texas Collector: Gaines de Graffenried.* Texian Press, Waco.
1996 De Graffenried, Gaines. In *The New Handbook of Texas*, Vol. 2, edited by R. Tyler, p. 565. Texas State Historical Association, Austin.

Frison, G. C.
1982 The Sheaman Site: A Clovis Component. In *The Agate Basin Site: A Record of Paleoindian Occupation of the Northwestern High Plains*, edited by G. C. Frison and D. J. Stanford, pp. 143-157. Academic Press, New York.
1991a The Clovis Cultural Complex: New Data from Caches of Flaked Stone and Worked Bone Artifacts. In *Raw Material Economies among Prehistoric Hunter-Gatherers,* edited by A. Montet-White and S. Holen, pp. 321-333. Publications in Anthropology 19. University of Kansas, Lawrence.
1991b *Prehistoric Hunters of the High Plains*. Second Edition. Academic Press, New York.

Frison, G. C. and B. Bradley
1999 *The Fenn Cache: Clovis Weapons and Tools.* One Horse Land and Cattle Company, Santa Fe.

Gramly, R. M.
1993 *The Richey Clovis Cache: Earliest Americans Along the Columbia River*. Monographs in Archaeology. Persimmon Press, Buffalo.

Green, F. E.
1963 The Clovis Blades: An Important Addition to the Llano Complex. *American Antiquity* 29(2):145-165.

Haynes, C. V., Jr.
1966 Elephant-hunting in North America. *Scientific American* 214: 104-112.

Hofman, J. L.
1995 The Busse Cache: A Clovis-Age Find in Northwestern Kansas. *Current Research in the Pleistocene* 12:17-19.

Huckell, B., J. D. Kilby, B. Buchannan, and L. W. Huckell
2002 Bifaces to Go: An Experimental Study of the Genesis of Transport Wear. Poster presented at the 67th Annual Meeting of the Society for American Archaeology, Denver.

Kay, M.
1999 Microscopic Attributes of the Keven Davis Blades. In *Clovis Blade Technology*, by M. B. Collins, pp. 126-143. University of Texas Press, Austin.

Mallouf, R. J.
1994 Sailor-Helton: A Paleoindian Cache from Southwestern Kansas. *Current Research in the Pleistocene* 11:44-46

Mason, R. J.
1962 The Paleo-Indian Tradition in Eastern North America. *Current Anthropology* 3:227-283.

Mehringer, Jr., P. J.
1988 Weapons of Ancient Americans. *National Geographic* 174:500-503.

Mehringer, Jr., P. J. and F. F. Foit, Jr.
1990 Volcanic Ash Dating of the Clovis Cache at East Wenatchee, Washington. *National Geographic Research* 6:495-503.

Miller, K. A.
1993 A Study of Prehistoric Biface Caches from Texas. Master's thesis, Department of Anthropology, The University of Texas at Austin.

Montgomery, J. and J. Dickenson
1992 Additional Blades from Blackwater Draw Locality No. 1, Portales, New Mexico. *Current Research in the Pleistocene* 9:31-32.

Morrow, J. E. and T. A. Morrow
1999 Geographic Variation in Fluted Projectile Points: A Hemispheric Perspective. *American Antiquity* 64:215-231.

Pearson, G. A.
2003 First Report of a Newly Discovered Paleoindian Quarry Site on the Isthmus of Panama. *Latin American Antiquity* 14:311-322.

Ranere, A. J. and R. G. Cooke
1991 Paleoindian Occupation in the Central American Tropics. In *Clovis: Origins and Adaptations*, edited by R. Bonnichsen and K. L. Turnmire, pp. 237-253. Center for the Study of the First Americans, Oregon State University, Corvallis.

Sharrock, F. W.
1966 *Prehistoric Occupation Patterns in S.W. Wyoming and Cultural Relationships with the Great Basin and Plains Culture Areas.* Anthropology Papers Number 77. University of Utah, Department of Anthropology, Salt Lake City.

Stanford, D. J.
1999 Paleoindian Archaeology and Late Pleistocene Environments in the Plains and Southwestern United States. In *Ice Age Peoples of North America, Environments, Origins, and Adaptations of the First Americans*, edited by R. Bonnichsen and K. L. Turnmire, pp. 281-339. Center for the Study of the First Americans, Corvalis.

Stanford, D. J. and M. A. Jodry
1988 The Drake Clovis Cache. *Current Research in the Pleistocene* 5:21-22.

Tankersley, K. B.
1998 The Crook County Clovis Cache. *Current Research in the Pleistocene* 15:86-88.
2002 *In Search of Ice Age Americans*. Gibbs, Smith Publisher, Salt Lake City.

Taylor, D. C.
1969 The Wilsall Excavations: An Exercise in Frustration. *Proceedings of the Montana Academy of Science* 29:147-150.

Titmus, G. L. and J. C. Woods
1991 Fluted Points from the Snake River Plain. In *Clovis: Origins and Adaptations*, edited by R. Bonnichsen and K. L. Turnmire, pp. 119-131. Center for the Study of the First Americans, Oregon State University, Corvallis.

Wilke, P. J., J. J. Flenniken, and T. L. Ozbun
1991 Clovis Technology at the Anzick Site. *Journal of Califronia and Great Basin Anthropology* 13(2):242-272.

Woods, J. C. and G. L. Titmus
1985 A Review of the Simon Clovis Collection. *Idaho Archaeologist* 8(1):3-8.

Yates, P. C.
1941 Central Texas Indian Mounds Yield Treasures. *Austin Daily Tribune*, Sunday, May 25, p. 9.

Young, B. and M. B. Collins
1989 A Cache of Blades with Clovis Affinities from Northeastern Texas. *Current Research in the Pleistocene* 6:26-28.

Exploring Paleoindian Site-Use at Bonfire Shelter (41VV218)

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ABSTRACT

Bonebed 2 at Bonfire Shelter (41VV218) has long been interpreted to be the site of a Paleoindian (ca. 10,080 radiocarbon years B.P.) bison jump (Dibble and Lorrain 1968), although in recent years it was suggested that it might instead represent a secondary processing site (Binford 1978). To explore these different interpretations more thoroughly, in 2003 we began a multi-pronged study of the site, including Geographic Information Systems (GIS) analysis and reanalysis of the bison skeletal remains (Byerly et al. 2005). While our GIS analysis did not reject the possibility that Bonfire Shelter was a jump kill, our zooarcheological analysis indicated that the types and frequencies of elements recovered suggested a processing site assemblage.

However, if Bonfire Shelter was a processing locality, it raises several additional questions: namely, why are lithic artifacts so rare? where did the kill take place? and, how and in what form were carcass parts transported into the shelter? To address these questions, we conducted additional field research at Bonfire Shelter during the summer of 2005. We present those results here, which include new radiocarbon dates from the site, as well as gastropod data recovered from a sediment column.

BONFIRE SHELTER: SITE-USE INTERPRETATIONS AND QUESTIONS

Bonfire Shelter is located near the northeastern corner of Mile Canyon neighboring Langtry, Texas, on the Stockton Plateau (Figure 1). The site has paleontological and archeological components, three of which (Bonebed 2, Bonebed 3, and the Fiber Layer) are unambiguously cultural, and range in age from ca. 10,000 to 1,500 years B.P. (hereafter, B.P.; Dibble and Lorrain 1968; but also see Bement 1986). The earliest of those cultural deposits, Bonebed 2, was interpreted by Dibble and Lorrain (1968) to represent three separate jump kill events totaling 120 or more *Bison antiquus*. They inferred that hunters stampeded a herd (or, on several occasions, different herds) of bison over the cliff edge through a cleft in the cliff face directly above the site. The animals died on the talus cone below, where their carcasses were subsequently butchered.

A jump kill, as recognized archeologically, includes many tactical variants (Brekke 1970; Forbis 1962; Frison 1991, 2004; Hornaday 2002; Malouf and Conner 1962; Polk 1979; Verbicky-Todd 1984; Witkind 1971). However, general consensus holds that bison jumps were a communal hunting strategy in which hunters drove animals over precipices to injure or kill them (Byerly et al. 2005:599; Frison 2004; Hurt 1962). While Paleoindian hunters were capable of driving and trapping large bison herds across the Great Plains (Hill 2001), it is not apparent that a jump strategy was ever utilized on the Southern Plains or as early as the Paleoindian period. Indeed, virtually all mass bison jump kills occur on the northern and northwestern Great Plains, and are Archaic (the oldest being ca. 5,700 B.P.) to Historic in age (Byerly et al. 2005: Figure 1; see also Barsh and Marlor 2003; Buehler 1997; Dibble 1970; Dyck and Morlan 2001; Fisher and Roll 1999; Forbis 1969; Reeves 1978). Being Late Paleoindian in age (ca. 10,080 B.P.) and located on the Stockton Plateau, Bonebed 2 thus represents the earliest (by some 4,300 years) and southernmost (by nearly 1,800 km) jump kill (or kills) in North America. The next earliest jump is the Middle Archaic deposit at Head-Smashed-In (Reeves 1978), and the nearest in distance, other than Bonebed 3 at Bonfire Shelter, is the Roberts Buffalo Jump in Larimer County, Colorado (Witkind 1971). Recent geomorphological

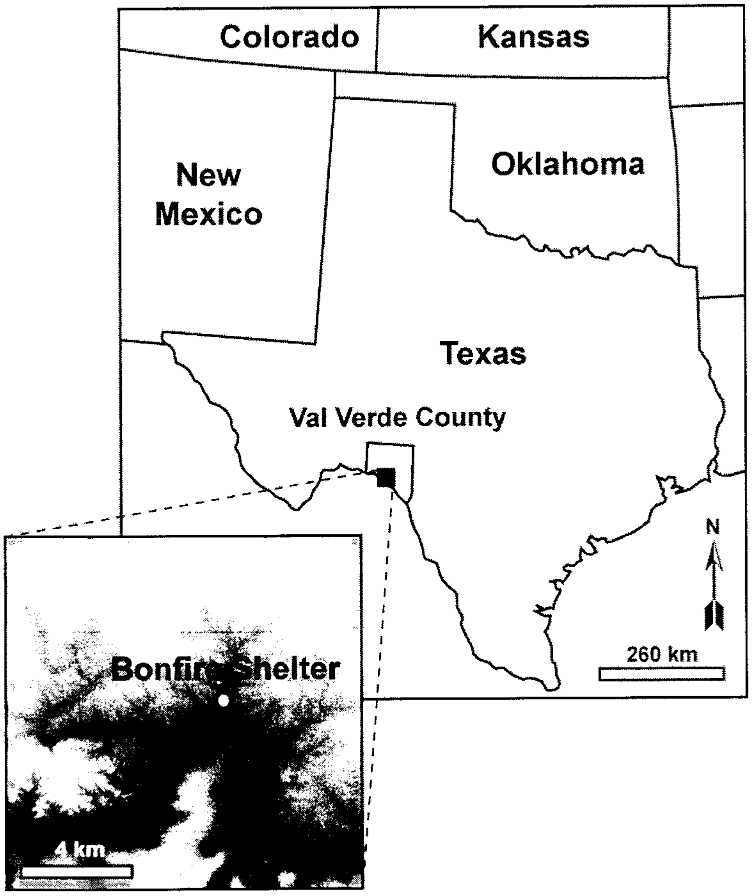

Figure 1. Location of Bonfire Shelter.

data suggest, however, that the Late Archaic Certain site in western Oklahoma may also be a jump kill (Bement and Buehler 2005). While this possibility would render Bonfire Shelter less of a geographic anomaly, Bonebed 2 would remain inconsistent with the known jump kill chronology for the Great Plains.

A jump kill interpretation was favored by Dibble and Lorrain (1968) because of the spatial confinement of Bonebed 2 around the talus cone; the preponderance of projectile points and the lack of butchery tools, fire features, and burned rock in the deposit; and the inferred implausibility of prehistoric hunters driving animals up Mile Canyon to slaughter and then dragging large carcass portions approximately 18 m uphill from the canyon floor into the shelter for further butchery (Dibble and Lorrain 1968). Binford (1978:476) subsequently advocated an alternative hypothesis. Citing a correlation between published bone frequencies and a model of bone abandonment at Nunamiut caribou processing sites, he argued that Bonebed 2 better resembled a secondary processing area—a place where carcass parts were transported to from a kill locality and rendered for food—than the site of a kill.

To test these competing interpretations, we conducted several analyses—in both the field and the laboratory—in 2003 and 2004, the results of which were recently published (Byerly et al. 2005). Since the completion of that article, we have conducted additional work at the site and on site collections, which we report on here, along with a brief summary of our previous analyses, which included two main elements: a GIS study of the local topography to assess the viability of this locality as a jump kill, and a reanalysis of the faunal remains recovered from the 1963-1964 excavations by Dibble and crew.

GIS Analysis

Dibble (1968) argued that the Bonfire Shelter deposits likely resulted from jump kills because the flanking upland terrain was conducive for jumping bison. This interpretation was made largely on a visual inspection of the landscape. In recent decades, Geographic Information Systems (GIS) technology has become available and permits fine-resolution mapping and modeling of landscapes. Using this technology and detailed field mapping of the site and surrounding area, the primary goal of our analysis was to systematically assess whether the terrain could have supported a jump kill during Bonebed 2 times.

To evaluate the viability of a jump kill at Bonfire Shelter, we turned our attention to other archeological examples of jump kills (Brekke 1970; Frison 1991, 2004; Polk 1979; Verbicky-Todd 1984; Witkind 1971). These sites share certain traits that might have played an integral role in the success of the kill. These include: (1) proximity to water and grass; (2) a long, level path linking a bison gathering area to a jump point that would allow the herd to reach a certain speed but without chance for escape; (3) a herd large enough to gain sufficient momentum in the approach; (4) an obscured jump point; (5) a cliff face orientation coupled with a prevailing wind direction that ensured the bison were upwind of the hunters; and (6) a cliff edge steep and sharp enough to guarantee the bison died or were severely maimed in the plunge. We acknowledged that these traits were not requirements, but that they might have improved the chances of a kill, and that their co-occurrence at Bonfire Shelter could at least support the possibility of a jump kill.

We assessed the viability of a jump kill first using published data and then by performing a detailed terrain analysis. A spike in grass pollen during Bonebed 2 times suggests suitable bison forage was in close proximity to the site (Bryant and Holloway 1985:Figure 3), and, while the climate is extremely arid, the Rio Grande is less than 1 km away, making water permanently available. As for a concomitant wind direction and cliff face orientation, we were unable to estimate wind direction during Bonebed 2 times, but concluded that the hunters could have chosen a day in which winds were favorable. Based on either published count (Lorrain 1968:80-81), there were enough animals in Bonebed 2 to execute a jump kill (Frison 1991:218). The estimated height of the fall, from the cliff edge to the top of the talus cone, would have been approximately 23 m (Dibble 1968:13, 70), a fall sufficient to kill or severely maim an animal.

Our terrain analysis indicated several corridors within the region that might have served as an effective drive lane. Of those, only the route approaching Bonfire Shelter led to an ideal jump point: one where a cliff was present, but the height and location of that cliff did not make carcasses exceedingly difficult to access. That same route also proved to be the least-cost path to approach the proposed jump point, or in other words, the path where both distance and terrain ruggedness were minimized. Finally, using a line-of-sight analysis, we concluded that, if the bison herd approached along that proposed path, the cliff edge would have been obscured until the herd was 25 m from the edge, and thus would have made it difficult for the entire herd to escape the fall.

In sum, we concluded that Bonfire Shelter met most of the criteria outlined above and was better suited to support a jump kill than other localities in the immediate area. However, while we grant that a jump kill *could* have occurred (and apparently did in the Late Archaic) we turned to zooarcheological evidence to determine if a jump kill *did* occur and was responsible for the Bonebed 2 deposit.

Zooarcheological Analysis

The original analysis of Bonebed 2 bison by Lorrain (1968) is one of the seminal studies (along with Frison [1974], Kehoe [1967], and Wheat [1972]) upon which modern bison bonebed analyses are modeled. However, the original Bonebed 2 bison bone frequency data (in Dibble and Lorrain 1968) are hard to interpret in contemporary zooarcheological vernacular, and are therefore difficult to use for analytic comparisons with other bison kill-butchery assemblages. Thus, we re-analyzed the bones from the 1963-1964 excavations to update bone frequency and taphonomic data and to evaluate the remains in terms of nutritional return and carcass transport models for bison (see Emerson 1990, 1993).

The updated bone element frequencies, when compared to bison food utility indices, showed a strong 'bulk-utility' profile (both for individual elements and carcass portions); such a profile is thought to be an indicator of selective hunter-gatherer transport of carcass parts (Binford 1978). Extensive disarticulation and limited green-bone fracturing also implied butchery activities geared towards meat removal and marrow processing. These patterns were not biased by carnivore activity or bone density. If this was indeed a locality to which carcass parts were transported, it makes certain intuitive sense: after all, its topographic setting is not just suitable for jumping bison, it is also a well-protected setting in which hunters could process transported elements. Given this was interpreted as a summer kill (Byerly et al. 2005), the site may have provided welcome shade and cooler temperatures, and some protection from meat spoilage.

Likewise, it seems apparent, based on a tight clustering of Age Group 3 individuals (2.2 to 2.4 yrs.; Byerly et al. 2005:Table 3), that Bonebed 2 represents a single event, rather than three separate kills as hypothesized by Dibble and Lorrain (1968). Furthermore, it does not appear it was a kill on the scale originally proposed: our Minimum Number of Individuals (MNI) estimates indicated that 24-27 animals is probably a closer approximation than the projected 120. These data suggested that the extant bison bone assemblage does indeed resemble a butchery site.

While this reanalysis confirmed Binford's site-use hypothesis in terms of the faunal component, questions about the nature of the lithic assemblage, the location of the kill, and the logistics of carcass transport persisted. Specifically:

1) If the bone assemblage indicates a butchery area, why are butchering tools and small resharpening debris so rare? Such remains ought to be abundant where intensive butchery occurred.
2) If the shelter was not the kill site, where did the kill take place? Was it on the upland surface, or perhaps on the canyon floor below?
3) And, finally, how and why were large carcass portions transported into such a difficult-to-reach location from either the upland surface or canyon floor?

Several hypotheses were posited to address these questions:

1) Small resharpening debris were not recovered from Bonebed 2 because: (a) water pouring from the notch reworked and removed small lithic debris indicative of tool production and maintenance activities; (b) tool production and maintenance, if it occurred at all, took place in an isolated, still unexcavated area of the shelter (such has been found to be the case at other Paleoindian bison kill-butcheries [Matthew G. Hill, personal communication 2005]); and/or (c) coarse screening methods employed during the 1963-1964 excavations biased the recovery of debitage.
2) The kinds and frequency of bone recovered within the shelter suggests that the kill was very close to the site. The closest probable location of the kill would have been the canyon floor. Previous work on cemented gravels in Mile Canyon (David J. Meltzer, unpublished data 2003) raised the possibility that the floor of the canyon may have been much higher during the Late Pleistocene and Early Holocene. If so, the perceived difficulty of dragging bison carcasses into the shelter is exaggerated. Evidence of ancient canyon floor levels should be present in extant deposits outside the shelter.

We conducted fieldwork at Bonfire Shelter in the summer of 2005 to test these hypotheses. Our investigations focused on evaluating whether coarse screening methods biased lithic recovery and if ancient canyon floor levels were observable outside the shelter.

2005 FIELDWORK

Backdirt Screening: Lithic Debitage

The analysis of chipped stone debris, and the integration of those data with stone tool analysis, is critical to understanding lithic production activities at archeological sites, and is ultimately essential to understanding prehistoric lifeways (Carr and Bradbury 2001:126-127). Experimental data indicate that the majority of lithic debris produced by tool production and maintenance activities is small (less than 6.35 mm in size; Baumler and Downum 1989). Indeed, the tens of thousands of small unmodified flakes recovered from prehistoric camp and bison processing sites like Big Goose Creek (Frison et al. 1978), Cattle Guard (Jodry 1999; Jodry and Stanford 1992), and Clary Ranch (Hill et al. 2002) speak to the intensity of tool production and maintenance activities that probably occurred at these locations over their respective use-histories. Unfortunately, detailed collection strategies geared towards the recovery of such small debitage, as exemplified in the archeological work conducted at these sites, has been implemented less often in field research elsewhere.

The screens used during the 1963-1964 excavations of Bonfire Shelter were, for example, coarse-grained (1/4 and 1/2 inch [6.35 and 12.70 mm]) and used only on occasion (Dibble 1968:19-20). Although this approach, along with constant inspection, satisfied the excavators that "little was lost" (Dibble 1968:19), this strategy probably biased against the recovery of small lithic debris (Baumler and Downum 1989).

To see if this was so for Bonfire Shelter, a sample of back dirt from the excavations was dry-screened through 1/16 inch (1.59 mm) mesh. At this capture size, most small lithic debris present in sampled matrix should be recovered. Three back dirt piles remain from the 1963-1964 excavations. In the summer of 2005, four hand-dug trenches (approximately 1 x 0.5 x 0.5 m) and seven auger holes were placed in the northernmost and largest of these piles (Figure 2). This effort yielded 1.38 m^3 of back dirt, primarily deriving from excavation units N98/W40, N110/W30, N110/W40, and N120/W30 (Elton Prewitt, personal communication 2005). Although this was an area of the site where artifact and bone recovery from Bonebed 2 were sparse (Bement 1986; Byerly et al. 2005; Dibble and Lorrain 1968), this back dirt was

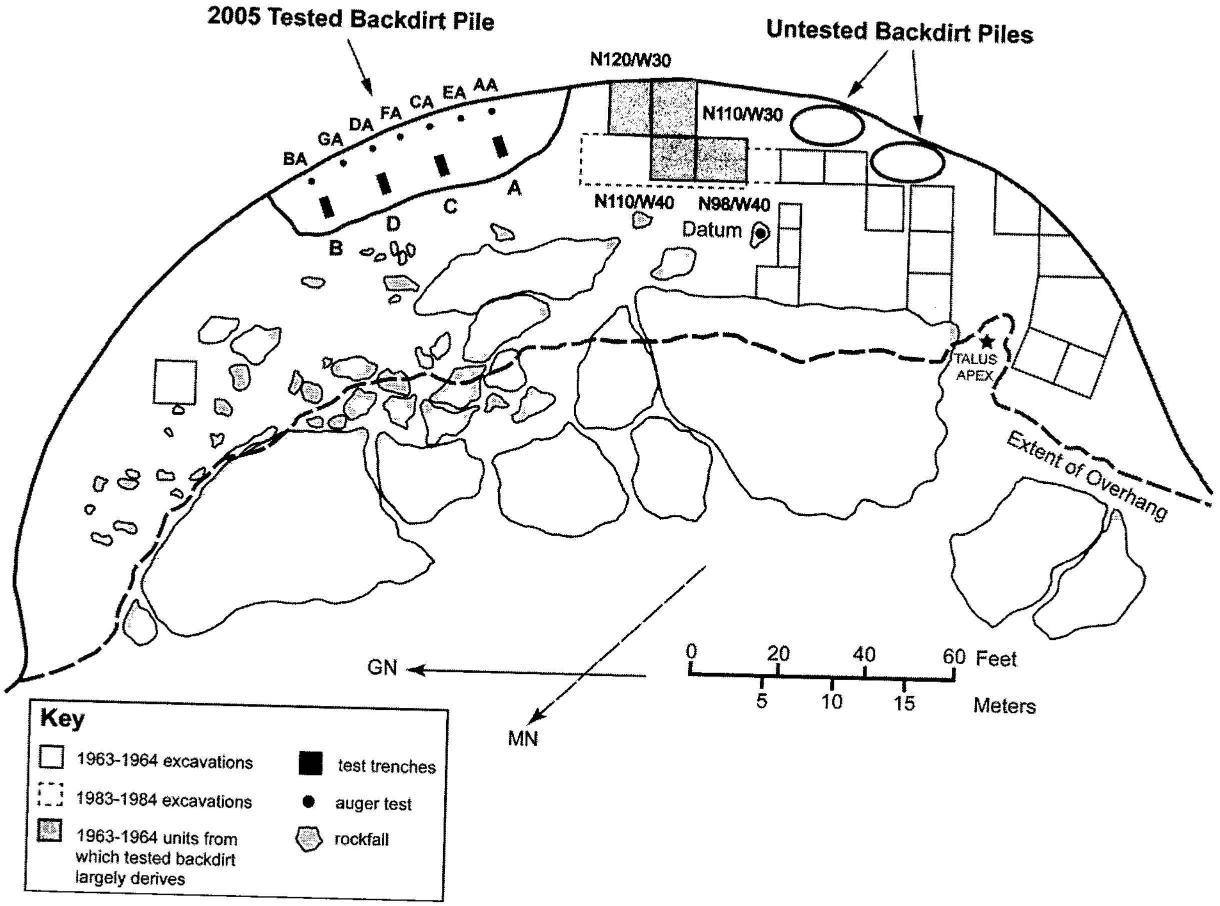

Figure 2. Plan map of 1963-1964 excavations of Bonfire Shelter showing tested and un-tested back dirt piles. Adapted from Dibble and Lorrain (1968:Figure 6).

chosen in the interest of protecting still open and unstable excavation units from potential work-related damage. All observed lithic and faunal material was recovered from the screens (Table 1). Recovered lithics consisted entirely of unmodified flakes.

Because sampled back dirt was a mix of cultural deposits, and because no comparison with the original lithic assemblage could be conducted (most of this material is currently unaccounted for; see Byerly et al. 2005:624), it was impossible to separate recovered lithic artifacts by component. Therefore, to compare our lithic findings to published lithic data, flake densities were calculated by summing the unmodified flake yield from *all* cultural layers of each excavated unit and dividing that by an estimated unit volume derived from published plan maps and profiles (see Dibble and Lorrain 1968). Although admittedly crude, this method sufficiently displays the spatial distribution and relative frequencies of the artifacts.

The back dirt sample contained approximately 1% of the total unmodified flake yield of the site from all cultural components, representing a sample volume little more than 0.5% of that of unmodified flake-bearing units (Table 2). Yet, this represents nearly twice the total flake density and six times the average density of the 1963-1964 excavations, if outlier units (e.g., N20/W50; n = 293; D = 49.91 flakes per m^3) are removed. Clearly, some artifacts

Table 1. Items recovered from back dirt testing.

Item	No.
unmodified flakes	5
macrofauna (large mammal, bison)	3158
microfauna (rodents, reptiles, birds)	341
gastropods	68

Table 2. Summary of unmodified flake density data.

	1963-1964	2005
total unmodified flakes	479	5
sample volume	$223.15\ m^{3*}$	$1.38\ m^3$
total unmodified flake density	$1.77\ fk/m^{3*}$	$3.62\ fk/m^3$
average flake density	$6.75\ fk/m^{3*}$	–
average flake density	$0.59\ fk/m^{3**}$	–

* Excludes data from N30/W50 and N225/W95 for which unit volume could not be estimated; total unmodified flakes = 396.
** Further excludes data from N20/W50; flake density = 49.91 flakes/m^3.

were overlooked during the 1960s excavations. However, while these data reveal what could have been missed during the original excavations, they only partially bear on tool production or maintenance activities within the shelter as size is also an important variable to consider (Table 3).

Again implementing Baumler and Downum's (1989) experimental data, it is apparent the flakes recovered from back dirt testing are on the upper size range of material expected from tool production and resharpening activities. Yet, these flakes are also well within the capture range of 1/4 and 1/2-inch mesh (Byerly et al. 2005). These data imply that while screening did not bias the recovery of small lithic debris in this area of the site, they did bias lithic recovery as a whole. This begs the question, assuming lithic reduction or production activities associated with intensive bison processing occurred: where did the small lithics go? If screens captured only the minority of what should be produced from tool production in an area of the site where artifact densities are lowest, where is the majority? Did minor localized water runoff originating from the notch remove small lithic debris from cultural deposits? Was tool production perhaps conducted in an isolated area of the site? Or conversely, did lithic reduction activities never occur within the shelter, at any point in time?

An elevation model of Bonebed 2 shows a clear north-trending gradient decline in the excavated area (Figure 3). If small lithic debris were at one time winnowed by a minor water flow, the debris may have been funneled past the excavated area to the northern end of the shelter near the back wall. However, excavations conducted north of the northernmost 1963-1964 units, 20 years after Dibble's work at Bonfire Shelter, failed to yield any lithic artifacts (Bement 1986). Although this matrix was again passed through 1/4-inch mesh, the fact that it was also floated and again sorted greatly reduces the probability that artifacts were overlooked and discarded (Bement 1986). It is possible that lithic debris was transported beyond this later excavation block—two unworked flakes were recovered in test unit N225/W95 at the far northern end of the shelter during the 1960s excavations (see Figure 4)—and perhaps further excavation in this

Table 3. Dimensions of back dirt-recovered unmodified flakes.

Specimen	POR	MLEN (mm)	MWID (mm)	MDEP (mm)
C-1	proximal	9.29	7.94	1.60
C-2	midsection	11.80	11.02	2.67
C-3	proximal	20.45	15.26	6.02
D-1	complete	9.00	6.46	0.85
D-2	proximal	12.87	8.18	3.21

POR = flake portion; MLEN = maximum length; MWID = maximum width; MDEP = maximum depth.

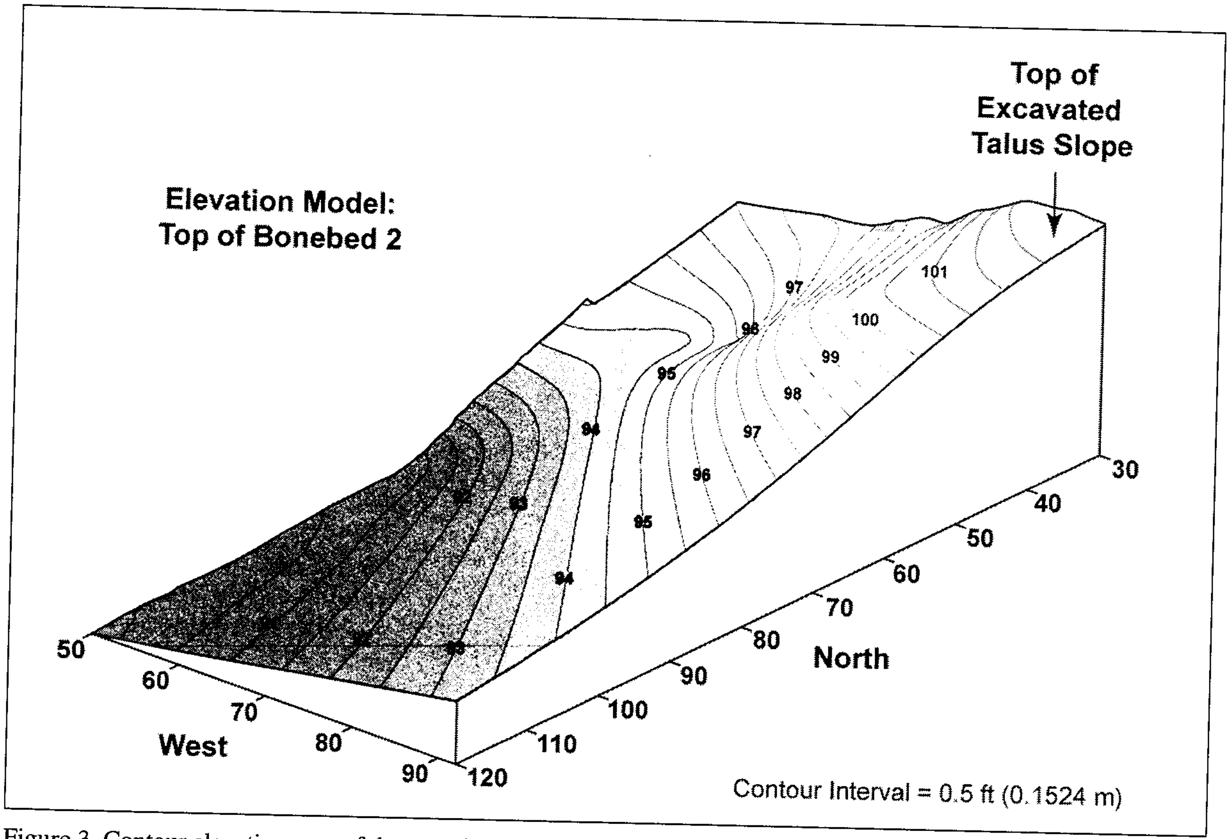

Figure 3. Contour elevation map of the top of Bonebed 2. Data derived from Dibble and Lorrain (1968:17, 21-23, 25). Figure adapted from unpublished data compiled by Jason M. LaBelle.

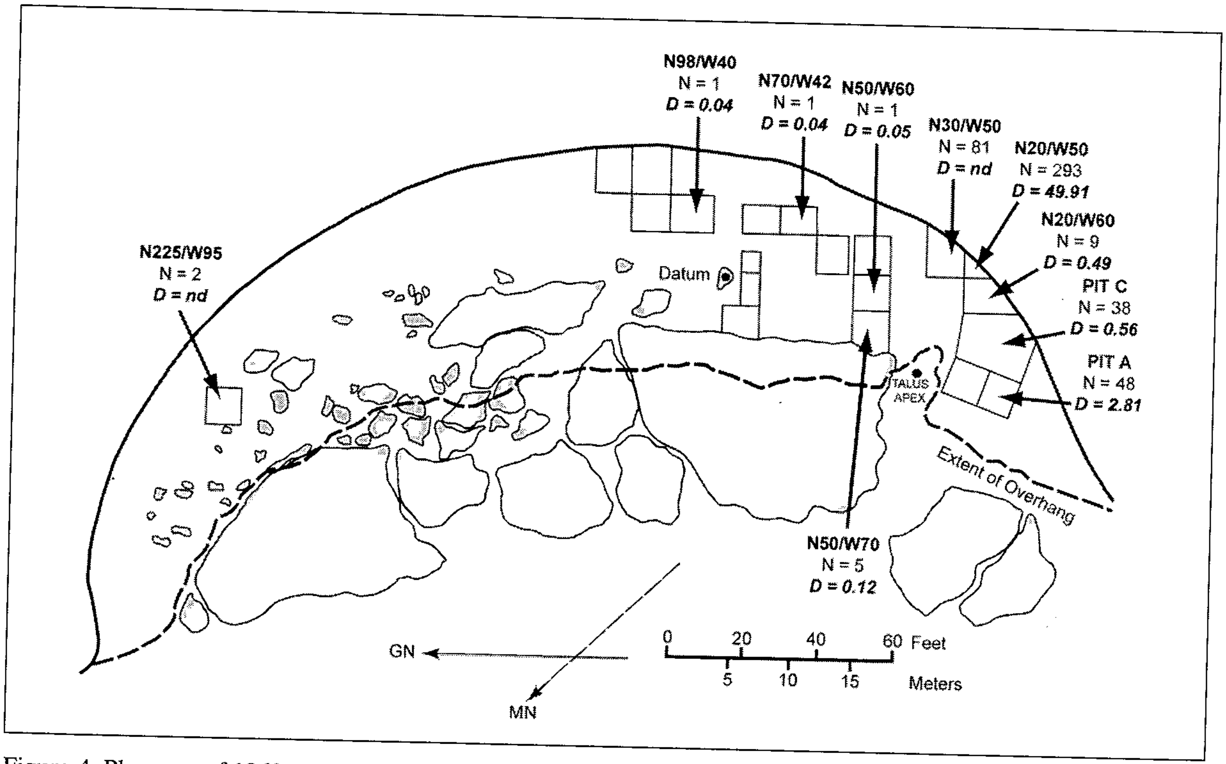

Figure 4. Plan map of 1963-1964 excavations of Bonfire Shelter showing combined unmodified flake frequencies and densities. Data from Dibble (1968). Adapted from Dibble and Lorrain (1968:Figure 6).

Table 4. Element frequency data for bison bone recovered from back dirt.

Element*	NISP	MNE
CRN	1	1
MR	1	1
CE	1	1
RB	1	1
SA	1	1
CA	5	5
HM	1	1
CPI	1	1
CPR	1	1
MC	1	1
IM	1	1
TRF	1	1
TRC	1	1
AS	6	2
CL	1	1
MT	1	1
PHF	4	3
PHS	1	1
SEP	1	1
Total	31	–

*See Byerly et al. (2005:608-609) for element codes.

northern end would yield high concentrations of lithic debris, either due to water flow within the shelter or clean-up by the prehistoric occupants of the site. Future work should concentrate on testing these possibilities.

Backdirt Screening: Bone

A total of 31 bison bones were identified from the 3000+ large mammal bones recovered from the tested back dirt; the identified elements are primarily carpals, tarsals, vertebrae, and phalanges (Table 4). Most are heavily burned and deformed, similar to bone from Bonebed 3 (see Lorrain 1965, 1968). The selective sampling of bone elements during the 1963-1964 excavation, owing to time and budget pressures, is noted in Dibble (1968:19). While no specific reference is made to which elements were discarded, other than to say the "better preserved" and "more diagnostic" bones were selected (these probably included limb epiphyseal ends; Elton R. Prewitt, personal communication 2005), it was subsequently found that in Bonebed 2 selection bias was primarily against lower axial elements and innominates, at least in the near-talus area of the excavated deposits (Byerly et al. 2005:606).

Lorrain (1965:30) further states that Bonebed 3 suffered more from this sampling strategy than did Bonebed 2. Regardless, those elements recovered from the tested back dirt, again probably deriving mostly from Bonebed 3, are the lowest frequency elements recovered from Bonebed 2. These data imply that if a similar bias intensity occurred in Bonebed 2, an inference of site-use based on bone frequency alone may be suspect. However, testing this is contingent upon a specific demonstration (in terms of skeletal element representation) of the extent to which excavator selection biased the extant Bonebed 2 bison bone assemblage. Future work concentrated on rescreening back dirt piles nearer the Bonebed 2 excavations around the talus cone should help resolve this issue.

Ancient Canyon Floor Levels

During our 2003 fieldwork we examined a 49 m long and 7 m high section of cemented sediment and gravel located high on the wall of Mile Canyon downstream of Bonfire Shelter and north of Eagle Cave. Although no dateable material was recovered, a fossilized *Equus* metapodial associated with the deposit suggested a Late Pleistocene age. It was posited that this feature represents the remnant of a Late Pleistocene fill that served as a semi-stable floor of Mile Canyon (Byerly et al. 2005:625). Given this assumption, and interpolating the elevation of this deposit up-canyon, it is probable that the Late Pleistocene or Early Holocene floor of Mile Canyon in front of Bonfire Shelter was much higher than it is at present, and the difference in elevation between the canyon floor and Bonfire Shelter much less. Thus, Bonebed 2 bison carcasses conceivably could have been dragged into the shelter from the canyon floor with relative ease (Byerly et al. 2005:625); for that matter, this may also help explain how the mammoth, horse, and other Bonebed 1 fauna entered the shelter (Bement 1986; Dibble and Lorrain 1968). They may have walked in.

The paleohydrologic history of this region of Texas is reasonably well-recorded, owing to the preservation of cemented gravels and alluvial slack water deposits in the canyon lands along the Pecos River (Kochel 1982; Kochel and Baker 1982; Patton and Baker 1976; Patton and Dibble 1982). Such features in Seminole and Presa canyons record over 10,000 years of large-scale, high-intensity flooding. Obviously the hydrological histories of these canyons are not necessarily the same as that of Mile Canyon; they do, nonetheless, represent a reasonable proxy for understanding flooding in Mile Canyon. In addition to these events, smaller-scale and more frequent flooding can also be quite powerful. For example, while conducting research in Mile Canyon in June 2003, 1.2 inches of rain fell in Langtry within the span of an hour, causing extensive flash flooding in Mile Canyon. This downpour represents four times the average amount received in early June that year (NOAA 2003). Although there was insufficient time or wherewithal to measure the force of the water being funneled into the canyon from its upland tributaries during this storm, it was sufficient to turn the otherwise dry Mile Canyon into a rapidly-flowing river (Figure 5). The canyon, subject as it was to multiple high-energy floods, has probably suffered numerous fill and scour events since the Late Pleistocene, raising and lowering the levels of the canyon floor. That the canyon floor was closer to Bonfire Shelter in Late Pleistocene times is certainly a testable possibility.

Bonfire Shelter is unique amongst rock shelter deposits in Mile Canyon because of the massive rock fall (portions of the cliff face) that obscures the opening of the shelter, and which at the shelter's north end have protected deposits from any flood scouring since at least the Late Pleistocene (Bement 1986; Dibble 1968). Of course, floodwaters hitting that rock fall may have also scoured out remnants of ancient stream gravels and traces of the one-time elevation of the valley floor. So, to assess whether portions of the Late Pleistocene valley floor are present as fill or gravels, we turned to the southern (downstream) end of the exterior of the shelter, since deposits ought to be protected from fluvial erosion in that area. A total of seven auger holes

Figure 5. Mile Canyon during the June 13, 2003 flash flood: (left) during, and (right) after.

was placed in a 4 x 3 m clearing in the exterior deposits surrounding Bonfire Shelter at the estimated upslope elevation of the cemented gravels (Figure 6). Auger holes penetrated an average depth of 0.84 m and were terminated at the point when the auger no longer turned. Unfortunately, no evidence of valley fill or gravel was recovered from these auger holes. Instead, all matrix consisted of a poorly-sorted, large colluvial talus debris that could not be breached beyond 0.95 m below surface. This obviously does not preclude the possibility that remnant Late Pleistocene gravels are present here, for this impenetrable colluvial drape could be relatively recent and assuredly masks older deposits. It does mean, however, that substantial excavation beyond our limited augering will be required to find such.

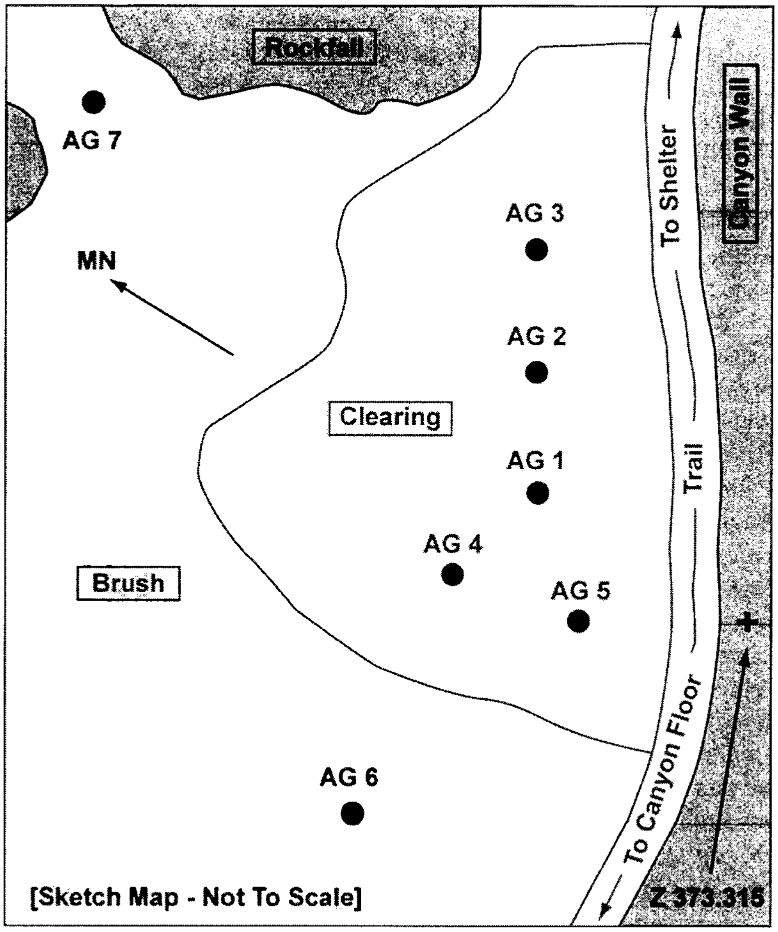

Figure 6. Sketch map of auger-hole locations on the talus slope outside the southern entrance of Bonfire Shelter.

RESEARCH IN PROGRESS

As part of a continuing research endeavor to elucidate the paleoecological history of Bonfire Shelter and Mile Canyon, a sediment column (2 x 0.2 x 0.05 m) was removed from the southeast corner of N98/W40 to search for gastropods (Figure 7). Gastropod remains are unreported in previous fieldwork at Bonfire Shelter and have the potential to add significantly to the extant paleoenvironmental record of the site (Bryant and Holloway 1985; Robinson 1997). Presently, dry sorting of this matrix has yielded no lithic artifacts, but did surrender Bonebed 1 and Bonebed 3 bone, charcoal, as well as gastropods from Middle Archaic (4340 ± 40 B.P.) deposits to the surface.

Sampled sediment contained a total of 877 snail shells. Terrestrial taxa account for 874 specimens, of which 20.3% (n=177) are unidentified juveniles. Nine taxa are represented in the 697 individuals identifiable to species, genus, or family. Of these, five taxa are represented by more than one individual. These include Succineidae (n=368), *Helicodiscus singleyanus* (n=134), *Hawaiia minuscula* (n=87), *Gastrocopta pellucida* (n=67), and *Rabdotus* alternatus/*Rabdotus* sp. (n=37). Four taxa are represented by single individuals and include *Gastrocopta pentodon*, *Vallonia* sp., cf. *Helicodiscus nummus*, and *Millerelix* cf. *M. mooreana* (Table 5). Aquatic snails are represented by two individual specimens of the genus *Gyraulus* sp. and one individual of the family Physidae, all three of which are juveniles.

The excellent preservation of the majority of shells recovered at Bonfire Shelter suggests rapid burial in calcareous sediments with little solar exposure. This indicates that most specimens were living near were they were recovered and probably did not arrive as empty shells carried by water runoff or gravity from the upland surface. The protected nature of the talus cone would have offered an ideal habitat for most of the common species recovered at the site.

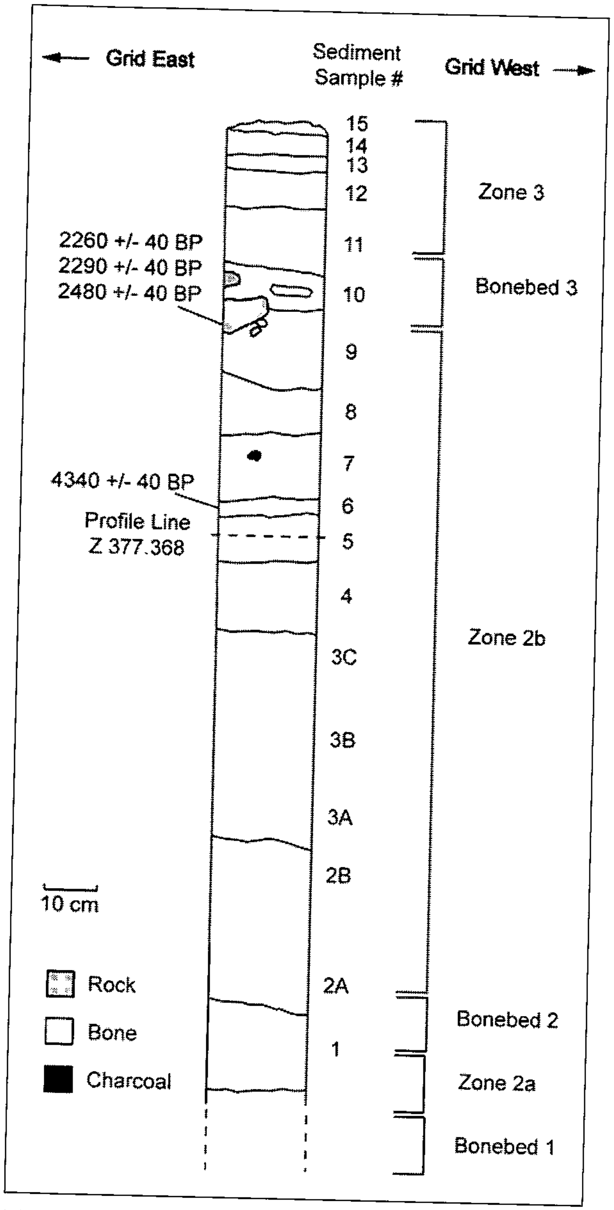

Figure 7. Profile of the sediment column taken from the south wall near N98/W40. Radiocarbon dates are from adjacent strata in the east wall near N98/W40.

The episodic runoff of water and organic detritus onto the debris cone coupled with little direct sunlight would produce an ideal habitat for Succineidae, *Helicodiscus singleyanus*, and *Hawaiia minuscula*. The continuous distribution of these taxa from Sample 14 to Sample 4 indicates the presence of a suitably moist micro-habitat and their paucity or absence from Sample 3C to Sample 1 suggests a drying of that habitat (Figure 8). These data support previous palynological (Bryant and Holloway 1985) and geologic-based (Dibble 1968) paleoclimatic interpretations for the Early Holocene of southwestern Texas as a whole and Bonfire Shelter specifically. Sample 13 shells were encrusted with a carbonate-like mineral, perhaps acquired in a very moist environment.

Gastrocopta pellucida is found in Samples 14 and 13 and again in Samples 8 through 3C. The distribution of *G. pellucida* may represent periods of higher precipitation with an increase in vegetation above or at the shelter. This interpretation for the *G. pellucida* 'zones' closely correspond with peaks in overall snail density and taxa diversity at the shelter.

The distribution of *Rabdotus* is restricted to Sample 14 through Sample 7, with the highest density in Samples 12 and 11. A single adult shell of *Rabdotus alternatus* was recovered, with the remaining 36 *Rabdotus* individuals being either unidentifiable juveniles or fragmented shell apices. This is a genus that is characteristically found in large colonies and their distribution indicates a local colony that may have flourished during the period represented by Samples 12 and 11. The fragmented *Rabdotus* apices are perhaps the result of predation by small mammals. The single individuals of *Vallonia* and *Chara* are from Sample 5 and have the opaque character of sub-fossils and may derive from an older deposit.

DISCUSSION AND SUMMARY: OF KILL SITES AND BUTCHERY SITES

Prehistoric hunter-gatherers utilized a variety of tactics to procure bison on the Great Plains. Owing to their size and archeological visibility, mass trap and jump kills have received the most attention in the literature, although isolated, smaller-scale kills were probably more typical of hunter-gatherer subsistence strategies (Fisher and Roll 1999; Frison 1973; Hill 2001; Landals 1990; McCartney 1990). Depending on the size of these kills, the number of people involved, and their location, any number of satellite butchery sites may have been generated. Initial butchery probably occurred at the site of the kill, with large carcass portions subsequently transported to other locations for more intensive disarticulation and meat and marrow procurement (Metcalf and Barlow 1992). These processing areas may have represented short-term hunter-gatherer camps or larger residential hubs, located very near the site of the kill or situated some distance from it (Hofman 1999a). Because

Table 5. Summary gastropod data.

Gastropod Shell NISP: sieved sediment less than 2 mm																		
Sample*	1	2A	2B	3A	3B	3C	4	5	6	7	8	9	10	11	12	13	14	
Volume (Liters)	1	1	1	1	1	1	1	1	0.6	1	1	1	1	1	1	0.6	0.7	
Terrestrial Taxa																		N
Gastrocopta pellucida						1	6	13	11	19	3					8	6	67
Gastrocopta pentodon												1						1
Vallonia sp. [juvenile]**								1										1
Rabdotus sp. [juveniles/fragments]										1	1		1	1	8	3	3	18
cf. *Helicodiscus nummus*																	1	1
Helicodiscus singleyanus							11	10	10	7	11	2	25	23	17	4	14	134
Succineidae					6	6	41	56	14	34	28	24	18	19	28	15	12	301
Hawaiia minuscula	1	8				4	18	8	1	3	5	2	1	21	7	4	4	87
terrestrial juveniles	2	2				1	22	24	9	30	11	5	16	23	3	17	12	177
Terrestrial Subtotal	3	10			6	12	98	112	45	94	59	34	61	87	63	51	52	787

Aquatic Taxa																		
Physidae [Juvenile]						1												1
Gyraulus sp. [Juveniles]								1							1			2
Aquatic Subtotal						1		1							1			3
Terrestrial & Aquatic Total	3	10			6	13	98	113	45	94	59	34	61	87	64	51	52	790
Chara sp.**								1										1
Gastropod Shell NISP: hand-picked sediment greater than 2 mm																		
Terrestrial Taxa																		N
Rabdotus alternatus															1			1
Rabdotus sp. [juveniles/fragments]										1	2		2	4	8			17
Millerelix cf. *M. mooreana*							1											1
Succineidae	1					1	15	5		5	3	6	5	11	11	2	2	67
terrestrial juveniles											1							1
Terrestrial Total	1					1	16	5		6	6	6	7	15	20	2	2	87
Sample Total	4	10			6	14	114	118	45	100	65	40	68	102	84	53	54	877

* See Figure 7 for sample location.
** Possible reworked sub-fossil.

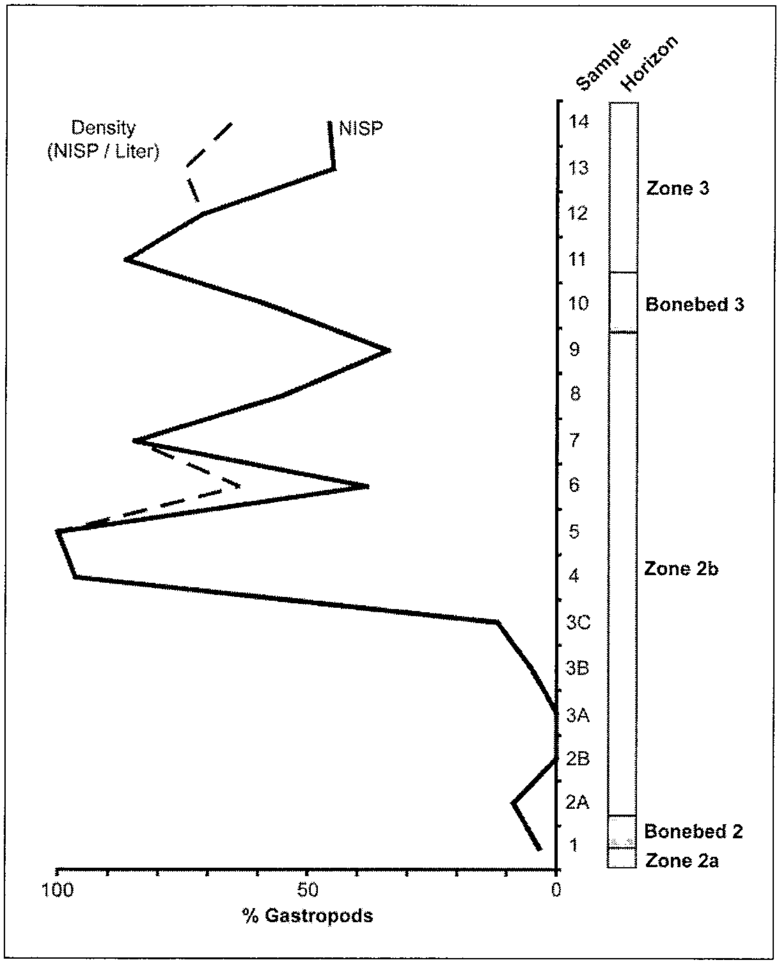

Figure 8. Sample gastropod data summarized by %NISP and %NISP Density.

different levels of activity occurred at each site, each would in turn produce their own unique material record (Binford 1980).

Amongst Great Plains bison kill-butchery sites, Bonfire Shelter Bonebed 2 occupies a middle ground in terms of inferred site-use (Figure 9). Bison kills are, by and large, expected to: (1) be in association with a natural or artificial trap; (2) display low artifact diversity with hunting weaponry (i.e., projectile points) dominating the lithic assemblage; (3) have minimal evidence of cooking or processing (i.e., few fire features and heat-altered rock); (4) be marked by low species diversity; and (5) have a preponderance of whole bones, usually low-utility elements, and articulated skeletons. By contrast, processing and camp sites are expected to: (1) display a preponderance of butchering tools and lithic debris; (2) have fire features and heat-altered rock; (3) possibly demonstrate high species diversity, depending on the type and length of occupation and the range of activities that occurred; and (4) consist of mostly broken, high-utility bones and have few articulated skeletons (Fisher and Roll 1997:432; Todd 1987a:231; Wheat 1978).

Indeed, comparing a sample of Great Plains kill-butcheries spanning the last 11,000 years, inferred kill sites are typified as having relatively greater projectile point and individual bison densities than inferred camp or processing sites (Table 6 and Figures 9 and 10), while non-projectile point tools and modified flakes are, on average, significantly more frequent in these camp and processing sites (F = 23.664, p = .000[1]; Table 6 and Figure 10). This observation holds for unmodified flakes also (F = 6.458, p = .019[1]), but the inconsistent strategies employed to collect these artifacts at each of these sites, as well as inconsistencies in reporting, challenge the validity of this relationship.

While these generalizations reflect observations of a wide-range of taphonomically-varied archeological deposits, it is clear that Bonfire Shelter displays many of the traits consistent with other jump kill sites (Table 7). The lithic component of Bonebed 2 is seemingly dominated by hunting weaponry and lacks butchering tools or debitage, highly suggestive of a kill (Dibble and Lorrain 1968). At the same time, however, Bonebed 2 stands out amongst other 'classic' jump sites in having far more non-projectile point tools and modified flakes per projectile fragment (see Table 6), even those where intensive primary butchery probably occurred (e.g., Glenrock). Likewise, projectile point frequencies are generally low, as are point to bison ratios, surpassed only by, interestingly, Bonebed 3 at Bonfire Shelter (see Table 6). The Roberts Buffalo Jump is a noted exception to this, although data for this assemblage are not separated into kill and processing area components (see Figure 9; Witkind 1971). Features and fire-cracked rock, typically absent from jump kill sites, are rare,

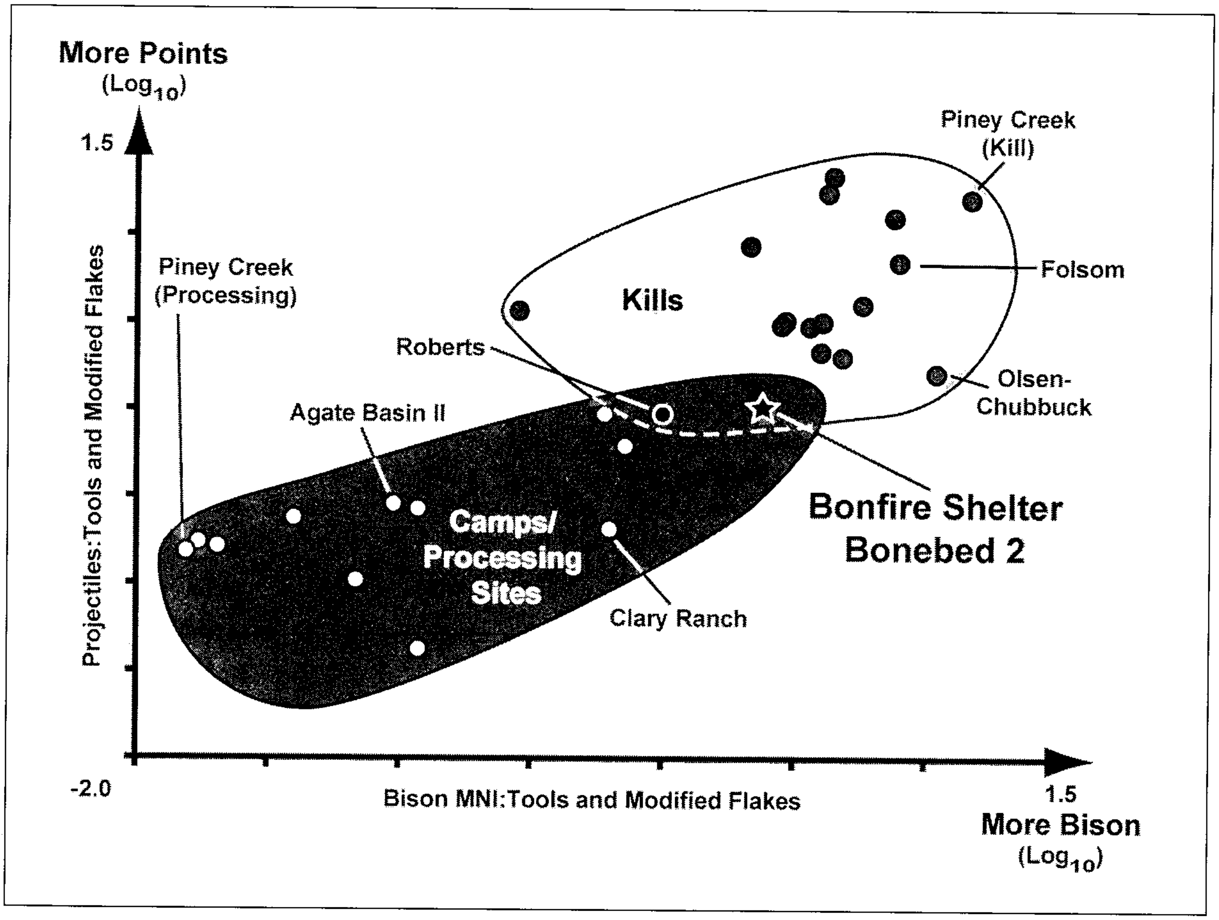

Figure 9. Scatterplot of $\log_{10}$ normalized projectile point to non-projectile tool and modified flake (PP/TMF), and bison MNI to tool and modified flake (MNI/TMF), ratios (Table 6). PP tallies include published counts of complete and broken projectile points and fragments. Tools include all published counts of non-projectile chipped stone tools and tool fragments (e.g., scrapers, bifaces, knives, gravers, drills, etc.) and otherwise modified flakes; core fragments and hammerstones are not included.

but present in Bonebed 2 (Dibble and Lorrain 1968). Although not unusual—Glenrock and Bonfire Shelter Bonebed 3 also have fire features—this does point to processing activities within the shelter.

Furthermore, of the classifiable projectile points from Bonebed 2, five different types are argued to be present (Folsom, Midland, Milnesand, and Plainview or Lubbock), ostensibly representing some 500 to 1,000 years of overlapping Southern Plains technological variation (Bousman et al. 2004:70; Cooper and Byerly 2005; Kerr 2000). This is all the more confusing given that the bison assemblage suggests a single event (Byerly et al. 2005). Indeed, overall, recovered bison remains appear to square better with a processing site interpretation (Binford 1978; Byerly et al. 2005). Arguably, the presence of so many projectile point types suggests multiple events or perhaps even cooperative activity among several groups. Yet given the diverse array of interpretations for the small projectile point assemblage in Bonebed 2, including the overlap of Folsom and Plainview, or Plainview-like, points in the lowest deposits of Bonebed 2 (Component A, Dibble 1968), how much confidence can be placed in the idea that points equal people in this instance? This apparently diverse assemblage might instead represent the idiosyncratic handiwork of several individual knappers (Bamforth 1991), or reflect the tendency of archeologists to "split" variants of the same projectile point type into multiple types, thereby complicating the Paleoindian chronological sequence.

With the noted collection bias against the recovery of both lithic and faunal material at Bonfire Shelter, can one artifact class have more analytical weight than the other (Bamforth 2002)? Where is

Table 6. Summary data for select Great Plains kill-butchery sites.

Site	Site-Use	Area (m^2)	PP	TMF	UMF	MNI	References
Agate Basin II (Folsom)	C	243.82	24	84	nd	8	Frison 1982; Hill 2001
Big Goose Creek	CP	219.48	155	653	11364	26	Frison et al. 1978
Bootlegger Trail (BI, BII)	P	124.00	339	360	nd	224	Roll and Deaver 1980
Cattle Guard	P	238.00	64	392	17367	8	Jodry 1999; Jodry and Stanford 1992
Clary Ranch	C	192.00	13	63	12103	41	Hill 2001; Hill et al. 2002
Jurgens I	C	110.00	11	261	1421	31	Wheat 1979
Jurgens II	C	58.00	20	116	488	2	Wheat 1979
Jurgens III	P	84.00	29	47	98	35	Wheat 1979
Mill Iron	C	110.00	11	41	3	5	Bradley and Frison 1996; Todd et al. 1996
Piney Creek (312)	P	821.65	69	453	3270	7	Frison 1967
Wardell	P	195.47	35	335	5065	23*	Frison 1973
Big Goose Creek	K	35.69	61	7	nd	15	Frison et al. 1978
Bonfire Shelter (BB2)	KP?	215.48	11	10	17	24	Byerly et al. 2005; Cooper and Byerly 2005; Dibble and Lorrain 1968
Bonfire Shelter (BB3)	KP	215.48	38	23	22	197	Dibble and Lorrain 1968
Bootlegger Trail (D)	K	25.00	70	4	nd	17	Roll and Deaver 1980
Casper	KP	1088.00	81	5	308	74	Frison 1974; Todd et al. 1997
Cooper (All)	K	24.09	33	11	125	40	Bement 1999; Hofman 1999
Folsom	K	252.70	28	4	0	32	Hofman 1999; Meltzer 2006
Glenrock (All)	KP	247.40	152	47	3722	138	Frison 1970
Jones-Miller	KP	508.00	104	26	11500*	150	Stanford 1975, 1978, 1999
Kobold II	K	247.81	51	16	813	65	Frison 1970
Kobold III	K	247.81	70	23	1319	65*	Frison 1970
Kobold IV	K	247.81	220	60	3033	17*	Frison 1970

Table 6. *(Continued)*

Site	Site-Use	Area (m^2)	PP	TMF	UMF	MNI	References
Lipscomb	K	50.60	30	14	17	56	Hofman 1999
Mill Iron	KP	29.87	12	6	2	29	Bradley and Frison 1996; Todd et al. 1996
Olsen-Chubbuck	KP	112.74	27	13	3	143	Wheat 1972
Piney Creek (312)	K	180.17	190	15	1145	114	Frison 1967
Roberts	KP	111.48	17	18	2001	18	Witkind 1971
Wardell	K	81.29	436	20	250	89*	Frison 1973

* Values estimated. PP = complete and fragmented projectile points; TMF = non-projectile tools and modified flakes; UMF = unmodified flakes; MNI = minimum number of individual bison. C = camp; CP = camp/processing; K = kill; KP = kill/processing. Excavated area data are derived from published site plan maps or directly from text. Note: Excavated area for Bonfire Shelter Bonebeds 2 and 3 reflect only the 1963-1964 excavations.

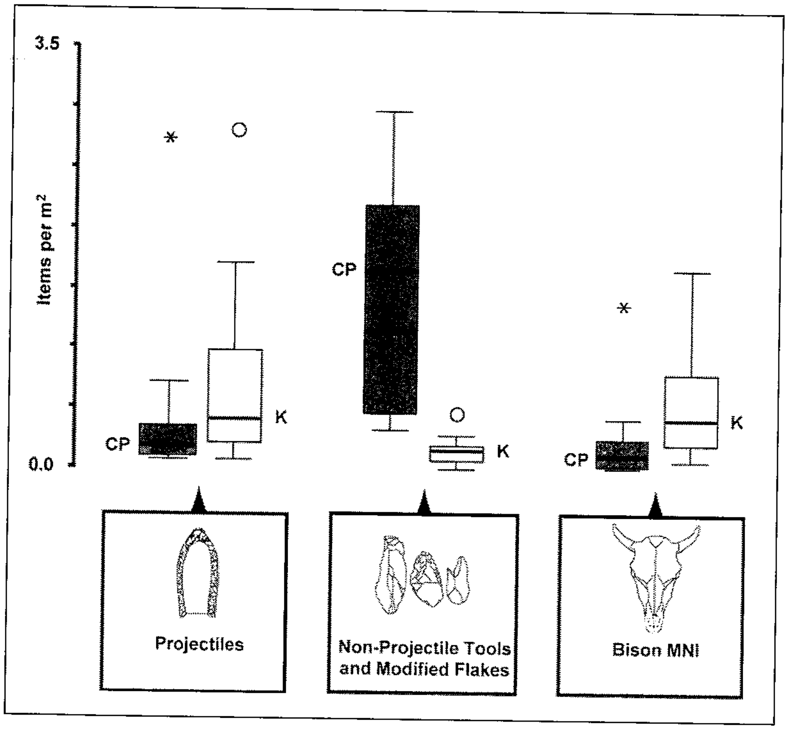

Figure 10. Artifact densities for those sites listed in Table 6, excluding Bonfire Shelter Bonebeds 2 and 3. CP = camp/processing sites; K = kill sites. Extreme outliers for projectiles and bison MNI from camp/processing sites represent the Bootlegger Trail site. Outliers for projectiles and non-projectile tools and modified flakes from kill sites represent the Bootlegger Trail and Cooper sites, respectively. An extreme outlier for kill projectiles representing the Wardell site is not shown.

the line drawn between sorting archeological sites into kills and processing localities based on these classes? Is drawing such a line even beneficial to understanding prehistoric hunter-gatherer behavior? Ultimately, little knowledge of past human behavior is gained by drawing such a line. Regardless of site use, it is clear that Paleoindian hunters at Bonfire Shelter (and elsewhere on the Plains) possessed the technological and organizational ingenuity to herd and dispatch large groups of dangerous, behaviorally-volatile animals with success (Frison 2004; Hill 2001). Indeed, whether Bonebed 2 is a processing site bears little on how the animals were killed (Byerly et al. 2005).

Artifact based site-use interpretations of Paleoindian bison kill-butcheries largely stem from the expectations of archeologists utilizing ethnographic and archeological examples of socio-economic systems probably far-removed

Table 7. Select data for some 'classic' bison jump kills.

Site	Cliff/Trap	Drive-Line	Fire	Articulated Skeletons	Burned Bone
Big Goose Creek (Kill)	■	■	nd	■	nd
Bonfire Shelter (BB2)	■	○	■	○	■
Bonfire Shelter (BB3)	■	○	■	■	■
Glenrock (All)	■	■	■	○	○
Kobold II	■	■	○	■	■
Kobold III	■	■	○	nd	■
Kobold IV	■	■	○	nd	■
Piney Creek (Kill)	■	■	nd	○	nd

■ = present; ○ = absent; nd = no data. No drive-line features were found around Bonfire Shelter but a GIS analysis does suggest that the surrounding topography is amenable to successful bison jumping (see Byerly et al. 2005).

from those actually practiced by Paleoindian peoples; a single fundamental artifact pattern characterizing the lifeways of ancient peoples does not exist (Hofman 1999a:123). It is important to remember that bison kill-butcheries existed within a continuum of activities against varied temporal and spatial scales, and their remains exist within dynamic taphonomic settings that have been subjected to varying degrees of analytical scrutiny (Todd 1987a, 1987b; Todd and Rapson 1999). The opportunity to use information gleaned from bison kill-butcheries to tactically enhance our understanding of the past (Binford 2001), and further enhance knowledge of prehistoric human behavior, comes in exploring why sites like Bonfire Shelter stand out in the archeological record. If Bonebed 2 was a Paleoindian bison jump, why is this strategy not utilized anywhere else on the Southern Plains (the Certain site, as noted, being a possible exception) or until the Archaic (perhaps Bonebed 3)? Further, if Paleoindian hunters had the technological and organizational capability to herd and kill bison, why are jumps not more prolific in the Paleoindian archeological record? Did regional and temporal differences in bison behavior discourage such a strategy, or was it simply not conducive to the lifeways of Paleoindian hunter-gatherers? Or, conversely, is it simply a matter of preservation stemming from the unique protection Bonfire Shelter offered from the destructive and continual erosional forces that affected areas like the Caprock Escarpment of the Southern High Plains throughout the Holocene (see Boyd et al. 1991:9, 47)? The first step in answering these questions is making sure available lithic and faunal data from proposed jump kills are analytically comparable with other archeological assemblages. Our 2003-2005 fieldwork represents the first stage in updating relevant data at Bonfire Shelter so that Bonebed 2 can be more accurately placed within the spectrum of archeological bison kill-butcheries.

In this regard, we suggest that Bonebed 2 cannot be interpreted directly in terms of Bonebed 3, lest the issue of site-use be obfuscated by coincidence. These assemblages are separated by nearly 7,000 years of human technological innovation, landscape change, and bison evolution. They are independent phenomena which may have a common cause, but that must be demonstrated; it cannot be assumed. Spatial correlation aside, Bonebeds 2 and 3 share very little in terms of their respective material records and it is of little analytical use to assume they do because of a singular geographic/geologic commonality (i.e., the notch above the shelter). However, while a direct behavioral association may be inappropriate, these assemblages can be compared with respect to their individual formation and excavation histories, and it is via such a comparison that perhaps a more thorough understanding of the archeological record of Bonfire Shelter is possible.

The results of the 2005 fieldwork, aimed at investigating potential lithic recovery bias and evaluating evidence of Late Pleistocene to Early Holocene floor levels in Mile Canyon, are as follows:

1) Back dirt screening recovered a higher density of unmodified flakes than the total and average densities of flakes from all cultural components of the site, but these artifacts are neither of the size nor frequency expected from intensive resharpening or tool production activities. Recovered discarded bone, although probably from Bonebed 3, are the lowest frequency elements in the extant Bonebed 2 assemblage. It is not apparent that screening methods employed during the 1963-1964 excavations were biased against the recovery of very small lithic debris, but it did bias the recovery of lithic material overall. Likewise, if the intensity of bone discard employed in the recovery of Bonebed 3 bison was similar for Bonebed 2 material, this would shift bone frequency data away from the interpolated bulk-utility profile.

2) Gravels and sediments similar to those from the analyzed cemented gravels are not present in the sampled exterior deposits of the shelter up to a depth of 0.95 m. No evidence of ancient canyon floor levels was found during the 2005 season.

3) Taxonomic analysis of recovered gastropods is consistent with previous palynological and geological interpretations of the paleoecological conditions within the central interior portion of Bonfire Shelter (Bryant and Holloway 1985; Dibble 1968). The paucity of Succineidae, *Helicodiscus singleyanus*, and *Hawaiia minuscule* in the lower sampled units (Sample 3C to 1, or mid-Zone 2B to 2A), in particular, suggests a dry or unstable habitat inhospitable to the proliferation of these taxa. Similarly, lower relative frequencies of gastropods in Samples 6 and 9, respectively (ca. Middle to Late Middle Holocene; see Figure 8), speaks to overall more arid conditions during these times. An increase in gastropod frequency coincident with the deposition of Bonebed 3 may further indicate a return to moister conditions during the Late Holocene and may also help explain the proliferation of bison in the region in sufficient numbers to conduct a mass kill(s) at this time.

These results suggest that further testing of back dirt piles, preferably those nearest the talus cone, will give a more accurate accounting of the size and frequency of lithic artifacts discarded or missed during the 1963-1964 excavations. Such testing will also give a better indication of what specific skeletal elements were discarded from Bonebed 2. Additional excavations in areas north of the 1963-1964 and 1983-1984 blocks may reveal if microdebitage was washed out of the bone bed concentrations, although available gastropod data indicate that even episodic runoff into the shelter may have been absent during Bonebed 2 times. Regardless, the rate of water runoff into the shelter during intense precipitation events, as well as experimental evaluation of the potential affect(s) of this runoff on shelter floor materials, must be empirically investigated before any conclusions about fluvial activity are made. Likewise, if tool production and maintenance activities occurred within the shelter, it is expected that such tasks would be relegated to areas outside the main activity area near the south entrance of the shelter. These additional excavations can also test this hypothesis.

Although no evidence of ancient canyon floor levels was found, continued testing of the talus slope or other areas around the shelter, deeper than that conducted during the 2005 season (greater than 1 m), are needed to resolve whether Late Pleistocene gravels are present and how they may relate to the floor level of Mile Canyon at the time of the Paleoindian occupation of Bonfire Shelter.

NOTES

1. Excludes data from Bonfire Shelter Bonebeds 2 and 3.

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REFERENCES CITED

Bamforth, D. B.

1991 Flintknapping Skill, Communal Hunting, and Paleoindian Projectile Point Typology. *Plains Anthropologist* 36:309-322.

2002 High-tech Foragers? Folsom and Later Paleoindian Technology on the Great Plains. *Journal of World Prehistory* 16:55-98.

Barsh, R. L. and C. Marlor

2003 Driving Bison and Blackfoot Science. *Human Ecology* 31:571-593.

Baumler, M. F. and C. E. Downum

1989 Between Micro and Macro: A Study in the Interpretation of Small-sized Lithic Debitage. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 101-116. BAR International Series 528. British Archaeological Reports, Oxford.

Bement, L. C.

1986 *Excavation of the Late Pleistocene Deposits of Bonfire Shelter, 41VV218, Val Verde County, Texas.* Archeology Series 1. Texas Archeological Survey, The University of Texas at Austin.

1999 *Bison Hunting at the Cooper Site: Where Lightning Bolts Drew Thundering Herds.* University of Oklahoma Press, Norman.

Bement, L. C. and K. J. Buehler

2005 The Certain Site Southern Plains Late Archaic Bison Kills. *Oklahoma Archaeology* 53:16-18.

Binford, L. R.

1978 *Nunamiut Ethnoarchaeology.* Academic Press, New York.

1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4-20.

2001 *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets.* University of California Press, Berkeley.

Bousman, C. B., B. W. Baker, and A. C. Kerr

2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Boyd, D. K., C. B. Bousman, and M. D. Freeman

1991 *Archeological Survey of Wildlife Mitigation Lands, Justiceburg Reservoir, Garza County, Texas.* Report of Investigations, No. 79. Prewitt and Associates, Inc., Austin.

Bradley, B. A. and G. C. Frison

1996 Flake Stone and Worked-Bone Artifacts from the Mill Iron Site. In *The Mill Iron Site*, edited by G. C. Frison, pp. 43-69. University of New Mexico Press, Albuquerque.

Brekke, A.

1970 Three Buttes Bison Kill (24BL104). *Archaeology in Montana* 11:39-54.

Bryant, V. M. and R. G. Holloway

1985 A Late-Quaternary paleoenvironmental record of Texas: an overview of the pollen evidence. In *Pollen Records of Late-Quaternary North American Sediments*, edited by V. M. Bryant and R. G. Holloway, pp. 46-66. American Association of Stratigraphic Palynologists Foundation, Dallas.

Buehler, K. J.

1997 Getting Over the Hump: Some Concluding Remarks on Southern Plains Bison Procurement/ Utilization Studies. In "Southern Plains Bison Procurement and Utilization from Paleoindian to Historic," edited by L. C. Bement and K. J. Buehler. Memoir 29. *Plains Anthropologist* 42:173-182.

Byerly, R. M., J. R. Cooper, D. J. Meltzer, M. E. Hill, and J. M. LaBelle

2005 On Bonfire Shelter (Texas) as a Paleoindian Bison Jump: An Assessment using GIS and Zooarchaeology. *American Antiquity* 70:595-629.

Carr, P. J. and A. P. Bradbury

2001 Flake Debris Analysis, Levels of Production, and the Organization of Technology. In *Lithic Debitage: Context, Form, Meaning*, edited by W. Andrefsky Jr., pp. 126-146. University of Utah Press, Salt Lake City.

Cooper, J. R. and R. M. Byerly

2005 The Significance of a Second Folsom Projectile Point from Bonfire Shelter, Texas. *Current Research in the Pleistocene* 22:41-43.

Dibble, D. S.
1968 The Archaeology. In *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas*, by D. S. Dibble and D. H. Lorrain, pp. 1-76. Miscellaneous Papers No. 1. Texas Memorial Museum, The University of Texas at Austin.

Dibble, D. S. and D. H. Lorrain
1968 *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas*. Miscellaneous Papers No. 1. Texas Memorial Museum, The University of Texas at Austin.

Dyck, I. and R. E. Morlan
2001 Hunting and Gathering Tradition: Canadian Plains. In *Plains*, edited by R. J. DeMallie, pp. 115-145. Handbook of North American Indians, Vol. 13, Pt. 1. Smithsonian Institution, Washington.

Emerson, A. M.
1990 Archaeological Implications of Variability in the Economic Anatomy of *Bison bison*. Ph.D. Dissertation, Department of Anthropology, Washington State University, Pullman.

1993 The Role of Body Part Utility in Small-scale Hunting under Two Strategies of Carcass Recovery. In *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*, edited by J. Hudson, pp. 138-155. Occasional Paper No. 21. Center for Archaeological Investigations, Southern Illinois University, Carbondale.

Fisher, J. W. and T. E. Roll
1999 Prehistoric Human Exploitation of Bison in the Great Plains of Montana (USA) During the Last 3,000 Years. In *Le Bison: Gibier et Moyen de Subsistance des Hommes du Paléolithique aux Paléoindiens des Grandes Plaines*, edited by J.-P. Brugal, F. David, J. Enloe, and J. Jaubert, pp. 417-436. Éditions APDCA, Antibes.

Forbis, R. G.
1962 *The Old Women's Buffalo Jump, Alberta*. Bulletin No. 180, Contributions to Anthropology, 1960, Pt.1:57-123. National Museum of Canada, Ottawa.

1969 Review of "Bonfire Shelter: a Stratified Bison Kill Site, Val Verde County, Texas." *American Antiquity* 34:90-91.

Frison, G. C.
1967 *The Piney Creek Sites, Wyoming 48JO311 and 312*. University of Wyoming Publications 33.

1970 The Glenrock Buffalo Jump, 48CO304. Memoir 7. *Plains Anthropologist* 15.

1973 *The Wardell Buffalo Trap, 48SU301: Communal Procurement in the Upper Green River Basin, Wyoming*. Anthropological Papers No. 48. Museum of Anthropology, University of Michigan, Ann Arbor.

1974 Archaeology of the Casper Site. In *The Casper Site: A Hell Gap Bison Kill on the High Plains*, edited by G. C. Frison, pp. 1-111. Academic Press, New York.

1982 Paleoindian Winter Subsistence Strategies on the High Plains. In *Plains Indian Studies: A Collection of Essays in Honor of John C. Ewers and Waldo R. Wedel*, edited by D. H. Ubelaker and H. J. Viola, pp. 193-201. Smithsonian Contributions to Anthropology No. 30. Smithsonian Institution Press, Washington, D.C.

1991 *Prehistoric Hunters of the High Plains*. 2nd Edition. Academic Press, New York.

2004 *Survival by Hunting: Prehistoric Human Predators and Animal Prey*. University of California Press, Berkeley.

Hill, M. G.
2001 Paleoindian Diet and Subsistence Behavior on the Northwestern Great Plains of North America. Ph.D. dissertation, Department of Anthropology, University of Wisconsin, Madison.

Hill, M. G., M. E. Hill, D. W. May, T. P. Myers, D. J. Rapson, F. Sellet, J. L. Theler, and L. C. Todd
2002 Palaeoindian Subsistence Behaviour at the Clary Ranch Site, Nebraska, USA. *Antiquity* 76:311-312.

Hofman, J. L.
1999a Folsom Fragments, Site Types, and Assemblage Formation. In *Folsom Lithic Technology: Explorations in Structure and Variation*, edited by D. S. Amick, pp. 122-143. Archeological Series 12. International Monographs in Prehistory, Ann Arbor.

1999b Unbounded Hunters: Folsom Bison Hunting on the Southern High Plains circa 10,500 BP, the Lithic Evidence. In *Le Bison: Gibier et Moyen de Subsistance des Hommes du Paléolithique aux Paléoindiens des Grandes Plaines*, edited by J.-P. Brugal, F. David, J. Enloe, and J. Jaubert, pp. 383-415. Éditions APDCA, Antibes.

Hornaday, W. T.
2002 *Extermination of the American Bison*. Smithsonian Institution Press, Washington, D.C.

Hurt, W. R.
1962 Survey of Buffalo Jumps in the Northern Plains 1962. MS on file, National Park Service, United States Department of the Interior, Washington, D.C.

Jodry, M. A.
1999 Folsom Technological Organization and Socioeconomic Strategies: Views from Stewart's Cattle Guard and the Upper Rio Grande Basin, Colorado. Ph.D. dissertation, Department of Anthropology, American University, Washington, D.C.

Jodry, M. A. and D. J. Stanford
1992 Stewart's Cattle Guard Site: An Analysis of Bison Remains in a Folsom Kill-Butchery Campsite. In *Ice Age Hunters of the Rockies*, edited by D. J. Stanford and J. S. Day, pp. 101-168. University of Colorado Press, Niwot.

Kehoe, T. F.
1967 The Boarding School Bison Drive Site. Memoir 4. *Plains Anthropologist* 12:1-165.

Kerr, A.C.
2000 Systematic Analysis of Unfluted Lanceolate Projectile Points. Master's thesis, Department of Anthropology, The University of Texas at Austin.

Kochel, R. C.
1982 Quaternary Geomorphology of Seminole Canyon State Historical Park Val Verde County, Texas. In *Seminole Canyon: The Art and the Archaeology*, edited by S. A. Turpin, pp. 227-276. Research Report No. 83. Texas Archeological Survey, The University of Texas at Austin.

Kochel, R. C. and V. R. Baker
1982 Paleoflood Hydrology. *Science* 215:353-361.

Landals, A.
1990 The Maple Leaf Site: Implications of the Analysis of Small-scale Bison Kills. In *Hunters of the Recent Past*, edited by L. B. Davis and B. O. K. Reeves, pp. 122-151. Unwin Hyman, London

Lorrain, D. H.
1965 Aboriginal Exploitation of Bison at Bonfire Shelter in Trans-Pecos Texas. Master's thesis, Department of Anthropology, The University of Texas at Austin.
1968 Analysis of the Bison Bones from Bonfire Shelter. In *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas*, by D. S. Dibble and D. H. Lorrain, pp. 77-132. Miscellaneous Papers No. 1. Texas Memorial Museum, The University of Texas at Austin.

Malouf, C. and S. Conner
1962 *Symposium on Buffalo Jumps*. Memoir 1. Montana Archeological Society, Billings.

Meltzer, D. J.
2006 *Folsom: New Archeological Investigations of a Classic Paleoindian Bison Kill*. University of California Press, Berkeley.

Metcalf, D. and K. Barlow
1992 A Model for Exploring the Optimal Tradeoff between Field Processing and Transport. *American Anthropologist* 94:240-256.

McCartney, P. H.
1990 Alternative Hunting Strategies in Paleoindian Adaptations. In *Hunters of the Recent Past*, edited by L. B. Davis and B. O. K. Reeves, pp. 111-121. Unwin Hyman, London.

National Oceanic and Atmospheric Administration (NOAA)
2003 *Hourly Precipitation Data, Texas, June 2003*. Publication of the National Environmental Satellite, Data and Information Service, Vol. 56, No. 3. National Climatic Data Center, Asheville.

Patton, P. C. and V. R. Baker
1976 Morphometry and Floods in Small Drainage Basins Subject to Diverse Hydrogeomorphic Controls. *Water Resources Research* 12:941-952.

Patton, P. C. and D. S. Dibble
1982 Archaeologic and Geomorphic Evidence for the Paleohydrologic Record of the Pecos River in West Texas. *American Journal of Science* 282:91-121.

Polk, M. R.
1979 Bison Jump Sites in the Northwestern Plains of North America: A Locational Analysis. Master's thesis, Department of Anthropology, Michigan State University, Lansing.

Reeves, B. O. K.
1978 Head-Smashed-In: 5500 Years of Bison Jumping in the Alberta Plains. In *Bison Procurement and Utilization: A Symposium*, edited by L. B. Davis and M. C. Wilson. Memoir 14. *Plains Anthropologist* 23:151-174.

Robinson, D. G.
1997 Stratigraphic Analysis of Bonfire Shelter, Southwest Texas: Pilot Studies of Depositional Processes and Paleoclimate. In "Southern Plains Bison Procurement and Utilization from Paleoindian to Historic," edited by L. C. Bement and K. J. Buehler. Memoir 29. *Plains Anthropologist* 42:33-43.

Roll, T. E. and K. Deaver
1980 *The Bootlegger Trail Site, A Late Prehistoric Spring Bison Kill*. Heritage Conservation and Recreation Service, Interagency Archeological Services, Washington, D.C.

Stanford, D. J.
1975 The Jones-Miller Site: A Study of Hell Gap Bison Procurement and Processing. *National Geographic Society Research Reports* 16:615-635.
1978 The Jones-Miller Site: An Example of Hell Gap Bison Procurement Strategy. In *Bison Procurement and Utilization: A Symposium*, edited by L. B. Davis and M. C. Wilson. Memoir 14. *Plains Anthropologist* 23:90-97.
1999 Analysis and Interpretation of Hell Gap Hunting Strategies and the Jones-Miller Site. In *Le Bison: Gibier et Moyen de Subsitance de homes du Paleolithique aux Paleoindiens des Grandes*

Plaines, edited by J.-P. Brugal, F. David, J. Enloe, and J. Jaubert, pp. 437-454. Editions APDCA, Antibes, France.

Todd, L. C.
1987a Analysis of Kill-Butchery Bonebeds and Interpretation of Paleoindian Hunting. In *The Evolution of Human Hunting*, edited by M. H. Nitecki and D. V. Nitecki, pp. 225-266. Plenum Press, New York.
1987b Taphonomy of the Horner II Bone Bed. In *The Horner Site: the Type Site of the Cody Cultural Complex*, edited by G. C. Frison and L. C. Todd, pp. 107-198. Academic Press, Orlando.

Todd, L. C. and D. J. Rapson
1999 Formational Analysis of Bison Bonebeds and Interpretation of Paleoindian Subsistence. In *Le Bison: Gibier et Moyen de Subsitance de homes du Paleolithique aux Paleoindiens des Grandes Plaines*, edited by J.-P. Brugal, F. David, J. Enloe, and J. Jaubert, pp. 480-499. Editions APDCA, Antibes, France.

Todd, L. C., D. J. Rapson, and J. L. Hofman
1996 Dentition Studies of the Mill Iron and Other Early Paleoindian Bison Bonebed Sites. In *The Mill Iron Site*, edited by G. C. Frison, pp. 145-175. University of New Mexico Press, Albuquerque.

Todd, L. C., M. G. Hill, D. J. Rapson, and G. C. Frison
1997 Cutmarks, Impacts, and Carnivores at the Casper Site Bison Bonebed. In *Proceedings of the 1993 Bone Modification Conference Hot Springs, South Dakota*, edited by L. A. Hannus, L. Rossum, and R. P. Winham, pp. 136-157. Occasional Paper No. 1. Archaeology Laboratory, Augustana College, Sioux Falls.

Verbicky-Todd, E.
1984 *Communal Buffalo Hunting Among the Plains Indians*. Occasional Paper No. 24. Archeological Survey of Alberta, Edmonton.

Wheat, J. B.
1972 *The Olsen-Chubbuck Site: A Paleo-Indian Bison Kill*. American Antiquity Memoir 26.
1978 Olsen-Chubbuck and Jurgens Sites: Four Aspects of Paleo-Indian Economy. In *Bison Procurement and Utilization: A Symposium*, edited by L. B. Davis and M. C. Wilson. Memoir 14. *Plains Anthropologist* 23:84-89.
1979 The Jurgens Site. Memoir 15. *Plains Anthropologist* 23.

Witkind, M.
1971 An Archaeological Interpretation of the Roberts Buffalo Jump Site, Larimer County, Colorado. Master's thesis, Department of Anthropology, Colorado State University, Fort Collins.

To Jump or to Drag: Reflections on Bonfire Shelter

Elton R. Prewitt

ABSTRACT

Reanalysis of Bonfire Shelter (Dibble and Lorrain 1968) materials by Byerly et al. (2005) and Byerly et al. (2007, this volume) have challenged Dibble's original interpretation that Bone Bed 2 represents a bison jump site, the oldest known in North America. Instead, they argue the bison remains associated with Plainview and Folsom artifacts reflect selected elements transported from an unknown kill location. The pros and cons of these conflicting views are reviewed critically. Dibble's hypothesis remains the more viable explanation for the Bone Bed 2 accumulation.

INTRODUCTION

Recently, Byerly et al. (2005) and Byerly et al. (2007, this volume) challenged David S. Dibble's interpretation that the Paleoindian-age Bone Bed 2 at Bonfire Shelter represents a multiple-episode bison jump site (Dibble and Lorrain 1968). In this article, I briefly review the site setting and Dibble's original analysis. I then review the reinterpretations proffered by Byerly et al. Finally, I offer a few observations about the site and its interpretation.

PHYSICAL SETTING

Bonfire Shelter (41VV218), a moderately-sized rockshelter about 100 m in length, has a maximum overhang of about 20 m. Located in the left or east wall of Mile Canyon, it is mid-way between the canyon rim and floor (Figure 1). The short sharply-incised boxed canyon extends upstream from the entrenched Rio Grande canyon near Langtry. Eagle Nest Creek, which drains a large area to the north, flows through the canyon. Stream flow at present is limited to infrequent rainfall events.

The canyon systems in this area are structurally controlled by jointing and fracturing of the Cretaceous limestone (Waechter et al. 1977). Where the joints intersect incised canyons, they frequently erode to form short steep notches or clefts into the canyon rims.

One such cleft forms the downstream end of Bonfire Shelter. During the Pleistocene, the shelter was at least twice as large as it is today. It collapsed to create a shelter that is hidden from view from the

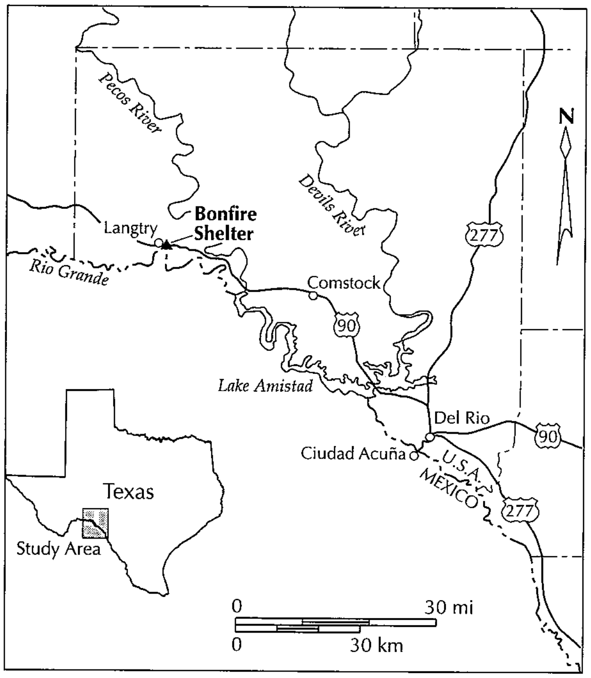

Figure 1. Location of Bonfire Shelter near Langtry, Texas.

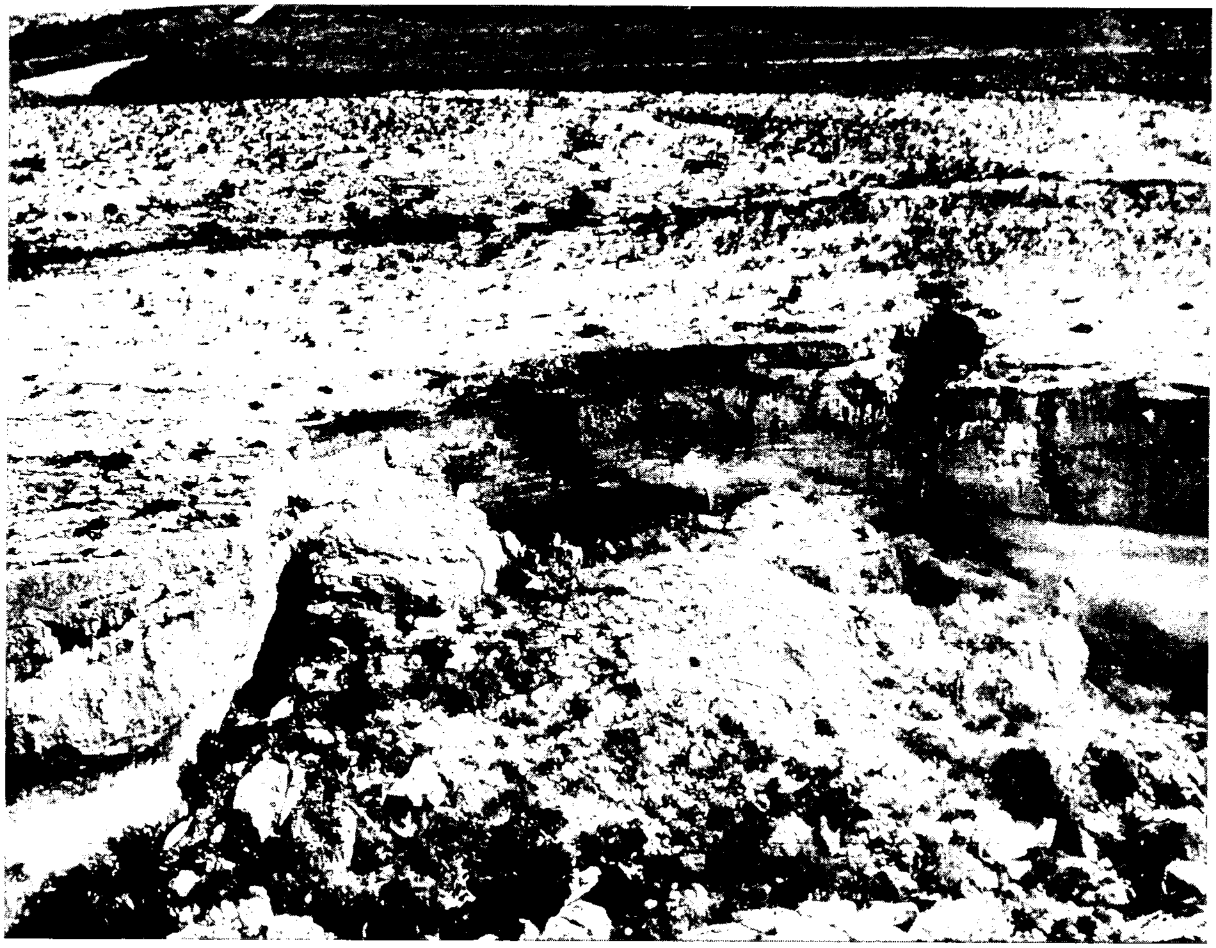

Figure 2. Oblique air photo of Bonfire Shelter, looking east-southeast, with the Rio Grande in background. Photo by David S. Dibble. Courtesy of Texas Beyond History.

valley floor. The collapsed blocks also removed the sloping upland margin of the valley wall, leaving an abrupt cliff that reached near the crest of the divide between Mile Canyon and the next canyon to the east (Figure 2). A talus cone over 5 m in height accumulated in the downstream end of the shelter directly underneath the notch; it is comprised of both washed-in natural detritus and sequentially deposited cultural materials.

ARCHEOLOGICAL SYNOPSIS

Dibble identified three major sedimentary zones within the shelter deposits containing five known or suspected cultural layers. The older Zone 1 hosts Bone Bed 1, a dispersed series of bones of extinct animal species radiocarbon dated to 12,460 years B.P. that may or may not be related to human use and is not considered in this article (Bement 1986:9).

Bone Bed 2 forms the boundary between Zone 1 and the overlying Zone 2. These bones are draped over and around the talus cone. Toward the lower flank of the cone, it is comprised of three superimposed layers of extinct bison bones (Figure 3), the middle one of which is burned and fragmented. That this lens of bones was burned in place is evidenced by lightly scorched sediments underlying it. Dibble interpreted this to mean there was a minimum of three kill episodes represented in Bone Bed 2. Associated artifacts include lanceolate dart and dart point fragments assignable to the Plainview and Folsom types. Four uncalibrated radiocarbon dates from a hearth near the top of Bone Bed 2 cluster at 10,300 years B.P. (Dibble and Lorrain 1968:33; Dibble 1970:251; Bement 1986:9).

Zone 2 above Bone Bed 2 is interrupted by sparse occupations dated with uncalibrated radiocarbon assays to between about 7,300 B.P. (Dibble and Lorrain 1968:40) and 4,270 B.P. (Bement

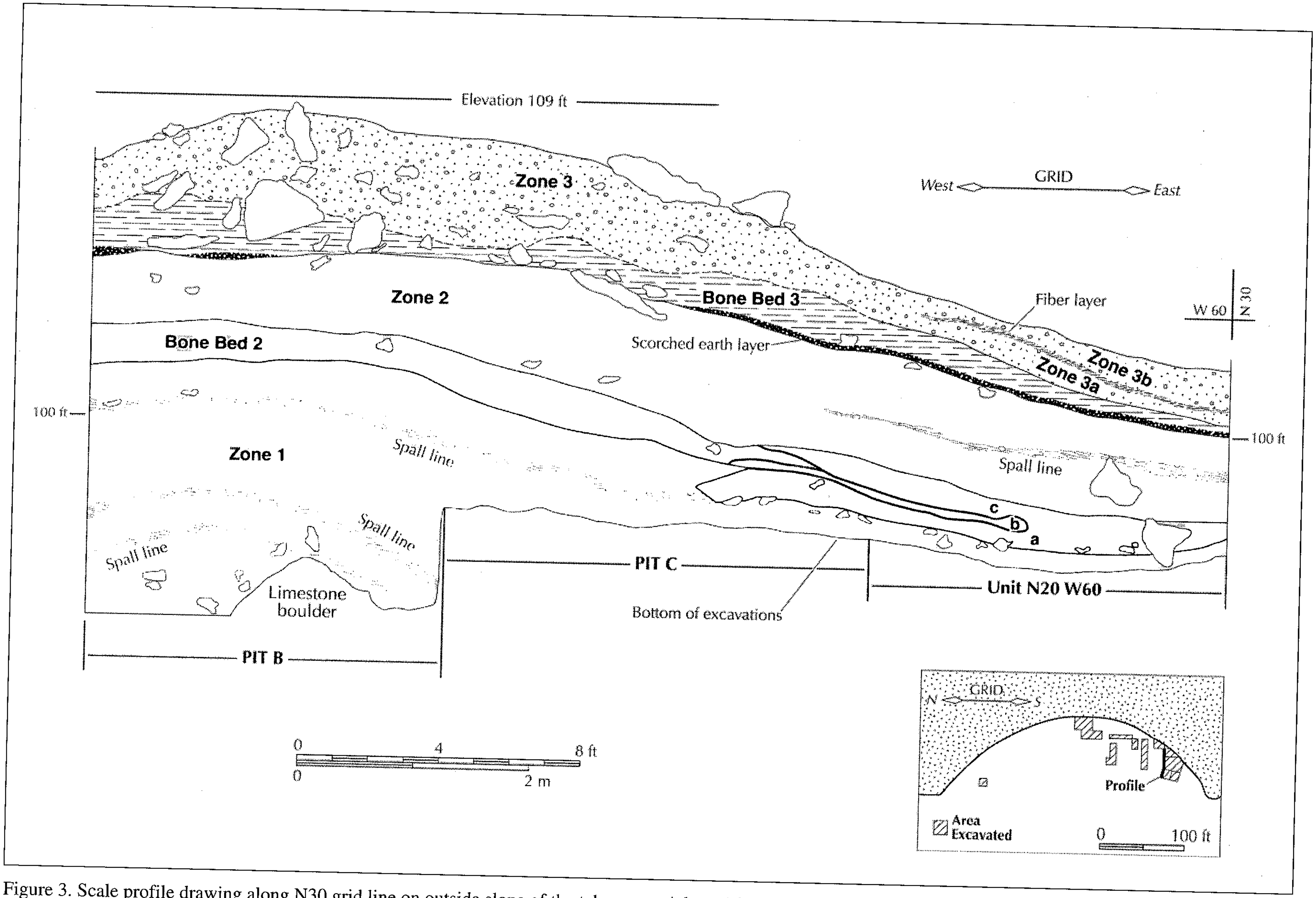

Figure 3. Scale profile drawing along N30 grid line on outside slope of the talus cone. Adapted from Dibble and Lorrain (1968:Figure 11).

1986:9). Capping Zone 2 is the massive Bone Bed 3 composed of the remains of modern bison; it dates (uncalibrated) to about 2,800 to 2,500 B.P. (Dibble and Lorrain 1968:51). Spontaneous combustion burned, warped, and calcined the bones, and scorched the underlying sediments. Associated artifacts include broad blade Late Archaic style projectile points such as Castroville and Montell. Butchering and use of the jump technique during this episode are demonstrated by the analyses presented by Dibble and Lorrain (1968).

Zone 3, the uppermost stratum, forms the modern shelter surface. A thin layer of Late Archaic occupational debris concentrated around the lower flanks of the talus cone extends discontinuously into the interior of the shelter. Uncalibrated radiocarbon dates between 1,700 and 1,400 B.P. are commensurate with the Paisano type dart points found in this layer, which consists primarily of discarded fibrous artifacts (Dibble and Lorrain 1968:57).

THE SITE AS A JUMP

Dibble argued convincingly for prehistoric use of Bonfire Shelter as a bison jump kill. His review of characteristics needed for use of this technique has not changed significantly by analyses of sites reported in the last 40 years. He considered alternatives such as using the canyon as a trap where bison were driven up from the Rio Grande, herded into the shelter, then slaughtered in the confined space. This scenario was dismissed due to the difficulty of herding groups of animals up a steep slope into such a narrow gap. An articulated juvenile bison skeleton in Bone Bed 3 had a twisted and broken rear end suggestive of having fallen off the rim of the shelter. Dibble then considered the possibility that bison were accidentally stampeded by thunderstorms and fell over the cliff. This idea was dismissed due to the repetition of jump episodes in both Bone Bed 2 and Bone Bed 3, and the clear presence of human butchering in both bone beds.

To quote Dibble regarding the site as a jump:

> The assumptions. . . are: during two widely separated time periods. . . hunters drove bison herds along the rolling country bordering the canyon and into the cleft. The near-vertical sides and steep bottom of this feature acted as an effective chute directing the tumbling animals downward off the lip leading to a vertical drop onto the crest of the talus cone immediately below. From the point of impact the animals could then come to rest or continue to roll either down the inward slope and back underneath the overhang or down the outer slope toward the floor of the canyon...Excavations were extensive enough, however, to establish that the great majority of the animals entered the level of the shelter by way of the cleft in the canyon rim at the downstream end of the site.
>
> Clearly, the effectiveness of this jump is due largely to this cleft. . . Oriented perpendicularly to the trend of the canyon, it cuts back from the site for a distance of about 50 feet. It bisects the center of a low knoll bordering the canyon, and upon approach, is invisible from a distance of more than a few feet. Bison stampeding from any direction would be suddenly faced with this almost vertical walled fissure before they could change the direction of their charge.
>
> Limited space is available. . . downstream from the cleft to the canyon of the Rio Grande. . . hence it is probable that the bison were stampeded over the rolling country rimming Mile Canyon from an upstream direction. . . and run off the upstream side of the cleft (Dibble and Lorrain 1968:69-70).

THE BYERLY ET AL. CHALLENGE

In 2003 and 2005 the QUEST Archaeological Research Fund team at Southern Methodist University led by David J. Meltzer conducted further investigations at Bonfire Shelter (Byerly et al. 2005, Byerly et al. 2007, this volume). The reports on these two seasons of work are discussed sequentially. Their 2003 focus on Bone Bed 2 included topographic analysis and reanalysis of the bones previously collected. Two questions were posed: could Bonfire Shelter have served as a jump locus, and, does the bone composition conform to models they expect in a bison jump?

To examine whether it could have served as a jump site, topographic data were collected and analyzed using modern Geographic Information Systems (GIS) techniques. They compiled a very useful summary of the physical conditions that must be met for successful bison jumps (Byerly et al. 2005:599), although I would argue the stated conditions are those demonstrated to have been met at archeologically documented jump kill sites. They also determined that pollen analysis showed significant grasslands were present at 10,300 B.P., and they considered the Rio Grande the only reliable water source. Finally, they reviewed effective herd size in relation to the number of individual bison present within Bone Bed 2. Using the archeologically collected bones, they estimate there are 24 to 27 animals.

The GIS analysis concludes that Bonfire Shelter is indeed a good place for conducting bison jumps, and that it probably is the best location within a 165 km^2 area. The path illustrated as the most likely route that could be used (Byerly et al. 2005:Figure 7) is similar to the route postulated by Dibble on the basis of simple logical observation of the terrain (Figure 4).

Omitted from the GIS study is the fact that while paleoenvironmental data show the Eagle Nest Creek drainage was a grassland ideal for bison habitat, it also suggests a moderate piñon pine forest cover on the uplands (Bryant 1969), a condition that increases the ability for hunters to place themselves into strategic positions to execute planned bison drives. Deadfall piñon also could have provided a source of brush from which to construct drive lanes that would not survive archeologically for over 10,000 radiocarbon years. Further, they do not take into account the notoriously poor monocular eyesight of bison. While modern bison are reported to be able to sense movement up to 2 km away, they rely on their acute senses of smell and hearing to alert them to danger (Meagher 1986:266). Because they do not see terrain details well, it is possible to successfully herd the animals into jumps, traps, and surrounds as demonstrated through the existence of numerous archeological sites and ethnohistorical descriptions.

In their consideration of the number of animals per jump episode, they treat Bone Bed 2 as a single event. They consider the 24 to 27 animals to be fewer than the normal minimum herd size for a successful jump (Byerly et al. 2005:600). However, this is the excavated sample from 1963-1964. Lorrain estimated that, based on the excavated and unexcavated volume of Bone Bed 2, there are approximately 120 animals that comprise the bone bed (Dibble and Lorrain 1968:84). Dibble's contention that three jump episodes are represented gives an average of about 40 animals per jump, which is commensurate with the number required for success (Frison 1991:218).

The greatest challenge to Dibble's interpretation comes from the reanalysis of the bone elements. Using a model developed by Binford (1978:60) relating to caribou skeletal elements transported and Emerson's (1993:40) skeletal element utility indices for modern bison, Byerly et al. (2005:621) conclude that Bone Bed 2 represents a processing area rather than a kill locality. Bement (2007) has refuted this contention that a paucity of lower food utility elements present in Bone Bed 2 reflects only secondary processing of animals killed elsewhere by pointing out the quantities of phalanges and crania recovered there. Further, the mixing of element comparisons among sites as noted by Bement (2007) makes the arguments presented by Byerly et al. (2005) questionable because their assemblage comparisons change at each graph.

It is appropriate to point out that in their discussion of meat utility indices for horses, Outram and Rowley-Conwy (1998:849) conclude ". . . that assumptions about anatomical resource distribution cannot be extrapolated safely from one species to another." These researchers prefer absolute indices for meat and marrow utility values, but agree that standardized and modified values are useful if they are applied correctly. They also criticize Binford's (1978) methods and the accuracy of his data (based on killing one caribou) throughout their article. More recently, Outram (2006:49-50, 58) directly challenged the applicability of Binford's indices to other species, and suggested methods that allow greater confidence in analyzing kill sites.

It is also significant that Metcalfe and Jones (1988) attempted to simplify Binford's overly complex method of calculating anatomical indices. They point out, for example, the problems Speth (1983) encountered while analyzing bison remains at the Garnsey site in New Mexico. They also note that cows provide only 60% usable meat in comparison to the quantity yielded by bulls. This kind of sexual dimorphism is not taken into account either by Binford's caribou data or by Byerly et al. (2005). Yet, Lorrain (Dibble and Lorrain 1968) and Bousman et al. (2004) demonstrate the presence of bison sexual dimorphism at Bonfire Shelter. Further, Metcalfe and Jones (1988) point out that there may be discrepancies between frozen carcass butch-

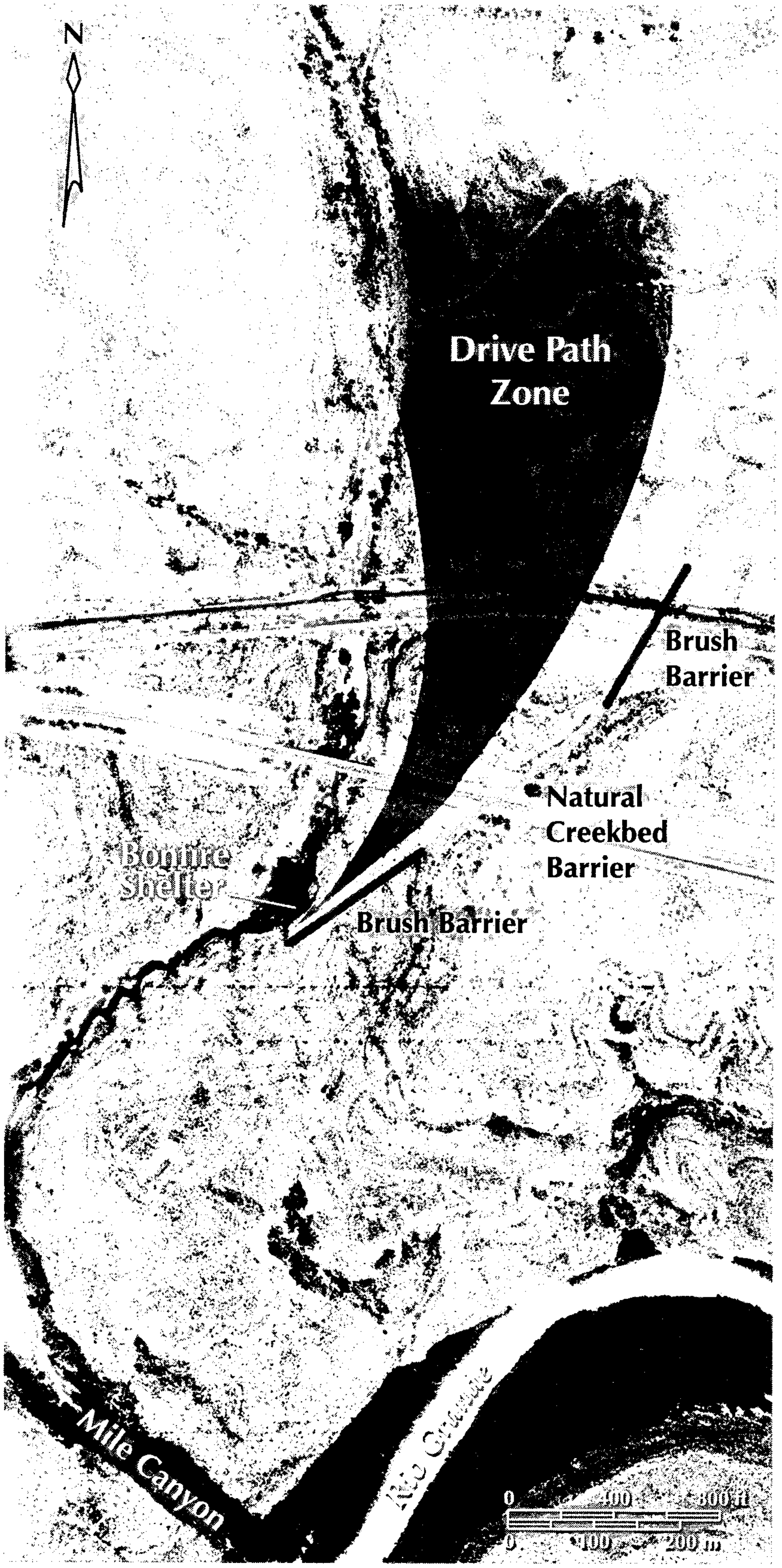

Figure 4. Air photo mosaic showing hypothetical drive path suggested by David S. Dibble. Mosaic assembled from Google Earth ® images © 2006.

ering (as observed by Binford) and temperate climate butchering of non-frozen carcasses as one would expect in the lower Pecos River region.

Regardless, a review of Lorrain's distribution table (Dibble and Lorrain 1968:Table 9) shows that more low food utility elements are on the outside slope of the talus cone while more high food utility elements are on the interior flank of the cone. This suggests initial butchering on the outer slope just below the point of impact, and secondary processing on the interior flank. The spoke-like array of bones around a small boulder reported by Bement (1986:29-32) just off the edge of the interior flank support this interpretation. Further, if one looks at Table 2 in Dibble's analysis (Dibble and Lorrain 1968:34), four tools (three projectile points and one scraper) were recovered from approximately 300 square feet of excavations on the interior flank of the talus cone while 16 tools (seven projectile points and nine scrapers) and 17 flakes were recovered from the approximately 690 square feet excavated on the outside flank. Even adjusting for the variations in volume excavated, this suggests greater initial processing on the outer slope commensurate with the bone data. Adjustments in artifact totals to account for an additional projectile point fragment noted in the unmodified flakes (Cooper and Byerly 2005) yield outer flank totals of 17 tools (eight projectile points and nine scrapers) and 16 flakes.

Another part of Byerly et al.'s (2005) reasoning is based on the fact that Bone Bed 2 is roughly 4,500 years older than other known jump kill sites in North America and is located far to the south of them, even though the 10,000 year old Hudson-Meng site (Agenbroad 1978) and others may also be bison jump kills. The sparse number of lithics similarly is used as an argument against Bone Bed 2 being a kill site even though the 11 reported lanceolate dart points and fragments comprise 30% of the 37 lithics in this component.

Finally, Byerly et al. (2005) rightfully review the potential configuration of the canyon floor deposits as they may have existed during the Late Pleistocene. Cemented gravels on the canyon walls downstream from Bonfire Shelter are used to project possible canyon fill that has since been eroded; their projections place the canyon floor only a few meters below the corresponding level of Bone Bed 2. The implication is that the bison were herded into the canyon and killed, then the more desirable carcass parts were dragged upslope into the shelter for final butchering. A problem is that the cemented gravels represent two distinct depositional environments and two sequential depositional events: colluvial fill overlain by alcove formation eboulis. Whether either of these could represent the valley floor during Bone Bed 2 times, or whether they are localized deposits, is far from resolved.

Extrapolating the canyon floor upstream on the scale suggested by Byerly et al (2005:625) is questionable. Based on the vertical relationship of the lower cemented colluvial gravel deposit with key bedrock strata that are visible extending upstream to the canyon floor beneath Bonfire Shelter, I suspect the valley floor was no more than 2 or 3 m higher than at present, leaving a steep slope at least 12 to 15 m high that was very uneven and over which parts of carcasses would have had to be dragged to get them up onto the flanks of the talus cone. Using a least effort analysis, it is unlikely that Paleoindian hunters would have butchered animals and moved the heavy carcasses upslope from their original resting places.

Yet, in their concluding statement, Byerly et al. (2005) do not rule out the possibility that bison could have been harvested using the jump technique. They suggest that while the jump locale might be nearby, it is not located at Bone Bed 2 draped around the talus cone. These assertions are repeated by Byerly et al. (2007, this volume) in their report of the additional work undertaken in 2005. During that effort, they dug auger holes on the outside slope downward from the talus cone, screened samples of back dirt inside the shelter, and removed a stratigraphic column from an exposed face within the shelter.

The additional radiocarbon assays touted in their abstract are not mentioned again except in a figure illustrating their sediment sample column. This same column provided the snail data described in the text, but neither the radiocarbon assays nor the snail data provide any new information about Bone Bed 2. Further, their assertion that no previous studies of gastropods have been undertaken at Bonfire Shelter is erroneous. Such studies were undertaken in 1965; I personally assisted in collecting the column used in the study reported by E. P. Cheatum (1966).

The discussion of sampling bias and fluvial winnowing of small flint flakes presented by Byerly et al. (2007, this volume) is strained, at best. Why is there a problem with there being few small lithic flakes at a jump kill/processing site? Their own data (Byerly et al. 2007: Table 6, this volume) shows that Bone Bed 2 sits squarely within the overlap between materials expected in kill sites versus what is expected in camp and processing sites. The answer seems pretty simple to me: Bone Bed 2 at Bonfire Shelter is both a kill site and a processing site: exactly how Dibble interpreted it.

The discussion and summary section presented by Byerly et al (2007, this volume) makes other inconsistent assertions regarding the artifacts recovered from Bone Bed 2. For example, they state "The lithic component of Bonebed 2 is dominated by hunting weaponry and lacks butchering tools or debitage; highly suggestive of a kill. . . At the same time, however, Bonebed 2 stands out amongst other 'classic' jump sites as having far more non-projectile tools and modified flakes per projectile fragment (Table 6). . ." (Byerly et al. 2007, this volume). Bone Bed 2 cannot simultaneously have too many and too few projectiles for a kill site! Of the 37 lithics from Bone Bed 2, eleven (30%) are projectile points or fragments while another ten (27%) are butchering tools that include two bifaces, five flake scrapers, and three worked flakes per Dibble's descriptions (1968:33-40) and Cooper and Byerly (2005). It seems to me that there is equal tool loss/ discard between the kill activities and the butchering activities. And, while 16 unmodified flakes may seem low and aberrant, it should not seem unusual if the Paleoindian people were dispatching animals and then quickly butchering the carcasses after jumping them over the rim of the shelter. This is a cool damp shelter that never gets sunshine, so why would people want to hang around refurbishing or making new tools when they can go to a more pleasant location outside the shelter to work?

The subsequent assertion by Byerly et al. (2007, this volume) that five projectile point types representing up to 1,000 years are present in what they consider to be a single event is puzzling, at best. Four of the more complete points are identifiable as within the variation of the Plainview type, and the fifth specimen is identified as of the Folsom type. Two distal fragments described by Dibble (1968:37) and the proximal fragment described by Cooper and Byerly (2005) were reexamined by me in early 2007; all three are within the range of variation expected in the Plainview type. While I am still hesitant to accept her conclusions, Kerr (2000) argues for the presence of Lubbock, Midland, and Milnesand along with Plainview and Folsom in the collection; if she is correct, then the single episode event argued by Byerly et al. (2007, this volume) is even less plausible. Further, with the recent advances in dating Paleoindian assemblages, it is now known that Plainview overlaps with Folsom in radiocarbon age (Holliday 2000:264-269). These observations suggest that less than 1000 years are represented in the three jump episodes contained within Bone Bed 2.

SOME REFLECTIONS AND SUGGESTIONS

Dibble reasoned carefully and logically that Bonfire Shelter is an ideal location at which to harvest bison using the jump technique, a conclusion supported by the sophisticated GIS analysis described by Byerly et al. (2005) and Byerly et al. (2007, this volume). Their questions focus on (1) the fact that Bone Bed 2 is at least 4,500 years older than any other known jump, (2) that it is an "outlier" because it is isolated some 1,800 km south of the concentration of known jump sites, and (3) that the composition of the bone elements are what one expects to find in a processing station based on models derived from a single ethnographic caribou kill and from highly selective comparisons with other bison kill sites. That the site was used as a jump kill about 2,800 years ago for multiple jump episodes over a 300 year period of time is not questioned, thereby negating their second point of argument.

While not wishing to plunge into the pre-Clovis and Clovis origins debate, it is useful to consider possibilities. First, as Dibble and I discussed at considerable length in 1963-1965, the implications regarding social structure and logistical planning among Paleoindian people to execute a bison jump are enormous. These were people who understood their resources and how to use them effectively, and they were highly organized. In 1965, this was a radical concept, causing Dibble to be very careful in his analysis and in his choice of words.

Second, current research and debate has shifted from older habitation sites being concentrated in the western half of North America to substantial occurrences in the eastern half. Increasing data point to Upper Paleolithic origins for both people and technology (whether from Europe or Asia) that became what we see archeologically as Paleoindian. Part of that Old World knowledge and technology included mass kills of herd animals.

The reinterpretation of Bone Bed 2 as a single event and that the tri-partite subdivision of the stratum is the result of fluvial re-deposition is untenable. Three distinct layers of bone were documented; the middle layer is burned, and the underlying sediments are lightly scorched. As one of the original excavators, I participated in the on-site discussions among Dibble, project supervisor Curtis D. Tunnell, and fellow field assistants Roy (not Ray as stated by Byerly et al. 2005) Little and Billy R. Harrison. None of us recognized any evidence of fluvial re-deposition within Bone Bed 2, especially since an intact hearth with charcoal was present within the uppermost lens.

In conclusion, I concur with Dibble's original interpretation that Bone Bed 2 at Bonfire Shelter represents an in situ extinct bison jump kill and processing station, and that a minimum of three episodes are supported both by stratigraphy and the associated projectile points. I applaud Byerly et al.'s (2005) and Byerly et al.'s (2007, this volume) reanalysis efforts and their recommendation for additional research of existing collections to resolve the questions surrounding Bone Bed 2.

After the landowner asked that I take responsibility for reviewing any proposals for future work done within the site, I convened a management meeting in Langtry in February 2003. The key agreement reached was that rather than conduct further excavations within Bonfire Shelter, we should focus efforts on stabilizing the open units to halt erosion and degradation of the deposits until such time in the future when significantly less-intrusive methods of investigation have been developed (Hammon and Prewitt 2003). That time is years in the future. In the meantime, I suggest we look for other examples of Paleoindian bison jump sites on the Southern Plains so we can start talking about patterns, not just a single example.

ACKNOWLEDGEMENTS

I thank the people who have helped me during the preparation of this paper. Jack and Wilmuth Skiles are gracious hosts as well as outstanding stewards of the archeological resources on their property, including Bonfire Shelter. David Meltzer and his students at Southern Methodist University raised provocative questions about interpretations of the site. Lee Bement freely shared his knowledge of Bonfire Shelter. Andrew Hemmings and David Madsen commented on earlier drafts of this article, and, along with Michael Collins, have prodded me to critically review the data in light of the broader current knowledge of Paleoindian archeology. Kerza Prewitt prepared the illustrations and provided moral support. Permission to use images from the Texas Beyond History (www.texasbeyondhistory.net) website was given by Steve Black. Access to the original artifact collections housed at the Texas Archeological Research Laboratory, The University of Texas at Austin, was arranged by Laura Nightengale and Monica Trejo. The editors of this volume—Michael R. Bever, C. Britt Bousman, and Timothy K. Perttula—are thanked for their insightful comments, corrections, good humor, and patience. This is an expanded version of a paper presented at the annual meeting of the Texas Archeological Society on October 21, 2006, in San Angelo, Texas.

REFERENCES CITED

Agenbroad, L. D.
1978 *The Hudson-Meng Site: An Alberta Bison Kill in the Nebraska High Plains*. University Press of America, Washington, D.C.

Bement, L. C.
1986 *Excavation of the Late Pleistocene Deposits of Bonfire Shelter, 41VV218, Val Verde County, Texas*. Archeology Series 1. Texas Archeological Survey, The University of Texas at Austin.
2007 Bonfire Shelter: A Jumping Off Point for Comments for Byerly et al. *American Antiquity* 72(2):366-372.

Binford, L. R.
1978 *Nunamiut Ethnoarchaeology*. Academic Press, New York.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Bryant, V. M., Jr.
1969 Late Full-Glacial and Post-Glacial Pollen Analysis of Texas Sediments. PhD. dissertation, Department of Anthropology, The University of Texas at Austin.

Byerly, R. M., J. R. Cooper, D. J. Meltzer, M. E. Hill, and J. M. LaBelle
2005 On Bonfire Shelter (Texas) as a Paleoindian Bison Jump: An Assessment using GIS and Zooarchaeology. *American Antiquity* 70:595-629.

Byerly, R. M., D. J. Meltzer, J. R. Cooper, and J. Theler
2007 Exploring Paleoindian Site-Use at Bonfire Shelter (41VV218). *Bulletin of the Texas Archeological Society* 78 :119-141.

Cheatum, E. P.
1966 Report on Mollusk Shells Recovered from Four Archeological Sites in the Amistad Reservoir. In *A Preliminary Study of the Paleoecology of the Amistad Reservoir Area*, assembled by D. A. Story and V. M. Bryant, Jr., pp. 227-243. Report of Research (GS-667) to the National Science Foundation by the Texas Archeological Research Laboratory, The University of Texas at Austin.

Cooper, J. R. and R. M. Byerly
2005 The Significance of a Second Folsom Projectile Point from Bonfire Shelter, Texas. *Current Research in the Pleistocene* 22:41-43.

Dibble, D. S.
1970 On the Significance of Additional Radiocarbon Dates From Bonfire Shelter, Texas. *Plains Anthropologist* 15:251-254.

Dibble, D. S. and D. Lorrain
1968 *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas*. Miscellaneous Papers, No. 1. Texas Memorial Museum, The University of Texas at Austin.

Emerson, A. M.
1993 The Role of Body Part Utility in Small-scale Hunting under Two Strategies of Carcass Recovery. In *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*, edited by J. Hudson, pp. 138-155. Occasional Paper No. 21. Center for Archaeological Investigations, Southern Illinois University, Carbondale.

Frison, G. C. (editor)
1991 *Prehistoric Hunters of the High Plains*. Second Edition. Academic Press, New York.

Hammon, D. S. and E. R. Prewitt
2003 Bonfire Shelter Management Meeting Notes, 28 February-2 March 2003. Unpublished draft transcript of meeting notes in possession of the author.

Holliday, V. T.
2000 The Evolution of Paleoindian Geochronology and Typology on the Great Plains. *Geoarchaeology* 15(3):227-290.

Kerr, A. C.
2000 Systematic Analysis of Unfluted Lanceolate Projectile Points. Master's thesis, Department of Anthropology, The University of Texas at Austin.

Meagher, M.
1986 Bison bison. *Mammalian Species* 266:1-8.

Metcalfe, D. and K. T. Jones
1988 A Reconsideration of Animal Body-Part Utility Indices. *American Antiquity* 53(3):486-504.

Outram, A. K.
2006 Juggling with Indices: A review of the Evidence and Interpretations Regarding Upper Palaeolithic Horse Skeletal Part Abundance. In *Horses and Humans: The Evolution of Human-Equine Relationships,* edited by S. L. Olsen, S. Grant, A. M. Choyke, and L. Bartosiewicz, pp. 49-60. International Series 1560. British Archeological Reports, Oxford.

Outram, A. and P. Rowley-Conwy
1998 Meat and Marrow Utility Indices for Horse (Equus). *Journal of Archaeological Science* 25:839-849.

Speth, J. D.
1983 *Bison Kills and Bone Counts*. University of Chicago Press, Chicago.

Waechter, N. B., F. E. Lozo, Jr., and Virgil E. Barnes
1977 *Geologic Atlas of Texas: Del Rio Sheet*. Bureau of Economic Geology, The University of Texas at Austin.

On an Alternative Interpretation of Paleoindian Site Use at Bonfire Shelter

David J. Meltzer, Ryan M. Byerly, and Judith R. Cooper

In the interest of fairness, the editors for this volume of the *Bulletin of the Texas Archeological Society* provided us with a copy of Elton Prewitt's response to our paper and gave us the opportunity to reply. We are largely content to let our papers (Byerly et al. 2005, and Byerly et al., this volume) speak for themselves, since they address many of the criticisms Prewitt raises: for example, the central point of our GIS analysis of the topography was that the site was indeed quite suitable as a jump (Byerly et al. 2005:605), and it was so regardless of ground cover or bison eyesight—though we are well aware of the greater role the latter can play in certain settings, having investigated a number of Paleoindian bison kills including the Folsom type site (Meltzer 2006). We also address the analytical flaw in Lorrain's quadrupling the number of animals in the bone bed, which is based on nothing more than the undocumented assumption that the density of bone is essentially uniform throughout the site (Byerly et al. 2005:610); and, because there are an equal number of bulls and cows in the bone bed (in so far as one can discern [Byerly et al. 2005:610]), it is analytically justifiable to use, as we do, Emerson's averaged utility indices for *bison* (we do not, as Prewitt mistakenly asserts, use Binford's caribou indices).

Beyond his criticisms, Prewitt offers a handy summary of Dibble's work and his recollections of the excavations there. He also makes additional assertions we would be delighted to see demonstrated by actual evidence as, for example, his suspicion that the valley floor in Paleoindian times was no more than "2-3 m higher than at present." But what specifically is the "vertical relationship" between the downstream cemented gravels and the site's bedrock? Have those gravels been recorded and mapped directly in the front of the shelter to show their relationship to the shelter floor in Paleoindian time? And the larger question: are those gravels indeed Pleistocene in age (we suspect as much, as does Prewitt, but none of us has yet demonstrated that)? Ultimately, these questions remain unresolved: as we noted. More data are needed.

And while we are smart enough not to enter a debate with Prewitt about point typology, we would note we are merely following precedent (Bousman et al. 2004:70; Dibble 1968:36) in the mention of Midland and Milnesand points. Moreover, if Prewitt is correct that the point fragment found by Cooper and Byerly (2005) is Plainview, that certainly fits nicely with our interpretation of this being a single component bone bed.

We raised an alternative interpretation of the use of Bonfire Shelter in Paleoindian times. Prewitt is not alone in objecting to it; Bement, who worked at the site in the 1980s, did as well (Bement 2007), and we have responded (Byerly et al. 2007). In that response we also addressed the interpretive problems with the supposedly cultural spoke-like arrangement of bones, and the logical fallacy—which Prewitt also commits—of assuming that because Bonfire Shelter was used as a jump in the Archaic, that it must have been used in the same manner in earlier Paleoindian times. Site use can change over time.

Importantly, we recognize that our alternative interpretation of the shelter's use in Paleoindian times may be correct, but appreciate it could also be wrong. Nor was it our intent to disparage in any way the results of Dibble's landmark excavations, on which we relied heavily in our re-analysis, and could do so only because of the care and thought Dibble and his crew put into that work.

That there is the possibility for an alternative interpretation of site use is hardly unique to Bonfire Shelter; it is true of many sites, including Hudson-Meng, which by more recent excavations and evidence does *not* appear to be a jump kill (Todd and Rapson 1999). Indeed, re-analysis of many sites using techniques unavailable at the time of their original investigations often highlight ambiguity in interpretation (Meltzer 2006). We made an honest effort to resolve these areas of ambiguity at Bonfire Shelter, but in many instances resolution will require data currently unavailable, as we explicitly discussed. Future work at the site may provide that data. Until then, it is just not enough to conclude, as Prewitt does, that the answer is "pretty simple." Archeology seldom is.

REFERENCES CITED

Bement, L.C.
2007 Bonfire Shelter: A jumping off point for comments for Byerly et al. *American Antiquity* 72:366-372.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Byerly, R. M., J. R. Cooper, D. J. Meltzer, M. E. Hill, and J. M. LaBelle
2005 On Bonfire Shelter (Texas) as a Paleoindian Bison Jump: An Assessment using GIS and Zooarchaeology. *American Antiquity* 70:595-629.
2007 A further assessment of Paleoindian site-use at Bonfire Shelter. *American Antiquity* 72:373-381.

Cooper, J. R. and R. M. Byerly
2005 The Significance of a Second Folsom Projectile Point from Bonfire Shelter, Texas. *Current Research in the Pleistocene* 22:41-43.

Dibble, D. S.
1968 The Archaeology. In *Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas*, by D. S. Dibble and D. H. Lorrain, pp. 1-76. Miscellaneous Papers No. 1. Texas Memorial Museum, The University of Texas at Austin.

Meltzer, D. J.
2006 *Folsom: New Archeological Investigations of a Classic Paleoindian Bison Kill.* University of California Press, Berkeley.

Todd, L. C. and D. J. Rapson
1999 Formational Analysis of Bison Bonebeds and Interpretation of Paleoindian Subsistence. In *Le Bison: Gibier et Moyen de Subsitance de homes du Paleolithique aux Paleoindiens des Grandes Plaines*, edited by J.-P. Brugal, F. David, J. Enloe, and J. Jaubert, pp. 480-499. Editions APDCA, Antibes, France.

Quantitative Variation in Late Paleoindian Projectile Points: A Perspective from Central Texas

John J. Taylor-Montoya

ABSTRACT

The Late Paleoindian archeological record shows evidence for diversification of projectile point styles and overall changes in lithic technology relative to the Early Paleoindian period. Several hypotheses have been put forth to explain these changes, but ultimately the problem must be addressed in terms of cultural transmission processes and the evolution of artifact forms. This article examines recent models of artifact variation that have been used to track cultural transmission processes via the coefficient of variation statistic (*CV*). A sample of Late Paleoindian points from Central Texas is analyzed and the *CV* calculated for seven variables. Comparisons within and between the groups of points suggest that many differences in *CV* between groups are linked to different use and maintenance strategies. While this study reveals some apparent patterns useful for future research into cultural transmission processes, it also emphasizes the need for incorporating use-wear and technological data into models of artifact evolution.

INTRODUCTION

Explanations of cultural change over time and space have long been a central concern for North American archeology. One of the more intriguing episodes of change in material culture in North America occurs during the Late Paleoindian period. This article is an examination of quantitative variation among Late Paleoindian projectile point classes using assemblages from two stratified Central Texas sites. The Early Paleoindian period in Texas is typically recognized via diagnostic fluted projectile points (i.e., Clovis and Folsom, also Midland if it is considered a variant of Folsom) and is accepted as occurring from ca. 11,500 to 10,200 B.P. based on radiocarbon dates associated with Clovis and Folsom sites (Bousman et al. 2004; Collins 2004; Hester 1976; see also Holliday 2000). The Late Paleoindian period is commonly associated with the several varieties of unfluted point styles (e.g., Plainview, Cody/Scottsbluff, St. Mary's Hall, etc.) dating from about 10,200 or 10,000 B.P. to 8500 B.P. (Collins 2004; Hester 1976; Holliday 2000).[1] In addition to changes in point styles, the shift from the Early to Late Paleoindian periods has been characterized as a shift in overall adaptive strategies. This has commonly been described as a change in focus from Pleistocene big-game hunting and high mobility to strategies focused on more localized resources and perhaps more limited mobility (Anderson 1996; Goodyear 1979; Haynes 1980; Hester 1976; Hofman 1989, 1999; Hofman and Graham 1998; Johnson and Holliday 1981; Kelly and Todd 1988; Stanford 1999).

Early syntheses of the Paleoindian record in North America characterized changes in lithic technology and subsistence as temporally distinct phases of cultural development (e.g., Irwin and Wormington 1970; Sellards, 1952; Wormington 1957). There is increasing evidence, however, that the Late Paleoindian period was a time of multiple artifact styles that were at least partially contemporaneous even within a particular region (e.g., the Great Plains, see Frison and Bonnichsen 1996; Sellet 2001; cf. Hofman and Graham 1998:115-116). Moreover, current reevaluations of the Paleoindian archeological record have suggested that Paleoindian adaptive strategies were more complex than previously thought (Bamforth 2002; Bousman et al. 2002; Cannon and Meltzer 2004; Collins 2004; Frison and Bonnichsen 1996; Hill 2005; Sellet 2001). For Central and southern Texas, Hester (1976:8) noted that the "terminal Pleistocene in Texas appears to have seen a wide range of adaptations, reflecting the use of fairly localized environments and resources, and leading to the development of regional lithic specializations." Overall, it appears that by 10,600 B.P. there were regionally distinctive projectile point types that are considered to be linked to specific adaptations, with sub-regional point styles emerging later in the Paleoindian period throughout the southern Plains region (indeed, throughout North America, Anderson 1995, 1996; Anderson and Faught 2000; Meltzer 2002:40; Morse et al. 1996; also Bonnichsen et al. 1987).

The record in Central Texas is particularly interesting due to the presence of a very early notched-point complex, the Wilson component at Wilson-Leonard, appearing at ca.10,000 B.P. (Bousman et al. 2002; Collins 1998). At the Wilson-Leonard site, the Wilson component is preceded and followed in the stratigraphic sequence by components with unfluted lanceolate projectile points more commonly associated with the Paleoindian period. These include an early unfluted point resembling Midland or Plainview (see Bousman et al. 2004; Collins 2004), Scottsbluff, St. Mary's Hall, Golondrina-Barber, and Angostura. Similar projectile points are found throughout the region, but some types appear to be concentrated in particular sub-regions of Texas. For example, Angostura has been interpreted as principally a Central Texas tradition (Hester 1976), while Scottsbluff points appear to be concentrated in eastern Texas (Bousman et al. 2004; Hester 1976). Explanations for these patterns include the hypothesis that point styles reflect sub-regional traditions linked to localized adaptations (Hester 1976), or changes in hunting strategies that require, or are attendant with, different hafting techniques as exemplified by the appearance of the Wilson component at Wilson-Leonard (Bousman et al. 2002:983). It has also been proposed that dissimilarities in haft morphology between Plainview and Golondrina points reflect different hafting strategies resulting from the different performance requirements of each point type: Plainview points were used primarily as weapon tips while Golondrina points were used as both points and knives (Kelly 1982, 1983; see also Bousman et al. [2004:20-21] for an updated discussion).

While previous explanations are compelling, if we are to fully understand the broader processes of culture change, and the evolution of artifact characteristics, we need methods that can track various processes over time and space on multiple scales. Moreover, we need objective methods to differentiate variation in artifacts that might be due to functional (i.e., adaptive) processes and those that are primarily due to processes inherent to cultural transmission (such as cultural drift). Adaptive responses to environmental conditions manifested in artifacts can produce similarities between objects (similar solutions to similar problems) that can be mistaken for historical relatedness (i.e., a phylogenetic relationship [Lipo et al. 1997]). This is the classic problem of identifying homology versus homoplasy, which remains an essential aspect of examining change through time (Lipo et al. 2006).

Cavalli-Sforza and Feldman (1981) developed a model of variation for a continuous trait under different conditions of cultural transmission. They compared the results of their model with data from a cache of Pomranky projectile points from Michigan (from Binford 1963). Some variables, such as length, were highly variable but thickness varied only slightly even when points from different sites and made on different raw materials were compared. They proposed that variance of metric traits is constrained when selective forces are at work (Cavalli-Sforza and Feldman 1981:319-325). In this case, the thickness of the points exhibited the least amount of variation and thus was characteristic of a trait under the strongest "selective pressure" among those that were analyzed. Cavalli-Sforza and Feldman surmised that thickness was controlled due to its relation to the functionality of the points (Eerkens and Lipo [2005] came to similar general conclusions regarding variation among Rose Spring points from the Owens Valley in California). It should be noted that the term "functional" is used here as a shorthand for variables affecting the performance characteristics of artifacts (Dunnell 1978; Dunnell and Feathers 1991; Feathers 1989; O'Brien and Holland 1990; Schiffer and Skibo 1997; Van Pool 2003). This is contrasted with "neutral" traits that contribute to artifact variation but do not directly affect the performance characteristics of the artifact.

The basic framework employed here follows Van Pool (2001, 2003). Drawing on engineering and actualistic studies, Van Pool noted that the performance requirements of a tool along with the raw materials used to fashion it impose mechanical constraints on the tool. These factors, in turn, will serve to limit variation in those attributes that affect the ability of the tool to fulfill its function. The degree of variation will differ depending on the selective forces at work and the nature of the mechanical restraints imposed on the tool. Nonetheless, we expect that, in general, functional attributes will be far less variable than neutral traits in any given artifact class. It has been shown that the coefficient of variation is an effective measure of artifact variation that can be used to track different processes of cultural transmission (see discussion below). In terms of Van Pool's model, we expect the coefficient of variation of functional traits to be much smaller than neutral traits.

An important shortcoming of these models is that they do not explicitly account for the effects of different use-life trajectories on the metric variation of tools. Such a consideration might not be relevant for the Pomranky burial cache example outlined above, but we must consider it for Late Paleoindian points on the Southern Plains or any other assemblage of lithic tools that were in "everyday" use in their systemic context.

Use-wear studies, while still limited in extent, have shown that Late Paleoindian points were often recycled for use in multiple tasks other than use as a weapon tip (e.g., Kay 1998). Moreover, there is evidence that trajectories of use changed over time and, consequently, are at least partly responsible for changes in the design of projectile points. Recycling of projectile points will also, due to attrition and reworking, affect the metric attributes of projectile points. Since all of these factors are potentially contributing to the variation in our samples, they must be taken into consideration when attempting to integrate use-wear and technological studies into questions regarding broader processes of artifact variation.

This article is not intended to answer basic questions of cultural transmission or artifact evolution. Rather, it is an examination of models of artifact variation that have been developed to address such problems. Since there have been few evaluations of these models using independent sets of data by independent researchers, this study is an attempt to contribute to this effort. Ultimately, answering these questions will require a diachronic analysis of projectile points at a regional scale. This study represents an attempt at initial pattern recognition. The first-order patterning that results from this study represents a starting point from which, it is hoped, more complex analyses can be executed (cf. Binford 1991, 2001).

THE SAMPLE

The projectile points used in this study were recovered during excavations at the Gault and Wilson-Leonard sites in Central Texas (Figure 1). Gault is a stratified site that has yielded abundant evidence of human occupation since at least Clovis times (Collins 2002, 2004; Collins and Brown 2000). To date, 153 early Holocene projectile points and chipped stone tools have been documented from Gault (Taylor-Montoya 2006). The Wilson-Leonard site yielded several stratified and radiocarbon-dated early Holocene components with abundant chipped stone tools, fauna, and multiple features. A female burial dating to the early Holocene, associated with the Wilson component, was also recovered (Collins 1998). Both sites are located in alluvial valleys along the Balcones Escarpment in what today is the Balcones Ecotone. This ecotone marks the boundary between the Gulf Coastal Plain and the eastern Edwards Plateau. In this transitional zone, the contrasting natural resources of the limestone uplands and coastal plains merge. Locally, mesic valley floors offer a diverse array of flora in contrast to the more xeric vegetation of the rocky uplands. Raw material for chipped stone tools occurs at or very close to each site.

This study focuses on variation within and between three Late Paleoindian projectile point classes: St. Mary's Hall, Golondrina-Barber, and Angostura (Figure 2). St. Mary's Hall points are dated to ca. 9500-8500 B.P., Golondrina-Barber points date to ca. 9200-8900 B.P., and Angostura points are dated to ca. 8800-8000 B.P. (Bousman et al. 2004; Collins 1998; Holliday 2000). A total of 78 points from both sites were analyzed for this study. Projectile points were included in the analysis if they were complete enough to provide measurements for the variables of interest (see below). The majority of points in the total sample are made on varieties of Edwards chert.

Gault and Wilson-Leonard are relatively close in proximity and both assemblages yielded the same sequence of Late Paleoindian points. The fact that both sites are in the same general area allows for control of access to resources as a variable (e.g., access to lithic raw material) and the effects of variation that could simply be a product of spatial distance. The fact that almost all of the points are made on Central Texas Edwards chert allows for control over differences in raw material. As an aggregate group the artifacts represent a larger subregional sample than would be afforded by either site alone. Moreover, the aggregate sample allows

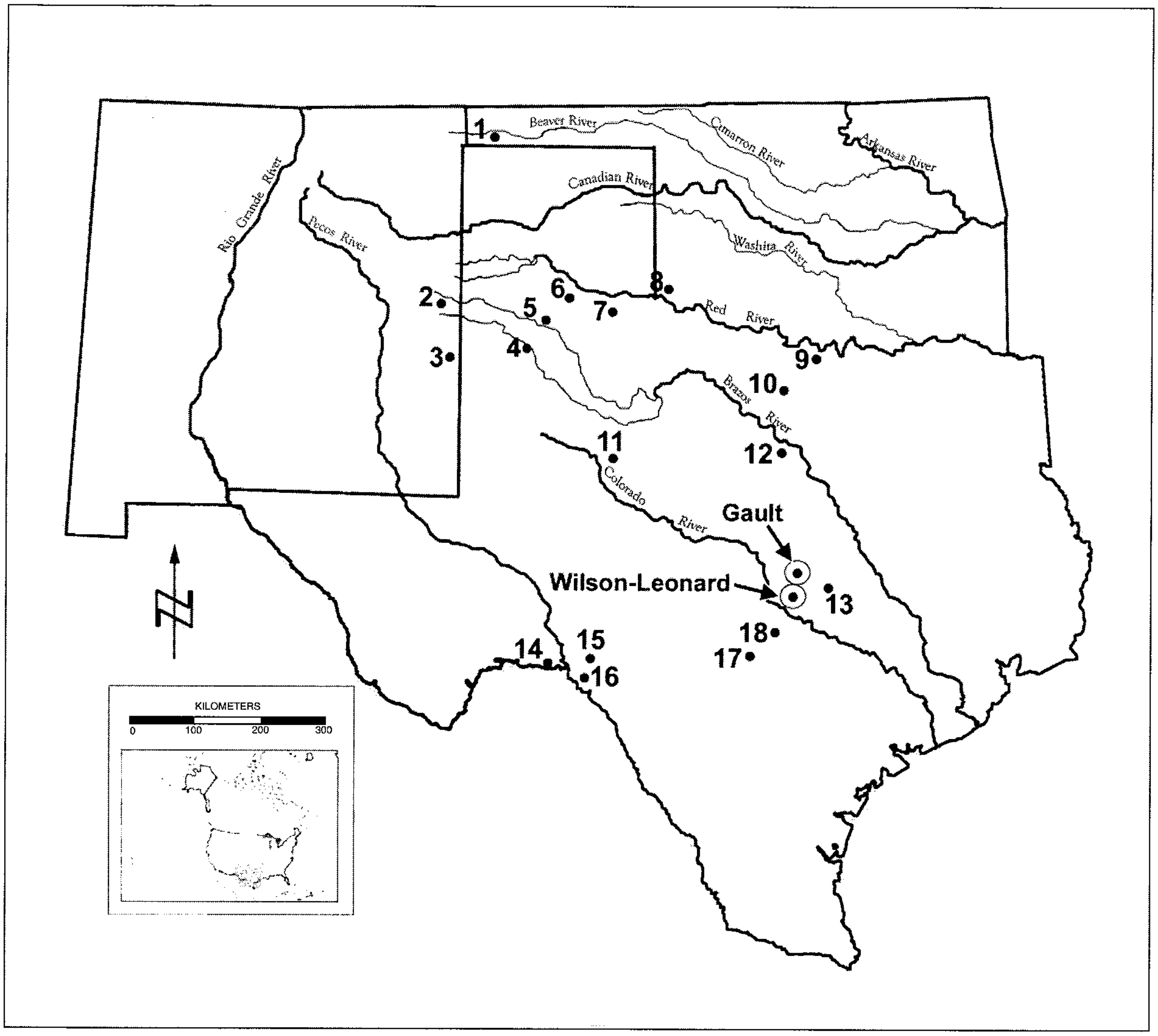

Figure 1. Map showing the location of Gault and Wilson-Leonard along with selected Paleoindian sites in the region that have yielded Late Paleoindian artifacts: (1) Nall, (2) Blackwater Draw, (3) Milnesand, (4) Lubbock Lake, (5) Plainview, (6) Rex Rodgers, (7) Lake Theo, (8) Perry Ranch, (9) Field Ranch, (10) George King, (11) Lone Wolf Creek, (12) Horn, (13) Loeve, (14) Bonfire Shelter, (15) Baker Cave, (16) Devil's Mouth, (17) St. Mary's Hall, and (18) Levi.

for a somewhat broader perspective than would be afforded by focusing on a single site.

METHODS

Models of cultural transmission have emphasized quantitative measures of trait variation as a means of tracking different processes of cultural transmission and variation over time and space (e.g., Bettinger and Eerkens 1990; Eerken and Lipo 2005; Van Pool 2001). For material culture, this has taken the form of measuring variation among metric attributes of artifacts at various scales. The coefficient of variation (*CV*) has been used to measure variation of metric attributes in these studies because it is a dimensionless, robust statistic that is not affected by significant differences in the means of the variables being compared (Eerkens and Bettinger 2001; see also Sokal and Rohlf 1995:57-59). Variables with significantly larger means will have significantly higher standard deviations. As such, a simple examination of the standard deviation or variance might lead to spurious results in significance tests. This is particularly relevant for this study since some variables (such as maximum length) will naturally have means an order of magnitude higher than the

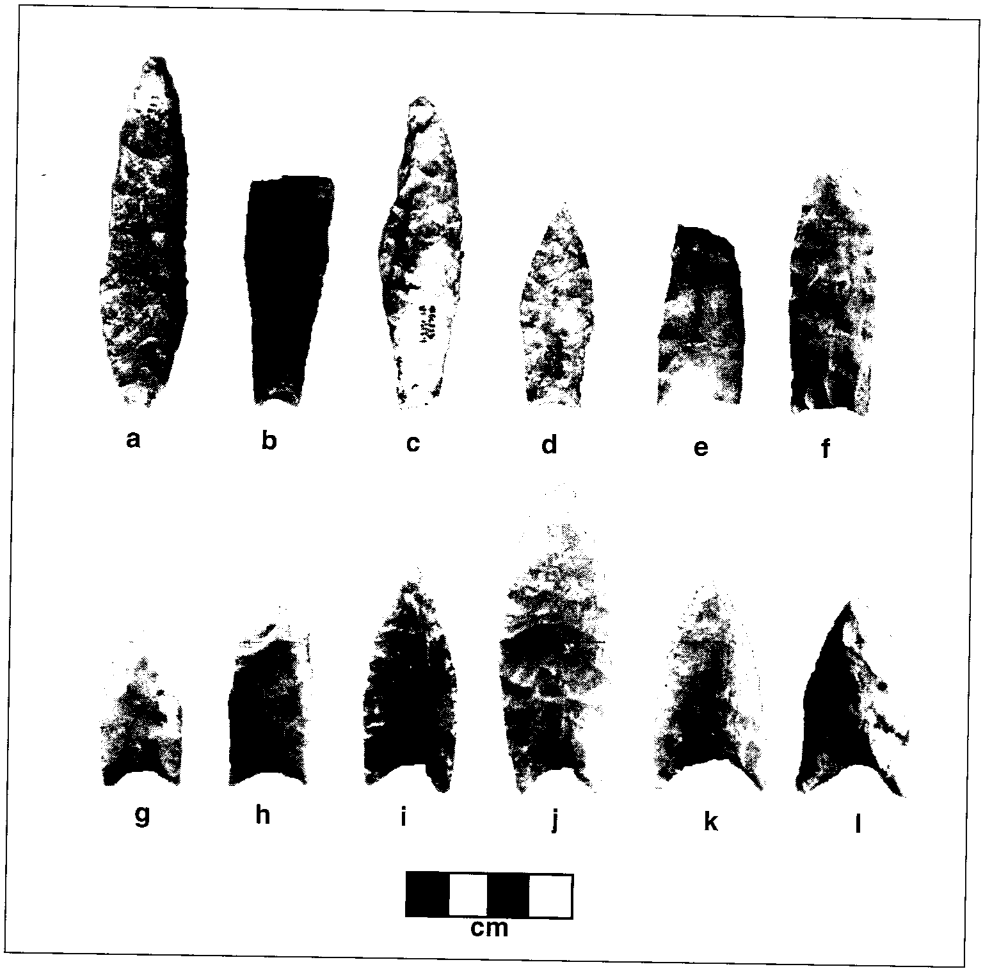

Figure 2. Examples of projectile points analyzed for this study. Angostura: (a) 1147-2, (b) 102-179, (c) 1512-1, (d) 1193-1. St. Mary's Hall: (e) 2058-13, (f) 34V18-1, (g) 7Q1, (h) O-1. Golondrina-Barber: (i) 50YA-1, (j) 15YI-1, (k) 10S-1, (l) 72-1.

means of other variables (such as maximum thickness). *CV* is calculated by dividing the sample standard deviation by the sample mean and multiplying the result by 100.

A series of metric variables were measured on each artifact using standard plastic metric calipers. The variables included commonly recorded volumetric measurements such as maximum length, maximum width, and maximum thickness. In addition, a series of variables associated with particular elements of each point were also recorded. These include the maximum width and thickness of the haft element and the extent of grinding on the lateral edges of the haft element. Figure 3 illustrates the measurements used in this study. The coefficient of variation was then calculated for each variable. Table 1 presents the descriptive statistics for the variables used in this study along with the *CV*.

RESULTS AND DISCUSSION

The projectile points from Gault and Wilson-Leonard were divided by typological class and *CV*s were calculated for the seven variables (Figure 4). Immediately apparent in Figure 4 is that there is a general trend in *CV* values for some variables across all classes. Overall, the various measures of width and thickness have the lowest *CV*s. Maximum thickness and haft thickness consistently pattern as the least variable attributes across all classes. Base width and average grinding length tend to have low *CV*s as well, but are more variable than the thickness variables and maximum width. Length is consistently one of the most variable attributes across all classes. This is to be expected, as variation in length can arise from multiple factors such as differences in raw material or blank size along with use-related

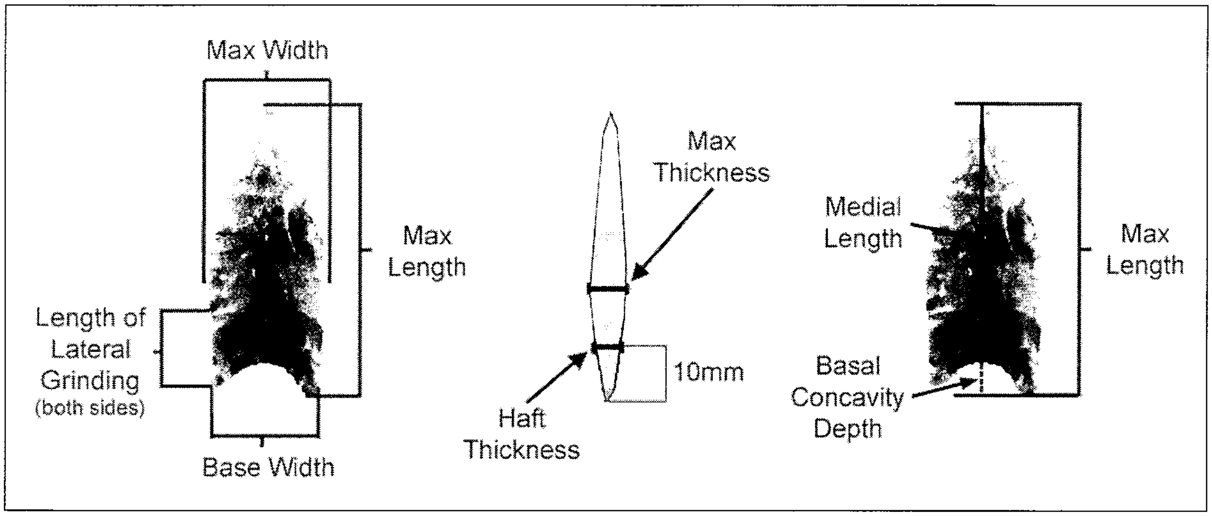

Figure 3. Illustration of measurements taken on projectile points.

Table 1. Descriptive statistics and *CV* of variables for the artifact samples.

Class		Length	Width	Base Width	Thickness	Average Grinding Length	Haft thickness	Basal Concavity Depth
Angostura	Mean	41.44	22.77	21.43	6.40	23.69	5.78	6.00
N=34	St. Dev.	16.27	1.59	1.75	0.95	7.42	0.90	1.45
	CV	39.26	6.98	8.17	14.84	31.32	15.57	24.17
Golondrina-Barber	Mean	51.85	28.04	27.15	6.77	24.85	5.97	6.70
N=30	St. Dev.	15.74	5.49	5.61	0.71	6.45	0.63	2.62
	CV	30.36	19.58	20.67	10.49	25.96	10.55	39.10
St. Mary's Hall	Mean	47.31	22.67	20.65	6.89	22.10	6.01	2.79
N=14	St. Dev.	11.91	1.66	2.01	0.91	4.75	0.80	1.20
	CV	25.17	7.32	9.73	13.21	21.49	13.31	43.01

Note: All measurements are in mm.

damage and reworking of the points. In this analysis, variation in length is also affected by the inclusion of incomplete specimens. Length measurements for incomplete points were included in this analysis for two reasons: (1) it was anticipated that length *CV*s from points discarded at multiple states of use and breakage would provide a comparative measure for variables that were affected by situational factors (i.e., breakage and reworking), and (2) calculating the *CV* for only complete specimens would severely diminish the number of points that could be included for each class (unbroken points comprise less than 10% of the total sample). One of the more striking commonalities among all point classes is the high *CV* for basal concavity depth relative to the other variables, even length. This is particularly surprising given the previously mentioned biases in the *CV*s of maximum length.

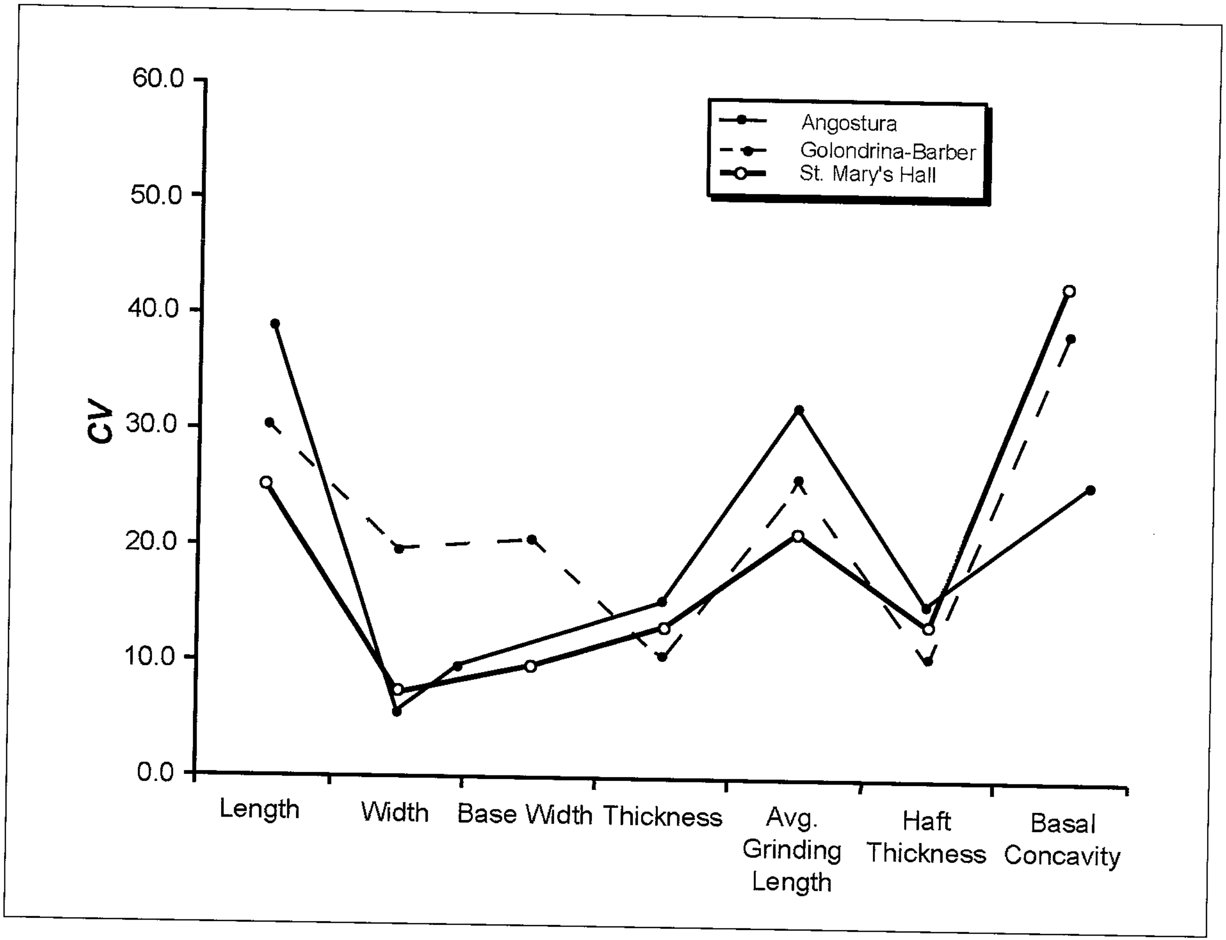

Figure 4. Comparison of *CV* values for each variable among projectile point classes.

Width and thickness variables exhibit the limited variation we would expect of functional attributes—i.e., attributes directly affecting performance characteristics—across all classes. Studies using independent archeological, ethnographic, and experimental evidence have shown that there is good reason to expect that width and thickness attributes are tied directly to projectile point performance. The maximum width and thickness dimensions of a projectile point, with perhaps a few exceptions, will be directly related to the size of the wound inflicted on a target as well as the efficiency of penetration of the projectile (Christenson 1986; Friis-Hansen 1990). Thickness has also been shown to be related to the durability of a projectile point (Shott 2002; cf. Cheshier and Kelly 2006). Additionally, as volumetric measurements, width and thickness are related to the gross weight of the projectile point which, as a weapon tip, would have influenced projectile balance (during flight, if propelled) and the amount of damage inflicted on impact (Christenson 1986; Cotterell and Kamminga 1990; Cundy 1989; Wilhelmsen 2001).

The average length of lateral grinding exhibits higher *CV*s across all classes than the width and thickness variables. In the case of the Angostura sample, the difference is not statistically significant. For the Golondrina-Barber sample, it is significantly different from the thickness variables but not the width variables. The St. Mary's Hall sample exhibits a significant difference in *CV* between average grinding and width variables but not the thickness variables. Lateral grinding on a projectile point is often taken as a feature of the haft configuration, perhaps to strengthen the sides of the haft element (Titmus and Woods 1991a). Length of grinding can be expected to vary (to some degree) among individual artifact makers and it will be affected by attrition (of both haft and blade) and resharpening. In this study, average grinding tends to fall closer to the width and thickness variables than others in terms of variation. Although difficult to assess, if lateral edge grinding is a functional attribute (as per VanPool's model), there are two factors that would account for the scale of variation seen in the sample: (1) lateral grinding is affected *greatly* by the vagaries of use and reworking and/or (2) the presence of grinding confers the functional advantage but the absolute length of grinding was less important.

As mentioned above, basal concavity exhibits higher *CV*s than any of the other variables across all projectile point classes. It should be noted, however, that there was no a priori expectation that basal concavity would parse out as a functional or neutral variable. This is the case because there have been several different hypotheses for the presence and characteristics of basal concavities in projectile points, none of which have been adequately tested. These hypotheses include the proposition that basal concavities were a stylistic "whim" (Gramly 1982); technological explanations where basal concavities were a byproduct of the reduction process (Witthoft 1952); and more functional explanations where the concavity helps secure the point in the haft and absorbs end shock when used as a projectile (Titmus and Woods 1991b).

If any of the functional hypotheses were accurate, we would expect the variation of basal concavity within any particular class to be much lower than it is. This is particularly the case since it is commonly assumed that the haft element would have undergone the least amount of attrition and reworking during the use-life of the point. This is not to say that the concavity did not serve a design purpose, as it obviously was involved in how the point was seated in the haft. Nonetheless, the measurable depth of the basal concavity does not conform to our expectations of a trait that affects the performance of the points.

There are several possibilities for the high level of variation in basal concavity depths, three of which seem most reasonable given the observations above. First, we may be seeing the end result of attrition to the base of the points from use as a projectile (i.e., breakage resulting from impact). For example, experiments have shown that Paleoindian points (of various types) tend to break at both the tip and near the junction of the haft and blade elements on impact (Frison 1989, 1991), requiring reshaping of the tip and the entire haft element (including the basal concavity) if the point was to be used again. Second, the variation could be the result of situational factors that arose during manufacture and/or maintenance requiring more flexibility in the construction of the point base relative to other elements. In an experimental study, Towner and Warburton (1990) discovered that they had to modify completed points to facilitate hafting. It is possible that prehistoric point makers encountered similar contingencies (although skill and experience may well serve to obviate such circumstances). Third, the dimension of the basal concavity varied from person to person and reflects either individual differences in the specific construction of hafts (or foreshafts) or was simply a byproduct of idiosyncrasies among individuals. In other words, the third possibility is that it reflects individual "style."

Experiments with stone projectile points have shown that damage to the haft element is common (Bergman and Newcomer 1983; Dockall 1997; Flenniken and Raymond 1986; Frison 1989; Frison and Stanford 1982; Odell and Cowan 1986; Titmus and Woods 1986; Towner and Warburton 1990). However, most of the cited experiments involve the use of notched points with haft configurations much different than those envisioned for the Paleoindian points in this sample. Moreover, many of the cited studies use obsidian as a raw material, which tends to be more brittle than chert. Replicated Clovis points in Odell and Cowan's (1986) experiments exhibited damage to the haft element in half the specimens and similar results have been obtained in other experiments with replicated Clovis weaponry (e.g., Frison 1989). However, no clear pattern of use-related breaks has been established for Paleoindian points that can be marshaled as an explanation for the high variability of basal concavity depth as seen in this study. More actualistic studies geared toward examining the effects of use-related damage on metric characteristics of Late Paleoindian points, similar to those for other varieties of projectile points (e.g., Hoffman 1985; Titmus and Woods 1986; Zeanah and Elston 2001), would be needed to further this line of argument.

The second possibility is that the high basal concavity *CV*s are due to the cumulative effects of essentially random occurrences: unpatterned modification of the haft for whatever situational conditions might have arisen. This is perhaps the most difficult proposition to test, especially given the limited scope of this study. However, the upper and lower limits of artifact variation (as expressed by *CV*) have been modeled (Eerkens and Bettinger 2001) and can be used as a baseline to evaluate the basal concavity *CV*s. Eerkens and Bettinger calculated *CV*s of 1.7 as the lower limit via human production, based on the average ability of people to reproduce objects without an external guide. Artifacts approaching this level of variation are highly standardized and intentionally made to conform to a strict template. None of the variables in this sample approach this lower limit; indeed, only three are below 10 (see Table 1). This is common for stone artifacts, however, which tend to exhibit substantially higher *CV*s than other products (Eerkens 2000), even when standardized production is involved (Torrence 1986; but see Cheshier and Kelly 2006). The "ceiling" for *CV* is estimated at 57.7, which represents random manufacturing processes: artifact makers are not concerned with following a pattern based on other forms. None of the point classes exceed the upper limit of 57.7 for basal concavity *CV*, so it appears unlikely that we are observing the by-product of strictly random processes or random production.

Attrition to the haft element of projectile points clearly occurred in prehistory based on the breakage patterns commonly seen on projectile points. Further, experimental studies have shown that damage to the haft commonly occurs on replicated projectile points (Dockall 1997; Odell and Cowan 1986; Titmus and Woods 1986). (The morphology of the point as well as the target and method of propulsion will also affect the type of damage incurred.) It may well be that such damage affected the metric attributes of projectile point haft elements more than has been assumed. On the other hand, the metric variation in haft element traits we see in these samples would fit the expectations of "neutral" traits. This would fall more in line with the third proposition of individual, perhaps "stylistic," differences among artifact makers.

While some variables follow a similar pattern across classes, it is also evident in Figure 4 that there are dissimilarities between the point classes. Two variables in particular, maximum width and base width, exhibit significant differences between classes. St. Mary's Hall points have significantly lower *CV* for maximum width than the Angostura and Golondrina-Barber samples. The differences in *CV* for width are likely due to the use-lives of the points. Kay (1998) performed a use-wear analysis on a sample of points from the Wilson-Leonard site. Based on the results of this analysis he determined that both Golondrina-Barber and Angostura points from Wilson-Leonard were used primarily as knives. Angostura points, in particular, appeared to Kay (1998) to have been constructed more for use as knives than points. On the other hand, St. Mary's Hall points were used primarily as weapon tips, although they had evidence for use as cutting implements as well.

The morphology of the points can play a role in how maximum width is affected by reworking, but this varies from class to class. Maximum width of points in the Golondrina-Barber class tends to occur at the proximal end up to the mid-point of the blade element in this sample (with the exception of heavily reworked specimens). Considering both the morphology and use-lives of Golondrina-Barber points, it is not surprising that maximum width varies more for this point class than St. Mary's Hall. Maximum width on this sample of Angostura points tends to be near the intersection of the haft and blade elements. In fact, there is a strong and significant correlation between the location of maximum width and the length of lateral grinding on this Angostura sample ($r = 0.703$; df=19; p=0.003). (The location of maximum width on Angostura points tends to shift from the blade element toward the intersection of the blade and haft elements as the extent of reworking increases.) As mentioned above, there is evidence that Angostura points were

Table 2. ANOVA of base width measurements for three groups of Golondrina-Barber points divided according to basal morphology: slightly constricting stems, parallel sided, and bases with flaring "ears."

	Sum of Squares	df	Mean Square	*F*	*p*
Between Groups	115.235	2	57.618	2.076	.162
Within Groups	388.507	14	27.751		
Total	503.742	16			

reworked along their entire length. The net effect of use and reworking on the maximum width of Angostura points is, therefore, similar to that for the Golondrina-Barber group. Many of the St. Mary's Hall points in this sample also have evidence for reworking and tend to exhibit maximum width on the blade near the intersection of the blade and haft elements. Unlike the other point types, however, maximum widths on St. Mary's Hall points are not highly variable. The latter may be an effect of being reworked while in the haft (or foreshaft). Consequently, while point morphology plays some role, the difference in *CV* for the Golondrina-Barber and Angostura points versus St. Mary's Hall points is attributable to dissimilarities in how the tools were used and refurbished.

Base width varies in *CV* between the classes in a way similar to maximum width. Angostura and Golondrina-Barber points have significantly higher *CV*s than St. Mary's Hall points. The higher *CV* for Angostura base width might reflect, similar to maximum width, the use life of the points in the sample. In his use-wear study, Kay (1998) identified microwear traces indicating that Angostura points had been turned around and recycled during their use-lives (i.e., they had been removed from the haft and the proximal end was turned into the distal blade element). Moreover, macro-flaking on some of the Angostura points clearly indicates that reworking occurred on both the blade and haft elements (see Figure 2c). It is not unexpected, then, that Angostura points would vary more in terms of base width than St. Mary's Hall points, which do not appear to have undergone such dramatic recycling. It should be noted, however, that *within* the Angostura sample, base width *CV* is not significantly different than the *CV*s for maximum width or either of the thickness variables. As an aspect of haft element morphology, it is not unexpected that base width would be controlled for, particularly if socketed hafts were used as has been suggested for points with contracting stems (Frison 1974; Zeanah and Elston 2001). As such, for Angostura base width, we are likely seeing an attribute that was controlled due to its function on the point, but exhibiting a high *CV* (relative to the other point classes) due to the use history of the points.

It was suspected that the high base width *CV* of Golondrina-Barber points might not be due to functional or stylistic factors, but rather the composition of the sub-sample. The sub-sample of Golondrina-Barber includes points with slightly contracting bases, parallel-sided bases, and points with bases that have flaring "ears." Variation in a sample can be inflated if artifacts are combined that should be divided into separate classes (cf. Eerkens and Bettinger 2001). In this case, the high base width *CV* might be spurious if each type of base morphology, on average, exhibits significantly different width measurements. To test this notion, the Golondrina-Barber sample was divided into groups of points with slightly contracting, parallel-sided, and flaring bases. An ANOVA was calculated and revealed that there are no statistically significant differences in mean base width among the morphological groups (Table 2). There is more variation within each morphological group than between them. Differences in base morphology, therefore, are not the likely cause of the high base width *CV*. Other processes must be at work to produce the high *CV*. Impact damage to points includes the breaking of the basal "ears" which would, presuming the same haft configuration was desired if the point was reused, entail reshaping the base of the point (e.g., Dockall 1997; Odell and Cowan 1986; Titmus and Woods 1986). The breakage and reforming of the basal "ears" are possible factors for the high *CV* of base widths among Golondrina-Barber points.

SUMMARY AND CONCLUSION

There are clear trends in the *CV*s of the variables used in this study for the Angostura, Golondrina-Barber, and St. Mary's Hall projectile point classes. Within each class, width and thickness variables consistently exhibit the least amount of variation. Traits that are under "selective pressure" will exhibit the least amount of variation and functional traits should fall into this category. Moreover, we have good reason to believe that width and thickness variables are tied to the performance characteristics of projectile points, based on research into the mechanics of projectile point form and function.

When *CV*s for each variable are examined between projectile point classes, there are clear differences in the same width and thickness variables. Both Angostura and Golondrina-Barber points exhibit higher *CV*s than St. Mary's Hall points for width variables and the length of lateral grinding. This dissimilarity is most likely the result of the different use histories of Angostura and

Golondrina-Barber points as opposed to St. Mary's Hall points. The former were heavily recycled as knives while the latter was used primarily as a weapon tip. These results are not unexpected, but should emphasize that explanations for differences in *CV*s of any particular lithic artifact, whether synchronic or diachronic, must take into account any potential variation in the use-lives of the artifacts. It does appear that, based on this limited sample, there was more variation among makers of Angostura points than makers of Golondrina-Barber and St. Mary's Hall points. This may well indicate a shift in cultural transmission processes for the manufacture of this particular tool class during this time. (One example would be the relaxation or loss of a conformist transmission mode leading to higher variation among manufacturers [cf. Eerkens and Lipo 2005:10].) However, differences among the *individual* variables can be explained via the different performance requirements for each group of projectile points.

The fact that variables measured on the haft element exhibit some of the highest *CV*s in this study is somewhat surprising for two reasons. First, the stone point weapon tip is often assumed to be the expendable component of the weapon system, while the haft is considered to be the more "expensive" component. Thus, it is assumed that, at least in some cases, stone points were fitted to the dimensions of the haft via close control of the dimensions of the haft element (e.g., Judge 1973; Keeley 1982; Zeanah and Elston 2001). Further, the position within the haft (or foreshaft) is often assumed to protect the projectile point base and haft element from major damage and reworking over its use-life (Andrefsky 1998, 2006; Goodyear 1974; Hoffman 1985). The low *CV* of haft thickness for all point classes and base width for the St. Mary's Hall sample fall in line with these assumptions. However, basal concavity, for all samples, varies more than is expected under such assumptions.

The high level of variation in basal concavity depth across all classes indicates one of two things. First, it might qualify as a "neutral" trait under VanPool's model. Indeed, a high level of variation about the mean would be expected for a trait under the process of drift, which tends to be the sorting mechanism for "neutral" traits (Eerkens and Lipo 2005; Lipo et al. 1997; Nieman 1995). It was not possible to discount other explanations in this study, however. The fact that many of the haft variables exhibit high *CV*s for all classes might instead indicate that damage and reworking of the haft element was of a larger magnitude and frequency than has previously been assumed. It may be difficult to test either proposition, but one method would involve experimental studies using replicated Late Paleoindian points. Kelly (1982, 1983) made great inroads along these lines, but more work is required to evaluate the propositions put forth here. Specifically, tests are needed where points are propelled against a target in a controlled environment and reworked as necessary, and the effects of this process on metric variables such as basal concavity recorded.

No matter the final outcome, the magnitude of basal concavity *CV* across all classes has implications beyond this study. Basal concavity depth is a measurement that has commonly been used to quantitatively group projectile points in typological studies (see Kerr 2000; Kerr and Dial 1998). Indeed, the typological classes used in this article are an outcome of Kerr and Dial's research into Late Paleoindian typology (see also Bousman et al. 2004). The basal concavity *CV*s exhibited in this sample of points is suggestive that it might not be productive to put too fine a distinction on differences in basal concavity between classes of unfluted concave base projectile points since the values vary so widely within each class. At the very least, the use of the measurement for classification purposes deserves closer scrutiny.

Ultimately, determining whether any of these phenomena are accurately portrayed here will require the analysis of a much larger sample of points. As mentioned earlier, this analysis represents part of a larger study that will ultimately utilize a more comprehensive sample of projectile points. Consequently, future work will be able to address issues regarding sampling that could not be addressed in this article. It should be noted that the general patterns seen in this study are expected to hold based on a similar study by the author of Paleoindian points from sites outside of Texas.

Despite some lingering questions, this article demonstrates that to fully understand metric variation among projectile points, in this case a sample of Late Paleoindian points, the results need to be viewed from a more comprehensive perspective (Collins 1993). Some of the morphological variation in projectile points is, as archeologists have long known, due to the use, maintenance, and reuse of the artifacts while in systemic context. If we are to explain the larger scale processes of culture change, we must first understand what processes are influencing variation at the scale of the artifact. By utilizing statistical methods, data from actualistic studies, and use-wear analyses, a better perspective can be gained of the problems and potential in current models of artifact variation. This comprehensive approach to exploring variation will hopefully lead to a better understanding of the processes behind the changes in lithic technology evident during the Late Paleoindian period in Central Texas and beyond.

NOTES

1. Bousman et al. (2004) has suggested that Plainview is actually an Early Paleoindian point type and likely dates to around 11,000 B.P. Vance Holliday has explored the problem of radiocarbon dates for Plainview sites in the Southern Plains region in depth and the reader is referred to his research (see Holliday 1997, 2000; Holliday et al. 1999). Holliday (2000:268) notes that Plainview "has proven to be problematic in terms of typological distinctiveness and age" but places it, based on current evidence, as occurring around 10,000 B.P. (perhaps as early as 10,200 B.P.). Holliday's findings are followed here, with the recognition that Plainview is a poorly dated and poorly defined complex and more empirical evidence is needed to resolve these issues.

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REFERENCES CITED

Anderson, D. G.
1995 Paleoindian Interaction Networks in the Eastern Woodlands. In *Native American interactions: multiscalar analyses and interpretations in the eastern woodlands*, edited by M. S. Nassaney and K. E. Sassaman, pp. 3-26. University of Tennessee Press, Knoxville.
1996 Models of Paleoindian and Early Archaic Settlement in the Lower Southeast. In *The Paleoindian and Early Archaic Southeast*, edited by D. G. Anderson and K. E. Sassaman, pp. 29-57. University of Alabama Press, Tuscaloosa.

Anderson, D. G. and M. K. Faught
2000 Palaeoindian artefact distributions: evidence and implications. *Antiquity* 74:507-513.

Andrefsky, W., Jr.
1998 *Lithics: Macroscopic Approaches to Analysis.* Cambridge University Press, Cambridge.
2006 Experimental and Archaeological Verification of an Index of Retouch for Hafted Bifaces. *American Antiquity* 71:743-757.

Bamforth, D.
2002 High-Tech Foragers? Folsom and Later Paleoindian Technology on the Great Plains. *Journal of World Prehistory* 16(1):55-98.

Bergman, C. and M. R. Newcomer
1983 Flint Arrowhead Breakage: Examples from Ksar Akil. *Journal of Field Archaeology* 10:238-243.

Bettinger, R. L. and J. Eerkens
1999 Point Typologies, Cultural Transmission, and the Spread of Bow-and-Arrow Technology in the Prehistoric Great Basin. *American Antiquity* 64(2):231-242.

Binford, L. R.
1963 Red Ochre Caches from the Michigan Area: a Possible Case of Cultural Drift. *Southwestern Journal of Anthropology* 19:89-108.
1991 There is Always More We Need to Know. In *The First Americans: Search and Research*, edited by T. D. Dillehay and D. J. Meltzer, pp. 275-286. CRC Press, Boca Raton.
2001 Where Do Research Problems Come From? *American Antiquity* 66:669-678.

Bonnichsen, R., D. J. Stanford, and D. Fastook
1987 Environmental change and developmental history of human adaptive patterns: The Paleoindian case. In *North America and adjacent oceans during the last deglaciation*, edited by W. F. Ruddiman and H. E. Wright, Jr., pp. 403-424. The Geology of North America, vol. K-3. Geological Society of America, Boulder.

Bousman, C. B., B. W. Baker, and A. C. Kerr
2004 Paleoindian Archeology in Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station.

Bousman, C. B., M. B. Collins, P. Goldberg, T. Stafford, J. Guy, B. W. Baker, D. G. Steele, M. Kay, A. C. Kerr, G. G. Fredlund, P. Dering, V. T. Holliday, D. Wilson, G. Wulf, S. W. Dial, P. Takac, R. Balinsky, M. Masson, and J. Powell
2002 The Paleoindian-Archaic transition in North America: new evidence from Texas. *Antiquity* 76:980-990.

Cannon, M. D. and D. J. Meltzer
2004 Early Paleoindian foraging: examining the faunal evidence for large mammal specialization and regional variability in prey choice. *Quaternary Science Reviews* 23(2004):1955-1987.

Cavalli-Sforza, L. L. and M. W. Feldman
1981 *Cultural Transmission and Evolution: A Quantitative Approach.* Princeton University Press, Princeton.

Cheshier, J. and R. L. Kelly
2006 Projectile Point Shape and Durability: The Effect of Thickness: Length. *American Antiquity* 71:353-364.

Christenson, A. L.
1986 Projectile Point Size and Projectile Aerodynamics: An Exploratory Study. *Plains Anthropologist* 31:109-128.

Collins, M. B.
1993 Comprehensive Lithic Studies: Context, Technology, Style, Attrition, Breakage, Use-Wear and Organic Residues. *Lithic Technology* 18:87-94.

2002 The Gault Site, Texas, and Clovis Research. *Athena Review* 3(2):31-41, 100-101.

2004 Archeology in Central Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 101-126. Texas A&M University Press, College Station.

Collins, M.B. (editor)
1998 *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas.* 5 Vols. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Report No. 10, Archeology Studies Program, Texas Department of Transportation, Environmental Affairs Division, Austin.

Collins, M. B. and K. M. Brown
2000 The Gault Gisement. *Current Archeology in Texas* 2(1):8-11.

Cotterell, B. and J. Kamminga
1990 *Mechanics of Pre-Industrial Technology: An Introduction to the Mechanics of Ancient and Traditional Material Culture.* Cambridge University Press, Cambridge.

Cundy, B. J.
1989 *Formal Variation in Australian Spear and Spearthrower Technology.* BAR International Series, No. 546. British Archaeological Reports, Oxford.

Dockall, J. E.
1997 Wear Traces and Projectile Impact: A Review of the Experimental and Archaeological Evidence. *Journal of Field Archaeology* 24:321-331.

Dunnell, R. C.
1978 Style and function: a fundamental dichotomy. *American Antiquity* 43:192-202.

Dunnell, R. C. and J. K. Feathers
1991 Late Woodland Manifestations of the Malden Plain, Southeast Missouri. In *Stability, Transformation, and Variation: The Late Woodland Southeast*, edited by M. S. Nassaney and C. S. Cobb, pp. 21-45. Plenum Press, New York.

Eerkens, J.
2000 Practice Makes Within 5% of Perfect: Visual Perception, Motor Skills, and Memory in Artifact Variation. *Current Anthropology* 41:663-668.

Eerkens, J. and R. L. Bettinger
2001 Techniques for Assessing Standardization in Artifact Assemblages: Can We Scale Material Variability? *American Antiquity* 66:493-504.

Eerkens, J. and C. P. Lipo
2005 Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. *Journal of Anthropological Archaeology* 24:316-334.

Feathers, J. K.
1989 Effects of Temper Strength of Ceramics: Response to Bronitsky and Hamer. *American Antiquity* 54:579-588.

Flenniken, J. J. and A. Raymond
1986 Morphological Projectile Point Typology: Replication, Experimentation, and Technological Analysis. *American Antiquity* 51:603-614.

Friis-Hansen, J.
1990 Mesolithic cutting arrows: functional analysis of

arrows used in the hunting of large game. *Antiquity* 64:494-504.

Frison, G. C.
1989 Experimental Use of Clovis Weaponry and Tools on African Elephants. *American Antiquity* 54:766-784.
1991 *Prehistoric Hunters of the High Plains*. 2nd edition. Academic Press, New York.

Frison, G. C. (editor)
1974 *The Casper Site: A Hell Gap Bison Kill on the High Plains*. Academic Press, New York.

Frison, G. C. and R. Bonnichsen
1996 The Pleistocene-Holocene Transition on the Plains and Rocky Mountains of North America. In *Humans at the End of the Ice Age*, edited by L. G. Straus, B. V. Eriksen, J. M. Erlandson, and D. R. Yesner, pp. 303-315. Plenum Press, New York.

Frison, G. C. and D. J. Stanford
1982 *The Agate Basin Site: A Record of the Paleoindian Occupation of the Northwestern High Plains*. Academic Press, New York.

Goodyear, A. C.
1974 *The Brand Site: A Techno-Functional Study of a Dalton Site in Northeast Arkansas*. Research Series No. 7. Arkansas Archeological Survey, Fayetteville.
1979 *A hypothesis for the use of cryptocrystalline raw materials among Paleo-indian groups of North America*. Research Manuscript Series 156:1-15. Institute of Archaeology and Anthropology, University of South Carolina, Columbia.

Gramly, R. M.
1982 *The Vail Site: a paleo-indian encampment in Maine*. Buffalo Museum of Science, Buffalo.

Haynes, C. V.
1980 The Clovis culture. *Canadian Journal of Anthropology* 1:115-121.

Hester, T.
1976 Late Pleistocene Aboriginal Adaptations in Texas. In *Papers on Paleo-Indian Archaeology in Texas: I*, edited by T. Hester, pp. 1-14. Special Report, No. 3. Center for Archaeological Research, The University of Texas at San Antonio.

Hill, M. E.
2005 A moveable (and non-moveable) feast: variations in use of faunal resources among central and western North American Paleoindian sites. Paper presented at the 70th Annual Meeting of the Society of American Archaeology, Salt Lake City, Utah.

Hoffman, C. M.
1985 Projectile Point Maintenance and Typology: Assessment with Factor Analysis and Canonical Correlation. In *For Concordance in Archaeological Analysis: Bridging Data Structure, Quantitative Technique, and Theory*, edited by C. Carr, pp. 566-612. Westport Press, Kansas City.

Hofman, J. L.
1989 Prehistoric culture history: hunters and gatherers in the southern Great Plains. In *From Clovis to Comanchero: Archeological Overview of the Southern Great Plains*, edited by J. L. Hofman, pp. 25-60. Research Series No. 35. Arkansas Archeological Survey, Fayetteville.
1999 Unbounded hunters: Folsom bison hunting on the Southern Plains circa 10 500 BP, the lithic evidence. In *Le Bison: Gibier et Moyen de Subsistance des Hommes du Paleolithique aux Paleoindiens des Grandes Plaines*, edited by J. Jaubert, J. Brugal, F. David, and J. Enloe, pp. 383-415. Editions APDCA, Antibes, France.

Hofman, J. L. and M. A. Graham
1998 The Paleo-Indian Cultures of the Great Plains. In *Archaeology of the Great Plains*, edited by W. R. Wood, pp. 87-135. University of Kansas Press, Lawrence.

Holliday, V. T.
1997 *Paleoindian Geoarchaeology of the Southern High Plains*. University of Texas Press, Austin.
2000 The Evolution of Geochronology and Typology on the Great Plains. *Geoarchaeology* 15:227-290.

Holliday, V. T., E. Johnson, and J. Thomas W. Stafford
1999 AMS Radiocarbon Dating of the Type Plainview and Firstview (Paleoindian) Assemblages: The Agony and the Ecstasy. *American Antiquity* 64(3):444-454.

Irwin, H. and H. M. Wormington
1970 Paleoindian tool types in the Great Plains. *American Antiquity* 35:24-34.

Johnson, E. and V. T. Holliday
1981 Late Paleo-Indian Activity at the Lubbock Lake Site. *Plains Anthropologist* 26:173-193.

Judge, W. J.
1973 *Paleoindian Occupation of the Central Rio Grande Valley in New Mexico*. University of New Mexico Press, Albuquerque.

Kay, M.
1998 Scratchin' the Surface: Stone Artifact Microwear Evaluation. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas, Volume III*, edited by M. B. Collins, pp. 743-794. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Report No. 10, Archeology Studies Program, Texas Department of Transportation, En-

vironmental Affairs Division, Austin.

Keeley, L. H.
1982 Hafting and Retooling: Effects on the Archaeological Record. *American Antiquity* 47:798-809.

Kelly, R. L. and L. Todd
1988 Coming into the country: early Paleoindian hunting and mobility. *American Antiquity* 53:231-244.

Kelly, T. C.
1982 Criteria for Classification of Plainview and Golondrina Projectile Points. *La Tierra* 9(3):2-25.
1983 The Barber Paleo-Indian Point. *La Tierra* 10(4):10-25.

Kerr, A. C.
2000 Systematic Analysis of Unfluted Lanceolate Projectile Points. Master's Thesis, Department of Anthropology, The University of Texas at Austin.

Kerr, A. C. and S. W. Dial
1998 Statistical Analysis of Unfluted Lanceolate and Early Bifurcate Stem Projectile Points. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas, Volume II*, edited by M. B. Collins, pp. 447-505. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Report No.10, Archeology Studies Program, Texas Department of Transportation, Environmental Affairs Division, Austin.

Lipo, C. P., M. E. Madsen, R. C. Dunnell, and T. Hunt
1997 Population Structure, Cultural Transmission, and Frequency Seriation. *Journal of Anthropological Archaeology* 16:301-333.

Lipo, C. P., M. O'Brien, M. Collard, and S. J. Shennan
2006 Cultural Phylogenies and Explanation: Why Historical Methods Matter. In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, edited by C. P. Lipo, M. O'Brien, M. Collard, and S. J. Shennan, pp. 3-18. Aldine Transaction, New Brunswick.

Meltzer, D. J.
2002 What Do You Do When No One's Been There Before? Thoughts on the Exploration and Colonization of New Lands. In *The First Americans: The Pleistocene Colonization of the New World*, edited by N. G. Jablonski, pp. 27-58. Memoir No. 27. California Academy of Sciences, San Francisco.

Morse, D., D. G. Anderson, and A. C. Goodyear
1996 The Pleistocene-Holocene Transition in the Eastern United States. In *Humans at the End of the Ice Age: The Archaeology of the Pleistocene-Holocene Transition*, edited by L. G. Straus, B. V. Eriksen, J. M. Erlandson, and D. R. Yesner, pp. 319-337. Plenum Press, New York.

Nieman, F.
1995 Stylistic Variation in Evolutionary Perspective: Inferences from Decorative Diversity and Interassemblage Distance in Illinois Woodland Ceramic Assemblages. *American Antiquity* 59:7-36.

O'Brien, M. J. and T. D. Holland
1990 Variation, Selection, and the Archaeological Record. In *Archaeological Method and Theory,* Vol. 2, edited by M. B. Schiffer, pp. 31-79. University of Arizona Press, Tucson.

Odell, G. H. and F. Cowan
1986 Experiments with Spears and Arrows on Animal Targets. *Journal of Field Archaeology* 13:195-212.

Schiffer, M. B. and J. M. Skibo
1997 The Explanation of Artifact Variability. *American Antiquity* 62:27-50.

Sellards, E. H.
1952 *Early Man in America: A Study in Prehistory.* University of Texas Press, Austin.

Sellet, F.
2001 A Changing Perspective on Paleoindian Chronology and Typology: A View from the Northern Plains. *Arctic Anthropology* 38:64-80.

Shott, M. J.
2002 Weibull estimation on use life distribution in experimental spear-point data. *Lithic Technology* 27:93-109.

Sokal, R. R. and F. J. Rohlf
1995 *Biometry.* 3rd edition. W. H. Freeman and Company, New York.

Stanford, D. J.
1999 Paleoindian Archaeology and Late Pleistocene Environments in the Plains and Southwestern United States. In *Ice Age People of North America: Environments, Origins, and Adaptations*, edited by R. Bonnichsen and K. L. Turnmire, pp. 281-339. Oregon State University Press, Corvallis.

Taylor-Montoya, J.
2006 Late Paleoindian Occupation of the Gault Site, Central Texas: The Lithic Evidence from the 1991, 1998-2000 Investigations. *Current Research in the Pleistocene* 23:149-150.

Titmus, G. L. and J. C. Woods
1986 An Experimental Study of Projectile Points. *Journal of California and Great Basin Anthropology* 8(1):37-49.
1991a A Closer Look at Margin "Grinding" on Folsom and Clovis Points. *Journal of California and Great Basin Anthropology* 13:194-203.
1991b Fluted Points from the Snake River Plain. In *Clovis:*

origins and adaptations, edited by R. Bonnichsen and K. Turnmire, pp. 119-131. Center for the Study of the First Americans, Oregon State University, Corvallis.

Torrence, R.
1986 *Production and Exchange of Stone Tools: Prehistoric Obsidian in the Aegean*. Cambridge University Press, Cambridge.

Towner, R. H. and M. Warburton
1990 Projectile Point Rejuvenation: A Technological Analysis. *Journal of Field Archaeology* 17:311-321.

Van Pool, T.
2001 Style, Function, and Variation: Identifying the Evolutionary Importance of Traits in the Archaeological Record. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 119-140. Bergin & Garvey, Westport, Connecticut.

2003 Explaining Changes in Projectile Point Morphology: A Case Study from Ventana Cave, Arizona. Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

Wilhelmsen, K. H.
2001 Building the Framework for an Evolutionary Explanation of Projectile Point Variation: An Example from the Central Mississippi River Valley. In *Posing Questions for a Scientific Archaeology*, edited by T. L. Hunt, C. P. Lipo, and S. L. Sterling, pp. 97-144. Bergin & Garvey, Westport.

Witthoft, J.
1952 A Paleo-Indian Site in Eastern Pennsylvania: An Early Hunting Culture. *Proceedings of the American Philosophical Society* 96:465-495.

Wormington, H. M.
1957 *Ancient Man in North America*. Popular Series No. 4. Denver Museum of Natural History.

Zeanah, D. W. and R. G. Elston
2001 Testing a Simple Hypothesis Concerning the Resilience of Dart Point Styles to Hafting Element Repair. *Journal of California and Great Basin Anthropology* 23:93-124.

Assessment of Botanical and Faunal Assemblages from Paleoindian and Early Archaic Components on the Periphery of the Southern Plains

Phil Dering

ABSTRACT

This study compares faunal and botanical assemblages from Early Paleoindian, Late Paleoindian, and Early Archaic components located on the southern periphery of the Great Plains. The region is located between 28 and 34 degrees latitude, stretching from the Eastern Woodlands to the Chihuahuan Desert and the Rocky Mountains. Along this ecological gradient, the annual rainfall ranges from near 100 cm in the east to 20 cm in the west, thereby providing a sliding scale of productivity along which to compare the prehistoric economies represented by these early components. I use plant and animal assemblages as a proxy by which to examine spatial and temporal economic changes between the Early Paleoindian and Early Archaic periods. The most daunting obstacle facing the archeologist describing and comparing organic remains from early components, hence assessing the economy of early components, is the poor preservation, or unevenly preserved nature, of the remains. In the current study, the diet-breadth model is offered as one means of accomplishing this task.

INTRODUCTION

One of the defining characteristics of Early Paleoindian deposits is the presence of extinct megafauna together with human artifacts. Clovis artifacts were first discovered at sites located in the Great Plains, in contexts with extinct bison and mammoth remains. The close association of certain organic remains and stone artifacts guided early interpretations of the Clovis and Folsom cultures as singular hunters of large game (cf. Roberts 1935; Wormington 1957). Research over the last 20 years has expanded on this simplified view of Paleoindian economy, and recent descriptions have emphasized the diversity of game in the diet, and, indeed, the utilization of plant foods (Bousman et al. 2004). As a result, the Clovis economy has since been described as a generalized foraging adaptation (Ferring 1989; Meltzer and Smith 1986; Stanford et al. 1995). Collins (1998a:62), for example, has characterized Clovis as "generalized hunter-gatherers with the technology to hunt big game, but without the need to rely exclusively on it." In contrast, archeologists tend to portray the Late Paleoindian as an "Archaic-like" adaptation (e.g., Collins 1998a:63). Others have described the Wilson component of the Late Paleoindian period at the Wilson-Leonard site as an economy based on at least a wide range of animals and possibly a wide range of plants (Bousman et al. 2002:988). Toward the end of the Late Paleoindian period, the Golondrina component at one site in southwestern Texas has provided evidence leading archeologists to assert that the deposits were left by generalized foragers that emphasized plant foods (Hester 1980:142). These statements, formulated as part of much broader studies, are quite meaningful within the restricted context of those studies. Yet taken alone, they tend to beg the question, "exactly how did the economy change between the Paleoindian and Archaic periods?" If at the dawn of the Paleoindian period the Clovis culture made a living as a generalized forager, and at its end, the Late Paleoindian cultures were generalized hunter-gatherers, what was it about the economy that changed, and how did it change? One approach to answering such questions is to examine in detail the faunal and botanical remains recovered from these components, and to deal with the good, bad, and ugly aspects of such data.

Although the myth of Paleoindians as big game hunters has been unraveling for over two decades, few comprehensive syntheses of Paleoindian plant and animal assemblages have been conducted. A recent continent-wide synthesis of plant and animal remains recovered from Clovis sites has documented the presence of 352 animal and plant taxa (Hemmings 2004). That study, which includes only Clovis sites, tackles the issue of Early Paleoindian economy and provides a useful baseline for the understanding of economic change during the Late Pleistocene/Early Holocene. In the study, Hemmings (2004:7) points out, "... the differences between Clovis and later Paleoindian and Early Archaic groups are not limited to stone projectile points."

Yet these differences remain to be described in detail. The goal of this article is to examine what happened after Clovis by selecting reasonably well-dated components with faunal assemblages and/or botanical assemblages with a view to fleshing out some of the changes that occurred during the transition from a Paleoindian to Archaic economy for this corner of the continent. To do this, I will present a detailed description of the assemblages from select components, so that at the very least the interested researcher may be able to mine this article for information and sources. Secondly, I hope to demonstrate that the diet-breadth model provides a useful framework for the comparison of organic assemblages that vary drastically in both quantity and quality. Finally, I hope to provide a sketch of the nature of economic change during the Early Holocene as it occurred from east to west along the southern edge of the Plains.

THE RECORD OF PALEOINDIAN AND EARLY ARCHAIC SUBSISTENCE

Organic remains from Paleoindian, Late Paleoindian, and Early Archaic sites provide evidence for the economic transition that occurred during these dynamic times. I have selected five sites containing Paleoindian or Late Paleoindian and Early Archaic components, three from the western and two from the eastern periphery of the Edwards Plateau (Figure 1). Ages of these components are compared in Figure 2. These sites contain Paleoindian and Early Archaic components for which there are both animal and plant remains. Faunal assemblages appear in Tables 1 and 2, and the macrobotanical assemblages in Table 3.

Wilson-Leonard (41WM235) is located on the northeast edge of the Edwards Plateau in the Lampasas Cut Plain on Brushy Creek (see Figure 1; Collins and Mear 1998:5). The site is enclosed within 6 m of fluvial deposits from Brushy Creek. There has been some colluvial deposition and little erosion. As a result, the deposits are unusually well-stratified, and there are three discrete Paleoindian components: Early Paleoindian (11,500-10,000 B.P.), Late Paleoindian with stemmed Wilson points (10,000-9500 B.P.), and Late Paleoindian with lanceolate points (9500-8250 B.P.) (see Figure 2).

Faunal remains from the Early Paleoindian component were recovered from a bone bed that predates 11,200 B.P. It contained bison, pronghorn/deer, horse, rabbit and hare, and other small game. The bone bed elements did not exhibit evidence of cultural modification, but they were recovered in context with stone tools, including a projectile point and several bifaces (Collins 1998b:147). Further, 11.5 percent of the bone from the 1/4-inch screen was burned, as was 45.3 percent of the bone from the 1/8-inch screen (Baker 1998:1506).

The Late Paleoindian Wilson component contains a broad range of animal resource taxa, including bison, pronghorn/deer, rabbit/hare, turtles, snakes/lizards, and birds. The artifacts and faunal remains in the Wilson component are somewhat characteristic of the Archaic period, including corner-notched dart points (Wilson points), hafted end scrapers, grinding stones, and small stone-lined hearths (Bousman et al. 2002:983; Collins 1998c:279). In the latest Paleoindian component (9500-8250 B.P), there is a rise in the number of medium and small game relative to bison and deer (Bousman et al. 2002:987). By the Early Archaic bison drops out of the assemblage and other taxa include pronghorn/deer, medium-sized mammals, and small game including lizards, snakes, and birds. Although bison drops out of the Early Archaic component at Wilson-Leonard, small game resources were a part of the subsistence system much earlier, by the onset of the Holocene (Baker 1998:1509).

Edible plant parts were not recovered from the Early Paleoindian deposits at Wilson-Leonard, and plant material from the Late Paleoindian component is represented only by walnut fragments, directly dated to 9750 ± 60 B.P. This is the earliest direct date for plant resources in south-central North America (Bousman 1998:163).

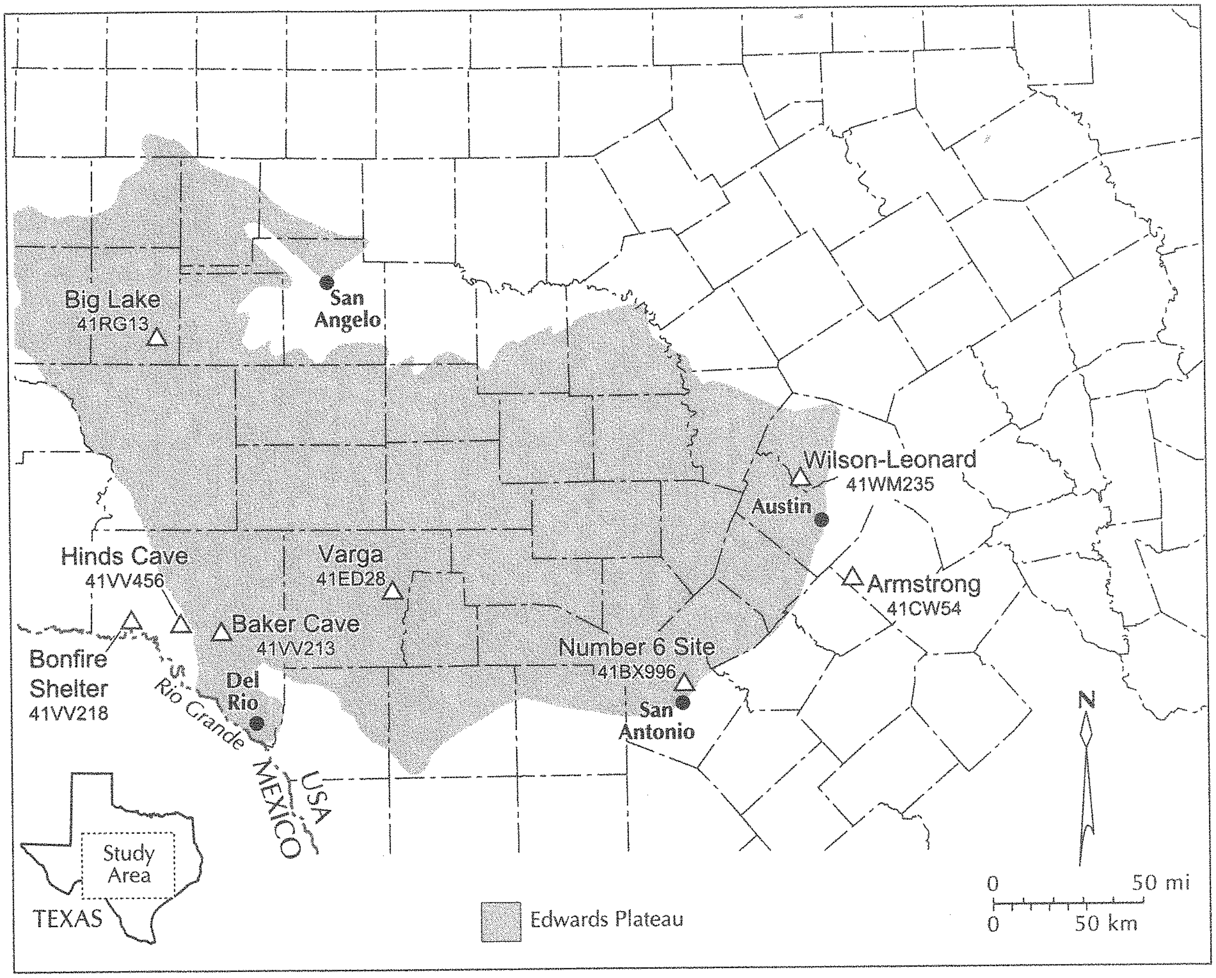

Figure 1. Location of sites discussed in the text.

The most archeologically visible development in the Early Archaic levels of Wilson-Leonard is the appearance of large fire-cracked rock features, represented by the heating element of Feature 181, which contained the charred remains of bulbs, identified as eastern camas, point-collected from the heating element (Dering 1998:1630). Nine AMS assays were obtained on these bulbs, and they yielded ages that clustered tightly around 8000 B.P., namely from 7890 ± 70 B.P. to 8130 ± 70 B.P. (Stafford 1998:1054). The heating element of Feature 181 underlies a large concentration of discarded fire-cracked rock that accumulated from the use of numerous earth ovens over the next several centuries. Feature 8, described as a large burned rock accumulation, also yielded a camas bulb with a direct date of 8250 ± 80 B.P. At least three separate rock-defined basins were described within this burned rock accumulation (Guy 1998:1111). Walnut was the only other plant material identified from Early Archaic levels, as plant preservation was very poor beyond the limits of the rock heating elements at this site.

The authors of the Wilson-Leonard report considered both Paleoindian and Early Archaic subsistence and technology at Wilson-Leonard to be focused on a broad suite of animal resources and most likely plant resources perhaps by 10,000 B.P. The Wilson component, marked by early stemmed projectile points, has a stone tool technology resembling the Early Archaic of eastern North America and subsistence was broadly based on small to large game (Collins 1998c:281). Bousman et al. (2002:988) note that the Wilson component predates comparable assemblages in eastern North America by 1250 years, suggesting that along the southern periphery of the Plains, technological and subsistence changes occurred considerably earlier than in areas to the east and north. A slightly later component with lanceolate points dates from 9500-8250 B.P., and contains a wide range of small game

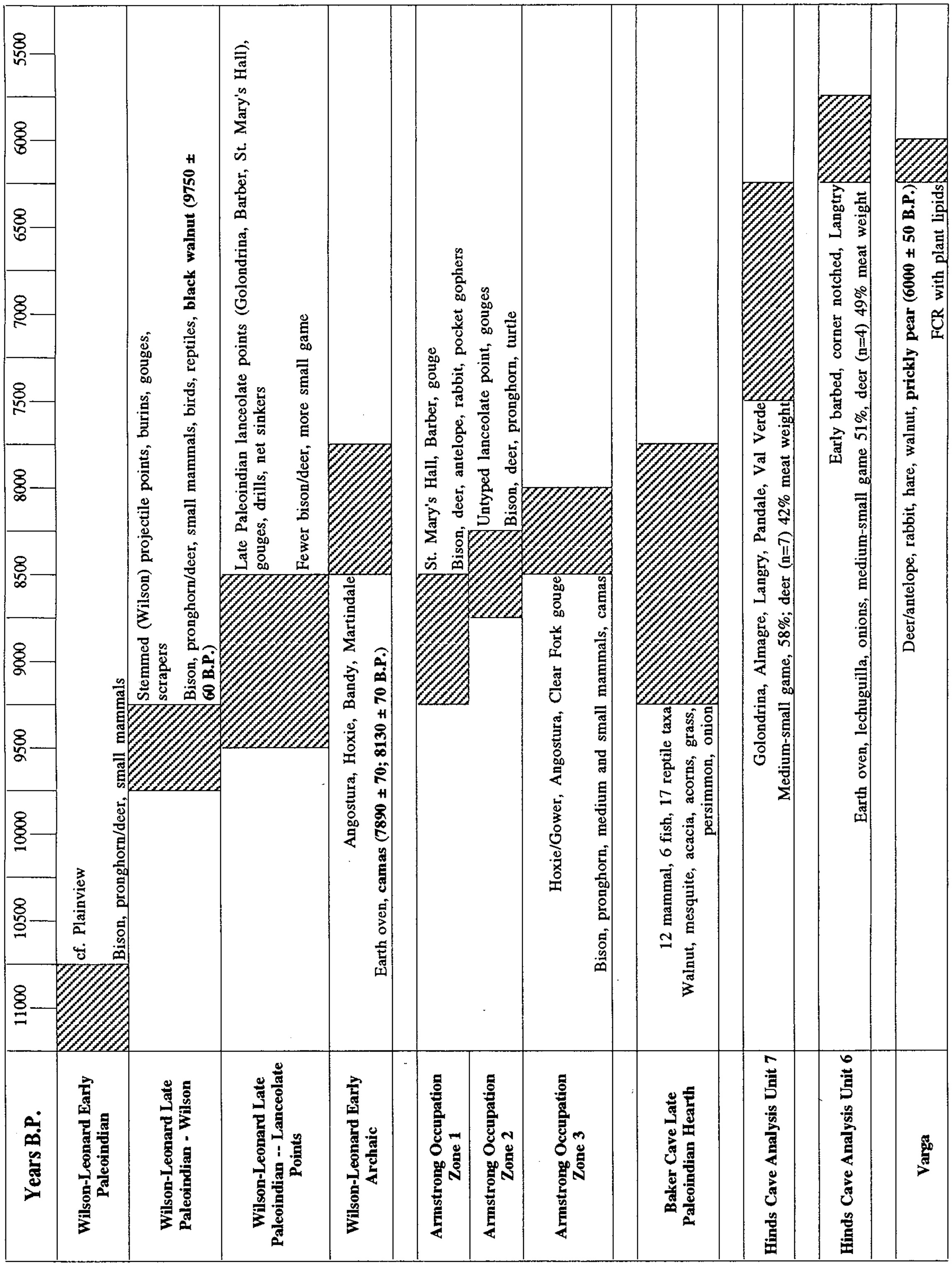

Figure 2. Ages of components with analyzed plant and animal assemblages. Direct dates on plant resources are given in bold.

Table 1. Osteofaunal remains from Paleoindian and Early Archaic contexts (NISP), open sites.

Site	Component (B.P.)	Ancient bison	American bison	Bison/bison-sized	Artiodactyl	Pronghorn/deer	Pronghorn antelope	Deer	Horse	Carnivore/canid	Indeterminate	Jackrabbit	Cottontail	Leporidae (hares & rabbits)	Rodent	Woodrat	Ground squirrel	Gopher	Plains pocket gopher	Muskrat	Shrew	Indeterminate mammal	Small mammal	Small/medium mammal	Medium mammal	Medium-large mammal	Large mammal	Fish	Turtle	Lizard/Snake	Bird	Large bird
41WM235 Wilson-Leonard	Early Paleoindian bonebed (11500-10000)	32	--	19	6	--	--	--	1	--	1379	1	2	26	--	--	--	--	--	--	--	--	2	--	2	186	17	--	5	--	--	--
41WM235 Wilson-Leonard	Late Paleoindian Stemmed Points (10000-9500)	--	--	7	8	20	--	6	--	10	8181	16	33	59	16	3	1	6	--	--	2	1	95	7	47	745	41	85	46	27	2	2
41WM235 Wilson-Leonard	Late Paleoindian Lanceolate Points (9500-8250)	--	--	5	1	10	--	--	--	4	1177	--	--	12	--	--	--	--	--	--	--	--	2	1	14	288	24	--	3	--	1	--
41WM235 Wilson-Leonard	Early Archaic (8250–7500)	--	--	--	4	14	--	3	--	3	8	19	35	4	2	--	1	12	--	--	--	--	53	2	25	349	10	--	5	78	22	1
41CW54 Armstrong	Early Archaic (8500–8000)	7	--	9	1	12	3		--	--	--	2	--	--	7	--	--	--	2	1		114	--	--	--	--	--	--	2	--	4	--
41ED28 Varga	Early Archaic (6000)	--	--	--	--	--	--	1	--	--	--	--	--	1		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 2. Osteofaunal remains from Late Paleoindian and Early Archaic sheltered sites, Hinds Cave and Baker Cave, southwestern Edwards Plateau (X=present, no counts available).

Site	Component (B.P.)	NISP or Ubiquity	Deer	Carnivore/canid	Canis sp.	Grey fox	Ringtail	Raccoon	Jackrabbit	Cottontail	Leporidae (hares & rabbits)	Skunk	River otter	Rodent	Squirrels	Gopher	Plains Pocket Gopher	Muskrat	Porcupine	Mice	Beaver	Cotton rat	Wood rat	Indeterminate Mammal	Frogs & amphibians	Fish	Turtle	Lizard/Snake	Bird	Large bird
41VV456 Hinds Cave	Early Archaic AU 6 (6540-6760)	NISP	14	--	15	--	5	3	16	77	76	1	--	187	7	9	--	14	3	--	3	25	95	606	8	37	11	48	65	1
41VV456 Hinds Cave	Early Archaic AU 6-7 (8250)	NISP	3	--	3	--	--	--	7	10	10	--	--	13		2	--	2	--	--	--	7	11	69	1	4	2	1	3	--
41VV456 Hinds Cave	Early Archaic AU 7 (8490-6750)	NISP	76	1	146	19	9	37	207	512	430	1	1	1789	23	53	--	46	2	65	1	268	666	3992	2	62	59	210	110	7
41VV456 Hinds Cave	Early Archaic (9120-8500) AU-7-8	NISP	--	--	2	2	1	--	21	63	33	--	--	256	1	11	--	--	3	3	--	37	78	99	2	5	1	9	75	
41VV456 Hinds Cave	Early Archaic AU 8 (9120)	NISP	1	1	3	2	4	2	40	351	207	1	--	1360	8	28	--	18	--	--	--	118	434	347	8	12	--	89	83	6
41VV456 Hinds Cave, Coprolites (n=29)	Early Archaic AU 8 (8180)	Ubiquity	1%	--	--	--	--	--	1%	2%	--	--	--	2%	--	--	--	--	--	--	--	--	--	10%	--	1%	--	2%	--	--
41VV456 Hinds Cave, Coprolites (n=26)	Early Archaic (7490-6750)	Ubiquity	--	--	--	--	--	--	--	--	--	2%	--	8%	--	--	--	1%	--	--	--	1%	--	8%	--	8%	--	--	--	--
41VV456 Hinds Cave, Coprolites (n=100)	Early Archaic (6270-5940)	Ubiquity	1%	--	--	1%	--	3%	--	--	13%	--	--	55%	3%	--	--	1%	--	3%	--	13%	19%	32%	1%	13%	--	9%	12%	--
41VV213 Baker Cave, Hearth	Late Paleoindian (9180-9020)	--	--	--	--	X	--	--	X	X	--	--	--	X	X	X	--	--	--	X	--	X	X	--	--	X	X	X	--	--

Table 3. Plant remains from Paleoindian and Early Archaic cotexts (X=present, count unrecorded).

Site	Component (B.P.)		Agavaceae (Leaf and fiber)	*Dasylirion texanum* Sotol, leaf and stem	*Dasylirion texanum* Sotol, seed	*Opuntia sp.* Prickly pear, pad	*Opuntia sp.* Prickly pear, seed	Geophytes - *Allium, Camassia, etc.* (bulbs)	*Juglans* sp. Walnut Nuts	*Quercus* spp. Acorns	*Celtis pallida* Desert hackberry, seed	*Diospyros texana* Persimmon, seed	*Prosopis glandulosa* Mesquite	*Acacia* spp. Blackbrush-guajillo, seed and legumes	*Eriochloa sericea* Texas cupgrass, seed	*Sporobolus* Dropseed grass seed	Poaceae Grass Family, seed	*Chenopodium/ Amaranthus*, Cheno-am type, seed
41WM235 Wilson-Leonard (macroplant only)	Late Paleoindian (9750)	Macroplant	--	--	--	--	--	--	7	--	--	--	--	--	--	--	--	--
	Early Archaic (8000)	Macroplant	--	--	--	--	--	9	4	--	--	--	--	--	--	--	--	--
41CW54 Armstrong Site (Flotation only, n=18, vol.=90 liters)	Occupation Zone 1 (8990-8560)	Flotation Count	--	--	--	--	--	--	--	7	--	--	--	--	--	--	--	--
		Flotation Ubiquity	--	--	--	--	--	--	--	16.7%	--	--	--	--	--	--	--	--
	Occupation Zone 3 (8000-8500)	Flotation Count	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--
		Flotation Ubiquity	--	--	--	--	--	5.5%	--	--	--	--	--	--	--	--	--	--
41ED28 Varga Site (n=4, vol.=16 liters)	Early Archaic (6000)	Flotation Count	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--
		Flotation Ubiquity	--	--	--	--	25%	--	--	--	--	--	--	--	--	--	--	--
		Macroplant Count	--	--	--	--	--	--	8	--	--	--	--	--	--	--	--	--
41VV213 Baker Cave Hearth	Late Paleoindian (9175)	No counts available	-	--	--	X	X	--	X	X	X	X	X	X	--	--	X	--
41VV456 Hinds Cave Unscreened Matrix Samples (n=15, 22.5 liters)	Early Archaic (6540-6160)	Count	97	48	63	7	1962	391	598	47	138	119	198	178	57	81	--	--
		Ubiquity	100.0%	46.7%	53.3%	20.0%	100.0%	93.9%	100.0%	33.3%	66.7%	53.3%	86.7%	73.3%	20.0%	26.7%	--	--
41VV456 Hinds Cave Coprolites (n=29)	Early Archaic (8180)	Ubiquity	--	--	--	27.6%	38.0%	55.2%	--	--	--	10.3%	--	--	--	6.9%	10.3%	--
41VV456 Hinds Cave Coprolites (n=26)	Early Archaic (7490-6750)	Ubiquity	--	--	--	7.7%	84.6%	57.7%	7.7%	--	--	30.8%	7.7%	--	--	42.3%	26.9%	7.7%
41VV456 Hinds Cave Coprolites (n=100)	Early Archaic (6270-5940)	Ubiquity	51.0%	--	--	70.0%	74.0%	40.0%	23.0%	--	--	14.0%	13.0%	--	--	42.0%	12.0%	4.0%

as well as bison, but no edible plant parts were recovered from these levels. The full expression of the Early Archaic is marked by the widespread use of large earth ovens with rock heating elements for cooking plant bulbs, 10 of which were directly dated to between 7890 ± 60 B.P. and 8130 ± 70 B.P., at Wilson-Leonard (Collins 1998c:282; Stafford 1998:1054).

Because the shift from Paleoindian to Archaic spans 2500 years, regional differences in Early Holocene economies characterized by technological and subsistence diversity may have developed much earlier than previously understood (Bousman et al. 2002:989; Collins 1998c:279). Indeed, many have noted regional variation in Early Paleoindian subsistence and adaptation throughout North America (Hemmings 2004; Meltzer 1988; Bever 2006), even though the stone tool technology was relatively consistent continent-wide. It may be expected that as our sample grows, so will our perception of economic variability. Diversity should increase in later Paleoindian components.

The Armstrong site (41CW54) is located east of the Edwards Plateau escarpment at the edge of the Blackland Prairie (Schroeder and Oksanen 2002). Bone preservation was poor and the number of specimens is quite low. A Late Paleoindian component defined in Occupation Zone 1 yielded dates on wood charcoal of 8990 ± 60 B.P. and 8560 ± 40 B.P. Shortly thereafter, activity in Occupation Zone 2 probably occurred after 8560 ± 40 B.P. and before 8490 ± 40 B.P. (Schroeder and Oksanen 2002:40; Schroeder 2002:11). Projectile points included the lanceolate types Golondrina, St. Mary's Hall, and Barber. This earlier component contained several animal resources, ranging from bison to pocket gophers (Schroeder and Oksanen 2002:50-51). Another component, Occupation Zone 3, is argued to occur between 8000-8500 B.P. (Schroeder 2002:31). Time-sensitive artifacts included a Hoxie/Gower point, an Angostura point, and a Clear Fork gouge. Faunal material from this context reflected a broad range of resources comprised of bison, pronghorn, and medium and small mammals (see Figure 2 and Table 1).

Recovery of plant materials from the Armstrong site was poor. However, acorn fragments were recovered from Feature 8, which consisted of two burned rock clusters and a scatter of burned rocks and caliche located in the earlier Occupation Zone 1. Feature 8 was considered to be an open roasting pit or boiling stone facility on which meat was prepared. Two lily family bulb fragments, probably eastern camas, were recovered from Feature 2, an area covering approximately 1 m in diameter and which was composed of three burned rock concentrations and burned caliche in Occupation Zone 3 (6780 B.P.) (Schroeder 2002:23).

On the western Edwards Plateau there are three sites containing Late Paleoindian or Early Archaic components from which both faunal and plant materials have been analyzed. The Varga site (41ED28) is an open residential campsite located on the southern edge of the Edwards Plateau near the head of the Frio River (see Figure 1). The other two sites are rockshelters located on the southwestern edge of the plateau.

The Early Archaic component from the Varga site dates to 6000 ± 50 B.P. (see Figure 2). The faunal assemblage in the Early Archaic component is limited to one deer/antelope bone, a few rabbit/hare bones, and mussel shell (Quigg et al. 2005). The lack of faunal bone may be directly tied to preservation bias, but the recovery of deer/antelope and rabbit suggest that if bison were present, some bison bone would have been present in the assemblage (see Table 1; Quigg et al. 2005). The plant remains from the Early Archaic levels at the Varga site were prickly pear seeds and walnut pericarp fragments (Quigg et al. 2005). A 6000 ± 50 B.P. date was obtained on a prickly pear seed from this context. Heat-altered rock from the Early Archaic component was analyzed for lipid residues and found to contain moderate to high quantities of plant-derived lipids, probably an indication of walnut processing, but no lipids from animal sources (Quigg et al. 2005).

At the southwestern edge of the Edwards Plateau, Baker Cave (41VV213) is situated in the Devils River canyon system, and Hinds Cave (41VV456) is located 50 km to the west in the Pecos River canyon system (see Figure 1). As sheltered sites, they represent rare archeological elements with unusually good preservation of subsistence remains. They contain deep midden deposits consisting of desiccated plant material, faunal remains, burned rock, ash, charcoal, artifacts and several imbedded feature types including hearths, earth ovens, sleeping mats, burials, and caches.

There has been limited analysis of the early deposits in Baker Cave, but studies have been conducted on material from a deeply buried hearth with two radiocarbon dates on charcoal at 9180 ± 220 B.P. and 9020 ± 150 B.P. This feature was capped with burned rock, and may be a trash-filled pit formerly used as a hearth (Bousman et al. 2004:50, 83). It was lined with oxidized soil and contained an extraordinary range of resources, including small and medium-sized game (no deer), 12 mammal taxa, six fish taxa, and 17 species of reptiles, most of which are burned. This feature also contained 14 edible plant taxa including little walnut pericarps, prickly pear seed, mesquite pod fragments, guajillo (an acacia) seeds, acorns, and grass seed (see Tables 2 and 3). Missing, perhaps significantly, from the feature were onion bulbs and Agavaceae fragments. Thus, the single Late Paleoindian example from Baker Cave yielded an assemblage of 59 plant and animal taxa, evidence for a broad resource base (Hester 1980:140-141).

The stratigraphy at Hinds Cave has been assigned to analysis units (AU) supported by 29 radiocarbon dates (Lord 1984:30). These dates, however, were run before it was common practice to correct them for isotopic fractionation. Except where noted, the following dates have been corrected using a δ^{13}C value of -25 ‰ by Black (2005) on the assumption that they were run on wood charcoal. Shafer (personal communication 2007) has confirmed that the assays from Hinds Cave, unless noted, were run on wood charcoal. All of the woody plants growing in the area use the C_3 photosynthetic pathway, so it is likely that Black's assumed δ^{13}C value of -25 ‰ is reasonably accurate. The earliest levels from Hinds Cave with accepted radiocarbon dates are designated AU-7 and bracket the period between 8490 ± 130 B.P. and 6750 ± 100 B.P. Although it is possible that the lowest levels of AU-7 are contemporaneous with the hearth from Baker Cave, it is more likely that most of the material represents occupation after 8500 B.P. Dart points from AU-7 include one Golondrina and an untyped lanceolate point, and 44 other points (one Almagre, one Langtry, two Pandale, seven Val Verde points, 14 Baker points, and 19 untyped), which are indicative of an Early to Middle Archaic occupation.

Faunal remains from AU-7 encompass a wide range of animal resources from deer to mice, birds, reptiles, and fish (see Table 2). As noted by Lord (1984), totals for the number of identifiable specimens (NISP) were highest in the AU-7 deposits. Rodents, hares, and rabbits accounted for the highest number of specimens. However, medium to small game accounted for 58 percent of the calculated meat weight and deer, represented by at least 7 individuals over this 1500-year period, accounted for 42 percent of the total meat weight (Lord 1984:248-249).

The earliest Hinds Cave coprolites were recovered in association with a radiocarbon date of 8180 ± 110 B.P. They contained a wide range of animal resources including deer, cottontail, jackrabbit, rodents, and snakes. Plant resources included onions, identified in 55 percent of the coprolites, and prickly pear, noted in over 40 percent of the coprolites (see Table 3). A slightly younger group of coprolites recovered from a level bracketed by dates of 7490 ± 100 B.P. and 6750 ± 100 B.P. contained muskrat, skunk, rodents, and fish bones. Prickly pear also was noted in over 80 percent and grass seed was recovered from over 40 percent of these coprolites (Stock 1983).

Excavations in Hinds Cave uncovered a large burned rock midden as part of the AU-6 archeological deposits, bracketed by dates ranging from 6540 ± 70 B.P. to 6160 ± 80 B.P. The faunal assemblage includes small, medium, and large mammals from virtually every taxonomic group in the region, except bison. Medium and small game comprised approximately 51 percent of the estimated meat weight calculated from the remains, and deer, represented by at least four individuals, totaled 49 percent of the total meat weight (Lord 1984:254).

Botanical analysis of unscreened samples associated with the earth oven feature identified over 40 plant taxa, including prickly pear seeds and pads, sotol, lechuguilla, onion, mesquite pods/seeds, little walnut, and dropseed. Only the most abundant resources appear in Table 4. *Agave lechuguilla*, sotol, and prickly pear are associated with earth oven cooking, and the remaining plants were mixed into the midden deposits by other plant processing activities and repeated use of the earth oven (Dering 1999).

A study conducted on 100 coprolites from Hinds Cave, dating to around 6000 B.P., noted that over 50 percent of the specimens contained agave/sotol fibers, over 74 percent contained prickly pear seeds or fibers, and 40 percent had onion bulb fragments (Williams-Dean 1978). Although the deposits from which these coprolites were recovered have been assigned to AU-5 and may be slightly later in time, Glenna Dean has recently obtained three AMS dates from coprolites drawn from the same sample: 5940 ± 80 B.P., 5920 ± 110 B.P., and 6270 ± 90 B.P. (Black 2005). One of these dates overlaps the younger dates from AU-6. Small, medium and large mammals, includ-

Table 4. Return rates for selected plant and animal resources.

Region	Common Name	Scientific Name	Resource Type	Preparation Method	Return Rate (kcal/hour)
Great Basin	Grass	Poaceae	Seeds	Mano-metate	250-385
Lower Pecos, Texas	Oak	*Quercus* sp.	Acorns	Mortar-pestle/leach	480-950
Lower Pecos, Texas	Sotol	*Dasylirion texanum*	Central stem	Earth oven	485-525
Indiana	Black walnut	*Juglans nigra*	Nut	Pound and Pick	600-800
Lower Pecos, Texas	Lechuguilla	*Agave lechuguilla*	Central stem	Earth oven	730-850
Great Basin	Tansy mustard	*Descurainia pinnata*	Seed	Mano-metate	1307
Lower Pecos, Texas	Mesquite	*Prosopis glandulosa*	Fruit	Mortar-pestle	1700- 2100
Pacific Northwest	Camas	*Camassia* spp.	Geophyte	Earth oven	2200
Lower Pecos, Texas	Onion	*Allium drummondii*	Geophyte	Earth oven	2200-2750
Lower Pecos, Texas	Prickly pear	*Opuntia lindheimeri*	Fruit	Mortar-pestle	2700-3500
Great Basin	Cattail	*Typha latifolia*	Pollen	Collect	2750-9360
Lower Pecos, Texas	Cottontail	*Sylvilagus* sp.	Small game	Butcher	7,700-8,300
Lower Pecos, Texas	Jackrabbit	*Lepus* sp.	Small game	Butcher	11000-11160
Lower/Trans-Pecos, Texas	Deer/Antelope	*Odocoileus* sp./*Antilocapra* sp.	Medium-large game	Butcher	20000-40000
Plains	Bison	*Bison bison*	Large game	Butcher	40000

ing mice, rats, muskrat, raccoon, hares or rabbits, and grey fox, were identified in this sample. The coprolite sample also contained fish, lizards, snakes, and birds. The δ ^{13}C values for the new coprolite assays vary between -12.5 ‰ and -17.1 ‰, high enough to provide another line of evidence that the inhabitants of Hinds Cave were eating a significant quantity of Crassulacean Acid Metabolism (CAM) plants such as agave and prickly pear.

DISCUSSION

Assessment of Paleoindian/Early Archaic Subsistence Assemblages

When these five sites, together with a few less thoroughly studied components, are considered in regional context, the changes in subsistence assemblages from Paleoindian to Early Archaic times can be described. The shortcomings of this description are obvious: only five components have been adequately studied in an area that is larger than the state of Louisiana, and that spans an ecological gradient from the Blackland Prairie to the Chihuahuan Desert, and from the southern Plains to the subtropical brush land of northern Mexico. Nevertheless an interesting, but decidedly preliminary, understanding of economic change emerges.

Paleoindian

On the eastern side of the Plateau, between 11,000 and 9500 B.P., reliance on bison decreases while the importance of medium to small game increases, a trend that continues through the Late Paleoindian and into the Early Archaic period. The evidence is provided by the Early Paleoindian bone bed at the Wilson-Leonard site, which dates prior to 11,200 B.P., and contains bison and deer/antelope along with a broad range of small and medium animal resources. In the succeeding Wilson component, the relative number of identified specimens for medium and small game increases and bison-sized and large game decreases. According to Collins (1998b) and Bousman et al. (2002), the faunal and tool assemblages from Wilson-Leonard indicate that (1) even by 11,200 B.P., a broad range of animal resources were utilized, and (2) dependence on small/medium game and plant resources increases steadily throughout the Late Paleoindian period. The earliest evidence in the study area for utilization of plant resources is in the Late Paleoindian Wilson component from Wilson-Leonard, where black walnut is dated to 9750 B.P. In the Late Paleoindian Golondrina levels dating to around 8990 ± 660 B.P. early use of acorn is recorded at the Armstrong site just east of the Plateau.

The western Plateau lacks an Early Paleoindian component with analyzed plant and animal remains, but Bonfire Shelter (41VV218) is the site of a bison processing or kill locus (see Figure 1). Bone Bed 2, dated to 10,230 ± 160 B.P., contained the remains of at least 25 *Bison antiquus* within the excavated area alone (Byerly et al. 2005:625; Dibble and Lorrain 1968:33; Turpin 1991:3). The radiocarbon ages and accompanying diagnostic artifacts consisting of Plainview and Folsom points demonstrate that bison remains in Bone Bed 2 predate the analyzed deposits from Baker Cave and Hinds Cave by about 1000 years.

The next earliest subsistence record dates to the Late Paleoindian period at Baker Cave, which contains a remarkably rich record of small and medium game but no deer or bison. This contrasts with evidence from a site located on Big Lake (41RG13), about 165 km due north of Hinds Cave and Baker Cave at the northwestern edge of the Edwards Plateau. A playa lake of Pleistocene origin, Big Lake most likely provided a water source during wetter years or decades, and around 7530 ± 150 B.P. to 8130 ± 120 B.P. it was the site of a bison kill event. Excavations were limited and the faunal analysis has not been completed. However, the existence of a bison kill/processing site indicates that bison were present at the northwestern reaches of the Edwards Plateau during Late Paleoindian times (Turpin et al. 1997:125).

The record of plant use at Baker Cave, dated to 9180 ± 220 B.P. and 9020 ± 150 B.P., is roughly concurrent with the lanceolate/Golondrina/Angostura levels at Wilson-Leonard and the Armstrong site. The assemblage contains 14 plant taxa including prickly pear, acacia, little walnut, mesquite, onions, and persimmons, but notably lacks the evergreen rosettes agave and sotol. Therefore, the earliest documented plant resources on the eastern side of the study area involve the harvesting of forest mast, including walnuts and acorns. This contrasts with the western side, where prickly pear fruit, mesquite pods, acacia seed, as well as little walnut, were widely utilized.

Early Archaic

On the eastern side of the study region, the beginning of the Early Archaic period is marked by the use of earth ovens to prepare large quantities of geophytes, or bulbs. The oldest of these features dates to 8250-8000 B.P. at the Wilson-Leonard site (Collins 1998c:282). This trend continues through the Early Archaic, where the ovens and bulb remains at the Armstrong site date to about 8000 B.P. Onion, camas, and other geophytes are associated with bulk processing in earth ovens on the eastern side of the plateau.

On the western side of the plateau, current radiocarbon dates indicate that bulk processing of plant resources in earth ovens did not commence until around 6500 B.P., and the evergreen rosettes agave and sotol, not bulbs, were the resources processed in the ovens. Instead, the advent of the Early Archaic is characterized by the bulk harvesting of prickly pear fruit by about 8200 B.P. Onion bulbs also occur in coprolites at the same time period (Stock 1983), but there is no evidence that they were processed in earth ovens. Onions can be consumed without baking, but at a cost in digestible calories. Wandsnider (1997) has noted that onions contain indigestible inulin and that baking them may increase available calories by 100 percent.

Is this absence of early earth ovens a sampling problem, or is there a delay in bulk processing using earth ovens in the arid west? Figure 3 compares early dates for earth oven facilities in the study region. A date from the Baker Cave oven facility is later, with an assay of 5150 ± 70 B.P. (Brown 1991:121). At Devils Rockshelter, large accumulations of burned rock overlay the Early Archaic deposits dated to 7400 B.P., and the Early Archaic deposits lack large earth oven cooking facilities (Prewitt 1966). Agave and sotol are present at lower levels in both Hinds Cave and Baker Cave, but the fibers and leaves of both plants have a long history of technological applications extending into the Early Archaic (Andrews and Adovasio 1980:327), and earth oven elements or large burned rock concentrations have not been noted at these lower levels.

As seen, the transition to Early Archaic across the plateau is marked by temporal and spatial variation in subsistence technology. In the mesic eastern

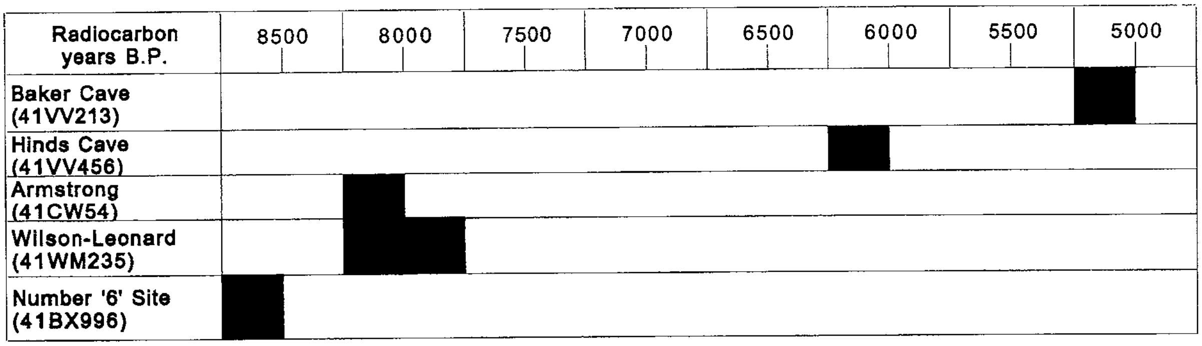

Figure 3. Early dates for earth oven features demonstrating that components in the east (Wilson-Leonard, 41BX996, and Armstrong) predate those in the west (Baker and Hinds Caves).

region, the shift to an Archaic economy is gradual and spans 2500 years; the full expression of the Early Archaic is characterized as a shift to bulk processing of geophytes in earth ovens around 8000 B.P. In the semi-arid west, a very broad range of plants and small game are utilized around 9000 B.P., and the Early Archaic diet is characterized by dependence on prickly pear and mesquite in addition to small game, qualitatively very similar to the Late Paleoindian economic pattern. In the west, the inception of the Early Archaic is actually marked by a change in projectile point styles, from the lanceolate Golondrina to Early Barbed types. Early dates from earth ovens on the western side of the study area run between 6540 ± 100 B.P. and 6160 ± 80 B.P., postdating Wilson-Leonard ovens by almost 1500 years.

Diet-Breadth Studies and the Archeological Record

Data in the current review underscore intersite variation not only in the subsistence remains, but also in the contexts from which these remains were recovered. Extreme variability in preservation and context presents a challenge for any attempt to describe the nature of subsistence changes during the two time periods in question. In this study, the diet-breadth model provides both a theoretical framework and a scale for ordering and viewing the data.

The theoretical basis for the diet-breadth model and its application to archeology has been discussed in numerous sources (Barlow 2002; Diehl and Waters 2006; Kelly 1995). The diet-breadth model is a specific type of an optimal foraging model. Simply stated, the diet-breadth model predicts (or retrodicts) whether a hunter-gatherer will take a specific resource when it is encountered. If a resource is taken, then under ideal conditions, this resource should appear in the archeological record. By applying this model, I assume that over the long-term people tend to select strategies or resources that give them the best return for their investment in time and effort. This process is termed optimization. People do not have to optimize, or utilize the best resources, but they often tend to make choices that optimize the return for their investment.

In the diet-breadth model, acquiring a resource is divided into two stages: search costs and handling costs. Search costs consider the time it takes to find a resource. Handling costs include the time required to pursue and kill game (if hunting), or the time required to harvest and process plant resources (if gathering). Handling costs are usually expressed as post-encounter return rates, or the amount of energy (kcal) gained per unit of time after finding the resource (Kelly 1995:78-79). Animal and plant resources are then ranked according to how much they cost measured against their caloric value. Because it is impossible to predict how long it takes to find a resource, especially an animal, each resource is ranked according to post-encounter return rates.

A critical requirement of diet-breadth studies is the establishment of return rates for key resources in a region. These return rates usually have to be determined by ethnographic observation, experimental studies, or a combination of both. No direct ethnographic observations have been made in the study region, but ethnographic descriptions from other areas have proved useful in designing and executing experiments. The results of several experiments have been assembled from various sources and are presented in Table 4 (Dering 1999; Diehl and Waters 2006; Simms 1987).

Repeated experiments compiled from several regions have demonstrated that resources tend to group into classes of higher or lower return rates. Therefore, the resource rankings provide a standard by which to compare plant and animal assemblages recovered from archeological sites even if the taxa are not identical. As shown in Table 4, medium and large game, including deer, antelope, and bison, provide the highest return rates. Plants, including acorns, some nuts, and cereals (grass seeds), provide the lowest return rates.

The phrase "diet-breadth" refers to the number or kinds of resources (expressed in the archeological record as numbers of taxa) that a group has to take in order to provide an adequate caloric intake. Diet-breadth should tend to narrow if sufficient quantities of higher ranked resources are acquired; that is, the group tends to focus on a few very profitable resources. As a result, some lower-ranked foods should be excluded, and the archeological record should be dominated by a few high-ranked plant and animal taxa. It follows that diet-breadth will broaden—i.e., the number of taxa in the record will increase—at times when few high-ranked resources are encountered.

The presence of high-ranked taxa in the economy does not necessarily ensure that diet-breadth is narrow. Environmental factors may cause a high-ranked resource such as bison or deer to be scarce with the consequence that pursuit remains too risky or expensive for it to be a dominant part of the economy and diet-breadth remains broad. For example, deer and/or antelope, high-ranked large game animals, are present throughout the archeological record in Hinds Cave and Baker Cave, yet subsistence studies from these sites arguably document some of the broadest diet-breadths in North America (Lord 1984; Stock 1983; Sobolik 1991; Williams-Dean 1978).

Diet-Breadth and the Paleoindian/ Early Archaic Transition

Three interesting trends can be identified by examining the assemblages within the diet-breadth model (Table 5). First, bison drops out of the faunal assemblages before Late Paleoindian times on the southwestern edge of the plateau, while it persists into the Early Archaic on the eastern side in the Blackland Prairie and probably was available on the northwestern edge of the region as well. Second, small and medium game are present in assemblages throughout the Late Paleoindian on both sides of the study area. Third, earth oven use on the mesic eastern side of the plateau appears to predate its use on the arid western side of the plateau by at least 1500 years.

Bison was present in the faunal assemblages from both Wilson-Leonard and the Armstrong site. At Wilson-Leonard, bison persisted through the Late Paleoindian period but dropped out by the Early Archaic around 8000 B.P. At the Armstrong site bison was present in both the Late Paleoindian and the Early Archaic components. By Wilson component times at 10,000-9500 B.P., the faunal remains and artifacts indicate a broad diet-breadth despite the presence of bison (Bousman et al. 2002:983). By the Early Archaic bison drops out of the assemblage and other remains include pronghorn/deer, medium-sized mammals, and small game, including lizards, snakes, and birds. Although bison drops out of the Early Archaic component at Wilson-Leonard, small game resources were a part of the subsistence system much earlier, by the onset of the Holocene.

By 8000 B.P. the use of earth ovens opens up a previously unavailable class of plant resources, namely plants that store their energy in forms that are indigestible by humans (Wandsnider 1997). This is a clear signal that people are working harder to extract more calories from the landscape, and is evidence for land-use intensification. Earth ovens require increased labor investment, and the subsequent reduction in energetic benefits is a sign that higher-ranked resources are not available in sufficient quantities to support the population. As the overall foraging return rates drop below that of the earth oven return rates, people begin to build enough earth ovens for them to become archeologically visible.

Direct evidence for earth oven use on the eastern side of the Plateau is provided by the 8250 B.P. date on a bulb from Feature 2, and 8000 B.P from Feature 181, at Wilson-Leonard. The earth ovens from the Armstrong site that date to about 8000 B.P. demonstrate the persistence of this technology through the Early Archaic. Early dates for large scale oven facilities exist both to the north and south of the region. The earlier dates at Wilson-Leonard are comparable to those from earth oven features at the Stigenwalt site in southeastern Kansas, where charred onion bulbs were recovered from a large burned rock feature (Feature 11) dated to 7410 ± 70 B.P. Feature 14, another large burned rock concentration resembling an earth oven facility but lacking charred bulbs, was dated to 8130 ± 130 B.P. (Thies 1990:109). At the southeastern edge of the Edwards Plateau, a large complex of earth

Table 5. Diet-breadth expressed as presence/absence of resource types.

Sites	Component (B.P.)	Large game (e.g., bison 40000 kcal/hr)	Medium-Large game (deer, antelope 20000-40000 kcal)	Small-Medium game (7700-12000 kcal/hr)	Prickly pear (2700-3500 kcal/hr)	Mesquite (1700 - 2100 kcal/hr)	Small agaves/sotol (485-850 kcal/hr)	Walnuts (600-800 kcal/hr)	Acorn (480-950 kcal/hr)	Small seeds (250-385 kcal/hr)	Earth Ovens (geophytes - 2200-200 kcal/hr; Agave 750 kcal/hr)
41WM235 Wilson-Leonard	Early Paleoindian - bonebed (11500-10000)	X	X	X	--	--	--	--	--	--	--
	Late Paleoindian-Stemmed Points (10000-9500)	X	X	X	--	--	--	X	--	--	--
	Late Paleoindian-Lanceolate Points (9500-8250)	X	X	X	--	--	--	--	--	--	--
	Early Archaic (8000)	--	X	X	--	--	--	X		--	X
Armstrong 41CW54 (OZ 1 & OZ 2)	Late Paleoindian/ Early Archaic (8500-7500)	X	X	X	--	--	--	--	X	--	--
41CW54 Armstrong (OZ 3)	Early Archaic (6780)	X	X	X	--	--	--	--	--	--	X
41ED28 Varga	Early Archaic (6000)	--	X	X	X	--	--	X	--	--	--
41VV213 Baker Cave Hearth	Late Paleoindian (9175)	--	X	X	X	X	--	X	X	X	--
41VV456 Hinds Cave Matrix	Early Archaic (6540-6160)	--	X	X	X		X	X	X	X	X
41VV456 Hinds Cave Coprolites	Early Archaic (8180)	--	--	X	X	--	--	--	--	X	--
	Early Archaic (6300-5660)	--	--	X	X	X	--	X	--	X	X
	Early/Middle Archaic (6270 - 5940)	X	--	--	X	X	X	X	--	X	X

oven heating elements at the Number-6 site (41BX996) yielded two dates: 8540 ± 50 B.P. and 8620 ± 90 B.P. (Black et al. 1998:30).

On the western side of the plateau, bison were absent from the taxon-rich Late Paleoindian or Early Archaic components from Baker Cave and Hinds Cave. Bison had been present in the southwestern region of the plateau during the Paleoindian period around 10,000 B.P., as evidenced by a faunal assemblage representing about 25 *Bison antiquus* in Bone Bed 2 at Bonfire Shelter (41VV218) (Byerly et al. 2005:625; Dibble and Lorrain 1968:33; Turpin 1991:3). This may indicate that diet-breadth narrowed during Folsom times, as suggested by Collins (1998a:62). Bonfire Shelter is a bison kill or processing site that has been studied with such a narrow focus that other activities that occurred at the locus have been overlooked, an often repeated approach to Early Paleoindian sites (see for example, Byerly et al. 2005; Meltzer et al.

2002). As a special activity site, Bonfire Shelter needs to be studied in the context of other sites of comparable age. We need a more comprehensive analysis of faunal and plant material from this and other Early Paleoindian sites before we can be assured that diet-breadth really narrowed during this time.

The radiocarbon ages and the accompanying artifacts consisting of Plainview and Folsom points demonstrate that bison remains in Bone Bed 2 at Bonfire Shelter predate the analyzed deposits from Baker Cave and Hinds Cave, suggesting that bison were no longer present in the southwestern plateau area by Late Paleoindian times. By the Late Paleoindian period, if not earlier, the economy on the southwestern edge of the Edwards Plateau was focused on low-return taxa, and diet-breadth was very broad (see Table 5). Evidence for large-scale (larger than 1 m in diameter) earth oven cooking facilities from the southwestern plateau occurs about 1500 years after the abundant presence of onions. Prickly pear may have provided most of the carbohydrates in the diet prior to the use of earth oven technology, and small game provided the protein. It is likely that the onions were either prepared in smaller rock-lined hearths, or were consumed as condiments and not for a primary source of carbohydrates. The use of large-scale baking facilities located along the southwestern plateau is tied to the presence of the evergreen rosettes lechuguilla, a small agave, and sotol. Both of these plants are not found in the context of earth ovens in the earliest levels at Baker Cave, the same levels which contain abundant remains of prickly pear, mesquite, acacia, and walnut. At Baker Cave charred remains of sotol leaves are present in levels dated to around 6500 B.P. and perhaps earlier, but large-scale cooking facilities do not become evident until 5000 B.P. (Brown 1991:121). Brown (1991:123) notes that the shift to earth oven cooking marks a shift to an economy of scale and argues that increasing diet-breadth and a least-risk strategy were responses to a deteriorating (e.g., drier) mid-Holocene environment. Lechuguilla and sotol are both present in Hinds Cave by 7000 B.P., but the large scale cooking facilities date to 6500 B.P.

That the utilization of prickly pear and onions predates the use of agave or sotol prepared in earth ovens can be explained at least in part by the return rates for these resources. Prickly pear fruit is easily collected and processed, and results in a good return rate for a plant resource. An oven packed with onion or camas bulbs will generate four or five times the calories of the same-sized oven packed with *Agave lechuguilla*, because agave and sotol have a high fiber content and smaller edible portions per plant. However, prickly pear and onions are seasonal resources while both agave and sotol are usually available all year (Buskirk 1986:169; Castetter et al. 1938:46). Increased emphasis on a lower-ranked resource such as agave, which is available throughout the year, may indicate a shift to a low-risk strategy necessitated by a seasonal lack of more easily processed higher return resources.

It is clear that diet-breadth was broad by Late Paleoindian times, shortly after 10,000 B.P., along the western edge of the region. The shift toward lower ranked foods occurred progressively as evidenced by heavy reliance on prickly pear, mesquite, onions, walnut, and acacia, all seasonally available resources, by 9000-8000 B.P. Around 7000-6000 B.P., the occurrence of large-scale earth oven facilities with associated agave remains signals a shift to an economy focused on lower risk, lower return resources that are available throughout the year. Current data suggest that this shift postdates the use of earth ovens on the eastern side of the plateau, perhaps because of the higher return rates of prickly pear.

CONCLUSIONS

This detailed examination of Early Holocene plant and animal assemblages from sites located on the southern Plains periphery is only a beginning step towards uncovering the layers of complexity in the economies of the region. The Clovis foragers entering the region faced extreme spatial variability and adjusted their subsistence strategies accordingly (e.g., Hemmings 2004). If, as Hemmings and others have asserted, Clovis people were generalized foragers, then Late Paleoindian groups, facing increasing competition and a changing landscape, were simply tapping into an increasingly broad range of small game and plant foods, differing from their predecessors perhaps more subtly than previously thought. But for the greater part of the Late Paleoindian period, people were not utilizing the most expensive carbohydrate sources on the landscape, those plant forms requiring earth oven technology to render edible. At the close of Late Paleoindian times, the use of earth ovens increases to the point that they become archeologically visible, first on the eastern and southeastern side of the Edwards Plateau around 8000 B.P. In this eastern area the ovens were utilized to process plants that store food in bulbs and tubers, providing a previously untapped carbohydrate source that supported, some argue, a growing population during the Archaic period (Thoms 2003). Collins et al. (1998:239) implicitly recognized this fact when they noted that the presence of earth oven facilities at Wilson-Leonard constituted the "major discontinuity" in the technology of the Early Archaic period. The steady intensification of carbohydrate sources using more expensive technology has been termed the carbohydrate revolution (Thoms 2005).

At the western, arid end of the region, the Baker Cave Late Paleoindian hearth, with dates centering around 9100 B.P., contains 59 species of plants and animals and provides evidence for a generalist forager economy that is probably slightly earlier than that inferred from the Wilson-Leonard site and other early ovens. But no evidence of massive earth oven facilities has been found in components dating to ages anywhere near 8000 B.P. In fact, the earliest ages are closer to 6000-6500 B.P.

Is this apparent 1500 year delay between the mesic eastern and arid western regions due to the small sample of early components in the west? Or is there a real delay brought on by the differences in the nature of the available resources? Desert succulents, particularly large stands of prickly pear, produce reliable crops in relatively unreliable precipitation regimes and the return rates compare favorably to oven-processed geophytes such as camas or onions. Further, oven-baked agave and other evergreen rosettes produce a much lower return rate, about one-third that of camas ovens or prickly pear (see Table 4). Earth ovens may be a means of land use intensification that opened up previously unavailable resources, but their relative productivity is entirely dependent on the local nature and availability of the plant resources. During the Early Holocene, the productivity of prickly pear in southern and southwestern Texas may have delayed the onset of earth oven processing for several centuries.

NOTES

1. Except where noted, radiocarbon assays are presented as radiocarbon years with the 1 sigma standard error range as submitted by the laboratory, corrected for isotopic fractionation.

REFERENCES CITED

Andrews, R. L. and J M. Adovasio
1980 *Perishable Industries from Hinds cave, Val Verde County, Texas*. Ethnology Monographs Number 5. Department of Anthropology, University of Pittsburgh, Pennsylvania.

Baker, B. W.
1998 Appendix 9: Faunal Taxa Descriptions. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume V: Special Studies*, assembled and edited by M. B. Collins, pp. 1686-1696. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Barlow, K. R.
2002 Predicting Maize Agriculture Among the Fremont: An Economic Comparison of Farming and Foraging in the American Southwest. *American Antiquity* 67:65-87.

Bever, M.R.
2006 Too Little, Too Late? The Radiocarbon Chronology of Alaska and the Peopling of the New World. *American Antiquity* 71(4):595-620.

Black, S. L.
2005 Hinds Cave Radiocarbon Compilation Notes. www.texasbeyondhistory.net/hinds/images/Hinds%20C14%20Assays.pdf. Accessed on January 3, 2007.

Black, S. L., J. Karbula, C. Frederick, , and C. Mear
1998 *Archeology along the Wurzbach Parkway. Module 5. Testing and Geoarcheological Evaluation at the Number-6 Site (41BX996) and Other Sites*. Studies in Archeology 29. Texas Archeological Research Laboratory, The University of Texas at Austin.

Bousman, C. B.
1998 Late Paleoindian Archeology. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 161-210. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Bousman, C. B., B. Baker, and A. Kerr
2004 Paleoindian Archeology in Texas. In *Prehistory of Texas*, edited by T. K. Perttula, pp. 15-97. Texas A&M University Press, College Station, Texas.

Bousman, C. B., M. Collins, P. Goldberg, T. Stafford, J. Guy, B. Baker, D. G. Steele, M. Kay, A. Kerr, G. Fredlund, P. Dering, V. Holliday, D. Wilson, W. Gose, S. Dial, P. Takac, R. Balinsky, M. Masson, and J. Powell

2002 The Palaeoindian-Archaic Transition in North America: New Evidence from Texas. *Antiquity* 76:980-990.

Brown, K.

1991 Prehistoric Economics at Baker Cave: A Plan for Research. In *Papers on Lower Pecos Prehistory*, edited by S. Turpin, pp. 87-140. Studies in Archeology 8. Texas Archeological Research Laboratory, The University of Texas at Austin.

Byerly, R. M., J. R. Cooper, D. J. Meltzer, M. E. Hill, and J. M. LaBelle

2005 On Bonfire Shelter (Texas) as a Paleoindian Bison Jump: An Assessment Using GIS and Zooarchaeology. *American Antiquity* 70(4):595-631.

Buskirk, W.

1986 *The Western Apache: Living with the Land Before 1950*. University of Oklahoma Press, Norman.

Castetter, E., W. Bell, and A. Grove

1938 *The Early Utilization and the Distribution of Agave In the American Southwest*. Ethnobiological Studies in the American Southwest, Vol. VI. The University of New Mexico Bulletin, Biological Series 5(4). Albuquerque, New Mexico.

Collins, M. B.

1998a Background to the Archeological Investigations. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 55-76. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

1998b Early Paleoindian Components. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 123-160. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

1998c The Place of Wilson-Leonard in Plains Prehistory. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 277-289. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Collins, M. B. and C. E. Mear

1998 The Site and its Setting. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 5-32. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Collins, M. B., J. Guy, and S. W. Dial

1998 The Archaic Period, 8800 to 1300 B.P. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume 1: Introduction, Background, and Syntheses*, assembled and edited by M. B. Collins, pp. 211-270. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Dering, P.

1998 Carbonized Plant Remains. In. *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas Volume V: Special Studies*, assembled and edited by M. B. Collins, pp. 1609–1636. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

1999 Earth-Oven Plant Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity* 64(4):659–674.

Dibble, D. and D. H. Lorrain

1968 *Bonfire Shelter: A Stratified Bison Kill site, Val Verde County, Texas*. Miscellaneous Papers No. 1. Texas Memorial Museum, The University of Texas at Austin.

Diehl, M. and J. A. Waters

2006 Aspects of Optimization and Risk during the Early Agricultural Period in Southeastern Arizona. In *Behavioral Ecology and the Transition to Agriculture*, edited by D. J. Kennett and B. Winterhalder, pp. 63-86. University of California Press, Berkeley.

Ferring, C. R.

1989 The Aubrey Clovis Site: A Paleoindian Locality in the Upper Trinity River Basin. *Current Research in the Pleistocene* 6: 9-11.

Guy, J.

1998 Analysis of Cultural and Natural Features. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume IV: Archeological Features and Technical Analyses*, assembled and edited by M. B. Collins, pp. 1067-1212. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Hemmings, C. A.

2004 The Organic Clovis. A Single Continent-Wide Cultural Adaptation. Ph.D. Dissertation, Department of Anthropology, University of Florida, Gainesville.

Hester, T. R.

1980 *Digging into South Texas Prehistory.* Corona Press, San Antonio, Texas.

Kelly, R. L.

1995 *The Foraging Spectrum.* Smithsonian Institution Press, Washington, D.C.

Lord, K.

1984 *The Zooarcheology of Hinds Cave, Val Verde County, Texas.* Hinds Cave Series. Department of Anthropology, Texas A&M University, College Station, Texas.

Meltzer, D. J.

1988 Late Pleistocene Human Adaptations in Eastern North America. *Journal of World Prehistory* 2:1-52.

Meltzer, D. J. and B. D. Smith

1986 Paleoindian and Early Archaic Subsistence Strategies in Eastern North America. In *Foraging, Collecting and Harvesting: Archaic Period Subsistence and Settlement in the Eastern Woodlands*, edited by S. W. Neusius, pp. 3-31. Occasional Paper No. 6. Center for Archaeological Investigations, Southern Illinois University, Carbondale.

Meltzer, D. J., L. C. Todd, and V. T. Holliday

2002 The Folsom (Paleoindian) Type Site: Past Investigations, Current Studies. *American Antiquity* 67(1):5-36.

Prewitt, E. R.

1966 A Preliminary Report on the Devils Rockshelter. *Texas Journal of Science* 18(2):206-224.

Quigg, J. M., J. D. Owens, G. D. Smith, and M. Cody

2005 *The Varga Site: A Multicomponent, Stratified Campsite in the Canyonlands of Edwards County, Texas.* Draft Technical Report No. 35319. TRC, Inc., Austin.

Roberts, F. H. H.

1935 *A Folsom Complex: Preliminary Report on Investigations at the Lindenmeier Site in Northern Colorado.* Smithsonian Collections 95, No. 10. Smithsonian Institution, Washington, D.C.

Schroeder, E. A.

2002 *Data Recovery at the Armstrong Site (41CW54) Caldwell County, Texas. Volume II: Cultural Interpretations.* Cultural Resources Report No. 0330. Paul Price Associates, Inc., Austin.

Schroeder, E. A. and E. R. Oksanen

2002 *Data Recovery at the Armstrong Site (41CW54) Caldwell County, Texas. Volume I: Background, Methods, and Site Contexts.* Cultural Resources Report No. 0284. Paul Price Associates, Inc., Austin.

Simms, S.

1987 *Behavioral Ecology and Hunter-Gatherer Foraging: An Example from the Great Basin.* International Series 381. British Archaeological Reports, Oxford.

Sobolik, K. D.

1991 *Prehistoric Diet and Subsistence in the Lower Pecos as Reflected in Coprolites from Baker Cave, Val Verde County, Texas.* Studies in Archeology 7. Texas Archeological Research Laboratory, The University of Texas at Austin.

Stafford, T. W.

1998 Radiocarbon Chronostratigraphy. In *Wilson-Leonard: An 11,000-Year Archeological Record of Hunter-Gatherers in Central Texas, Volume IV: Archeological Features and Technical Analyses*, assembled and edited by M. B. Collins, pp.1035-1066. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Stanford, D., M. Jodry, and L. Banks

1995 Early Paleoindian Diet Breadth as Seen from the Lewisville Site, Texas: Critter Buffet as an Alternative to Mammoth Barbeque. Abstracts of the 60th Annual Meeting of the Society of American Archaeology, Minneapolis, Minnesota.

Stock, J.

1983 *The Prehistoric Diet of Hinds Cave, Val Verde County, Texas.* Published version of Master's thesis, Department of Anthropology, Texas A&M University, College Station, Texas.

Thies, R. M.

1990 *The Archeology of the Stigenwalt Site, 14LT351.* Contract Archeology Series Publication Number 7. Kansas State Historical Society, Topeka.

Thoms, A. V.

2003 Cook-Stone Technology in North America: Evolutionary Changes in Domestic Fire Structures during the Holocene. In *Colluque et Experiment en au Neolithic aux Auges du Metaux*, edited by M.C. Frere-Sautot, pp. 87-96. Collection Prehistories N. 9. Editions Monique Mergoil, France.

2005 Ancient Savannah Roots of the Carbohydrate Revolution in South-Central North America: 9000-500 B.P. Paper presented at the 48th Annual Meeting of the Society of Economic Botany, Fort Worth, Texas, June 2005.

Turpin, S. A.

1991 Time Out of Mind: The Radiocarbon Chronology of the Lower Pecos River Region In *Papers on Lower Pecos Prehistory*, edited by S. A. Turpin, pp. 1-50. Studies in Archeology 8. Texas Archeological Research Laboratory, The University of Texas at Austin.

Turpin, S. A., L. C. Bement, and H. H. Eling, Jr.

1997 Stuck in the Muck: The Big Lake Bison Kill Site (41RG13), West Texas. *Plains Anthropologist* 42 (159), Memoir 29:119-133.

Wandsnider, L.

1997 The Roasted and the Boiled: Food Composition and Heat Treatment with Special Emphasis on Pit-Hearth Cooking. *Journal of Anthropological Research* 16:1-48.

Williams-Dean, G.

1978 Ethnobotany and Cultural Ecology of Prehistoric Man in Southwest Texas. Ph. D. dissertation, Department of Botany and Anthropology Research Laboratory, Texas A&M University, College Station, Texas.

Wormington, H. M.

1957 *Ancient Man in North America*. Denver Museum of Natural History, Denver.

The Evolution of *Bison bison*: A View from the Southern Plains

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ABSTRACT

Morphological changes in late Quaternary bison generally have been defined by a rapid decline in body size and a reorientation of the horns. This morphological shift is used to mark the emergence of modern *Bison bison*, a transition conventionally thought to have originated on the Northern Plains after 5,000 B.P. Hypotheses regarding the impact of human hunting on this morphological transition vary from negligible to the driving force behind a speciation event. New data from the Southern Plains, however, define better the transition and the role that hunting may have played in driving this event. This research on Southern Plains bison indicates that fully modern bison appear on the Southern Plains much earlier (between 8,000 to 6,500 B.P.) than on the Northern Plains and that this morphological transition also involved a decrease in relative bone strength (robusticity). The morphological transition in bison does not correlate with changes in tool technology, hunting intensity, or hunting techniques. Therefore, the impacts of human hunting do not adequately account for the observed morphological changes in bison morphology. The change in bison morphology on the Southern Plains is correlated better with the spread of the C_4 short grass ecosystem between 8,000 to 7,500 B.P. The properties of C_4 grasses explain both the size reduction and the gracilization of late Quaternary bison.

INTRODUCTION

The North American bison was a critical species for people inhabiting the Plains during the late Quaternary, serving as an important source of food and raw materials for many cultures. More broadly, however, bison impacted the lives of all Plains-dwelling peoples as the keystone species of the Plains ecosystem (Frison 1991; McHugh 1972). Any change in bison would have had a significant impact on the peoples of the Plains, and the evolutionary forces acting to change bison would have impacted all other species that were part of the Plains ecosystem, including humans. For these reasons, defining and understanding the changes in late Quaternary bison and the underlying causes for those changes are essential to the interpretation of prehistoric Plains cultures.

Hypotheses proposed to explain the morphological changes in bison following the Wisconsin glaciation constitute some of the most compelling and contentious questions surrounding the evolution of Quaternary macrofaunas (McDonald 1981; Reeves 1973). Most hypotheses implicate either climatic changes (e.g., Wilson 1975) or the effects of human hunting (e.g., Lott 2002; McDonald 1981) to explain changes in the bison lineage, and are based primarily on data from the Northern Plains. While Southern Plains bison have been studied from an archeological point of view (e.g., Bement 1999; Johnson 1987), hypotheses concerning the emergence of modern bison have yet to be explored fully in this region. New data, however, from a continuous and well-dated sequence of bison metapodials from the Lubbock Lake Landmark, supplemented with specimens from two other Southern Plains localities, allow an improved understanding of the pattern of morphological change in the late Quaternary bison lineage. These new data have led to the formulation of a new hypothesis regarding the selective force guiding these changes in bison.

Changes in the bison lineage during the terminal Pleistocene and early Holocene generally are described as a decrease in overall body size (ca. 20% reduction in linear measurements) and a reorientation of the horn cores (Dalquest and Schultz 1992; McDonald 1981; Wilson 1974a, 1975). These changes are suggested to have occurred gradually beginning in the late Pleistocene and continuing through the Holocene. Modern bison are reportedly present on the Northern Plains after ca. 5,000 B.P. (uncalibrated radiocarbon age) (McDonald 1981; Wilson 1975). Changes in horn core morphology are vague, however, due to their highly variable nature (McDonald 1981; Wilson 1975) and plasticity (Guthrie 1966), such that attempts to use horn cores in taxonomic and phylogenetic analyses find them to be of limited utility. As such, horn cores, accepted as being fully modern in morphology on the Southern Plains by 10,000 B.P. (Dalquest and Schultz 1992), are not addressed further.

Both human hunting and climatic change have been posited as the principle force behind the decrease in bison body size. Human hunting hypotheses generally suggest that hunting selected either for smaller body sizes or against larger body sizes (Lott 2002; McDonald 1981). Climatic hypotheses associate the warming temperatures of the Holocene with decreases in body size, following Bergmann's rule (Bergmann 1847) and the modern size cline (a decrease in body size from north to south) seen in today's bison (Wilson 1975). Most of the evidence given in support of these hypotheses is derived from Northern Plains populations from multiple localities, and is based principally on cranial characteristics known to be highly variable. To define better the rate and pattern of change in bison populations, a morphologically conservative element should be used and the sample broadened to include populations beyond the Northern Plains. Correlations between changing bison morphology and parameters associated with human hunting and climatic change hypotheses then can be examined. This study, therefore, focuses on Southern Plains bison metapodials to determine if the timing and pattern of change is similar to that defined on the Northern Plains and which of the competing hypotheses is best supported.

METHODS

While much of the historic research regarding bison phylogeny has relied heavily on cranial characteristics (Guthrie 1990; McDonald 1981; Skinner and Kaisan 1947; Wilson 1975; Wyckoff and Dalquest 1997), this study focuses on the metapodials. Metapodials are functionally important weight-bearing elements for bison (Bedord 1974) and, more broadly, for the family Bovidae (Scott 1985). Metapodials are conservative morphologically, showing little variation in shape across the bovids (Scott 1985). Any significant changes in metapodial morphology, therefore, likely represent a functional, behavioral, or genotypic shift in bison relevant to hypotheses about the forces that were acting to shape the bison skeleton. Metapodials also are common elements in late Quaternary faunal assemblages (Kreutzer 1992), allowing for robust statistical analyses.

Metapodial size, shape, and robusticity (relative cortical bone thickness) data were collected from osteometric and radiographic examination of a temporal series of 463 late Quaternary bison metapodials from three sites on the Southern Plains (Figure 1). Of those metapodials, 254 specimens were from Lubbock Lake (Johnson 1987) in western Texas. Dates were assigned to the Lubbock Lake specimens using multiple radiocarbon ages associated with archeological features and geologic strata (Holliday et al. 1983, 1985). In addition, 75 metapodials from Cooper (Bement 1999) and 134 from Certain (Buehler 1997), both sites located in western Oklahoma, were examined. These metapodials were dated according to radiocarbon assays and known ages of diagnostic stone tools (Bement 1999; Buehler 1997).

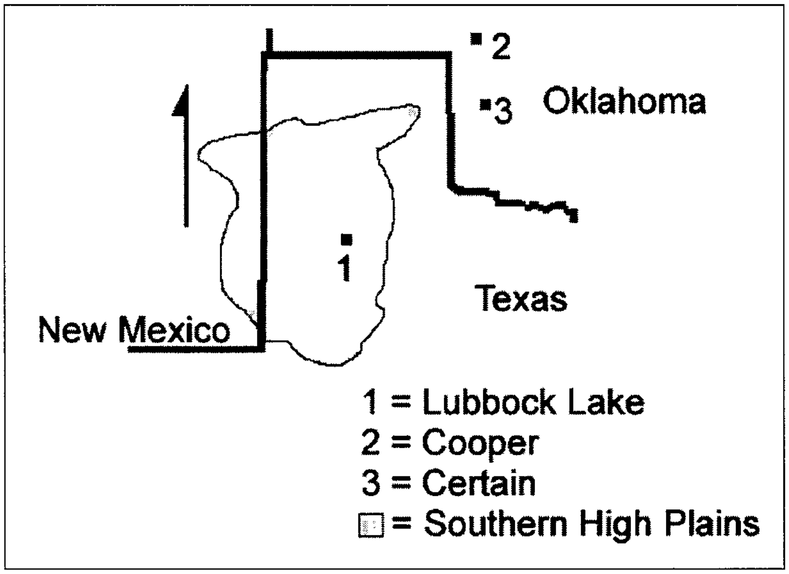

Figure 1. Southern Plains and archeological sites where the fossil bison metapodials in this analysis were recovered.

Proximal and distal anteroposterior and mediolateral width measurements were collected at the extremes on complete metapodials at the proximal and distal ends using sliding calipers. Unfused metapodials were not included in the study. Overall element length was taken at the extreme using an osteometric measuring board. Shaft diameters in the anteroposterior view and the mediolateral view also were collected from X-rays using sliding calipers. Robusticity (relative cortical bone thickness) was calculated using a published formula incorporating medullary cavity area, cortical bone thickness, and element size adjusted for estimated body mass (Trinkaus et al. 1994). Data were tested using ANOVA and Pairwise post-hoc Bonferroni/Dunn tests. A confidence level of 0.05 was set for all statistical tests.

RESULTS

Data from the Southern Plains indicate a different pattern of size change than that seen on the Northern Plains. The Southern Plains pattern is one of relative stasis in body size before 8,000 B.P. and following 6,500 B.P. (Figure 2). A rapid decrease in size occurs between 8,000 and 6,500 B.P. This pattern is found in both sexes and for both metatarsals and metacarpals. No statistically significant difference exists between the populations 8,000 years old and older, nor does a significant difference occur between those populations 6,500 years old and more recent. Pairwise tests find that the only significant difference between the bison populations is between the population dating to 8,000 B.P. and the population dating to 6,500 B.P.

A slight shift in metapodial shape appears to accompany this size decrease (Figure 3). Metapodials of similar length vary significantly by width (at the midshaft) when specimens from the group dating to 8,000 years and older are compared to specimens dating 6,500 years old and more recent (see Figure 3). A decrease in bone robusticity also is found, using a standard robusticity index adjusted for body size referred to as J/stand (Trinkaus et al. 1994). Again, this decrease in bone robusticity, or gracilization, of the metapodials occurs between 8,000 B.P. and 6,500 B.P. in concert with the change in body size and metapodial shape (Figure 4).

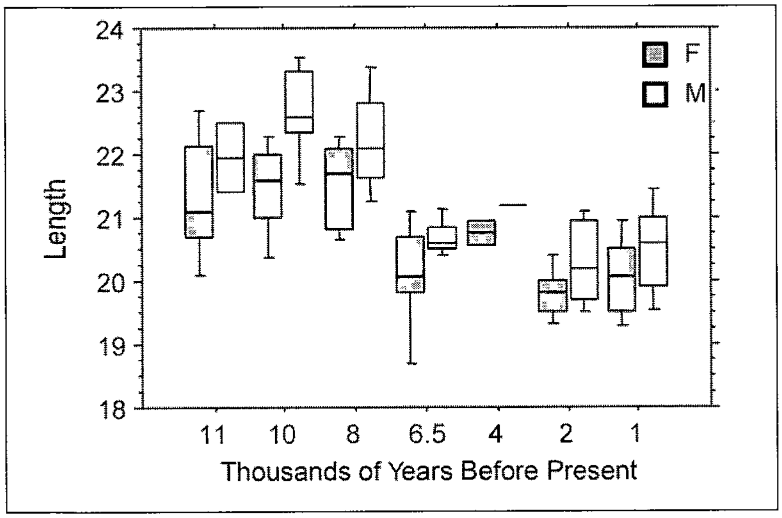

Figure 2. Change in metacarpal length for male and female bison for the Lubbock Lake populations.

DISCUSSION

In general, the pattern of morphological change on the Southern Plains is quite different than that reported on the Northern Plains. The Southern Plains pattern is best summarized as relative stasis before 8,000 B.P., a rapid change in size, shape, and robusticity between 8,000 B.P. and 6,500 B.P., followed by stasis after 6,500 B.P. Bison reach their modern form on the Southern Plains, then, sometime in the 1,500 year period between 8,000 B.P. and 6,500 B.P., well before the appearance of modern morphology in Northern Plains bison at ca. 5,000 B.P. (McDonald 1981; Wilson 1975). The extremely rapid shift in Southern Plains metapodial morphology also contrasts starkly with the gradual pattern of change reported for Northern Plains bison (Wilson 1974a). With the pattern of morphological change on the Southern Plains established, variables associated with both the human hunting hypothesis and the climatic change hypothesis can be examined.

The period of rapid change in bison did not correlate with an increase in population pressure (Haynes 2002; Meltzer 2000). Bison were hunted intensively on the Southern Plains both before and after this change without any significant change in bison morphology. Also, no selection against

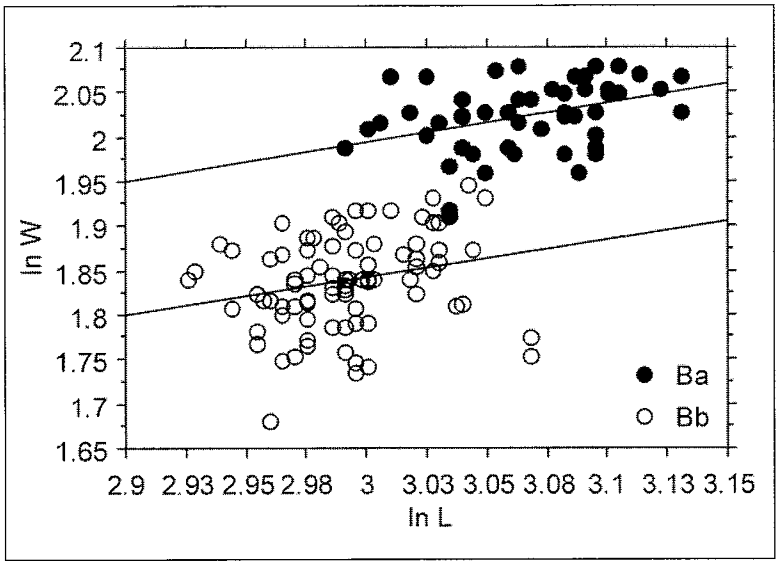

Figure 3. Change in metacarpal shape as based on log length (lnL) to log mid-shaft width (lnW) measurements for ancient bison (Ba=8,000 B.P. and older) and modern bison (Bb=6,500 B.P. and more recent).

large animals occurred during the period of change, as kills continue to have females, juveniles, and males, and exhibit similar standard deviation levels for metric variables. Selection against large individuals also would not explain why a change in shape and robusticity of the metapodials occurs.

McDonald (1981) suggests that the change in size was not driven by selection of large animals, but that smaller bison would have had an advantage over larger bison. Smaller bison supposedly would be better able to escape and to breed more quickly. At issue with this hypothesis, however, is the fact that humans were not the primary predator of bison (Fuller 1959; Lott 2002; McHugh 1972). While humans were hunting bison during the period of rapid morphological change in the lineage, wolves remain their primary predator. It does not follow from a natural selection point of view for bison to become smaller in order to escape their secondary predator if such a change increased the likelihood of their being killed by their primary predator.

No major shift in hunting strategy precedes the change in bison morphology, nor does a dramatic change occur in tool technology (Frison et al. 1976; Johnson 1997). While it may be argued that the change from Paleoindian to Early Archaic tools constitutes a major change in technology, when undeniable paradigmatic shifts in hunting strategy and tool type do occur (e.g., the introduction of the bow and arrow, guns, and horses) no change in bison morphology is found. Likewise, increased predation from humans should be associated with increased herd movements. Such increases in movement would increase the bending forces and, therefore, be associated with more robust bones. Just the opposite is found, as bone robusticity decreases sharply with the decrease in body size. No obvious mechanism is apparent that would connect changes in bison morphology with human hunting based on the variables examined here.

In general, the changes in bison morphology appear to be explained better by the changing climate. Body size does decrease with warming temperatures, as would be expected (Wilson 1975). A correlation exists between metapodial shape and vegetation density in modern bovids, whereby

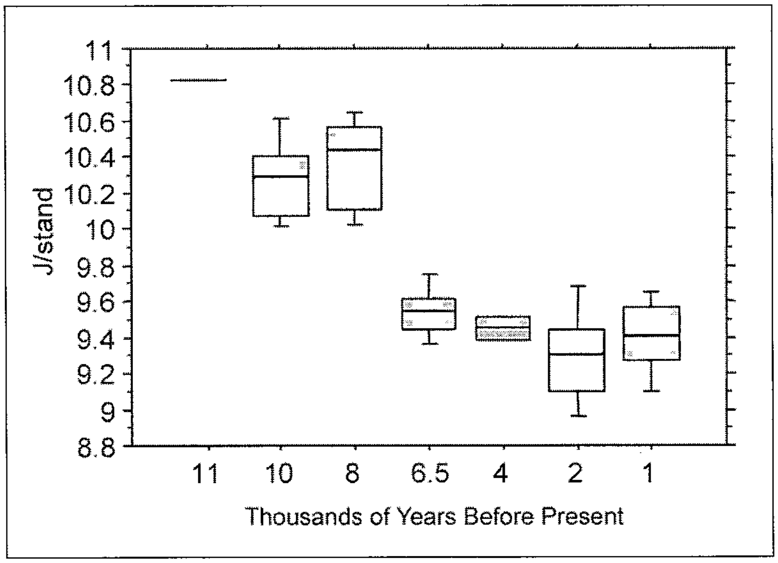

Figure 4. Boxplot of log J/standard (J/stand) for male metatarsals, estimating bone robusticity. Median, 75th percentile, and 90th percentile are depicted.

species associated with denser vegetation typically have relatively wider metapodials than those in areas where vegetation is sparse (Scott 1985). As the amount of brushy vegetation on the Southern Plains decreased, bison metapodials become thinner. Lastly, given the earlier date of modern morphology on the Southern Plains than on the Northern Plains, the pattern of morphological change spreads south to north along with the temperature gradient.

When changes in temperature and rainfall are examined with the changes in bison morphology, however, several shortcomings of the climatic hypothesis become evident. Based on both floral and faunal changes (see Johnson 1987), the late Pleistocene and early Holocene are characterized by a warming and drying trend on the Southern Plains. This trend peaks at ca. 7,000 to 5,000 B.P., during the deposition of stratum 3 at Lubbock Lake (Figure 5), and is followed by a return to cooler, moister conditions. Bison morphological change, therefore, occurs as the climate reaches its warmest and driest conditions. But, if bison morphology were tracking closely with temperature and rainfall, then the decrease in body size would have begun much earlier when the climate first began to change. While the warming and drying trends appear to explain the progression toward relatively smaller bison in the late Quaternary, it does not explain the period of rapid change between 8,000 and 6,500 B.P.

Likewise, if the morphological changes during this period were strictly phenotypic responses to changing temperatures, then they should have reversed when the conditions cooled after ca. 4,500 B.P. (stratum 4 at Lubbock Lake). Also, the decrease in metapodial robusticity during the late Quaternary is inconsistent with a drying, degrading habitat where bison would have been forced to range further to find adequate food. This increased movement would have increased bending forces on the skeletal elements of the limbs and led to more robust metapodials, not less robust metapodials. The climatic model, as it stands, fails to address these inconsistencies.

Recent phytolith analyses from Southern Plains localities (Fredlund 2002; Fredlund et al. 2002, 2003) offer a possible explanation for both the decrease in body size and in robusticity. A dramatic and rapid shift from C_3 to C_4 grass occurs on the Southern Plains beginning at ca. 10,000 B.P. and completed by 8,000 B.P., just when changes in bison morphology begin to appear in the fossil record. C_4 short grasses have an advantage over C_3 long grasses under warm Holocene conditions, as C_3 grasses are less tolerant of warm, dry conditions. The decrease in bison body size begins at approximately the same time that tall grass (C_3) ecosystems begin to give way to short grass (C_4) ecosystems on the Southern High Plains in the early Holocene. Additionally, both C_4 grasses and smaller bison spread northward during the Holocene. Once C_4 grasses become dominant on the Southern High Plains ca. 8,000 to 7,500 B.P., C_3 grasses never rebound despite the cooling climate of the late Holocene (Fredlund 2002; Fredlund et al. 2002, 2003).

The timing and pattern of the short grass ecosystem's spread follows that of all morphological changes in bison metapodials on the Southern Plains. The productivity and nutrition of C_4 grasses may explain why the transition in grass types would cause such a suite of changes in bison morphology. C_4 grasses are more productive per acre than are C_3 grasses (Howe 2000). With greater productivity, bison would not be required to range as far to find similar amounts of food. Such a change in grass types may have led, therefore, to a

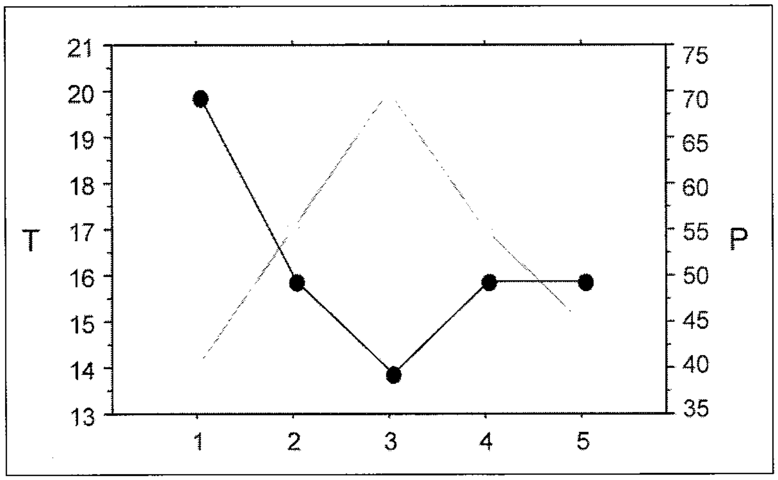

Figure 5. Changes in temperature (T, grey points) and precipitation (P, black points) for the 5 strata at Lubbock Lake. Stratum 1 dates from ca. 11,500-11,000 B.P., stratum 2 dates from ca. 11,000-8,000 B.P., stratum 3 dates from ca. 8,000-5,000 B.P., stratum 4 dates from ca. 5,000-1,000 B.P., and stratum 5 dates from ca. 1,000 B.P. to today (Johnson 1987).

decrease in herd movements and a subsequent reduction in range during the late Quaternary. This reduction in movement patterns would have led to decreased bending forces on the skeletal elements of the limbs and ultimately to less robust metapodials. The pattern of robusticity change would be a rapid shift during the period of transition from C_3 to C_4 grasses, followed and preceded by relative morphological stasis.

Despite higher productivity, C_4 grasses possess a larger cell wall and less protein than their C_3 counterparts, and are thus less nutritious (Howe 2000). Such a change in nutritional quality may have selected for bison with smaller body sizes, as smaller mammals generally require absolutely fewer calories and have reduced protein demands (Calder 1984). Larger mammals have higher total rates of metabolism than do smaller species, and the increase in metabolic rate is not proportional to mass (Calder 1984). A doubling of mass necessitates a 64% increase in basal metabolic rate, for example, while decreasing the mass by half reduces the basal metabolic rate by only 39% (McNab 1990). A mammal, therefore, can respond to decreases in available energy by either reducing mass or reducing the metabolic rate at a fixed mass (McNab 1990). Thus, change in bison body size would have been rapid during the transition from C_4 to C_3 grasses (and may have occurred passively, as bison fed on protein-poor C_4 grasses), and been followed and preceded by general morphological stasis.

NEW HYPOTHESIS

The new hypothesis proposed, therefore, is that the changing grasslands of the Southern Plains drove morphological changes in the late Quaternary bison lineage. This hypothesis, focused on the spread of an abundant but nutritionally poor primary food source for bison, explains both the decrease in bone robusticity and the decrease in body size. The timing of morphological changes and the earlier appearance of modern bison on the Southern Plains also are explained, as both modern bison morphology and C_4 grasses continued to spread northward as the late Quaternary climate dried and warmed. The effect of changing vegetation on late Quaternary bison provides increasing evidence that the dramatic changes in the North American fauna following the Wisconsin glaciation were driven primarily by the altering environment rather than hunting pressure from humans.

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REFERENCES CITED

Bedord, J. N.
1974 Morphological Variation in Bison Metacarpals and Metatarsals. In *The Casper Site: A Hell Gap Bison Kill on the High Plains*, edited by G. C. Frison, pp. 199-240. Academic Press, New York.

Bement, L. C.
1999 *Bison Hunting at Cooper Site: Where Lightening Bolts Drew Thundering Herds*. University of Oklahoma Press, Norman.

Bergmann, C.
1847 Über die Verhältnisse der wärmeökonomie der Thiere zu ihrer Grösse. *Göttinger Studien* 1:595-708.

Buehler, K. J.
1997 Where's the Cliff? Late Archaic Bison Kills in the Southern Plains. In "Southern Plains Bison Procurement and Utilization from Paleoindian to Historic," edited by L. C. Bement and K. J. Buehler, pp. 135-144. *Plains Anthropologist* 42 (159).

Calder, W. A.
1984 *Size, Function, and Life History*. Harvard University Press, Cambridge.

Dalquest, W. W. and G. E. Schultz
1992 *Ice Age Mammals of Northwestern Texas*. Midwestern University Press, Wichita Falls, Texas.

Fredlund, G. G.
2002 Phytolith Evidence for Change in Late Pleistocene and Holocene Grassland Composition on the Southern High Plains. Paper presented at the 60th Annual Plains Anthropological Conference, Oklahoma City.

Fredlund, G. G., V. T. Holliday, and E. Johnson

2002 The Rise of the Short Grass Steppe Ecosystem on the Southern High Plains: Evidence from the San Jon Site, Eastern New Mexico. Paper presented at the 2nd International Past Grasslands Research Conference, St. Cloud, Minnesota.

2003 Vegetation Change on the Southern High Plains During the Pleistocene-Holocene Transition. Paper presented at the 16th INQUA Congress, Reno, Nevada.

Frison, G. C.

1991 *Prehistoric Hunters of the High Plains.* Academic Press, San Diego.

Frison, G. C., M. Wilson, and D. J. Wilson

1976 Fossil Bison and Artifacts from an Early Altithermal Period Arroyo Trap in Wyoming. *American Antiquity* 41:28-57.

Fuller, W. A.

1959 Behavior and Social Organization of the Wild Bison of Wood Buffalo National Park, Canada. *Arctic* 13:2-19.

Guthrie, R. D.

1966 Bison Horn Cores—Character Choice and Systematics. *Journal of Paleontology* 40:738-740.

1990 *Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe.* University of Chicago Press, Chicago.

Haynes, G.

2002 *The Early Settlement of North America: The Clovis Era.* Cambridge University Press, Cambridge.

Holliday, V. T., E. Johnson, H. Haas, and R. Stuckenrath

1983 Radiocarbon Ages from the Lubbock Lake Site, 1950-1980: Framework for Cultural and Ecological Change on the Southern High Plains. *Plains Anthropologist* 28:165-182.

1985 Radiocarbon Ages from the Lubbock Lake Site: 1981-1984. *Plains Anthropologist* 30:277-291.

Howe, H. F.

2000 Grass Response to Seasonal Burns in Experimental Plantings. *Journal of Range Management* 53:437-441.

Johnson, E.

1987 *Lubbock Lake: Late Quaternary Studies on the Southern High Plains.* Texas A&M University Press, College Station, Texas.

1997 Late Quaternary bison utilization at Lubbock Lake, Southern High Plains of Texas. In "Southern Plains Bison Procurement and Utilization from Paleoindian to Historic," edited by L. C. Bement and K. J. Buehler, pp. 45-62. *Plains Anthropologist* 42(159).

Lott, D. F.

2002 *American Bison: A Natural History.* University of California Press, Berkeley.

Kreutzer, L. A.

1992 Bison and Deer Bone Mineral Densities: Comparisons and Implications for the Interpretation of Archaeological Faunas. *Journal of Archaeological Science* 19:271-294.

McDonald, J. N.

1981 *North American Bison: Their Classification and Evolution.* University of California Press, Berkeley.

McHugh, T.

1972 *The Time of the Buffalo.* Alfred A. Knopf, New York.

McNab, B. K.

1990 The Physiological Significance of Body Size. In *Body Size in Mammalian Paleobiology: Estimation and Biological Implications*, edited by J. Dammuth and B. J. MacFadden, pp. 11-23. Cambridge University Press, Cambridge.

Meltzer, D. J.

2000 Human Responses to Middle Holocene (Altithermal) Climates on the North American Great Plains. *Quaternary Research* 52:404-416.

Reeves, B. O. K.

1973 The Concept of an Altithermal Cultural Hiatus in Northern Plains Prehistory. *American Anthropologist* 75:1221-1253.

Scott, K. M.

1985 Allometric Trends and Locomotor Adaptations in the Bovidae. *Bulletin of the American Museum of Natural History* 179:197-288.

Skinner, M. F. and O. C. Kaisen

1947 The Fossil *Bison* of Alaska and Preliminary Revision of the Genus. *Bulletin of the American Museum of Natural History* 89:123-256.

Trinkaus, E., C. E. Churchill, and C. B. Ruff

1994 Postcranial Robusticity in *Homo*, II: Humeral Bilateral Asymmetry and Bone Plasticity. *American Journal of Physical Anthropology* 93:1-34.

Wilson, M.

1974a The Casper Local Fauna and its Fossil Bison. In *The Casper Site: A Hell Gap Bison Kill on the High Plains*, edited by G. C. Frison, pp. 125-171. Academic Press, New York.

1974b History of the Bison in Wyoming with Particular Reference to Early Holocene Forms. In *Applied Geology and Archaeology: The Holocene History of Wyoming*, edited by M. Wilson, pp. 91-99. Report of Investigations No. 10. The Geological Survey of Wyoming, Laramie.

1975 Holocene Fossil Bison from Wyoming and Adjacent Areas. Masters of Science Thesis, University of Wyoming, Laramie.

Wyckoff, D. G. and W. W. Dalquest.
1997 From Whence They Came: The Paleontology of Southern Plains bison. In "Southern Plains Bison Procurement and Utilization from Paleoindian to Historic," edited by L. C. Bement and K. J. Buehler, pp. 5-32. *Plains Anthropologist* 42(159).

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