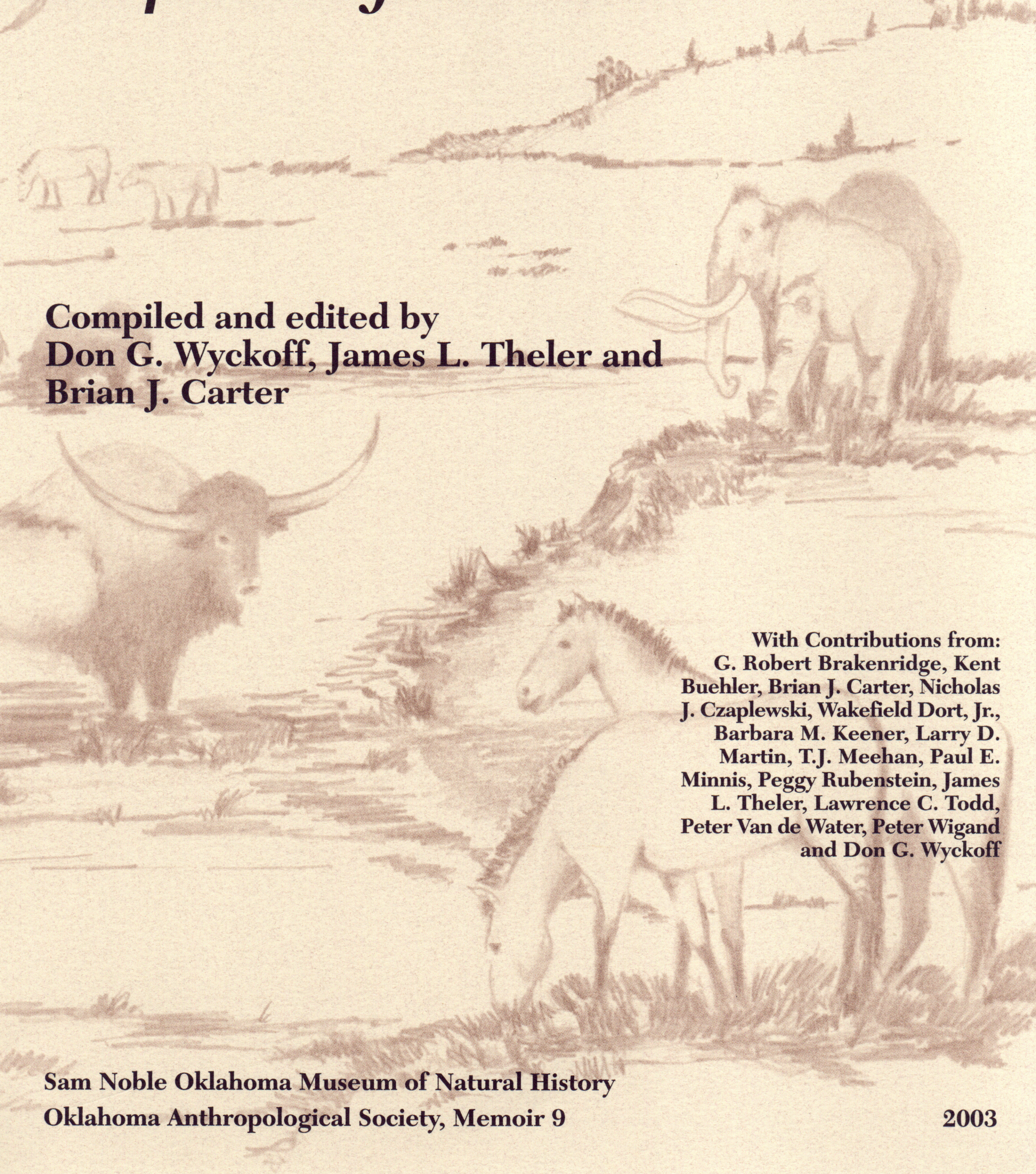
The Burnham Site in Northwestern Oklahoma: *Glimpses Beyond Clovis?*



Compiled and edited by
Don G. Wyckoff, James L. Theler and
Brian J. Carter

With Contributions from:
G. Robert Brakenridge, Kent Buehler, Brian J. Carter, Nicholas J. Czaplewski, Wakefield Dort, Jr., Barbara M. Keener, Larry D. Martin, T.J. Meehan, Paul E. Minnis, Peggy Rubenstein, James L. Theler, Lawrence C. Todd, Peter Van de Water, Peter Wigand and Don G. Wyckoff

Sam Noble Oklahoma Museum of Natural History
Oklahoma Anthropological Society, Memoir 9

2003

Preface to the Burnham Site Odyssey

This all started simply enough. A phone call came to me in May of 1986 when I was with the Oklahoma Archeological Survey. A rancher-farmer acquaintance in northwestern Oklahoma reported that some large bones were uncovered while building a small pond on his dad's land. Knowing of my interest in ice age animals as clues to studying Oklahoma's past environments, he thought maybe I'd want to come see if these bones were worth investigating. So, a week or two later, I stopped by Keith Burnham's property in western Woods County. Accompanying me were Dr. Wakefield Dort and Dr. Larry Martin from the University of Kansas. They had joined me to help with some final geological and paleontological evaluations at the Hajny mammoth site down in Dewey County. Upon our arrival at the Burnham property, snail-rich gray deposits were visible at three spots around the small pond. Fragments of horse and mammoth bones were evident at two seemingly separate, gray exposures on the pond's west side. On the east side, the bulldozer graded, steep slope showed one gray deposit. It was distinguished by many snails and a few bone fragments. However, mid-way up the slope, Larry Martin recognized that the bulldozer had scraped across the overturned skull of a big-horned bison. Noting that its virtually severed right horn core was quite thick, Larry suggested that the skull might be *Bison latifrons*, and, if so, it would be worthy of recovery because so few had been found on the Southern Plains in discrete contexts with other vertebrate remains. Accordingly, Larry recommended that someone return to the site; uncover, preserve, and retrieve the bison skull; and waterscreen about a ton of dirt around the skull to see if they couldn't also find bones of small animals sensitive to the local settings and climate at the time that the deposit accumulated.

So, the Burnham site research began as an innocent job of salvaging an ancient bison skull and preliminarily assessing the site's potential for studying the environment of the ice ages. This work was undertaken during four days in late October and early November of 1986 by three avocational and two professional archeologists. Colleague Peggy Flynn Rubenstein and I had no way of knowing that these four days were the prelude to an odyssey, one that would persist for more than a decade, entail four intensive sessions of field work, involve diverse kinds of researchers and dozens of avocational archaeologists who contributed hundreds of hours of tedious labor, and take all of us down faint trails to understanding the past. Some paths led us to new discoveries, others to contradictory conclusions, and a few to heated disagreements. Along the way we gained steadfast friends, interesting critics, respect for both, and better perceptions of the late Pleistocene Southern Plains. Hopefully, this monograph conveys both the experiences and the knowledge gained.

The monograph's title implicates that the Burnham site involves a mystery. It does. Among our findings at this site are clues that people inhabited North America much earlier than most archaeologists currently believe. In this regard, the Burnham findings are controversial. They are also ironic. This is because the site is some 300 miles down the Cimarron River from the Folsom site, the New Mexico location where, in 1927, paleontologists first conclusively proved that humans inhabited North America during the last ice age. Could it be, that after 70 years of searching across the continent, evidence for a much earlier human presence is also in the Cimarron watershed?

Because the Burnham research spanned a decade and involved different specialists at separate phases of work, this monograph has been a challenge to organize. Believing it the most logical sequence, the monograph is arranged so that a history of the field work and its rationale is followed by reports on the findings of the contributing researchers. The final chapters synthesize these findings in order to summarize the site's contributions to understanding the late Pleistocene environment in this part of the Southern Plains, the processes that created the site's differenct geologic contexts, their ages, and the site's evidence for the early peopling of North America.

Don G. Wyckoff
Associate Curator of Archaeology
Sam Noble Oklahoma Museum of Natural History
University of Oklahoma

Cover: This mid-Wisconsinan scene was done in pencil by Ron Ford of Oklahoma City. Ron is a member of the Oklahoma Anthropological Society and was a frequent participant in the field work at the Burnham site.

The Burnham Site in Northwestern Oklahoma: Glimpses Beyond Clovis?

Compiled and Edited by:

Don G. Wyckoff, James L. Theler, and Brian J. Carter

With Contributions by:

G. Robert Brakenridge, Department of Geography, Dartmouth University
Kent Buehler, Oklahoma Archeological Survey, University of Oklahoma
Brian J. Carter, Plant and Soil Sciences, Oklahoma State University
Nicholas J. Czaplewski, Paleontology, Sam Noble Oklahoma Museum of Natural History, University of Oklahoma
Wakefield Dort, Jr., Department of Geology, University of Kansas
Barbara M. Keener, Department of Anthropology, University of Oklahoma
Larry D. Martin, University of Kansas Museum of Natural History
T.J. Meehan, University of Kansas Museum of Natural History
Paul E. Minnis, Department of Anthropology, University of Oklahoma
Peggy Rubenstein, Archaeology, Sam Noble Oklahoma Museum of Natural History, University of Oklahoma
James L. Theler, Department of Archaeology and Sociology, University of Wisconsin-LaCrosse
Lawrence C. Todd, Department of Anthropology, Colorado State University
Peter Van de Water, Oregon State University, Corvallis, Oregon
Peter Wigand, Great Basin and Mojave Paleoenvironmental Consulting
Don G. Wyckoff, Archaeology, Sam Noble Oklahoma Museum of Natural History University of Oklahoma

A Joint Publication of the

Sam Noble Oklahoma Museum of Natural History, University of Oklahoma
and the
Oklahoma Anthropological Society (Memoir 9)

2003

Acknowledgments

Seventeen years working on one archaeological project usually results in the support and interest of many individuals and organizations. The Burnham site research is no exception. Regrettably, through these years several dear friends integral to the Burnham studies have passed away. Following this acknowledgment section, this monograph is dedicated to the memory of Keith Burnham, Harold Kamas, Harold Brown, Preston and Margaret George, Dick Williams, Harriet Peacher, Devonna Minnich, and Lee Woodard.

First and foremost in deserving thanks are the several Burnham families. Lillian and her late husband Keith kindly gave permission for all of the field work and were gracious hosts to all the volunteers who helped at the site and camped by the beautiful Burnham lake. Lillian and Keith were always ready to listen and help decide what should and would be done during the five seasons that were eventually spent at the site. Vic Burnham was instrumental in involving archaeologists with the finds, and his support and friendship over the years were invaluable. The Gene Burnham family was helpful and considerate during the field work. Special thanks to Gene for his expertise in fixing everything from broken coring equipment to cranky water pumps.

Major funding for important parts of the Burnham field work came from notable organizations and many kind individuals. The major excavations in 1989 were partially supported by the National Geographic Society (grant #4414-89). In 1992 the National Science Foundation partially funded the extensive geoarchaeological work as well as an undergraduate research fellowship (grant #DBS-9120314). Especially helpful, and most appreciated, were the timely monetary donations from the Freedom Chamber of Commerce, the Alva Chamber of Commerce, Cargill Salt Division, Cojeen Archaeological Services, John and Mildred Shore, Dan Wofford, Thomas Laity, Hank Kerr, Dr. Virginia Watson, Dr. and Mrs. Robert E. Bell, Roland Meyer, Byron Sudbury, Paula Baker, Helen Affsprung, Dr. James Benedict, Mr. and Mrs. Curt Hendricks, Mr. and Mrs. Gene Hellstern, Paul Ferguson, Ken and Leah Richardson, Mr. and Mrs. Glen Muse, Kim Nelson, Phil Cannon, Tim Klinger, James Vater, Bob Newbury, John Hoard, Dr. Jim Cox, Bill Bellamy, W.W. Cook, Jim and Dora Malone, Rena Caffey, and Wade Rice. Much logistic support came from the Oklahoma Archaeological Survey. Dr. Michael A. Mares (Director, Oklahoma Museum of Natural History) is recognized for graciously funding the first radiocarbon dates for the site.

Numerous volunteers helped with the manual excavations undertaken in 1986, 1988, 1989, 1991, and 1992. Appendix A lists each season's participants and illustrates some of them at work. The volume and quality of the work accomplished each season are testimonies to these people's desires to help in so many constructive ways. My personal thanks goes to each of those listed in Appendix A.

During the five field seasons individuals often stepped forth to volunteer needed equipment and/or supplies. Mr. and Mrs. Terry Turner and the Turner Transport drivers hauled thousands of gallons of water needed for waterscreening. Useful equipment was provided at critical times by Jim DeVous, Jim Woodard, and Charles Wallis. Gwen and Harold Kamas frequently tracked down and brought needed supplies as did Bob Brooks and Lois Albert of the Oklahoma Archeological Survey and Dr. Leland Allen of Woodward.

As mentioned above, little would have been accomplished if it hadn't been for the field work volunteers, most of whom were avocational members of the Oklahoma Anthropological Society. Among these individuals, several merit special recognition for their diligence and devotion in fulfilling assigned responsibilities. In particular, Scott Francis deserves a medal for introducing the use of laser beacons for accurate elevation readings and thus eliminating untrustworthy strings and line levels. We thank Charlie (Charlette) Gifford for her unceasing help in supervising excavation teams; Leslie Anderson for assisting with almost all of the profiling and mapping; and Claude Long, Paul Ferguson, and Paul Benefield for avocational leadership. John Flick and Ken Bloom always provided wise counsel, encouraging words, and close friendship. Jimmie Martin, Terrell Nowka, and the late Lee Woodard offered zest and humor that benefited everyone. Phil Ward III was a constantly contributing assistant to Brian Carter during the coring and profiling.

During the analyses of the Burnham findings, Nick Czaplewski and Walt Dalquest (now deceased) were invaluable consultants on things paleontological. We especially appreciate the help and advice of Doug Donahue (University of Arizona Radiocarbon Dating Facility), Herbert Haas (formerly of Southern Methodist University), Bonnie Blackwell (Williams College), and Joseph McKee and Rodger Sparks (New Zealand Institute of Geological and Nuclear Sciences). For their interest and words of encouragement, the "Alva faculty" of Paul Nighswonger, Vern Powders, and Roland Meyer are acknowledged and appreciated.

We are indebted to Gwen Kamas, Byron Sudbury, Genevieve Lounsbury, Charlette Gifford, Linda Mager, George Odell, Bill Thompson, and the Daily Oklahoman for photos used in this monograph. Also, we thank Roger Burkhalter (SNOMNH Paleontology Curatorial Specialist) for his help in photographing the chipped stone objects. A big thanks goes to Paul King of the Museum's computer staff for teaching and helping me with the intricacies of Pagemaker. Paul, Patrick Fisher, and Chris Gant also deserve appreciation for scanning slides and trouble-shooting computer problems. We thank Dr. Mike Eggleton, Research Assistant in ornithology (SNOMNH), for his help in developing the graphs of radiocarbon dates. At Oklahoma State University, Debbie Porter and Vickie Brake are acknowledged for helping with manuscripts and illustrations.

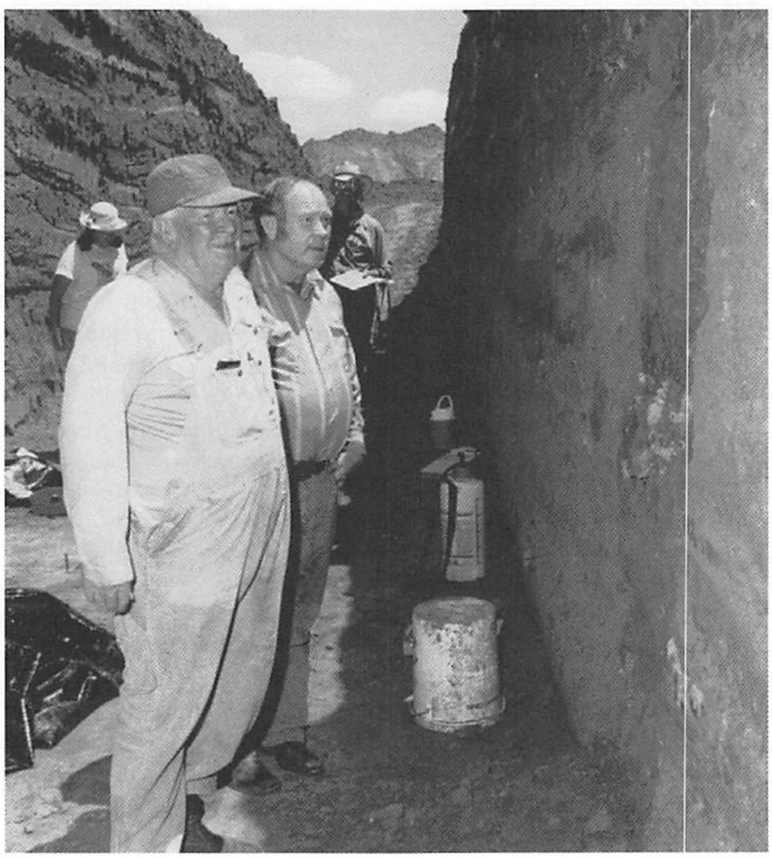
Finally, we thank Ruth Wyckoff, Peggy Rubenstein, Arnold Coldiron, Chuck Rippy, and Pete Thurmond for their support and encouragement throughout all of the Burnham research, and especially while this monograph was compiled, formatted, and edited.

Don G. Wyckoff
Sam Noble Oklahoma Museum of Natural History
Department of Anthropology
University of Oklahoma
Norman, Oklahoma

Brian J. Carter
Department of Plant and Soil Sciences
Oklahoma State University
Stillwater, Oklahoma

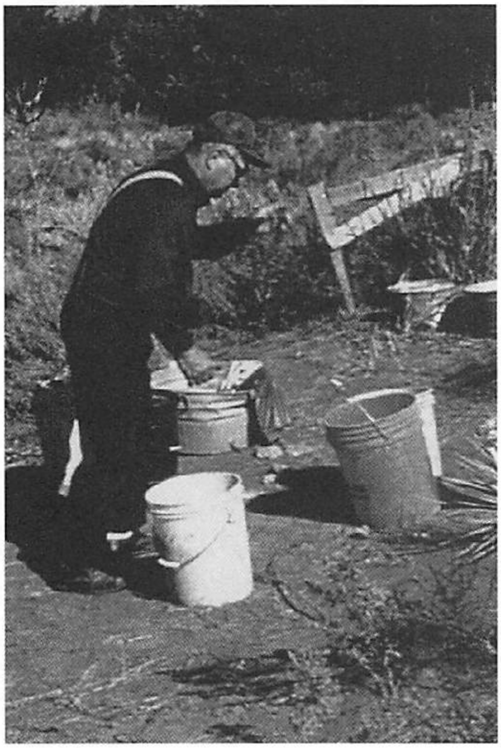
James L. Theler
Department of Sociology and Archaeology
University of Wisconsin-LaCrosse
LaCrosse, Wisconsin

In Memory



Keith Burnham

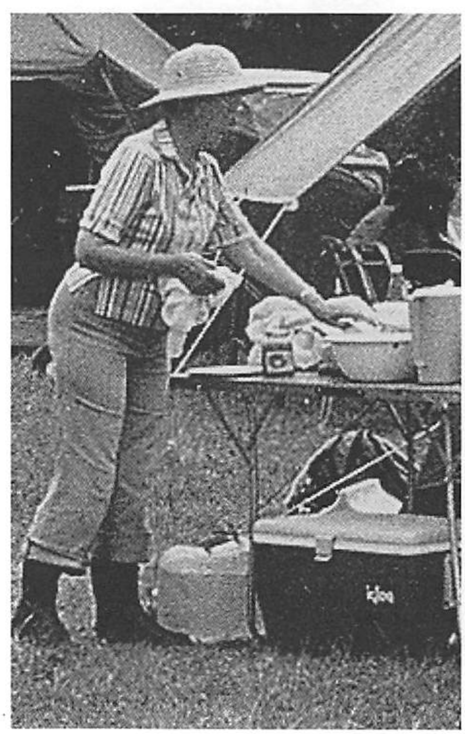
In Memory



Harold Brown

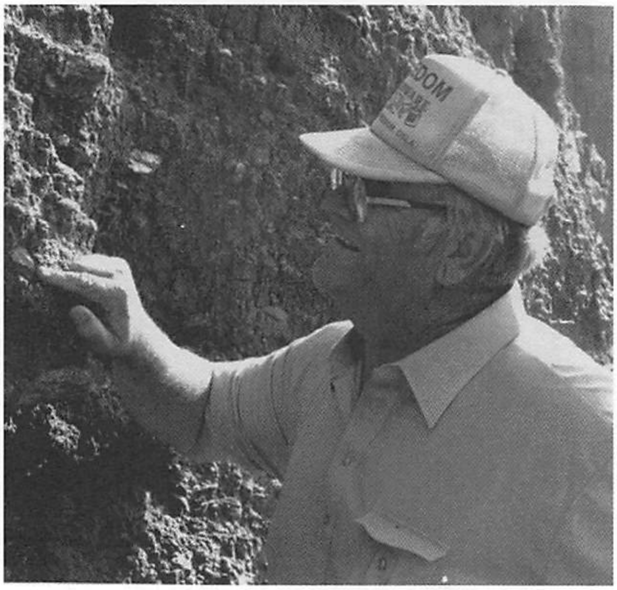
Ralph Caffey

Preston George

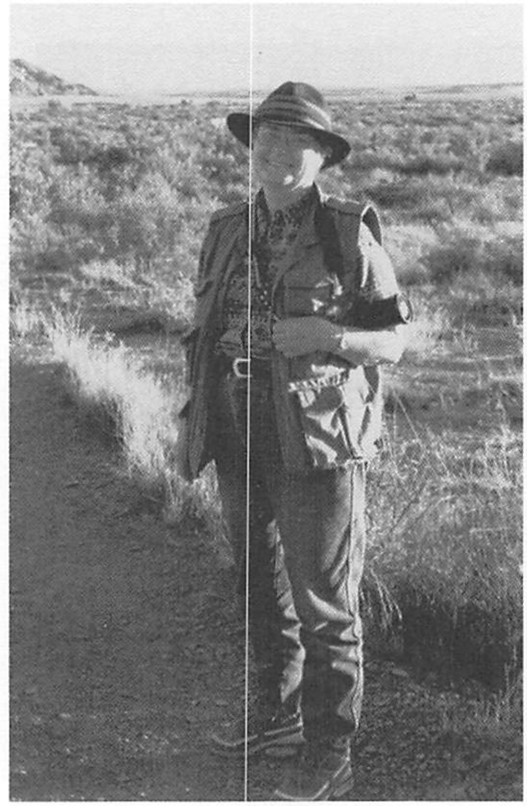


Margaret George

In Memory

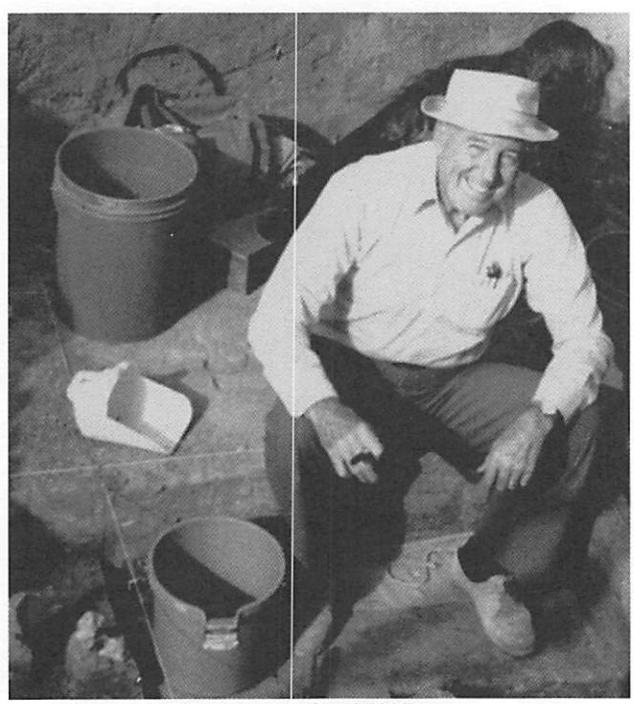


Harold Kamas



Devonna Minnich

Harriet Peacher



Richard C. Williams

In Memory

Lee Woodard

The Burnham Site in Northwestern Oklahoma: Glimpses Beyond Clovis?

Table of Contents

Chapter 1
The Burnham Site Location, Setting and Pleistocene Relevance

Don G. Wyckoff

The Burnham site is in western Woods County of northwestern Oklahoma (Fig. 1.1). In May of 1986 the site was first observed when a steep ravine bank was graded down to build the dam of a small pond. Gray dirt containing many snail shells and some bones was visible on both sides of this ravine. Inspection in June and August of 1986 (Plates 1a and 1b) reinforced the belief that the Burnham exposure was a paleontological site. Consequently, no official record was made of the location until October 27, 1986. A record was made then because paleontological salvage excavations using archaeological techniques were about to begin. An archaeological site form was completed and filed with the Oklahoma Archaeological Survey. Responsible for codifying and maintaining records on Oklahoma's archaeological resources, this state agency assigned the Burnham site the state number of 34Wo73. This signifies that the location is in Oklahoma (34 is the Smithsonian Institution's code for Oklahoma) and that the location was the 73[rd] site recorded in Woods County.

Obtaining an archaeological site number for a paleontological site was somewhat unusual. Because the spot seemed to be a paleontological site, and because Oklahoma doesn't have a centralized system for formally registering such sites, the location could have gone unrecorded. However, Peggy Rubenstein and I had just excavated and studied taphonomic processes at another paleontological site (Wyckoff et al. 1992), and we were interested in continuing such research. We planned to remove defined levels from a grid of metric squares in order to document bone positions during the short field work planned for the Burnham site. Thus, we believed it appropriate to give the location official status.

The Burnham site was recommended for both paleontological salvage and test excavations. During his June 1986 visit to the site, paleontologist Larry Martin observed a partially damaged large horn bison skull that he thought merited recovery. He also urged that at least a ton of fill from around the skull be waterscreened in order to assess the presence and kinds of bones of environmentally sensitive small animals.

Stabilizing and recovering the bison skull occurred in late October and early November of 1986. Assisted by three avocational archaeologists, Peggy and I carefully exposed, plastered, and retrieved the large skull. Also, nearly a cubic meter of gray sediment around the skull was washed through 2 mm mesh hardware cloth. This latter work recovered occasional bones of small vertebrates, hundreds of snail shells, a few pebbles, and thousands of small carbonate nodules. Sorting of this debris began in November of 1986 and continued into the early summer of 1987. During this sorting, two tiny flakes of flint were found. Both appeared to result from resharpening chipped stone tools. These finds started changing our perception of the Burnham site. The flakes came from the gray sediment around the bison skull. Larry Martin had identified the skull as a form earlier than *Bison antiquus*, the species known to have been hunted by North America's late Pleistocene human inhabitants. Was there a chance that Burnham was one of the long sought locations bearing witness to people occupying North America before the generally accepted 11,000 to 12,000 years ago?

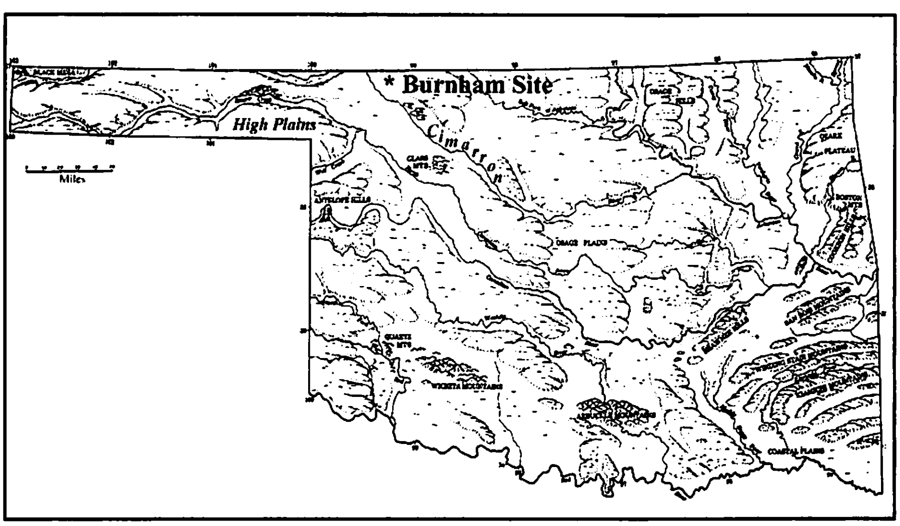


Figure 1.1. Location of the Burnham site along the eroded eastern edge of the High Plains. Adapted from Morris et al. 1986:Fig. 5.

The Burnham Site's Location

The Burnham site covers about 2.5 acres in the SE1/4 of the SW1/4 of the NE1/4 of Section 30, Township 28 North, Range 18 West. This property belongs to Keith and Nellie Burnham.

The Burnham site is but one of many late Pleistocene paleontological and archaeological sites reported for the High Plains' eastern border in southwestern Kansas, northwestern Oklahoma, and the adjacent Texas panhandle (Dalquest and Schultz 1992; Hibbard 1970; Hibbard et al. 1965; Zakrzewski 1975). In this area the plains border is very eroded. The observant traveler sees steep bedrock escarpments, deeply incised canyons, occasional collapse basins, mesas, and long interfluvial ridges that retain the stratigraphy and relatively flat surface of the High Plains (Gustavson et al. 1991; Madole et al. 1991; Osterkamp et al. 1987). In fact, the mesas and ridges are eroded outliers of the High Plains. Among the notable ridges are the Red Hills, a series of rounded, high uplands which, like the High Plains, have red Permian bedrock escarpments overlain with Cenozoic outwash (the Ogallala Formation) from the Rocky Mountains (Fenneman 1931:28-30). Along the Kansas-Oklahoma boundary, a portion of the Red Hills form a prominent east-west, dolomite capped ridge (Fig. 1.2) that lies between the Cimarron River and the Salt Fork of the Arkansas River. The Burnham site lies just below this ridge's southern escarpment (Figs. 1.3 and 1.4) at an elevation of 1740 feet above sea level (a.s.l.).

This is deceptive country. Flying over it you perceive the landscape as rolling with a few ridges or narrow, deeply incised valleys here and there. In fact, however, this country is rugged with significant local relief. Four miles north of the Burnham site, the east-west ridge (which is a High Plains outlier) has a maximum elevation of 2136 feet a.s.l. Six miles south of the site, the Cimarron River flows east at an elevation of 1540 feet a.s.l. In essence, within a distance of ten miles the local relief exceeds nearly 600 feet! Some appreciation of this relief and the Burnham site's position on it can be gained from the computer generated orthographic projections provided in Figures 1.5 and 1.6.

Covered with as much as 100 ft. of Ogallala Formation sand and gravel, the ridge north of the Burnham site is sharply defined (Fig. 1.3) by scarp-forming outcrops of Permian dolomite and sandstone. The integral beds for this escarpment are the chert-bearing Day Creek dolomite, the non-chert Moccasin Creek dolomite, and the thick sandstone of the Rush Springs Formation (Fay 1965:Pl. I). The Burnham site lies between East and West Moccasin creeks, which join three miles south of the site before flowing on to the Cimarron. Both East and West Moccasin creeks have their headwaters on the ridge and drain off it through twisted, deep canyons. South of the ridge and its escarpment the terrain slopes south and is underlain by a very erodible, fine-grained, red sandstone of the Permian-age Marlow Formation. Numerous draws and steep walled gullies have eroded into this sloping terrain (Fig. 1.4). The Burnham site is near the head of one such gully while also being close to the southern margin of the land underlain by the Marlow Formation. South of the site, Permian shale and gypsum beds are overlain by a series of Quaternary terrace deposits attributed (Fay 1965:Pl. I) to the Cimarron River.

Initially, we wondered if the Burnham site might be part of an ancient course of the Cimarron River. A mile west of the site, geologist R. O. Fay (1965:Pl. I) plotted a small, north-projecting lobe of Cimarron terrace deposits. To assess this possibility, Peggy and I spent several days in November of 1987 inspecting gully walls, creek banks, and plowed fields around the site to see if we could identify Cimarron alluvial deposits. We found none and concluded that the site represented some other kind of Quaternary geologic context.

Figure 1.2. *View northeast of the Red Hills as manifest by the ridge north of the Burnham site. Photo taken in May of 1991.*

A north-south geomorphic cross section (Fig. 1.7) through the site to the Cimarron River reveals that the site is farther north, and lower, than any mapped (Fay 1965:Pl. I) alluvium believed left by the ancient Cimarron. In fact, the site is far enough north that it lies almost between two promontories of the receding bluff-line of the ridge to the north. While the northeast oriented orthographic projection (Fig. 1.5) shows that the site is on a terrace-like setting, the northwest oriented orthographic projection (Fig. 1.6) and the geomorphic cross section (Fig. 1.7) show that the site is nestled near

Figure 1.3. View east-northeast of Burnham site's East Exposure (far side of pond) and the upland ridge and escarpment in the background. Photo taken in July of 1987 by Don Wyckoff.

Figure 1.4. View southwest from ridge crest in Figure 1.3. Eroded terrain slopes west-southwest toward the Burnham site (right center of picture). Photo taken in June of 1992 by Don G.. Wyckoff.

the base of the long slope eroded from the soft Marlow Formation sandstone. Thus, the site's location is not believed to be on a strath terrace of the Cimarron River.

The bluff north of the site and the long slope on which the site rests result from geomorphic processes well documented elsewhere along the eroding edge of the Southern High Plains (Gustavson and Simpkins 1989; Simpkins and Gustavson 1987; Ostercamp et al. 1987). Like other major streams cut into the Southern High Plains, the Cimarron River probably formed in a regional fracture zone where subsurface dissolution of Permian salt induced subsidence (Gustavson and Finley 1985). Subsurface ground water flow and salt dissolution are noted to occur currently in Woods County (Fay 1965). In fact, extensive salt deposits are on the Cimarron River today: the Big Salt Plain (4100 acres), which is 7 miles southwest of the Burnham site and the Little Salt Plain (2000 acres), which is 13 miles west (Fay 1965:93 and Pl. I). Believed correlated with past climatic changes, downcutting, lateral erosion, and aeolian deposition are Quaternary geomorphic processes creating terrain like that bordering the Cimarron River (Osterkamp et al. 1987). Lateral erosion of the Cimarron valley, like that recorded along Texas panhandle drainages (Gustavson and Simpkins 1989), is primarily by ground water flow below the caprock. Spring sapping undercuts the caprock, resulting in rockfalls and some rotational slumping. Traces of these processes are evident in the upper reaches of East and West Moccasin creeks north of the Burnham site.

In this locality, the south sloping uplands are drained by a dendritic series of draws, arroyos, and two deeply incised streams that merge to form West Moccasin Creek (Fig. 1.4). Although often steep sided, these streams have discontinuous small remnants of alluvial terraces. These sometimes contain lenses of gravel that include redeposited Ogallala Formation clasts as well as cobbles and boulders of Day Creek dolomite and the other formations exposed in the Red Hills escarpment to the north. Some terraces are perched 6 to 10m above the present stream bed. A few of these settings contain gray to black pond deposits that yield late Pleistocene invertebrate and vertebrate fauna. Along these upland drainages the red Marlow Formation sandstone and the underlying Dog Creek shale are frequently exposed (Fay 1965). Overlying these Permian red beds are 2 to 3m of soils formed from bedrock disintegration, colluvium, and wind blown material (Fitzpatrick et al. 1950).

At the Burnham site, however, over 5m of unconsolidated red soil was visible. Consequently, the site seemed unusual. When first visited in June of 1986 the site showed many effects from construction of the small pond. This pond's dam axis ran east and west and was about 4m high. Its fill came from using a bulldozer to scrape down the ravine's sides adjacent the dam. Originally, the ravine's east side was bare, perpendicular, and an estimated 6m high. In contrast, the ravine's west side was a 6% slope vegetated with yucca and bunch grass. Construction work only slightly altered this west side. But in removing the topsoil and some underlying colluvium, the bulldozer exposed two separate lenses of gray sediment that contained fossil bones and gastropods. Designated the Northwest (NW) and Southwest (SW) exposures (Fig. 1.8), these gray lenses appeared to have their bases at comparable elevations (Plate 1b)

Most of the dam fill came from the ravine's east side. Here, south sloping terrain was lowered more than 2m, and the once vertical bank was graded to a 4% slope (Fig. 1.3 and Plate 1a). This uncovered what first appeared to be the cross section of a prehistoric gully filled with gray loamy sand and capped with a nearly continuous layer of carbonate (Plate 1a). The base of this aggraded gully seemed to be the same elevation as those of the Northwest and Southwest exposures (Fig. 1.8). Like them, this East Exposure contained many gastropod shells and some bones, including the overturned skull of the large horned bison.

In summary, prior to any scientific excavations and formal surveying, the Burnham site appeared to consist of three separate exposures of gray sediments containing similar kinds of gastropods and mammal bones of different ice age species. Because of their similar elevations, sediments, and fossils, the three exposures were assumed to be remnants of one alluviated creek or lacustrine setting.

Present and Past Environments

Stopping erosion was one reason for building the small pond where the Burnham site was exposed. Erosion is very evident in the uplands around the site (Fig. 1.4). The contributing factors behind this erosion are the pronounced local relief, the nature of the bedrock, the soils formed from bedrock, historic land use, and climatic conditions.

Composed mainly of very fine sandy loam surface soils on 6 to 12% slopes (Fitzpatrick et al. 1950: Northwest soil map), the landscape around the Burnham site is very erodible. In fact, during our research at the site Mr. Burnham took the surrounding field out of cultivation and enrolled it in the federal Conservation Reserve Program. This enabled planting a variety of forbs and grasses that have greatly stabilized the fine textured, south sloping ground.

Prior to historic farming, western Woods County was part of the Shortgrass Plains biotic district (Blair and Hubbell 1938:Fig. 1). Historically, this area averages about 26 inches of annual precipitation. Approximately 37% of that falls during the growing season (Johnson and Duchon 1995:Figs. 3.1 and 4.27). The growing season is from around April 29 to November 4, or 187 days (Johnson and Duchon 1995:Figs. 4.24 and 4.42). While lengthy, this season is marked by high temperatures, especially in July and August, when evaporation greatly exceeds seasonal precipitation (Johnson and Duchon 1995: Figs. 4.25, 6.17, 6.18, 6.19, and 6.20).

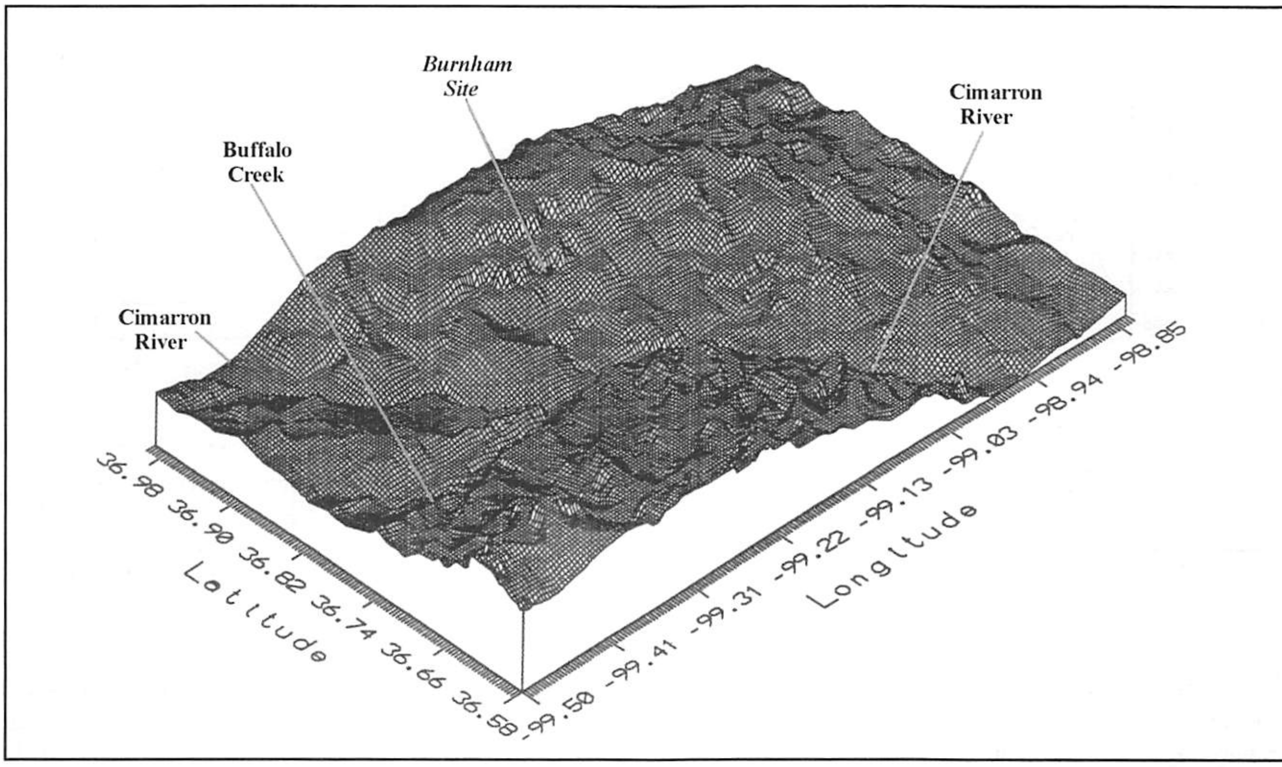


Figure 1.5. Orthographic projection looking northeast at the Burnham site within the Cimarron River valley of Woods County, Oklahoma. Illustration courtesty of Pete Thurmond.

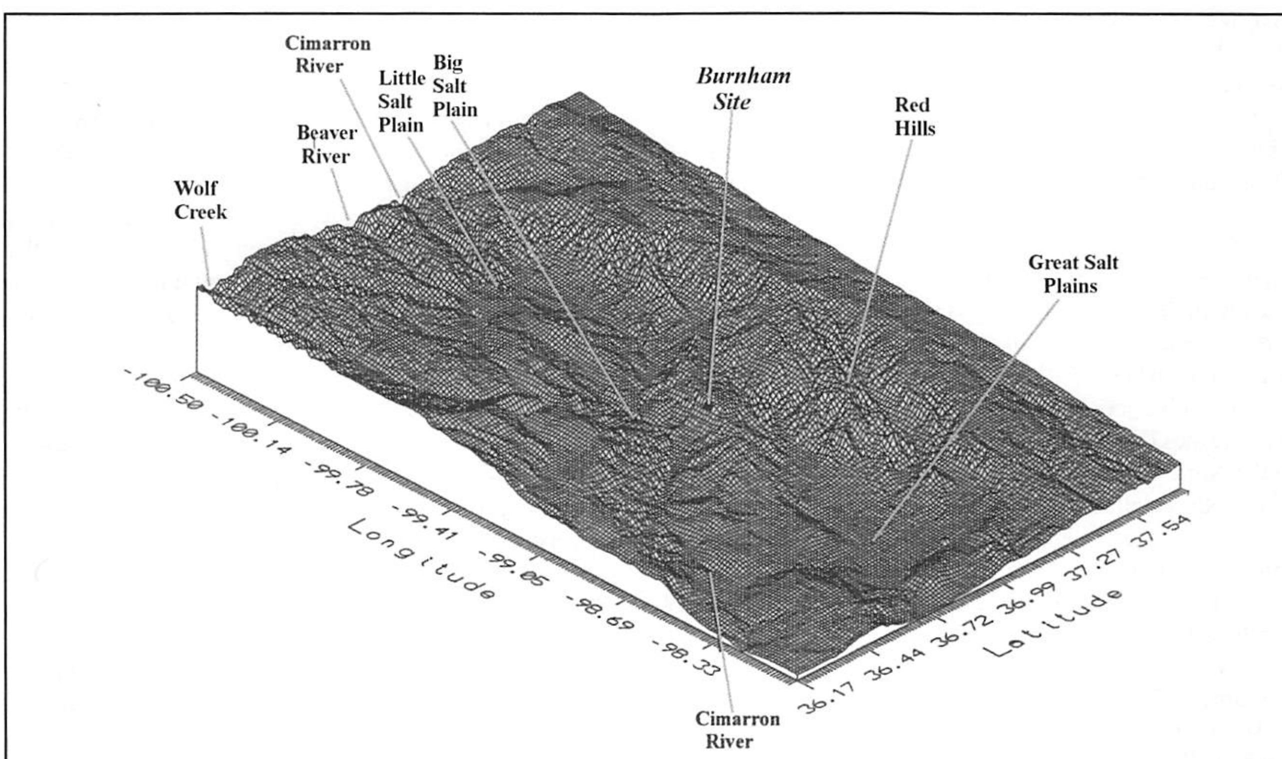


Figure 1.6. Orthographic projection looking northwest at the Burnham site within the Cimarron River valley of Woods County, Oklahoma. Illustration courtesy of Pete Thurmond.

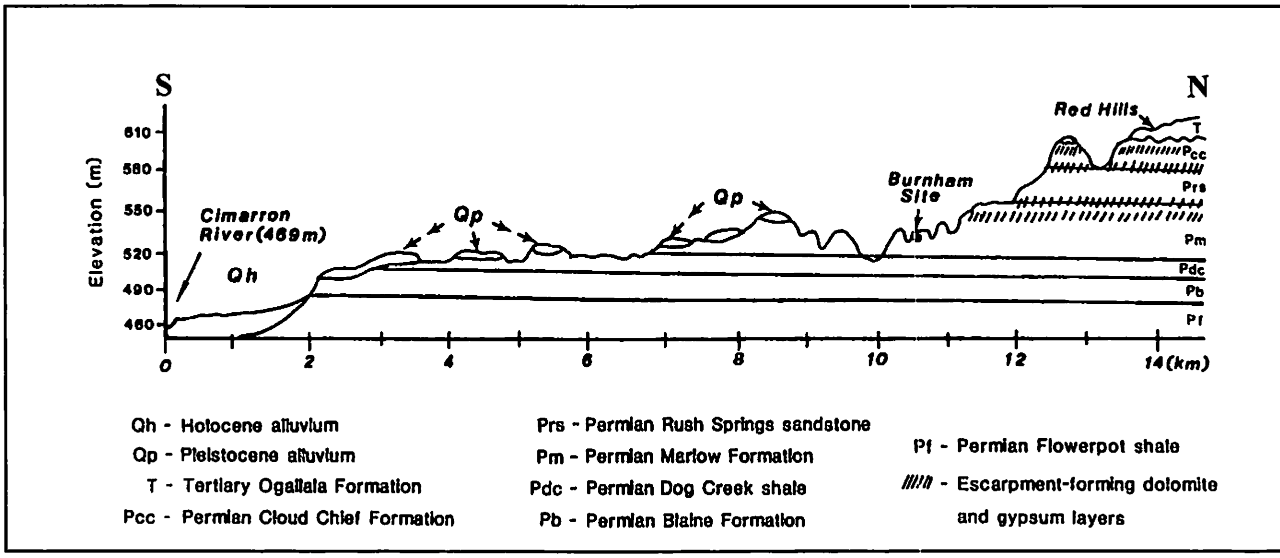


Figure 1.7. North-south topographic cross section through the Burnham site, Woods County, Oklahoma. Prepared by Brian J. Carter.

Given that the historical climate is usually dry during the growing season, it is little wonder that the prevailing pre-farming vegetation was short grasses. Most common in the uplands were buffalo grass (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), hairy grama (*B. hirsuta*), and yucca (*Yucca glauca*; Blair and Hubbell 1938:441). Small annuals noted (ibid.) to occur in this association include fescue (*Festuca octoflora*), and stick-tights (*Lappula occidentale*). Willows (*Salix* sp.) and cottonwoods (*Populus deltoides*) flourish in moist, sandy locations along streams (ibid.), and hackberry (*Celtis* sp.) grows spottily along ravines and draws draining the uplands. Over the past 50 years, red cedar (*Juniperus virginianus*) has increasingly invaded upland draws and pastures as a result of historic fire suppression.

Before historic settlement, this country was noted for herds of bison (*Bison bison*), flocks of turkey (*Meleagris gallopavo*) and quail (*Colinus virginianus*), prairie dogs (*Cynomys ludovicianus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and mountain lions (*Felis concolor*; Chrisman 1998; Records 1997). Native people who historically frequented this country were the Osages from the east and the Kiowas, Comanches, and Southern Cheyennes from the Central and Southern Plains. Especially favored spots for camping and bison hunting were the Great Salt Plains, on the Salt Fork River some 50 miles east of the Burnham site, and the Big Salt Plain (Fig. 1.6). This latter location is on the Cimarron River just 7 miles southwest of the Burnham site (Fay 1965:Plate I).

Climatic fluctuations have noticeably affected vegetation in Woods County twice in the past century. In the 1930s, western Woods County was on the eastern edge of the droughts that created the Dust Bowl on the Southern Plains of the Oklahoma and Texas panhandles (Worster 1979). In 1933, the official total annual precipitation recorded for Alva (30 miles east of Burnham) was only 15.47 inches (39.3 cm; Fitzpatrick et al. 1950:Table 1). In the 1950s, this area was impacted again by below average precipitation. In 1954, near the beginning of a six-year drought, Freedom received 10.34 inches (26.3 cm) of annual precipitation (U.S. Department of Commerce, Annual Climatological Summary, 1954). This 1950s drought had disastrous effects on crops and pastures in the Burnham locality. Elsewhere in Oklahoma, the 1950s drought caused dramatic, measureable losses of upland forests (Rice and Penfound 1959).

Site Relevance to Pleistocene Studies

The Burnham site initially interested us because it contained a bison skull that looked like a form that existed early in the last (Wisconsinan) ice age. Uncovered by mechanical grading, this skull was *in situ* in snail-rich, gray sediments. The skull manifested broadly sweeping, large horn cores that paleontologist Larry Martin thought could represent *Bison latifrons*. Seven examples of this species are reported within 150 miles of the Burnham site (Wyckoff and Dalquest 1997), but only two of these come from deposits that yielded other vertebrate or invertebrate fauna. Because horse and mammoth bones and diverse snail shells readily were visible at the Burnham exposures, the locations seemed to offer an opportunity to study fauna and the environment of a Wisconsinan setting in this part of the Plains.

Actually, much information on ancient settings and biota exists for this part of the Great Plains. Just northwest of the Burnham site lies Meade County, Kansas. Here, the late Claude W. Hibbard started paleontological studies over 60 years ago (Zakrzewski 1975). Beginning in 1936 and continuing through 39 subsequent summer field sessions, Hibbard and his students surveyed, tested, and intensively dug at dozens of vertebrate and invertebrate paleotological sites in Meade County. These locations are mostly in the Crooked Creek watershed. Draining south off the High Plains,

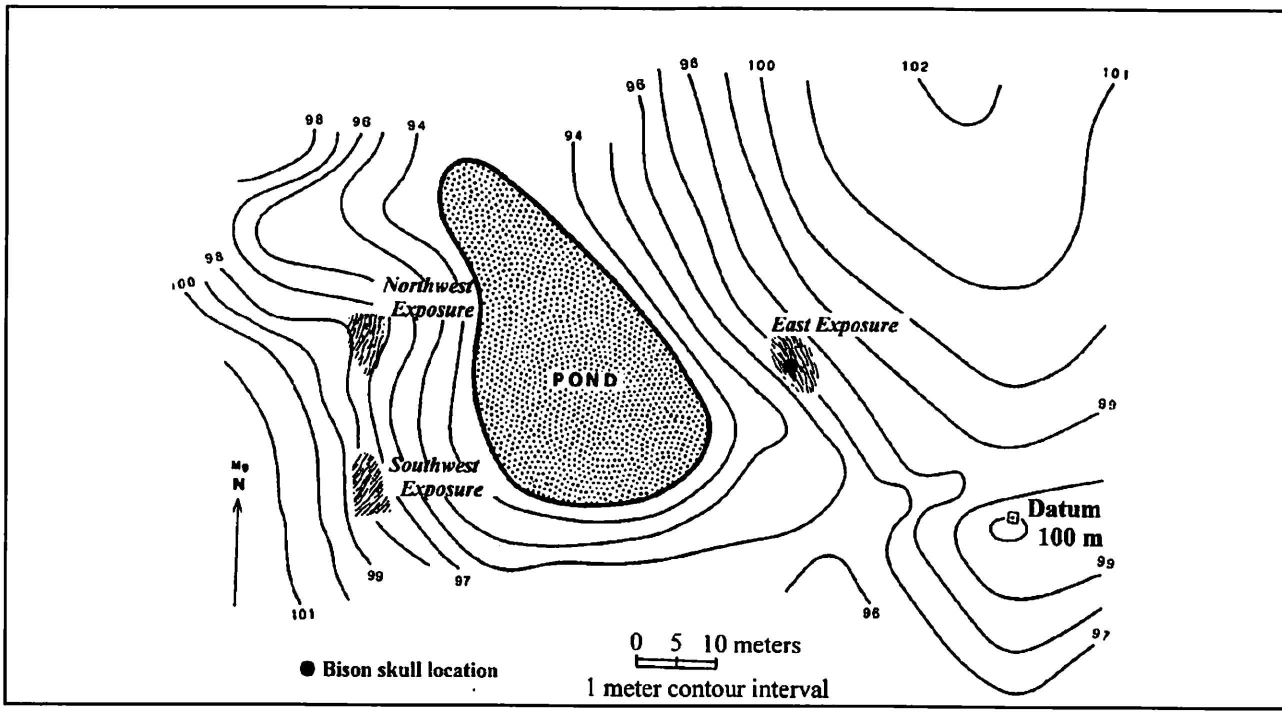


Figure 1.8. Contour map of the Burnham site prior to the October 1986 fieldwork.

Crooked Creek joins the Cimarron River some 40 miles west of the Burnham site (Fig. 1.9).

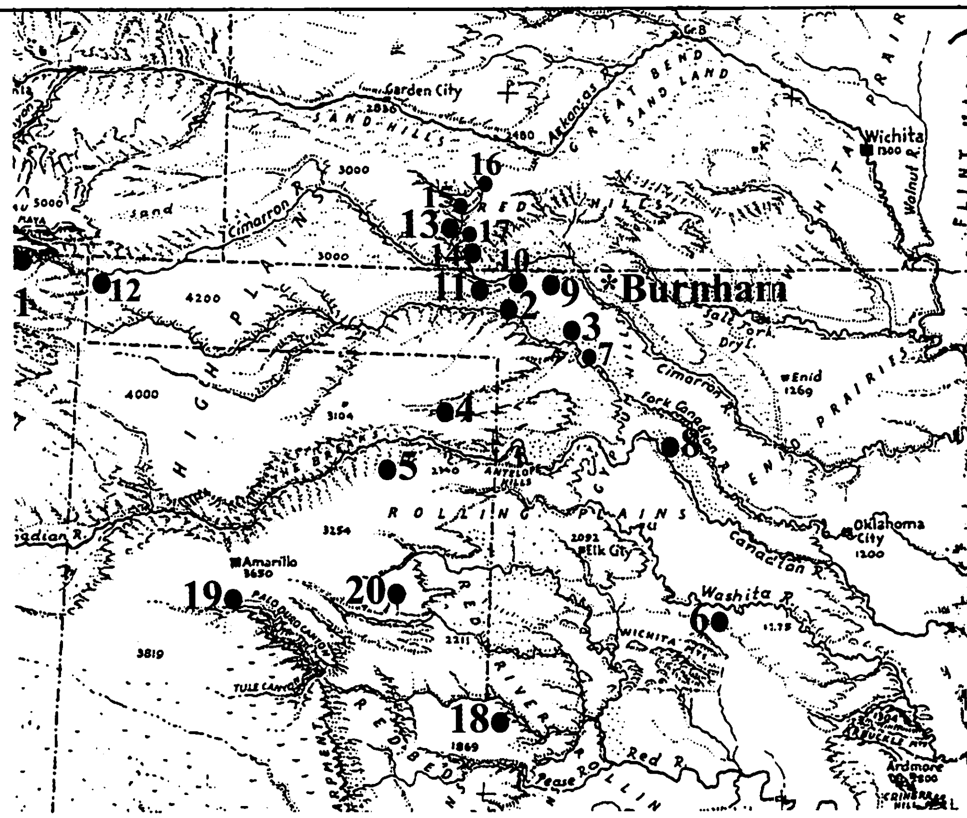
The many fossil-bearing sites studied by Hibbard and his students occur in different, and sometimes stratified (occasionally with volcanic ash beds), geologic contexts throughout the Crooked Creek drainage. The fossil-bearing locations in Meade County have yielded an exceptional North American record of a long succession of vertebrate and invertebrate fauna (Frye and Hibbard 1941b; Hibbard 1937, 1950; Hibbard and Riggs 1949). The majority were interpreted as Pleistocene.

As they worked with the Meade County sequence of fossil mammals and gastropods, Hibbard and his students believed they could correlate different faunal assemblages with the Pleistocene glacial-interglacial cycles as these were understood in the 1950s and 1960s (Hibbard 1958, 1960, 1970: Hibbard et al. 1965). Since Hibbard's (1970) last such correlation, much has been learned about the duration and cyclicity of the Pleistocene glacial-interglacial periods and the ages of the Meade County faunal assemblages (Miller 1975; Morrison 1991; Richmond and Fullerton 1986; Smiley et al. 1991). With the application of radiocarbon and other dating techniques to materials from Meade County sites, it is evident these fossil assemblages comprise a discontinuous record that goes back more than two million years (Miller 1975; Miller and McCoy 1991; Zakrzewski 1975).

As noted above, volcanic ash deposits are recorded in this area. Once thought to represent a single ash fall (Frye and Leonard 1965), fission-track dating has provided evidence that these deposits are of different ages (Boellstorff 1976; Carter et al. 1990; Naeser et al. 1973). In fact, their ages range from roughly 0.5 to nearly 2.0 million years. Resulting from chronologically different caldera eruptions in the Rocky Mountains and the Sierra Nevadas, these ash beds are proving to be important Pleistocene markers for studying past landscapes, erosion rates, soil development, and fossil assemblages older than can be assessed by radiocarbon dating (Carter 1985, 1991; Carter et al. 1990; Boellstorff 1976; Boellstorff and Steineck 1975; Naeser et al. 1973; Ward 1990, 1991a, 1991b).

Meade County fossil sites with late Pleistocene dates are shown in Figure 1.9. Also illustrated are selected late Pleistocene paleontological and archaeological sites reported for northwestern Oklahoma, northeastern New Mexico, and the Texas panhandle. The archaeological sites include many of the first studied camps and game kills yielding evidence that people inhabited North America during the last stages of the Wisconsinan ice age. These sites are now affiliated with the Clovis and Folsom material cultures recognized on the Southern Plains (Hofman 1989; Gunnerson 1987; Holliday 1997).

The geologic settings, contents, and ages of the late Pleistocene paleontological and archaeological sites near Burnham are very similar to those reported (Caran and Baumgardner 1990; Gustavson et al. 1991) for the southern part of the Texas panhandle. There, the exposures constitute a thick, complex sequence of aeolian, fluvial, lacustrine, and alluvial-fan deposits considered a "sediment apron" (the Lingos Formation) that lies directly east of the Southern High Plains escarpment (Caran and Baumgardner 1990).



1. *Folsom site (Haynes et al. 1992; Wormington 1957)*
2. *Waugh (Folsom) site (Hofman 1991, 1995; Hill and Hofman 1997)*
3. *Cooper (Folsom) site (Bement 1999)*
4. *Lipscomb (Folsom) site (Hofman1995; Hofman and Todd 1990; Hofman et al. 1989, 1991; Todd et al. 1990, 1992; Schultz 1943)*
5. *Miami (Clovis) site (Holliday et al., 1994; Sellards 1938)*
6. *Domebo (Clovis) site (Leonhardy 1966)*
7. *Bartow mammoth (Kerr 1964; Pitts 1969)*
8. *Hajny mammoth (Wyckoff et al. 1992)*
9. *Bar M fauna site (Miller 1975; Myers 1965; Shaak and Franz 1978; Taylor and Hibbard 1955)*
10. *Doby Springs faunal site (Stephens 1960)*
11. *Berends fauna site (Miller 1966)*
12. *Tesesquite Canyon fauna site (Dalquest and Stangl 1989)*
13. *Crooked Creek locality, Bird fauna site (Miller 1975; Stettenheim 1957)*
14. *Crooked Creek locality, Robert fauna site (Miller 1975; Schultz 1969)*
15. *Crooked Creek locality, Spring Valley fauna site (Davis 1975)*
16. *Crooked Creek locality, Boyd fauna site (Miller 1975)*
17. *Crooked Creek locality Classen fauna site (Miller 1975)*
18. *Howard Ranch fauna site (Dalquest 1965)*
19. *Little Sunday Canyon fauna site (Johnson and Savage 1955)*
20. *Carrol Creek fauna site (Kasper 1989)*

Figure 1.9. Selected archaeological and paleontological sites near the Burnham site (34WO73), Woods County, Oklahoma. Adapted from Raiz 1957.

No pretense is made that the initial field work at the Burnham site was undertaken to clarify geologic relationships between the Lingos Formation in northwest Texas and similar deposits in southwestern Kansas and adjacent parts of Oklahoma. The Burnham site did represent an opportunity to conduct taphonomic studies on ancient bone-bearing deposits. Moreover, the Burnham site was in Oklahoma, the one Southern Plains state where Pleistocene paleontological sites seldom have been studied in detail. Thus it was that we undertook paleontological salvage and test excavations there in late October of 1986. Little did we know what we were getting into.

References Cited

Bement, L. C. 1999. *Bison Hunting at Cooper Site, Where Lightning Bolts Drew Thundering Herds.* University of Oklahoma Press, Norman.

Blair, W. F. and T. H. Hubbell. 1938. The Biotic Districts of Oklahoma. *The American Midland Naturalist* 20:425-455.

Boellstorff, J. D. 1976. The Succession of Late Cenozoic Volcanic Ashes in the Great Plains: A Progress Report. *Stratigraphy and Faunal Sequences-Meade County, Kansas, Guidebook of the 24th Annual Midwestern Friends of the Pleistocene*, compiled by C.K. Bayne, pp. 37-71. Kansas Geological Survey, Guidebook Series 1. Lawrence.

Boellstorff, J. D. and P. L. Steineck. 1975. The Stratigraphic Significance of Fission Track Ages on Volcanic Ashes in the Marine Late Cenozoic of Southern California. *Earth Planetary Science Letter* 27:143-154.

Caran, S. C. and R. W. Baumgardner, Jr. 1990. Quaternary Stratigraphy and Paleoenvironments of the Texas Rolling Plains. *Bulletin of the Geological Society of America* 102:768-785.

Carter, B. J. 1985. Preliminary Study of Soil-Landscape Age Using Pleistocene Volcanic Ash Buried in High Terrace Deposits across Oklahoma. *Geological Society of America, Abstracts of Programs* 17:153.

Carter, B.J. 1991. Soils and Soil Parent Material in Northwest Oklahoma. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 15-23. Oklahoma State University, Department of Agronomy, Stillwater.

Carter, B. J., P. A. Ward III, and J. T. Shannon. 1990. Soil and Geomorphic Evolution within the Rolling Red Plains Using Pleistocene Volcanic Ash Deposits. *Geomorphology* 3:471-488.

Chrisman, H. E. 1998. *Lost Trails of the Cimarron.* University of Oklahoma Press, Norman.

Dalquest, W. W. 1965. New Pleistocene Formation and Local Fauna from Hardeman County, Texas. *Journal of Paleontology* 39(1):63-79.

Dalquest, W. W. and G. E. Schultz. 1992. *Ice Age Mammals of Northwestern Texas.* Midwestern State University, Wichita Falls.

Dalquest, W. W. and F. B. Stangl, Jr. 1989. Late Pleistocene Mammals from the Northwestern Corner of the Oklahoma Panhandle. *Texas Journal of Science* 41(1):35-47.

Davis, L. C. 1975. *Late Pleistocene Geology and Paleoecology of the Spring Valley Basin, Meade County, Kansas.* Ph.D. dissertation, Department of Geology, University of Iowa, Iowa City.

Fay, R. O. 1965. *Geology of Woods County.* Oklahoma Geological Survey, Bulletin 106.

Fenneman, H. M. 1931. *Physiography of Western United States.* McGraw-Hill Book Company, Inc., New York.

Fitzpatrick, E. G., O. E. Stout, W. W. Lytle, and D. H. McMahen. 1950. *Soil Survey of Woods County.* U.S. Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering. Washington, D.C.

Frye, J. C. and C. W. Hibbard. 1941a. Pliocene and Pleistocene Stratigraphy and Paleontology of the Meade Basin, Southwestern Kansas. *State Geological Survey of Kansas, Bulletin* 38(13):389-424.

Frye, J.C. and C. W. Hibbard. 1941b. Stratigraphy and Paleontology of a New Middle and Upper Pliocene Formation of South-Central Kansas. *Journal of Geology* 49(3):261-278.

Frye, J. C. and A. B. Leonard. 1965. Quaternary of the Southern High Plains. *The Quaternary of the United States*, edited by H.E. Wright, Jr. and D.G. Frey, pp. 203-206. Princeton University Press, Princeton, New Jersey.

Gunnerson, J. H. 1987. *Archaeology of the High Plains.* U.S. Bureau of Land Management, Cultural Resources Series 10. Denver.

Gustavson, T. C., R. W. Baumgardner, Jr., S. C. Caran, V. T. Holliday, H. H. Mehnert, J. M. O'Neill, and C. C. Reeves, Jr. 1991. Quaternary Geology of the Southern Great Plains and an Adjacent Segment of the Rolling Plains. *Quaternary Nonglacial Geology, Conterminous United States*, edited by R.B. Morrison, pp. 477-501. Geological Society of America, The Geology of North America, Vol. K-2. Boulder.

Gustavson, T. C. and R. J. Finley. 1985. *Late Cenozoic Geomorphic Evolution of the Texas Panhandle and Northeastern New Mexico—Case Studies of Structural Controls on Regional Drainage Development.* University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 148.

Gustavson, T. C. and W. W. Simpkins. 1989. *Geomorphic Processes and Rates of Retreat Affecting the Caprock Escarpment, Texas Panhandle.* University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 180.

Haynes, C. V., Jr., R. P. Beukens, A. J. T. Jull, and O. K. Davis. 1992. New Radiocarbon Dates for Som Old Folsom Sites: Accelerator Technology. *Ice Age Hunters of the Rockies*, edited by D.J. Stanford and J.S. Day, pp. 83-100. Denver Museum of Natural History and University Press of Colorado, Niwot, Colorado.

Hibbard, C. W. 1937. An Upper Pliocene Fauna from Meade County, Kansas. *Transactions of the Kansas Academy of Science* 40:239-265.

Hibbard, C.W. 1949. Pleistocene Stratigraphy and Paleontology of Meade County, Kansas. *University of Michigan, Museum of Paleontology, Contributions* 7(5):63-90.

Hibbard, C.W. 1950. Mammals of the Rexroad Formation of Fox Canyon, Meade County, Kansas. *University of Michigan, Museum of Paleontology, Contributions* 8(6):113-192.

Hibbard, C.W. 1958. New Stratigraphic Names for Early Pleistocene Deposits in Southwestern Kansas. *American Journal* Plains and Central Lowlands Province of the United States.

Hibbard, C.W. 1960. An Interpretation of Pliocene and Pleistocene Climates in North America. *Michigan Academy of Science, Arts, and Letters, 62nd Annual Report*, pp. 5-30.

Hibbard, C.W. 1970. Pleistocene Mammalian Local Faunas from the Great Plains and Central Lowlands Provinces of the United States. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Knox, Jr., pp. 395-433. University of Kansas, Department of Geology, Special Publication 3.

Hibbard, C. W., D. E. Ray, D. E. Savage, D. W. Taylor, and J. E. Guilday. 1965. Quaternary Mammals of North America. *The Quaternary of the United States*, edited by H.E. Wright, Jr. and D.G. Frey, pp. 509-525. Princeton University Press, Princeton, New Jersey.

Hibbard, C. W. and E. S. Riggs. 1949. Upper Pliocene Vertebrates from Keefe Canyon, Meade County, Kansas. *Bulletin of the Geological Society of America* 60:829-860.

Hill, M. E., Jr. and J. L. Hofman. 1997. The Waugh Site: A Folsom-Age Bison Bonebed in Northwestern Oklahoma. Southern Plains Bison Procurement and Utilization from Paleoindian to Historic, edited by L.C. Bement and K.J. Buehler, pp. 63-83. *Plains Anthropologist Memoir* 29.

Hofman, J. L. 1989. Chapter 4: Prehistoric Culture History-Hunters and Gatherers in the Southern Plains. From Clovis to Comanchero: Archeological Overview of the Southern Great Plains, by J.L. Hofman, R.L. Brooks, J.S. Hays, D.W. Owsley, R.J. Jantz, M.K. Marks, and M.H. Manhein. *Arkansas Archeological Survey, Research Series* 35:25-60.

Hofman, J.L. 1991. The Waugh Site: A Folsom-Bison Association in Northwestern Oklahoma. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 24-37. Oklahoma State University, Department of Agronomy, Stillwater.

Hofman, J.L. 1995. Dating Folsom Occupations on the Southern Plains: the Lipscomb and Waugh Sites. *Journal of Field Archaeology* 22(4):421-427.

Hofman, J. L. and L. C. Todd. 1990. The Lipscomb Bison Quarry: 50 Years of Research. *Transactions of the 25th Regional Archaeological Symposium for Southeastern New Mexico and Texas*, edited by P. Brothers, pp. 43-58. Midland Archaeological Society, Midland, Texas.

Hofman, J. L., L. C. Todd, C. B. Schultz, and W. Hendy. 1991. The Lipscomb Bison Quarry: Continuing Investigation at a Folsom Site on the Southern Plains. *Bulletin of the Texas Archeological Society* 60:149-189.

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

Holliday, V. T., C. V. Haynes, Jr., J. L. Hofman, and D. J. Meltzer. 1994. Geoarchaeology and Geochronology of the Miami (Clovis) Site, Southern High Plains of Texas. *Quaternary Research* 41(2):234-244.

Johnson, H. L. and C. E. Duchon. 1995. *Atlas of Oklahoma Climate.* University of Oklahoma Press, Norman.

Johnson, C. S. and D. E. Savage. 1955. A Survey of Various Late Cenozoic Vertebrate Faunas of Faunas of the Panhandle of Texas, Part I:Introduction, Description of Localities, Prelimiminary Faunal Lists. *University of California Publication in Geological Science* 31:27-50.

Kasper, S. 1989. *Vertebrates from the Late Pleistocene Carrol Creek Local Fauna, Donley County, Texas.* M.S. thesis, Department of Biology, Midwestern State University, Wichita Falls, Texas.

Kasper, S. 1992. Mammals from the Late Pleistocene Carrol Creek Local Fauna, Donley County, Texas. *Southwestern Naturalist* 37(1):54-64.

Kasper, S. and D. Parmley. 1990. A Late Pleistocene Herpetofauna from the Lower Texas Panhandle. *Texas Journal of Science* 42(3):289-294.

Kerr, H. P. 1964. The Bartow Mammoth Site. *Newsletter of the Oklahoma Anthropological Society* 12(5)4-8.

Leonhardy, F. C. (editor). 1966. *Domebo: A Paleo-Indian Mammoth Kill in the Prairie-Plains.* Contributions of the Museum of the Great Plains 1. Lawton.

Madole, R. F., C. R. Ferring, M. J. Guccione, S. A. Hall, C. Johnson, and C. J. Sorenson. 1991. Quaternary Geology of the Osage Plains and Interior Highlands. *Quaternary Nonglacial Geology, Conterminous United States*, edited by R.B. Morrison, pp. 503-546. Geological Society of America, The Geology of North America, Vol. K-2. Boulder.

Miller, B. B. 1966. Five Illinoian Molluscan Faunas from the Southern Great Plains. *Malocologia* 4(1):173-260.

Miller, B.B. 1975. A Sequence of Radiocarbon-Dated Wisconsinan Nonmarine Molluscan Faunas from Southwestern Kansas-Northwestern Oklahoma. *Studies on Cenozoic Paleontology and Stratigraphy*, edited by G.R. Smith and N.E. Friedlund, pp. 9-18. University of Michigan, Museum of Paleontology, Ann Arbor.

Miller, B. B. and W. D. McCoy. 1991. Age of Late Cenozoic Fossil Assemblages from SW Kansas and NW Oklahoma Interpreted from Isoleucine Epimirization Data. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 73-81. Oklahoma State University, Department of Agronomy, Stillwater.

Morris, J.W., C.R. Goins, and E.C. McReynolds. 1986. *Historical Atlas of Oklahoma*, 3rd edition. University of Oklahoma Press, Norman.

Morrison, R. B. 1991. Introduction. *Quaternary Nonglacial Geology: ConterminousUnited States*, edited by R.B. Morrison, pp. 1-12. Geological Society of America, The Geology of North America, Vol. K-2. Boulder.

Myers, A. J. 1965. Late Wisconsinan Date for the Bar M Local Fauna. *Oklahoma Geology Notes* 25:168-170.

Naeser, C. W., G. A. Izett, and R. E. Wilcox. 1973. Zircon Fission-Track Ages of Pearlette Family Ash Beds in Meade County, Kansas. *Geology* 1:187-189.

Osterkamp, W. R., M. M. Fenton, T. C. Gustavson, R. F. Hadley, V. T. Holliday, R. B. Morrison, and T. J. Toy. 1987. Chapter 6: Great Plains. *Geomorphic Systems of North America*, edited by W.L. Graff, pp. 163-210. Geological Society of America, Centennial Special Vol. 2. Boulder.

Pitts, B. 1969. Dating the Bartow Mammoth. *Newsletter of the Oklahoma Anthropological Society* 17(6):5.

Raiz, E. 1957. *Landforms of the United States.* Sixth edition of privately printed map.

Records, L. S. 1997. *Cherokee Outlet Cowboy.* Edited by E.J. M. Wheeler. University of Oklahoma Press, Norman.

Rice, E. L. and W. T. Penfound. 1959. The Upland Forests of Oklahoma. *Ecology* 40(4):593-608.

Richmond, G. M. and D. S. Fullerton. 1986. Summation of Quaternary Glaciations in the United States of America. *Quaternary Glaciations in the Northern Hemisphere*, edited by V. Sibrava, D.Q. Bowen, and G.M. Richmond, pp. 183-196. Pergamon Press, New York.

Schultz, C. B. 1943. Some Artifact Sites of Early Man in the Great Plains and Adjacent Areas. *American Antiquity* 8(3):242-249.

Schultz, G. E. 1969. *Geology and Paleontology of a Late Pleistocene Basin in Southwest Kansas.* Geological Society of America, Special Paper 105. Boulder.

Sellards, E. H. 1938. Artifacts Associated with Fossil Elephant. *Bulletin of the Geological Society of America* 49:999-1010.

Shaak, G. D. and R. Franz. 1978. Faunal Succession and Environments of Deposition of Pleistocene Lake Buffalo, Northwestern Oklahoma. *Oklahoma Geology Notes* 38:175-190.

Simpkins, W. W. and T. C. Gustavson. 1987. *Erosion Rates and Processes in Subhumid and Semiarid Climates, Texas Panhandle: Statistical Evaluation of Field Data.* University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 162.

Smiley, T. L., R. A. Bryson, J. E. King, G. J. Kukla, and G. I. Smith. 1991. Quaternary Paleoclimates. *Quaternary Nonglacial Geology,Conterminous United States*, edited by R.B. Morrison, pp. 13-44. Geological Society of America, The Geology of North America, Vol. K-2. Boulder.

Stephens, J. J. 1960. Stratigraphy and Paleontology of a Late Pleistocene Basin, Harper County, Oklahoma. *Bulletin of the Geological Society of America* 71:1675-1702.

Stettenheim, P. 1957. Bird Fossils from the Late Pleistocene of Kansas. *Wilson Bulletin* 70:197-199.

Taylor, D. W. and C. W. Hibbard. 1955. A New Pleistocene Fauna from Harper County, Oklahoma. *Oklahoma Geological Survey, Circular* 37. Norman.

Todd, L. C., J. L. Hofman, and C. B. Schultz. 1990. Seasonality of the Scottsbluff and Lipscomb Bison Bonebeds:Implications for Modeling Paleoindian Subsistence. *American Antiquity* 55(4):813-827.

Todd, L.C., J. L. Hofman, and C.B. Schultz. 1992. Faunal Analysis and Paleoindian Studies: A Re-examination of the Lipscomb Bison Bonebed. *Plains Anthropologist* 37(139):137-165.

Ward, P. A., III. 1990. *Uranium Fission-Track Dating of Glass Shards from Selected Volcanic Ash Deposits in the Southern High Plains Border Region.* M.S. thesis, Department of Agronomy, Oklahoma State University. Stillwater.

Ward, P.A., III. 1991a. Glass Shard Uranium Fission-Track Ages of Volcanic Ash Deposits in the High Plains Border Region. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 50-64. Oklahoma State University, Department of Agronomy, Stillwater.

Ward, P.A., III. 1991b. Preliminary Correlations of Southern High Plains Border Volcanic Ashes. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 65-72. Oklahoma State University, Department of Agronomy, Stillwater.

Wormington, H.M. 1957. *Ancient Man of North America.* Denver Museum of Natural History, Popular Series 4. Denver.

Worster, D. 1979. *Dust Bowl, The Southern Plains in the 1930s.* Oxford University Press, New York.

Wyckoff, D. G., B. J. Carter, P. Flynn, L. D. Martin, B. A. Branson, and J. L. Theler. 1992. *Interdisciplinary Studies of the Hajny Mammoth Site, Dewey County, Oklahoma.* Oklahoma Archeological Survey, Studies of Oklahoma's Past 17. Norman.

Wyckoff, D. G. and W. W. Dalquest. 1997. From Whence They Came: The Paleontology of Southern Plains Bison. Southern Plains Bison Procurement and Utilization from Paleoindian to Historic, edited by L.C. Bement and K.J. Buehler, pp. 5-52. *Plains Anthropologist Memoir* 29.

Zakrzewski, R. J. 1975. Pleistocene Stratigraphy and Paleontology in Western Kansas: The State of the Art, 1974. *Studies on Cenozoic Paleontology and Stratigraphy*, edited by G.R. Smith and N.E. Friedland, pp. 121-134. University of Michigan, Museum of Paleontology, Ann Arbor.

Chapter 2
History of the Burnham Site Research

Don G. Wyckoff and Peggy Rubenstein

Investigation of the Burnham site began in 1986. The unexpected discovery of archaeological materials from a geologic context predating the last glacial maximum led to intensive field work in 1988, 1989, 1991, and 1992. In addition, between 1986 and 1992, innumerable brief excursions were taken to check on the site's condition, inspect particular details of its geology, and investigate fossil finds there and at nearby locations. The intensive field sessions were undertaken to resolve questions about the presence of human artifacts, their contexts, and their age.

A Burnham site research team was established in 1989 for the field work that was partially funded by the National Geographic Society. Unfortunately, not all members of this team were able to be there throughout the 1989 field work or to participate in all subsequent field sessions. As principal investigator, Don Wyckoff was on hand for all field work. Soils scientist Brian Carter and archeologist Kent Buehler were present for nearly two-thirds of all field investigations. All other team members were there for less than a fourth. As a result, some of these individuals' contributions to this monograph are based on their observations and findings during particular segments of the field research. For that reason, a history of the Burnham site research is merited. Such a history serves to acquaint the reader with the sequence of field work, the diverse questions or goals being addressed during each field session, and who was involved with the work.

Thanks to colleagues like Brian Carter, Jim Theler, Larry Todd, and Jack Hofman, the overriding emphasis of the Burnham site research has been learning how and when the artifacts got to where we found them. Now is the time to lay these findings before interested scholars and let them decide the significance.

Initial Discovery

It was late May of 1986 when Vic Burnham called Don Wyckoff and reported that brother Gene Burnham had uncovered some large bones while building a small erosion-control dam in a ravine on their dad's property. Wyckoff had met the Burnhams in 1984 while visiting western Woods County to look at archaeological sites with avocationalists Harold Kamas and Gwen Webber. Vic had a broken Folsom point he had found near his house, and he knew that Wyckoff was interested in studying artifacts and fossils that dated to the end of the last ice age. Between 1984 and 1986, Vic had called the Oklahoma Archaeological Survey several times about fossil finds. He and Gene operated earth-moving equipment to build ponds and terraces on eroding fields in western Woods County. Having already reported a mammoth tusk and part of a ground sloth skeleton, both of which were recovered by Oklahoma Archaeological Survey staff members, Vic was a person that the Survey staff had come to trust and respect.

The May 1986 call came at a fortuitous time. We had just completed recovery of mammoth and other fossil bones at the Hajny site (Wyckoff et al. 1992) some 70 miles southeast of western Woods County, and we were troubled by some geological findings there. Because Larry Martin, paleontologist at the University of Kansas, had agreed to analyze the non-mammoth bones from Hajny, Wyckoff called him and made arrangements for he and geologist Wakefield Dort to drive down and inspect the Hajny site in early June. We agreed to meet in Blackwell, a town in northern Oklahoma along Interstate 35. By going west from Blackwell, we could swing by the Burnham find, make a brief inspection, and then travel down and spend the rest of the day at the Hajny site.

Larry Martin, Wakefield Dort, and Don Wyckoff visited the site on June 9, 1986. Vic led us east through his dad's pasture to a ravine draining a field planted to sorghum. Near the ravine's mouth, an earthen dam had been built by grading down the ravine's banks and pushing dirt up from its floor. On the bulldozer-scraped slopes east and west of the dam were exposed discontinuous layers of gray sediment that contained many snail shells and some bone fragments. Mammoth and fossil horse were identifiable from pieces found on the west bank. On the east side the bulldozer had crushed horse or bison long bones and had scraped through part of an overturned bison skull. The visible horn core was very thick, and Larry Martin's first impression was that it could be *Bison latifrons*, the big-horned bison believed associated with early to middle Wisconsinan glacial times on the Southern Plains (Wyckoff and Dalquest 1997). Based on these finds, the site was considered to be potentially important for its vertebrate and invertebrate faunal record. On Larry Martin's recommendations, plans were made to return in the fall. At that time we would recover the skull of a rare form of bison and waterscreen about a ton of the surrounding gray sediment in order to obtain bones of small animals that would help us assess the site's potential for researching late Pleistocene environments.

October 14, 1986, Reconnaissance

On this date, Peggy Rubenstein and Don Wyckoff traveled to the Burnham site. Our visit was to accomplish two goals: plan the upcoming recovery of the bison skull and the field processing of sediment to retrieve bones of small vertebrates; and also assess the damage to the site. The area had received several hard rains over the summer, and we wanted to make sure the skull was intact.

We spent over two hours at the site looking at the fossil-bearing deposits and gathering bone fragments. Summer rains had washed off much of the loose, graded dirt; eroded rivulets into the slopes; and exposed the stratigraphy better than what was visible in early June. It now appeared that two separate bone-bearing, gray deposits were on the west side of the dam. The northernmost had the clear profile of a channel filled with alluvium, whereas the southernmost deposit seemed to be a lateral remnant of gleyed sediment that contained fewer gastropods and bones than that to the north (Fig. 2.1). East of the dam, nearly 2.0m of gray sediments seemed confined to a U-shaped channel and appeared capped by a thin (5 to 10cm) layer of nearly continuous carbonate, above which was red soil containing large, well solidified, carbobonate nodules (Plate 1a).

Although deep rivulets were on both its sides, the bison skull was not damaged by erosion. We planned to recover it by positioning it within a block of 1x1 meter squares which we would lay out relative to a site datum (with an assigned elevation of 100 m) on a little knoll some 15m southeast of the skull. Because the slopes were dry and hard, much of the rain had drained off to form a small pond behind the dam. Observing how hard the ground was, we decided to follow Larry Martin's suggestion that we waterscreen the gray sediment removed from the four squares around the skull. Using a water pump, we planned to wash the excavated fill from the base of the bison skull through 2mm mesh hardware cloth.

Skull Recovery and Sediment Sampling

We returned to the site to recover the bison skull and to sample the deposit for other bones on October 29, 1986. Assisting us were three volunteers from the Oklahoma Anthropological Society: Claude Long of Oklahoma City, Scott Francis of Perry, and Harold Brown of Ponca City.

A site datum was established on the knoll (with 5/8 inch rebar), and a north-south baseline for a metric grid was laid out along a magnetic north line north of the datum. An alidade and plane table were used to do this. From this baseline, we measured west and set up four 1x1m squares around the bison skull. This fossil was mainly in square S2-W22 (22 m west of the north-south baseline and 2 m south of our designated east-west baseline), but we also decided to excavate squares S1-W22, S1-W23, and S2-W23 in order to fully expose the skull and get it on a pedestal so that we could jacket it in plaster. This would stabilize the skull and enable removing it intact. Also, the removal of gray sediment from these adjacent squares would provide the amount of fill that Larry Martin suggested be waterscreened.

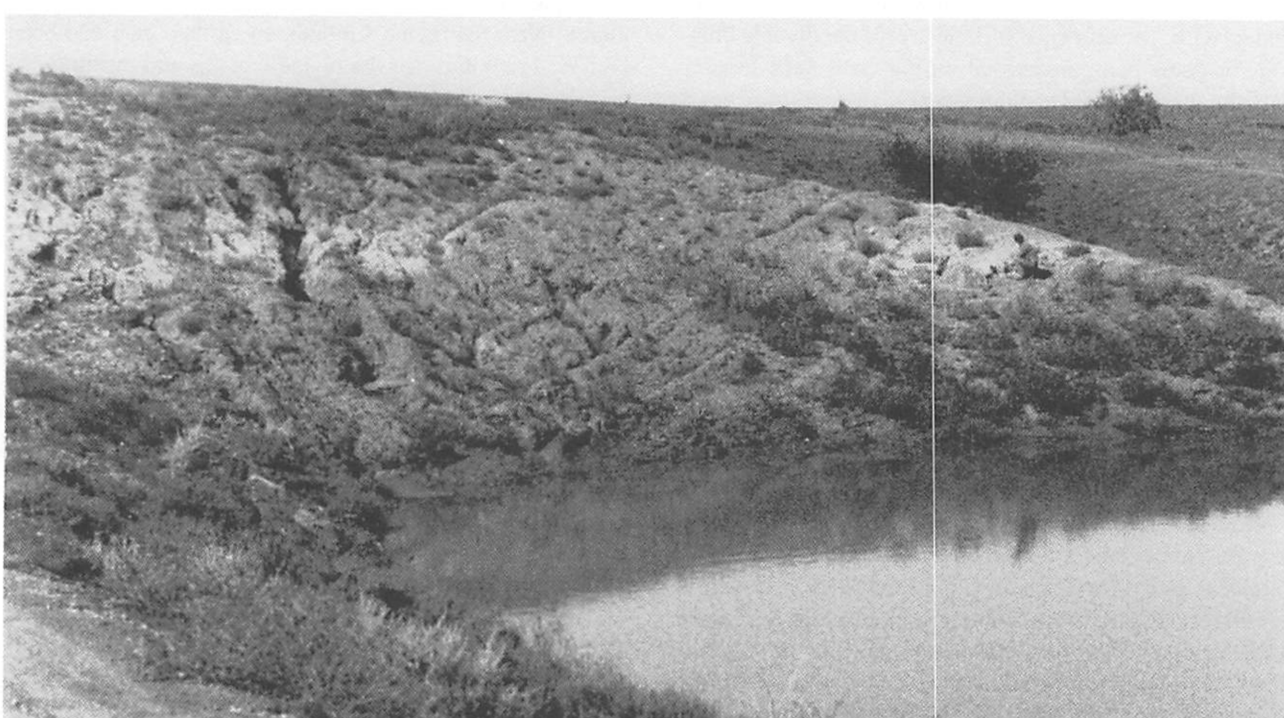


Figure 2.1. View northwest of the Southwest (left) and Northwest (right) exposures of gleyed sediments on the west side of the Burnham pond. Photo taken October 14, 1986, by Don Wyckoff.

Starting in square S1-W22 (Fig. 2.2), we dug in 10 cm levels that were measured from the northeast corner (stake 0-W22) where the sloping ground was at elevation 97.26m relative to datum (which had an assigned elevation of 100.0m). By starting nearly a meter north of the skull, we were able to dig carefully south toward and around the skull.

Our work revealed several notable characteristics of the deposit. First, the bulldozer had disturbed less than 5cm of the uppermost gray sediment (Fig. 2.3). Second, a discontinuous layer (3 to 6 cm thick) of hard carbonate extended across squares S1-W22 and S2-W22. This carbonate layer was above the north-sloping left side of the bison skull (Fig. 2.4). The skull was in an overturned position, and its right side was higher than the left. This right side was scraped by the bulldozer blade, removing the right side of the maxilla and nearly severing the right horn core (Fig. 2.5; Plate 1b). Third, as each 10 cm level was removed from the four squares, the floor of the excavation was carefully troweled. These cleaned floors revealed colorful swirls of gray, gray-green, yellow, and red sediments unbroken by any krotovinas or other disturbances traceable to the recently graded surface (Fig. 2.6). Lastly, as we reached a depth of 70 cm (ele. 96.56) below the graded surface at stakes 0-W22, S1-W22, and S2-W22, the bison skull was nearly completely exposed, and its remaining cranium and left maxilla were in gray sediment while its left horn core extended down through the gray sediment into an underlying red loamy sand.

Because of the angle at which the skull was lying, the left horn core required digging the northern squares deeper than the southern ones. While excavating these northern squares we encountered a bison left scapula and a large flint cobble (Fig. 2.7). Both were in the red sediment north of, and lower than, the bison skull. Both were plotted; the cobble was photographed *in situ;* and both were placed in bags labeled with all pertinent provenience information.

Figure 2.2. View northeast of excavation starting in square S1-W22 of East Exposure. Waterscreen set up at pond margin (lower left). Photo taken October 29, 1986, by Don Wyckoff.

We then finished removing sediment from around the skull. The skull was pedestaled so that it could be wrapped with strips of gunnysack and jacketed in plaster. While doing this final cleaning, we ascertained that the right horn core was essentially cut through by the bulldozer blade and that its unsheared portion was poorly preserved (Fig. 2.8). We also discovered that the bison's left mandible was lying directly under the skull. The proximal end was to the west, and this was carefully exposed so that the skull could be plastered and removed.

All fill from the 10cm levels dug from each square was washed through 2mm mesh hardware cloth on a portable nested screen loaned to us by Charles Wallis, archeologist with the Oklahoma Conservation Commission. All material recovered from the screen was kept and bagged according to square and level.

By the morning of November 1, we had the skull ready for jacketing and removal. However, this work could not be completed at that time. A cold front blew in that morning, the air temperature fell below freezing, and snow began to fall. Because the plaster would not set in the cold temperatures, the skull was carefully wrapped and covered with tarps.

We returned the next week and with the help of Lois Albert, Vic Burnham, Harold Kamas, and Gwen Webber, we jacketed the skull in plaster (Fig. 2.9). After it was dry, we cut it away from the pedestal and loaded it for the trip to the Oklahoma Archeological Survey laboratory in Norman. Also, we exposed and removed the left mandible that had been under the skull.

1987 Laboratory Work and Artifact Discovery

Notes about the field work and findings were published in the 1987 issue of *Current Research in the Pleistocene* and in the *Newsletter* of the Oklahoma Archeological Survey (Wyckoff and Flynn 1987; Wyckoff et al. 1987). In both cases, the site's potential for studying late Pleistocene environments was emphasized. To get some idea of the site's age, fragments of bison bone and samples of dark sediment from around the bison skull were submitted to the Washington State University Radiocarbon Lab.

During the following months, student lab helpers sorted through the waterscreened residue to separate potentially identifiable bone fragments from the thousands of snail shells, carbonate fragments, and occasional pebbles. Some seven months after the field work, the first of two flint flakes was found. Discovered during the sorting of waterscreened debris, this flake was complete with a flake-faceted platform (that slightly overhangs on the ventral face), a discernible bulb of force, and a dorsal face that shows scars of previously removed flakes. Within a month of this find, a broken, second flake was

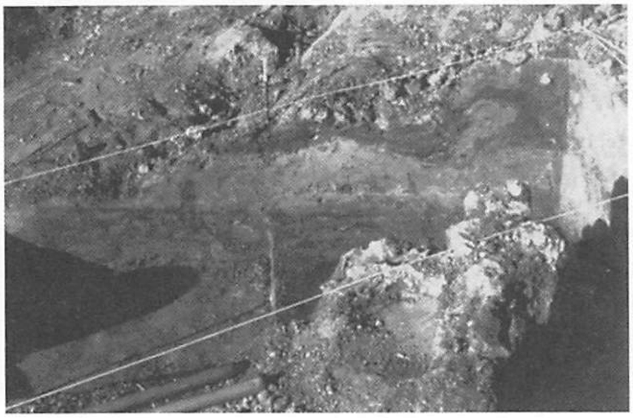


Figure 2.3. View northeast of north wall profile at square S1-W22 at 30 cm below the surface. Dark horizon on top is the depth of disturbance due to grading and erosion. Photo taken October 29,1986, by Don Wyckoff.

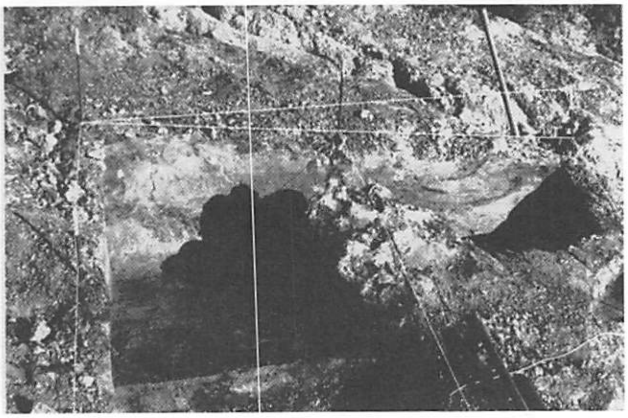


Figure 2.4. View east of carbonate layer over bison skull in squares S1-W23 and S2-W22. Photo taken October 29, 1986, by Don Wyckoff.

Figure 2.5. View southeast of bison skull being uncovered. Photo taken October 30, 1986, by Don Wyckoff.

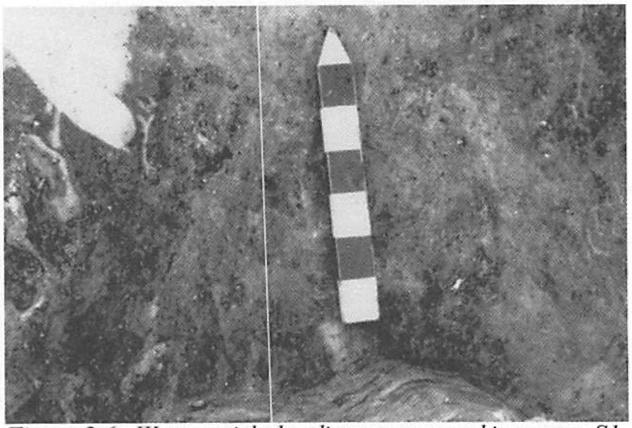


Figure 2.6. Water swirled sediments exposed in square S1-W22 directly north of the bison skull. Marker is in 5 cm increments and points north. Photo taken October 30, 1986, by Don Wyckoff.

found. It appeared to be of exotic stone, a root beer colored variety of Edwards chert from central Texas.

Both flakes looked to be of human origin. Both came from the gray sediment around the bison skull and from levels below those churned by the grading. The discovery of these flakes prompted reinspection of the Day Creek chert cobble found just below the bison skull. Upon cleaning, this cobble displayed two flake scars that were not abraded or had patina like others on the specimen. These scars looked like those made when a flintknapper tests a cobble.

By August of 1987, the staff at the Washington State University radiocarbon laboratory reported they were unable to obtain dates from the bone and sediment samples. Believing it imperative that some age estimate be established for the deposit, we submitted a sample of snail shells from 50 to 70 cm below the surface in square S1-W22 to a commercial laboratory. In October of 1987, Beta Analytic informed us that the sample dated 31,150 +/- 700 years ago (Beta-23045;Wyckoff and Flynn 1988). Even allowing for the often noted (Taylor 1987:52) unreliability of fresh water snails for accurate radiocarbon dates, that age seemed reasonable. By October, paleontologist Larry Martin had studied the bison skull and concluded that it represented a form transitional between *Bison latifrons* and *Bison antiquus*. Given the geologic ages of these two forms (McDonald 1981), the Burnham site radiocarbon date seemed consistent for an intermediate form like the Burnham skull.

In late October of 1987, we attended the annual meeting of the Texas Archeological Society. Held in Waco, a major symposium of this meeting focused on the interaction of humans and elephants in prehistory. Although we weren't participants in that symposium, Peggy gave the first public presentation of work and findings at the Burnham site at the meeting. Peggy's talk generated interest from several symposium participants, including Rob Bonnichsen who looked at the artifacts, discussed their geologic occurence, and encouraged us to continue studying the site.

Figure 2.7. View south of exposed bison skull with flint cobble under it. Photo taken November 1, 1986, by Don Wyckoff.

Figure 2.8. View northeast of bison skull lying in gray sediments. The mandible underlying it has not yet been exposed. Photo taken November 1, 1986, by Don Wyckoff.

Figure 2.9. View south of plaster jacketed bison skull in East Exposure of the Burnham site. Photo taken November 8, 1986, by Don Wyckoff.

The November 1987 Reconnaissance

Some questions posed at Waco caused Peggy Rubenstein and Don Wyckoff to return to the Burnham site on November 17 and 18, 1987. We did this to get a better understanding of the geology around the site. In particular, we wanted to learn just how unique were the gleyed, fossil-bearing sediments. Accordingly, we spent these two days walking ravines and studying profiles within a quarter mile radius of the site.

Our primary interest was to see if other gleyed deposits were present. If so, were they potentially related to the same geologic processes that created the Burnham site? Also, we were concerned to learn if archaeological materials were nearby and upslope. Could the artifacts found in the waterscreen debris have been redeposited from a Holocene archaeological site that had eroded in the past?

During our reconnaissance we saw many diverse exposures, most showing accumulations of carbonate enriched soil over Permian sandstone. We also observed redeposited Ogallala Formation gravels at scattered locations. No where did we find gleyed deposits with fossil bones or shells. We also didn't find any archeological sites. In essence, we came away with the impression that the gleyed deposits of the Burnham site were locally unique and that there was little likelihood that the artifacts from the deposits had been redeposited from a nearby Holocene or Pleistocene archaeological site.

1988 Proposal Submission

Based on our understanding of the Burnham site's age and the presence of human artifacts, we submitted a proposal to the National Geographic Society in January, 1988. This proposal sought funds to continue manual excavations near the bison skull in order to see if more artifacts could be found. Also, we proposed a series of backhoe trenches be dug at selected locations north and east of the bison skull. These were planned to expose the site's geologic contexts and hopefully help us learn more about the processes creating these contexts and their ages. Allowing for an eight month review period, we anticipated hearing about our proposal in August.

1988 Field Trips

Although pressed by several other projects, a couple of field trips were made to the Burnham site between January and August of 1988. These trips were prompted by several heavy rains and by Vic and Gene Burnham discovering additional fossil-bearing deposits in the vicinity.

On April 20, Don Wyckoff, Peggy Flynn, and Richard Drass (archaeologist with the Oklahoma Archeological Survey) visited the site after Vic Burnham called to report that some bones were washing out of the grey exposures west of the modern pond. There, we recovered several parts of horse leg bones and also several pieces of charcoal *in situ* in the gleyed deposits. On this trip we saw enough evidence to cause us to conclude that the two gleyed deposits west of the modern pond were not connected. Accordingly, we decided to refer to these deposits as the Southwest and Northwest Exposures so that we could appropriately provenience any fossils or artifacts found.

A second field trip occurred on July 29, 1988. Again, a rainstorm had swept the locality and washed graded dirt while cutting deep rivulets on the slopes east and west of the modern pond. On this trip, Francie Gettys (archaeologist with the Oklahoma Archeological Survey) joined Don Wyckoff to begin formal mapping of carbonate layers, identifiable fossil elements, and chert clasts evident at the three exposures. Our mapping focused mainly on the gleyed deposits east of the modern pond. We began referring to these sediments as the East Exposure. Twelve bone fragments were plotted at varying depths amidst the East Exposure deposits. A couple of these bones were encased in a thick caliche layer now visible capping nearly all of the gray sediments. Several dolomite and chert clasts were also plotted. A few of the latter were crushed by the grading machines; none showed signs of having been knapped prehistorically.

Another notable excursion to the site was made on August 14, 1988. Recent rain had cut significant gullies into the Southwest and Northwest Exposures. While destroying parts of these deposits, these gullies helped clarify the extent and depth of the gleyed deposits. They also provided more insight to the contents of these deposits. The Southwest Exposure was now readily visible as a meter thick layer and roughly 10m long (north-south) bed of greenish gray sandy loam sediments with few snails, occasional bones, and rare gravel clasts (Fig. 2.1). When identifiable, the bones typically were from prehistoric horse. In contrast, the Northwest Exposure had a U-shaped cross section filled with gray sandy loam that contained thousands of snail shells, occasional waterworn cobbles and boulders of Day Creek dolomite, and fragments of bones and teeth attributable to horse, mammoth, and turtle.

Another rain washed the site around August 22, 1988. Vic Burnham called Don Wyckoff to tell him that bones were washing out of the East Exposure. An August 24, 1988, trip to the site revealed that several parts of apparent ungulate leg bones were eroding out of an indurated layer of carbonate that seemed to cap the East Exposure (Fig. 2.10). Although fairly intact while in the carbonate layer, these bones broke up longitudinally while weathering out of the carbonate.

September 1988: Further Testing

By July of 1988, the National Geographic Society had notified us that they were not funding our proposal for intensive field work at the Burnham site. Their decision hinged on, "There just seems....to be little evidence of human presence there to go ahead on the basis you plan" (E.W. Snider letter of June 14, 1988). Unknown to the Society's Committee for Research and Exploration, eight more flint flakes had been found while Peggy and her student help sorted the remaining waterscreen residue. Two sections of flakes appeared to be of the translucent brown (root beer) variety of Edwards chert from central Texas. One other was the distal end of a secondary decortication flake of Ogallala quartzite.

Convinced that the East Exposure contained human artifacts, an appeal was made to 38 experienced and trusted members of the Oklahoma Anthropological Society to help conduct further excavations in September of 1988. The goals of the planned work were to see if more artifacts and bison bones could be found and to learn more about the stratigraphy of the deposit where they were found. Also, we hoped to recover material more suitable than snail shells for radiocarbon dating. Twenty-seven people volunteered and helped for different intervals between September 14 and 30, 1988. All funds for this work came from a few modest donations and from the very limited field budget of the Oklahoma Archeological Survey.

This 1988 excavation was all manual and concentrated on digging and waterscreening (2mm mesh) more sediments out of the initially excavated four squares (S1-W22, S1-W23, S2-W22, and S2-W23) as well as one more square (S3-W21) to the south and six to the north (Fig. 2.11). Approximately six cubic meters of sediment were dug and waterscreened. More bones of the large-horned bison were uncovered. Ribs were west of where the skull had been exposed, and parts of ribs and thoracic vertebrae were southeast. Especially exciting were two fragments of chipped stone tools, one a combination cutting-scraping implement and the other a portion of a bifacially flaked edge (Wyckoff 1988). Both were in the same stratum as the bison skull, and both were about 2.0 m north of the skull (Fig. 2.11). In addition to these artifacts, sorting the 1988 waterscreen residue recovered six more flakes. These were less than a centimeter in maximum dimension, and all looked like debris from resharpening chipped stone tools.

Because of the number of volunteers, it was possible to excavate in one of the other exposures. As it appeared to have more bone fragments, the Northwest Exposure was chosen. Besides recovery of faunal material, a test excavation of the Northwest Exposures enabled studying the taphonomic processes operating on bones there. Finally, human artifacts might also be recovered. Six 1x1m squares were staked out to form a north-south trench along the Northwest Exposure's easternmost edge. A 5/8 inch rebar was mapped adjacent this trench and marked with a known elevation (relative to site datum) so that levels could be measured (with string and line levels) as they were removed from the squares. All excavation was done with trowels, and all fill removed from each 10cm level of each square was kept separate and waterscreened through 2mm mesh hardware cloth. Although not all squares were dug to the same elevation, 0-S3 and 0-S4 were taken to elevation 96.54 where their floors clearly were in red, unconsolidated, loamy fine sand. This same material showed at 96.64 in square 0-S5, and the rest of the profile displayed gray sediment in a northwest-southeast trending wide, shallow, gully. A large, tabular boulder of Day Creek dolomite rested on the gully floor. It displayed water polish and scattered around it were broken bones with edges rounded and polished from sediment carried by water (Fig. 2.12). No artifacts were recovered from this trench in the Northwest Exposure.

All in all, the 1988 excavations revealed several notable details about the Burnham site. By now we had seen enough to believe that the three exposures were similar, but not alike. While not actually dug, the Southwest Exposure was evident because gullies now exposed east-west profiles through it. These showed nearly a meter thick stratum of greenish gray fine sandy loam which contained few gastropods, sparse animal bones, and rare charcoal flecks. The occasional bones found were of fossil horse, were not articulated, and occurred at different elevations in the sediment. This deposit was visible for nearly 10m and lay horizontally and not in a U-shaped basin. Hardly a dozen meters north, the Northwest Exposure stood in marked contrast. Consisting of greenish gray loamy fine sand, the Northwest Exposure's sediment clearly was confined to a U-shaped channel and contained thousands of gastropods and numerous fragments of bone and teeth. The latter were identifiable as horse, camel, and mammoth. Turtle was very evident among the bone fragments. Discovered at the base of the deposit, a large clast of dolomite and nearby bone fragments were abraded and polished, all bearing witness to fast flowing water of considerable volume. However, given its many complete aquatic snail shells, this U-shaped gully must have been cut by turbulant

Figure 2.10. View east of indurated calcium carbonate layer (above scale) containing some bones that capped the East Exposure of the Burnham site. Photo taken August 24, 1988, by Don Wyckoff.

runoff and then aggraded under a different stream regimen.

The 1988 work on the East Exposure was limited, but the findings furthered our view that those deposits were more diverse and complexly arranged than any manifest elsewhere on the site. By digging one meter south of the bison skull, we intersected the south edge of a prehistoric channel. Clearly, the bison skull and all recovered artifacts were within this channel. Moreover, the bison skull and all recovered artifacts were in one stratum of this channel. This stratum, a gray silt loam containing many gastropod shells, thins somewhat to the north and displays an unusually irregular (bioturbated?) boundary with the underlying red loamy fine sand (Fig. 2.13; Plates 2b and 3a). At the bison skull a discontinuous layer of hard carbonate nodules capped the gray silt loam (and the skull), but north of the skull these nodules were at essentially the same elevation but in a reddish brown loam, a stratum minimally expressed over the skull but much more evident two and three meters north. At least a meter above this reddish brown loam occurred a nearly continuous layer of indurated carbonate. This second carbonate layer seemed to cap the prehistoric gully. Because our excavations didn't extend far enough east, we didn't know what other strata lay between this uppermost carbonate layer and the reddish brown loam exposed on top of our excavations.

The 1986 and 1988 findings at the Burnham site were preliminarily reported (Flynn et al. 1988) at the 1988 Plains Anthropological Conference held between November 2 and 5 in Wichita, Kansas. After giving this presentation, Wyckoff was interviewed about the site and its contents by Karen Turnmire. This information was published (Tratebas 1989) in an article on the Burnham site in the *Mammoth Trumpet*, a quarterly newsletter of the Center for the Study of Early Man at the University of Maine.

Research Proposal Resubmission

From October 1988 through June 1989, students supervised by Kent Buehler, Lab Manager of the Oklahoma Archeological Survey, cleaned and sorted the waterscreen residue from the September 1988 excavations. Funds for this processing were provided by the University of Oklahoma Research Council. By June, we had 10 small resharpening flakes in addition to the 2 broken tools and 1 flaked cobble. Dr. Michael A. Mares, Director of the Oklahoma Museum of Natural History, gave us funds for more radiocarbon dates on the East Exposure deposits. Through the interest of Vance Haynes, Jr., Austin Long, and Doug J. Donahue, the Univer-

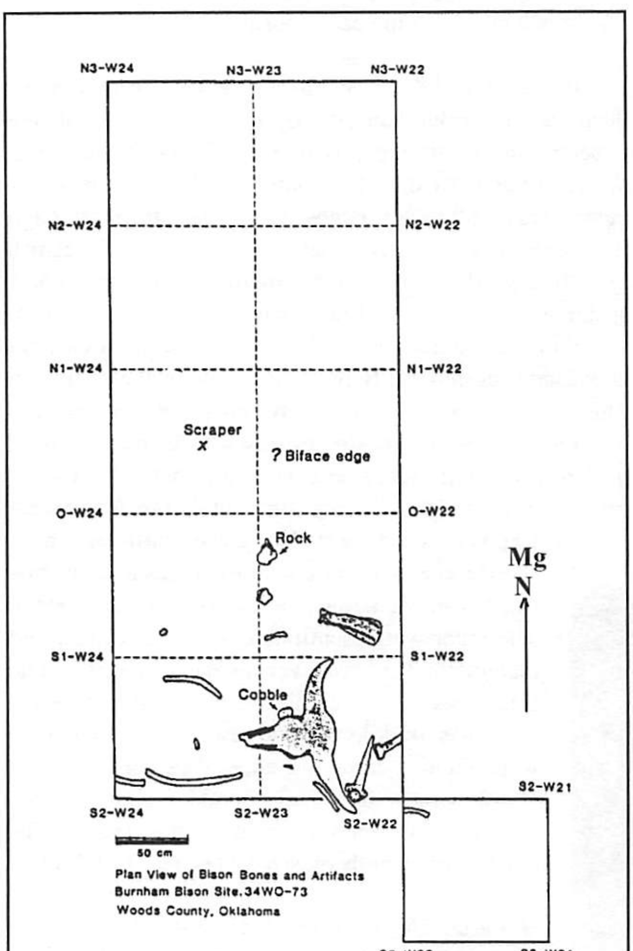


Figure 2.11. Bison bones and chipped stone items found in the 1988 excavations at the Burnham site's East Exposure.

Figure 2.12. Water polished boulder and bone fragments found in the 1988 testing of the Northwest Exposure. Marker points north and is in 5 cm increments. Photo taken September 28, 1988, by Don Wyckoff.

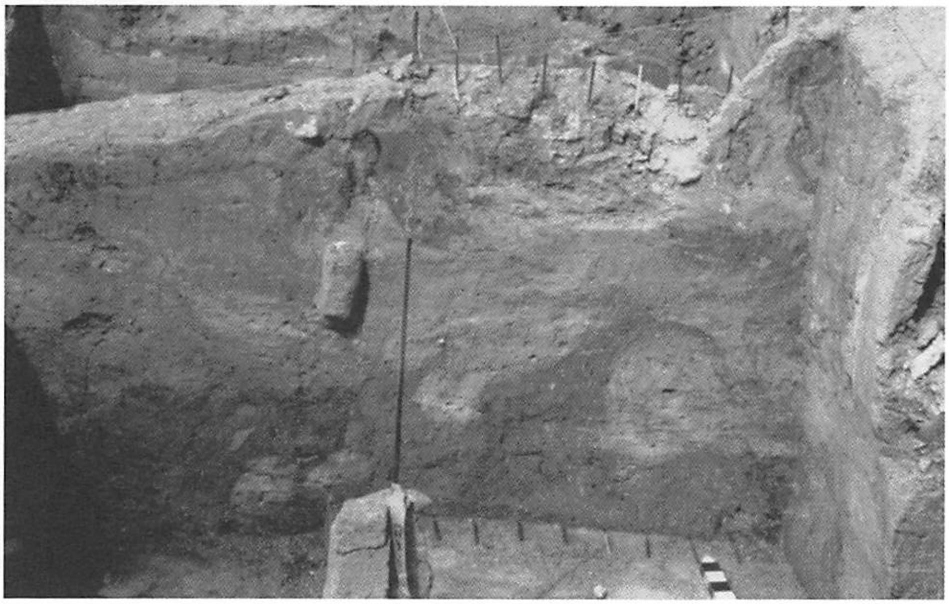


Figure 2.13. View north of bioturbated boundary between artifact-bearing gray sediments and underlying red sediments in north wall profile of square 0-W23, East Exposure. Marker is in 5 cm increments and points north. Photo taken September 28, 1988, by Don Wyckoff.

sity of Arizona Accelerator Facility was used to obtain dates of 35,890 +/- 850 (AA-3837) on unsorted snail shells from near the bison skull, 40,900 +/- 1600 years ago (AA-3840) on charcoal from sediment above (elevation 97.06) the skull, and 26,820 +/- 350 years ago (AA-3838) on charcoal from the red sediment below (elevation 96.26) the bison skull (Wyckoff 1989a).

With these early dates and a larger inventory of artifacts, a proposal for field research funds was submitted to the National Geographic Society in March of 1989. This proposal requested funds to expand manual excavations of East Exposure squares near the bison skull, to do deep coring around the East Exposure deposits, and to do limited backhoe trenching near and into the East Exposure deposits. The coring and trenching were planned to help study and assess the geologic contexts, the processes forming these deposits, and their ages. Most importantly, the requested funds would help cover the expenses of an interdisciplinary team: Dr. Wakefield Dort, Jr. (geology), Dr. G. Robert Brackenridge (alluvial geology), Dr. Brian J. Carter (pedology), Dr. Larry D. Martin (vertebrate paleontology), Dr. Larry C. Todd (vertebrate taphonomy), and Dr. James L. Theler (invertebrate paleontology). Don Wyckoff was serving as principal investigator, and Kent Buehler was enlisted as assisting archaeologist. We sought $18,739 from the National Geographic Society to cover costs basic to the field work. We also sought private donations of $7000 to help cover field expenses (Wyckoff 1989a).

First World Summit Conference: Peopling of the Americas

In April of 1989, Dr. Rob Bonnichsen of the Center for the Study of the First Americans (University of Maine-Orono) invited Don Wyckoff to be a presenter at the World Summit Conference on the Peopling of the Americas. Scheduled for May 24 to 28, this conference was billed as a meeting to:

1. put together the American prehistory puzzle from Siberia to Tierra del Fuego;
2. share the stewardship of America's oldest inheritance;
3. and work for the public trust of America's earliest prehistory.

Wyckoff was asked to present a paper on the Burnham site findings and on any other Southern Plains evidence for a Pleistocene human presence.

Emphasizing the significant role of interdisciplinary studies in learning about the first Americans, Wyckoff's paper examined the Clovis-Folsom-Plainview cultural continuum documented on the Southern Plains. It then briefly looked at evidence for pre-Clovis occupations reported for such sites as Lewisville, Cooperton, Levi Shelter, and Bonfire Shelter before summarizing the Burnham site work and findings. Given on May 26, the paper received little comment from conference attendees. Instead, interest and attention was focused on presentations concerning findings at Monte Verde, Chile, and Piedra Furada, Brazil.

Although all papers given at this conference were to be published soon, the volume containing regional, or site specific summaries, did not get published until 1999. The initial manuscript (Wyckoff 1999) on the Burnham site is part of that volume.

Nearby Paleontological Sites

In early June of 1989, the Burnham neighborhood was washed by intense thunderstorms. Nearly 3.0 inches of rain fell in a short time on the upland ridge north of the site, and the resulting runoff was heavy enough that it threatened to wash out several dams the Burnham family had built on West Moccasin Creek. To strengthen a dam 2.0 miles north of the Burnham site, a hillside at the dam's west end was graded for fill. This work exposed a 10m profile of nicely stratified calcic soil (3.0m thick) over a sequence of fluvial sand and gravel, clay loam alluvium, and coarse gravel.

At the urging of Vic Burnham, Don Wyckoff visited this exposure (called the Olson Exposure) on June 15, 1989. Assisted by John Flick, Wyckoff recovered bone fragments and snails from the reddish brown clay loam that comprised the second lowest stratum in the profile. A narrow gully in this stratum had partially uncovered the mandible of a juvenile bison. While uncovering this, a large fleck of charcoal was found nearby and collected. (This charcoal was later submitted for accelerator dating, and the result was > 48,000 years ago [AA-5617]).

Believing that the Olson Exposure comprised evidence of the late Pleistocene in this watershed, Wyckoff and Kent Buehler returned to the location on June 29, 1989, to make a detailed contour map of the hillside and the boundaries between strata. A few more bone fragments, including part of a camel phalanx, were found during this mapping.

Then, in August of 1989, Vic Burnham called to report a gully was cutting into deposits containing bones in a field a quarter mile south of the Burnham site. Owned by Albert Bouzidan, this field was visited that month. This trip revealed a gully which had eroded perhaps 10m into the northeast edge of a 3.0m thick deposit of gleyed silt loam. Small carbonate nodules, occasional snails, and even fewer bones were evident in the deposit as revealed by the gully. A survey of the field itself revealed the black sediments of this deposit extended over a roughly circular area of some 5 acres. A sample of snails collected here was examined by Jim Theler (University of Wisconsin-LaCrosse) who noted that cold-adapted species were present that were not in any of the Burnham site samples.

Burnham Site Excavations in 1989

In July of 1989, the National Geographic Society notified us that they were funding (Grant #4414-89) two-thirds of the request for intensive, interdisciplinary research at the Burnham site. Accordingly, the October schedule for work was confirmed with Keith Burnham, the landowner, and arrangements were made with him for camping around a nearby lake by those helping with the field work. The interdisciplinary team members were contacted, and their on-site schedules were confirmed. Also, volunteers from the Oklahoma Anthropological Society were invited to help with the manual excavations (Wyckoff 1989b). The use of a backhoe and access to auxillary water for waterscreening (in case the modern pond went dry) were also arranged.

On September 1 and 2, Brian Carter and assistant Phil Ward met Don Wyckoff and Kent Buehler at the site and began deep coring east and north of the East Exposure (Fig. 2.14) with a truck-mounted Giddings coring rig. Going from 4 to 6.5 m below the surface, seven cores showed thin gleyed lenses underlain by alluvium in which paleosols were not evident. None of the gleyed lenses were deeper than the gleyed deposits visible on the graded slope

The main field work began September 28 and continued until October 24. Twenty-five days were spent digging and recording the findings. During this period, nearly 80 volunteers manually dug 27.5 cubic meters of fill from 1x1 m squares in the East Exposure (Fig. 2.15). In addition to the 7 cores taken nearby (Fig. 2.14), 45m of 3 to 4m deep trenches were dug with a backhoe into and adjacent the East Exposure (Fig. 2.14). A few squares were started in the Northwest Exposure, but none were dug to the bottom of that deposit.

In 1989, control over the manual excavations was enhanced by the rental of a laser beacon (Fig. 2.16) and three receptors mounted on rods scaled in centimeters. By setting the revolving laser beacon at a known elevation (relative to the elevation at site datum), and by placing the beacon where it had a clear sight-path to squares being dug by hand, the workers could easily check and record the depths of excavations. This eliminated the need for strings and line levels and added much consistency and accuracy to recording the depths at which objects were found, the boundaries between strata, and the depths of levels removed within a stratum.

Documentation of the 1989 findings was facilitated greatly by the work of the interdisciplinary team members. Brian Carter directed the coring on September 1 and 2 and worked on profile descriptions and soil sampling from September 30 through October 4, October 14 and 15, and October 20 and 21. Bob Brakenridge intensively studied profiles from October 12 through October 21. Wakefield Dort studied profiles on October 3 and 4 and again on October 20 and 21. Larry Martin assisted Dr. Dort with profiles and made notes on paleontological finds on October 20 and 21. Larry Todd recorded taphonomic details of paleontological finds on October 16 and 17. Last but not least, Jim Theler collected soil-sediment columns (for snails) from the East Exposure, visited theOlson and Bouzidan exposures, and collected samples of living land snails from niches in the Burnham pasture north of the site from October 6 through 8.

The coring and backhoe trenching revealed that the East Exposure contained a complex record of late Pleistocene alluviation, soil formation, erosion, and pond development. Initially, red loamy sandy alluvium accumulated over gravel in a 6 to 7m deep depression, possibly a dissolution collapse basin but more likely a stream-cut channel (Fig. 2.17). Below elevation 97.6 this alluvium showed no signs of having undergone soil-forming processes. At this elevation, however, the eroded remnant of a calcic, slightly argillic soil horizon was manifest east and north of the artifact-bearing stratum (Fig. 2.17). Containing some very weathered bone fragments and many pieces of charcoal, this paleosol appeared to be the earliest one formed at the site. During the initial backhoe trenching, a large piece of charcoal was recovered from this paleosol (Fig. 2.17). Identified as pawpaw *(Asimina triloba)*,

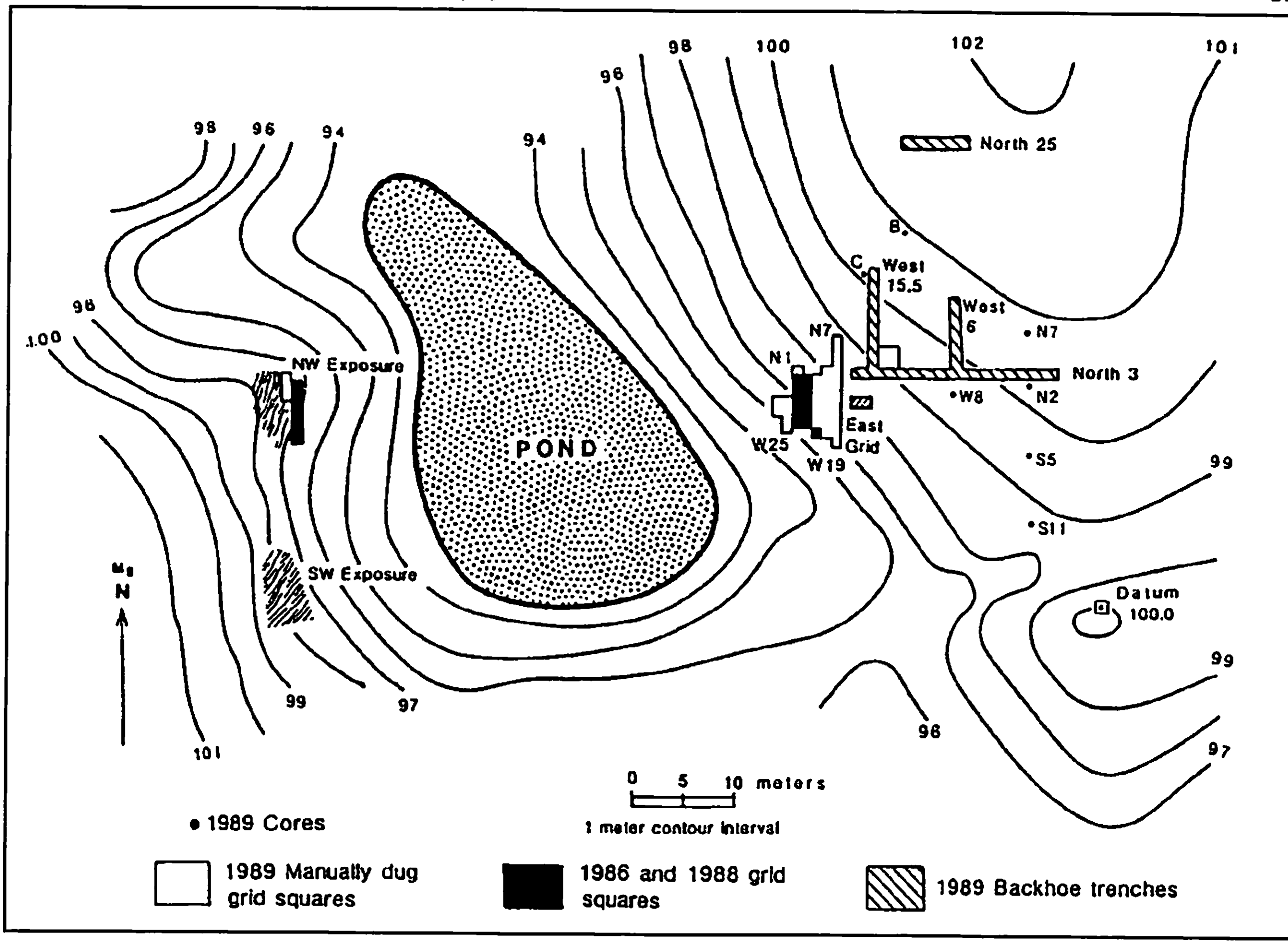


Figure 2.14. Locations of Burnham site areas excavated by hand, coring rig, and backhoe during the 1989 fieldwork partially funded by the National Geographic Society.

this charcoal has yielded radiocarbon dates of "greater than 38,000" (Beta-33950) and 34,750 +/- 1040 years ago (SMU2422).

Above this paleosol accumulated 3.0m of carbonate enriched soil. Composed mainly of red silt or silt loam, this fine textured calcic soil is believed to be of aeolian origin. It has undergone enough pedogenesis to contain both soft and hard carbonate nodules, some of fist-size dimensions. While this calcic soil accumulated it was cut by at least two erosion episodes. Both created channels or depressions with northeast-southwest orientations. The lowest eroded depression has its base at elevation 95.7 and can be traced as high as 98.5. Nearly 15m wide, this depression contains seven nested, pond deposits (Fig. 2.17), including the snail-rich gleyed unit that yielded the bison bones and artifacts. This particular unit was discerned to be the second lowest (at elevation 96.2) in the sequence of stratified fluvial deposits in this depression. Three of these ponded deposits persisted long enough to support relatively rich paludal habitats and to be visited by prehistoric horse, bison, camel, mammoth, and diverse small vertebrates typical of marshes, meadows, and grasslands.

Situated at elevation 99.0, the second, and uppermost, depression contains a thin, gleyed, sandy deposit that lacks gastropods and bones. This uppermost cut-and-fill is manifest only over the northwest part of the East Exposure (Fig. 2.17). Charcoal from slightly below this uppermost gleyed deposit yielded an accelerator date of 11,580 +/- 320 years ago (NZA-1090), so this erosion and unstratified infilling represents an interval of erosion and brief ponding that occurred near the time of Clovis people's presence on the Southern Plains (Johnson 1991).

At elevation 98.0, some 10m east of where the bison skull and artifacts were found, occurs a gleyed fine sandy loam sediment with undisturbed remnants of a fossil bone bed. Profiles of this deposit display red vertical krotovinas that are interpreted as burrows (probably crawfish). Despite these clues to biogenic disturbance, this gray deposit contained a remarkably uniform horizontal bed of bones, mainly those of horse but a few of large-horned bison (Fig. 2.18). No human artifacts were found here, and the few recovered charcoal fragments disintegrated during chemical pretreatment for radiocarbon dating. As a result, this deposit's age was not determined. Because this deposit is within the channel

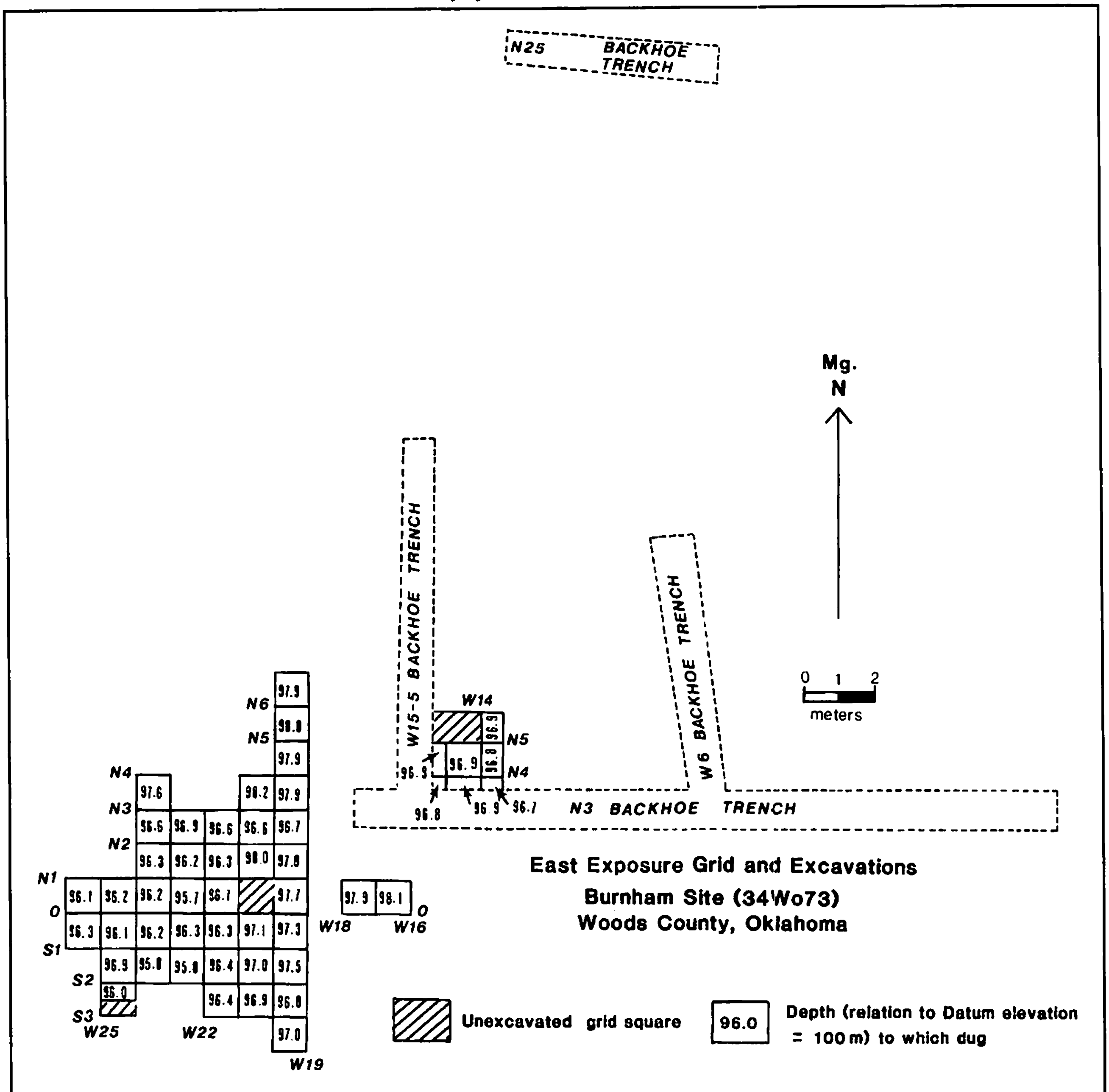


Figure 2.15. The 1989 manual and mechanical excavations in the East Exposure of the Burnham site.

eroded through the 34,000 year-old paleosol, the deposit must be younger.

The 1989 field work involved trowelling and waterscreening several cubic meters of the artifact-bearing gleyed sediment north, south, and east of the original find. Only two more bison bones and three flakes were recovered. Carefully cleaned floors in squares two to three meters east and northeast of the bison skull displayed occasional red krotovinas, so some parts of the artifact-bearing deposit were biogenically disturbed. Several charcoal fragments from this stratum were submitted for radiocarbon dating, but they, too, disintegrated during chemical pretreatment. Consequently, the 1989 findings didn't immediately generate more dates for this stratum.

While the 1989 work produced meager new information on the artifact-bearing stratum, expanded and deeper excavations into the underlying stratum helped clarify some details about both. Specifically, the artifact-bearing unit is inset or nested into the reddish brown loam that comprises the lowest of the East Exposure's four ponded deposits (Fig. 2.17; Plate 2b). The base of this lowest alluvium was at elevation 97.5. It does contain some broken and complete bones, including elements from camel, alligator, horse, and bison. Also, numerous gastropod shells are present, and many of these are broken. A charcoal fragment near this lowest alluvium's base was accelerator dated at 36,300 +/-

Figure 2.16. Laser beacon (right) and receptor in use for accurately measuring elevations during the 1989 excations at the Burnham site. Photo taken September 30, 1989, by Don Wyckoff.

1700 years ago (NZA1416). This result is nearly 10,000 years older than the date obtained on charcoal from the top of this stratum. No artifacts were recovered from this lowest alluvium.

With the conclusion of the 1989 work, some three acres adjacent to the site were fenced to keep livestock out, and the East Exposure excavations were covered with a wood frame and construction plastic.

The Burnham Site Research Review Session

It took 18 months to sort, analyze, identify, and date the findings from the 1989 field work supported by the National Geographic Society. When the findings were nearly compiled, the interdisciplinary team convened to review and discuss their findings and interpretations. This meeting was held on June 20 and 21, 1990, at the Oklahoma Archeological Survey offices in Norman, Oklahoma. Attending were Brian Carter, Wakefield Dort, Larry Martin, Jim Theler, Larry Todd, Don Wyckoff, and Kent Buehler. Also present was Dr. Jack Hofman, an interested colleague who was working for the Survey at that time.

The meeting was most fruitful. While the diverse findings were complementary in helping understand the site's prehistoric environment, the ages of the various deposits were not clear. Also, much discussion centered on the site's geologic record and whether that attested to a large or small ponded setting. Jim Theler's analysis of fossil gastropods helped characterize the nature of the prehistoric pond, and he provided some insight that it was spring-fed. Larry Todd reported that his preliminary analysis indicated that there were taphonomic differences between the "Horse Bone Bed" and the area where the bison bones and artifacts were recovered. This latter area displayed much more evidence for having been disturbed by some kind of process.

Overall, the 1989 excavations exposed and documented clues that the Burnham site was a location where a complicated record of soil accumulation, horizon development, erosion, and alluviation occurred between roughly 40,000 and 11,000 years ago. As plant remains, gastropods, and vertebrate fauna were identified and correlated with particular strata or horizons, constructs were developed of the habitats and their constituents that briefly thrived there (Wyckoff 1990; Wyckoff et al. 1991). Notably, the overwhelming ma-

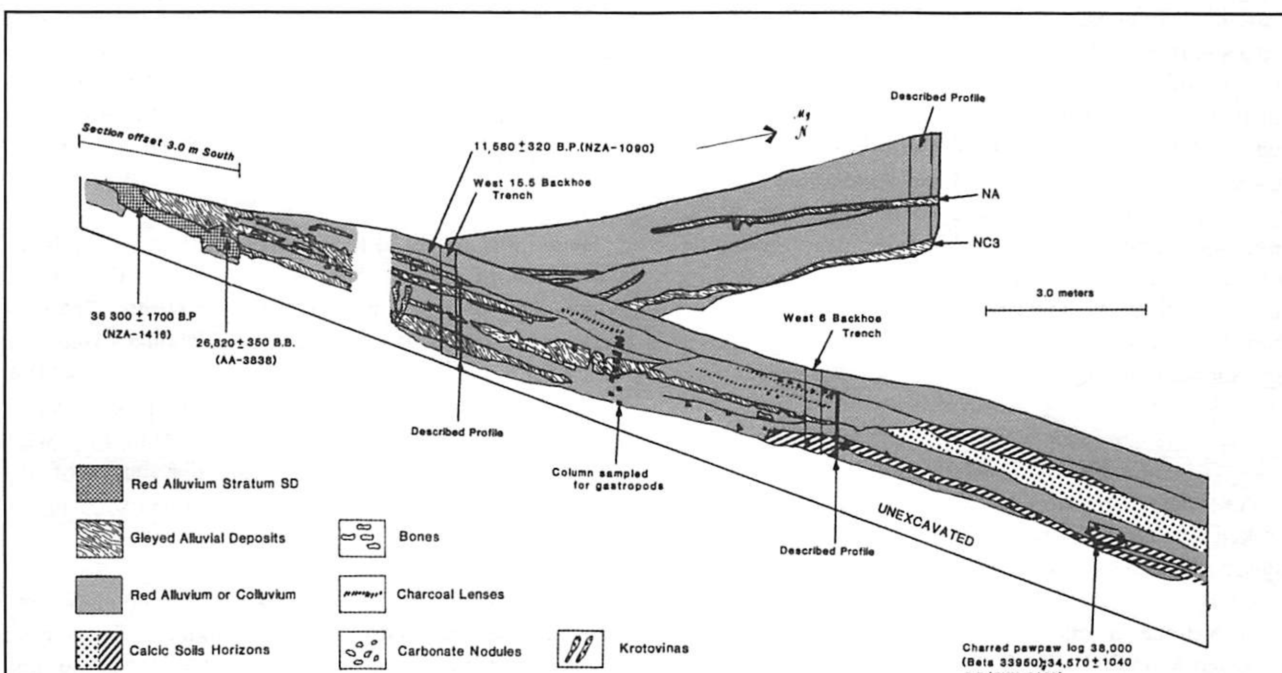


Figure 2.17. Three-dimensional perspective of soil horizons and sedimentary strata found in East Exposure during 1989 excavations. Prepared by G. Robert Brakenridge.

Figure 2.18. View north of the "Horse Bone Bed" in squares N4-W14 and N4-W15 during 1989 excavations in the East Exposure. Photo taken October 11, 1989, by Don Wyckoff.

jority of the radiocarbon dates attest to these habitats predating the Wisconsinan glacial maximum. It was increasingly clear that the human artifacts (which now numbered over 50) were redeposited (Buehler 1992; Wyckoff et al. 1991), but all available evidence pointed to them becoming incorporated into a ponded sediment that was deposited long before 11,500 years ago. The unpatinated, unabraded character of most flakes was interpreted as a clue that they had eroded from near where they were found.

All participants agreed that the Burnham site contained important paleontological and environmental information about times before the Wisconsinan glacial maximum of 18,000 to 19,000 years ago. In addition to these biologic and climatic contributions, we recognized that the Burnham site had a significant anthropological component. We did have human artifacts, and these appeared restricted to one stratum that was stratigraphically below a soil horizon radiocarbon dated to Clovis times. This stratum was understood to be fluvial in origin, and Kent Buehler presented evidence that the artifacts were secondarily deposited there. At this point, the big questions were: when were the artifacts redeposited, and from where did they originate? To answer these questions, all participants in the meeting recognized that more field work was needed on the site's geology, pedology, and chronology.

The 1990 NSF Proposal

A proposal for such field work was thought about and worked on before the research review meeting. Accordingly, a proposal entitled "Late Pleistocene Settings and Pre-Clovis Human Adaptations" was completed and submitted to the National Science Foundation by July 3, 1990. We requested $106,754 to help cover costs for expanding the manual and mechanical excavations. Specifically, we wanted to manually dig more squares east and north of the original bison-artifacts find. By doing so, we would be able to better assess the distribution of artifacts and perhaps refine our ideas about from where they had washed into the ancient pond. Also, we planned manual excavations in the Northwest and Southwest exposures in order to obtain additional comparative data on the presence of bones and artifacts. The requested funds included some to do more deep coring and backhoe trenching and the concomitant study and recording of findings in these excavations. Given that many of the recovered flakes were of local chert, the deep coring and backhoe trenching would help assess the presence of flint-bearing gravel deposits and the role of natural processes in creating flakes. Equally important, we hoped that such coring and trenching would reveal traces of an eroded paleosol from which the artifacts had washed into the ancient pond. Finally, essentially $15,000 of the requested funds were allocated for laboratory study of newly exposed paleosols, sediments, pollen, phytoliths, and radiocarbon dating. Knowing that the site's chronology needed much improvement, the research team recommended that a second proposal for even more radiocarbon dating be prepared and submitted to the National Geographic Society.

The Burnham Symposium at the 1990 Plains Conference

On the basis of the research review meeting's presentations and converging understanding of the site, participants agreed to prepare formal summaries of our findings for a Burnham site symposium at the upcoming 1990 Plains Anthropological Conference. Besides serving as a venue to present our research and findings to professional colleagues, this symposium would be a stimulus to complete detailed summaries of our interdisciplinary research. These were needed for the final report to fulfill Grant #4414-89 for the National Geographic Society, and they would provide a basis for a synthesis that we proposed submitting to *American Antiquity*, the premier journal for North American archeologists.

Held from October 31 to November 3, 1990, in Oklahoma City, the 48th Annual Plains Anthropological Conference was well attended. Many came to the symposium "Interdisciplinary Research at Northwestern Oklahoma's Burnham Site: Glimpses Beyond Clovis?". All team members but Bob Brakenridge were able to attend and participate. Overall, the symposium was well received, and good questions were raised about the number, character, and distribution of artifacts and about the inadequately dated strata overlying the artifacts.

Symposium participants did provide brief summaries and supportive tables and illustrations of findings. These were incorporated into the report "Late Pleistocene Settings and People at Northwestern Oklahoma's Burnham Site" which was submitted to the National Geographic Society on November 8, 1990. Data from this report was extrapolated and used in a short summary of the 1989 work and findings for *Current Research in the Pleistocene.* This summary was published in 1990 (Wyckoff et al. 1990).

Progress on the Burnham research began to falter after the 1990 Plains Anthropological Conference. The proposed chapters were slow and sporadic in coming, and in early December the National Science Foundation notified us that they were unable to fund our proposal. The NSF Review Panel noted that the outside reviewers were generally positive and supportive of the proposal, but the Panel members believed that the project was not adequately presented or designed tightly enough. They did, however, encourage submittal of a revised proposal. After discussions with Drs. Carter, Dort, Martin, and Theler, Don Wyckoff decided to forego an article for *American Antiquity* and to focus instead on finding funds for more field work. Rather than publish on incomplete or poorly understood findings from insufficient field work, additional field research seemed appropriate. Then, all work and findings could be synthesized.

After the 1989 field work, we tried to protect the hand-dug squares in the East Exposure with a wood frame-plastic sheeting cover. While this was generally successful, the remainder of the site suffered throughout 1990 and 1991. Thunderstorms continued washing rivulets and gullies into the Southwest and Northwest exposures, and this erosion uncovered bones and teeth that merited plotting and recovery. Field trips to collect and plot such finds were taken on March 21, August 3, November 20, and November 29 of 1990. Most damaging was standing water in the hand-dug and backhoe trenches (Fig. 2.19). Standing water dissolved the base of vertical walls, and the weight of those undercut masses caused them to slough into the water and melt into an amorphous mass. Viewing this process over a year was instructive about natural processes that prehistorically could have created some of the observed taphonomic differences, but this sloughing and dissolution was most destructive of stratified areas where we hoped to conduct additional controlled excavations.

Figure 2.19. View northwest of East Exposure area where "Horse Bone Bed" and adjacent backhoe trenches were eroded by standing water. Photo taken May 10, 1990, by Ken Bloom.

1991 TERQUA Presentation

At the urging of Wakefield Dort, Don Wyckoff prepared a brief summation of the Burnham site research for the 1991 TERQUA Symposium in Lawrence, Kansas. Founded at the University of Nebraska and associated with the Nebraska Academy of Sciences, the Institute for Tertiary-Quaternary Studies has been important for hosting and publishing symposia involving geologists, pedologists, paleontologists, climatologists, and archaeologists studying Tertiary and Quaternary sites and localities on the Central Plains. The 1991 TERQUA Symposia were held on the University of Kansas campus on February 28 and March 1, 1991. Wyckoff's presentation was titled "Interdisciplinary Research of the Peopling of the Americas: A Northwestern Oklahoma Case", and it stressed the interdisciplinary approach and results of the 1989 field work and the need to focus on finding the primary context from which the human artifacts eroded.

1991 Field Trips and Field Work

The Burnham site research team urged resubmission to NSF of a proposal more focused on the site's geology and chronology. Because the NSF deadline for 1991 was already passed, the earliest we might get such funds was late spring of 1992. Given the continued erosion of the site, field work in 1991 was imperative. Thus, Wyckoff prepared a proposal to host the 9-day archaeological field school of the Oklahoma Anthropological Society in the spring of 1991. This proposal went to the Society's Dig Committee, and they approved it at a March 2, 1991, meeting. Also, they established the field school to run from May 25 to June 2.

Because no funds were available to cover expenses of the interdisciplinary research team, the work proposed for 1991 was designed to sample deposits already recorded and to refrain from excavations in deposits not previously available to the interdisciplinary researchers.

As plans for this field session were being finalized, Brian Carter and assistant Phil Ward were working out details to host a South Central Friends of the Pleistocene field trip in northwestern Oklahoma and southwestern Kansas. Besides several Pleistocene ash deposits which Brian and Phil were dating by the fission-track method, the itinerary was to include interesting paleontological and archaeological sites. The Burnham site was included, and a detailed summary of the research and findings was written (Wyckoff et al. 1991) for a guidebook prepared for the trip's registrants. Held on May 17, 18, and 19, this FOP trip was attended by over 80 scholars from Kansas, Iowa, Arkansas, Colorado, Texas, and Oklahoma. During their visit to the Burnham site, many of them voiced their interest in and appreciation of the interdisciplinary research undertaken there.

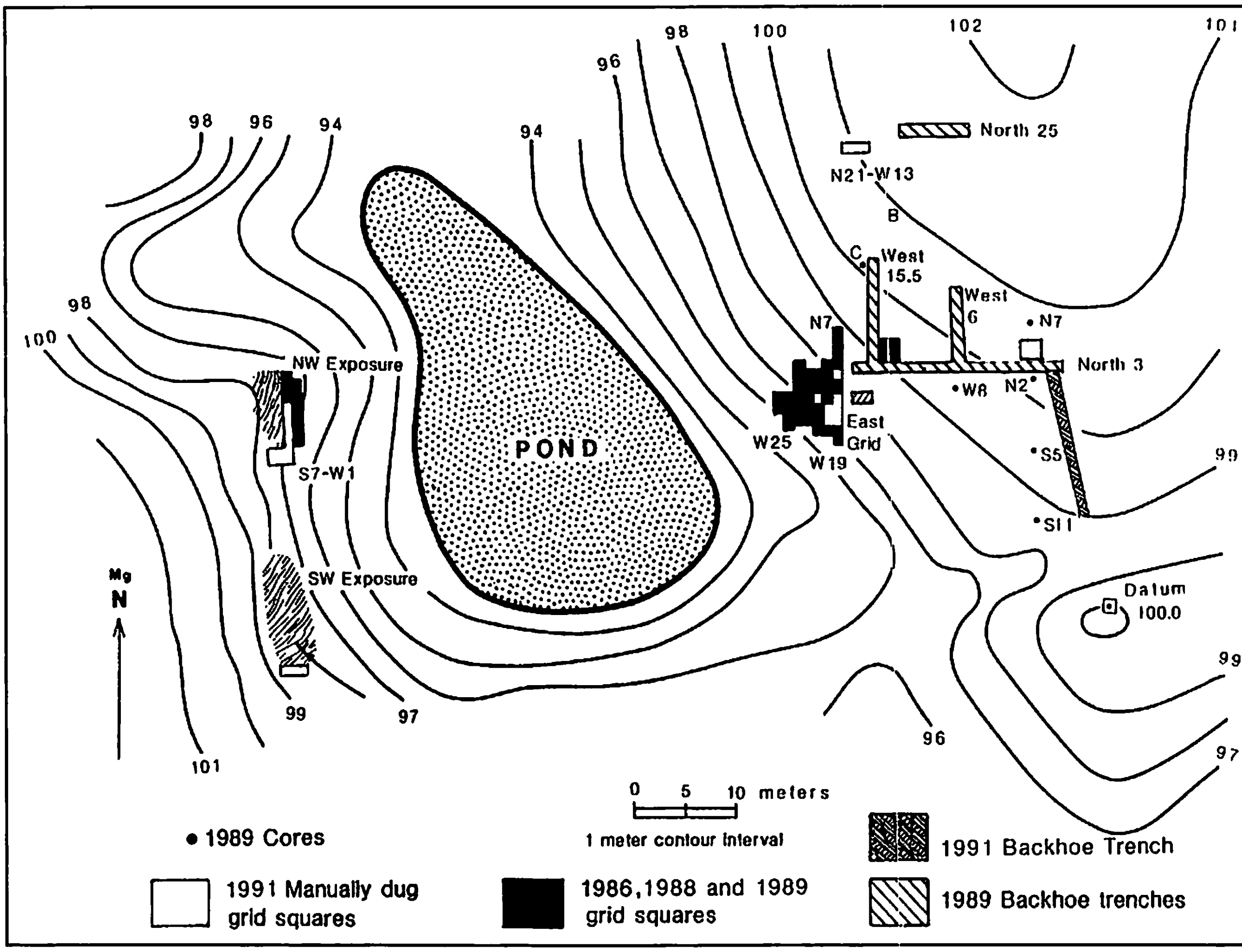


Figure 2.20. Locationsof the manual and mechanical excavations of the 1991 field work at the Burnham site.

In preparation for the pending FOP trip and the soon-to-follow archaeological field school, the Burnham site's East Exposure excavations had to be uncovered and cleaned. Assisted by Oklahoma Anthropological Society member Ken Bloom, Don Wyckoff dismantled the wood-visqueen cover, cleaned profiles, and skimmed out packrat nests and sediment washed onto the lower squares. In spite of the protective cover, rain blew under the its north end. This damaged some profiles, and several east-west balks between squares were cut away by water-washed tunnels or had collapsed. Five to 15 cm of red to reddish gray sediment washed onto the lower, southern squares dug in 1989. This material came mainly from the higher, graded slope north of the 1989 excavations. This eroded higher part of the East Exposure was above the soil that dated to Clovis times.

Despite some wicked storms, nearly 100 members of the Oklahoma Anthropological Society came and helped with the 1991 excavations (Wyckoff 1991). These workers undertook several important goals. To assure that flint flakes were truly unique to the East Exposure, the Northwest Exposure was thoroughly cross-sectioned (Fig. 2.20) and the first controlled excavations were conducted on the Southwest Exposure (Figs. 2.21). Because several of the East Exposure squares started in 1989 were not dug through the artifact-bearing stratum, these squares were excavated to see if more bison bones, artifacts, and/or datable charcoal could be recovered. To begin investigating potential sources of the redeposited human artifacts, three 1x1 meter squares (N21-W14, N21-W15, and N31-W16) were dug atop an undisturbed remnant of the original landscape east of the modern pond (Fig. 2.20). Also, six squares (0-N4, N4-E1, N4-W1, 0-N5, N5-E1, and N5-W1) were established and dug in the 34,000 year-old paleosol near the east end of the primary (North 3) backhoe trench dug in 1989 (Figs. 2.20 and 2.22). These squares were directly north of the charred pawpaw wood and bone fragments found in 1989. Excavations in this paleosol were facilitated by the availability of a backhoe. It was used to peel off nearly 2.0m of red, carbonate enriched soil over the paleosol. Almost three cubic meters of fill from this paleosol was removed with trowel and waterscreened through 2mm mesh. While many charcoal and some bone fragments were uncovered in this paleosol, nothing was found to indicate that people had once trod this former surface.

With the availability of the backhoe, and because colleague Brian Carter was at hand, it was decided to dig one

Figure 2.21. Looking south at the Southwest Exposure (light colored sediments) prior to the 1991 excavations. Photo taken May 27, 1991, by Don Wyckoff

Figure 2.22. View northwest of manual excavations in the 34,000 to 38,000 year-old paleosol at the Burnham site's East Exposure. Photo taken May 27, 1991, by Don Wyckoff.

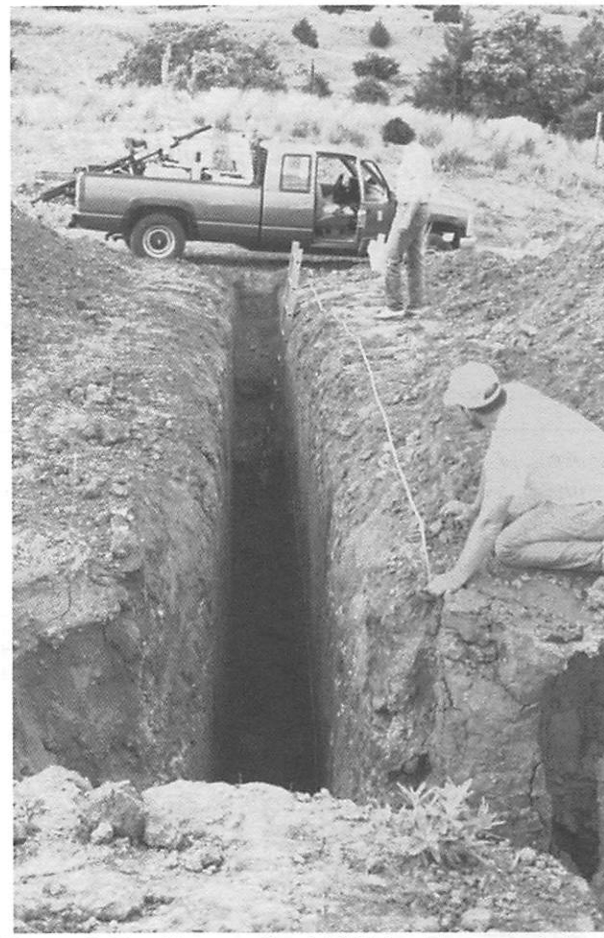


Figure 2.23. View south of 1991 backhoe trench in the East Exposure. Bedrock wall visible by ladder. Photo taken May 28, 1991, by Don Wyckoff.

trench south from the area where the paleosol was being manually dug (Fig. 2.23). This trench was very informative. Its profile (Fig. 2.24) not only included the top of the underlying alluvium (which had not undergone pedogenesis and which contained calcite crystals), but it revealed the 34,000 year-old paleosol extending south to where it merged with lenses of gravel. Thus, we had discovered that the paleosol had formed in a canyon-like, stream-cut setting in which all of the unconsolidated material had accumulated.

Atop the remnant of the undisturbed land some 30m north-northeast of the bison skull find (Fig. 2.20), a 1x3m trench was dug in 10cm levels to 80 or 90cm below the ground surface. No archaeological materials were found in this remnant of the original terrain and soil. This finding wasn't unexpected. South and west of this remnant the graded surface had been exposed and eroded for five years. It had been surface hunted routinely, but it never had yielded any artifacts. Still, because it was the only area upslope from the bison skull to retain the site's original pedon, it was an obvious place to look for late Pleistocene or Holocene artifacts.

Approximately two cubic meters more of the artifact-bearing stratum were dug and waterscreened from the selected squares in the East Exposure (Fig. 2.20). Datable pieces of charcoal but no artifacts or bison bones were found.

Some 2.5 cubic meters of gray sediment were dug and waterscreened from five squares in the Northwest Exposure (Fig. 2.20). No human artifacts were recovered here, but numerous datable pieces of charcoal and some broken bones were uncovered. These latter included examples from mammoth (Fig. 2.25) and ancient box turtle. As was noticed during the 1988 excavations, the bones tended to be concentrated near the bottom of the deposit and they lay at diverse angles and orientations. These characteristics are believed to attest to the bones being deposited during very rapid flow or runoff. Weathered surfaces on some bear witness to their having been exposed to the sun and air before being washed and buried in the gray sediment.

Less than half a cubic meter was dug and waterscreened from the Southwest Exposure, and no artifacts were found.

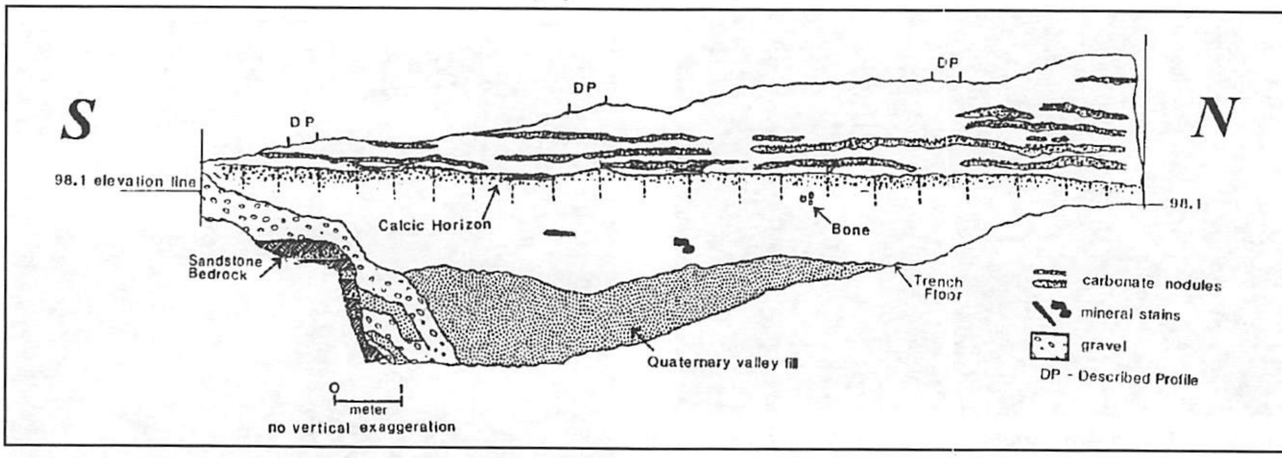


Figure 2.24. South-north profile of backhoe trench dug in East Exposure in 1991. The 34,000 to 38,000 year-old calcic-argillic paleosol merges with north-dipping gravel that was drapped over a vertical wall of Marlow Formation sandstone.

Figure 2.25. View west of split mammoth bone in square S6-W1 of the Northwest Exposure. Photo taken May 29, 1991, by Don Wyckoff.

Some charcoal fragments were recovered, mainly from a gully wall just north of the two squares worked there. Several more horse bones were found. While complete, these bones were disarticulated and lying at east-dipping angles.

1991 Proposals

After the 1991 excavations, we became even more convinced that human artifacts were uniquely distributed at the Burnham site (Wyckoff 1991). Subsequent laboratory processing of all the waterscreen residue failed to recover any artifacts from the Southwest or Northwest exposures. Moreover, no artifacts were found in the residue from testing the East Exposure's undisturbed modern soil solum or the 34,000 year-old paleosol. In essence, our 1991 excavations reaffirmed that artifacts seemed restricted to the second lowest of four stratified pond deposits.

With the 1991 findings in mind, proposals for funding of additional geoarcheological and chronological research were completed in the fall and early winter of 1991. With colleagues Brakenridge, Carter, Dort, Martin, and Theler, Wyckoff submitted the proposal "Late Pleistocene Settings and Pre-Clovis Human Adaptations" to the National Science Foundation on July 1, 1991. We asked for $89,016.00 to cover extensive coring, backhoe trenching, bulldozer trenching, and radiocarbon dating of buried soils and sediments north of the East Exposure excavations. Our attention turned to the north and northeast because we believed our previous work had demonstrated that artifact-bearing paleosols were not east, southeast, or south of where the artifacts were found. Because the terrain to the north was higher than the site, we suspected that the artifacts eroded from there.

On December 15, 1991, the proposal "Late Pleistocene Chronology and Human Occupation at Northwestern Oklahoma's Burnham Site" was submitted to the National Geographic Society. This proposal requested $4000.00 for nine accelerator dates. These were to come from charcoal samples collected during the proposed 1992 excavations.

By January 17, 1992, the National Geographic Society had notified us that they were unable to process and fund our proposal within the time frame that we wanted. Our disappointment with this news was uplifted late February when the National Science Foundation notified us that they would partially fund our proposal. Specifically, they offered to fund some $21,000.00 provided we would focus strictly on coring and trenching that would enhance understanding of the site's geologic contexts. We agreed to do this and submitted a revised proposal and budget for field work planned to start June 1, 1992.

Receipt of this grant made us eligible to apply for an NSF grant of $4000.00 for support of an undergraduate student to participate in the research. Knowing that such a student would profit greatly from working with the interdisciplinary team, we applied for and received this additional support. This year-long position was advertised through the University of Oklahoma Department of Anthropology, and ten student applicants were interviewed. Because of her good grades and interest in archaeology, freshman Jane Cornelius was selected for the undergraduate research support. Her role during the field work was to collect and record all charcoal samples exposed during the excavations. In the subsequent laboratory work, she was to be responsible for organizing the charcoal samples and working with Dr. Wyckoff to select and submit samples for radiocarbon dating.

The 1992 Field Work

Upon notification of the NSF support, Wyckoff contacted all members of the interdisciplinary team and sought their schedules for visiting and participating in the field work. Drs. Carter and Theler responded quickly and set dates for their participation. For various reasons, the rest of the team could not make commitments. Some, like Larry Todd and Bob Brakenridge, already were pledged to other projects and simply couldn't be both places at once. The others indicated they would try to visit during the field work. Wyckoff also sent invitations to select members of the Oklahoma Anthropological Society to assist in the work. These individuals were people who had helped previously, had demonstrated notable ability to excavate and record in the ways stressed for the site, and had volunteered to assist if ever the opportunity came to return to the site.

Despite heavy rain, the 1992 investigations started on June 1. Except for two weekends (June 6-7 and 13-14), we were in the field continuously through June 28. During this period, Brian Carter and assistants Phil Ward and Leslie Anderson were coring and recording profiles on the site for 10 days. Jim Theler was present the last two days to collect columns of soil and sediment (for snail extraction) from profiles selected to augment our current knowledge of the site's prehistoric niches and environmental history. Of special concern was the collection of a sediment column from the Northwest Exposure (Fig. 2.26). We wanted this in order to compare that deposit's gastropod assemblage with those from the sequence of sediments in the East Exposure. Also, we planned to submit examples of aquatic and terrestrial snails for accelerator dating, and we wanted to compare results from the Northwest and East exposures.

Most of the 1992 field work focused on studying the geology and soil sequences in the south sloping area north of the East Exposure (Figs. 2.27 and 2.28). The goal was to find either a paleosol that was the source of the redeposited artifacts or evidence for a prehistoric drainage feature that might be traced to a humanly inhabited, former surface. To accomplish this goal, deep coring, backhoe trenching, and bulldozer trenching were undertaken north of the East Exposure (Figs. 2.27 and 2.28). Modest manual excavations were also completed as test squares were established in select backhoe and bulldozer trenches to test soil horizons and sediment strata that might contain artifacts. All fill from these test squares was waterscreened through 2mm mesh hardware cloth.

A small but dependable crew of volunteers were on hand for most of the field work. A few of these individuals dug the 1x1 test squares established in the backhoe and bulldozer trenches north of the East Exposure. Some assisted with mapping and profiling. Most volunteers worked at controlled excavations in the Northwest Exposure. Here, seven 1x1m squares (Fig. 2.26) were dug in 10cm levels in order to increase the sample of vertebrate remains from this gleyed sediment, to reassess the stratigraphy of this gleyed sediment, and to see if any human artifacts could be recovered. Nearly 2.0 cubic meters of sediment was dug and waterscreened from the Northwest Exposure. The resulting profiles showed the single unit of deposition seen in previous excavations. Bone and charcoal fragments were frequently uncovered during this work. All charcoal fragments were frequently uncovered during this work. All charcoal fragments observed while trowelling were piece-plotted (relative to the SE corner of the square in which they were found), and their depths were measured with a laser beacon. Bones were uncovered in situ and piece-plotted as well as having their orientations and dip measured with a Brunton compass.

Testing by Coring

From June 2 to June 8, the principal work consisted of recovering 18 deep cores. The first core (#92-1) was taken with a Giddings soil corer 20 m west of the Southwest Exposure to see if that gleyed deposit extended under the present south-sloping ridge. Core #92-1 was 5.69 m long and

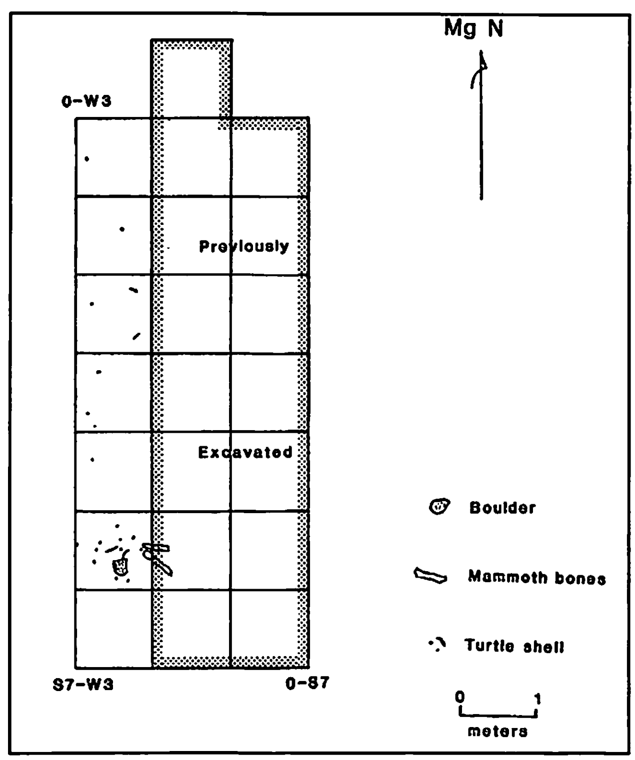


Figure 2.26. Northwest Exposure squares and plan views of some paleontological finds made during the 1992 field work.

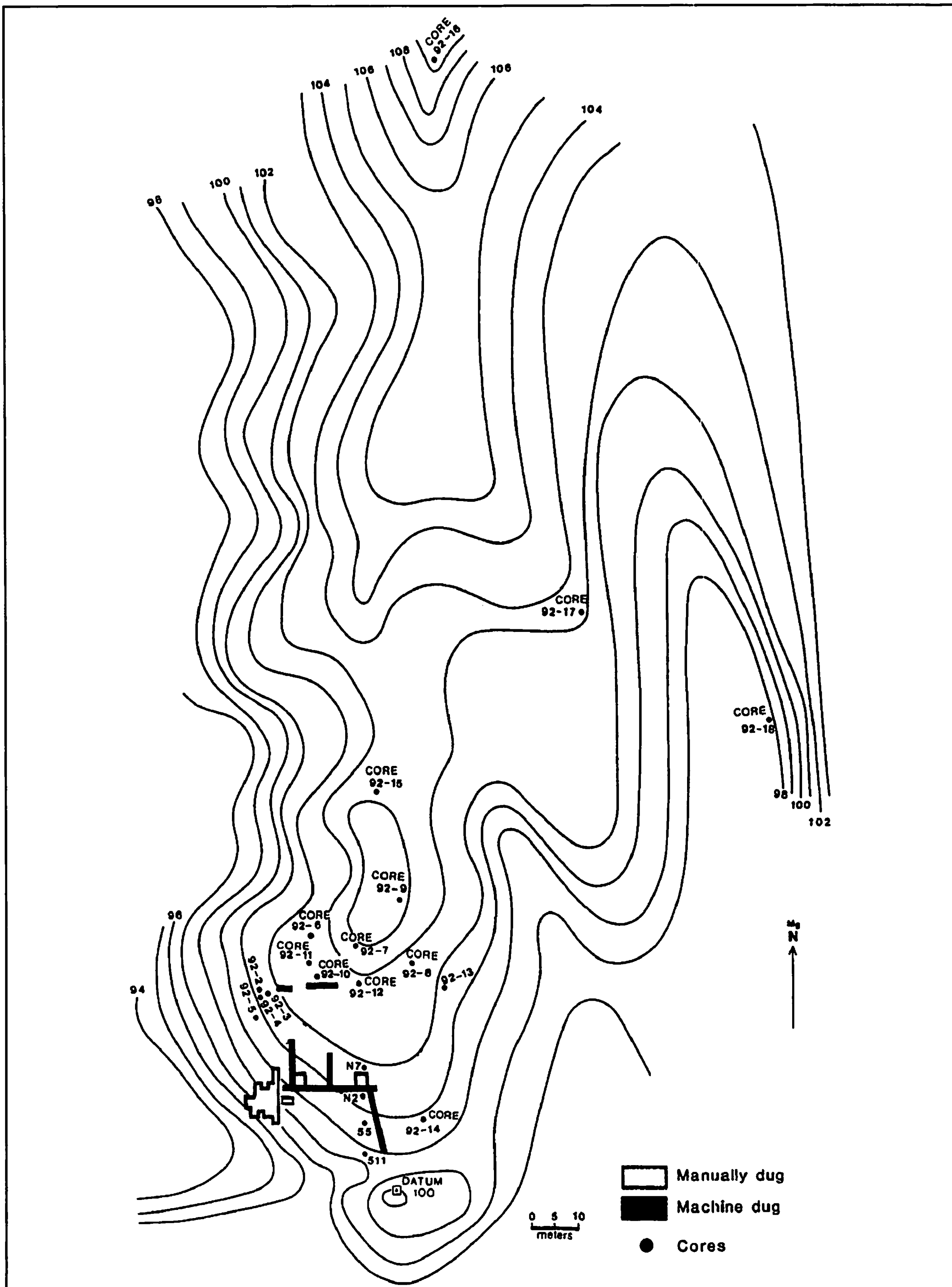


Figure 2.27. Locations of cores taken north and east of the Burnham site's East Exposure during the 1992 geoarchaeological investigations.

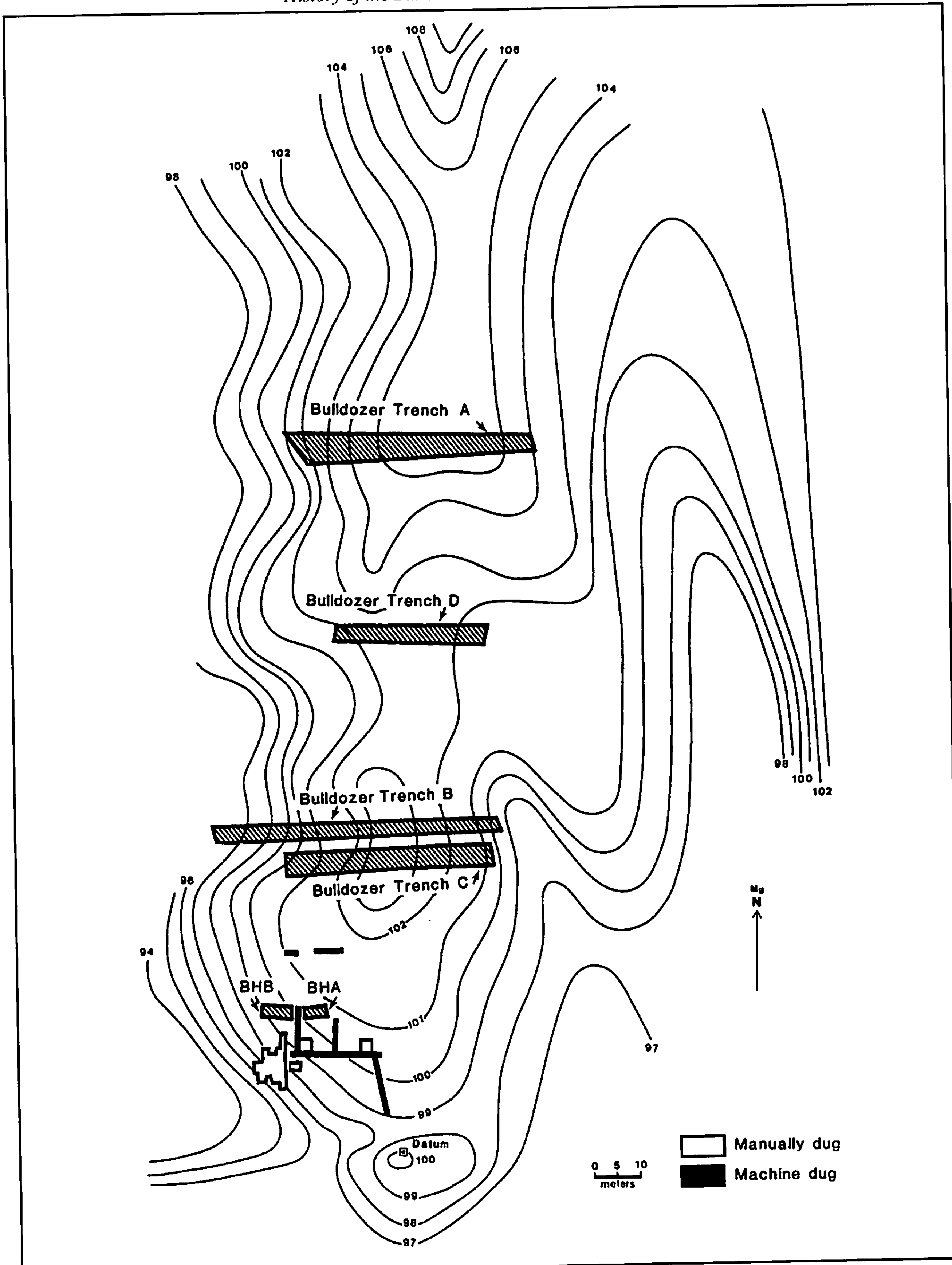


Figure 2.28. Locations of backhoe and bulldozer trenches excavated during the 1992 geoarchaeological investigations at the Burnham site.

thus reached to elevation 94.43 (relative to datum elevation 100). This core's profile revealed a buried paleosol (at elevation 99.67) but no traces of ancient ponded sediments (Table 6.2). On this basis, the Southwest Exposure appears to be a small, lateral remnant of one ponding episode.

The remaining 17 cores were taken with the Giddings rig or with a manual auger (7.6cm diameter) north and northeast of the East Exposure (Fig. 2.27). Cores #92-2 through #92-5 were some 20 m north of the East Exposure's original excavations. These were done with a hand auger (because the slope and previous excavations inhibited use of the truck-mounted Giddings rig) in order to intersect possible northern extensions of the artifact-bearing and uppermost pond deposits. Actually, Cores #92-2 and #92-3 weren't completed because indurated deposits were 1.5m below the surfaces. Consequently, Core #92-4 was 50 cm from Core #92-3, and the 5.65 m long profile recorded for Core #92-4 is described (Table 6.2). Core #92-5 (Table 6.2) was also hand-augered. It was situated between Core #92-4 and the East Exposure in order to document the character and extent of gleyed deposits closer to their exposures from the 1989 excavations.

Cores #92-6 through #92-19 were taken along a general east-west alignment 60 to 80m northeast of the East Exposure (Fig. 2.27). Varying from 2.82 to 8.74m in depth, these cores were collected to learn if paleosols existed upslope from the East Exposure. The profile descriptions (Table 6.2) for these seven cores do attest to the presence of paleosols. These cores also were placed in order to study a suspicious find made during the limited coring of 1991. At that time a core designated #91-A had penetrated a thin layer of snail-rich, gleyed sediment in this area. Given its thickness, distance, and direction from the East Exposure, this gleyed sediment looked like an alluvial lens in a restricted context, most likely sediment in a prehistoric gully.

The 1992 coring seemed to confirm this. Snail-bearing, fine textured, gray sediments were recorded in Cores #92-7, #92-8, and #92-9 (Appendix B). The locations of these cores are near the longitudinal axis of the south-sloping ridge north of the East Exposure (Fig. 2.27). The gleyed sediments were found only in these cores and bear witness to a narrow, thin alluvial deposit that slopes with the terrain. These characteristics are interpreted to indicate the presence of at least one alluvium-filled drainage that led toward the ponded deposits where the artifacts were found.

Cores #92-14 through #92-18 are east, northeast, and north of the East Exposure (Fig. 2.27). Varying from 4.45 to 8.10m in length, these cores were taken to assess the extent and character of paleosols as well as to garner more information about the physical setting and soil-forming processes in these areas. The horizon characteristics and sequences manifest in Cores #92-14 through #92-18 are described in Table 6.2.

Backhoe Trenching

Because Cores #92-7, #92-8, and #93-9 were revealing traces of a likely prehistoric gully, Carter and Wyckoff decided that an east-west backhoe trench should be dug between these cores and the East Exposure. With such a trench perhaps the prehistoric drainage could be interesected near its juncture with the East Exposure's ponded sediments. By finding this location we could determine with which of the ponded strata the gully's mouth correlated. Also, we could then manually excavate the gully fill at this location to see if human artifacts were present.

Accordingly, a backhoe was brought to the site on June 8, and an east-west trench was dug. This trench's alignment was 10m north of the long backhoe trench (designated North 3) dug in 1989 (Fig. 2.28). The 1992 trench was positioned between the three cores and the East Exposure where the thickness of the overburden nearly equaled the depth that the backhoe's arm and bucket could excavated. The completed trench was in two segments, was nearly 13m in length, and was 1.5 to 2.0m in width. The two segments resulted from digging the trench across the W15.5 backhoe trench dug in 1989. The 7.0m long west segment (designated Backhoe Trench 92-B) was 1.5 to 3.0m deep, and it exposed a beautiful cross section of the uppermost pond deposit (Figs. 2.29 and 2.30). The 5.5m long east segment (Backhoe Trench 92-A) was 3.0 to 5.0m deep. Its south wall revealed (Fig. 2.31) a profile of the east end of the uppermost pond deposit as well as the northern extension of the pond deposit (at elevation 98.0) with the partial skeletons of ancient horse and bison uncovered in 1989. Initially believed to be the oldest pond deposit, it clearly isn't. At elevation 97.0 occurs a gleyed loamy fine sand containing gastropods and occasional bone fragments (Fig. 2.31). These fossils and gray sediments were confined to a narrow strip that looked like an aggraded gully that was oriented slightly northeast. Nearly 3.0m of these lower sediments were uncovered at the backhoe trench's east end (Fig. 2.32), and these were manually excavated in 10cm levels with all fill being waterscreened through 2 mm mesh.

Bulldozer Trenching

Once the coring was finished a preliminary study of the findings disclosed that remnants of two paleosols were evident 50 to 60 m north of the East Exposure while one extended as far as 200 m north. These paleosols manifested a finer texture, less developed structure, and darker chroma than horizons above them. Notably, none appeared organically enriched, and this characteristic was considered a clue that these paleosols might be eroded. The irregular depths of their upper boundaries were considered to result from erosion. Because of their eroded looking, fine textured character, these buried soils became the most likely source for the Burnham artifacts. However, we remained alert to the possibility that the artifacts could have washed from almost anywhere in the soil profiles.

Figure 2.29. Looking north at profile in 1992 Backhoe Trench B. The gray stratum is the uppermost pond deposit in the East Exposure. Photo taken June 10, 1992, by Bill Thompson.

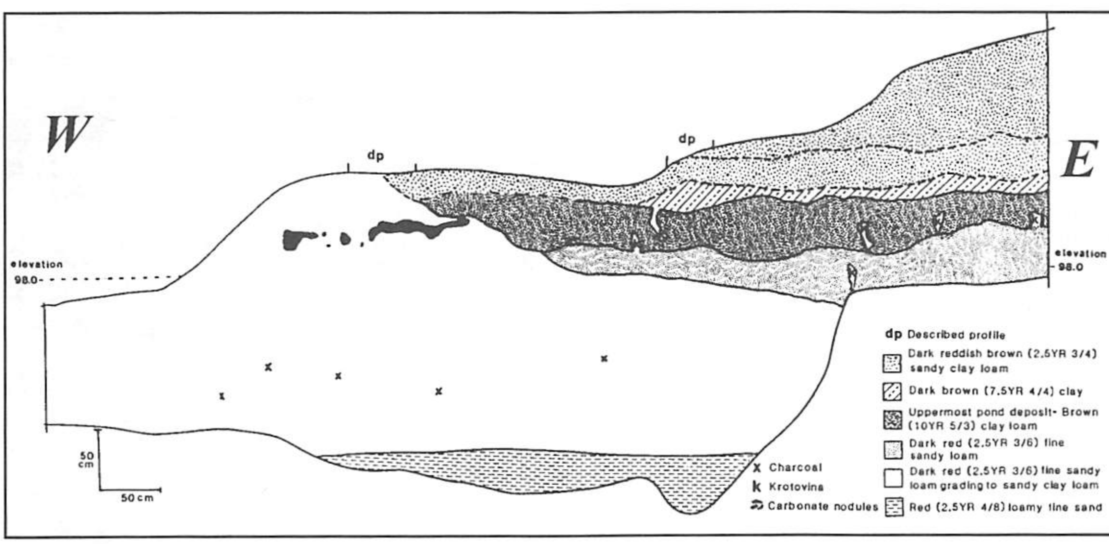


Figure 2.30. North wall profile of 1992 Backhoe Trench B. A profile description of this exposure is in Table 6.2.

Given the depths and extent of the paleosols, we needed a way to expose these buried horizons and search them for signs of human habitation. More explicitly, we needed a means to carefully peel off the horizons above the paleosols while also uncovering large areas of the paleosols' surfaces. Once uncovered, these could be manually dug and waterscreened to see if artifacts were present. A regular backhoe was deemed unsatisfactory; its arm wouldn't reach deep enough, and its narrow bucket couldn't efficiently dig deep enough. A trackhoe (the larger version of a backhoe) could easily dig deep enough, but its wide bucket might tear the soil into very large clods and thus make it difficult to see artifacts or quickly identify a humanly inhabited surface. Because of its problem with pushing dirt aside once it reaches any depth, a road grader clearly wasn't suitable. Having successfully used bulldozers many times to strip off overburden to expose prehistoric house floors, hearths, trash pits, caches, burials, and activity areas (Wyckoff 1964, 1967, 1968), Wyckoff decided to use a bulldozer that could operate a 12 ft. blade. Similar and larger machines were used 30

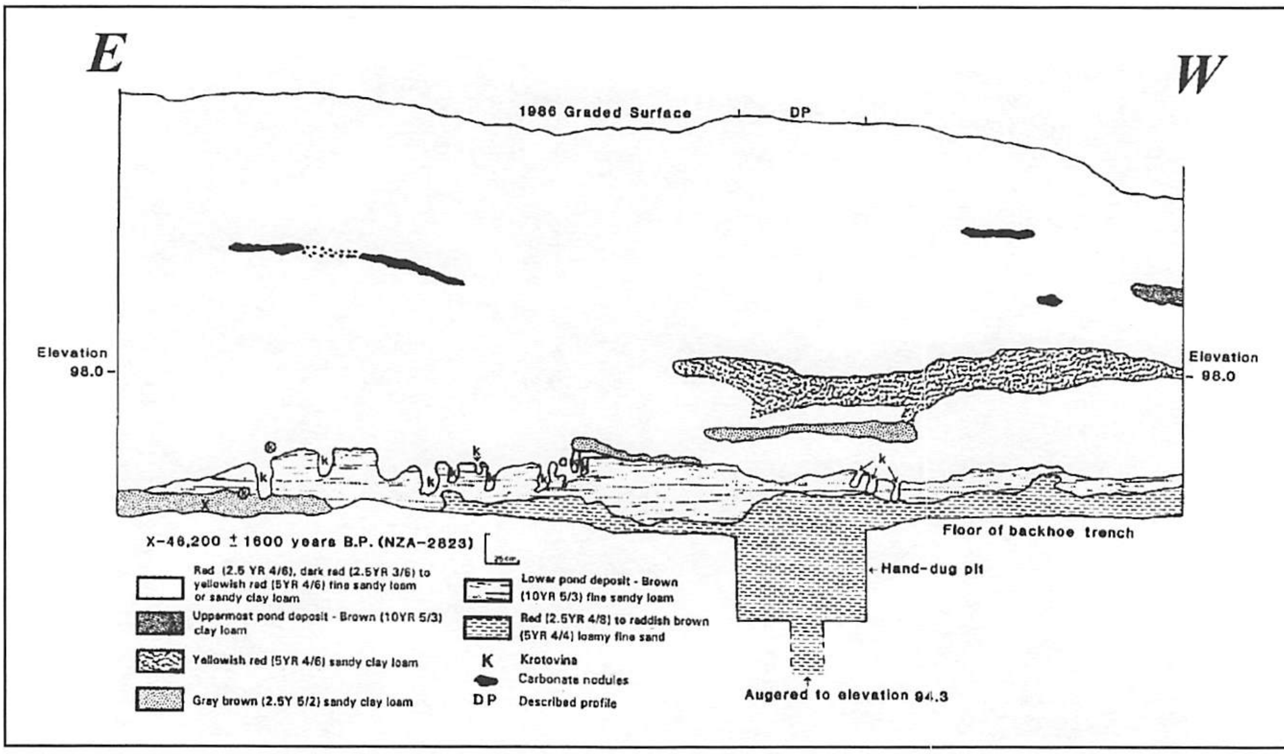


Figure. 2.31. South wall profile of 1992 Backhoe Trench A. A description of the soil horizons and sediment strata in this profile is in Table 6.2.

years ago while searching for signs of pre-Clovis people's presence at Tule Springs, Nevada (Wormington and Ellis 1967). Machines of this size can peel off a 4m wide swath for a long distance, so they were deemed the most efficient means of uncovering a sizeable area to a considerable depth.

Having chosen a bulldozer to cut wide, deep trenches to the buried soils, we also decided to start well north of where the two buried soils were last recorded. We aligned the initial trench (Bulldozer Trench A; Figs. 2.28, 2.33, and 2.34) east-west to obtain a cross section of the ridge sloping toward the East Exposure. By starting at least 100m north of this exposure we could practice stripping with the machine well away from where artifacts were known to occur and also away from where there were two suspicious paleosols, one of which apparently was drained by a gully or shallow ditch that was heading towards the East Exposure.

The trenching involved having the bulldozer operator peel off 5 to 10cm of soil with each pass. This proved to be a slow process given the eventual lengths and depths of these trenches. However, making shallow cuts ensured that potential habitation features were not destroyed while also helping keep the trench clean (because the dozer wasn't pushing so much dirt that it spilled over the blade and back onto the trench floor). Because each trench had to be refilled eventually, the dirt was pushed eastward onto a gentle slope where it could be easily regathered. As the bulldozer made each pass, Wyckoff (and often one other person) walked behind with a trowel and shovel to uncover any

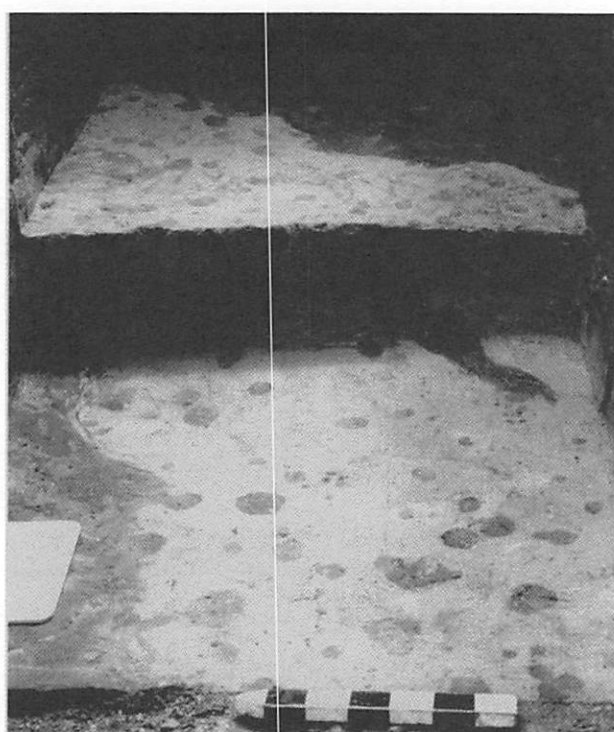


Figure 2.32. View east of bioturbated gully fill uncovered in 1992 Backhoe Trench A. Photo taken June 19, 1992, by Don Wyckoff.

bones, stones, or suspicious areas that were freshly exposed. As each trench was deepened, one or two 50cm wide columns were cleaned with pick and shovel along the south

Figure 2.33. View southwest of Bulldozer Trench A showing cleared columns and calcic horizons. Photo taken June 25, 1992, by Don Wyckoff.

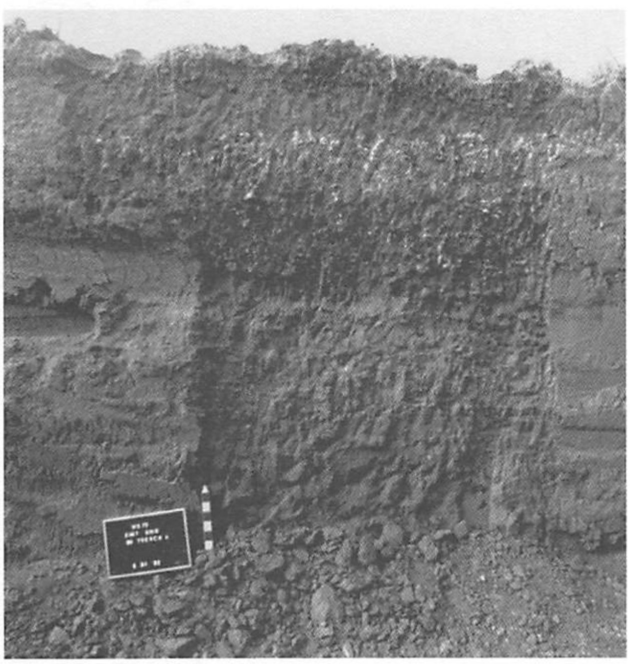


Figure 2.34. Looking south at a cleaned profile at west end of Bulldozer Trench A where calcic soils overlie layers of silt and loamy sand alluvium. Scale is in 5cm increments. Photo taken June 24, 1992, by Don Wyckoff.

wall in order to monitor the soil profiles. The south wall was chosen because it was always shaded and thus slowed the profiles from drying out as fast as they did on the exposed north wall.

Between June 11 and 23, the bulldozer cut four long, deep trenches north of the East Exposure (Fig. 2.28). These were designated Bulldozer Trenches A, B, C, and D in the sequence that they were dug. Generally, the trenches were taken to depths well past the buried soils discerned in nearby cores. Once to the desired depth, a base line was established at a measured elevation (relative to datum) along the south wall, and then that wall was profiled. This involved using picks to clean 50-60cm wide columns every 2.0m along the south wall. In areas where interesting horizons or complex changes occurred, wider columns were cleaned. Once the base line was set and the columns cleaned, the south wall in each trench was examined by soil scientist Brian Carter. He made notes on the stratigraphy and completed detailed profile descriptions at selected locations. Finally, horizons and boundaries were recorded for all the columns cleaned along that wall.

Situated 140m north of the East Exposure, Bulldozer Trench A was 52m long, 4m wide, and 3.5m deep (Figs. 2.28 and 2.33). One buried soil was found 1.1m below the surface in the eastern half of this trench, and this soil extended to the trench's floor (Fig. 2.34). Unfortunately, no bones, worked or unworked flakes, fire-cracked rocks, or datable charcoal were recovered from Trench A.

Positioned only 50m north of the East Exposure, Bulldozer Trench B was the longest (64m), deepest (7m) trench dug at the site (Figs. 2.28, 2.35, 2.36, and 2.37). Two buried soils were discerned in it. The uppermost was approximately 60cm below the surface in the western half of the trench and over double that depth in the eastern half. Other than carbonate nodules, nothing was found associated with this paleosol. The second buried soil was discerned nearly 3.0m below the surface (Fig. 2.36), and it contained traces of a narrow gully, occasional bone fragments, and a burned area that initially looked like a hearth. The gully was near the trench's east end and 3.9m below the surface. Less than a meter wide, its gleyed fill contained gastropods but no bones or artifacts. Just a few meters west of this gleyed gully fill, a slightly deeper burned area was carefully excavated and revealed to be a prehistoric rodent burrow (Figs. 2.35 and 2.37). This yielded hundreds of charred hackberry (*Celtis* sp.) seeds and a few bones and teeth of *Neotoma floridana*, the eastern woodrat. Burned seeds from this feature were radiocarbon dated at nearly 38,000 years ago (Cornelius 1993), so this lowest buried soil seems contemporaneous with the paleosol found directly east of the East Exposure.

Hoping to expose more bones and clues to ancient plants and animals, Bulldozer Trench C was aligned south of and parallel to Trench B (Fig. 2.28). Using the Trench B profile as a guide, we planned to grade Trench C down to within 5 cm of each of the two recognized buried soils and then manually excavated several 1x1m squares to test for human artifacts. If none were found, the trench would be slowly graded with the bulldozer to see if bones or charcoal could be found. At 2.5m below the surface, two 1x1m squares were dug in the uppermost paleosol (Fig. 2.38). Finding nothing, the bulldozer was allowed to grade to 3m below the surface where three test squares were dug into the lowest buried soil. While these squares yielded a couple of small dolomite nodules, nothing indicative of people was found. Like in Trench B, several bone fragments were recovered during further grading through this lowest buried soil. Eventually, Trench C was 47m long, 4m wide, and some 3.25m deep.

Although funds for bulldozing were about expended, a short trench was dug between Trenches A and B. Called Trench D (Fig. 2.28), this excavation was undertaken to see if the former gully buried in Trench B could be found farther north. When finished, Trench D was 34m long, 4m wide, and 4.1m in maximum depth. No trace of the prehistoric gully was found nor were bones, stones, or charcoal observed.

Thanks to the efforts of Brian Carter, Phil Ward, Kent Buehler, and Leslie Anderson, all of the bulldozer trenches were profiled and recorded in a few days. Then, the trenches were refilled. Meanwhile, the volunteers were completing the manual excavtion of the north-south series of squares in the Northwest Exposure.

The 1992 field investigations ended with Jim Theler collecting soil/sediment columns for snail extraction from the Northwest Exposure and from Backhoe Trench 92B. With that done, all East Exposure excavations were refilled to preserve and stabilize unexcavated deposits there. After discussions with Keith and Vic Burnham, we decided to leave the Northwest and Southwest Exposures uncovered. The Burnhams wanted to leave some fossil-bearing deposits visible for visitors, and we all hoped that future rains might uncover more vertebrate fossils in these gleyed sediments that had never yielded artifacts.

The Bouziden Exposure

During the first weekend of the 1992 field work, John Flick, Jana Cornelius, Michella Miller, and Don Wyckoff visited a setting a quarter mile south of the Burnham site. Owned by Albert Bouziden, this location consisted of a large, plowed field where very dark soil was visible on a terrace-

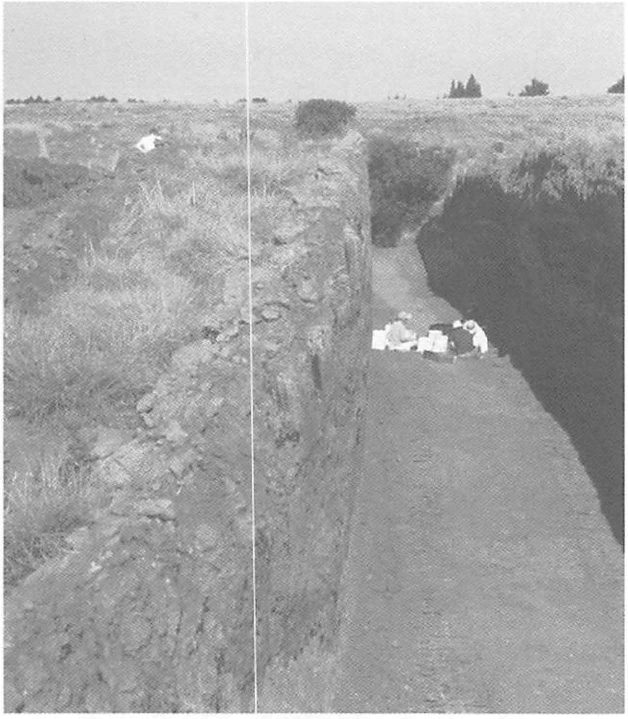


Figure 2.35. View west of Bulldozer Trench B. Individuals are at location of burned hackberry seeds in ancient rodent burrow. Photo taken June 18, 1992, by Don Wyckoff.

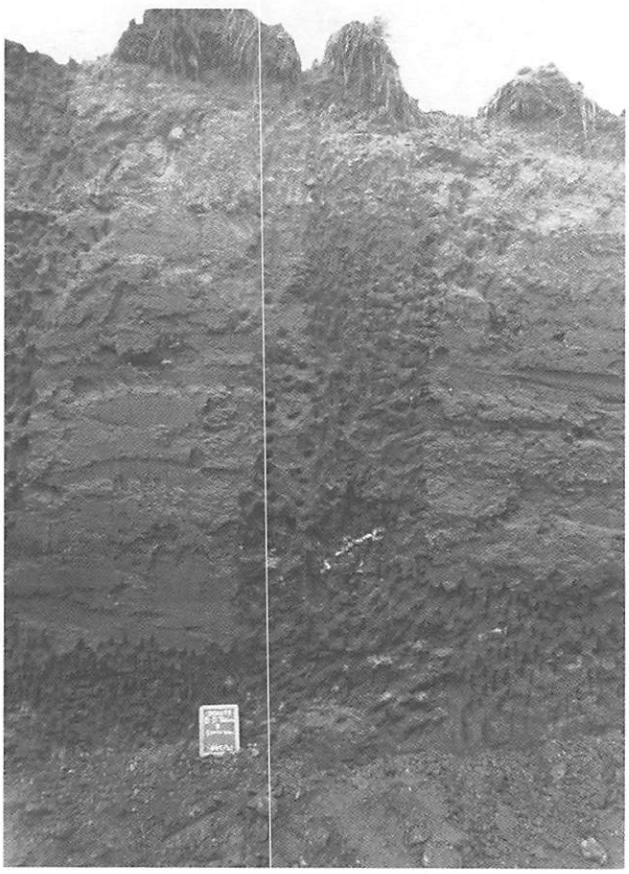


Figure 2.36. Cleared column in south wall of Bulldozer Trench B showing calcic paleosols. Photo taken June 17, 1992, by Don Wyckoff.

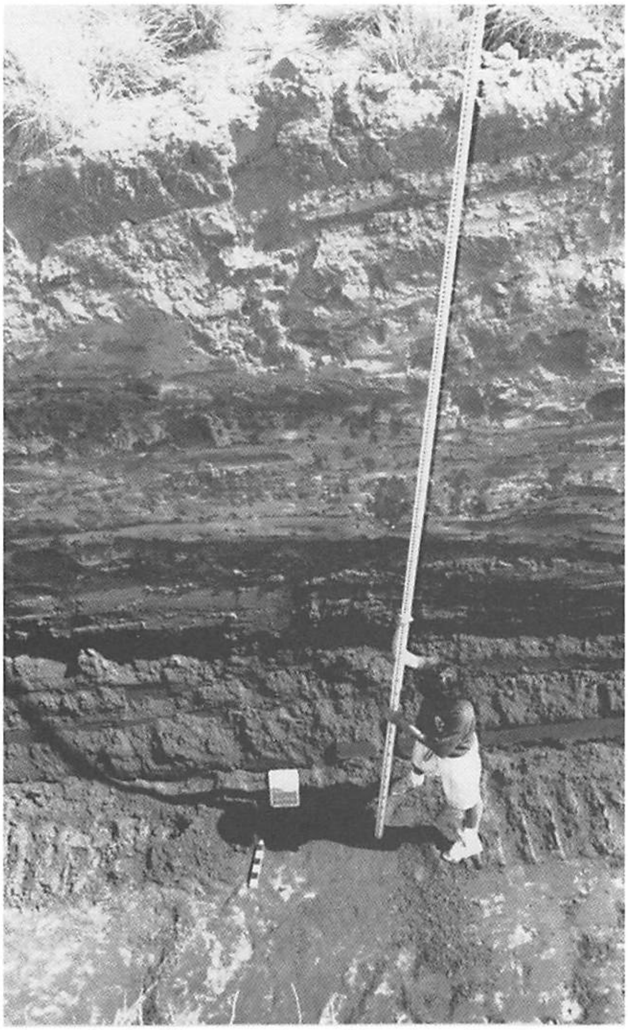


Figure 2.37. Mapping the prehistoric rodent burrow in the paleosol 5.0 m below the surface at Bulldozer Trench B. Photo taken June 19, 1992, by Don Wyckoff.

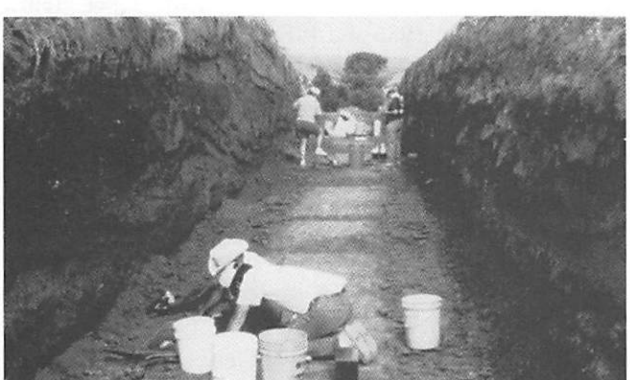


Figure 2.38. View west at test squares being excavated into upper paleosol of Bulldozer Trench C. Photo taken June 23, 1992, by Don Wyckoff.

like setting of some five acres. Chipped stone artifacts, including late Archaic corner-notched dart points, reportedly were found here, but our attention was drawn to the darkened soil which contrasted with the reddish brown soil common to the neighborhood. Vic Burnham had noticed this anomaly and thought it might be geologically related to the Burnham site deposit. During our visit we found a deep gully that was eroding into the very northeast corner of the elliptical area containing the dark soil. The gully profile revealed nearly 3.0m of gray to black sediment that contained a few bone fragments and many snail shells.

At the end of the Burnham site field work, Jim Theler was taken to the "Bouziden Exposure", and he recognized that the snails included cold adapted species not represented in any of the Burnham site sediments. On this basis, the Bouziden Exposure was considered to relate to full glacial times and thus merited documentation and dating. Accordingly, Jim collected a column through the sediment for snail extraction, and Brian Carter and Phil Ward did a detailed profile description at the same place. Subsequently, donated funds were used to obtain accelerator dates on shells of two snail species. A few (0.5g) of the aquatic species *Stagnicola caperatus*, which were collected 30 to 50cm below the surface, yielded a date of 18,105+/-160 years BP (AA-11685). In contrast, 0.7g of the terrestrial species *Pupilla muscorum* from the same depth in the column were dated at 20,520+/-175 years B.P. (AA-11686). Clearly, the Bouziden Exposure does relate to Wisconsinan full glacial times, a period not documented for any of the ponded sediments at the Burnham site.

Interpreting and Reporting the Burnham Site to the NSF

From July 1992 to November of 1993, the materials documented and recovered during the 1992 investigations were sorted, organized, cleaned, and/or submitted for pertinent analysis. Brian Carter, the only soils/geology team member to actually participate in the 1992 field work, processed soil samples and worked up final profile descriptions for the cores, backhoe trenches, and bulldozer trenches. Jim Theler processed the sediment samples and compiled information on the aquatic and terrestrial snails from the Northwest Exposure and Backhoe Trench B. Under Wyckoff's supervision, Jana Cornelius and several other students sorted the waterscreen residue from all the manual excavations. This resulted in numerous bags of bone fragments that were taken to Larry Martin and his student assistant, T.J. Meehan, at the University of Kansas Museum of Natural History for identification and speciation. Charcoal and plant remains were sorted and bagged according to provenience, and Cornelius and Wyckoff consulted on ranking charcoal samples for eventual radiocarbon dating. Lastly, the waterscreen debris was carefully sorted to see if any human artifacts had been missed by the volunteer screeners. Unfortunately, no artifacts were found.

By July 1994, the research team had completed analyses of the respective materials and had submitted their findings for inclusion in the final report to the National Science Foundation. Because the grant was specifically for resolving questions about the site's depositional sequence and chronology, a major concern was getting more radiocarbon dates for the site. Consequently, in the fall following the field work

Jana Cornelius and Don Wyckoff reviewed the dozens of charcoal samples collected during the 1992 excavations. After inventorying the samples, we discussed dating priorities with Brian Carter and Jim Theler and concluded that dates were most needed on the lowest ponded sediment found in Backhoe Trench 92-A (Fig. 2.31), the deepest paleosol found in Bulldozer Trench B (Fig. 2.37), and the as yet undated Northwest Exposure. Accordingly, charcoal samples from those contexts were selected and submitted for AMS dating at the University of Arizona and the New Zealand Institute of Geological and Nuclear Sciences.

By March of 1994, five accelerator dates were received from the samples sent to Arizona and New Zealand. By this time Wyckoff was organizing and formatting the data garnered from analyzing the materials recovered during the NSF-supported field work. Because none of the 1992 excavations were in the artifact-bearing stratum of the East Exposure, and because there was enough uncommitted NSF money to pay for one more accelerator date, he decided to submit one more sample for radiocarbon dating. Remembering that some charcoal fragments were recovered during the 1988 excavations on the East Exposure, Wyckoff selected one (from S1-W22) which he thought would be relevant to dating the stratum from which the artifacts were recovered. The result came in July: 10,210+/-270 years B.P. (NZA4381). This surprisingly late date affected the entire tenor and conclusions of the final report to the National Science Foundation.

Having witnessed nearly 40 years of publicity and disappointment with "pre-Clovis" claims for places like Lewisville, Tule Springs, Calico Mountain, and Old Crow, Wyckoff harbored skepticism that the Burnham artifacts were really as old as they appeared. Yes, there were times when this skepticism was overridden with the enthusiasm of the moment, most notably after the 1988 recovery of two broken tools from the right stratum and well below any sign of modern erosion or bioturbation (Wyckoff 1988; Tratebas 1989). Yet, even after the 1988 finds of broken tools, Wyckoff (Wyckoff 1990:3; Wyckoff et al. 1991:118) emphasized that the Burnham site must be studied with an interdisciplinary approach that focused on determining when, how, and from where the artifacts got to where they were found. Having espoused this philosophy for six years, it's confounding how he chose to abandon it when writing the final report to the National Science Foundation in 1994.

In reviewing the situation now, several factors were operating. The Burnham artifacts include a few flakes that appear to be of central Texas cherts. Knowing that these cherts are well represented by Clovis and Folsom artifacts found in western Oklahoma (Hofman 1991, 1993; Hofman and Wyckoff 1991), Wyckoff clung to the possibility that the Burnham examples might be clues to a Clovis or Folsom site nearby. A Folsom point was reported for a spot a half mile west of the site, and a Clovis-like lanceolate point was known to have been found less than a quarter mile south-southeast of the site (Neel and Burnham 1986). Then, during the 1992 work, a couple of small flakes were found on the eroded, graded slope 65m north of the East Exposure, and these were taken as the first hints that archeological materials might occur north and above the stratum that had yielded the Burnham artifacts. Because the uppermost pond deposit was known to roughly approximate Clovis times, Wyckoff began considering the possibility that the Burnham artifacts were redeposited from some very temporary, terminal Pleistocene presence of humans directly north of the East Exposure. The Burnham artifacts did manifest a distribution that implicated redeposition (Buehler 1992), and they all came from a stratum that appears nestled within the oldest ponded sediment (Plate 2b). So, when an approximately Folsom-age radiocarbon date was received on charcoal thought to come from the artifact bearing stratum, Wyckoff jumped to the conclusion that the "nested" profile was evidence of a terminal Pleistocene cut-and-fill and that the artifacts were redeposited by erosion around 10,000 years ago. He made this interpretation without consulting any of his colleagues, and he wrote this interpretation as the conclusion in the final report (Wyckoff et al. 1994) to the National Science Foundation.

It should come as no surprise that several Burnham research colleagues were shocked and dismayed when they read the final report. Brian Carter, the principal pedologist-geologist on the site during most of the field work, invited Wyckoff to Stillwater about two months after receiving the NSF report and, using Wyckoff's slides and all profiles, spent some two hours demonstrating and explaining how Wyckoff's interpretation was both ill-conceived and erroneous. A thorough review of the provenience for the charcoal sample resulted in Wyckoff concluding that he had submitted a sample from recently redeposited sediments, a reddish brown loamy sand that had washed off the upper graded slope between the 1986 and 1988 excavations. Moreover, Carter used slides and profiles to show that the artifact bearing stratum extends north and well under the deposits dated to terminal Pleistocene times. At the conclusion of this session, Wyckoff could come to no conclusion except that his interpretation in the NSF final report was wrong. Subsequently, at the 1997 Society for American Archeology meetings in Nashville and at the 1998 symposium "Early Humans in the Americas" (sponsored by the Maryland Historical Trust and the Archeological Society of Maryland) he reported on the Burnham site as yielding evidence for people being in North America more than twice as long ago as Clovis.

Further Dating the Burnham Site

Reporting such antiquity is contentious, especially since the Burnham artifacts appear redeposited and are still not well dated. Some help with the latter problem came unexpectedly in 1994 from the University of California at Berkeley. In the spring of that year, Don Wyckoff received an inquiry from Dr. Yang Wang, a post-doc running the Ecosystem Science Division laboratory for the Department of

Environmental Science, Policy, and Management. Specifically, Dr. Wang and Ph.D. student Hope Jahren were soliciting the submission of fossil hackberry seeds for study of their potential for yielding substantive data on past environments and chronology. Because hackberry seeds were represented in several of the Burnham site's strata and soil horizons, it was easy to provide them with samples.

Six samples of hackberry seeds were submitted to Wang and Jahren in May of 1994. By May of 1995, they had completed accelerator dating the endocarp of single hackberry seeds from six different contexts at the Burnham site. While one of the samples yielded a modern date, and does attest to recent redeposition (probably during the 1989 to 1991 period when the East Exposure was covered with plastic and packrats nested under the cover), the other five samples yielded dates ranging from 22,600 to 40,200 years ago (Wang et al. 1997).

Summary

Seventeen years after research began at the Burnham site this monograph on the work and findings will go to press. Ideally, it should have been ready in 1996, but insufficient time and other commitments prevented that. Then, in July of 1996, after being affiliated with the Oklahoma Archeological Survey for 28 years, Don Wyckoff changed jobs and became Associate Curator of Archeology for the Oklahoma Museum of Natural History. Despite this institution's involvement with developing exhibits and moving into a new 190,000 sq. ft. building, Director Michael Mares graciously allowed Wyckoff to have some research time to get the Burnham site work and findings compiled and published. Besides this published means of making the Burnham findings available for scrutiny and thought, the Museum developed a major exhibit on Burnham for its grand opening in the Spring of 2000. Meanwhile, Wyckoff, Carter, Theler, and other colleagues are examining a series of Pleistocene deposits in western Oklahoma to assess what they might tell us about environments dating back to nearly 50,000 years ago. We also hope that through these studies we can refine just when people came onto these ancient landscapes.

References Cited

Buehler, K.J. 1992. Morphological and Distributional Characteristics of the Burnham Site Lithics. *Current Research in the Pleistocene* 9:63-66.

Cornelius, J. 1993. Packrat Found in 38,000 Year-Old Soil in Woods County. *Newsletter of the Oklahoma Archeological Survey* 13(1):1-2.

Flynn, P., D.G. Wyckoff, B. Carter, W. Dort, L. Martin, J. Theler, and L.C. Todd. 1988. Beyond Clovis: A Glimpse from the Burnham Site.*46th Annual Plains Conference Program and Abstracts*, p. 35. Wichita State University, Wichita, Kansas.

Hofman, Jack L. 1991. Terminal Pleistocene Archaeology of the Northwestern Oklahoma Area:Clovis and Folsom Evidence. *A Prehistory of the Plains Border Region,Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P. Ward III, pp. 38-49. Oklahoma State University, Department of Agronomy.

Hofman, Jack L. 1993. An Initial Survey of the Folsom Complex in Oklahoma. *Bulletin of the Oklahoma Anthropological Society*, Vol. 41: 71-105.

Hofman, Jack L. and Don G. Wyckoff. 1991. Clovis Occupation in Oklahoma. *Current Research in the Pleistocene* 8:29-32.

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

McDonald, J.N. 1981. *North American Bison, Their Classification and Evolution.* University of California Press, Berkeley.

Neel, C. and V. Burnham. 1986. More Early Points from Northwest Oklahoma. *Newsletter of the Oklahoma Anthropological Society* 34(1):5.

Taylor, R.E. 1987. Radiocarbon Dating, An Archeological Perspective. Academic Press, Orlando.

Tratebas, A. 1989. The Burnham Site: Possible Pre-Clovis Evidence from Oklahoma. *Mammoth Trumpet* 5(1):1, 5, 8.

Wang, Yang, A. Hope Jahren, and Ronald Amundson. 1997. Potential for C14 Daing of Biogenic Carbonate in Hackberry (*Celtis*) Endocarps. *Quaternary Research* 47:337-343.

Wormington, H.M. and D. Ellis (editors). 1967. *Pleistocene Studies in Southern Nevada.* Nevada State Museum, Anthropological Papers 13. Carson City.

Wyckoff, D.G. 1964. The Jug Hill Site, My-18, Mayes County, Oklahoma. *Bulletin of the Oklahoma Anthropological Society* 12:1-53.

Wyckoff, D.G. 1967. *The E. Johnson Site and Prehistory in Southeast Oklahoma.* University of Oklahoma Research Institute, Oklahoma River Basin Survey, Archaeological Site Report 6. Norman.

Wyckoff, D.G. 1968. *The Beaver Site and Archaeology of the Broken Bow Reservoir Area, McCurtain County, Oklahoma.* University of Oklahoma Research Institute, Oklahoma River Basin Survey, Archaeological Site Report 9. Norman.

Wyckoff, D.G. 1988. Back to Burnham: There Were Pre-Clovis People in Oklahoma. *Newsletter of the Oklahoma Archeological Survey* 8(2):1-3.

Wyckoff, D.G. 1989a. An Update on the Burnham Site Research. *Newsletter of the Oklahoma Archeological Survey* 8(4):2.

Wyckoff, D.G. 1989b. The Burnham Site: A Fall 1989 Project? *Newsletter of the Oklahoma Archeological Survey* 9(1):1-2.

Wyckoff, D.G. 1990. The Burnham Experience: What Did We Learn in 1989? *Newsletter of the Oklahoma Archeological Survey* 9(3):1-3.

Wyckoff, D.G. 1991. Summarizing the 1991 Spring Dig at the Burnham Site. *Newsletter of the Oklahoma Anthropological Society* 39(6):2-4.

Wyckoff, D.G. 1992. 1992 Research at the Burnham Site. *Newsletter of the Oklahoma Archeological Survey* 12(1):1-3.

Wyckoff, D.G. 1993. Radiocarbon Dating the Burnham Site. *Newsletter of the Oklahoma Archeological Survey* 12(3):1.

Wyckoff, D.G. 1999. The Burnham Site and Pleistocene Human Occupaions of the Southern Plains of the United States. *Papers of the World Summit Conference on the Peopling of the Americas*, edited by R. Bonnichsen, in press. Oregon State University, Center for the Study of the First Americans. Corvallis.

Wyckoff, D.G., G.R. Brakenridge, K. Buehler, B.J.Carter, W. Dort, L.D. Martin, J.L. Theler, and L.C. Todd. 1991. Interdisciplinary Research at the Burnham Site (34WO73), WoodsCounty, Oklahoma. *A Prehistory of the Plains Border Region, Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P. Ward III, pp. 82-121. Oklahoma State University, Department of Agronomy.

Wyckoff, D.G., G.R. Brakenridge, K. Buehler, B.J. Carter, W. Dort, L.D. Martin, J.L. Theler, and L.C. Todd. 1994. *Geoarcheology at the Burnham Site: 1992 Investigations at a "Pre-Clovis Site" in Northwestern Oklahoma.* Special Publication of the Oklahoma Archeological Survey, University of Oklahoma, Norman.

Wyckoff, D.G., B.J. Carter, W. Dort, G.R. Brakenridge, L.D. Martin, J.L. Theler, and L.C. Todd. 1990. Northwestern Oklahoma's Burnham Site: Glimpses Beyond Clovis? *Current Research in the Pleistocene* 7:60-63.

Wyckoff, D.G., B.J. Carter, P. Flynn, L.D. Martin , B.A. Branson, and J.L. Theler. 1992. *Interdisciplinary Studies of the Hajny Mammoth Site, Dewey County, Oklahoma.* University of Oklahoma, Oklahoma Archeological Survey, Studies of Oklahoma's Past 17. Norman.

Wyckoff, D. G. and W.W. Dalquest. 1997. From Whence They Came: The Paleontology of Southern Plains Bison. *Plains Anthropologist Memoir* 29:5-32.

Wyckoff, D.G. and P. Flynn. 1987. Ancient Bison Uncovered in Woods County. *Newsletter of the Oklahoma Archeological Survey* 6(3):1-2.

Wyckoff, D.G. and P. Flynn. 1988. Radiocarbon Date for the Burnham Site. *Newsletter of the Oklahoma Archeological Survey* 7(3):2.

Wyckoff, D.G., P. Flynn, B.J. Carter, and B.A. Branson. 1987. Research on the Late Pleistocene in Oklahoma. *Current Research in the Pleistocene* 4:41-43.

Chapter 3
Introduction to the Geological Studies

Don G. Wyckoff

After the 1986 construction of the small pond, diverse soils and sediments were readily evident at the Burnham site. More insight to the site's stratigraphic complexity was gained during the October 1986 recovery of the large horned bison skull. Its left horn core extended from gray into underlying red sediments, both showing hints of being moved by water. Even more evidence came to light during the manual excavations in 1988. This work created profiles at both the East and Northwest exposures. These profiles manifested different stratigraphic sequences, and the East Exposure displayed very divergent strata and unusual boundaries between them.

Given the varied sediments and soils evident at Burnham, one priority in developing an interdisciplinary research team was to enlist appropriately trained geologists and soils scientists. Because the bones, gastropods, and artifacts were coming from gleyed, mottled deposits, a geologist familiar with waterlaid sediments was deemed very important. At the recommendation of several colleagues, Dr. G Robert Brakenridge (Department of Geography, Dartmouth College) was contacted, and he graciously consented to help. Having participated in similar collaborative efforts in Missouri and Tennessee (Brakenridge, 1981, 1983, 1984), Bob was to be responsible for identifying, characterizing, and interpreting fluvial sediments at Burnham. Dr. Brian J. Carter (Department of Plant and Soils Sciences, Oklahoma State University) was sought to study and document the red calcic soils of varying depths that overlie and surround the fossil and artifact bearing deposits. Brian previously had worked in Woods County and was interested in soil-landscape associations (Carter, 1991; Carter et al., 1990). Dr. Wakefield Dort (Department of Geology, University of Kansas) was asked to be principal coordinator and overseer of geological investigations at the Burnham site. Dr. Dort was present during the first visit to Burnham, and he brought to bear considerable experience studying diverse deposits of Pleistocene age (Dort, 1968, 1975, 1985, 1987a, 1987b). In particular, Dr. Dort was to plan the overall geological research, pose key questions, and stimulate studies and discussions designed to learn as much as possible about the Burnham site's varied deposits, their formation processes, and their ages.

The above scholars collaborated well during the 1989 fieldwork sponsored by the National Geographic Society. For several reasons, this collaboration lagged thereafter. Health problems plagued Dr. Dort, and Dr. Brakenridge's time was constrained as he got involved with NASA-funded studies of the geological processes affecting Martian landscapes. As a result, Dr. Carter became the primary researcher of the Burnham site's setting, soils, and sediments. He was on-site for much of the 1989 fieldwork, and he was the only one of the geology-pedology team present during the 1991 and 1992 excavations.

Given the above historical background, the following contributions do reflect the respective scholars' observations and interpretations at the particular times they were at the site. All of their contributions have helped shape subsequent research and sharpen perceptions of the Burnham site's stratigraphy and the processes that affected it.

References Cited

Brakenridge, G. R. 1981. Late Quaternary Floodplain Sedimentation along the Pomme de Terre River, Southern Missouri. *Quatenary Research* 15:62-76.

Brakenridge, G. R. 1983. Late Quaternary Floodplain Sedimentation along the Pomme de Terre River, Southern Missouri:Part II, Notes on Sedimentology and Pedogenesis. *Geologisches Jahrbuch, Reihe A* 71:265-283.

Brakenridge, G. R. 1984. Alluvial Stratigraphy and Radiocarbon Dating along the Duck River, Tennessee: Implications Regarding Flood-plain Origin. *Geological Society of America Bulletin* 95:9-25.

Carter, B.J. 1991. Soils and Soil Parent Materials in Northwestern Oklahoma. Prehistory of the Plains Border Region, edited by B.J. Carter and P.A. Ward III, pp. 15-23. *Oklahoma State University, Department of Agronomy, Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*. Stillwater.

Carter, B. J., P. A. Ward III, and J. T. Shannon. 1990. Soil and Geomorphic Evolution with the Rolling Red Plains Using Pleistocene Volcanic Ash Deposits. *Geomorphology* 3:471-488.

Dort, W., Jr. 1968. Paleoclimatic Implications of Soil Structures at the Wasden Site (Owl Cave). *Tebiwa* 11:31-38.

Dort, W., Jr. 1975. Archaeogeology of Jaguar Cave, Upper Birch Creek Valley, Idaho. *Tebiwa* 17:33-57.

Dort, W., Jr. 1985. Field Evidence for More than Two Early Pleistocene Glaciations of the Central Plains. Nebraska Academy of Sciences, *TER-QUA Symposium Series* 1:41-51.

Dort, W., Jr. 1987a. Salient Aspects of the Terminal Zone of

Continental Glaciation in Kansas. Quaternary Environments of Kansas, edited by W. C. Johnson, pp. 55-66. *Kansas Geological Survey, Guidebook Series* 5. Lawrence.

Dort, W., Jr. 1987b. Type Descriptions for Kansas River Terraces. Quaternary Environments of Kansas, edited by W.C. Johnson, pp. 103-108. *Kansas Geological Survey, Guidebook Series* 5. Lawrence.

Chapter 4
Geology of the Burnham Site (34Wo73), Woods County, Oklahoma: A 1991 Perspective

Wakefield Dort, Jr. and Larry D. Martin

Introduction

In May, 1986, landowner Keith Burnham was having an arroyo sideslope bulldozed to obtain fill for a small dam he was building across a fingertip tributary of West Moccasin Creek, Woods County, Oklahoma (Fig. 4.1). Recognizing bone fragments on the cut surface, he ceased operation and notified Don Wyckoff at the Oklahoma Archeological Survey, who in turn invited us to visit the site in early June. At that time, Larry Martin identified the skull of a long-horned bison as the source of the fragments. Because *in situ* finds of this animal are rare, the locality clearly had paleontological importance.

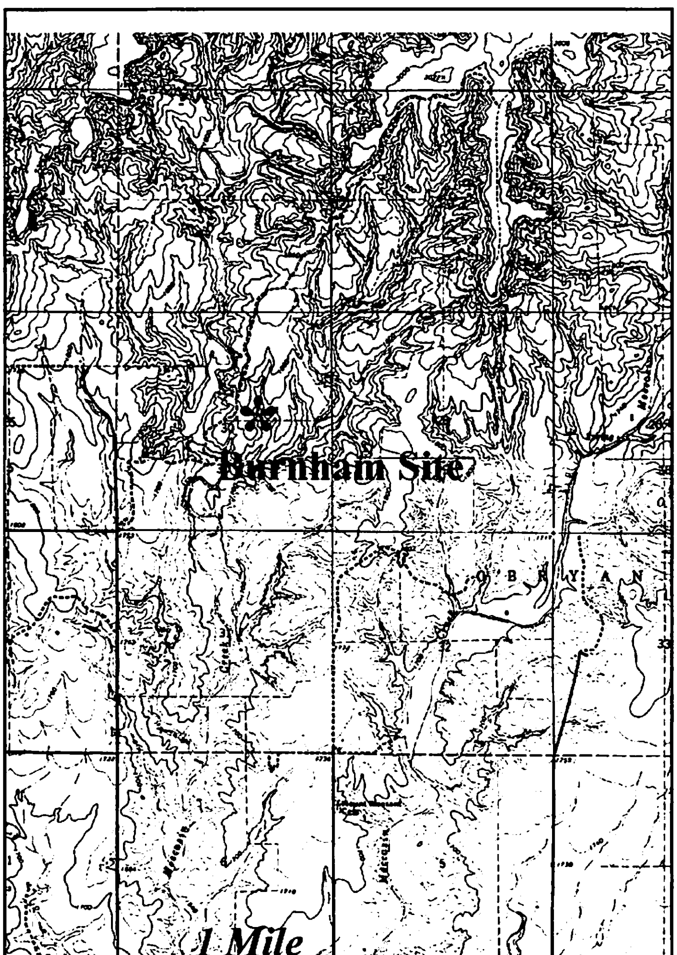


Figure 4.1. Topography of the Burnham site area; contour interval is 20 feet. Remnants of the High Plains surface, underlain by Ogallala gravel, lie at about 2000 feet a.s.l. in the northern (top) and eastern (right) parts of the map.

Excavation to recover the skull was undertaken by the Oklahoma Archeological Survey during five days in October of 1986. Found to be nearly intact, the skull was first believed to be *Bison latifrons*, but now is thought to be more similar to *Bison alleni* or *Bison chaneyi*. A left mandible, right scapula, several partial ribs, and vertebrae, all presumably from the same animal, were found in close proximity to the skull. When the upside-down skull was uncovered, a large angular cobble of chert was revealed below it. Because all of the enclosing sediment was sand, silt, or clay, the presence of this large rock attracted immediate attention. Laboratory examination of the coarsest sediment fraction, isolated by waterscreening, led to the recovery of several small chert flakes of unquestionable human origin, produced during reshaping of chipped stone tools; in other words, artifacts. The locality thus became a *bona fide* archaeological site and has been given the designation 34WO73, the Burnham site.

Occurrences of *Bison alleni* (or *chaneyi*) have been poorly documented; dating is tenuous. Nevertheless, it is believed that this form existed from approximately 40,000 years before present to perhaps 20,000 B.P., long before the generally accepted earliest arrival of humans in the New World. Radiocarbon dates of 40,000 +/- 1500 (AA-3849 on charcoal), 35,890 +/- 850 (AA-3837 on gastropod shells), and 31,150 +/- 700 (Beta-23045 on gastropod shells), all from the general area where the skull was found, intensified the belief that this could be a very old site indeed. It might, therefore, provide evidence of a pre-Clovis human presence.

Any site purporting to contain evidence of pre-Clovis humans must withstand intense scrutiny and outright disbelief. The burden of proof will be heavily on those who propose the great age. This certainly is true for the Burnham site. The first controlled excavation clearly demonstrated the close spatial association of bones of an extinct animal, flakes of apparently worked chert, and organic material that yielded old radiocarbon dates. However, these same excavations exposed sedimentary units that obviously had been deformed after deposition. This observation highlighted the clear possibility that there had been vertical mixing of objects of notably different ages, that is, the worked flakes might have been introduced from a higher, considerably younger horizon. Assessment of this possibility and attempts at validation of greater ages must be based on careful geological studies. If it can be shown that one or more sedimentary units are continuous and unbroken where they cap the horizons bearing the bones and artifacts, then no younger objects could have penetrated downward. The deeper units would have been sealed and protected by the caps. If, however, the presence of a seal cannot be demonstrated unequivocally, then interpretation of the site will remain open to question.

Geologic Setting

The eastern margin of the High Plains has been shifting westward as a consequence of erosion and headward lengthening by streams flowing toward the east across the Central Lowland. The zone of intense dissection is known as the Plains Border (Fenneman 1931; Frye and Swineford 1949) or the Dissected High Plains (Schoewe 1949). Relatively great relief occurs in an area that spans the central part of the Oklahoma-Kansas border (Fig. 4.2). This area generally is called the Red Hills, in reference to the strong coloration of the Permian bedrock or, sometimes the Cimarron Breaks, because this is where sharply incised minor tributaries of the Cimarron River have produced especially intricate dissection (Adams 1903; Moore 1930; Schoewe 1949). The Burnham Site is situated within the area of the Breaks, about 10km (6 miles) north of the Cimarron River and only 1.5km (1 mile) from southerly remnants of the High Plains surface (Fig. 4.1).

The Burnham Site is located at an elevation of approximately 530m (1750 ft) on a minor tributary of West Mocassin Creek, which in turn flows southward to join the main stem of Mocassin Creek (Fig. 4.1) and thence to the Cimarron River at about 470m (1540ft). The lower reaches of West Mocassin Creek have a gradient approaching 7 m/km (35 ft/mile). This and other creeks nearby head on the main scarp below remnants of the flat High Plains surface, here at 610m (2000 ft). About 60m (200ft) below the High Plains surface there are long, narrow remnants of another surface. In some places the local interfluves are almost horizontal; near the Burnham Site their slope nears 20 m/km (100 ft/mile). When the site was first visited, it was thought that these interfluve surfaces represented a dissected pediment. However, excavations at the site have shown that these surfaces are underlain by several meters of loose sediment, not bedrock, and so appear to be the result more of deposition than erosion. They are, therefore, not pediments in the strict sense. More accurate delineation and interpretation of this lower surface must await additional exploration in the field.

Bedrock beneath all but the highest parts of the area is of Middle Permian age (Fig. 4.3). Red-brown sandstone and shale of the Marlow Formation crop out in the close vicinity of the Burnham Site (Fay 1965). This unit, approximately 36m (117ft) thick, overlies the Dog Creek Shale, a red-brown silty shale 14-19m (48-62ft) thick with the 1.2m (4ft) Haskew Gypsum Bed near its base. Beneath the Dog Creek, but exposed in the lower portions of all major creek valleys, is the Blaine Formation. It is composed of

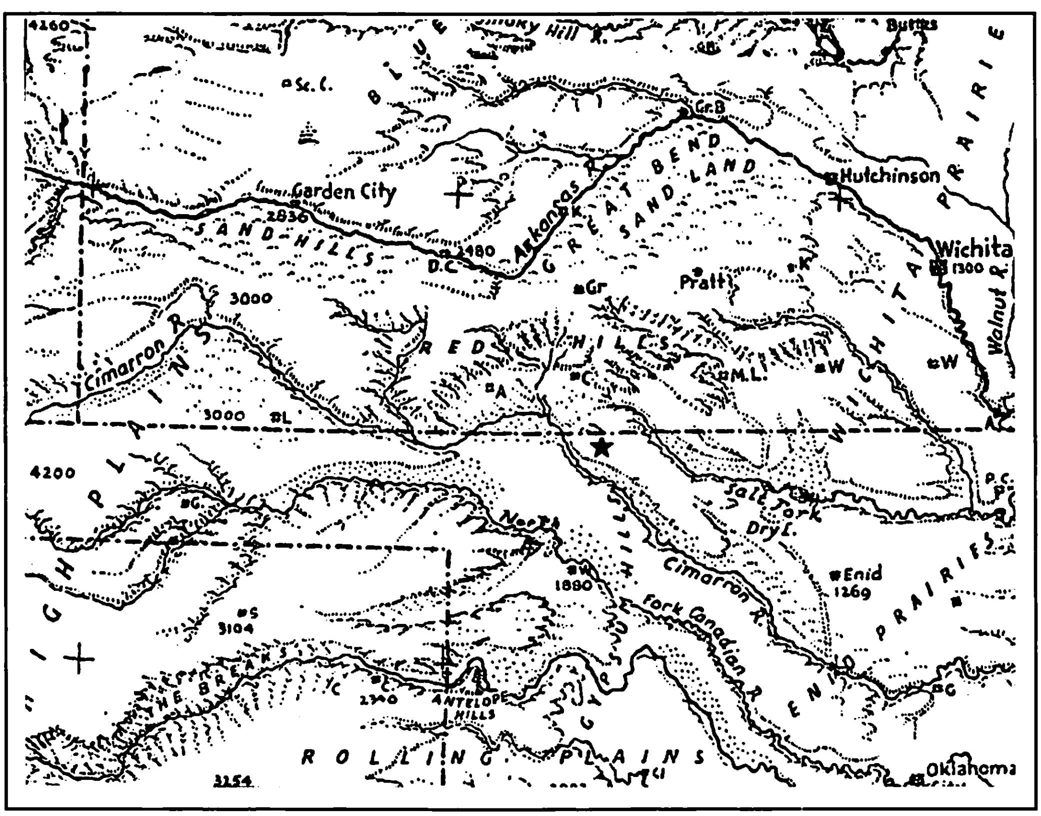


Figure 4.2. Landforms of western Oklahoma and southwestern Kansas. The Burnham site's location is indicated by a star. Adapted from Raisz 1957.

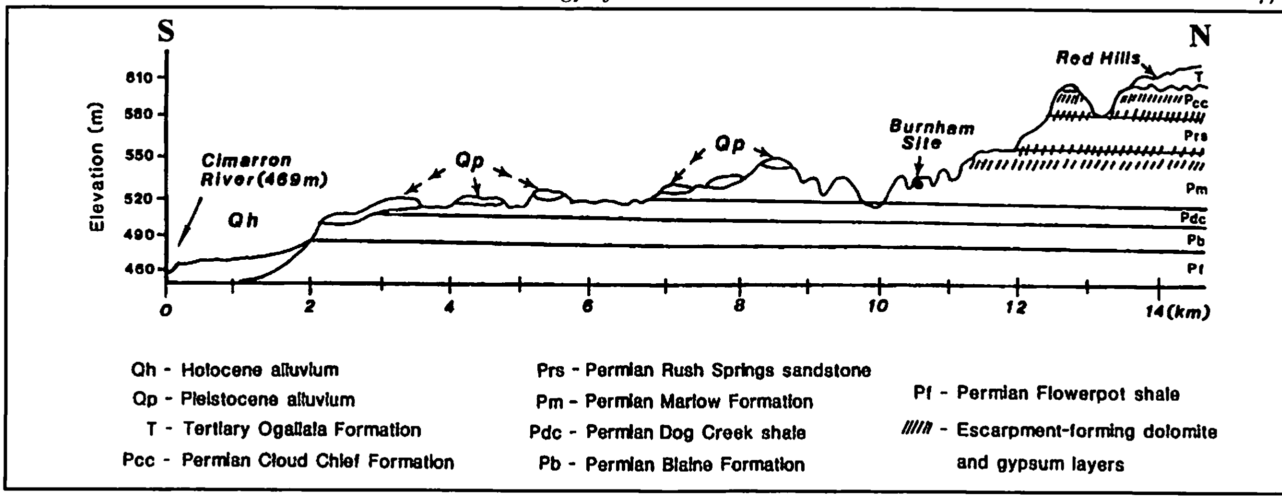


Figure 4.3. Regional stratigraphic section at the Burnham site, Woods County, Oklahoma. Drawn by Brian Carter.

three white gypsum beds, in descending order the Shimer (3.4-5.8m or 11-19ft thick), the Nescatunga (3.0-3.4m or 10-11ft thick), and the Medicine Lodge (6.7-9.4m or 22-31ft thick). Between these strata are thin dolomite and shale beds. Lower in the section is a thickness of more than 90m (300ft) of the gypsiferous Flowerpot Shale.

The prominent scarp north of the Burnham Site is eroded on the uppermost part of the Marlow Formation and sandstones, shales, dolomites, and gypsum beds of the Rush Springs and Cloud Chief Formations. Much of the High Plains surfaces are underlain by up to 30m (100ft) of irregularly cemented gravel, sand, silt, and volcanic ash of the Pliocene Ogallala Formation.

Hand-Dug Excavations

The purpose of the brief period of excavation in the fall of 1986 was to remove the bison skull and to find out what else might be present. This was accomplished, and several other bison bones were recovered as well as bones of small mammals, gastropod shells, and the tantalizing fragments of worked chert. These discoveries led to 14 days of excavation in 1988 and an additional 23 days in 1989 (Fig. 4.4). A total of 40 one-meter squares was opened, some to depths exceeding two meters.

The sediments exposed in the sides of the 1988 squares were clearly divisible into red masses and gray masses, but the *pattern* formed by those two colors was not at all distinct. In general, gray appeared to overlie red, but there were also zones of thin alternations, or even ostensibly discrete blobs, at least as seen on planar surfaces, of one color surrounded by the other. Most spectacular were flame structures of red sediment protruding upward into gray (Plate 2a).

Most of the sediment was fine-grained clay, silt, and fine sand, but locally there were small blebs that might have been highly weathered granules and tiny pebbles (Plate 2a). In some places, color boundaries seemed to cross possible depositional contacts; the relationship between color and stratification could not be determined more accurately during the brief time we were there to make observations. In 1989, exposed surfaces were expanded by further controlled excavation, but our attention was effectively diverted to backhoe trenches. We therefore gathered no additional information about the sediment exposed in the manually dug squares.

Backhoe Trenching

Exposure created by controlled excavation in 1986 and 1988 showed evidence of considerable soft-sediment deformation and movement. In contrast, the close juxtaposition of several elements of the bison skeleton seemed to indicate an absence of appreciable movement, at least on a scale that would affect large bones. Therefore, it was clearly necessary to seek some means of demonstrating that the worked chert flakes were indeed within the same depositional unit as the bison skull and could not have been introduced into that location by a mixing process or by intrusion from above. An acceptible alternative would, of course, be to discover similar relationships of bones and artifacts elsewhere at the site.

Because the bison skull had been found by exposure during bulldozing of an arroyo sideslope, and some of the worked chert flakes were only a few centimeters beneath the artificially created surface, there was no possibility of directly demonstrating that mixing or intrusion had not happened. The best chance of indirect evidence seemed to lie with a band of caliche masses exposed a little higher on the slope. If it could be shown, through further excavation, that these were the surface manifestation of an unbroken layer of caliche that extended both along the slope and into the subsurface for distances of at least several meters, and that the bison-bearing sediments were continuous beneath that caliche, then it could be argued that this carbonate layer had constituted a tight seal above the critical unit in which bones and artifacts were present. There might have been mixing

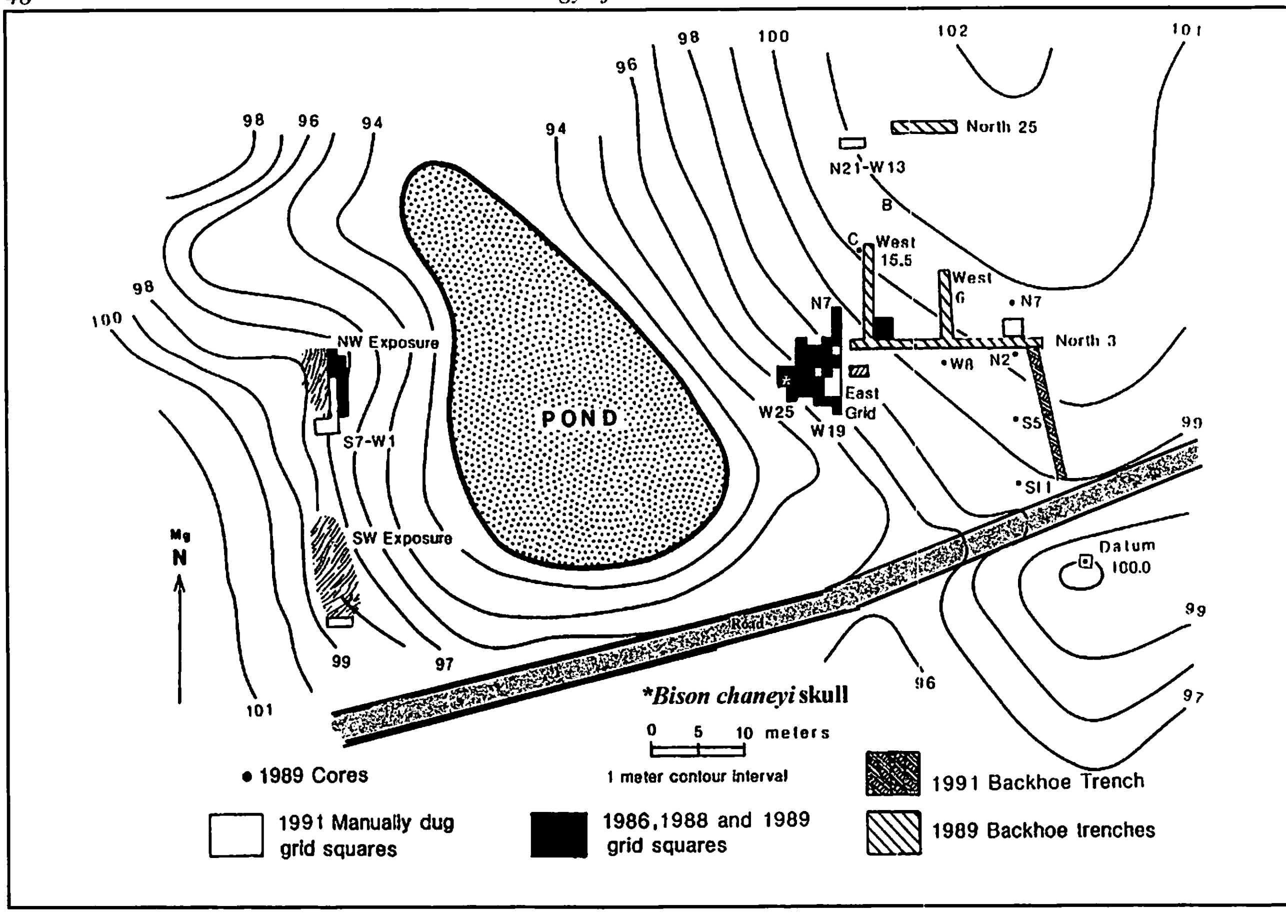


Figure 4.4. Map of the 1986, 1988, 1989, and 1991 excavations at the Burnham site. Compiled by Don Wyckoff.

within that unit, as indicated by the deformed contacts between red and gray sediments, but there could not have been intrusion of material from younger horizons above.

To test this possibility, additional excavation into the slope would be necessary. Such excavation could also search for any kind of definitive evidence that had not yet been considered. The fastest method would be to have a backhoe dig a deep trench. Such a trench would rapidly provide the necessary view of geological units and relationships beneath the surface, although carrying some risk of damage to buried archaeological and paleontological materials.

The backhoe trench, known as Trench N3 (Fig. 4.4), was dug on October 2 and 3, 1989. Although its exact location was selected purely on a hunch, its long axis was oriented almost precisely at right angles to the north of the controlled excavation grid, an orientation that was also about at right angles to the elongated crest of the interfluve lying east of the site. Digging began one meter east of the controlled squares and extended 23m farther eastward into the slope (Fig. 4.4). Depth was restricted by the maximum reach of the backhoe boom, and varied from 250 to 300cm. Consequently, as the land surface rose gently eastward, so did the floor of the trench. This meant that deeper units, uncovered in the controlled squares and at the western end of the trench, remained buried and unseen in the middle of the trench and at its eastern end. After this main west-to-east trench had been dug as far as seemed practical, two subsidiary trenches were opened for shorter distances northward to provide additional three-dimensional information.

As backhoe excavation proceeded, it became clear that complex stratigraphic units were being exposed and that detailed mapping would be necessary before their relationships could be understood. To this end, a horizontal datum line was installed using a cord attached to nails at 50cm intervals along the north face of the main backhoe trench. Positions of sedimentary boundaries, individual caliche nodules, bones, etc., were measured laterally and vertically from the points on the datum line. Spatial relationships thus recorded (Figs. 4.4 and 4.5) are described most clearly by commencing at the eastern end, farthest from the place where the bison skull was found. Unfortunately, a very rapid pace of backhoe excavation necessitated hurried efforts to trowel down and smooth the north face of the trench before the newly exposed surface dried in the sunshine and became unworkable. By the time detailed mapping had been completed, the face was so hard that small scale controlled sampling of specific sedimentary units was impossible. Descriptions of sediments are, therefore, only qualitative and generalized.

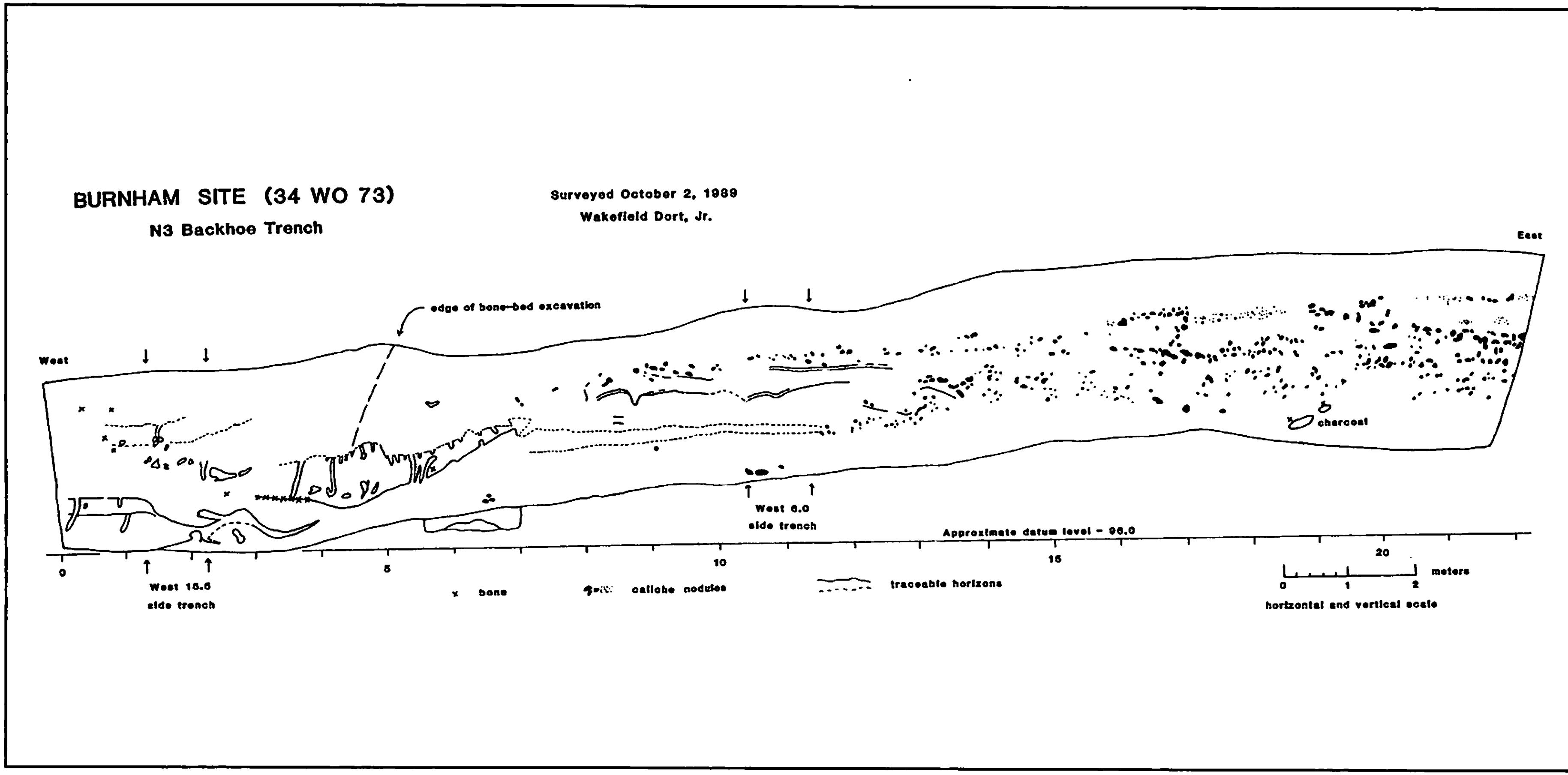


Figure 4.5. Stratigraphic section of North 3 backhoe trench dug in 1989.

Stratigraphy of the East-West Trench

From the 23-meter mark at the eastern end of the trench westward to about 13.5m (Fig. 4.6), the north face exposed massive reddish sandy sediment all the way down to the floor of the excavation at a depth of 305cm. No variation was discerned in this matrix. There were present, however, numerous masses of caliche. These ranged in size from specks less than 3cm across to blobs somewhat greater than 20cm in longest dimension. A generalized "average" approximated 5cm. Some of the larger accumulations appeared to be aggregates of several conjoined smaller nodules. Shapes were highly irregular, with sharp points and voids common. Most of the largest masses were roughly tabular and lay horizontally.

Distribution of the caliche masses appeared at first to be random, but mapping of the individual nodules proved otherwise (Fig. 4.6). Where the trench floor was deepest, no caliche was present in the lowest 80cm. The uppermost 70 cm also were barren. In the middle of the section, caliche was concentrated in discrete zones. The most prominent of these had a thickness of about 20cm and sloped westward approximately parallel to the undisturbed part of the overlying land surface (Fig. 4.6). Deeper zones gave the impression of being roughly horizontal, except for one that disappeared into the end of the trench 160cm above the floor. It seemed to slope gently down toward the east, but this may be a subjective interpretation of sparse data. In some places, nodules were also scattered between the poorly defined zonal concentrations.

The most unusual find in this area lay between 18 and 19 meters. Two pieces of wood charcoal were exposed in the trench wall. One was about 40cm long and 20cm high in the plane of the face, the other 15cm long and 10cm high. The long axis of each piece sloped about 35 degrees toward the west, as did the line connecting the two. On the upper surface of each piece of charcoal lay an irregularly worked fragment of bone, each being about 5cm long. Two samples of this charcoal yielded radiocarbon ages of 34,750 +/- 1040 (SMU-2422) and greater than 38,000 (Beta-33950) years before present. The wood was first identified as birch (*Betula* sp.) by Julio Betancourt, but is now believed by Peter Van de Water to be pawpaw (*Asimina triloba*). The bone fragments are unidentifiable, but are thick and large enough to come from an animal the size of a small deer.

The uppermost zone of caliche nodules was traceable, with localized variations in size, number, and spacing of these, westward in the trench face all the way to the 8.4-meter mark (Fig. 4.7). The deeper zones disappeared between 13.3 and 11.5 meters. The matrix of reddish sandy sediment also continued westward, but with faint suggestions of stratification appearing. Most tantalizing were two horizons in which the pervasive red was darkened by the addition of disseminated dark gray or black material. Each of these horizons, which had a distinctly higher clay content, was about 2cm thick (Plate 2b). Both upper and lower contacts of each showed numerous small-scale irregularities. Beneath each dark horizon was a parallel band, perhaps twice as thick, in which the sediment was of a markedly lighter color than that of the face in general. An immediately considered working hypothesis was that each dark layer contained charcoal from a grassfire, the underlying lighter zone being the product of bleaching by the heat. Chemical and mineralogical analysis of these sediments should easily prove or disprove this idea.

The eastern limit of the lower of the two dark horizons

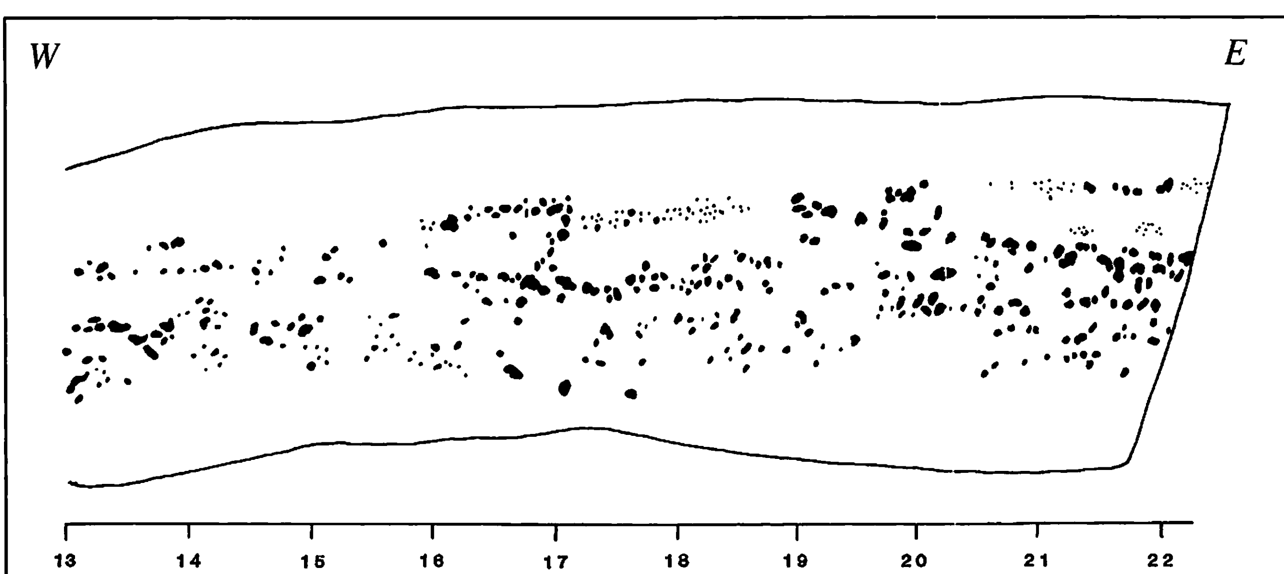


Figure 4.6. Detail of caliche nodule distribution in the eastern half of the North 3 (east-west) backhoe trench dug in 1989. See Figure 4.4 for location. Scale in metric intervals. Prepared by Wakefield Dort, Jr.

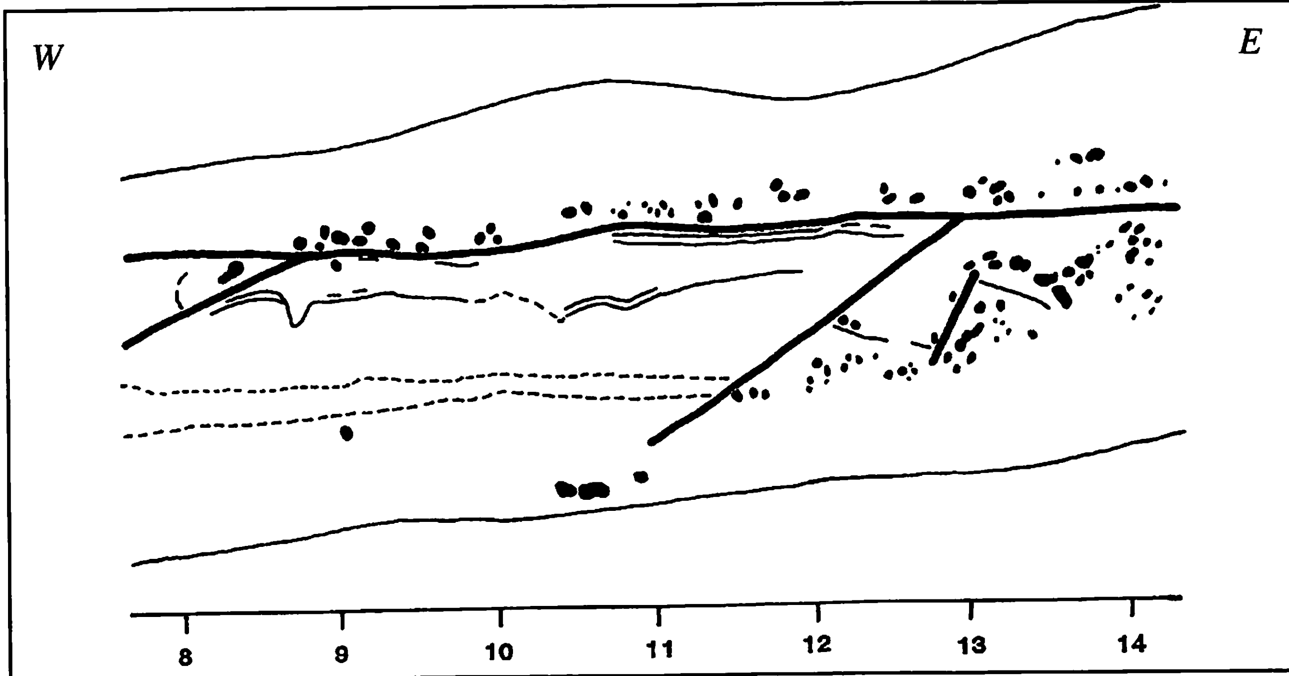


Figure 4.7. Detail of stratigraphy and possible faults in the middle portion of the North 3 backhoe trench dug in 1989. See Figure 4.4 for location. Intervals are in meters. Prepared by Wakefield Dort, Jr.

was at about 11.9m (Fig. 4.7). Only 20cm farther east, a possible continuation of that horizon lay 40cm lower, sloping gently eastward and interrupted once for a short distance. Another possible segment farther east and 35cm higher, also sloped eastward (Fig. 4.7). If these are indeed all segments of a single, once-continuous horizon, then faulting and tilting have occurred, the faults being invisible in the massive sandy sediment. Worthy of note is an apparently similar step in the zone of caliche nodules, although the offset is somewhat greater and the spatial relationship between the dark horizon and the caliche zone is not directly parallel. Almost certainly, some sort of deformation has occurred in this interval. The western limit of the lower dark horizon is at the 8-meter mark, where the upper zone of caliche nodules also ends. The upper dark horizon is clearly traceable westward to 10.6 meters and possibly continues to 9.0 meters (Fig. 4.7).

The uppermost zone of caliche nodules ends at 8.4 meters, the upper dark horizon nearby, and the lower dark horizon at 8.0 meters (Fig. 4.7). Beneath those horizons is a flat-lying unit, 10 to 20cm thick, that is composed of laminated gray sediment (Plate 2b). Its eastern end lies at 11.6 meters, close to the western end of the lowest caliche zone and the place where the lower dark horizon appears to be faulted (Fig. 4.7). It is not at all clear whether there is an erosional unconformity here, or a fault, or merely sedimentary facies changes.

To the west, the gray laminated sediments terminate abruptly at 7.1 meters (Fig. 4.8). A line connecting the western ends of the uppermost caliche zone, the lower dark horizon and the laminated gray unit slopes westward at an angle of about 25 degrees and, when extended, meets the inclined base of one of the most prominent sedimentary features in the entire trench. Extending from the 7.0 meter mark to about 3.0 meters is a gently curved mass of gray sediment shaped something like part of a crescent moon, concave upward as seen in the two-dimensional face of the trench (Fig. 4.8). Prominent in this dull matrix are bands of red sediment, some straight, some curved, but all essentially vertical (Plate 3a). These are believed to be sections through tubular burrows that were excavated downward into the gray sediment, then were filled with red sediment that subsequently was deposited on top.

Some the burrows extend through the total thickness of the gray zone, but many extend downward only 10-15cm from the base of the red unit (Plate 3a). It is believed that these short ones constitute only the lowest portions of burrows that actually were much longer. Since no continuation of any of these features is visible in the basal part of the overlying red unit, it is further believed that the burrows were excavated from a surface on the gray sediment that was situated many centimeters above the present top of that unit and that the missing portions were removed by erosion before the red sediment was deposited. The contact between the gray and the overlying red is, therefore, an erosional unconformity and time break.

When the trench was opened, at least 8 bones were visible along the basal contact of the massive gray unit with the underlying red sediment between 3.8 meters and 2.6 meters from the western end (Fig. 4.5). Subsequent excavation, first by backhoe, and then by archaeological techniques, resulted in the uncovering of nearly 60 bones. More than half

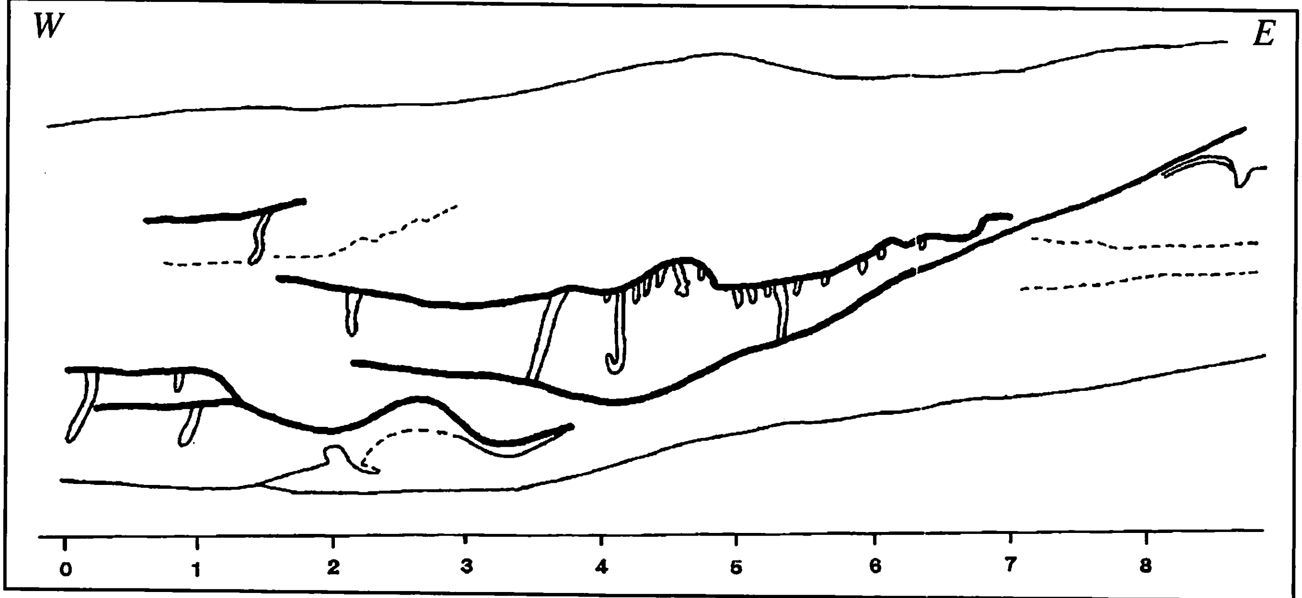


Figure 4.8. Detail of stratigraphic units and possible unconformities in the western part of the North 3 backhoe trench dug in 1989. See Figure 4.4 for location. Scale in meters. Prepared by Wakefield Dort, Jr.

of these belonged to two small horses. The remainder included bones of bison and mammoth, various small mammals, reptiles, amphibians, birds, and fish.

Sedimentary features and stratigraphic relationships are much more complicated in the westernmost 4m of the trench, the part the backhoe excavated first (Fig. 4.8). The rapidity of the backhoe operation made it impossible to smooth the face by trowel, map complex forms, and keep up with the advancing cut. Therefore, only the largest, clearest lineations were recorded. At the 1-meter mark, the generalized sequence consists of 60cm of massive gray sediment at the bottom, overlain by 30cm of laminated gray sediment, which is succeeded by 190cm of red material. Such a description, however, omits the many intricate details of alternating red and gray beds, laminations, lenses, and blobs. At least four levels of burrows are present, each marking excavation below a former land surface, and all filled with red sediment (Figs. 4.5 and 4.8).

The floor of the trench at its western end is almost exactly the same elevation as the location, about 4.5m farther west, of the bison skull. The complex of red and gray sediments revealed by the controlled archeological excavations appears to be, at least in the broad sense, correlative with the sediments seen in the lower levels of the western part of the trench.

Stratigraphy of the North-South Trenches

To provide subsurface information in the third dimension, the backhoe dug two shorter trenches northward from the edge of the long east-west cut. These intersected the long trench at 1.4 to 2.4 m and at 10.2 to 11.3 m. The eastern side-trench, known as Trench West 6.0 (Fig. 4.4), was roughly 6.5m long with a sloping end. It exposed more of the massive red sediment seen in the eastern half of the long trench (Fig. 4.9). Caliche nodules were concentrated in two horizontal zones that extended the full length of the side-trench. Of the possibly burned dark horizons seen in the long trench, the upper one could be traced 1.4m northward, the lower one 3.7 m (Fig. 4.9).

The western side-trench, known as Trench West 15.5 (Fig. 4.4), was 12.8m long and revealed a highly complex distribution of gray and red sediments in its southern portion (Fig. 4.10). The sedimentary structures are closely similar to those seen at the western end of the long trench and in the controlled excavations. Orientation of beds, lenses, and contacts visible in the side-trench wall is generally horizontal across the first 3 meters. Farther northward up the trench contacts rise gently toward the north at angles slightly less steep than that of the trench floor, which in turn roughly paralleled the land surface. All but the lowest gray and red units disappear by the 5-meter mark, leaving only massive red sediment similar to that exposed in the eastern half of the long trench and in most of the eastern side-trench. Two zones of caliche nodules are visible in the last 80cm of the face (Fig. 4.10).

Interpretation and Discussion

Paleontological and archeological materials at the Burnham site are contained in a series of unconsolidated sedimentary units. These rest on and are in some manner inset into the Permian bedrock. Artificial exposures of the loose sediments reveal local facies changes, cut-and-fill configurations, and deformational structures. Decipherment of the implied, as well as the directly demonstrable, sequence and chronology of geological changes will provide the best possible basis for assessment of the antiquity and archeological importance of the site.

The bison bones and artifacts were recovered from layers of fine-grained gray and red sediments. These appear to be set into older, nearly massive dark red material. Reconstruction of the geologic history of the sedimentary section must, therefore, begin with the latter.

The Massive Sediment

It is believed that the oldest sediment exposed by excavation, at least on the eastern side of the arroyo, lies in the bottom of Trench N3, the long east-west backhoe trench. Because the floor of this trench rises toward the east, the stratigraphically lowest part would be located near the western end (Fig. 4.5). However, the oldest sediment actually present in the area is at some unknown location and depth, and is unseen.

In September, 1989, four exploratory holes were drilled along a north-south line that passed approximately through the 18-meter mark of the backhoe trench (Fig. 4.4). None of these holes reached bedrock, although all were reported to have bottomed in what was at the time considered to be "basal gravel" (September 15, 1989, letter from Wyckoff). This designation is open to question, however, because one of the holes was extended 129cm below a gravelly zone, which would surely have been called a "basal gravel" if drilling had stopped there, yet it still did not encounter bedrock. Therefore, its total depth of 658cm (21 feet 7 inches) is only a minimun thickness of the cover of loose sediment at that spot; the true thickness remains unknown.

The elevation of the bottom of this hole is only about 50 cm above the floor of the nearby arroyo that cuts through the site. No bedrock is visible between the floor of that arroyo and the excavations and backhoe trench on the eastern slope. The implication is that unconsolidated sediment extends to greater depths here. Bedrock is, however, exposed nearly halfway up the slope on the western side of the valley. Furthermore, bedrock crops out at the ground surface close to the crest of the ridge about 30m south of the backhoe trench on the eastern side. This means that there is a buried bedrock scarp just south of the trench. It must be at least 5 m high (with allowance for the inclination of the land surface there), and may be, at least in part,vertical. (A new backhoe trench excavated in late May, 1991, exposed the upper part of this bedrock face, as shown in Fig. 4.11. It is vertical.) Because this scarp has been seen at only one point, its orientation and configuration remain unknown, as does the total relief on the bedrock surface and, therefore, the maximum thickness of sediments overlying the bedrock.

A thickness of approximately 350cm of this sediment was exposed by the long backhoe trench designated N3. Superficial examination by us as excavation proceeded indicated that it is mainly a fine sand with varying percentages of silt and clay. Subsequent analyses by Carter (this volume) determined that the silt content generally equals the sand or exceeds it by up to double. Clay comprises from 17% to 25% of each sample. We could discern no stratification; Carter identified two faintly developed paleosols in the lower part of the section near the eastern end.

Although this sandy silt appears, in itself, to be massive

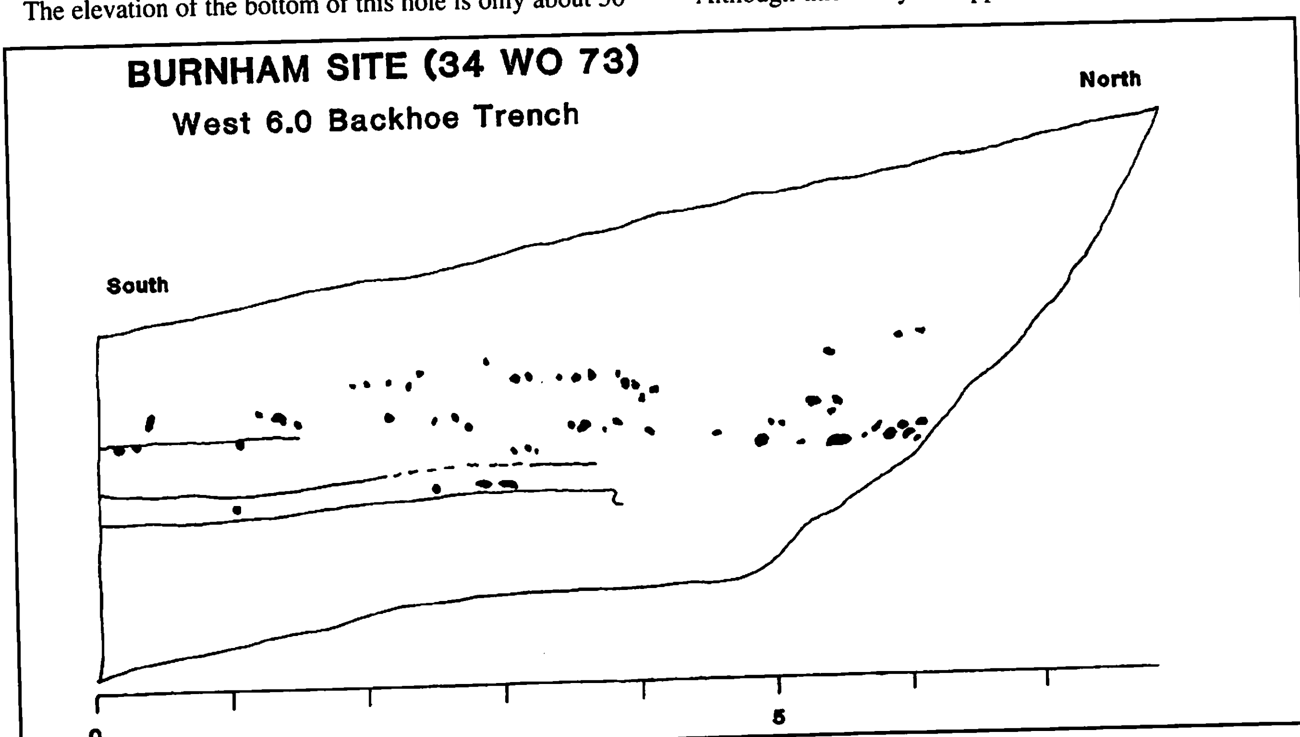


Figure 4.9. Stratigraphic section of West 6 backhoe trench dug in 1989. See Figure 4.4 for location. Scale is in meters. Prepared by Wakefield Dort, Jr.

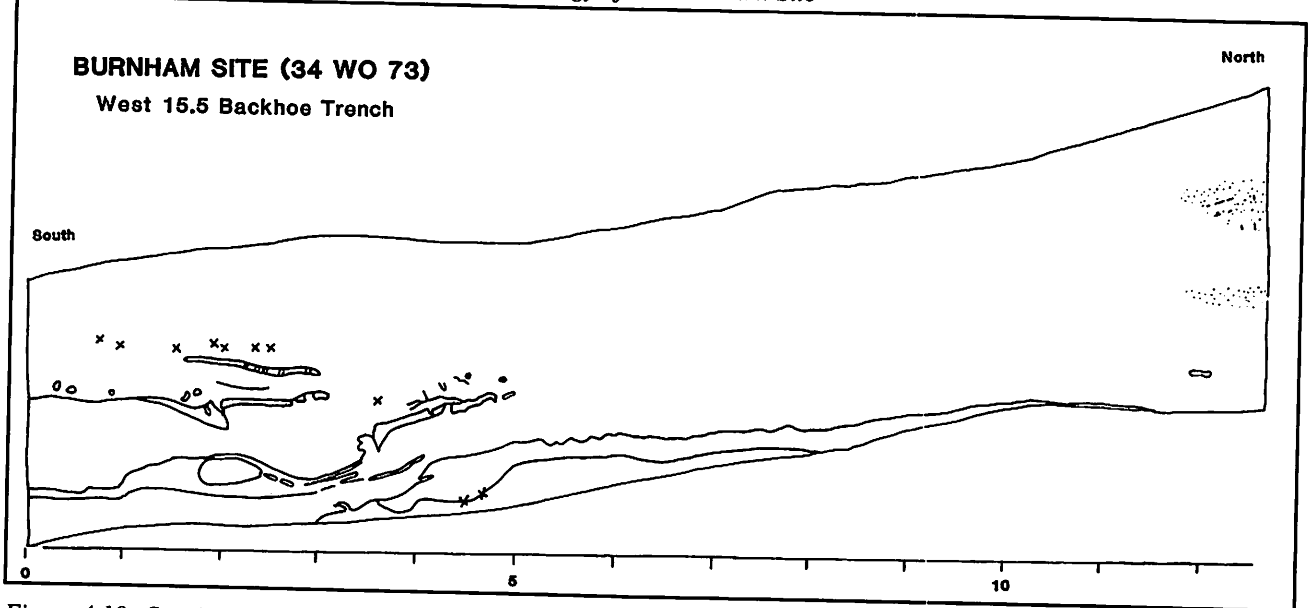


Figure 4.10. Stratigraphic details of West 15.5 backhoe trench dug in 1989. See Figure 4.4 for location. Scale is in meters. Prepared by Wakefield Dort, Jr.

and unstratified, a pseudostratification is created by caliche nodules. As already mentioned in the section on stratigraphy, precise mapping of individual carbonate masses revealed a non-random distribution. The pattern is not perfectly clear, but there do seem to be at least three zones of nodule concentration that are sub-horizontal to roughly parallel to the overlying ground surface (Fig. 4.6). Near the eastern end of the trench there is a possible zone that appears to slope down toward the east (Fig. 4.6).

Pedogenic development of masses of calcium carbonate can be influenced by several factors. However, in the absence of bed of distinctly different grain size distributions, hence with contrasting permeabilities and groundwater movement, it is believed that these zones of caliche nodules are related to water table positions or depths of penetration of roots. Roots release carbon dioxide into the soil air, increased carbon dioxide pressure causes solution of calcium carbonate, bicarbonate ions migrate downward to a horizon in which biological activity is less, and calcium carbonate is reprecipitated. Alternatively, in areas of low rainfall, such as western Oklahoma, evaporation raises soil water by capillary action, carbon dioxide is lost and calcium carbonate is precipitated. In either situation, the resulting caliche zone will be close to the soil surface (Blatt 1982). Under the influence of either of these mechanisms, or both together, the three zones of concentrated nodules at the Burnham site could represent three episodes of particularly favorable climatic parameters separated by times of change in soil water and depth to the water table. It may, however, be more likely that these zones are surrogates for three positions of a ground surface that was being episodically aggraded. They appear to constitute a State II accumulation of authigenic carbonate (Birkeland 1984; Gile et al. 1966). It is possible, however, that the situation is more complicated, including, perhaps, partial silicification of the nodules (suggested by Vance Holliday in a telephone conversation, October, 1991).

Near the middle of the long backhoe trench, between 13.3 and 11.5m, the lower zones of caliche nodules terminate abruptly against markedly different sediments (Figs. 4.5 and 4.7). To the east is the massively sandy silt; to the west are stratified sands, silts, and clays. We believe that this sharp change holds important clues to the origin and history of the unconsolidated sediments at this site.

In massive, nearly homogeneous sediment like the sandy silt it might be expected that conditions favoring formation of nodular concentrations of calcium carbonate would change gradually in a lateral direction and that the number and size of nodules would taper off through an appreciable distance--at least several tens of centimeters, perhaps more. This is not what happens here. Some of the largest nodules in the entire trench face are located less than one meter from the abrupt termination.

Of primary importance are answers to the questions: do the zones of caliche nodules end specifically because the host sediment ended? Or was it because some condition in the host sediment, such as soil water, ended at the time precipitation of carbonate was taking place? Or did both the massive host sediment and the enclosed nodules formerly extend farther to the west, and that portion has since been displaced or removed? Nevertheless, the three-dimensional extent of zones of nodule concentration, seen in the trench walls as lines, may well provide indication of the slope of the overlying land surface at one or, perhaps, several periods in the past.

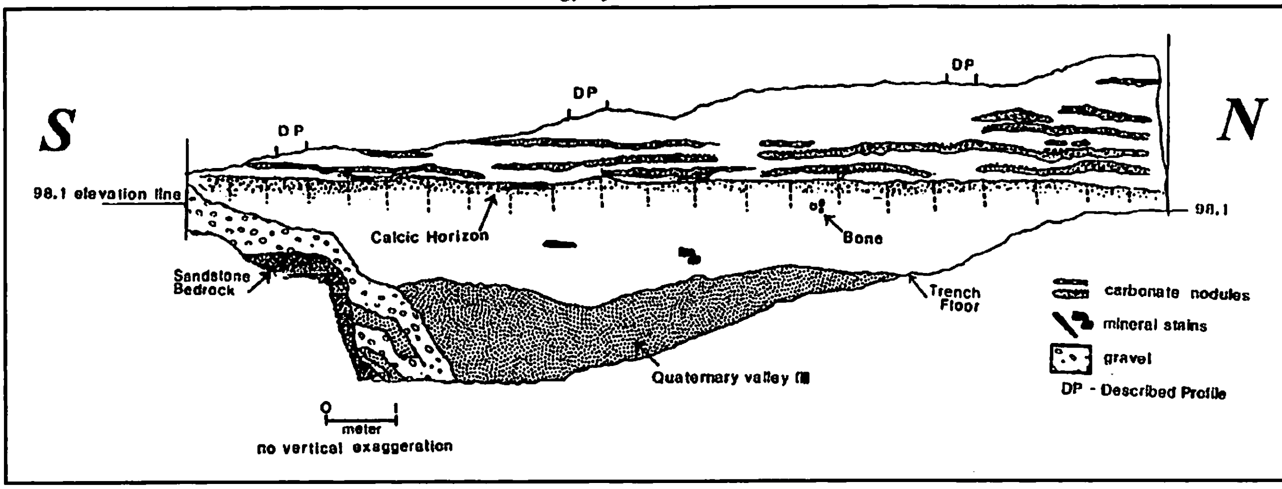


Figure 4.11. North-south profile of the 1991 backhoe trench at the Burnham East Exposure. See Figure 4.4 for location. Note apparent draping of gravel down the bedrock face. Prepared by Don Wyckoff.

The potential significance of this lateral change of sediment was not recognized at the time the trench was being excavated. Because of time constraints, no samples were taken, no detailed descriptions written. The trench has since collapsed so that the exposure no longer exists, although it could be re-excavated. Only the field map is now available for interpretation.

Another aspect pertinent to interpretation of the spatial distribution of the nodules is the origin of the host sediment and of the abutting sediment to the west. The latter is locally well stratified. As will be discussed in subsequent paragraphs, it clearly accumulated in ponds and perhaps, small, slowly moving streams. In contrast, the nodule-bearing sediment is devoid of visible stratification. Either it was not deposited by or in water, or original stratification has been completely destroyed by turbation, perhaps chemiturbation. Until samples have been subjected to close scrutiny in the laboratory, we cannot be certain, but the working hypothesis is that this sandy silt is of eolian emplacement. Where exposed at the site, it shows little variability. On nearby slopes, however, are scatterings of rounded pebble gravel, undoubtedly of fluvial origin, and perhaps reworked from the Ogallala Formation that underlies the High Plains to the north. Also present are pebbles and cobbles, generally subangular, of creamy white dolomite. These probably are clasts of the Day Creek Dolomite, which supports steep slopes on the High Plains escarpment. How these fragments were transported across the gently sloping surface on top of the sandy silt is an intriguing question. One suspects some form of periglacial, i.e. frost-climate, mass movement.

If, indeed, the caliche nodules are contained in an eolian sediment, then it is reasonable to propose that this unit was deposited as a blanket continuous across at least the nearby countryside. It is possible that the upper surface was occasionally and locally indented by swales or closed hollows. It does not seem possible, however, that on an actively aggrading surface these could have had side slopes with angles approaching 40 degrees, which is the angle of a line drawn along the western margin of the lower nodule zones (Fig. 4.7). It is therefore likely that this margin is the result of later erosion, being the eastern edge of a small valley. An alternative, to be discussed later, is that this margin is the plane of a small fault or, more likely, a slump. Indeed, a single faint line of apparent stratification seems to show both offsetting and drag curvature such as could be produced during step-slumping of unconsolidated sediment. This could, of course, happen along the side of a stream valley. A similar situation is present at the termination of the upper nodule zone.

The uppermost zone of caliche nodules extends farther westward, all the way to the 8.4-meter mark (Fig. 4.7). This means that it extends almost 5 m beyond the termination of the lower zones. It therefore overlies, and must be younger than, the stratified sediment. Furthermore, the base of the upper zone, where it rests on stratified sand and silt, must be a disconformity. This surface cannot be traced eastward through the massive sandy silt. Nevertheless, the westward prolongation of the upper nodule zone, and, especially its host sediment, clearly demonstrates that aggradation of massive sediment continued after the section of stratified sediments had been deposited. It does not necessarily follow, though, that the process of accumulation was always exactly the same. Sediments of similar appearance can originate in differing ways. Only close laboratory study of these materials can elucidate further detail.

The Stratified Sediment

Stratified sand, silts, and clays are exposed in the western half of the long backhoe trench (N3) and in all of the hand-dug archeological squares. Because all of the cultural material and all of the bones were extracted from these strata, determination of their extent, sequence, chronology, and environments of deposition is a prerequisite for any archeological evaluation of the site.

For convenience of discussion, the stratified sediments visible in the wall of the North 3 backhoe trench can be divided into three parts. Strata in contact with the western termination of the lower portions of the massive sandy silt and the lower zones of caliche nodules can be traced, with some modifications, to the western end of the trench (Fig. 4.5). Inset into this sequence is a depression filling that is cut by numerous burrow fillings. That, in turn, is overlain by a third group of beds.

The lower, hence older, group of strata shows considerable diversity. Near the top of this part of the section there are thin dark horizons that may have been created by grass fires (Plate 2b). Extending roughly from 12.4 to 8.1 meters, these directly underlie the westward extension of the uppermost zone of caliche nodules (Fig. 4.7). They are somewhat discontinuous and have local relief of about 20 cm. Both upper and lower contacts are diffuse in detail. General thickness of each layer is a little less than 10cm. The host sediment of these layers, and for as much as 60cm below them, is a dark pink to red, faintly stratified sand/silt mixture, with at least one 10cm unit in which dark red clay is dominant.

Deeper in the section there is a unit that is clearly traceable from 11.5 to 7.0 meters (Fig. 4.5). Up to 20cm thick over all, it is composed of numerous thin layers and laminae that are horizontal in general, but locally disturbed, and also cut by filled burrows. Colors of individual beds range from light pink to very dark red; some are a contrasting light gray (Plate 2b; Plate 3b). Compositions range from silt to a material that in the field appeared to be essentially pure clay. Below this heterogeneous unit only massive red sandy silt is present above the floor of the trench.

It is nearly axiomatic that a thinly laminated, fine-grained sediment must have accumulated in an aqueous environment subjected to extremely low energy levels. Clays generally indicate standing water. This particular unit mentioned above probably resulted from episodic deposition in a small, shallow pond, or perhaps on the floor of a depression that only occasionally was wetted. Wind-generated currents were insufficient to keep clay particles in suspension. Further interpretive details are at present unavailable. No samples were obtained, therefore, no laboratory analyses can be made.

This lower group of strata is cut into by the concave upward base of a younger deposit that is visually outstanding because it consists of nearly featureless, massive to faintly laminated, light gray sediment set sharply into the prevailing reds. The concave shape of the bottom of this unit looks like the transverse profile of a small valley with gently sloping sides (Fig. 4.8). Indeed, this is almost certainly an erosional form because it appears to cut off strata of the lower group of sediments. It is difficult, however, to explain how the bottom of a small valley could become filled with a massive deposit of fine-grained material entirely different from that in the unconsolidated banks, which apparently did not slough or slump. One might suggest that it happened in a single event or pulse; had there been recurrent pulses, clear stratification should have been preserved.

Rendering this exposure even more spectacular are numerous burrow fills that interrupt the gray matrix. Some of these fillings are gray, either slightly darker or, in most instances, slightly lighter than the background. Most outstanding are the burrows filled with red sediment that form brilliant bands, 4-8cm wide, vertically through the gray mass (Fig. 4.8; Plate 3b). The exact shapes of these bands are determined by the position of the plane of the exposure relative to the burrow tubes. All are longitudinal sections, of course, but not all cuts are strictly parallel to the long axes of the burrows, or coincide with their maximum diameters. Branching or bulbous lower ends may represent "living quarters."

Detailed mapping recorded 19 of these features protruding downward from the upper contact of the massive gray unit. Some extend completely through the presumed channel fill, enter the underlying red sediment, and become indistinguishable. The majority, however, project downward only 10 to 15cm. It is not known whether all of these burrows were dug by small rodents such as ground squirrels, or whether some might have been produced by crawfish. Nevertheless, in either instance a total depth of only 10-15 cm appears to be much too shallow. It is therefore believed that the present top of the gray unit is actually an erosional surface. Most of the burrows were dug from a higher ground level, then truncated by an episode of degradation. It must be noted, however, that a few of the burrows can be traced upward at least a few centimeters into the overlying red sediment. Therefore, not all of these were excavated at the same time from the same ground surface.

The burrows are separated by intervals ranging from less than 5cm to a bit more than 20cm. This spacing indicates intense use of a limited area by fossorial organisms. Even though the actual time span represented remains unknown, it could not have been very long, and a considerable population density may therefore be proposed.

One additional outstanding aspect of this channel-fill deposit is its bone content. By great good fortune, the northern face of the North 3 backhoe trench cut through several small bones lying on the bottom of the gray fill between 3.8 and 2.6m (Fig. 4.5). Because no bones were seen in the backdirt from the trench, it was hoped that additional specimens might be present in the unexcavated sediment to the north. Exploration proceeded here in 1989 with spectacular results (Fig. 4.12). A concentration of more than 50 bones was uncovered, permitting identification of mammoth, bison, several species of small mammals, reptiles, amphibians, birds, fish, and, of perhaps greatest interest, two small horses (Wyckoff et al. 1991).

In a preceding paragraph it was suggested that the apparently homogeneous nature of this gray channel fill indicates a single pulse of deposition. In opposition to this idea, the bones contained in this fill display a range of degree of preservation (Wyckoff et al. 1991). This aspect suggests that there were multiple events of bone placement on an aggrading valley floor. An alternative would be that bones showing various degrees of weathering were lying on the land surface nearby and that all were washed into the valley during a single event. This proposal would seem to be strengthened by the fact that most of the animals were represented by very few skeletal elements, such as might have remained on the ground after scavengers had been busy. Only the horses were relatively complete. A careful sedimentological analysis should provide details of the origin and significance of this deposit.

Up to this point, the discussion has been concerned with the massive sandy unit and its enclosed caliche nodules in the eastern part of the trench and stratified sediments to the west. Mentioned so far were the deep strata near the center and an inset gray channel fill containing a number of red burrows. To the west of the channel fill the stratigraphy and, in a sense, the structure of the sediments are extremely complex. The longitudinal profile of the trench wall (Fig. 4.5) provides only the barest hint of the intricacies present. Sediments range in color from cream to pink to red to very dark red. Strata range from thin clay-rich laminations to massive sandy units. Multiple generations of burrows extend downward from several internal surfaces, both erosional and, possibly, depositional in origin. Some strata lie in their original attitudes, others have been highly deformed.

It is obvious that this area, even though perhaps very localized, has been extraordinarily dynamic and changeable. Almost countless episodes of deposition and erosion, some of momentary stability, have been linked in a kaleidoscopic environmental sequence. Many, perhaps most, of the intervals have been short. Some laminae may record single storms. Full reconstruction of the history is probably impossible. However, detailed mapping and careful analysis of individual sedimentary units would yield a great deal of information and therefore, should be accomplished after the collapsed trench has been re-excavated.

The sedimentary record exposed in the hand-dug archeological squares west of the end of the long trench is not as intricately complex as the relationships visible near the western end of the trench itself. This may in part be the conse-

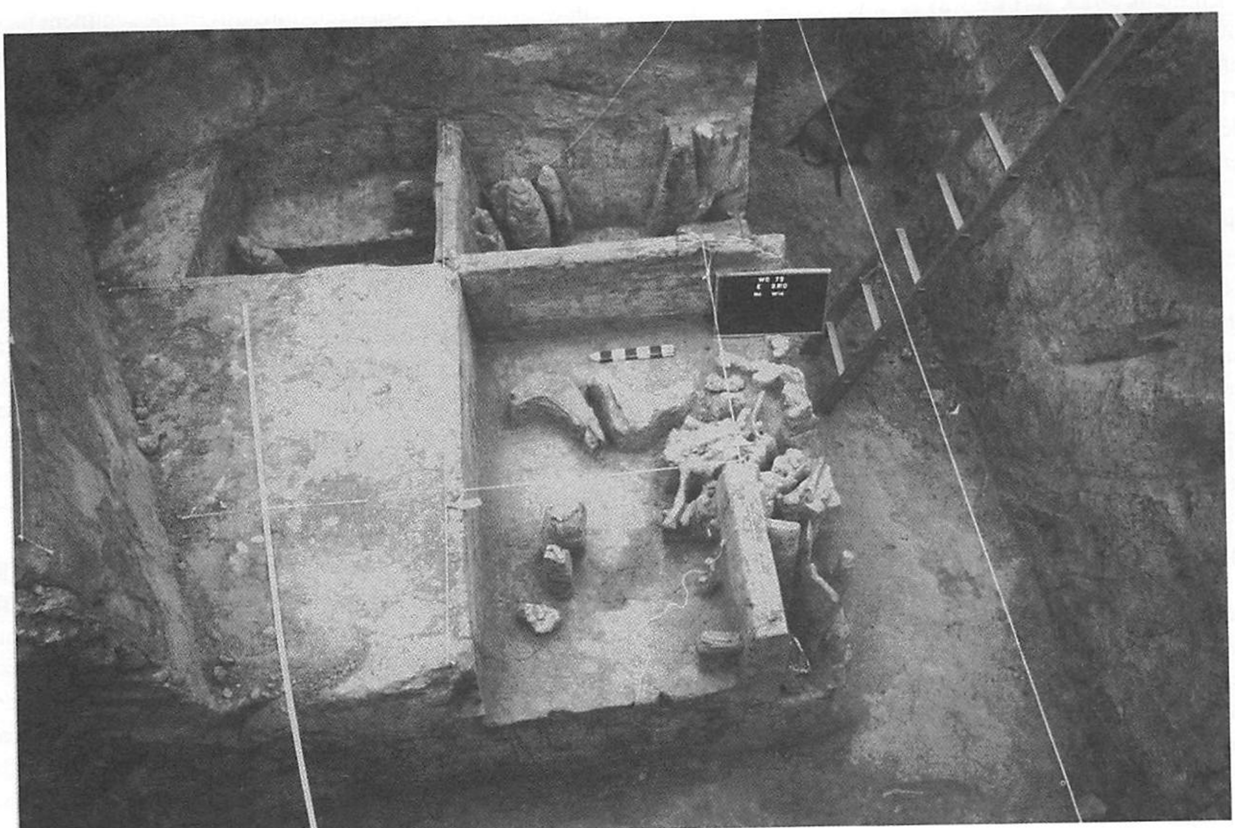


Figure 4.12. View east of the "Horse Bone Bed" exposed on the northern side of the North 3 backhoe trench dug in 1989. Photo taken October 16, 1989, by Don Wyckoff.

quence of removal of upper strata, first by erosion of the valley, then by the bulldozer when the bison skull was discovered. But even the sediments still visible in excavation balks display fewer complications than are seen near the end of the trench.

Chronology and Proposed History

For the purpose of reconstructing the history of the Burnham archeological site, compilation can be restricted to the unconsolidated sediments. What transpired before deposition of these sediments can be ignored.

What appears to be the oldest land form in the vicinity of the site is the gently sloping, now dissected surface extending southward from the base of the High Plains escarpment. This was initially thought to be an old pediment, but both natural and artificial exposures show that it cuts across unconsolidated sediments. So, apparently, this land form is not a pediment in the strict sense, and is not very old at all. The dissection channels obviously must be even younger.

The oldest sediments seen at the site are those of the massive sandy silt and its associated gravel zones. It is known from outcrops, trenching, and drillhole information that these sediments rest on an uneven bedrock surface, determination of the origin of which is important for reconstruction of the history of the site as a whole. In the 1991 south backhoe trench the bedrock surface was seen to be locally vertical. However, landscapes in general do not include vertical segments. One could, however, result during scarp retreat on a particularly resistant rock unit, by undercutting on the outside of a stream meander, or by abrupt downward movement of a block by faulting or subsidence.

Permian formations in western Oklahoma and adjacent areas include a number of beds of gypsum ranging up to at least 10m (30ft) in thickness. Solution by circulating ground water has resulted in subsidence or collapse at many locations. Depending on the thickness of the dissolving unit, the area affected by solution, and its depth, a closed depression may form in the ground surface, a type of sink hole. Some of these features in Oklahoma and Kansas have been important sources of Pleistocene faunal remains (e.g., Fenneman 1931; Frye 1942; Hibbard 1949; Schultz 1969; Smith 1940; Stephens 1960).

Cuts along U.S. Highway 64, only 4km (2.5 miles) south of the Burnham site, clearly show thick gypsum beds with abrupt lateral terminations beyond which there is only unconsoldiated sandy sediment. These exposures appear to be cross sections of the margins of collapse structures formed as a result of solution removal of deeper layers of gypsum. It is proposed that the stepped bedrock surface at the Burnham site formed in the same way.

Collapse of this sort would surely cause deformation of bedding in unconsolidated surficial deposits, especially near the margins of subsiding blocks. As already noted, however, the deepest exposed sediments of the Burnham site are massive and so lack planes of stratification that would reveal any deformation. Therefore, it cannot be determined from the general sediments whether they were part of a block that subsided or, conversely, whether they were deposited later in a surface depression created by a previous subsidence. Zones of caliche present in all of the backhoe trenches are high in the section, well separated from bedrock contacts, and indicate only that there has not been major tilting since they formed. If these are indeed related to soil water, then there probably is no relationship between them and the origin of the underlying bedrock surface.

The south backhoe trench, excavated in June of 1991, exposed a gently-sloping bedrock surface which changed laterally to nearly vertical and plunged beneath the floor (Fig. 4.11). Resting on the upper part of the bedrock was a gravelly unit 30-50cm thick. It appeared to be composed of angular clasts of the local bedrock averaging perhaps 2 cm across. In the deeper area, where the face of the bedrock was almost vertical, there seemed to be two or three gravelly zones sloping less steeply away from the rock face. Between these zones and above them was the massive sandy silt.

The trench exposure is not sufficiently extensive to display clearly the spatial relationships of the sediment facies. If there were a bedrock-rimmed surface depression that gradually filled with sediment, one would expect that the coarse, marginal gravel facies would show intertonguing into the finer sand and silt of the basin center. All strata would be nearly horizontal. On the other hand, if a gravel layer had been deposited more or less across the aggrading basin floor and then further subsidence occurred, gravel could be draped along the steep bedrock face. The resulting relationships would be such as is exposed in the south backhoe trench, although the presence of three apparently separate gravel layers remains unexplained. An even more drastic possibility would be complete filling of a depression with gravel, followed by erosional removal of all but the marginal zone, then refilling with sandy silt. This seems to be an unlikely scenario.

Much additional subsurface information will be needed before this problem can be solved, yet understanding the origin and environment of deposition of the massive sandy silt and its gravel zones is basic to interpretation of the site. It must be remembered that exposures in the east-west trench (N3) demonstrated that although the artifact and bone-bearing stratified sediments are set down into the massive material, they also are in part over-ridden by an apparent expansion of that material. It would therefore appear that processes resulting in accumulation of the massive sediment continued to operate after some of the stratified units had been deposited.

Regardless of the many unanswered questions about the accumulation of the older massive sandy silt, we believe that this occurred within the framework of the subsiding, probably episodically subsiding, floor of a closed depression formed by subsurface solution of gypsum and consequent collapse of overlying strata. That this phenomenon also affected many parts of the surrounding area is indicated by stream-cut and road-cut exposures of the sandy silt set against vertical faces of gypsum beds.

It is clear that the developing depression at the Burnham site came to be occupied by a body of standing water. The size and shape of this pond or lake remain unknown, though almost surely it was both small and shallow (Theler, this volume). Exposures of its sediment accumulations are not extensive. The water probably came mainly from springs, although overland surface flow clearly contributed at times. However, the pond rarely overflowed to form a stream linking it with a creek or river; fish bones are very scarce in the sediment fill.

Well-defined sedimentary strata are set into the collapse basin and therefore abut against the massive sandy silt. Most of these layers have sharply distinct upper and lower contacts. Some are sandy or silty and as much as ten or more centimeters thick. Others are only a few millimeters thick and are composed largely of clay. All were deposited in a definitely low-energy environment that was affected by conspicuous pulses of sediment introduction. It is not at all clear what factors governed accumulation of millimeter-scale laminations of alternating red and gray clay-rich sediments. No samples were obtained from individual sedimentary units. Therefore, no detailed data are available to serve as a basis for paleoenvironmental interpretation.

This quiet depositional situation was interrupted from time to time. Either declining water level exposed marginal zones or further subsidence lowered local base level. Probably both events happened. In any event, there was dissection of older sediments by small channels, which were themselves later filled when effective water levels rose again. Within the limits of the excavations, there also appear to be extensive, essentially planar unconformities. These seem to record episodes of stripping of sediment from locally widespread surfaces, as opposed to concentrated linear gullying. Sediment thus removed was, of course, carried to a topographically lower point, unless the degradation was accomplished solely by wind. The locus of redeposition of this sediment remains unknown.

Much of the stratified sequence shows abundant evidence of soft-sediment deformation. In a thin sedimentary section, this is probably the result not so much of loading by subsequent deposits as it is a consequence of rapid lowering of water level and consequent removal of support. In other words, saturated sediments flowed irregularly toward deeper parts of the basin. Obviously, if there is flowage and deformation of sedimentary strata, there can also be mixing of objects contained within these strata, thereby directly endangering contextural relationships. We believe that although individual units suffered deformation and internal mixing, the stratigraphic integrity of groups or bundles of strata has been maintained. This would mean that sequences are correct and spatial associations remain valid. Therefore, the apparent occurrence of cultural materials with the skull of an extinct bison seems to be real. However, only collection of additional data will place this conclusion beyond reasonable debate.

At some point the pond became dry, whether through loss of water supply or by breaching of the retaining barrier is not known. The remnant of the depression was then filled, at least in part with the upper massive sandy silt. After an interval of unknown, though short, duration, Moccasin Creek and its developing tributaries began dissection of those sediments and the present topography was created. Most of the radiocarbon dates obtained from samples of bones, snails, and charcoal are older than 26,000 B.P., clustering in the mid-30s (Wyckoff et al. 1991). It therefore appears that the present wave of dissection began sometime after 35,000 years ago and is probably a Late Wisconsinan phenomenon that has continued into the Holocene.

Throughout this report it has been emphasized that observations and data pertaining to the geology of the Burnham site are very far from complete. Investigations into the geologic processes that formed and modified the sedimentary sequence, and thus influenced the context of both faunal and cultural remains, have really only just begun. Nevertheless, there are sound reasons for believing that the cultural material is indeed considerably older than conventional limits of the Clovis interval and further, detailed studies are most definitely warranted.

References Cited

Adams, G.I. 1903. Physiographic Divisions of Kansas. *Transactions of the Kansas Academy of Science* 18:109-123.

Birkeland, P.W. 1984. *Soils and Geomorphology*. Oxford University Press, New York.

Blatt, H. 1982. *Sedimentary Petrology*. W.H. Freeman and Company, San Francisco.

Fay, R.O. 1965. *Geology and Mineral Resources of Woods County, Oklahoma*. Oklahoma Geological Survey Bulletin 106. Norman.

Fenneman, N.M. 1931. *Physiography of Western United States*. McGraw-Hill Book Company, New York.

Frye, J.C. 1942. *Geology and Ground-water Resources of Meade County, Kansas*. Kansas Geological Survey Bulletin 45. Lawrence.

Frye, J.C. and A. Swineford. 1949. The Plains Border Physiographic Section. *Transactions of the Kansas Academy of Science* 52:71-81.

Gile, L.H., F.F. Peterson, and R.B. Grossman. 1966. Morphological and Genetic Sequences of Carbonate Accumulation in Desert Soils. *Soil Science* 101:347-360.

Hibbard, C.W. 1949. Pleistocene Stratigraphy and Paleontology of Meade County, Kansas. *University of Michigan, Museum of Paleontology Contributions* 7:63-90.

Moore, R.C. 1930. *The Surface Features of Kansas.* Kansas Geological Survey, map. Lawrence.

Raisz, E. 1957. *Landforms of the United States.* Sixth edition of privately printed map.

Schoewe, W.H. 1949. The Geography of Kansas: Part II-Physical Geo-graphy. *Transactions of the Kansas Academy of Science* 52: 261- 333.

Schultz, G.E. 1969. *Geology and Paleontology of a Late Pleistocene Basin in Southwest Kansas.* Geological Society of America, Special Paper 105.

Smith, H.T.U. 1940. *Geologic Studies in Southwestern Kansas.* Kansas Geological Survey Bulletin 34. Lawrence.

Stephens, J.J. 1960. Stratigraphy and Paleontology of a Late Pleistocene Basin, Harper County, Oklahoma. *Geological Society of America Bulletin* 71:1675-1702.

Wyckoff, D.G., G.R. Brakenridge, K. Buehler, B.J. Carter, W. Dort, Jr., L.D. Martin, J.L. Theler, and L.C. Todd. 1991. Interdisciplinary Research at the Burnham Site (34WO73), Woods County, Oklahoma. *A Prehistory of the Plains Border Region, South-Central Friends of the Pleistocene Guidebook*, pp. 82-121. Oklahoma State University, Department of Agronomy, Stillwater.

Plate 1a. View east of the East Exposure of the Burnham site. A nearly continuous carbonate cemented layer occurs near the individual's elbow. Below that is a red alluvuium that is underlain by the gray sediments containing the Bison chaneyi *skull (left center) and artifacts. Photo taken in October of 1986 by Don Wyckoff.*

Plate 1b. View west-northwest of gray sediments designated the Southwest Exposure (where figure is kneeling) and Northwest Exposure (center of picture) of the Burnham site. Photo taken in October of 1986 by Don Wyckoff

Plate 2a. View east of Bison chaneyi *skull in situ in square S2-W22 of the Burnham East Exposure. Skull is tilted and laying in gray sediment. Artifacts were recovered from sediment around skull. Photo taken November 1, 1986, by Don Wyckoff.*

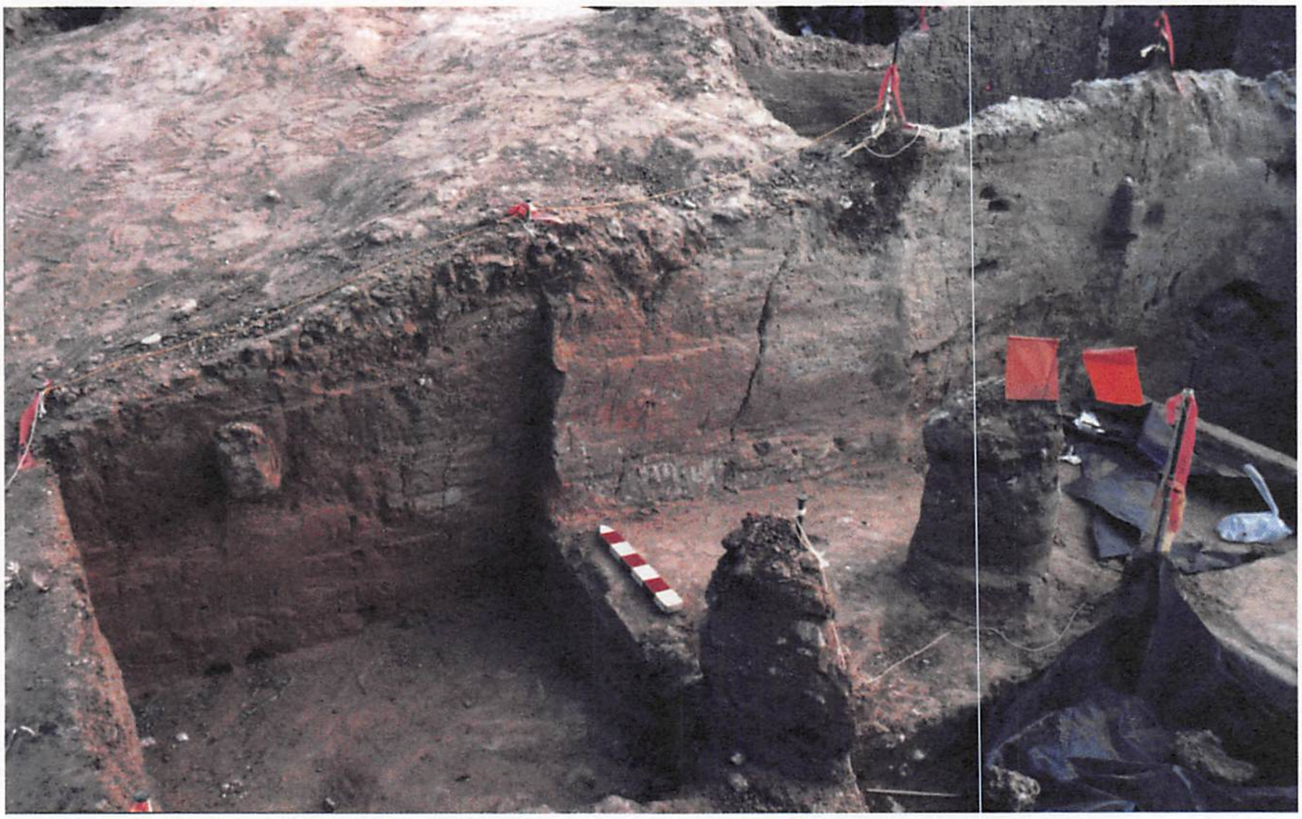


Plate 2b. View north of stratigraphy in north walls of squares 0-W25 (left), 0-W24, and 0-W23 of the East Exposure. Artifact yielding gray sediment is nested in the reddish lowest ponded sediment manifest in the East Exposure. Photo taken November 7, 1989, by Don Wyckoff.

Plate 3a. Deformed sediments exposed on north face of manually dug square 0-W22 of East Exposure. Note scattered small pebbles in both red and gray units. Scale markings are 5 cm increments. Photo taken by Wakefield Dort, September 28, 1988.

Plate 3b. Middle part of North 3 backhoe trench dug in 1989 in East Exposure. Note light colored caliche nodules near top, thin dark horizon in middle and deformed laminations at bottom. Rod scale is in feet. Photo by Wakefield Dort.

Plate 4a. Filled burrows in channel fill in western part of North 3 backhoe trench (dug in East Exposure in 1989). See Figure 4.8 for location. Photo by Wakefield Dort.

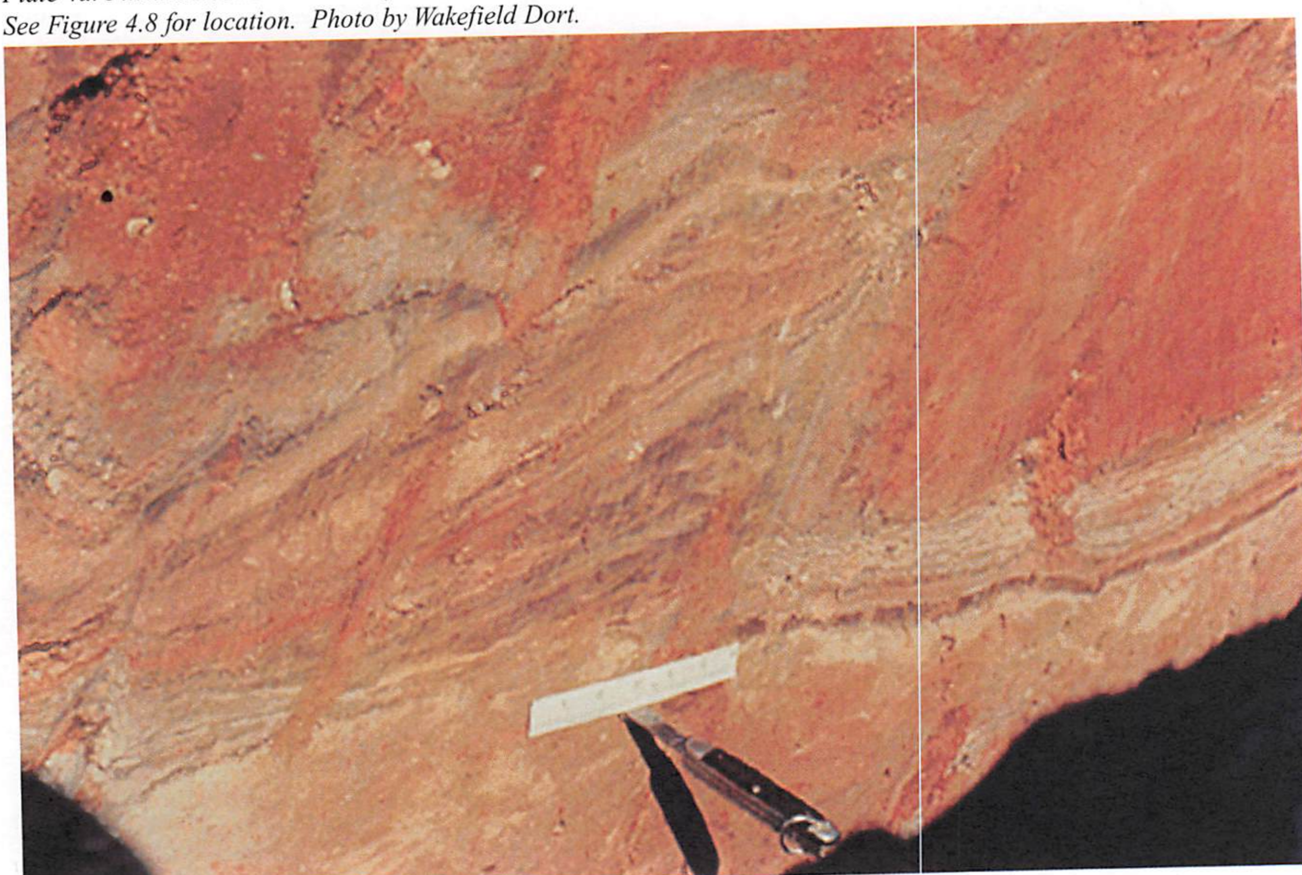


Plate 4b. Deformed laminated clays and silts near bottom of North 3 backhoe trench at its western end. Scale units are in inches. Photo by Wakefield Dort.

Chapter 5
Burnham Site Pedology: A 1991 Perspective

Brian J. Carter

Introduction

Soil investigation at the Burnham site was started to determine the pedologic and diagenetic processes and the mode of soil parent material deposition for sediments that may contain evidence of late Pleistocene human occupation and that did contain stone tool fragments and small-scale debitage (Buehler 1990; Flynn 1988; Wyckoff 1989, 1990; Wyckoff and others 1990). The site also yields an array of late Pleistocene vertebrates and snails (Martin 1990; Theler 1990; Todd 1990).

Overview of Bedrock and Surficial Geology and Geomorphology

Sediments of three major geologic eras were exposed within or near the study area (Fig. 5.1). The study area is contained within the West Moccasin Creek drainage basin located in west-central Woods County, Oklahoma. These geologic eras include the Paleozoic, Mesozoic, and Cenozoic. A detailed review of the geology of Woods County, Oklahoma, can be found in Fay (1965). An abbreviated geologic overview is included here to emphasize bedrock control of landforms in the study area (Figs. 5.1 and 5.2). The upper Paleozoic Era is represented by the Permian System. The upper Mesozoic Era is represented by the Cretaceous Kiowa Shale. The upper Cenozoic Era is represented by the late Tertiary and Quaternay Systems. Most Permian rocks are lithified but range from nearly consolidated sandstone (locally termed "pack-sand") to lithified shale, sandstone, gypsum, limestone, and chert. The landscape adjacent to the study area contains prominent escarpments. These escarpments are produced by layers of gypsum, limestone, cherty limestone, and sandstone which resist erosion relative to the underlying incompetent shale and pack-sand. Much of the escarpment wall below the resistant nick-point is not covered by soil. The escarpments also have a concave-upward slope curvature which gives the general landscape surrounding the site a distinctly arid aspect. The study area lines within a continental, temperate, and subhumid climatic regime (Fitzpatrick et al. 1950).

The bedrock immediately below the study site is the Permian Marlow Formation (Fig. 5.3). The Marlow Formation at the study site is predominantly a weakly consolidated fine-grained sandstone. The pack-sand nature of the Marlow Formation within the study area makes it extremely difficult to distinguish from subsoil. The Marlow Sandstone at the study site can be separated from soil by a distinctive rock color pattern. Often, small (several cm in diameter) circular grayish-green mottles within an orange rock matrix are found within the Marlow Sandstone, but they are not observed within the subsoil.

The Cretaceous Kiowa Shale is found in west-central Woods County but not within the upper West Moccasin Creek drainage basin which is the location of the study site. The Permian rocks are directly overlain within the study area by the Tertiary Ogallala Formation. The Kiowa Shale does separate the Permian rocks from the overlying Ogallala Formation immediately to the northwest of the study area. The Ogallala Formation is exposed within the headwaters of West Moccasin Creek. It caps the divide north of the study area between the Cimarron River and the Salt Fork of the Arkansas (Fig. 5. 3). The Ogallala Formation ranges from unconsolidated gravel through

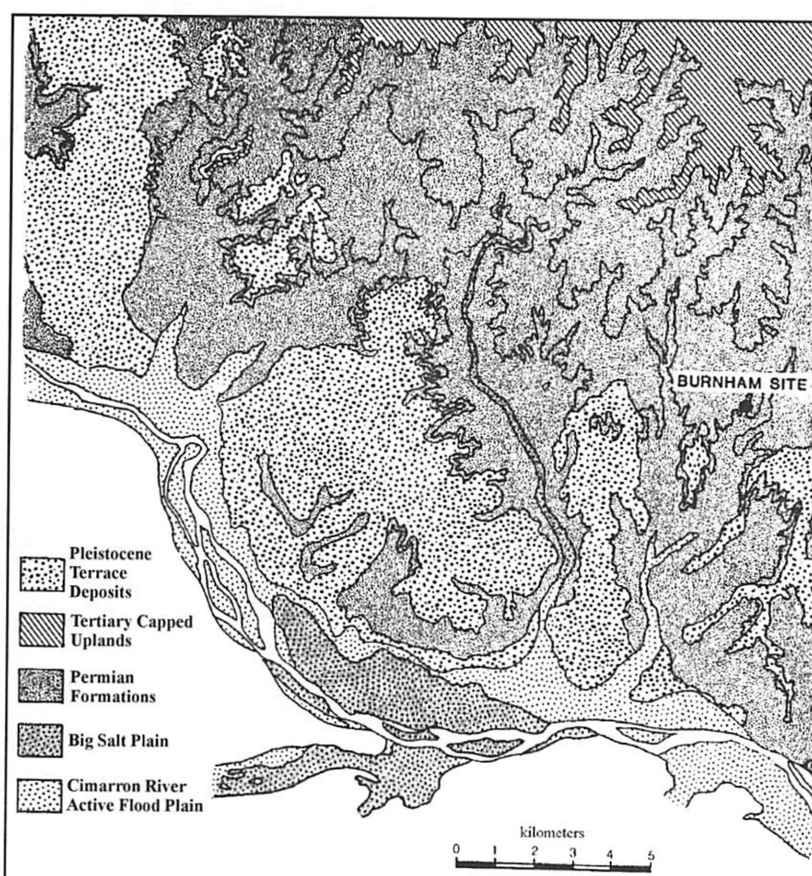


Figure 5.1 The Burnham site's location relative to nearby geologic exposures. Adapted from Fay 1965.

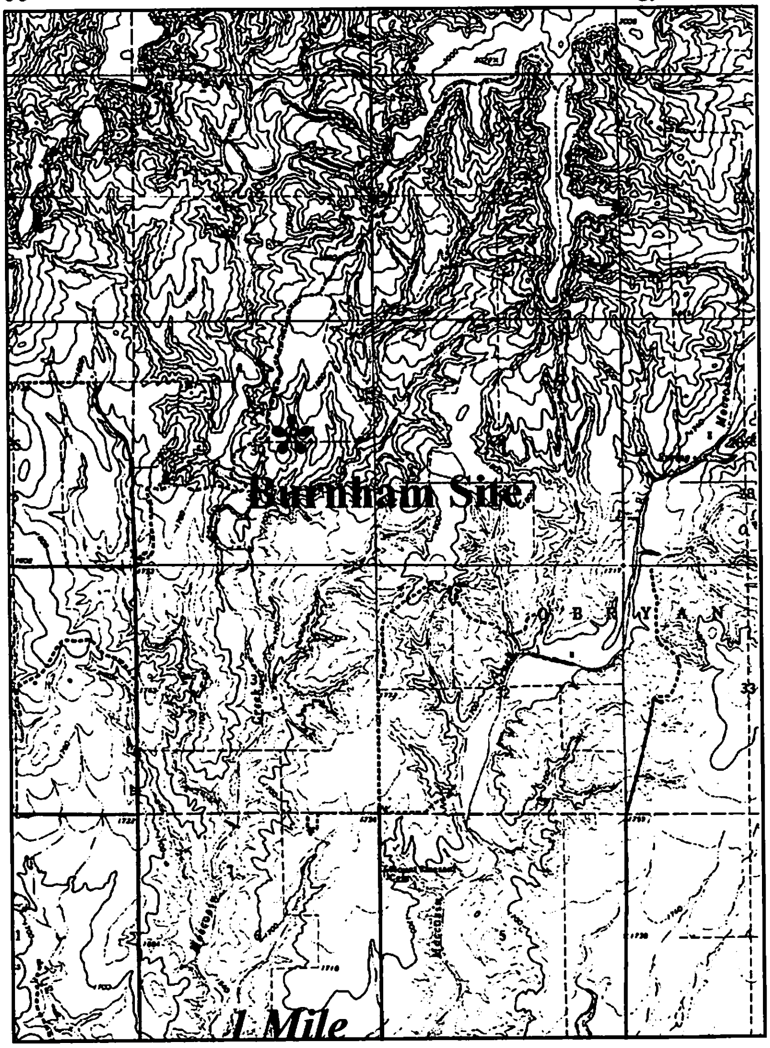


Figure 5.2. Topographic map of Burnham locality, Woods County.

stratified layers of sand and silt. The Ogallala Formation contains layers cemented by calcite and referred to as caliche, calcrete, or petrocalcic soil horizons.

The Permian, Cretaceous, and Tertiary rocks are exposed in the study area (Figs. 5.1 and 5.3) in ascending order in both time and space (younger rocks are higher in elevation than older rocks). Rocks of the Quaternary Period within the study area do not follow this ascending order. Pleistocene and Holocene deposits are related to modern stream systems within the study area. After deposition of the Ogallala Formation, the Cimarron River incised through Tertiary, Cretaceous, and well into Permian rocks. Eolian, colluvial, and alluvial deposits of the Quaternary Period are draped on top of Tertiary, Cretaceous, and Permian rocks. The Pleistocene Epoch is represented by stream terraces bordering the Cimarron River, mainly on the north side. Stream terraces are also found along second-order streams which flow to the Cimarron River. These secondary streams developed as the Cimarron River incised into older rocks. West Moccasin Creek is a prominent tributary stream to the Cimarron River (Fig. 5.4). Eolian sand and colluvium rework Quaternary alluvium into hillslope and dune landforms. The predominant constructional geomorphic surfaces with the study area are Holocene floodplain, dune, and hillslope landforms. Constructional Pleistocene and Holocene terrace surfaces are present but are not widespread (Carter et al. 1990).

The study site is located adjacent to an unnamed tributary ephemeral stream to West Moccasin Creek (Fig. 5.4). West Moccasin Creek is a south-flowing tributary to the Cimarron River. Recent geologic and soil surveys are not available for the study area (Fitzpatrick et al. 1950). The USDA Soil Conservation Service is currently mapping soils at a 1:20,000 scale within Woods County but have not covered the study area. Much of the initial information for geologic and soil materials in the general study site is obtained from road-cut and natural gully-wall exposures.

Gypsum layers are found within Permian rocks 30 to 50m below the study site. The three layers of gypsum each range in thickness from 3 to 8m. They are separated from each other by 0.5m dolomite beds and 5 to 8m thick shale beds. Caves and sinks are not found within the study area. Caves and karst topography associated with the dissolution of gypsum are found within a 10 to 100km radial distance from the study site where gypsum occurs closer to the ground surface. The dissolution of gypsum can be an important landscape forming process in the study area. However, because of the thick unit of shale between the gypsum beds and the study site, gypsum dissolution (forming karst topography) may not be an important geomorphic process immediately affecting the deposits at the study site.

Gully-Wall Exposures and Site Specific Soil-Geomorphology

The study site is located on a gully-wall exposure of unconsolidated sediment, soil, and Permian redbeds (Figs. 5.5, 5.6, 5.7, and 5.8). The sediments at the study site are distinctive because they are gray (Table 5.1; see soil profile descriptions for Munsell color notation). The small gully tributary of West Moccasin Creek which contains the study site has prairie vegetation across the constructional flood-surface of the gully bottom (Fig. 5.5). The gully does not contain a channel. The gully walls are approximately 90% covered by vegetation (Fig. 5.5). Where plant cover exists it is sparse. The gully walls, therefore, supply sediments to

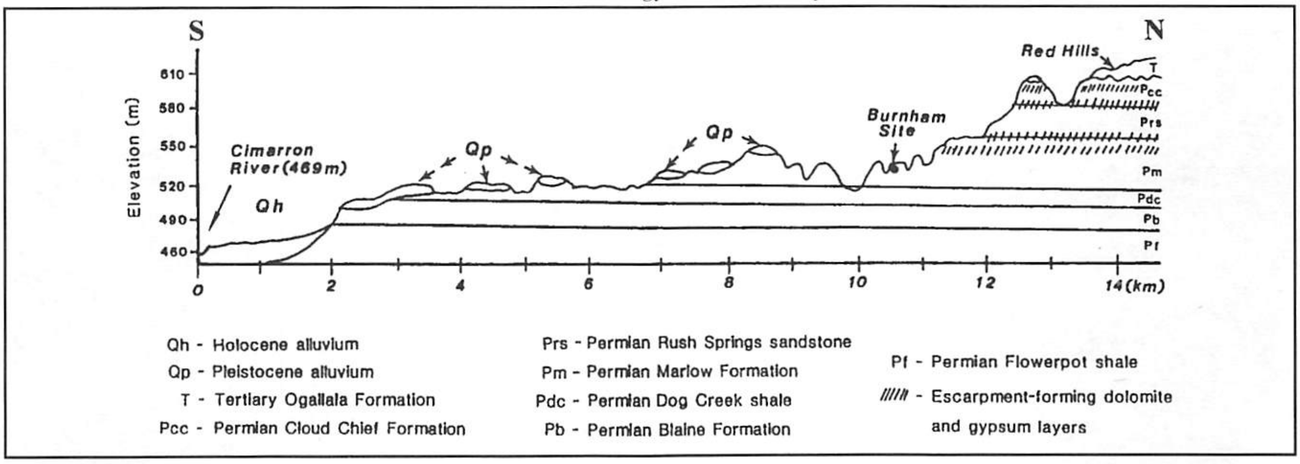


Figure 5.3. North-south topographic cross section through the Burnham site, Woods County, Oklahoma.

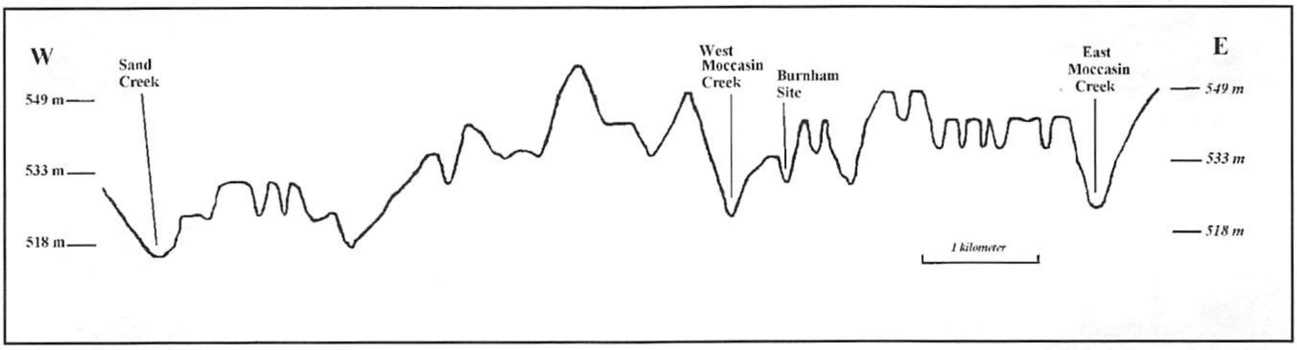


Figure 5.4. West-east topographic cross section through the Burnham site.

Figure 5.5. Aerial view southeast of the Burnham site. Site is on both sides of pond in top right. Photo taken August 4, 1992, by Don Wyckoff.

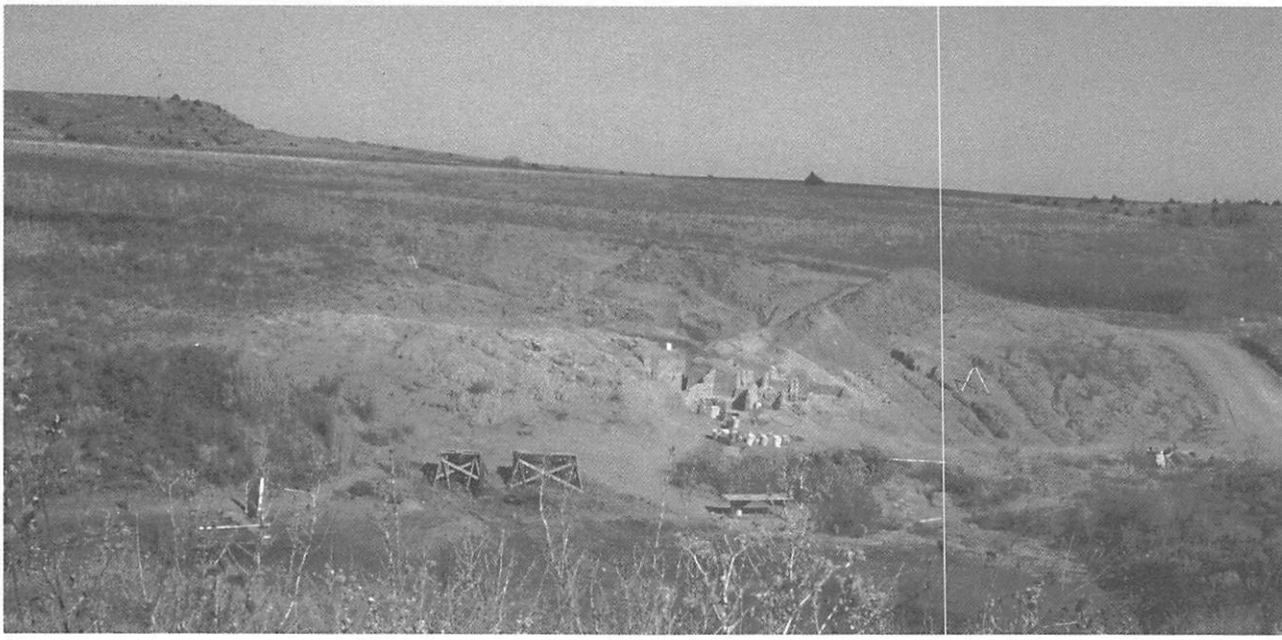


Figure 5.6. View east of Burnham East Exposure during the 1989 excavations. Gray pond sediments are interbedded with red sediments (below) and soils (above). Photo taken October 22, 1989.

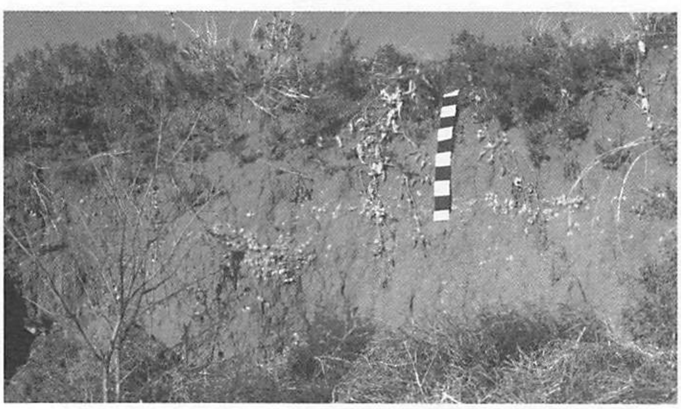


Figure 5.7. View east of calcic soil profile some 200 meters north of the Burnham site. Photo taken November 17, 1987.

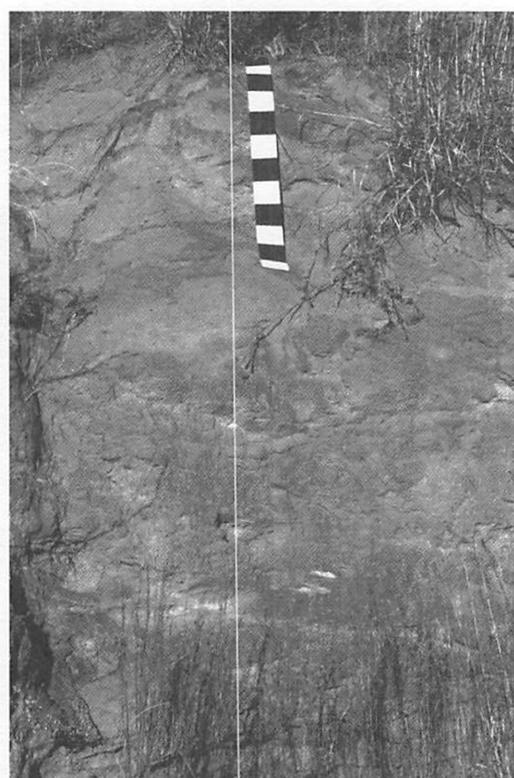


Figure 5.8.. Thin soil over Marlow sandstone exposed in gully some 200 m north of the Burnham site. Photo taken November 17, 1987, by Don Wyckoff.

a cummulic soil on the floor of the gully. This soil has probably been forming for the past several hundred to possibly several thousand years. The hillslopes above the gully walls have been cultivated and are highly eroded (Fig. 5.6). Erosion of agricultural fields has also provided sediments to the floodplain surface. Sediments shed from the gully walls and surrounding fields are incorporated into the soil on the floodplain. Annual grass species maintain a vegetative cover and incorporate the sediment into the soil on this gully bottom. Some sediment reaches the floodplain soil surface by gully-wall mass wasting. Hillslope sediment runoff enters the gully through smaller, shorter lateral gullies (Fig. 5.5). Several trees (cottonwoods [*Populus* spp.] and hackberry [*Celtis* sp.]) that can tolerate trunk burial by sediment also exist on the gully floor adjacent to the study site (Fig. 5.5). The vegetation which originally covered the site was probably a native mid-grass prairie dominated by little bluestem (*Andropogon scoparius*).

Several types of sediments are exposed along the gully wall near the study site and yield valuable information on the origin of the deposits within the site. Exposed at the bottom of the gully wall is the Permian Marlow Formation (Fig. 5.8). It is a fine-grained sandstone that contains distinctive 5 to 10mm diameter circular gray mottles within a reddish orange rock matrix. The sandstone is especially prominent down (south) the gully toward its intersection with West Moccasin Creek. Immediately above the Marlow Formation is a gravel layer 10 to 30cm thick. This gravel is composed of angular, subangular, and rounded rocks, and these clasts lie on a very smooth boundary formed with the underlying beckrock. This smooth beckrock contact was produced by moving water that transported the gravel. The rock lithologies consist of chert, limestone, and quartzite and originate from the Ogallala and Permian formations. These exist north of the study site within the West Moccasin Creek drainage basin. Gravels are especially well exposed within the gully wall south and west of the study site toward the intersection with West Moccasin Creek.

Above the gravels are fine-grained unconsolidated sediments. These contain both the gleyed and the mottled soil layers and the bones, snails, and human-produced chert flakes which constitute the study site. The bedrock and unconsolidated sediment contact is generally level but does reach an abrupt topographic high immediately south and adjacent the study site. This buried contact separates the gully containing the study site from a smaller tributary gully toward the east. Gravels are draped on this steeply inclined bedrock-alluvial contact, indicating relatively rapid stream flow preceding deposition of the fine textured soils manifest at the dig site. Sediment cores taken at the study site also revealed the bedrock and gravel contact observed within the gully-wall exposures. Another bedrock topographic high is found east of the study area and west of West Moccasin Creek (Figs. 5.2, 5.4, and 5.6). This bedrock high parallels West Moccasin Creek and underlies the small divide separating West Moccasin Creek from the study site. Gravels are also found near this bedrock high but exposures are lacking to observe materials which directly overlie the bedrock.

Soil Morphology and Sediment Stratigraphy from Undisturbed Cores

Initial investigation of soil morphology was made by eight widely spaced, undisturbed cores north of the study site (Figs. 5.9 and 5.10). These cores were placed on both sides of the gully through the study area, and they went to depths of 1 to 2m. At that time, Jim Ford, soil scientist working in Woods County on an active soil mapping program for the USDA Soil Conservation Service, considered the soils within the hillslope study area to represent four soil series. These series include Madge, Aspermont, Woodward, and Carey. Because of recent erosion, these soils are considered as eroded phases of the representative series. Soil texture (field grading) is predominantly a silt loam. Soils contained either an ochric or mollic surface epipedon and an argillic or cambic subsurface horizon. Calcium carbonate soil formation was

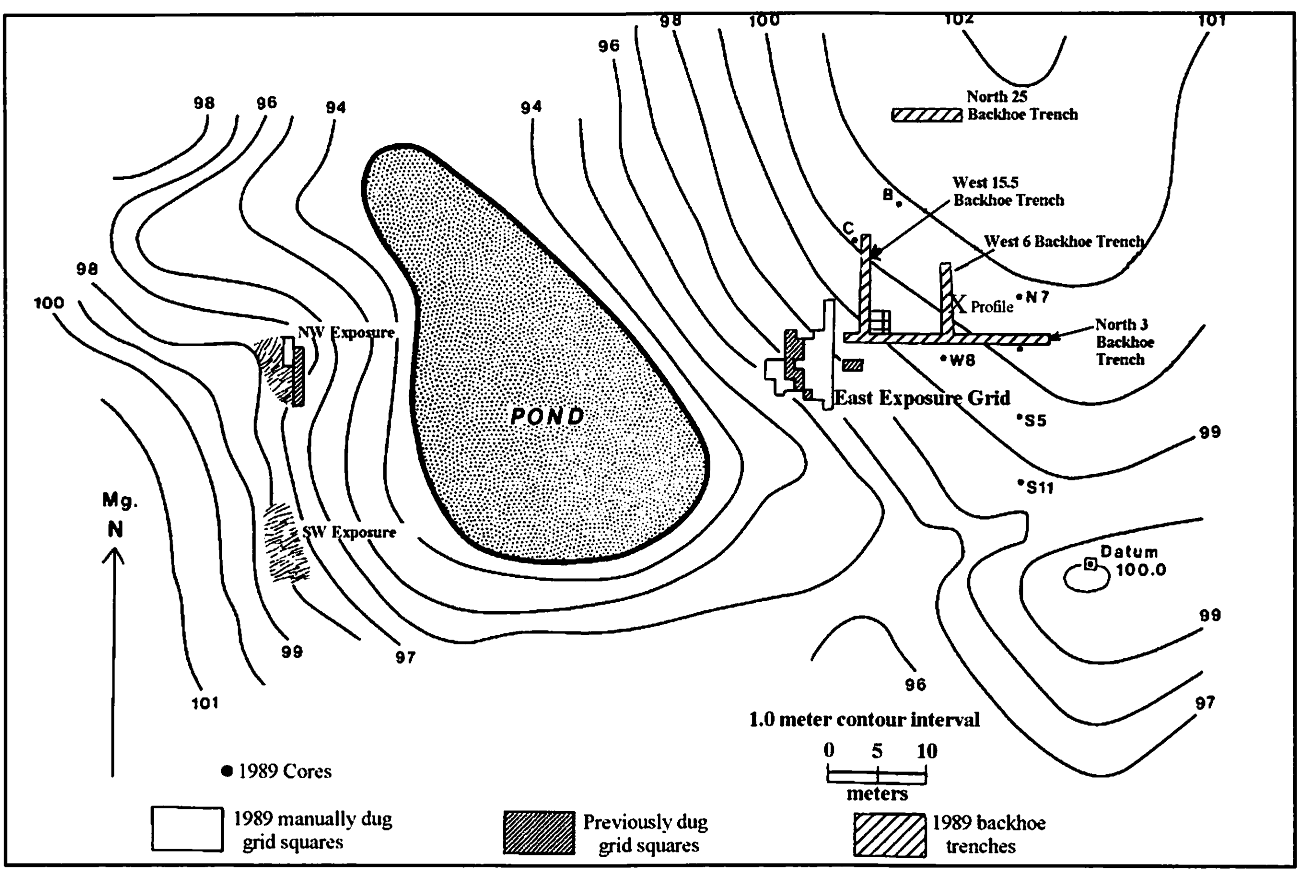


Figure 5.9. Contour map of Burnham site and locations of 1986, 1988, and 1989 excavations.

noted in all subsoils (Fig. 5.7). Classification of these soils are Woodward, Coarse-silty, mixed, thermic Typic Ustochrept; Aspermont, Fine-silty, mixed, thermic Typic Ustochrept; Carey, Fine-silty, mixed, thermic Typic Argiustoll; and Madge, Fine-loamy, mixed, thermic Udic Argiusoll. Few gravels were encountered during coring or found at the surface. Hard calcium carbonate nodules limited coring depth. These carbonate nodules were 2 to 5cm in diameter and were found within the subsoil. Jim Ford (personal communication, 1989) considered the soil parent material to be terrace alluvium.

Soil coring began at the study site several meters north and east of the hand-excavated meter squares (Figs. 5.9) in order to determine the extent of the gray sediment layer which yielded bones, snails, and flint flakes. The original ground surface in this area was not distinguishable because of recent erosion of the bulldozer graded surface (Fig. 5.6). Surface soil materials also were not present directly above the sediments containing the snails, bones, and flakes. Construction of a dam blocking the gully immediately south and west of the study site had removed the natural surface soil and gully-wall materials (Figs. 5.5 and 5.6). Soil-formed calcium carbonate nodules and soft concretions were the only reference point to determine the approximate level of the original ground surface. At least one meter of sediment and soil was removed by a bulldozer from the study site during dam construction. This grading, and the subsequent erosion, did expose the bones which led to discovery of the study site.

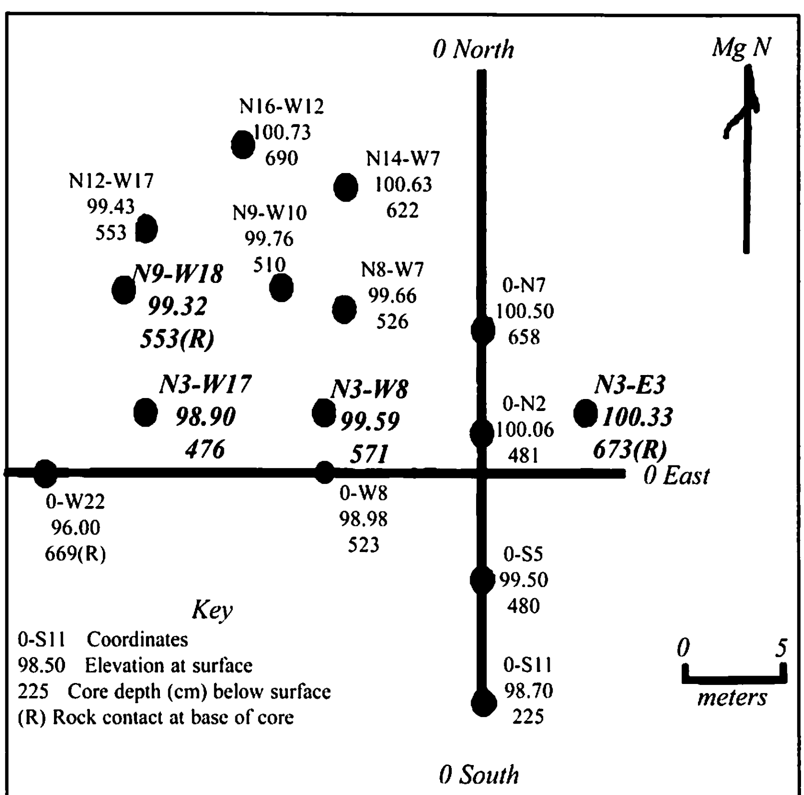


Figure 5.10. Location and depth of cores in relation to base lines of the East Grid of the Burnham site. Boldface, italicized entrys are cores linked to profiles along 1989 backhoe trenches.

Ten soil cores within close proximity of the hand-excavated meter squares and eventual backhoe trenches reached a depth ranging from 2.25 to 6.90 m below the current ground surface (Fig. 5.10). The shallowest soil and bedrock core-exposed contact occurred near the bedrock outcrop along the access road to the study site. Soil cores revealed layers of sand, loam, and silt loam (Table 5.1). Few thin (1 to 4cm) gravel layers were also present. Coring was stopped by a coarse gravel layer which was estimated to be the gravel layer immediately overlying bedrock originally observed in gully-wall exposures. This bedrock contact was verified by hand augering through undisturbed core openings and later within backhoe trenches. Soil coring did not reveal buried A horizons, but buried gleyed and mottled soil horizons containing weak to moderate soil structure were noted. Boundaries between soil and sediment layers were abrupt, especially between gleyed and ungleyed horizons. Soil-formed calcium carbonate concretions were most often found at shallow core depths.

Soil Morphology and Sediment Stratigraphy within Backhoe Trenches, Hand-Excavated Squares, and Hand-Augered Borings

Ten soil-sediment detailed profile descriptions were made equally spaced along the range of backhoe trench exposures (Table 5.1). Notes and sketches of soil and sediment character were also taken between these detailed profile description areas (Figs. 5.11, 5.12, and 5.13). The overall sediment character was described as soil B and C horizons. Buried (b) horizons, mottling, gleying, clay translocation (t), calcite (k), and gypsum (y) formation, snails, bones, charcoal, and gravels further helped define the B and C horizons. The A horizons, which are dark and enriched with organic materials, were not evident within the buried soils. Laboratory analysis of organic carbon with two soil profiles from the study site supported the lack of A horizons (Table 5.2). The organic carbon distribution with depth did not indicate horizons with higher levels of organic carbon that would normally be expected of subsoil horizons. Organic carbon, which is a good indicator of organic matter, ranged from 0.09 to 0.16% by weight of the total soil.

Nine out of the ten soil profiles were unique. The soil profile (N5-W6) from within the east trench and the middle soil profile (N3-W7) from within the south trench were very similar. They were also closely spaced and started at a similar ground surface reference

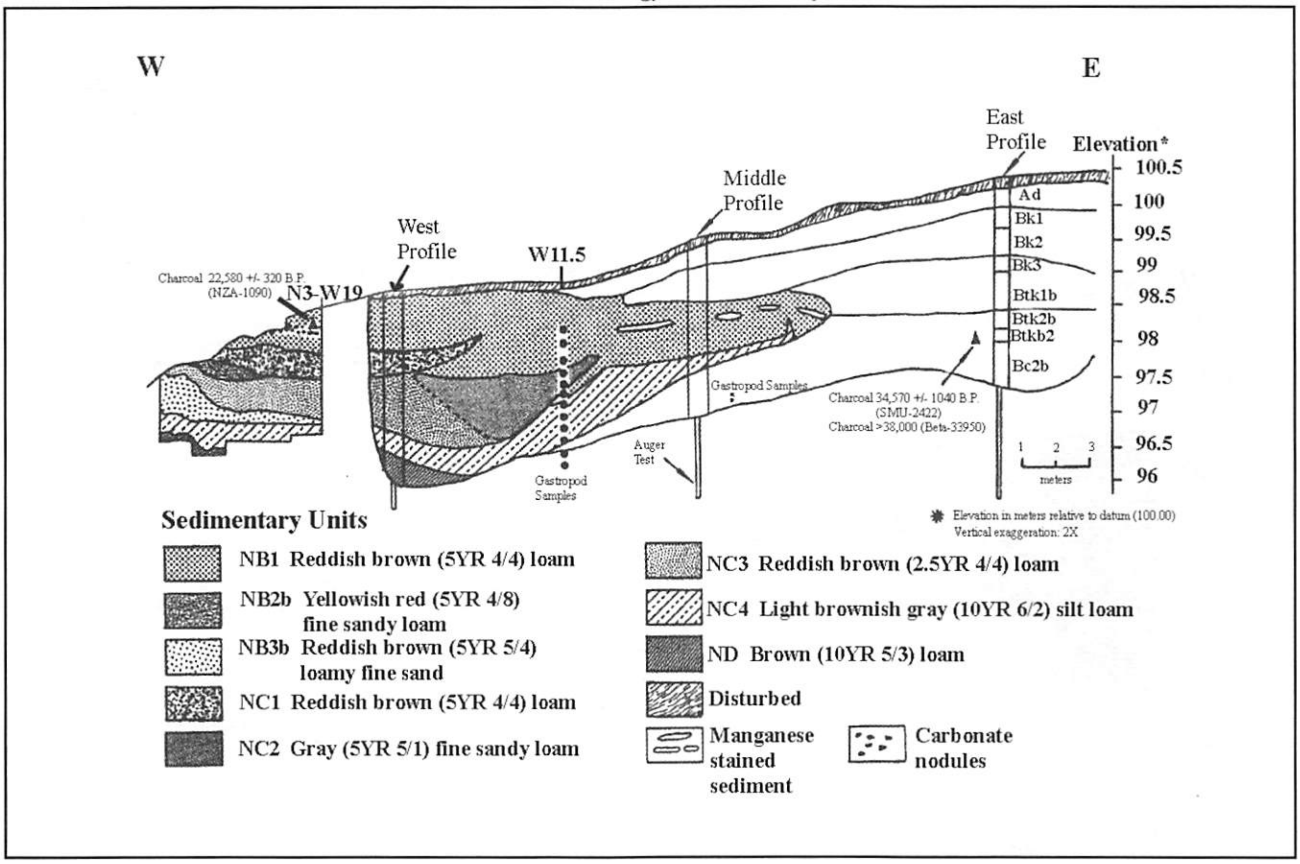


Figure 5.11. East-west profile along North 3 backhoe trench and manually dug squares, East Grid, Burnham site.

point. The nine soil profiles are further divided into three groups based on general soil and sediment character. The North 25, North 3, West 15.5, and West 6 backhoe trenches' (Figs. 5.9, 5.11, 5.12, and 5.14), west trench north (W15.5-N15) soil profiles are included in the upper group (III) based on a low percentage of soil mottles and a high percentage of calcite formation.

The remaining soil profiles (W15.5-N9; N5-W6; N3-W7; and N3-W17) represent the second group. This middle group is characterized by soil mottling, bone and snail fragments, and a low percentage of calcite formation. The horizon differentiation within this second group was produced by aggradation. Buried soil horizons, a result of this aggradation, are common. Horizons produced by a change in the mode of deposition (other than alluvium) were not observed. Lithologic discontinuities are therefore not noted in the profile descriptions. Abrupt soil horizon boundaries were present within the deepest part of the west trench middle (W15.5-N9) and the south trench west (N3-W17) soil profiles. The abrupt boundary is caused by aggradation of sediments within soil profiles of group two.

The lowest group (I) is limited to one soil profile in the north-south backhoe trench dug in 1991. This profile manifests the contact between the coarse alluvial gravels and the underlying Permian bedrock.

Within the upper soil horizons of Group III, calcite formation was the most visual soil forming process. Laboratory analysis for carbonate content showed a range of 1.0 to 9.0% calcium carbonate equivalence (Table 5.2) for the soil horizons representative of Group III located with the south trench east (N3-E2) profile. Calcite formation also occurred within soil of Group II. Laboratory analysis for carbonate content showed a range of 2.9 to 7.8 calcium carbonate equivalence for soil horizons representative of Group II located within the south trench west (N3-W17) profile. But calcite formation within soils of Group II was not apparently closely associated with the current ground surface or past ground surfaces represented by buried horizons. Calcite within soils of Group II were formed by the drying of water-laden sediments containing dissolved calcium carbonate. Precipitation of calcite surrounding bones is common. The bone fragments, snails, and other debris contained within the sediments were nuclei for crystal growth of calcite. Well drained soils (soils lacking mottles; i.e., Group III) contain calcite soil formation that was associated with the current ground surface or past ground surfaces (buried soils). The calcite soil formation within soils of Group III was caused by illuviation. Water entering the soil profile at the ground surface eluviated calcium carbonate from the surface soil horizons. Calcite originating from surface soil horizons was deposited as illuvial calcite in Bk horizons. Calcic soil horizons are major features within arid, semi-arid, and

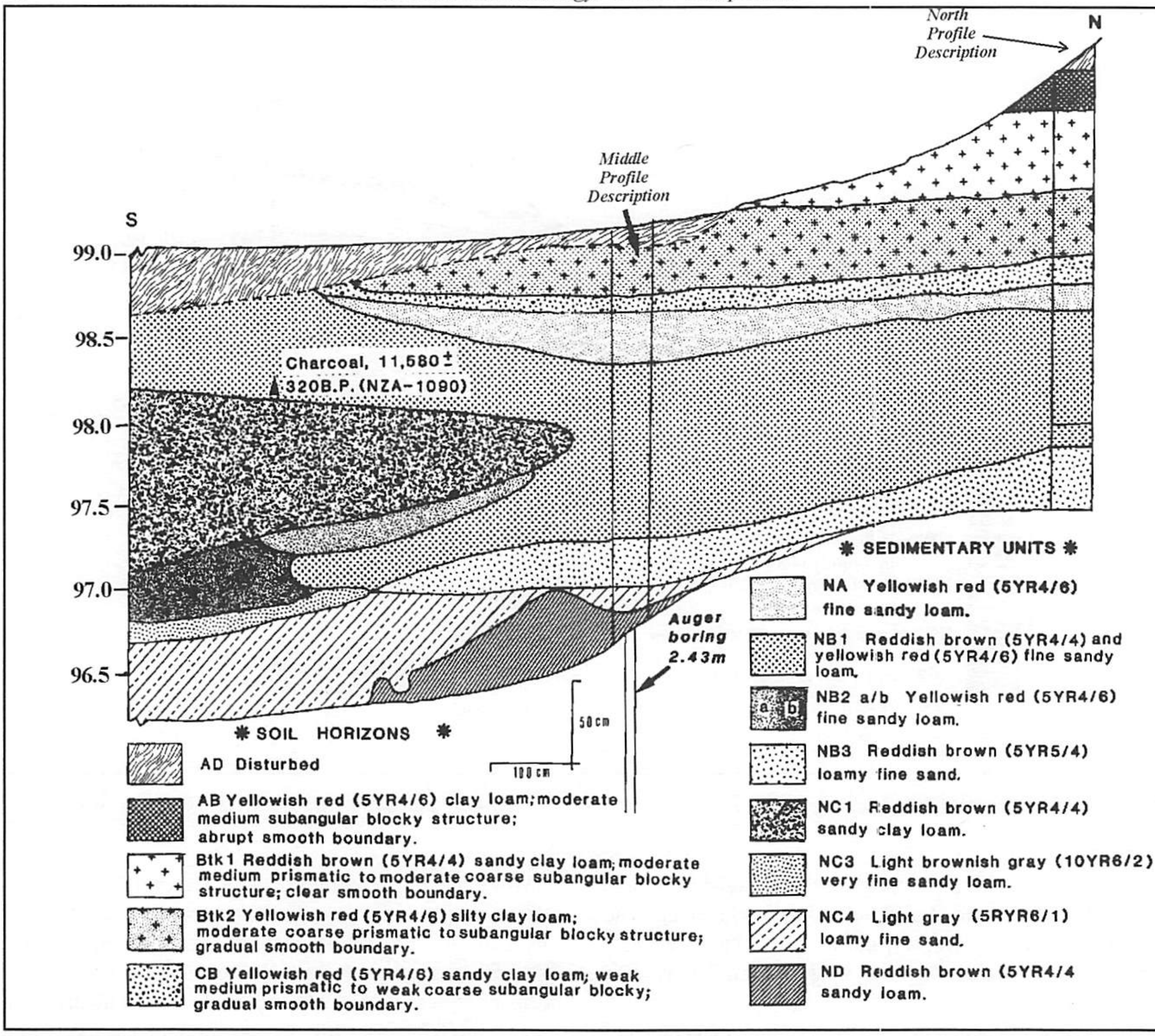


Figure 5.12. West wall profile of the West 15.5 backhoe trench dug in 1989 at the Burnham site. See Figure 5.9 for location.

subhumid climates where the entire profile is often dry.

Soil texture (particle size analysis or field grading) did not show extreme variation (Tables 5.1 and 5.2) except for the horizons containing gravel within the north-south backhoe trench dug in 1991. This trench's soil profile represented Group III. The south trench east (N3-E2) and south trench west (N3-W17) soil profiles were chosen for labortory particle size analysis. These represent Groups III and II, respectively. Sand, silt, and clay content for both soil profiles ranged from 21.3 - 76.8, 16.5 - 58.2, and 6.1 - 28.6, respectively. Soil textures included loams, silt loams, sandy loams, clay loams, and loamy sands. Clay translocation was identified by clay coatings on ped surfaces. The suffix "t" was added to B horizons which showed signs of clay translocation. Laboratory particle size analysis did not support the classification of argillic horizon development. Clay translocation which could significantly alter sediments was not considered a diagnostic soil forming process within these soils. Changes in particle size analysis are related to mode of deposition of the soil parent materials. Finer textured soil horizons were deposited by slower moving water compared to coarser textured soil horizons. The site's first deposits (Group I: lower in the profiles) were laid down by relatively fast moving water compared to upper (deposited later) soil horizons. Loamy sand horizons (containing up to 76.8% sand with layers of fine gravel) characterize lower soil horizons within soil cores, hand-auger borings, and trenches. Above these lower horizons, finer textured sediments (clay and silt loams) containing up to 58.2% silt and 28.6% clay were found between moderately textured loams and sandy loams. The most prevalent texture throughout the profiles was a loam containing approximately 40% sand, 40% silt, and 20% clay.

Table 5.1. **Particle-Size Percent, $CaCO_3$ Equivalence, and Percent Organic Carbon for North 3 Backhoe and West 15.5 Backhoe Trenches Profiles for the Burnham Site.**

			Sand fractions – mm						Total-mm		
Horizon	Depth Cm	Soil Textural Class	v. coarse 2.00-1.00	coarse 1.00-0.05	med. 0.05-0.25	Fine 0.25-0.10	v. fine 0.10-0.05	sand	silt 0.05-0.002	clay <0.002	CaC equ
			%								
North 3 Backhoe Trench at East Soil Profile (Line Level at 222 cm; Fig. 5.11)											
Akp	0-28	L	7.0	0.9	0.4	2.7	29.9	40.8	39.3	19.0	6
Bk1	28-60	L	0.5	0.2	0.2	3.4	35.9	40.1	41.4	17.8	3
Bk2	60-102	L	2.3	0.3	0.2	1.9	29.0	33.7	45.7	20.2	1
Bk3	102-127	SiL-L	1.4	0.4	0.2	1.1	21.8	24.9	51.2	23.4	5
Btk1b	127-184	L	0.1	0.1	0.1	3.0	35.5	38.9	43.2	17.2	3
Btk2b	184-209	SiL	0.2	0.1	0.1	2.0	26.4	28.8	52.5	18.3	7
Btkb2	209-231	SiL	5.9	0.7	0.3	0.6	13.9	21.3	57.9	20.4	9
BCb2	231-290	SiL	0.1	0.1	0.1	1.5	21.7	23.5	58.2	17.4	4
	517-570	SL	0.0	0.3	0.6	14.1	44.1	59.1	32.8	7.5	3
	579-630	SL	0.0	0.4	3.2	19.3	41.0	63.8	27.2	8.2	5
	650-673	LS	17.2	1.2	3.6	25.5	28.5	76.1	16.7	6.7	9
West 15.5 Backhoe Trench Soil Profile (Line Level at 79 cm; Fig. 5.12)											
AP	0-23	L	0.2	0.2	0.4	5.7	36.1	42.6	40.2	17.0	3
AB	23-38	L	0.3	0.4	0.8	7.1	37.2	45.9	36.9	16.8	3
Bt1	38-71	L	0.5	0.4	0.5	7.1	37.0	45.6	35.1	19.1	3
Bt2	71-97	L	0.7	0.3	0.6	7.7	35.2	44.5	36.5	18.8	3
Bt3	97-132	L	0.6	0.4	0.6	9.2	36.1	46.9	34.5	18.4	2
Bt1b	132-179	L	1.1	0.7	0.8	7.4	35.8	45.8	36.4	17.6	4
Bt2b	179-209	CL	0.1	0.3	2.3	0.9	19.9	23.5	47.5	28.6	5
Bg1b2	209-223	SiL	0.0	0.0	0.1	1.3	24.9	26.2	51.3	22.1	5
Bg2b2	223-244	L	0.8	0.9	1.2	7.1	33.3	43.3	38.3	18.1	5
BCb2	244-285	L	2.6	1.9	1.8	7.0	35.9	49.1	36.5	14.0	7
	372-404	SiL	0.0	0.0	0.1	2.0	26.7	28.8	56.1	14.6	
	420-434	L	0.6	0.9	0.8	4.2	36.1	42.6	45.8	11.4	
	451-461	L	21.3	2.9	1.4	5.1	19.2	49.9	36.8	12.7	

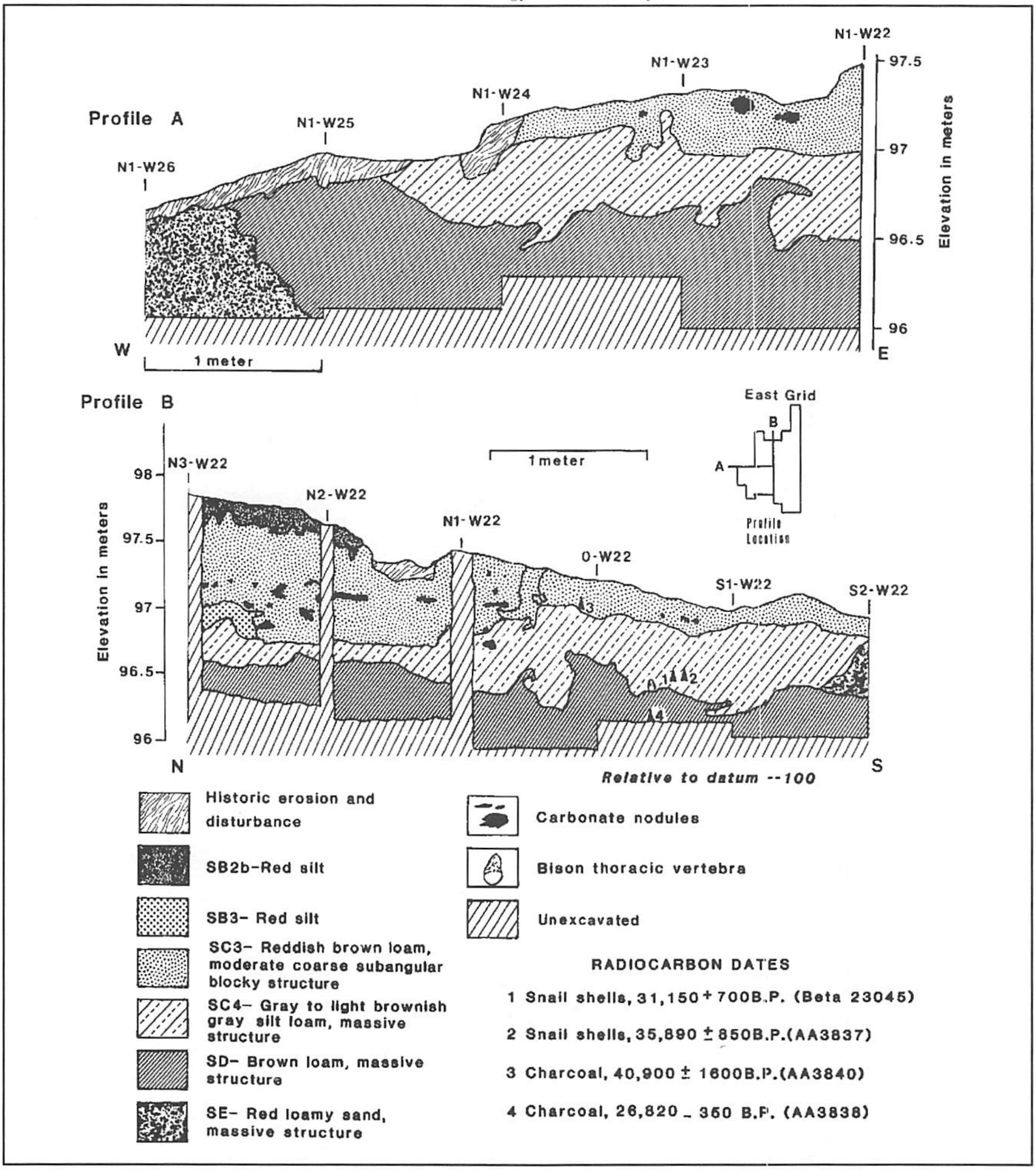


Figure 5.13. East-west and north-south profiles of selected squares in the manually dug East Grid of the Burnham site.

Salt efflorescence and gypsum formation were observed within the lower soil horizons of the North 3 backhoe trench middle (N3-W7) profile (Figs. 5.14 and 5.15). Halite is the major mineral within the salt efflorescence. Soluble salt and gypsum formation are common soil-formed features in soils of Woods County (Carter and Inskeep 1988). Halite and gypsum beds are described within Permian Formations in the study area. Soil and ground water dissolves these beds and redistributes halite and gypsum as secondary diagenetic and soil precipitates. Presence of salt efflorescence and gypsum indicates that soils and sediments from within the study site are not highly leached. Presence of these precipitates indicates that the soil and deposits are not weathered because initial products of weathering (salts and gypsum) have not been removed from the deposits. The time and exact origin of these salts and gypsum within the hillslope are unknown. It is possible for salt and gypsum to come from mineral sources several meters vertically or kilome-

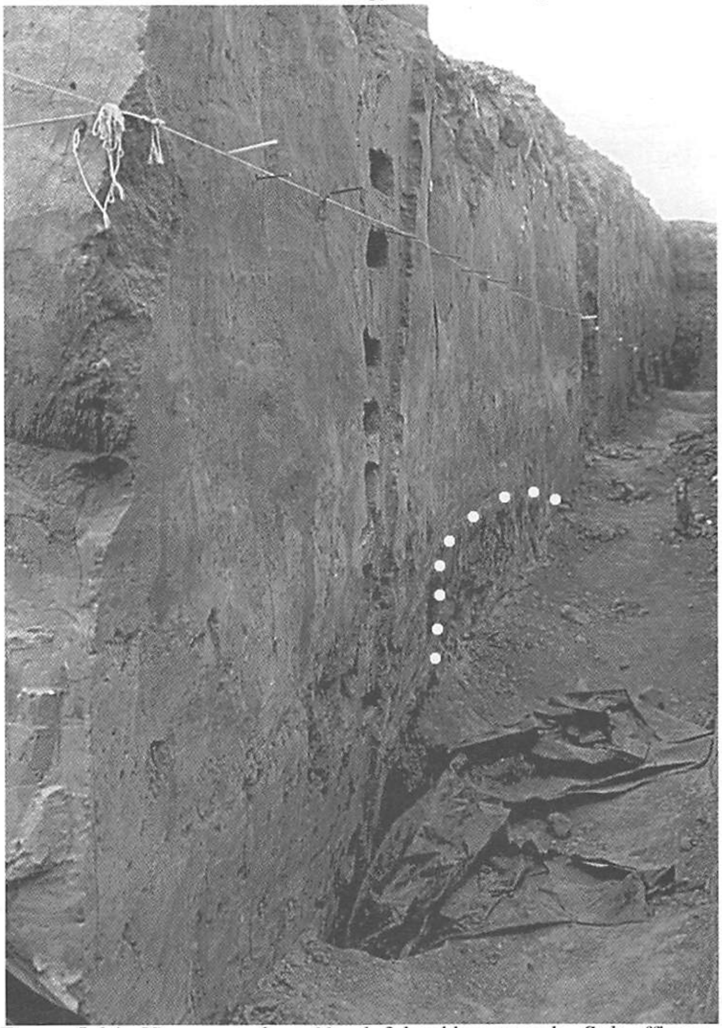


Figure 5.14. View east along North 3 backhoe trench. Salt efflorescence visible (in area below dashed white line) along base of profile beyond the visqueen tarp and gastropod sampling column.Photo taken October 20, 1989, by Brian Carter.

Figure 5.15. Closeup of salt efflorescence at base of North 3 backhoe trench. Photo taken October 20, 1989, by Brian Carter.

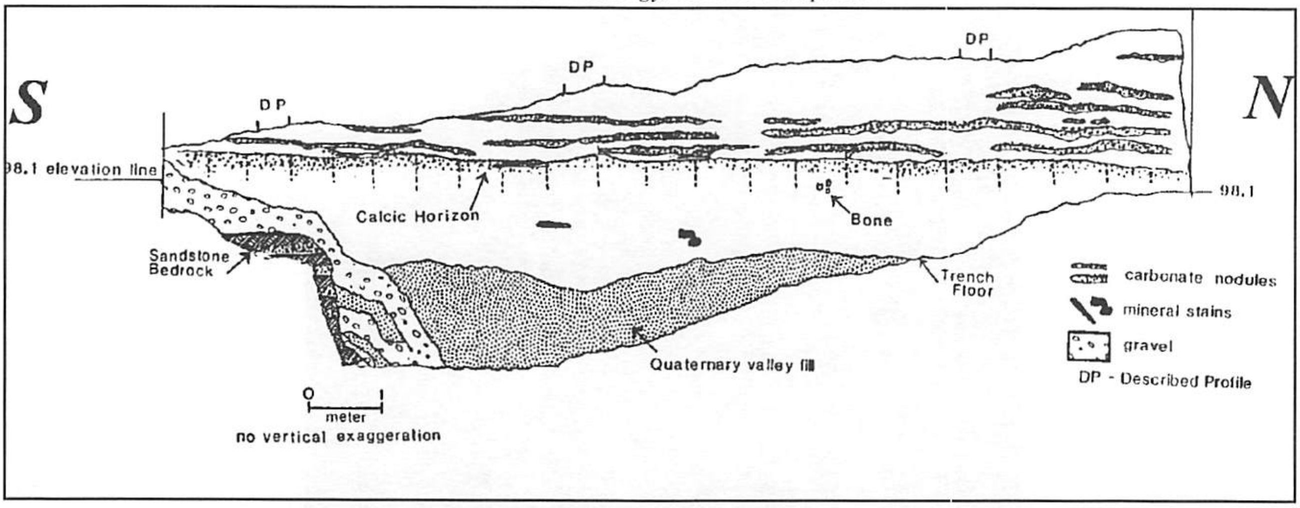


Figure 5.16. North-south profile of the 1991 backhoe trench dug in the East Exposure at the Burnham site.

ters laterally removed from the study area.

The lateral extent of soil horizons produced an interfingering of soil profiles between Groups III and II. The interfingering of sediments was caused by transgressive-regressive sequences which placed "upland" soil horizons from Group III above mottled "pond" sediments of Group II. Gleyed soil horizons were laterally discontinuous, producing lentil-shaped deposits. Unique soil boundaries were also observed within soils of Group II. Animal burrows interrupted soil horizons, producing dicontinuities. Irregular soils boundaries with unusual and undefined zones of mixing were also common to soils of Group II. These zones of mixing included swirl and flame structures not observed previously by research investigators involved in this study (Figs. 5.14, 5.15, and 5.16).

Hypotheses and Conclusions Concerning Soil and Landscape Development and Sediment Origin

Two important questions must be answered before the archeological, paleontological, and geological signficance of the Burnham site can be fully realized. These questions are:

1. what are the environment(s) of deposition and diagenetic processes that formed the study site; and
2. where do ground surfaces exist (buried or not buried) where human and animal occupation occurred which were the source for detrital flakes and bones currently deposited at the study site?

The sites of human and animal occupation are needed to

Figure 5.17. Flame structure in boundary between lowest pond deposit and the artifact-bearing gray sediment. North wall of 0-W22 square of the East Exposure grid. Photo by Don Wyckoff.

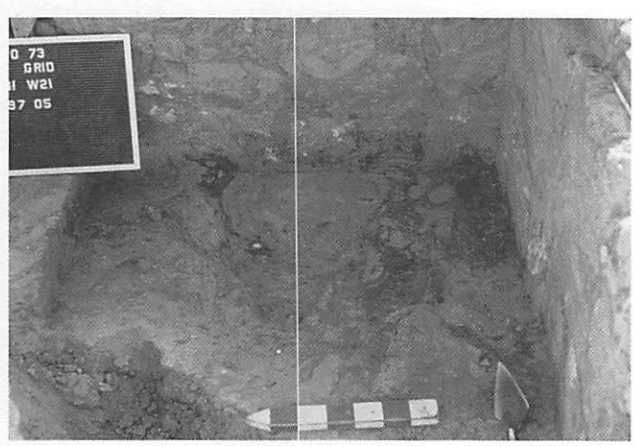


Figure 5.18. Looking east at water-swirled and bioturbated red and gray sediments exposed at elevation 97.05 in East Exposure grid square N1-W21. Photo by Byron Sudbury.

Figure 5.19. East wall profile of East Exposure square N1-W21 with floor at elevation 96.65. Profile shows effects of water-swirled sediments and krotovinas. Photo taken October 17, 1989, by Don Wyckoff.

firmly establish the condition of life in the area during the late Pleistocene. Question #1 must be answered before Question #2 can be adequately addressed. Some hypotheses can be developed and conclusions drawn from the current data developed at the study site. The current level of geologic information collected for the study area does not provide a clear understanding of the environment of sedimentation or site location of human or animal occupation.

Several facts serve to limit the possible environments of deposition for the study site and suggest likely scenarios. The presence of sorted and stratified horizons of sand, silt, and clay and of gravel on a smooth bedrock contact found beneath the study site and within the surrounding gully-wall exposures suggests that the sediment at the site is alluvium. The lack of observation of sediments surrounding the site restricts the identification of the alluvial system. Alluvium can originate from a hillslope fan, stream, ephemeral gully, or karst environment. Mottled soil horizons indicate the site at the time of deposition contained standing water which saturated the soil profile. The thin and short extent of the gleyed lentils which contain soil mottling indicates the areas of standing water were small (less than 1ha.; Carter and Brackenridge 1990). Lack of buried A horizons and lithologic discontinuities suggest that deposition was continuous across time periods that did not allow the development of permanent vegetative cover producing soil humus. The presence of buried B and C horizons indicate that deposition may have stopped for months or several years, thus allowing drying and cracking that produced soil structure and the formation of calcium carbonate. The 6m. sediment depth at the site indicated by soil coring and augering suggests the deposits may extend several km. into the surrounding hillslopes. The alluvium which is the study site was probably deposited by an ancient West Moccasin Creek or its tributary.

The formation of gully erosion which naturally exposed the site suggests that there was a lowering of base level following the deposition of sediments that now comprise the study site. Natural erosion continues to the present and has removed the constructional surface form that corresponded to the study site deposits. The erosional hillslpe surface now defining the site masks the direct interpretation of the mode of deposition. The environment of deposition is often determined from the analysis of constructional surface form. The presence of calcic horizons of Group III does suggest that relative hillslope erosion has not been rapid. Calcic horizon formation often takes tens of thousands of years to form. Because radiocarbon dating suggests the late Pleistocene as the time of sediment deposition within the study site, and considering the length of time needed for calcic formation, not more than several meters of soil could be removed from the study site. A higher rate of erosion, and therefore and larger loss of soil, would limit the formation of calcic horizons. From the presence of the calcic horizon at the site, it is likely that the original constructional surface that would have accompanied the sediments at the study site was several meters above the current ground surface before removal of sediments by the bulldozer constructing the dam for the modern pond.

Upon aggradation of alluvium at the site, back or slack-water deposits containing standing water and saturated soil conditions probably extended through time but changed laterally as the channel or main concentration of water migrated. Plant and animal communities migrated along with the aggradation of these small ponds, which were similar to current floodplain depositional systems. Ponded deposits may also have been induced by partial collapse of sediments into solution cavities produced by the groundwater dissolution of gypsum underlying alluvium. Complete karst topography capturing the entire stream flow does not seem likely. Identification of aquatic snails requiring a perennial pond setting with marshy margins (J. Theler, personal communication) suggests more than a slack water floodplain pond for the deposits at the site. Also, fish species identified by Dr. Larry Martin and colleagues suggest a significant lacustrine environment. The identification of snails within wet and moist conditions will further define possible conditions of deposition at the study site.

The environment of formation and deposition of soils at Burnham are ascertained by site field description. The major themes of soil parent material deposition and soil formation are:

1. alluvium;
2. anaerobic soil condition (excess or saturated soil conditions);
3. erodible surface soil conditions (buried truncated soils);
4. bioturbation; and
5. a drying of the climate as manifest by calcic soil horizons.

Each theme is supported by a major feature(s). These features are field evidence that support hypotheses of site development. As more evidence is unearthed, hypotheses can be refined or redefined. New field evidence will be discovered largely by increasing the size of the study site.

References Cited

Buehler, K. 1990. Burnham Site Lithics. Abstract for the Symposium on Interdisciplinary Research at the BurnhamSite,Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Carter, B.J. and G.R. Brackenridge. 1990. Soil and Sediment Stratigraphy at the Burnham Site. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Carter, B.J., P.A. Ward III, and J.T. Shannon. 1990. Soil Geomorphic Evolution within Rolling Red Plains Using Pleistocene Ash Deposits. Geomorphology 3:471-488.

Carter, B.J. and W.P. Inskeep. 1988. Accumulation of Pedogenic Gypsum in Western Oklahoma Soils. Journal of theSoil Science Society of America 52:1107-1113.

Dort, W., Jr. and L.D. Martin. 1990. Tentative Geological Synopsis for the Burnham Site, Woods County, Oklahoma. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma. 48th Plains Anthropological Conference, Oklahoma City.

Fay, R.O. 1965. Geology and Mineral Resources of Woods County. Oklahoma Geological Survey Bulletin 106. Norman.

Fitzpatrick, E.G., O.E. Stout, W.W. Little, and D.H. McMahen.
1950 Soil Survey of Woods County, Oklahoma. U.S. Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering and the Oklahoma Agricultural Experiment Station.

Flynn, P., D.G. Wyckoff, B.J. Carter, W.Dort, Jr., L. Martin, J.L. Theler, and L.C. Todd. 1988. Beyond Clovis: A Glimpse from the Burn ham Site? Paper presented at the 46th Plains Anthropological Conference, Wichita, Kansas.

Martin, L.D. 1990. Late Pleistocene Fauna at the Burnham Site. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Theler, J.L. 1990. Burnham Site Gastropod Analysis. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Todd, L.C. 1990. Taphonomic Investigations of the Burnham Site Bison and Equid Bonebeds. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Wyckoff, D.G. 1990. The Burnham Site: Background and Current Research Status. Abstract for the Symposium on Interdisciplinary Research at the Burnham Site, Northwestern Oklahoma, 48th Plains Anthropological Conference, Oklahoma City.

Wyckoff, D.G., B.J. Carter, W. Dort, Jr., G.R. Brackenridge, L.D. Martin, J.L. Theler, and L.C. Todd. 1990. Northwestern Oklahoma's Burnham Site:Glimpses Beyond Clovis? Current Research in the Pleistocene 7:60-63.

Wyckoff, D.G. 1989. The Burnham Site and Pleistocene Human Occupations of the Southern Plains of the United States. Paper presented at the World Summit Conference on the Peopling of the Americas, University of Maine, Orono.

Table 5.2. Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color*	Structure*	Texture*	Consistence*	Boundary*	Reaction*	Special features*
Profile in North 25 Backhoe Trench (Fig. 5.12)								
Ap	0-28	5YR3/4	1,f,pl	VFSL	fr	c,w	ste	Common fine irregular carbonate soft accumulations, commc medium rounded carbonate nodules.
AB	28-54	5YR4/4	2,m,pr	L	fr	c,s	ve	Many fine irregular carbonate soft accumulations in pores, fe rounded carbonate nodules, common medium worm castings. quartzite gravels.
Btk1	54-120	5YR4/4	2,c,pr/ 3,c,sbk	SiCL	fr	c,s	ve	Many fine irregular carbonate soft accumulations in pores, common medium irregular carbonate nodules, many prominent clay coatings on peds.
Btk2	120-189	5YR4/4	3,c,pr/ 3,c,sbk	SiCL	fr	c,s	ve	Common fine faint 5YR6/2 mottles, many medium coarse irregular carbonate soft accumulations + nodules in pc prominent clay coatings on peds.
Btk3	189-214	5YR4/6	3,c,pr	SiC	fi	c,b	ve	Many fine medium distinct 5YR6/1 mottles, few coarse irreg carbonate nodules, many rounded detrital carbonate gravels ε many fine N2/0 manganese coatings in pores, few prominent coatings on peds.
Btk4	214-244	5YR5/4	2,c,pr	SiC	fi	g,s	ste	Common medium distinct 10YR6/2 mottles, many fine rounc carbonate nodules, few prominent clay coatings on peds, 1 bi bone.
BC	244-280+	5YR4/4	2,m,pr	SCL	fr	---	ste	Common medium faint 5YR5/2 mottles, common fine mangε coatings in pores, few coarse snails.
North Profile of West 15.5 Backhoe Trench(Fig. 5.12) *(100.38 m surface elevation relative to datum)*								
Ap	0-24	2.5YR- 5YR4/4	1,f,pl	SCL	fr	c,w	ste	Many fine angular carbonate nodules, few fine + medium roots, many fine carbonate soft accumulations in pores.
AB	24-54	5YR4/6	2,m,sbk	CL	fr	a,s	ste	Few fine carbonate soft accumulations in pores, few fine rool medium faint 5YR5/6 mottles.
Btk1	54-102	5YR4/4	2,m,pr/ 3,c,sbk	SCL	fr	c,s	ste	Many fine medium irregular carbonate nodules, few fine roots, common distinct clay coatings on peds, few medium di 7.5YR6/2 mottles.
Btk2	102-142	5YR4/6	2,c,pr/ 2,c,sbk	SiCL	fr	g,s	ste	Many fine + medium irregular carbonate soft accumulations in pores, few fine roots, many faint clay
CB	142-159	2.5YR- 5YR4/6	1,m,pr/ 1,c,sbk	SCL	fr	g,s	---	Common fine + medium irregular carbonate soft accumulations in pores, few fine roots, many faint clay coatir pores.

Table 5.2 (cont.) Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
North Profile of West 15.5 Backhoe Trench (cont.)								
Bwlb	159-174	5YR4/4	M	FSL	fr	c,s	ste	Many fine rounded carbonate nodules, common fine N2/ or manganese fragments, few fine + medium roots, many prominent 10YR6/2 mottles.
Bw2b	174-242	5YR4/4	2,c,pr	L	fi	a,s	ste	Common fine subangular carbonate nodules, common fir carbonate soft accumulations in pores, common fine suba charcoal or manganese fragments, many common promir 10YR5/2 mottles.
Clb	242-256	5YR4/6	M	LFS	vfr	c,s	e	Few fine rounded carbonate nodules, many distinct strati layers 1 cm thick, many fine faint 5YR5/2 mottles.
C2b	256-273+	5YR4/6	M	LFS	vfr	g,s	-	Few fine rounded carbonate nodules, many coarse promi 10YR6/2 mottles.
Middle Profile of West 15.5 Backhoe Trench (Fig. 5.12) *(99.32 m surface elevation relative to datum)*								
Ap	0-29	5YR4/6	1,f,pl	SCL	fr	c,s	ste	Many fine + medium irregular carbonate soft accumulati common medium + coarse irregular carbonate nodules, f roots, + many fine faint 5YR6/2 mottles.
Btk	29-57	5YR4/4	2,c,pr/ 2,c,sbk	SCL	fr	g,s	e	Many fine charcoal or manganese N2/0 fragments, many fine + medium carbonate soft accumulations in pores, fe
Bg	57-67	10YR5/2	2,m,pr	SL	fr	a,w	ste	Common fine charcoal or manganese N2/0 fragments, fe irregular carbonate soft accumulations, few fine roots, m distinct 7.5YR4/6 mottles.
Bkb	67-98	5YR4/6	2,m,pr	FSL	fr	c,s	ste	Common medium irregular carbonate nodules, common prominent 2.5Y6/2 mottles, few fine + medium snails, m krotovinas 2.5Y6/2
Bwb2	98-127	5YR4/4	2,c,pr/ 2,c,sbk	FSL	fr	c,s	ste	Common fine charcoal or manganese fragments, commo fine snails, common medium distinct 10YR5/2 mottles.
Cb2	127-144	5YR4/6	M	FSL	fr	d,s	ste	Few fine rounded carbonate nodules, many coarse kroto 10YR5/1, many coarse prominent 10YR5/1 mottles.
Bwb3	144-187	2.5YR4/4	2,m,pr	FSL	fr	a,s	ste	Many fine + few coarse snails, many coarse krotovinas 7 common fine distinct 5YR5/3 mottles.
Clb3	187-203	7.5Y7/4	M	S	fr	a,s	ste	Many fine snails, few medium krotovinas, stratified laye (SL) + 5YR4/4 (CL).

Table 5.2 (cont.) Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Middle Profile of West 15.5 Backhoe Trench (cont.)								
C2b3	203-234	5YR5/4	M	LFS	vfr		ste	Many fine snails, common coarse irregular krotovinas, + coarse prominent 2.5YR5/6 + 10YR6/2 mottles.
Cgb3	234-252	5Y6/1	M	LFS	fr	a,w	ste	Many fine + coarse snails, many fine faint 5Y5/6 mottl
C1b4	252-260	5YR4/4+ 7.5YR6/4	M	SL	fr	a,s	e	Stratified + convoluted 1 cm layers of 5YR4/4 + 7.5YR6/4 sands.
C2b4	260-330	2.5YR4/4	M	VFSL	vfr		ste	Common fine stratified sands, common fine irregular c accumulations in pores, many coarse irregular carbonat nodules.
	330-357	5YR5/6		LVFS			ste	Few fine subangular carbonate gravels.
	357-390	5YR5/6		LFS			ste	Many fine subangular carbonate gravels.
	390-418	5YR5/6		LFS			ste	
	418-439	2.5YR5/6		GLS			ste	Many fine + medium subangular dolomite gravels.
	439-477	2.5YR4/6		LFS			ste	Few fine rounded quartzite gravels, few medium suban sandstone gravels, many fine subangular carbonate gra
	477-500	2.5YR4/6		LVFS			e	Few medium rounded "clay balls", common fine carbo
	500-519	2.5YR3/4		LFS			e	Common coarse subrounded Permian sandstone gravel rounded carbonate gravels.
	519-553	2.5YR4/6		GLS			ste	Many fine rounded carbonate gravels, many coarse sub calcite gravels, common medium subangular + roundec hematitic gravels.
R	553-573+	2.5YR5/8		LFS			-	Permian sandstone
East Profile of North 3 Backhoe Trench (Fig. 5.11)								
(100.33 m surface elevation relative to datum)								
Ap	0-28	2.5YR4/4	1,f,pl	SiCL	fr	c,w	ve	Many coarse irregular carbonate nodules, many fine irr carbonate soft accumulations in pores, few fine roots, f coatings on peds.
Bk1	28-60	2.5YR4/4	2,c,sbk	SCL	fr	c,s	ste	Many fine cylindrical carbonate concretions, few fine r distinct clay coatings on peds.
Bk2	60-102	5YR4/6	2,m,pr 2,m,sbk	L	fr	g,s	ste	Many medium and coarse irregular carbonate nodules, common fine carbonate soft accumulations in pores, m irregular N2/0 charcoal or manganese soft accumulatio few fine roots.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
East Profile of North 3 Backhoe Trench (cont.)								
Bk3	102-127	2.5YR-5YR4/4	2,m,sbk	SCL	fr	g,s	ste	Many coarse irregular carbonate nodules, common fine carbonate soft accumulations in pores, many prominent clay c on peds, few fine roots.
Btk1b	127-184	5YR5/8	2,c,pr 3,c,sbk	VFSL	fr	g,s	ste	Many coarse irregular carbonate nodules, many coarse irregular carbonate soft accumulations in pores, many fine irr N2/0 charcoal or manganese soft accumulations in pores, cor distinct clay coating on peds.
Btk2b	184-209	5YR5/6	2,c,pr 2,c,sbk	VFSL	fr	g,s	ste	Common coarse irregular carbonate nodules, many fine irregular charcoal fragments, common distinct clay coatings c common fine roots, many fine distinct 5YR6/2 mottles in roo 1 large wood-charcoal fragment which was dated.
Btkb2	209-231	5YR5/6	3,m,pr	SiCL	fr	g,s	ste	
BCb2	231-290	2.5YR4/6	3,c,sbk	SiCL	fr		ste	Few medium irregular carbonate soft accumulations, few fair coatings on peds, few fine roots, few fine pores filled w/ 5YR sand.
	290-305	5YR4/4	M	L	fr	g,s	e	Many fine charcoal fragments, few fine snails.
	305-331	5YR4/3		VFSL			ste	Many coarse irregular carbonates nodules.
	331-355	2.5YR3/6		L			ste	Many fine subrounded carbonate gravels.
	355-487	5YR5/6		VFSL			-	
	487-517	5YR3/4		GLS			ste	Few medium subangular carbonate gravels, many fine rounde quartzite gravels.
	517-570	2.5YR3/6		SL			e	
	570-579	2.5YR3/6		GLS			ste	Many fine subrounded quartzite gravels, many fine subround carbonate gravels, few fine subangular Permian sandstone gr
	579-630	2.5YR3/6		FSL			ste	
	630-650	2.5YR3/6		LFS			ste	Common medium subangular Permian sandstone gravels.
	650-673	2.5YR3/6		GLS			ste	Common coarse subangular calcite gravels, few medium irreg carbonate gravels, many fine rounded and subrounded quartz gravels.
R	673+	2.5YR5/8		LFS			-	Permian sandstone

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Middle Profile of North 3 Backhoe Trench (Fig. 5.11)								
(99.59 m surface elevation relative to datum)								
Ap	0-40	5YR5/8	1,f,pl	SCL	fr	g,s	ste	Common coarse irregular carbonate nodules, few fine roots, 1 distinct 7.5YR6/2 mottles in pores.
Bk1	40-63	5YR4/4	2,c,sbk	L	fr	g,s	ste	Common irregular carbonate soft accumulations, few fine roo
Btk2	63-92	5YR4/6	2,m,pr 2,c,sbk	SCL	fr	g,s	ste	Common coarse irregular carbonate nodules, many medium irregular carbonate soft accumulations, few fine root common faint clay coatings on peds.
Bk1b	92-148	5YR4/6	1,c,pr/ 2,c,sbk	L	fr	g,s	ste	Common fine irregular cylindrical charcoal fragments, few fine roots, common faint clay coatings on peds, common medium irregular carbonate soft accumulations, few medium 5YR6/2 mottles.
Btk2b	148-156	2.5YR3/6	3,c,sbk	SiC	fi	g,s	ste	Many fine irregular carbonate soft accumulations + nodules, coarse prominent clay coatings on peds.
Btk3b	156-174	5YR4/4	2,m,pr	SCL	fr	g,s	ste	Many fine snails, many fine irregular carbonate concretions, fine and medium distinct 7.5YR6/2 mottles, common faint cl coatings on peds.
ABb2	174-198	2.5YR4/4	2,c,sbk	VFSL	fr	g,s	ste	Few medium irregular carbonate soft accumulations, many fi medium prominent 2.5Y5/2 mottles, few fine + medium gyps crystal masses in pores + on peds.
Bkyb2	198-260	5YR5/8	2,m,pr	SiCL	fr		ste	Many fine + medium irregular carbonate soft accumulations i many fine N2/0 charcoal or manganese soft accumulations in common medium faint 7.5YR5/4 mottles, few fine + medium gypsum crystal masses in pores + on peds, few coarse irregul carbonate nodules in pores.
	260-277	5YR4/4		FSL			ste	Few fine gypsum crystal masses in pores, common fine irregı carbonate soft accumulations.
	277-294	2.5YR3/6		VFSL			ste	Few fine rounded quartzite gravels, common fine angular car gravels.
	294-306	5YR4/4		SiL			e	Common fine angular carbonate gravels.
	306-318	5YR4/4		FSL			ste	Few fine angular carbonate gravels.
	318-327	5YR5/6		LFS			e	Few fine subrounded carbonate gravels.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Middle Profile of North 3 Backhoe Trench (cont.)								
	327-335	5YR5/8		LVFS			-	
	335-359	5YR4/4		GLS			ste	Few coarse subrounded calcite gravels, common fine quartzit gravels, many fine rounded carbonate gravels.
	359-389	5YR4/6		FSL			ste	Common fine rounded carbonate gravels.
	389-408	5YR4/4		VFSL			ste	
	408-430	5YR4/4		LFS			ste	Common medium subangular dolomite gravels, common fine subrounded carbonate gravels.
	430-456	5YR4/6		VFSL			ste	Common fine subrounded carbonate gravels.
	456-489	5YR4/4		LFS			ste	Common fine subrounded carbonate gravels.
	489-507	5YR4/4		FSL			ste	Few fine subrounded carbonate gravels.
	507-571	5YR4/4		GLS			ste	Common medium subrounded calcite gravels, few medium subrounded Permian sandstone gravels, many fine rounded a: subrounded quartzite gravels, common coarse subangular cal gravels.
	571-580+	5YR5/6		LFS			-	
Profile in West 6 Backhoe Trench (Fig. 5.9) ***(100.2 m surface elevation relative to datum)***								
Ap	0-80	5YR5/8	1,f,pl	SCL	fr	g,s	ste	Common coarse irregular carbonate nodules, few fine roots, 1 distinct 7.5YR6/2 mottles in pores.
Bk1	80-120	5YR4/4	2,c,sbk	L	fr	g,s	ste	Common irregular carbonate soft accumulations, few fine roc
Btk2	120-160	5YR4/6	2,m,pr/ 2,c,sbk	SCL	fr	g,s	ste	Common coarse irregular carbonate nodules, many medium irregular carbonate soft accumulations, few fine root common faint clay coatings on peds.
Bk1b	160-200	5YR4/6	1,c,pr/ 2,c,sbk	L	fr	g,s	ste	Common fine irregular cylindrical charcoal fragments, few fine roots, common faint clay coatings on peds, common medium irregular carbonate soft accumulations, few medium 5YR6/2 mottles.
Btk2b	200-225	2.5YR4/6	2,c,sbk	SCL	fr	g,s	ste	Many fine irregular carbonate soft accumulations + nodules, coarse prominent clay coatings on peds.
Bwb2	225-235	2.5YR4/4	2,c,sbk	VFSL	fr	g,s	ste	Few medium irregular carbonate soft accumulations, many fi medium prominent 2.5Y5/2 mottles, few fine + medium gyps crystal masses in pores + on peds.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Profile in West 6 Backhoe Trench (cont,.)								
Bkyb2	235-270+	5YR5/8	2,m,pr	SiCL	fr		ste	Many fine + medium irregular carbonate soft accumulations i many fine N2/0 charcoal or manganese soft accumulations in common medium faint 7.5YR5/4 mottles, few fine + medium gypsum crystal masses in pores + on peds, few coarse irregul carbonate nodules in pores.
West Profile of North 3 Backhoe Trench (Fig. 5.11)								
(98.9 m surface elevation relative to datum)								
Ap	0-23	5YR5/3	2,c,pl	VFSL	fr		ste	Many fine irregular carbonate nodules, common fine faint 5Y mottles.
AB	23-38	5YR4/4	2,c,sbk	FSL	fr		ste	Many fine subrounded carbonate gravels, many fine N 2/0 ch or manganese fragments.
Bt1	38-71	5YR4/4	2,m,sbk	SiCL	fr	c,s	ste	Few fine irregular carbonate soft accumulations, few fine roo common fine faint 5YR5/3 + distinct 7.5YR7/2 mottles.
Bt2	71-97	5YR4/4	2,m,pr	SCL	fr	c,w	ste	Few fine irregular carbonate soft accumulations in pores, few medium irregular carbonate nodules, few faint clay coatings (few fine roots, common fine + medium distinct 10YR6/2 + 5, mottles.
Bt3	97-132	5YR4/4	2,c,sbk	SCL	fr	c,s	ste	Many fine irregular carbonate soft accumulations in pores, cc fine subrounded carbonate nodules, few coarse bones, many medium prominent 10YR5/3 + 5/1 mottles.
Bt1b	132-179	2.5YR4/4	2,c,sbk	VFSL	fr	d,c	ste	Common medium irregular carbonate soft accumulations in p few coarse snails, many fine + medium prominent.
Bt2b	179-209	2.5YR4/6	2,m,pr/ 2,c,sbk	SiC	fr	a,w	ste	Common fine irregular carbonate soft accumulations in pores, common fine subrounded carbonate nodules, few faint coatings on peds, many coarse prominent 2.5Y6/2 + 7.5YR5, mottles.
Bg1b2	209-223	10YR6/2	M	VFSL	vfr	a,w	ste	Few fine stratified and convoluted 10YR4/2 SCL layers.
Bg2b2	223-244	5Y6/1	M	LFS	vfr	a,w	ste	Few coarse rounded krotovinas filled W/ 7.5YR5/4 sand, cor coarse distinct 5Y5/4 mottles.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
West Profile of North 3 Backhoe Trench (cont.)								
BCb2	244-285	10YR5/3	M	FSL	fr		ste	Many fine subrounded Permian sandstone gravels, many fine medium subrounded to rounded carbonate gravels, few coars many fine faint 7.5YR5/4 mottles.
	285-298	5YR4/2		VFSL			ste	Many fine rounded + angular Permian sandstone gravels, few faint 5YR5/6 mottles.
	298-310	7.5YR4/2		VFSL			ste	Common fine faint 7.5YR6/2 + 10YR5/8 mottles.
	310-323	5YR5/6		LFS			ste	Many fine N 2/0 angular charcoal or manganese fragments.
	323-336	5YR4/4		LVFS			ste	
	336-364	5YR4/6		VFSL			ste	Many coarse irregular carbonate nodules.
	364-387	5YR5/6		SCL			ste	
	387-412	5YR5/6		SL			ste	Common fine angular carbonate nodules, common fine snail fragments, common coarse 5YR6/1 mottles.
	412-425	5YR4/4		SCL			ste	Many coarse angular calcite gravels, many fine carbonate sof accumulations in pores, many fine root pores.
	425-458	5YR4/6		SiC			ste	Many fine angular carbonate gravels.
	458-464	5YR5/8		GSL			ste	Many fine angular carbonate detrital nodules, many fine subr dolomite and calcite gravels.
	464-470	5YR5/6		GLS			ste	Many fine and coarse subrounded calcite and dolomite grave fine angular detrital carbonate nodules.
	470-476+	5YR4/6		GFSL			ste	Many fine and coarse subrounded dolomite and calcite grave fine angular detrital carbonate nodules, common fine rounde quartzite gravels.
Auger Hole in 0-W22 Square (Fig. 5.10)								
	0-31	10YR4/1		SCL			ste	Many medium prominent 2.5YR4/6 mottles.
	31-48	10YR4/3		L			ste	Many fine distinct 7.5YR5/8 mottles.
	48-57	2.5Y5/2		VFSL			ste	Many fine prominent 2.5YR4/6 + 10YR5/8 mottles, many fir irregular N 2/0 charcoal or manganese fragments + in pores.
	57-70	10YR4/3		SiL			ste	Many fine distinct 7.5YR5/4 mottles, common fine irregular carbonate soft accumulations in pores.
	70-102	2.5YR4/6		L			ste	Few fine irregular carbonate soft accumulations, common fin irregular subangular N 2/0 charcoal fragments + in pores.
	102-123	2.5YR4/6		LVFS			ste	
	123-142	2.5YR4/6		LS			ste	Common fine subrounded detrital carbonate gravels.
	142-151	2.5YR3/6		LFS			e	

Table 5.2 (cont.). Soil Profiles and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Auger Hole in 0-West 22 Square (cont.)								
	151-196	2.5YR3/6		GLS			ste	Many fine + coarse subangular calcite gravels, many fine rou 2/0 hematitic gravels.
R	196-224+	2.5YR5/8		LFS			-	Permian sandstone
Soil Core at N8-W7 (Fig. 5.10)								
(99.76 m surface elevation relative to datum)								
BCk1	0-73	5YR4/6	2,m,sbk	VFSL	fr		ste	Few coarse irregular carbonate nodules.
BCk2	73-128	5YR4/6	1,c,sbk	L	fr	d	ste	Few coarse irregular carbonate nodules, few coarse diffuse c: soft accumulations, few fine faint 5YR5/2 mottles especially pores.
C1	128-174	5YR4/6	M	VFSL	fr	g	ste	Few medium faint 10YR6/3 mottles.
C2	174-196	2.5-5YR3/6	M	L	fr	g	ste	Few medium snails.
Bwb	196-210	2.5YR3/4	2,c,sbk	L	fr	c	ste	Few faint clay coatings on peds, few medium snails.
Byb	210-242	5YR4/6	2,c,sbk	L	fr	g	ste	Few fine irregular carbonate soft accumulations in pores, con fine gypsum crystal clusters, common coarse prominent 10YI mottles.
BC1b	242-293	5YR4/6	2,c,sbk	FSL	fr	g	ste	Few fine irregular carbonate soft accumulations in pores, con fine charcoal fragments, common fine broken snail shells, co coarse faint 7.5YR5/6 mottles.
BC2b	293-317	5YR4/6		VFSL	fr	g	ste	Few fine irregular carbonate soft accumulations in pores.
C1b	317-455	5YR5/6		LFS	vfr	c	ste	Few fine irregular carbonate soft accumulations in pores, few stratified layers of clay.
C2b	455-480	2.5YR5/8	M	GLS	vfr	c	ste	Common fine calcite, quartzite, and Permian sandstone grave
C3b	480-526+	2.5YR5/8 5/6	M	LS	vfr		ste	

Table 5.2 (cont.). Soil Profiles and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Soil Core at N9-W10 (Fig. 5.10)								
(99.76 m surface elevation relative to datum)								
BCk	0-14	2.5YR3/6	1,c,sbk	VFSL	fr	g	e	Common medium to coarse irregular carbonate nodules, roots.
C1	14-90	5YR4/6	M	FSL	fr	a	ste	Few fine irregular carbonate soft accumulations, few fine irr 2/0 manganese soft accumulations, few fine faint 5Y6/1, mot
C2	90-144	5YR4/6	M	LFS	fr	g	---	Few fine irregular carbonate soft accumulations, few fine roo
C3	144-185	5YR4/6	M	FSL	fr	g	---	Few fine irregular carbonate soft accumulations, common distinct 5YR6/2 mottles, few fine roots.
C4	185-233	7.5YR4/4	M	LFS	fr	a	e	Many medium prominent 7.5YR6/2 mottles, few fine roots.
C5	233-261	7.5YR4/6	M	L	fr	b	ste	Few medium snails, few fine rounded quartzite and detrital c nodules.
BCgb	261-285	5YR4/4	M	VFSL	fr	a	ste	Few medium snails, stratified layers of SiC 5YR4/6, prominent 2.5Y5/2 mottles.
C1b	285-447	5YR5/6	M	LVFS	vfr		ste	Few fine N 2/0 manganese soft accumulations in pores.
C2b	447-456	5YR5/6	M	GLS	vfr	a	ste	Many fine rounded quartzite gravels, many fine angula gravels, few fine angular Permian sandstone gravels.
Soil Core at N9-W10 (cont.)								
C3b	456-472	5YR5/6	M	LVFS	vfr	a	ste	Common fine irregular carbonate soft accumulations in pores
C4b	472-499	5YR5/6	M	GLS	vfr	a	ste	Common medium angular calcite gravels, many fine quartzite gravels.
C5b	499-510+	5YR5/6	M	VFLS	vfr	a	ste	
Soil Core at N14-W7 (Fig. 5.10)								
(100.63 m surface elevation relative to datum)								
	0-23	5-2.5YR 3/4	2,m,sbk	SiC	fr	g	ste	Common fine irregular carbonate soft accumulations in pores.
	23-63	2.5-5YR 4/6	2,m,sbk	CL	fr	a	ste	Few fine irregular carbonate soft accumulations in pores, few distinct clay coatings on peds, common fine irregular ma soft accumulations in pores.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Soil Core at N14-W7 (cont.)								
	63-130	5YR4/6	1,m,sbk	L	fr	c	ste	Many fine irregular carbonate soft accumulation in pores, fev distinct clay coatings on peds.
	130-157	5YR4/4	2,m,sbk	VFSL	fr	a	ste	Common fine irregular carbonate soft accumulations in pores common medium irregular carbonate soft accumulations, few irregular manganese or charcoal N 2/0 soft accumulations in
	157-206	5YR4/4	2,m,sbk	SCL	fr	c	ste	Many fine prominent 10YR6/1 mottles, few coarse irregular carbonate nodules, common fine irregular N 2/0 manganese c charcoal soft accumulations.
	206-265	5YR4/4	2,m,sbk	L	fr	d	ste	Common fine prominent 10YR6/1 mottles, few fine irregular carbonate soft accumulations in pores, few fine irregular N 2, manganese or charcoal soft accumulations in pores.
	265-305	5YR4/4	1,m,sbk	SCL	fr	c	ste	Many medium distinct 10YR6/3 mottles, many fine irregular carbonate soft accumulations, common distinct clay coatings
	305-337	5YR4/6	2,c,sbk	SCL	fr	a	ste	Many common prominent 2.5Y5/2 mottles, few fine carbona accumulations in pores, common fine snail shells, common fi irregular N 2/0 manganese or charcoal soft accumulations in common distinct clay coatings on peds.
	337-379	5Y7/1	M	LFS	vfr	a	ste	Many fine irregular carbonate soft accumulations in pores, cc fine distinct 5Y6/8 mottles.
	379-436	2.5YR3/6	M	CL	fr	a	ste	Many fine irregular carbonate soft accumulations, many fine manganese or charcoal soft accumulations in joints, few fine sand filling joints.
	436-575	5YR4/4	sg	LFS	vfr	g	ste	
	575-622+	5YR4/4	sg	S	l		ste	Few stratified clay layers.
Soil Core at 0-S11 (Fig. 5.10)								
(98.7 m surface elevation relative to datum)								
	0-80			SiL			ste	Carbonate nodules.
	80-160			SCL			ste	
	160-180			SCL			sle	
	180-220			FSL			ste	
	220-225+			GFSL			e	Gravels.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Soil Core at 0-S5 (Fig. 5.10)								
(99.5 m surface elevation relative to datum)								
	0-24			SiCL			sle	
	24-130			SL			sle	Many carbonates.
	130-180			SiL			e	Common carbonate soft accumulations, few carbonate nodul
	180-260			S			---	Stratified w/ LS.
	260-480+			S			ste	
Soil Core at 0-N2 (Fig. 5.10)								
(100.06 m surface elevation relative to datum)								
	0-60			SiCL				Many carbonates.
	60-120			SL				Coarse irregular carbonate nodules.
	245-340			SL				
	340-400			LFS				
	400-478			LS				
	478-481+			GLS				Permian sandstone gravels.
Soil Core at 0-N7 (Fig. 5.10)								
(100.50 m surface elevation relative to datum)								
Ap	0-35	5YR3/4		SiCL				
	35-40	5YR4/4		C				
Bk1	40-73	5YR4/4		SCL				Carbonates.
	73-75	5YR4/4		C				
Bk2	75-160	5YR4/4		SCL				Carbonates.
	160-195	5YR4/4		L				
Bk3	195-240	5YR4/4		SL				Carbonates.
	240-345	5YR4/4		L				
	345-385	5YR4/6		LFS				
	385-435	5YR4/6		FSL				
	435-450	5YR4/6		LFS				
	450-460	5YR4/6		C				Carbonates and sandstone fragments.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Soil Core at 0-N7 (cont.)								
	460-465	5YR4/6		LFS				
	465-469	5YR4/6		C				
	469-489	5YR4/6		FSL				
	489-504	5YR4/6		LS				
	504-524	5YR4/6		FSL				
	524-529	5YR4/6		GLS				
	529-624	5YR4/6		LFS				
	624-648	5YR4/6		LS				
	648-658+	5YR4/6		GLS				
Soil Core at 0-West 8 (Fig. 5.10)								
(98.98 m surface elevation relative to datum)								
Bk1	0-115	5YR4/6		VFSL				Carbonate nodules.
Bk2	115-140	7.5YR5/6		SiCL				7.5YR4/4 LS layers, few snails.
Bk3	140-220	5YR3/4		L				Few carbonate soft accumulations.
	220-340	5YR4/6		SiC				Few fine carbonate soft accumulations in pores, stratified LS
	340-360	5YR5/6		LFS				Stratified layers of LS.
	360-370	5YR5/6		GLS				
	370-475	5YR5/6		LFS				Stratified layers of LS.
	475-485	5YR5/6		GLS				
	485-523+	5YR5/6		LFS				Stratified layers of LS.
Soil Core at N16-W12 (Fig. 5.10)								
(100.73 m surface elevation relative to datum)								
	0-65	5YR3/4		SiL				Many fine carbonate soft accumulations in pores, few coarse carbonate nodules.
	65-80	5YR4/4		SiCL				Few fine carbonate soft accumulations in pores.
	80-140	5YR4/4		SiCL				Many fine carbonate soft accumulations in pores.
	140-240	5YR4/4		SiL				Common fine + medium round carbonate soft accumulations.
	240-350	7.5YR4/2		L				Few fine faint 5YR4/6 mottles.
	350-360	7.5YR4/6		FSL				Many coarse prominent 2.5YR6/2 mottles.
	360-420	7.5YR4/6		LFS				Few medium faint 10YR5/4 mottles.

Table 5.2 (cont.). Soil Profile and Auger Descriptions for 1989 Excavations at the Burnham Site.

Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Reaction	Special features
Soil Core at N16-W12 (cont.)								
	360-420	7.5YR4/6		LFS				Few medium faint 10YR5/4 mottles.
	420-480	5YR4/6		FSL				
	480-530			CL				
	530-560			LFS				Few fine + medium carbonate soft accumulations.
	560-620			L				
	620-690+			GLS				Few fine + medium carbonate soft accumulations, few suban; dolomite stones, few rounded quartzite, dolomite, and Permi: sandstone gravels, coarse sand is composed of Permian sand quartzite, ironstone, chert, and dolomite.
Soil Core at N12-W17 (Fig. 5.10)								
(99.43 m surface elevation relative to datum)								
	0-115	5YR4/4		FSL				Medium N 2/0 manganese soft accumulations, few fine faint 10YR5/4 mottles.
Bg	115-130			L				Common medium distinct mottles.
	130-140	5YR4/3		LFS				Stratified layers of clay.
	140-145			C				
	145-180	5YR4/6		LFS				Few fine faint 10YR6/4 mottles especially in pores.
	180-190	5YR4/4		SCL				2.5Y6/2 mottles.
	190-240	5YR4/6		LFS				10YR5/4 mottles.
	240-295	5YR4/6		SCL				Common medium distinct 10YR5/3 mottles.
	295-315			SCL				Gleying along prismatic ped surfaces, common root pores, ch and snails.
	315-395	5YR4/6		L				
	395-530	5YR4/6		FSL				Few carbonate soft accumulations in pores.
	530-553+	5YR4/6		GLS				

*All color readings are moist. Structure abbreviations: 1, weak; 2, moderate; 3, strong; f, fine; m, medium; s, strong; Pl, platy; Pr, prismatic; SBK, suban; blocky; SG, single grain; M, massive. Texture abbreviations: v, very; f, fine; S, sand; C, clay; Si, silt; L, loam; G, gravelly. Consistence abbreviatio h, hard; vfr, very friable; fr, friable; fi, firm; l, loose. Boundary abbreviations: g, gradual; cl, clear; a, abrupt; w, wavy; s, smooth; d, diffuse. Reactic (effervescence) abbreviations: ve, violently; ste, strongly; sle, slightly. Special feature abbreviations: Fw, few; Cn, common; Mn, many; f, fine; m, n c, coarse; ft, faint; dt, distinct; pt, prominent; frag, fragments.

Chapter 6
The Environment of Deposition, Authigenic Features, and the Age of the Burnham Site: A Post-1991 Perspective

Brian J. Carter

Introduction

In 1992, with funding from the National Science Foundation, it was possible to undertake extensive coring and trenching at the Burnham site to better assess the geological context of the fossil and artifact bearing Pleistocene deposits. Information and insight gained from that field work greatly augments previous understanding of the site, and this chapter focuses on these new findings and how they relate to the geological processes that formed the site's diverse strata.

The Burnham site contains layers of pond and stream sediments with distinct detrital and authigenic characteristics overlying soft sandstone. Understanding the depositional and post-depositional features is important for enunciation of the Burnham site history. Two distinct detrital particle-size distributions include: 1) the predominantly sandy and loamy textures which are the basal Permian Marlow Formation (predominantly a weakly consolidated fine-grained sandstone) and the unconsolidated Pleistocene Burnham upper alluvium and 2) the gravelly sand, loamy coarse sand, and sandy loam textures which are the Pleistocene Burnham lower alluvium. The study site consists of the Upper Burnham alluvium (Groups II and III, dried pond and overbank stream deposits, respectively) overlying the Lower Burnham alluvium (Group I, rapid stream flow regime deposits), which in turn overlies the Permian Marlow Formation (Group 0; Fig. 6.1). The Burnham alluvium is Late Pleistocene in age, and this assignment is supported by several radiocarbon dates (Table 6.1). The range in radiocarbon dates is discussed in the last section after discussion of the Burnham sediment stratigraphy. Finally, all core and profile descriptions from the 1992 work are provided in Table 6.2 at the end of this chapter.

Because Burnham is a Quaternary study site, the depositional and diagenetic nature of the Permian Marlow Formation is not pertinent and will not be discussed. The Upper and Lower Burnham sediments contain several distinguishing authigenic (including pedogenic) features. The four prominent authigenic features include: 1) gleying and redoximorphic soil features (Fig. 6.2), 2) calcium carbonate formation in soil (Fig. 6.3), 3) water-saturated sediments, and 4) soft sediment deformation and animal burrowing. Formation of soil structure, gypsum, and clay translocation are also localized authigenic soil features in the Burnham alluvium.

Faulting and soft sediment deformation caused by regional or local subsidence were not observed. However, bioturbation of some sediment layers (especially Group II) is extensive and distinct. In some layers animal trampling and burrowing extended across gray and red sediment layer boundaries and mixed or obscured boundaries. Floral and faunal remains found in Group II deposits are discussed in detail within other chapters. These remains include bones, shells, seeds, charcoal fragments, calcified *Chara* sp., and will be spatially set within geologic units discussed below. Investigations before 1991generally identified (Chapter 5, this volume) three separate geologic groups (I, II, and III) within the Burnham site. Field studies between 1991and the present further discovered the spatial distribution and

Figure 6.1. Panoramic view east of the gleyed pond sediments (Group II deposits) underlain by red alluvium and Permian bedrock (not visible but on the right) at the Burnham site's East Exposure. Photo taken October 4, 1989, by Brian Carter.

Figure 6.2. View north-northwest of central part of the North 3 backhoe trench (dug in 1989) with pedogenic carbonate (Bk at 6 ft. mark) overlying redoximorphic Fe-Mn oxide accumulations(black) and depletions (gray at 5 ft.) and top of pond IIB (redoximorphic depletions-gray soil matrix at 3.5 ft.). Pins are spaced at 0.5 m intervals. Photo taken by Brian Carter in October 1989.

the detrital and authigenic nature of these sediment groups.

Depositional Settings and Sediment Stratigraphy

Based primarily on 1992 field investigations, the Burnham site consists of four sediment layers: Group 0 – Permian Marlow formation (basal sandstone unit; unit O is continuous across study site); Group I – Lower Burnham alluvium (identified by stratified gravels and sands; unit I is continuous across study site); Group II (units II B-G) – Upper Burnham alluvium (identified by 1) gley and redoximorphic soil features also referred to as pond deposits and 2) calcite nodules and bone encrusted with calcite within past water-saturation sediments laterally associated with past ponding; unit II is discontinuous across study site); and Group III – Upper Burnham alluvium (identified by pedgenic carbonate soil zones [Bk]; unit III is continuous across study site). A generalized vertical relationship of these layers for the Burnham site is represented in Figure 6.4, whereas an actual view of the soil profile in the North 3 backhoe trench (dug in 1989) is provided in Figure 6.5.

Figure 6.3. View northeast of prominent pedogenic carbonate nodules of the Btkb horizon in the North 3 backhoe trench. The exposure depth is about 2.0 m. Photo by Brian Carter.

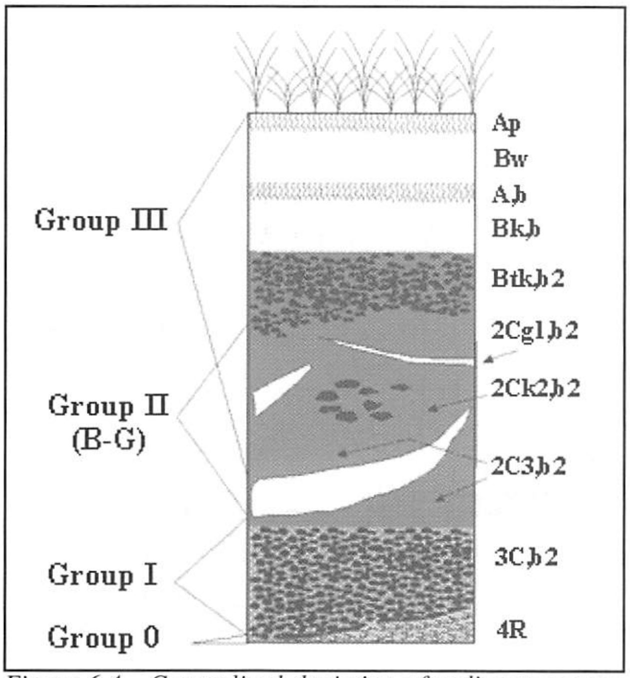


Figure 6.4. Generalized depiction of sediment groups, horizon characteristics, and sequence at the Burnham site.

Soil borings and diverse excavations (Fig. 6.6) focused on determining the lateral extent of Groups 0 through III in the main study area initially described in Chapter 5 (Table 5.1). This main study area is referred to as the East Exposure (Fig. 6.1). Groups 0, I, and III are laterally extensive across the main study site. However, Group II (pond deposits) is concentrated in an area (which was extensively dug by hand in meter squares; Chapter 2), and is found occasionally across the remaining subsurface Burnham site areas (especially in the adjacent subordinate study area referred to as the NW exposure). Laterally, Group II is at the same relative elevation (or slightly lower) and adjacent to Group III layers (Groups II and III are found as interstratified units; Fig. 6.7). Group I is continuous across the Burnham site (below Groups II and III) and ends abruptly on the underlying bedrock (Group 0; Fig. 6.8).

The contact between Group 0 and Group I sediments is at about 94 meters (relative to the site datum established as 100.00 m; Fig. 6.9). Group I ranged in thickness from 1-3m with a mean thickness of 1.8m. Group I deposits grade upward into Group II and III deposits. The lowest relative elevation of the contact between Group I and Group II sediments occurs where Group II deposits (stacked dried pond sediments) are most numerous (Fig. 6.10). This "sag" in the upper Group I contact with Groups II and III units indicates an area where spring-fed ponds formed in the Burnham alluvium. This "sag" and associated ponded depressions formed by stream channel scour and was likely augmented by beaver dam building activity (Dalquest et al. 1990).

Initial synopsis of detrital site history and depositional environment indicates that Group I sediments were deposited by a stream with a rapid flow regime which scoured the soft Marlow sandstone. The plane bed forms consist of alternating layers of gravel and sands with occasional cobbles and stones marking the contact of Group I with the underlying Marlow sandstone (Group 0). Stream flow slowed quickly and permanently after deposition of Group I, producing the overlying pond deposits of Group II. The Burnham site lies 0.5 km northeast of the confluence of West Moccasin Creek and an unnamed tributary creek. Both creeks are spring fed. A site development scenario suggests the Burnham site was once at or near the confluence of these creeks (represented by the Lower Burnham alluvium; Group I units), and as the local drainage pattern shifted (probably due to aggradation) West Moccasin Creek migrated to the west, leaving the Burnham site as a small pond and spring-fed by a small aggrading (unnamed) tributary creek (represented by Upper Burnham alluvium; Group II units). Both West Moccasin Creek and its unnamed tributary entrenched to their current position subsequent to ponding and aggra-

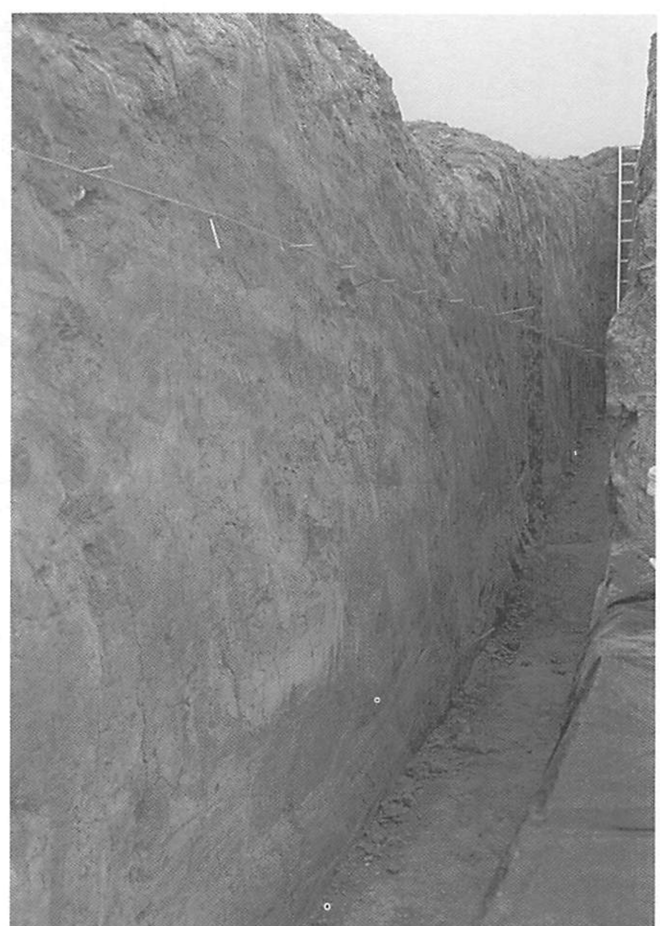


Figure 6.5. View northeast of eastern half of North 3 backhoe trench showing pond IIC (horse bone bed) thinning rapidly tpward the ladder. This pond deposit contains many redoximorphic depletions(gray areas) and red bioturbated intrusions. Pins spaced at 0.5 m intervals. Photo by Brian Carter.

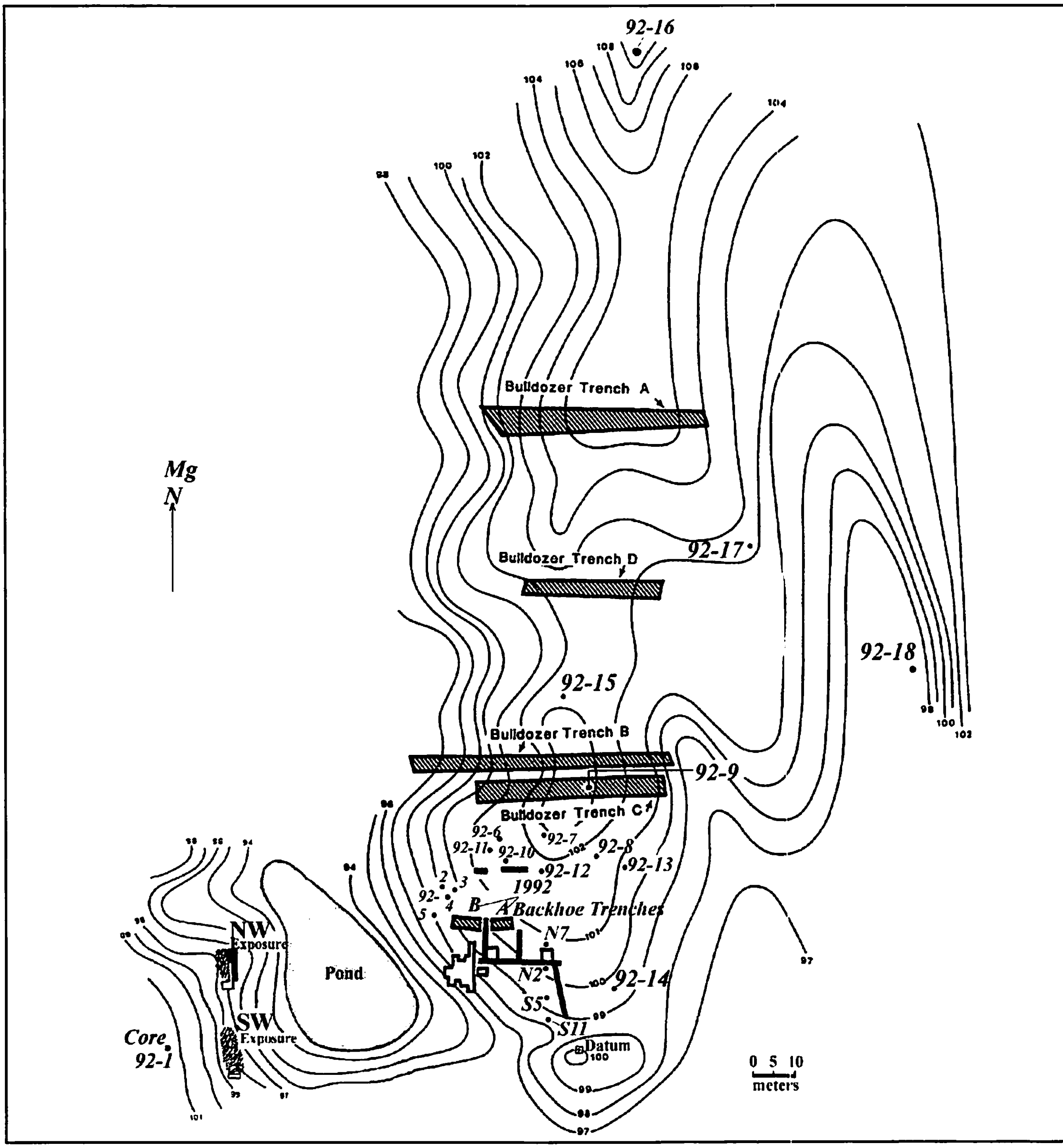


Figure 6.6. Map of all 1992 cores, backhoe trenches, and bulldozer trenches relative to previous manual and mechanically dug areas.

dation. During or shortly after stream migration the Burnham site developed at least five cycles of spring-fed ponding, followed by overbank deposition (represented by interstratified Group II and Group III units). Overbank deposition dominated the last sequence of Upper Burnham alluvium (Group III units). Eventually deposition ended completely and the site became part of the present hillslope uplands now eroded by sheet, rill, and gully erosion as regional baselevel lowered (i.e., the Cimarron River incised highly erodable Permian rock 10.5km to the south of the site). West Moccasin Creek is a local tributary of the Cimarron River. The Cimarron River flows through highly erodable Permian rock and now occurs at a 470m elevation above sea level at the confluence with West Moccasin Creek.

Authigenic Features in Buried Pond Deposits

How quickly did these site conditions change? Are there major gaps in site history? How old is the site? These important questions can be answered by observing sediment layer contacts, authigenic features in sediments and soils (i.e., chemical and physical weathering, chemical precipitates, redoximorphic features, and soil formation), and radiocar-

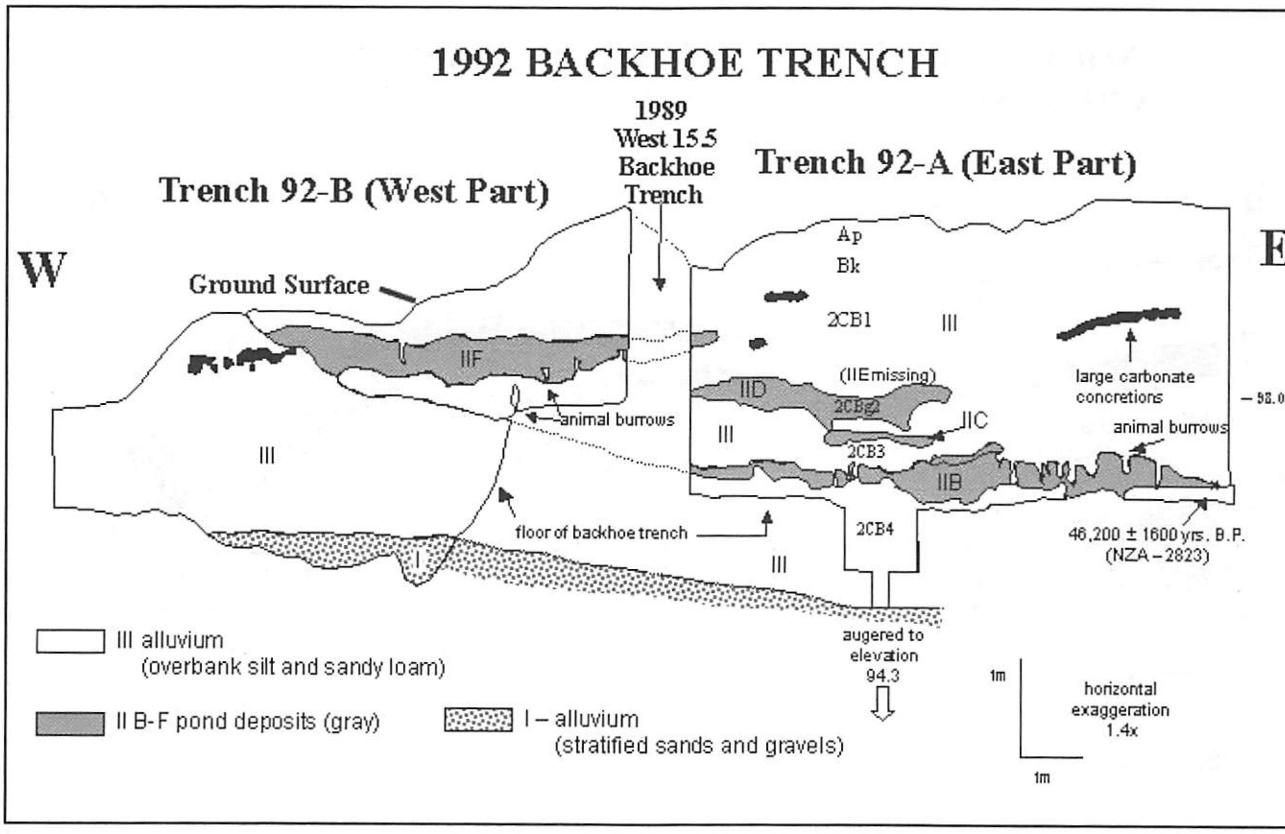


Figure 6.7. West to east cross section of 1992 backhoe trench showing interstratification of Group II (pond) and Group III (overbank) deposits.

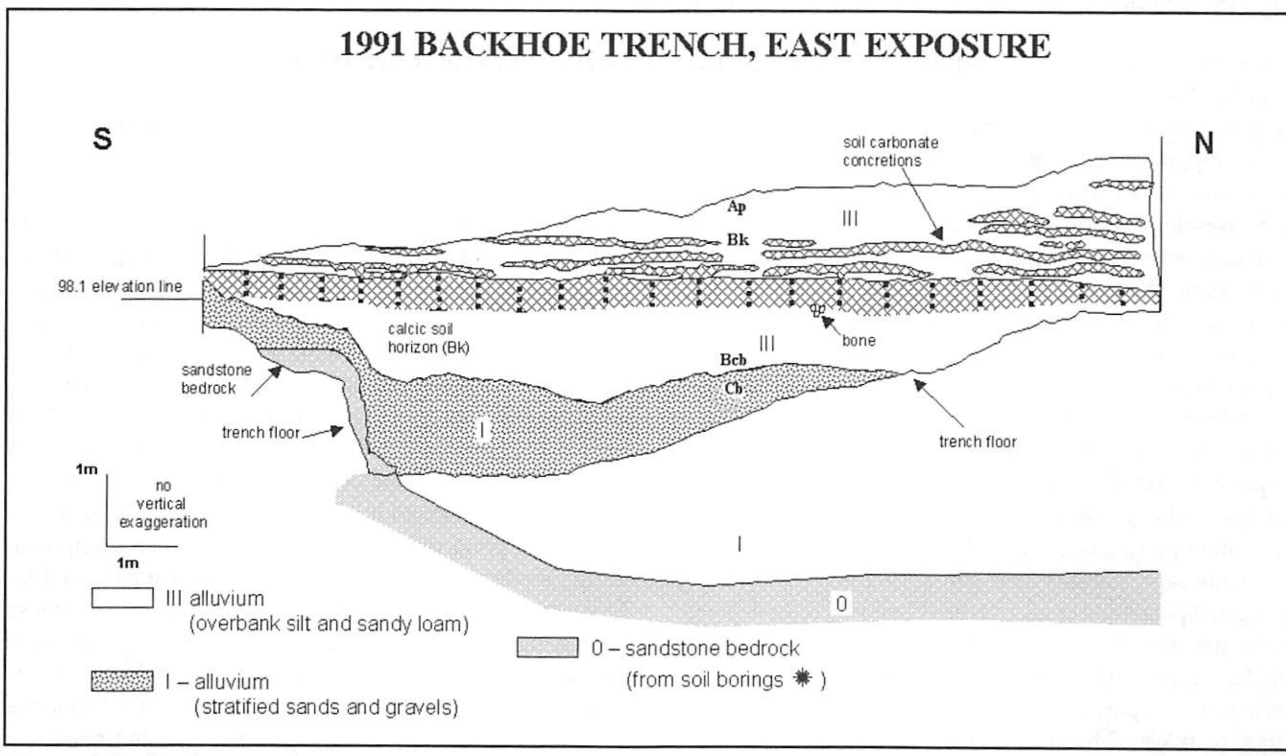


Figure 6.8. South to north cross section of 1991 backhoe trench showing pedogenic carbonates (Group III) overlying gravel and sands (Group I) and Permian bedrock (R).

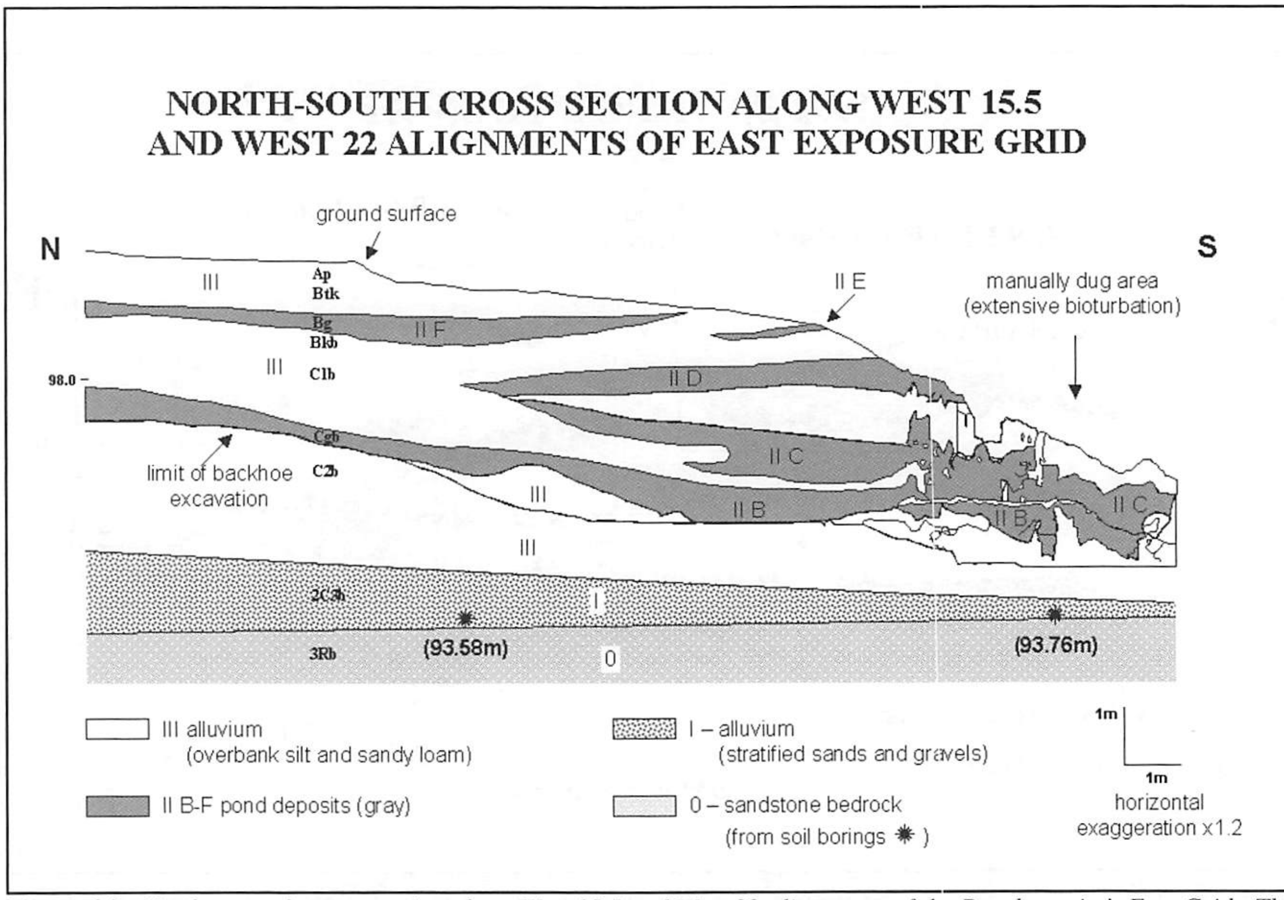


Figure 6.9. North to south cross section along West 15.5 and West 22 alignments of the Burnham site's East Grid. This cross section shows the stratified pond deposits (Group II), the overbank deposits (Group III), and the contact between the rapid stream flow deposits (Group I) and Permian bedrock (0).

bon dates. One hiatus occurs at the site between the Permian Marlow formation (Group 0) and the Burnham sediments (Group I). After initial rapid stream flow regime deposition stopped (gravels and sands of Group I), spring-fed ponds and overbank sedimentation immediately developed in the Burnham site area. Adjacent to ponded areas existed overbank sediments in floodplains, which contained better drained soils than those on pond peripheries. Gleying (gray colors, anaerobic decomposition of pond-bottom organic debris) occurred in areas of consistent ponding, and redoximorphic soil conditions (red and gray zones) occurred in pond peripheral wetlands. Periodically these ponds, wetlands, and well-drained soils were flooded and buried by suspended-load silts, very fine sands, and clay. This suspended-load aggradation continued for several cycles with alternating periods of ponding followed by periods of relative landscape stability and soil formation. Eventually spring-fed ponds and creek overbank deposits ceased, ponds dried, and the Burnham site became part of the upland hillslope erosional environment. This decrease and final cessation of deposition probably occurred as the unnamed tributary of West Moccasin Creek incised to or near its current valley position 0.5km (and 18m lower) to the southeast. Based on at least 5 cycles of ponding and multiple buried soils, the Burnham sediments probably took several thousands of years to accumulate.

Group I deposits (Lower Burnham alluvium) contain few remains of flora and fauna and are not of immediate archeologic, paleontologic, or biologic interest except as a reference point in the depositional site history. The Burnham site during rapid stream flow regime (Group I deposits) was not conducive to the presence and preservation of flora and faunal remains. However, as the Burnham site developed spring-fed ponds with adjacent overbank riparian environments, the site captured and preserved the remains of the animals and plants living within and near the site. Archeological and biological materials are predominantly found in or near spring-fed ponds (mainly Group II with some in Group III). In fact, an initial bison skull was found within the lowest pond deposit, exposed by modern equipment during modern farm-pond construction (Chapters2 and 8). Much frustration deciphering the site history occurs because at least part of the pond deposit is eroded by present-day "modern" human induced hillslope erosion. Also, the west-facing modern-gully ground surface is juxtaposed upon the several pond deposits (of the NE exposure and main site area) containing archeologic and biologic materials, exposing them to surface conditions including root penetration, erosion, and weathering. The modern gully also separates

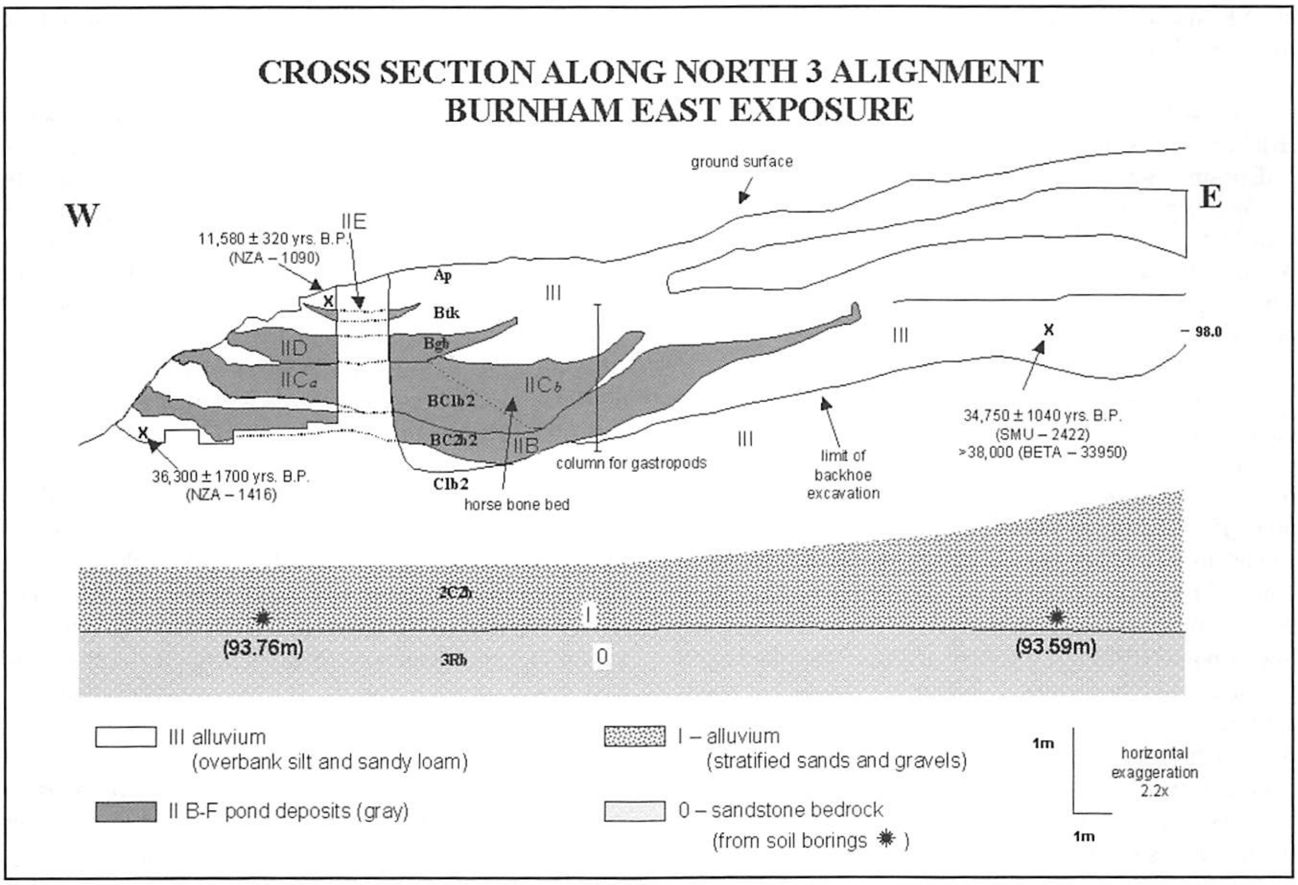


Figure 6.10. West to east cross section of the East Exposure along the North 3 alignment of the East Grid. This profile shows stacking of lower pond deposits IIB through IIE.

Figure 6.11. Looking west-northwest at the Southwest (left center) and Northwest exposures of Pleistocene ponds on the west side of the modern gully through the Burnham site. Photograph taken June 17, 1992, by Bill Thompson.

the NE (main site area) from the NW and SW exposures (minor study areas; Fig. 6.11).

At least five cycles of ponding followed by overbank sedimentation occur at the Burnham site and represent Group II deposits. Several detailed investigations occur in these Group II deposits (Chapter 16, "bison bone bed" and "horse bone bed";Chapter 11, gastropods; Chapter 17, archeology). A charred paw paw log segment (Chapter 13) was found within Group III overbank deposits just east of area that contained deposits of the 5 dried ponds.

Pond deposits are identified and mapped by gray soil colors (Figs. 6.12 and 6.13). This gray color (gley) was produced by anaerobic microbial decomposition of organic-rich debris existing in pond bottoms during water saturation. Ponds were present for at least several years, long enough to accumulate organic debris from plant and animal remains, producing eutrophic pond conditions. Gray pond deposits range in thickness from 10 to 75cm. The first and lowest pond (IIB; Figs. 6.1, 6.10 and 6.13) has the largest lateral extent (approximately 600m^2). Subsequent ponds are smaller, such as IIE (the smallest; Figs. 6.9, 6.10, and 6.12), with an aerial extent of only 40 m^2. Pond deposits are elongated in a NE to SW direction which is similar to the current orientation of the adjacent unnamed tributary creek (to the southeast) and its valley.

The deposits of these buried ponds contain irregular and swirled boundaries. These swirled and mixed zones were caused by both large mammal traffic and burrowing of animals such as crayfish. Burrowing and mixing may also be caused by turtles, insects, and other aquatic animals living in or near this water resource (Chapters 8 and 11). Burrowing and mixing produced by gophers and other terrestrial burrowing animals also occur in overbank (red) sediments juxtaposed with pond deposits (Fig. 6.5). Burrows in surface soils produced by modern gophers are numerous at the Burnham site today.

Figure 6.12. View north of 1992-B backhoe trench with distinct gray pond (IIF) deposit (center of photo above string line). Photograph taken June 10, 1992, by Don Wyckoff.

As ponds diminished in size, Group III overbank silts, very fine sands, and some clayey deposits encroached laterally by aggradation toward and above these pond deposits (Figs. 6.7 and 6.12). Calcic soils formed on floodplains and toeslope (Fig. 6.14) landscape positions adjacent to the ponds, and help distinguish the Group III unit. The last vestige of any pond deposit (IIG) is observed in Bulldozer Trench B at a relative elevation of about 99.5m (Fig. 6.15). Also, observed in Bulldozer Trench C, are sands and gravels (Group I) marking the recurrence of high water flow regime of a small stream channel within Group III deposits.

Authigenic Features: Buried and Surface Soils

Buried and surface soils within Burnham sediments are identified by 1) calcite soil formation (Bk), 2) gleying (gray Bg reduced pond-bottom sediments), 3) redoximorphic features including red, orange and black accumulations and yellow and gray depletions (in dried ponds and wetland areas), 4) soil structure (Bw, Bt, Bk), 5) clay tanslocation (Bt), and 6) gypsum formation (By).

Sediments within the Burnham alluvium and Marlow sandstone are calcareous. The uplands contain the Permian Rush Springs and Cloud Chief Formations and the Teritary Ogallala Formation (Fay, 1965). These uplands are source areas of the Burnham alluvium which generally contain sandstone, shale, calcite, dolomite, gypsum, and quartzite soil and rock fragments. Spring-fed stream and pond waters are calcareous. Ground water calcium carbonate precipitates are found in sediments laterally equivalent to pond deposits and represent a vadose zone formation of calcium carbonate nodules in overbank deposits (Figs. 6.3, 6.7, and 6.12). Calcite precipitation occurs in pond peripheries and effectively mark the boundary between water-saturated and unsaturated levels in poorly and somewhat poorly drained soils. Biogenic carbonate is also found in the remains of *Chara* sp. (Theler, this volume), an aquatic algae living in the ponds. Bones are found in buried ponds incased in calcium carbonate, creating nodules and concretions indicating precipitation of calcite onto bone surfaces in ponds, seasonally wet (vadose) zones, and poorly and somewhat poorly drained soils. Pedogenic calcic development is a distinct authigenic feature in well drained soils formed in overbank deposits of Group III. Several periods of soil formation (Bk horizons) in soils adjacent to ponds were followed by burial as the ponds and adjacent areas were covered by overbank deposits. A particularly well-formed (as identified by a thick laterally continuous calcic Bk soil horizon) soil is found lateral and adjacent to the first and lowest dried pond (Figs. 6.3 and 6.10). This pond and surrounding land area was relatively extensive and stable as indicated by the large pond and thick calcic soil formation (Figs. 6.3 and 6.8)

Figure 6.13. View north of gray pond deposit IIB (right) overlying overbank deposit III (left) in squares 0-W24 and 0-W25 of the East Grid, Burnham site. Photo taken in October of 1989 by Brian Carter.

The Bk soil horizons are easily identified by white calcite accumulations, soft bodies, and nodules and are most often used to identify buried soils. The presence of Bk horizons (in buried soils) as soft calcite accumulations in pores and root channels indicate roughly the same climatic (semi-arid, 16°C mean annual soil temperature) conditions prevailed during the past formation of buried soils as exist at the site today. Bk horizons also form currently in a range of arid to subhumid conditions in soil temperature regimes from at least 6°C to 22°C mean annual temperatures. Large calcite nodules are found associated with redoximorphic soil depletions and accumulations, and pond deposits. These large calcite nodules are calcite precipitated from past water-saturated soil conditions and indicate soil formation in poorly drained and somewhat poorly drained soils (wetlands) on pond peripheries and in wet meadows. Bk horizons identified by large calcite nodules were prevalent in Group II deposits while Bk horizons identified by soft calcite accumulations in pores and root channels are common in Group III deposits. Buried soils in Group III deposits contained Stage I and II carbonate development (Birkland, 1999).

Of particular interest throughout all buried soils is the lack of a distinct mollic A horizon, which is present above surface soils containing calcic horizons in western Oklahoma. Buried A horizons are common and distinguish Holocene – aged soils and sediments of alluvial deposits in Oklahoma (Carter 1990). Dark mollic A horizons are often Holocene sediment marker beds, which indicate periods of aggradation and burial of soils. These A horizons were slowly and continuously oxidized after burial during thousands of years of aerobic decomposition thereby removing humus (and its dark colors). This oxidation of organic matter and removal of the dark A horizon colors indicate that the site is pre-Holocene and tens of thousands of years old.

Redoximorphic soil features (previously referred to as soil mottles in soil science literature; Buol et al., 1997) include redoximorphic accumulations (usually more red or orange than surrounding soil matrix) and depletions (grayer than surrounding soil matrix). Redoximorphic soil features were common and characteristic of Group II sediments because shortly after Group II deposition, these ponds, wetlands, and wet meadows were sites of anaerobic decomposition of organic matter. As anaerobic decomposition intensified in and near water-saturated soils, gray colors (depletions) increased in size. Buried soils and sediments with predominantly gray color (gleying indicated by Bg or Cg soil horizon designation) are identified as pond-bottom sediments. Snail identification supported the degree of ponding and wetness by observing aquatic snail remains in dominantly gray (gley) sediments, both aquatic and terrestrial snails in areas of some gray and red redoximorphic colors, and terrestrial snails (some xeric types) in soils and sediments with no evidence of redoximorphic features (entirely red) (Theler, this volume). Redoximorphic features also included black Mn-Fe oxide accumulations, which indicate incipient anaerobic conditions not extreme enough to pro-

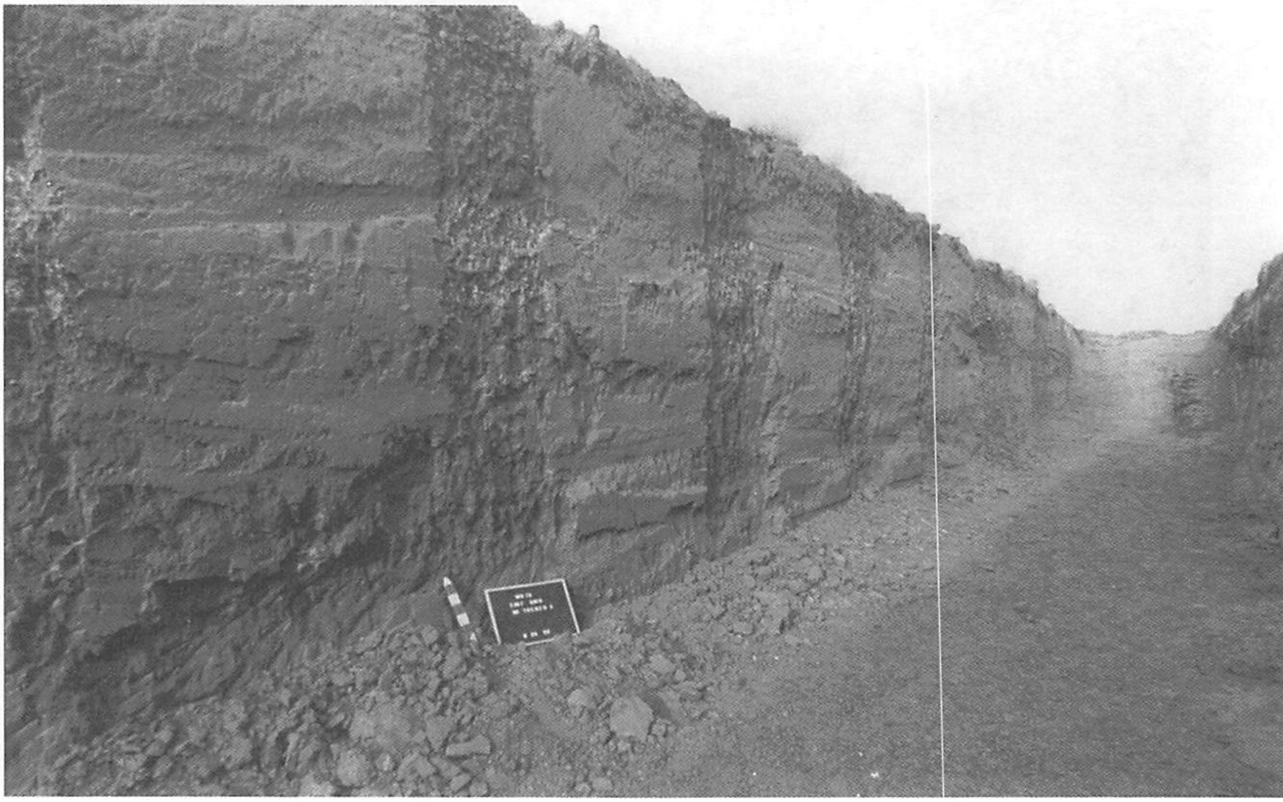


Figure 6.14. View southwest of west part of Bulldozer Trench A showing calcic horizons, most prominent is about 1.6 m below the surface. Photo taken June 23, 1992, by Don Wyckoff.

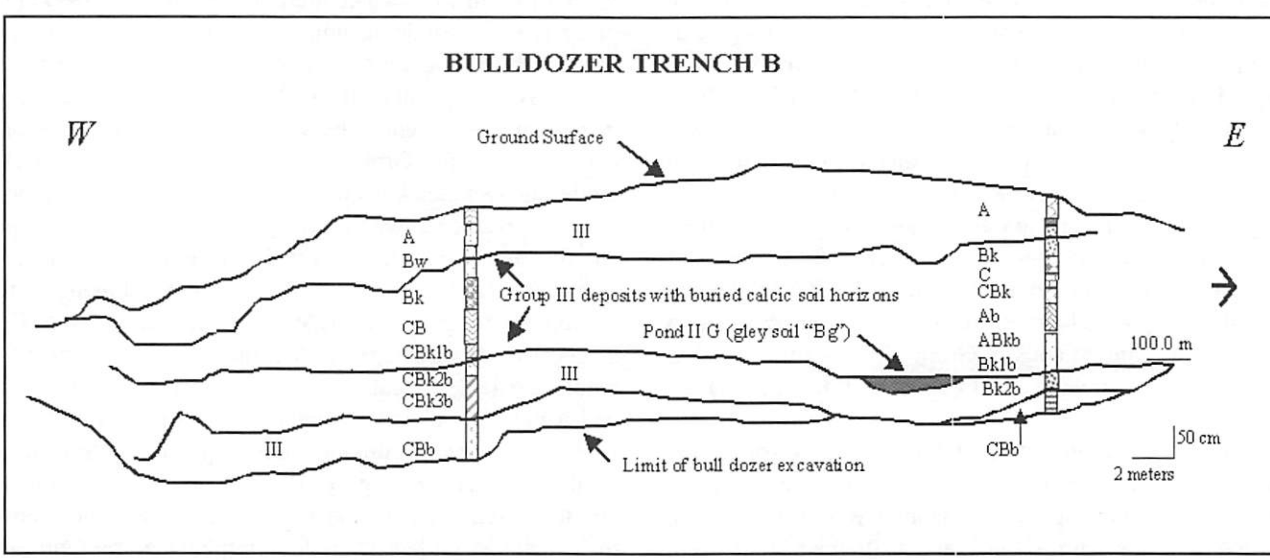


Figure 6.15. Profile of south wall of Bulldozer Trench B dug in 1992. This profile contained the farthest north gleyed sediments and Burnham paleosol found at the site.

duce gray soil zones (Buol et al., 1997). Black soil Mn-Fe oxide accumulations do indicate seasonal water-saturated areas and are common in Group II sediments as soft accumulations in soil pores, sediment bedding planes, and on ped faces.

Gypsum formed in buried soil and sediments of Groups I and II especially in the southeast Burnham site area. Gypsum pockets and sand-sized crystals were observed in soils and sediments in only 5 of the 46 soil profile descriptions and only in the southeast area of the Burnham site. Authigenic gypsum crystals indicate that sediments are rich in detrital gypsum from upland Permian bedrock sources. Allogenic gypsum is dissolved by percolating soil and ground water and form authigenically in soil pores and sediment voids as this water dries (especially along wetting fronts). As water containing Ca^{+2} and $SO4^{-2}$ is translocated through soils and sediments, CaSO4 2H2O (gypsum) is precipitated as sand-sized crystal bundles in pores and voids.

Soil structure (formation of soil peds) indicates that sediment layers, especially in Group II and II, were exposed to periodic wetting and drying cycles from aerial exposure to the atmosphere. Soil structure identified buried soils, which occur in both well drained soils and poorly drained soils of wetlands. Moderate and weak grade soil peds formed in overbank and sediments after they were deposited. Medium and coarse sized subangular blocky shaped peds are prominent in these loamy soils. Formation of soil structure and identification of buried soils in sediment layers support cyclic drying, periodic ponding, and reoccurring sedimentation in Group II and III deposits.

Buried soils contained small amounts of clay translocation. Few and common discontinuous clay coatings were observed in Bt horizons of some buried soils. Buried soils lacked soil argillic horizons (soil horizons containing 3 to 8% more translocated clay than the above surface horizon and at least 15cm thick (Soil Survey Staff, 1999)). Lack of argillic horizons and many continuous clay coatings on peds indicate that buried soils where not exposed to periods of soil formation for more than several hundreds of years. Argillic horizons are found in modern surface soils near the Burnham site but indicate landscape stability and soil formation periods of several thousands of years (Hall et al., 1982).

Radiocarbon Dates

Twenty radiocarbon ages are available for the entire Burnham site (Table 6.1). Seventeen samples used for radiocarbon determinations came from Group II and two samples came from Group III sediments. The range in radiocarbon ages was 10,210 ± 270 yrs. b. p. (NZA-4381) to 46,200 ± 1600 yrs. b. p. (NZA-2833) (Table 6.1).

Three radiocarbon dates came from within the subordinate site area (deposits similar to Group II), across a modern gully (NW exposure). Because extensive soil borings were not made in the NW Exposure area these deposits (No. 6, 12, 19) can't be directly linked to the NE Exposure and main site area. However, the fauna discovered, the types of soils and sediments, and relative elevation of the NW Exposure are very similar to those in the NE exposure and suggest a continuation of the main site area toward the southwest. The mean age determination for a small pond deposit within the NW Exposure is 36,720 ± 27,212 (t=0.05 for 2 degrees of freedom).

Two radiocarbon ages (No. 1; 30 ± 60 yrs. b. p., RA-C0416: No15; >38,000 yrs. b. p., Beta- 33950) were not used to calculate the mean. The nearly modern age of sample RA-CO416 which came from a buried rodent burrow is questionable because ages of 37,790 ± 680 yrs. b. p. (NZA-3009) and 40,130 ± 1280 yrs. b. p. (RA-CO353) were also obtained for this buried rodent burrow. The sample RA-CO416 was contaminated with modern carbon or confused with another unknown sample. Sample Beta-33950 was not used because it represented a "greater than" (>38,000) and not a specific age. This sample (Beta-33950) came from a charred paw paw log which received another usable radiocarbon age determination of 37,790 ± 680 yrs. b. p. (NZA-2824).

Radiocarbon ages were determined from various organic debris including small (10mm) detrital charcoal fragments, snail shells, hackberry seeds (*Celtis* sp.), and a charred paw paw (*Asimina triloba*) log. The fifteen (Table 6.1; Sample No. 2, 3, 4, 5, 7, 9, 10, 11, 13, 17, 18, 20) radiocarbon dates used to calculate the mean age for the site (32,519 ± 22,460; t=0.05 for 14 degrees of freedom) were obtained from sediments in close proximity to artifact- and bison- bearing layers within and near the contact between Group IIi and Group II sediments. The lack of radiocarbon age uniformity within layers and systematic decrease in radiocarbon age with decreasing depth of sediment burial indicates that radiocarbon analysis was not sensitive enough to discern relatively short depositional periods (100-1000 yrs.) for sediments at the site compared to the relative age of the site (range 10,210 ± 270 yrs. b. p. NZA-4381 to 46,200 ± 1600 yrs. b. p. NZA-2833). Evidence from fossil vertebrate and invertebrate faunas, and sediment stratigraphy indicates the site aggraded, producing continuous layers uninterrupted by an erosional hiatus. Deposition probably occurred over tens to hundreds of years during the Late Pleistocene. The most likely interpretation of the 18 radiocarbon dates (3 from NW exposure) assumes a varying amount of carbon contamination throughout the samples (mainly due to bioturbation) and that the mean of these dates presents the best estimate for the mean age of the animal and plant remains, and human artifacts. Based on 18 radiocarbon determinations the mean age of the site deposition is 33,223 ± 20,850 yrs. b. p. (t=0.05 for 17 degrees of freedom). Paleobioturbation and modern bioturbation has mixed small parts of all sediment layers at the site. Bioturbation and the presence of detrital charcoal are a likely process and condition, which explains bimodal

Table 6.1. Radiocarbon Ages for the Burnham Site..

Sample No.	Provenance	yrs. B.P. 14 C age	LAB. No.	Sediment† Group	Relative elevation (m)	Depth below surface (m)
1 (16)	Hackberry (*Celtis* sp.) Seed from rodent burrow (Bulldozer Trench B) (accelerator date)	30 ± 60	RA - CO289	III(_) (BD TRENCH)	98.95	4.0
2	Small (mm) charcoal fragment from handdug squares S1-W22; sample recovered 45 cm west of bison scapula	10,210 ± 270	NZA - 4381	IIB2	96.35	1.5
3	Small (mm) charcoal fragment from handdug square N5-W19 (accelerator date). Stratum underlies the uppermost gray ponded sediment	11,580 ± 320	NZA - 1090	IIF1	98.20	0.7
4	Hackberry (*Celtis* sp.) Seed from handdug square S1-W23; sample comes from gleyed alluvial deposit that yielded human arifacts (accelerator date)	22,670 ± 330	RA -C0352	IIB2	96.30	1.5
5	Small (mm) charcoal fragment from handdug square S1-W22 (accelerator date) from top of brown sandy loam stratum containing some bones of *Bison chaneyi*	26,820 ± 350	AA - 3838	IIB1	96.26	2.0
6	Small (mm) charcoal fragment from handdug square S5-W22 of northwest exposure	30,160 ± 390	NZA - 3009	II? (NW EXPOSURE)	97.89	x
7 (10)	Whole and broken gastropod shells (76g) from gray fine sediment from handdug square S1-W22; Sample comes from sediment around overturned skull of *Bison chaneyi*; arifacts were also found here	31,150 ± 700	Beta - 23045	II(□)B2	96.66	1.2
8 (15)	Charred paw paw (*Asimina triloba*) log (cm) from North 3 backhoe trench. Bone fragments present, also	34,750 ± 1040	SMU -2422	II(°)B1	98.00	2.4

Table 6.1 (cont.).. Radiocarbon Ages for the Burnham Site.

Sample No.	Provenance	yrs. B.P. 14 C age	LAB. No.	Sediment[†] Group	Relative elevation (m)	Depth below surface (m)
9	Hackberry (*Celtis* sp.) seed from handdug square N2-W20, Sample comes from gleyed alluvial deposit that yielded human arifacts (accelerator date)	35,680 ± 710	RA - CO354	IIB2	96.80	1.3
10 (7)	Whole and broken gastropod shells (76g) from gray fine sediment from handdug square S1-W22; Sample comes from sediment around overturned skull of *Bison chaneyi*; arifacts were also found here (Accelerator date)	35,890 ± 850	AA - 3837	II(□)B2	96.66	1.2
11	Small (mm) charcoal fragments from handdug square 0-W25. Acceleration date from brown sandy loam near bottom of stratum	36,300 ± 1700	NZA - 1416	IIB1	96.20	0.8
12 (19)	Aquatic snails (*Physella virgata*) from northwest exposure. Handdug square S5-W2	37,215 ± 940	AA - 11687	II(X) (NW EXPOSURE)	97.8	x
13	Hackberry (*Celtis* sp.) Seed from handdug square S3-W24 (NW¼ of square). Sample comes from gleyed alluvial deposit under the one which yielded human arifacts. Dating is critical for establishing maximum age for deposition of arifacts as well as dating early cut and fill sequence evident here (accelerator date)	37,590 ± 820	RA - CO291	IIB2	96.10	0.5
14 (1, 16)	Small (mm) charcoal fragment from rodent burrow (Bulldozer Trench B) (same sediment as sample no. 1 and 16)	37,790 ± 680	NZA - 2824	III(_)(BD TRENCH)	98.95	4.0
15 (8)	Charred paw paw (*Asimina triloba*) log (cm) from North 3 backhoe trench. Bone fragments present, also	>38,000	Beta - 33950	II(°)B1	98.00	2.4

Table 6.1 (cont.).. Radiocarbon Ages for the Burnham Site.

Sample No.	Provenance	yrs. B.P. 14 C age	LAB. No.	Sediment[†] Group	Relative elevation (m)	Depth below surface (m)
16(1)	Hackberry (*Celtis* sp.) seed from rodent burrow (Bulldozer Trench B) (accelerator date)	40,130 ± 1280	RA – C0353	III(_)(BD TRENCH)	98.95	4.0
17	Hackberry (*Celtis* sp.) Seed from handdug Square S1-W22. Sample comes from critical gleyed alluvial deposit that yielded human artifacts	40,190 ± 870	RA - CO419	IIB2	?	
18	Small (mm) charcoal fragment from handdug square 0-W22. Accelerator date From stratum above one containing arifacts and *Bison chaneyi* bones	40,900 ± 1600	AA - 3840	IIB2	97.02	0.4
19 (12)	Terrestrial snails (*Hawaiia minuscula*) from northwest exposure. Handdug square S5-W2	42,785 ± 1800	AA - 11688	II(X) (NW EXPOSURE)	97.80	X
20	Small (mm) charcoal fragment from handdug square 3 in Backhoe Trench A	46,200 ± 1600	NZA - 2823	IIB1	96.72	3.8

[†] indicates age determination from same sample (_) (°) (□) and (x)

distribution of radiocarbon ages (Fig. 6.16), and the wide range and variance of radiocarbon age with depth of burial. Based on present radiocarbon data and age distribution, it is unlikely that further radiocarbon determinations on detrital and bioturbated materials within the Burnham sediments will be able to specifically date a particular unit except to indicate the occurrence of ponds, animal and plant remains, and human artifacts at the site approximately 33,000 years ago.

References Cited

Birkeland, P.W. 1999. *Soils and Geomorphology.* Oxford University Press, New York.

Buol, S.W., F.D. Hole, R.J. McCracken, and R.J. Southard. 1997. *Soil Genesis and Classification,* 4th edition. Iowa State University Press, Ames.

Carter, B.J. 1990. Soils within the Deer Creek Flood Plain. A Survey of Archeological Resources and an Evaluation of Buried Site Potential in Northwestern Oklahoma County, edited by J.L. Hofman and R.R. Drass, pp. 31-43. Oklahoma Archeological Survey, *Archeological Resource Survey Report* 36. Norman.

Dalquest, W.W., F.B. Stangl, Jr., and M.J. Kocurko. 1990. Zoogeographic Implications of Holocene Mammal Remains from Ancient Beaver Ponds in Oklahoma and New Mexico. *The Southwestern Naturalist* 35:105-110.

Fay, R.O. 1965. *Geology and Mineral Resources of Woods County.* Oklahoma Geological Survey, Bulletin 106. Norman.

Hall, G.F., R.B. Daniels, and J.E. Foss. 1982. Rate of Soil Formation and Renewal in the USA. *Determinants of Soil Loss Tolerance*, edited by D.M. Kral and S. Hawkins, pp. 23-39. Soil Science Society of America, Madison.

Soil Survey Staff. 1999. *Soil Taxonomy,* 2nd edition. U.S. Department of Agriculture, Natural Resources Conservation Service, Agricultural Handbook 436. U.S. Government Printing Office, Washington, D.C.

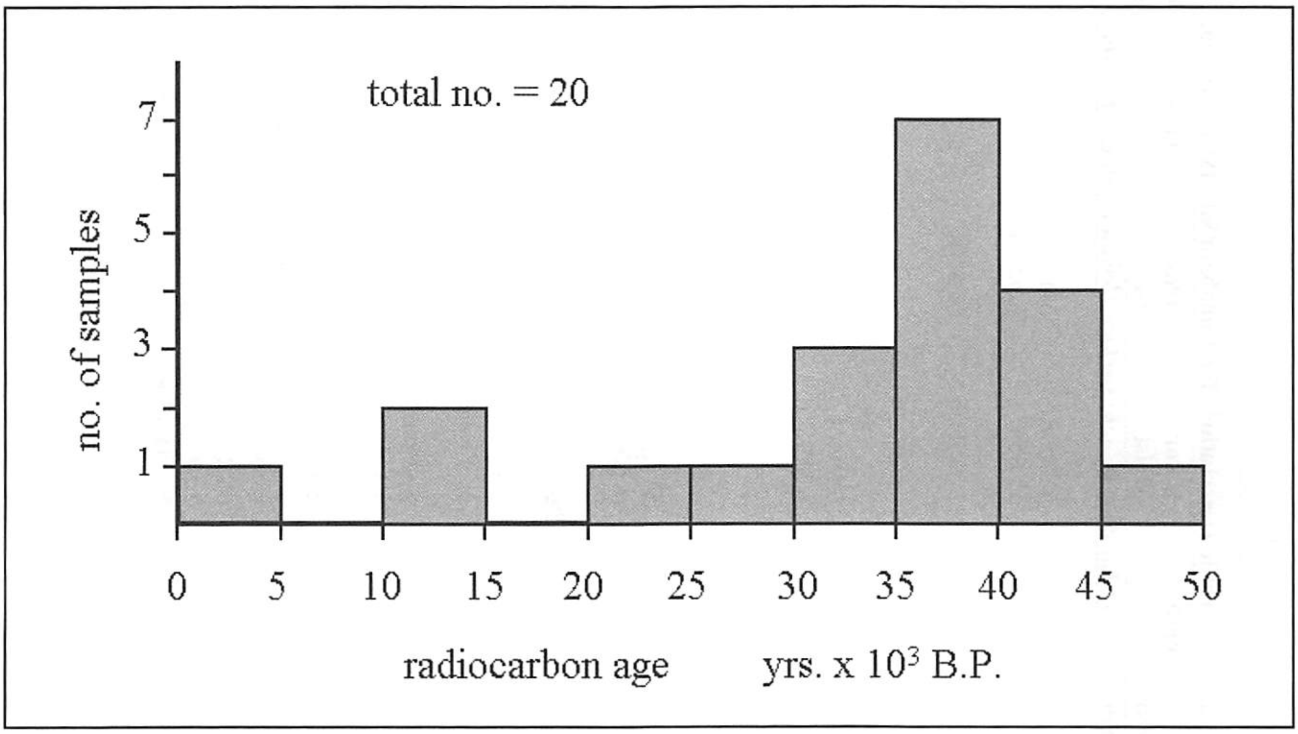


Figure 6.16. Histograph showing frequency of radiocarbon determinations for the Burnham site.

Table 6.2 Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc-ture	Tex-ture	Consis-tence	Bound dary	Reac-tion	Special Features
South profile 1991 backhoe trench; surface elevation relative to datum 98.92 m (Fig. 6.8)								
Bk	0-20	5YR5/8	2,m,SBK	L	fi	c,s	ve	My, c, $CaCO_3$ nodules.
Bk1b	20-44	5YR5/6	2,m,SBK	SiL	fi	c,s	ve	Cn, c, $CaCO_3$ nodule; Cn, m, $CaCO_3$ soft bod pores; Cn, m, gypsum crystals.
Bk2b	44-69	2.5YR4/6	1,c,SBK	L	fr	c,s	ve	Fw, c, $CaCO_3$ nodules; Cn, m, $CaCO_3$ soft bo pores; Cn, m, black (N2/0) layers 5-15 cm lo m, gypsum crystals.
BCb	69-100	2.5YR4/6	1,c,SBK	VFSL	fr	c,s	ste	Fw, m, gypsum crystals.
C1b	100-124	5YR5/8	M	LVFS	fr	a,w	ste	5% gravels.
C2b	124-159	2.5YR4/6	SG	GS	l	a,i	ve	Fw cobbles and stones; My, c, Mn oxide laye gravels (black) coating pebbles; most gravels to subangular sandstone, shale, chert, and lim (local Permian); Fw rounded quartzite gravel cobbles).
2Rb	159-189+	5YR5 to 6/8	M	LVFS	vfi	-	-	My, f + m, white spheres (redoximorphic features); discontinuous $CaCO_3$ cementation boundary of C2b and 2Rb (bedrock).
Middle soil profile 1991 backhoe trench; surface elevation relative to datum 99.49 m (Fig. 6.8))								
Bk1	0-15	2.5YR3/6	2,m,SBK	SiCL	fi	c,s	ve	My, c, $CaCO_3$ nodules.
Bky2	15-54	2.5YR4/6	2,c,PR/ SBK	L	fr	c,s	ve	My, m, gypsum crystal bundles on ped surfaces; Fw, f, $CaCO_3$ soft bodies in pores.
Bkb	54-117	2.5YR4/8	1,c,Pr	L	fr	c,s	ve	My, m + c $CaCO_3$ nodules; Fw, m, gypsum c
Bk1b2	117-154	2.5YR4/6	2,m,SBK	SiCL	fi	g,s	ve	Cn, m, $CaCO_3$ nodules.
Bk2b2	154-177	5YR4/6	1,c,SBK	L	fr	g,s	ste	Fw, m, gypsum crystals; Fw, m, $CaCO_3$ nodu
BCb2	177-206	2.5YR4/6	1,c,SBK	VFSL	fr	a,s	ste	Fw, m, gypsum crystals; stratified alluvium.
C1b2	206-225	2.5YR4/6	M	VFSL	fr	a,s	ste	Fw, m, gypsum crystals; stratified alluvium.
C2b2	225-281	5YR5/8	M	VFSL	fr	a,s	ste	Fw, m, gypsum crystals; stratified alluvium.
C3b2	281-289	5YR5/8	M	LVFS	vfr	a,s	sle	Fw, m, gypsum crystals; stratified alluvium.
C4b2	289-319	2.5YR4/6	M	SiL	fr	a,s	ste	Fw, m, gypsum crystals; stratified alluvium.
C5b2	319-380+	5-2.5YR4/8	M	LVFS	vfr	-	sle	Fw, m, gypsum crystals; stratified alluvium.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
North soil profile 1991 backhoe trench; surface elevation relative to datum 99.92 m(Fig. 6.8)								
Bk1	0-24	5-2.5YR4/4	2,c,PR/ 2,m,SBK	SiL	fi	c,s	ve	My, f + m, $CaCO_3$ soft bodies in pores and matrix.
Bk2	24-68	5YR4/6	1,c,PR/ 1,m,SBK	L	fr	c,s	ve	Cn, f, $CaCO_3$ soft bodies in pores and matrix.
Bkb	68-97	2.5YR3/4	3,m,SBK	SiCL	fi	c,s	ve	My, f, $CaCO_3$ soft bodies in pores and matrix gypsum crystals.
Bkyb	97-142	5-2.5YR4/6	1,c,PR/ 1,m,SBK	L	fr	g,s	ve	Cn, c, $CaCO_3$ nodules; Fw, m, gypsum crystals; thin Mn oxide (black, N 2/0) layer.
Bkb2	142-185	5-2.5YR4/4	1,c,PR/ 1,m,SBK	L	fi	a,s	ve	Cn, c, $CaCO_3$ nodules; Fw, m, gypsum crystals.
Bk1b3	185-208	2.5YR4/4	2,m,SBK	SiCL	fi	c,s	ve	Cn, m, $CaCO_3$ nodules; Fw, m, $CaCO_3$ soft b pores; Fw, m, gypsum crystals.
Bk2b3	208-220	5-2.5YR4/4	1,c,SBK	L	fr	g,s	sle	Fw, f, $CaCO_3$ nodules; Fw, gypsum crystals.
BCb3	220-278	2.5YR4/4	1,c,SBK	FSL	fr	a,s	sle	
Cb3	278-300+	5-2.5YR5/8	M	LFS	vfr	-	sle	
Soil Core 92-1; surface elevation relative to datum 101.88(Fig. 6.6)								
Ap	0-28	5YR3/4	1,m,SBK	VFSL	Vfr	c	ste	My, f + m, roots.
Ab	28-74	2.5YR4/6	2,f,SBK	SiL	Vfr	g	ve	My, f, roots.
Bk	74-109	2.5YR4/8	1,m,SBK	VFSL	Vfr	g	ve	Cn, f, roots; Cn, m, $CaCO_3$ soft bodies.
BCk	109-168	5YR5/8	1,c,SBK	LVFS	fr	g	ve	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies; Fw, c, nodules.
C	168-221	5YR5/8	M	S	fr	a	ve	Stratified sands.
A1b	221-246	5YR4/6	1c,SBK	L	fr	c	ve	Fw, f, $CaCO_3$ nodules.
A2b	246-262	5YR4/6	2,c,SBK	L	fr	c	ve	F, f, roots; C, f, $CaCO_3$ in root tracings.
Btkb	262-302	5YR3/4	2,m,SBK	SiCL	fr	g	ve	My, m, $CaCO_3$, soft bodies + nodules.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-1 (cont.)								
Bkb	302-399	5YR4/6	1,m,PR	SiL	fr	g	ve	Cn, f + m, $CaCO_3$ soft bodies + nodules.
Bkb	399-447	2.5YR3/6	1,c,SBK	Sil	fr	c	ste	Fw, m, $CaCO_3$ soft bodies + nodules.
CBb	447-478	2.5YR4/8	1,c,SBK	VFSL	fr	g	ste	
Clb	478-584	2.5YR4/8	M	VFSL	vfr	g	ste	Fw, f, snail shells.
C2b	584-627	2.5YR4/8	M	SiL	vfr	g	ste	
C3b	627-815	2.5YR4/8	M	LVFS	vfr		ste	
Soil Core (augered) 92-4, elevation 100.22 (Fig. 6.6)								
	91-142	2.5YR3/4		SiCL			ve	My, f + m, $CaCO_3$ frag.
	142-163	2.5YR4/4		CL			ve	Cn, f, $CaCO_3$ frag.
	163-206	2.5YR4/4		L			ve	Cn, f, $CaCO_3$ frag.
	206-229	2.5YR4/4		SiC			ve	My, f, m, + C, $CaCO_3$ frag.
	229-282	2.5YR3/4		SiCL			ve	Cn, f, $CaCO_3$ frag.
	282-330	2.5YR4/4		VFSL			e (in spots)	Fw, f, $CaCO_3$ frag.
	330-424	2.5YR3/4		FSL			ste	Cn, f, $CaCO_3$ frag.
	424-472	2.5YR4/4		L			ste	Cn, f, $CaCO_3$ frag.
	472-521	2.5YR4/4		FSL			ste	Fw, f, $CaCO_3$ frag.
	521-569	10R4/4		GSL			ve	My, f, $CaCO_3$ fragments; gravels are quartz, + sandstone
Soil Core (augered) 92-5, elevation 99.26 (Fig. 6.6)								
	107-130	2.5YR4/4		SCL			ve	My, f, $CaCO_3$ frags.
	130-165	2.5YR4/4		FSL			ste	Fw, f, $CaCO_3$ frags.
	165-206	2.5YR4/4		FSL			ste	Cn, f, $CaCO_3$ frags.
	206-279	2.5YR4/4		L			ve	My, f, $CaCO_3$ frags.
	279-335	2.5YR4/4		L			ve	Fw, f, $CaCO_3$ frags; Cn, m, $CaCO_3$ nodules
	335-389	2.5YR4/4		FSL			ste	Cn, f, $CaCO_3$ frags.
	389-439	2.5YR4/4		LFS			e	Fw, f, $CaCO_3$ frags.
	439-467	10R4/4		GLS			ve	My, f, detrital $CaCO_3$ nodules; Gravels are subangular chert + quartz.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-6, elevation 101.55 (Fig. 6.6)								
A	0-33	5YR3/4	1,m,SBK	VFSL	fr	a	ste	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies.
Btk	33-91	5YR3/4	1,c,PR	CL	vfr	c	ve	Fw, f, roots My, f, $CaCO_3$ soft bodies; Fw, c, concretions at base.
BC	91-107	5YR3/4	1,c,PR	SiL	fr	c	ste	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
Btk1b	107-175	5YR4/4	2,c,PR	SiCL	h	a	ve	No roots; Fw, f, MnO_2 soft bodies; Cn, f, CaC nodules My, f, $CaCO_3$ soft bodies; Cn m, CaC bodies.
Bt2b	175-211	5YR4/4	1,m,SBK	SiCL	h	g	ste	Fw, f, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft b
Bt3b	211-236	2.5YR3/4	2,m,SBK	SiC	h	g	ste	Cn, f, $CaCO_3$ soft bodies.
Cb	236-297	2.5YR4/4	M	VFSL	fr	a	ste (in spots)	Fw, f, MnO_2 soft bodies fly stratified; Fw, f, $CaCO_3$ soft bodies.
Btk2b	297-348	2.5YR4/4		L	fr	c	ve	Cn, f, MnO_2 soft bodies; My, f $CaCO_3$ soft bc Cn, m, $CaCO_3$ nodules.
Btk22b	348-389	2.5YR4/4	1,c,PR	SiCL	fr	c	ste	Cn, f, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft b
Btk32b	389-447	2.5YR4/4	2,c,PR	C	fi	a	e	Fw, f, (less than 1 cm diam.) shell fragments; (less than 1 cm diam.) charcoal frag.; Fw, f, C soft bodies; Fw, f, MnO_2 soft bodies.
C2b	447-836	2.5YR4/4	2,c,PR	LFS	vfr		e	Gravel zone at 787 cm stratified LFS, FS, SL layers; Quartz + chert gravels.
Soil Core 92-7, elevation 102.92 (Figure 27)								
Ap	0-20	2.5YR3/6	1,m,SBK	SiL	fr	cl	ve	Fw, f + m, roots.
Bk1	20-46	2.5YR4/8	1,m,SBK	SiL	vfr	a	ve	Fw, f + m, roots; Fw, c, $CaCO_3$ soft bodies.
Bk2	46-96	2.5YR4/8	1,c,SBK	VFSL	vfr	a	vc	Fw, f, roots; My, c, $CaCO_3$ soft bodies + nod
Ab	96-137	2.5YR3/4-6	1,m,SBK	SiL	fr			Fw, f + m roots; Fw, m, $CaCO_3$ soft bodies.
Bkb	137-234	2.5YR4/6	1,m,PR	SiL	fi	a	ve	Fw, vf, roots; My, m, $CaCO_3$ soft bodies + nc
BCb	234-328	2.5YR4/6	1,c,SBK	FSL	fr	g	ste	

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc-ture	Tex-ture	Consis-tence	Bound dary	Reac-tion	Special Features
Soil Core 92.7 (cont.).								
BC2b	328-353	2.5YR3/6	1,c,PR	VFSL	fr	a	-	Fw, vf, roots; Fw, m, dt, redox + Mn, coating 10YR5/2.
BCg3b	353-391	7.5YR4/6	1,c,PR	VFSL	fr	a	e (in spots)	Fw, f, dt, redox, 5YR4/6.
BC4b	391-411	5YR4/6	1,c,PR	VFSL	fr	a	-	Cn, m, dt, redox, 10YR5/2.
BCg5b	411-427	10YR5/3	1,m,SBK	SiCL	fi	a	e	
BC6b	427-488	7.5YR5/8	1,m,SBK	SCL	fi	a	e	My, cn, dt, redox Fw, f, snails 5YR3/4.
CBb	488-589	2.5YR4/8	1,m,SBK	CL	vfr	g	ste	Fw, f, $CaCO_3$ soft bodies.
C1b	589-673	2.5YR4/8	M	LVFS	vfr	g	e (in spots)	
C2b	673-871	2.5YR3/5	M	GSCL	vfr	a	ste	Stratified sand, silt, clay, + gravels up to 2 cn
R	871-874	5YR5/8	-	LFS	fr		-	
Soil Core 92-8, elevation 101.44 (Fig. 6.6)								
Ap	0-20	2.5YR4/6-8	1,f,SBK	SiL	vfr	a	ve	Cn, f + vf, roots.
Btk	20-112	2.5YR4/6	2,m,SBK	SCL	fr	g	ve	Fw, f + vf, roots; Cn, m, $CaCO_3$ soft bodies + nodules.
Bk	112-193	2.5YR4/6	1,m,SBK	L	fi	a	ve	Cn, c, $CaCO_3$ soft bodies + nodules.
A,b	193-206	5YR5/6	1,m,SBK	CL	fr	a	ve	Cn, f, $CaCO_3$ soft bodies + nodules.
Bkb	206-277	5YR4/6	1,m,SBK	SCL	fi	g	ve	My, f + m, $CaCO_3$ soft bodies + nodules.
CB1b	277-323	5YR5/8	M	LVFS	fr	cl	-	Cn, m, ft, 5YR3/4 redox; Fw, f, snails.
CB2b	323-378	5YR5/8	1,m,SBK	VFSL	fr	cl	ste	Cn, m, dt, 10YR5/3 redox; Fw, f, snails; gley cm thick.
C1b	378-472	5YR5/8	M	VFSL	fr	cl	ste	
C2b	472-508	2.5YR4/6	M	SiL	fr	cl	ste	
C3b	508-602	2.5YR4/8	M	LVFS	vfr	g	ve	
C4b	602-683	2.5YR3/6	M	GS	l		ve	Gravels up to 3 cm.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-9, elevation 103.10 (Fig. 6.6)								
A	0-23	5YR3/4	1,m,SBK	L	fr	c	ste	Fw, f, roots; Fw, f, $CaCO_3$ nodules @ base.
AB	23-56	2.5YR3/6	1,m,SBK	SCL	fr	c	ve	Fw, f, roots; My, f, $CaCO_3$ soft bodies.
Btk	56-74	5YR5/4	2,m,SBK	SiCL	fr	a	ve	Fw, f, roots; My, f, $CaCO_3$ soft bodies; Cn, f $CaCO_3$ concretions.
Btkb	74-135	5YR3/4	2,c,PR	SiC	fi	a	ste	Fw, f, roots; My, f, $CaCO_3$ soft bodies; Cn, f $CaCO_3$ concretions; Cn, thin clay skins on pe
BC1b	135-160	5YR3/4	2,c,PR	VFSL	fi	c	ste	Fw, f, roots; Fw, f, $CaCO_3$ nodules.
BC2b	160-196	5YR4/3	1,c,PR	SCL	fi	a	ve	Fw, f, roots; My, f, $CaCO_3$ soft bodies; Fw, f, nodules.
BC3b	196-224	5YR4/3	1,c,PR	SCL	fi	g	ve	Fw, f, $CaCO_3$ soft bodies; Fw, f, Mn O_2 soft b
BC4b	224-274	5YR4/3	2,m,SBK	VFSL	fr	g	ve	Fw, f, $CaCO_3$ soft bodies; Cn, m, $CaCO_3$ nod m, reduced 2.5YR5/2 spots (<1 to 2 cm dia.).
BC5b	274-330	5YR4/3	1,c,PR	FSL	fi	c	ste	Fw, f, $CaCO_3$ soft bodies.
BC6b	330-371	5YR4/4	1,c,PR	SCL	fi	c	ve	My, f, $CaCO_3$ soft bodies.
BC7b	371-399	5YR4/4	1,c,PR	FSL	fi	c	ve	Cn, f, $CaCO_3$ soft bodies; My, f, dt, 10YR6/2
BC8b	399-434	2.5YR4/4	1,c,PR	SCL	fi	g	ste	Cn, f, $CaCO_3$ soft bodies; Cn, f, dt, 10YR6/2 Fw, intact snails (spherical).
C1b	434-472	2.5YR3/4	M	SCL	fi	g	e	Cn, f, $CaCO_3$ soft bodies; My, f, pt, 5YR5/2 r
C2b	472-488	2.5YR4/6	M	SCL	exfi	a	e	Cn, f, $CaCO_3$ soft bodies; Fw, c, krotovinas f w/7.5YR5/6 sand.
C1b2	488-671	2.5YR4/4	M	VFSL LFS	fr	a	e (in spots)	Fw, f, $CaCO_3$ soft bodies; stratified in <1 cm lenses.
C2b2	671-721	2.5YR3/4	M	SC	fi	a	ste	Cn, f, $CaCO_3$ soft bodies.
C3b2	721-739	2.5YR4/8	M	GLFS	fr		ste	My, subrounded chert gravels, Cn, f, $CaCO_3$ bodies.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc-ture	Tex-ture	Consis-tence	Bound dary	Reac-tion	Special Features
Soil Core 92-10, elevation 101.92 (Fig. 6.6								
A	0-13	5YR4/4	1,m,SBK	SiL	vfr	a	ve	Fw, f + m, roots; Fw, fn $CaCO_3$ soft bodies.
Btk	13-36	2.5YR4/4	2,m,SBK	SiCL	fr	g	e	Fw, f, roots; Cn, m, $CaCO_3$ soft bodies.
Btk2	36-61	2.5YR4/3	2,m,SBK	SiCL	fr	a	ve	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies.
Btk1b	61-140	2.5YR3/4	2,c,PR	CL	fr	g	ve	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies.
Btk2b	140-196	2.5YR3/4	2,c,PR	SCL	fi	g	ste	My, f, $CaCO_3$ soft bodies; Fw, f, roots.
Btk3b	196-249	2.5YR3/6	3,c,PR	SCL	exfi	c	ve	Cn, m, $CaCO_3$ concretions Fw, f, roots; Cn, f soft bodies.
BC1b	249-320	2.5YR3/6	1,c,PR	SCL	fi	a	ste	Cn, F, MnO_2 soft bodies Cn, f, $CaCO_3$ soft b My, m, $CaCO_3$ soft bodies + nodules at base.
BC2b	320-378	2.5YR3/6	2,m,SBK	SCL	fr		ste	Cn, m, $CaCO_3$ soft bodies; Cn, F, MnO_2 soft
Soil Core 92-11, elevation 101.95 (Fig. 6.6)								
A	0-15	5YR4/4	1,m,SBK	L	vfr	c	ve	Fw, f, roots; f, $CaCO_3$ soft bodies.
AB	15-33	5YR3/4	2,m,SBK	SCL	vfr	a	ve	Fw, f, roots; Fw, f, $CacO_3$ soft bodies.
Btk	33-66	2.5YR4/6	2,m,SBK	VFSL	vfr	a	ve	Fw, f, roots; Cn, m, $CaCO_3$ soft bodies.
Bt1b	66-112	2.5YR3/4	2,c,PR	SCL	fi	c	ste	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies; Fw, f, soft bodies.
Bt2b	112-140	2.5YR4/3	1,c,PR	SCL	fi	c	ve	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies; Fw, f, soft bodies.
Bk1b	140-206	5YR4/4	1,c,PR	VFSL	h	c	ve	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies; Cn, f, nodules; Fw, f, MnO_2 soft bodies.
Btkb	206-249	2.5YR4/4	2,c,PR	CL	exh	c	ve	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies; Cn, m nodules.
Bk22b	249-282	2.5YR4/6	2,c,PR	VFSL	h		ve	Cn, f, $CaCO_3$ soft bodies, Cn, m, $CaCO_3$ nod
Bk32b	249-282	2.5YR4/6	2,c,PR	VFSL	h		ve	Cn, f, $CaCO_3$ soft bodies; Cn, c, $CaCO_3$ conc
BC8b	399-434	2.5YR4/4	1,c,PR	SCL	fi	g	ste	Cn, f, $CaCO_3$ soft bodies; Cn, f, dt, 10YR6/2 Fw, intact snails (spherical).
C1b	434-472	2.5YR3/4	M	SCL	fi	g	e	Cn, f, $CaCO_3$ soft bodies; My, f, pt, 5YR5/2

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92.12, elevation 101.92 (Fig. 6.6)								
A	0-18	2.5-5YR3/4	1,m,SBK	VFSL	fr	c	ve	Fw,f, roots; My,f, $CaCO_3$ soft bodies
Bw1	18-51	2.5-5YR3/4	1,m,SBK	L	vfr	a	ve	Fw,f, roots; Cn, f, $CaCO_3$ soft bodies
Bw2	51-91	2.5YR3/4	1,c, PR	VFSL	vfr	a	ve	Fw, f, roots; Fw. f. $CaCO_3$ soft bodies
C	91-119	2.5YR3/4	M	S	l	a	ve	Fw, f, roots; My, f, $CaCO_3$ soft bodies
Bkb	119-142	5YR3/4	2,c,PR	SiL	fi	g	ve	My,f + m, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies
Btkb	142-198	5YR3/4	2,c,PR	CL	fi	g	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies; Cn, m, $CaCO_3$ nodules @ base; Fw, f, MnO_2 soft bodies.
BCkb	198-249	5YR3/4	1,c,PR	VFSL	fi	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies
BCb	249-269	5YR4/4	1,c,PR	SL	fr	a	c	Fw, f, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
Btk2b	269-307	2.5YR4/4	3,c,PR	SC	fi	c	v	Fw, f, roots; My, f + m, $CaCO_3$ soft bodies; Cn, m, $CaCO_3$ nodules ; Fw, f, MnO_2 soft bodies.
BC2b	307-351	2.5YR3/6	1,c,PR	SCL	fr	a	e	Cn, f, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
Btk3b	351-394	2.5YR3/6	2,c,PR	SCL	fi	c	ve	My, Cn, m, $CaCO_3$ soft bodies; Cn, c, $CaCO_3$ nodules @ top; Fw, f, MnO_2 soft bodies.
BC13b	394-424	2.5YR3/6	l,c,PR	VFSL	fi	g	ve	Cn, f + m, $CaCO_3$ soft bodies; Cn, f, MnO_2 soft bodies.
BC23b	424-460	2.5YR3/6	l,c,PR	SiCL	fr	g	e	N_2O accumulation @445cm; Fw, f, $CaCO_3$ nodules; Cn, f + m, $CaCO_3$ soft bodies; Cn, f, MnO_2 soft bodies.
BC33b	460-599	2.5YR3/6	1,c,PR	SiCL	fr	a	e	Cn, f + m, $CaCO_3$ soft bodies; Fw, f, charcoal fragments.
C13b	599-688	2.5YR4/6	M	FSL LFS	vfr	a	e	Stratified layers of FSL + LFS; My. f, $CaCO_3$ soft bodies.
C23b	688-726	2.5YR4/6	M	LS	l		ve	Fw, subrounded chert gravels; My, vf, detrital $CaCO_3$ nodules.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-13, elevation 100.38 (Fig. 6.6)								
A	0-15	5YR3/4	1,m,SBK	SiL	vfr	a	ve	Fw, f, roots, Cn, f, $CaCO_3$ soft bodies.
Btk1	15-76	2.5YR4/3	2,m,SBK	L	fr	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies + nodules.
Btk2	76-119	2.5YR3/6	2,c,PR	SCL	fr	c	ve	Fw, f, roots; My, f + m, $CaCO_3$ soft bodies + nodules.
Btk3	119-211	2.5YR4/3	2,c,PR	SCL	h	g	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies + nodules.
BC1	211-244	2.5YR4/3	1,c,PR	VFSL	h	g	ste	Cn, f + m, $CaCO_3$ soft bodies.
BC2	244-312	2.5YR4/4	1,c,PR	VFSL	fi	a	ste	Cn, f, $CaCO_3$ soft bodies; Cn, m, $CaCO_3$ nodules at base.
Btkb	312-384	2.5YR4/6	1,c,PR	SCL	fr	c	ste	Cn, f + m, $CaCO_3$ soft bodies.
C1b	384-526	2.5YR3/4 2.5YR4/4	M	FSL LFS	vfr	a	ste	Stratified FSL + LFS layers Fw, f, $CaCO_3$ soft bodies.
C2b	526-538	2.5YR4/3	M	LS	l		ve	My, f, detrital $CaCO_3$ nodules.
Soil Core 92-14, surface elevation relative to datum 99.74(Fig. 6.6)								
A	0-15	5YR3/4	1,m,SBK	VFSL	fr	a	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies; Fw, m, subrounded detrital $CaCO_3$ nodules @ base.
AB	15-41	2.5YR4/4	1,m,SBK	FSL	vfr	a	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
Btk1	41-86	2.5YR3/4	2,c,PR	SiCL	fi	c	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies and nodules.
Btk2	86-132	2.5YR4/3	2,c,PR	SCL	fi	g	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies; Fw, f, $CaCO_3$, soft nodules.
Bk3	132-211	2.5YR4/3	2,c,PR	L	vh	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies and nodules; Fw, c, krotovinas filled w/5YR6/3 FS.
Bw1b	211-241	2.5YR4/6	1,c,PR	SCL	h	g	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies; Cn, c, $CaCO_3$ soft bodies @ top; N 2/0 stains (Mn oxide) on ped faces @ top (10 cm thick).
Bw2b	241-318	2.5YR4/4	1,c,PR	FSL	fr	g	ste	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies; My, f, $CaCO_3$ soft bodies in root traces @ base.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-14 (cont.)								
BC1b	318-371	2.5YR4/4	M	VFSL	fr	a	ste (in spots)	Fw, f, detrital $CaCO_3$ nodules.
BC2b	371-409	2.5YR4/4	1,c,PR	SiCL	fi	a	ste	Fw, f, $CaCO_3$ soft bodies; Cn, c, krotovinas filled w/2.5YR4/6 FS.
C1b	409-564	2.5YR4/6	M	LVFS	fr	a	e (in LFS)	Stratified zones of LFS + VFSL; stratifications vary from < 1cm to 10 cm thick.
C2b	564-584	2.5YR4/3	M	LS	l		ve	My, f, detrital subrounded $CaCO_3$ nodules.
Soil Core 92-15, elevation 102.75 (Fig. 6.6)								
A	0-13	5YR4/4	1,m,SBK	L	fr	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies.
Btk	13-69	2.5YR4/4	2,m,SBK	SiCL	vfr	c	ve	Fw, f, roots; Cn, m, $CaCO_3$ soft bodies nodules.
BC	69-109	2.5YR4/4	1,m,SBK	CL	fr	a	ve	Fw, f, roots; Fw, f + m, $CaCO_3$ soft bodies.
BCk	109-213	2.5YR4/3	1,c,PR	VFSL	h	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies.
Bk1b	213-272	2.5YR3/4	2,c,PR	VFSL	fr	g	e (in spots)	Cn, f, $CaCO_3$ soft bodies.
Bk2b	272-345	2.5YR3/4	1,c,PR	VFSL	fr	a	ve	My, f, $CaCO_3$ nodules + soft bodies at base; Fw, f, roots; Cn, f, $CaCO_3$ soft bodies.
Bt3b	345-404	2.5YR3/4	1,c,PR	CL	fi	a	ve	My, m + c, $CaCO_3$ soft bodies, Cn, m, $CaCO_3$ nodules at top.
BCk1b	404-437	2.5YR4/6	1,c,PR	L	fr	c	ste (in spots)	Cn, m, $CaCO_3$ nodules at base Fw, f + m, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
BC2b	437-478	2.5YR4/4	1,c,PR	VFSL	fr	c	ste	N 2/0 (possibly charcoal).
Btk3b	478-508	2.5YR4/4	1,c,PR	SiCL	fi	c	ve	(possibly charcoal) Cn, c, $CaCO_3$ soft bodies + nodules; My, f, MnO_2 soft bodies.
BCk4b	508-556	2.5YR3/6	1,c,PR	VFSL	fr	a	ve	Cn, f, MnO_2 soft bodies (possibly charcoal) My, f + m, $CaCO_3$ soft bodies; Fw, f, $CaCO_3$ nodules.
BCk5b	556-602	2.5YR4/4	1,c,PR	L	h	a	ve	My, f, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
BCk6b	602-663	2.5YR4/6	1,c,PR	L	fr	g	ste	Cn, f, $CaCO_3$ soft bodies.
C1b	663-780	2.5YR4/6	M	VFSL	fr	g	ste	Cn, f, $CaCO_3$ soft bodies.
C2b	780-810	2.5YR4/6	M	LFS	fr		ste	Fw, f + m, $CaCO_3$ soft bodies.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc- ture	Tex- ture	Consis- tence	Bound dary	Reac- tion	Special Features
Soil Core 92-16, elevation 109.50 (Fig. 6.6)								
Ad	0-15	5YR3/3	1,f,PL	VFSL	fr	a	-	Cn, f, roots.
Bt1	15-43	5YR3/2	3,m,PR	SiC	fi	a	-	Cn, f, roots; My thick dt clay skins on ped faces.
Bt2	43-64	5YR3/3	2,m,PR	SiC	fr	a	-	Fw, f, roots; Cn, thin dt clay skins on ped faces.
Bk3	64-114	5YR3/3	2,c,PR	SiCL	fi	a	ste	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies; Fw, thin clay skins ped faces.
Bk4	114-135	2.5YR4/6	1,c,PR	L	exh	g	ste	Fw, f, roots; My, f, $CaCO_3$ soft bodies.
BCk5	135-193	2.5YR4/6	1,c,PR	L	exh	a	e	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies.
Bk1b	193-239	5YR5/6	2,m,SKB	L	exh	g	ve	My, f + m, $CaCO_3$ nodules; Fw, f, MnO_2 soft bodies.
Bk2b	239-274	2.5YR4/6	1,c,PR	L	fr	g	ve	Cn, f + m, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
C1b	274-432	2.5YR4/4	1,c,PR	VFSL	fr	a	ve	Fw, f + m, $CaCO_3$ soft bodies; Fw, f, MnO_2 soft bodies.
2b	432-445	2.5YR4/6	M	GrSL	fr		ve	Graves are subrounded to subangular chert fragments.
Soil Core 92-17, elevation 102.37 (Fig. 6.6)								
A	0-20	5YR3/3	1,m,SBK	VFSL	fr	a	ve	Cn, f, roots; Fw, f, detrital $CaCO_3$ nodules.
Btk	20-66	2.5YR3/4	2,m,SBK	CL	vfr	a	ve	Fw, f, roots; My, f + m, $CaCO_3$ soft bodies; Fw, thin, clay skins on ped faces.
Btk2	66-107	2.5YR4/6	1,c,PR	SCL	fr	g	ve	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies.
C	107-135	2.5YR4/6	1,c,PR	FSL	vfr	a	ste	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
Btk1b	135-198	2.5YR3/4	2,m,SBK	SiC	fi	a	ve	Fw, f, roots; My, f + m, $CaCO_3$ soft bodies; Cn, c, krotovinas filled w/2.5YR4/6 VFS and Cn, thick clay films on ped faces.
Bt2b	198-257	2.5YR4/4	2,c,PR	SiCL	h	c	e (in spots)	Fw, f, $CaCO_3$ soft bodies.
Bt3b	257-292	2.5YR4/4	2,c,PR	SiCL	fr	g	e (in spots)	Fw, f, $CaCO_3$ soft bodies; Cn, m, krotovinas filled w/2.5YR4/6 VFS.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Soil Core 92-17 (cont.)								
BCb	292-335	2.5YR4/6	1,c,PR	VFSL	fr	a	ste	Fw, m, $CaCO_3$ soft bodies.
Btb2	335-371	2.5YR4/4	2,m,SBK	SiC	fi	a	ve	Fw, f, detrital $CaCO_3$ nodules; Fw, f, $CaCO_3$ soft bodies. Cn, c, krotovinas filled w/2.5YR4/4 VFS.
BCb2	371-424	2.5YR3/6	2,m,SBK	SiL	fr	a	ste	Fw, m, krotovinas.
BCkb2	424-478	2.5YR4/3	1,c,PR	VFSL	fi	a	ve	Cn, f + m, $CaCO_3$ soft bodies.
C1b2	478-660	2.5YR4/4 2.5YR4/3	M	VFSL LFS	fr	a	ste	Stratified layers of VFSL + LFS; Fw, f, $CaCO_3$ soft bodies.
C2b2	660-683	10R4/4	M	GrS	l		ve	Fw, m, detrital $CaCO_3$ nodules, subangular + subrounded chert w/some quartz + sandstone My, vf, detrital $CaCO_3$ nodules.
Soil Core 92-18, elevation 97.42 (Fig. 6.6)								
A	0-10	2.5YR3/4	1,m,SBK	SiL	fr	a	ve	Cn, f, roots; Fw, f, detrital $CaCO_3$ nodules.
Btk	10-46	2.5YR3/4	2,m,SBK	SiCL	fr	c	ve	Fw, thin discontinuous clay skins; Fw, f, roots; Cn, f + m, $CaCO_3$ nodules + soft bodies.
Btk2	46-76	2.5YR3/4	1,c,PR	L	vfr	a	ve	Fw, thin, discontinuous clay skins; Fw, f, roots; Cn, f, $CaCO_3$ soft bodies.
BCk	76-130	2.5YR3/6	1,c,PR	L	h	a	ve	Fw, f, roots; Cn, f + m, $CaCO_3$ soft bodies.
Btkb	130-188	2.5YR4/4	2,f,PR	CL	exh	a	ve	2.5YR3/6 FS; Cn, f + m, $CaCO_3$ soft bodies; Cn, c, krotovinas filled w/Fw, f, roots; Cn, thick continuous clay skins on pedfaces.
BCb	188-251	2.5YR4/4	1,c,PR	SiL	fr	c	ve	Fw, f + m, $CaCO_3$ soft bodies.
Clb	251-312	2.5YR3/6	M	FSL	fr	g	ve	
C2b	312-457	2.5YR3/4 2.5YR4/4	M	FSL LFS	exh	a	ve	Stratified FSL + LFS layers.
C3b	457-470	10R4/4	M	GLS	l		ve	Subangular chert fragments; My, vf, detrital $CaCO_3$ nodules; Gravels subrounded.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc-ture	Tex-ture	Consis-tence	Bound dary	Reac-tion	Special Features
1992 Backhoe Trench A, Described Profile on South Wall, surface elevation 96.05(Fig. 6.7)								
Bk	0-59	2.5YR4/6	2,m,SBK	VFSL	vfr	a	ve	My, c, $CaCO_3$ soft bodies + nodules; Fw, f, roots; Fw, f, $CaSO_4$ cluster casts; Fw, c, tubular vertical krotovinas.
BC1	59-132	2.5YR3/6	1,c,SBK	FSL	vfr	cl	ve	Fw, c, $CaCO_3$ nodules; Cn, f, Mn stains; Cn, m, $CaSO_4$ cluster casts; Fw, f, roots; Fw, c, tubular vertical krotovinas.
BC2	132-162	5YR4/4	2,c,PR	SCL	fr	g	e	Cn, f, ft, 10YR8/3 redox, Fw, f, snails; Fw, f, roots; Fw, c, tubular vertical krotovinas.
2CB1	162-201	5YR4/6	2,c,PR	FSL	vfr	g	ste	My, m, ft, 2.5YR6/2 redox; Fw, c, 2 cm SCL, 5YR3/3 lenses; Fw, f, roots; Fw, f, snails; Fw, c, tubular vertical krotovinas.
2CB2	201-220	5YR4/6	2,c,PR	SCL	vfr	a	ste	Fw, m, $CaCO_3$ nodules; Cn, m, dt, 2.5Y6/2 redox; Fw, f, roots; Fw, f, snails, Fw, c, tubular vertical krotovinas.
2CB3	220-224	2.5Y5/2	2,c,PR	SCL	vfr	a	ste	Fw, f, ft, 7.5YR5/2, redox; Fw, f, roots; Fw, f, snails; Fw, m, $CaCO_3$ nodules; Fw, c, tubular vertical krotovinas.
2CB4	224-236	5YR4/4	2,c,PR	FSL	fr	g	ste	Cn, m, dt, 10YR6/2 redox; Cn, f + m, snails; Fw, f, roots; Fw, c, tubular vertical krotovinas; Fw, m, $CaCO_3$ nodules.
2CB5	236-261	2.5YR4/6	2,c,PR	FSL	fr	a	ste	Cn, m, dt, 10YR6/2 redox; Fw, f, roots; Fw, c, tubular vertical krotovinas; Cn, f + m, snails; charcoal.
2CB6	261-274	10YR5/3	2,c,PR	FSL	vfr	a	ste	Cn, f + m, snails; Fw, f, 2.5Y6/8 Fe stains; Fw, f, roots; Fw, c, tubular vertical krotovinas.
2CB7	274-285	5YR4/4	2,c,PR	L	fr	g	ste	Stratified layers of 5YR3/4 clays 2 cm lenses; stratified layers of 10YR6/2 sands 2.cm lenses; Fw, f, snails; Fw, f, roots, Fw, c, tubular vertical krotovinas; Fw, m, $CaSO_4$ clusters.
2CB8	285-365	5YR4/4	2,c,PR	CL	fr	a	ste	Stratified layers of 5YR6/8 sands 2 cm lenses; stratified layers of 10YR6/2 sands 2 cm lenses; Fw, f, snails; Fw, f, roots, Fw, c, tubular vertical krotovinas; Fw, m, $CaSO_4$ clusters – boulder at base.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
1992 Bachhoe Trench A Described Profile (cont.)								
3C1	365-445	2.5YR4/8	(auger	LVFS			ste	
3C2	445-483	2.5YR4/6	starts)	LFS			ste	
3C3	483-502	2.5YR4/8		LS			ve	
3C4	502-518	2.5YR3/6		VGLS			ve	Subangular + subrounded chert + $CaCO_3$ gravels up to 6 cm.
3C5	518-549	2.5YR5/8		LFS			ve	Cn, subangular + subrounded chert + $CaCO_3$ gravels up to 3 cm.
3C6	549-551+	2.5YR5/8		GLVFS			ve	Cn, subangular + subrounded chert + $CaCO_3$ gravels up to 3 cm.
1992 Backhoe Trench B, East Column; surface elevation relative to datum 99.02 m (Fig. 6.7)								
BC	0-38	2.5YR3/4	1,c,SBK	SCL	fr	cl,w	ve	Cn, f, dt, 10YR5/2 redox; Cn, m, vertical tubular krotovinas; Fw, f, roots; Cn, f, Mn stains; Fw, f + m $CaCO_3$ threads + concretions.
CB1	38-52	7.5YR4/4	1,c,SBK	CL	fr	w,s	ve	Cn, f, ft, 10YR6/1 redox; Fw, f, roots; Fw, f + m, $CaCO_3$ threads + concretions; Fw, f, snails; Cn, m, vertical tubular krotovinas.
CB2	52-83	10YR5/3	1,c,SBK	CL	fr	a,w	ste	My, f, snails; Fw, f + m, $CaCO_3$ threads + concretions; Fw, f, roots. Cn, m, dt, 5YR5/8 redox; Cn, m, vertical tubular krotovinas.
2CB3	83-109	2.5YR3/6	1,c,PR	FSL	fi	d,s	-	Cn, m, vertical tubular krotovinas; Fw, f, roots; Fw, f, snails.
2CB4	109-153	2.5YR3/6	1,c,PR	FSL	fi	d,s	-	Cn, m, vertical tubular krotovinas; Fw, f, roots; Fw, f, snails.
2CB5	153-256	2.5YR3/6	1,c,PR	SCL	fi	g,s	e (in spots)	Fw, f, roots; Fw, f, charcoal fragments; Cn, m, $CaSO_4$ cluster casts; Cn, m, vertical tubular krotovinas.
2C	256-282+	2.5YR4/8	M	LFS	vfi	-	e	Stratified, f, sands + gravels.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
1992 Backhoe Trench B, West Column; surface elevation relative to datum 98.62 (Fig. 6.7)								
Bk	0-35	2.5YR3/6	1,m,SBK	VFSL	fr	cl,w	ste	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies + concretions; Fw, m, vertical tubular krotovinas; Fw, f, snails.
CB1	35-109	2.5YR3/6	1,c,PR	FSL	fr	g,s	e	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies as threads on pores; Fw, f, charcoal fragments; Fw, m, $CaSO_4$ cluster casts; Fw, m, vertical tubular krotovinas; Fw, f, snails.
CB2	109-206	2.5YR3/4	1,c,PR	SCL	fi	cl,s	-	My, m, $CaSO_4$ cluster casts; Fw, f, roots; Fw, f, $CaCO_3$ soft bodies as threads on pores; My, f, charcoal fragments; Fw, m, vertical tubular krotovinas.
C	206-227	2.5YR3/6	M	VFSL	fr		e (in spots)	Stratified f + m, sands.
BH-C: 6-10-92 Con't. west of the N. Trench 100.50 m								
Ap	0-30	5YR3/4	1,m,SBK	VFSL	fr	cl,s	ve	My, f + m, roots.
A	30-51	5YR3/3	2,m, SBK	VFSL	fr	g,s	ve	My, f + m, roots.
AB	51-93	5YR4/4	2,m,SBK	VFSL	fr	cl,s	ve	My, f + m, roots; My, f, $CaCO_3$ concretions; Fw, c, tubular krotovinas.
Btk1	93-143	7.5YR3/4	3,m,SBK	L	exh	g,s	ve	Fw, c, tubular krotovinas; Cn, f + m, roots; My, f + m, $CaCO_3$ concretions.
Btk2	143-179	5YR4/6	3,m,SBK	CL	exh	cl,w	ste	My, f + m, $CaCO_3$ concretions; Fw, c, tubular krotovinas; Cn, f, roots.
BCk	179-254	2.5YR3/6	2,m,ABK + PR	CL	h	d,s	ste	Fw, f, roots; Cn, m + c, $CaCO_3$ soft bodies + concretions seem to fill krotovinas; Fw, m, $CaSO_4$ cluster casts.
CB	254-314	2.5YR4/6	1,c,PR	CL	fi	g,s	ste	Fw, f, roots; Fw, f, snails.
C	314-345+	2.5YR3/6	M	VFSL	fr	-	e	Fw, f, roots.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc- ture	Tex- ture	Consis- tence	Bound dary	Reac- tion	Special Features
Bulldozer Trench A West Soil Profile 104.94 m (Fig. 6.6)								
Ap	0-28	5YR3/4	1,c,SBK	SiL	vfr	a,s	-	My, f + m + c, roots.
Bw	28-54	2.5YR4/6	2,m,SBK	VFSL	vfr	a,w	sle	Cn, f + m, roots; Fw, f, $CaCO_3$ soft bodies Fw, f, roots; Cn, m, $CaCO_3$ soft bodies + nodules.
Bkb	54-69	5YR4/6	2,c,SBK	SiL	fr	a,s	ste	Cn, f + m, roots; Fw, f, $CaCO_3$ soft bodies Fw, f, roots; Cn, m, $CaCO_3$ soft bodies + nodules.
Btkb	69-130	2.5YR4/6	3,c,PR	SiCL	fi	a,w	ve	Fw, f, roots; Cn, m, $CaCO_3$ soft bodies + nodules.
BCb	130-158	2.5YR4/6	1,c,SBK	Si	fr	a,w	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies + nodules.
CB1b	158-180	2.5YR3/6	2,c,SBK	SiL	fr	a,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules; fly stratified.
CB2b	180-207	2.5YR4/4	1,c,SBK	LVFS	fr	a,w	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies; fly stratified.
CB3b	207-216	2.5YR4/6	1,m,SBK	C	fi	a,w	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies; fly stratified.
CB4b	216-225	2.5YR4/6	1,c,SBK	SiC	fr	c,w	e	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
CB5b	225-300	2.5YR3/6	1,c,SBK	LVFS	fr	c,w	sle	Cn, f, $CaCO_3$ soft bodies + nodules; Fw, f, roots.
CB6b	300-331+	2.5YR4/6	1,c,SBK	LFS	vfr		sle	Fw, f, roots; fly stratified.
Bulldozer Trench A Middle Soil Profile 105.25 m (Fig. 6.6)								
Ap	0-20	5YR3/4	1,c,SBK	SiL	vfr	a,w	-	My, f + m, roots.
Bw1	20-53	5YR4/6	1,m,SBK	SiL	fr	c,s	-	Cn, f + m, roots.
Bw2	53-110	2.5YR4/6	1,m,SBK	SiL	vfr	a,w	e	Fw, f + m, roots; Fw, c, (less than 5 cm); Cn, f, $CaCO_3$ soft bodies as ped coating.
Bkb	110-138	5YR5/8	3,f+m,SBK	SCL	vh	c,s	ve	Fw, f, roots; My, m, $CaCO_3$ nodules + soft bodies.
Btkb	138-184	2.5YR3/6	3,m,ABK	SiC	exh	a,w	ve	My, c, $CaCO_3$ m + c, soft bodies + nodules; Fw, f, roots; Cn, dt, clay skins.
BC1b	184-207	2.5YR4/6	2,c,SBK	SiL	h	a,w	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
BC2b	207-214	2.5YR4/6	2,f,SBK	SiC	h	a,w	ve	Fw, f, roots; Fw, f, $CaCO_3$ soft bodies.
CB1b	214-309	2.5YR4/6	1,c,SBK	SiL	h	a,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules; fly stratified; approx. 1.2 m west a clay layer ends abruptly.
CB2b	309-337	2.5YR4/6	1,m,SBK	SiL	fr	d,w	ve	Fw, f, roots.
CB3b	337-343+	2.5YR4/6	1,m,SBK	VFSL	fr	-	ve	Fw, f, roots.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Struc-ture	Tex-ture	Consis-tence	Bound dary	Reac-tion	Special Features
Bulldozer Trench B East Soil Profile 103.02 (Figs. 6.6 and 6.15)								
A	0-33	5YR4/6	1,m,SBK	SiCL	fr	a,w	ve	My, f + m, roots.
AB	33-44	5YR4/6	2,m,SBK	SiL	fr	a,w	ve	Cn, f + m, roots.
Bk	44-91	2.5YR4/6	2,c,SBK	SiL	fr	a,w	ve	Cn, f, roots; Cn, f + m, $CaCO_3$ soft bodies + nodules; fly stratified.
CB1	91-117	5YR5/8	1,m,SBK	SiL	vfr	a,w	ve	Fw, f, roots; fly stratified.
CBkm2	117-141	5YR5/8	1,m,SBK	VFSL	vfr	a,w	ve	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies + nodules; fly stratified.
Ab	141-165	5YR4/6	1,c,SBK	SiL	vfi	c,w	sle	Fw, f, roots; Cn, f, $CaCO_3$ soft bodies + nodules.
ABkb	165-213	5YR3/4	3,c,PR	SiCL	exfi	c,w	ste	Fw, f, roots; My, m, $CaCO_3$ soft bodies + nodules; Cn, pt, clay skins on ped faces.
Bk1b	213-273	5YR4/4	2,c,PR	SiCL	vfi	c,w	ve	Fw, f, roots; My, f, $caCO_3$ soft bodies + nodules; Cn, pt, clay skins on ped faces.
Bk2b	273-299	5YR4/4	1,c,SBK	SiCL	exfi	a,w	ste	Fw, f, roots; My, f + m, $CaCO_3$ soft bodies + nodules; Cn, ft, clay skins on ped faces.
CB1b	299-337	5YR4/4	1,c,PR	SiL	fr	a,w	ste	Fw, f, roots; Fw, f + m, $CaCO_3$ soft bodies + nodules; Fw, ft, clay skins on ped faces; fly stratified.
Bulldozer Trench B West Soil Profile 101.63 m (Figs. 6.6 and 6.15)								
ACp	0-27	5YR4/6	1,m,SBK	VfSL	vfr	a,s	ste	My, f + m, roots.
Ab	27-59	5YR3/4	1,c,SBK	SiL	vfr	c,w	ste	My, f + m, roots.
Bwb	59-108	5YR3/4	1,c,SBK	L	fr	a,w	ste	Cn, f + m, roots; Fw, f, $CaCO_3$ soft bodies + nodules.
BCkb	108-159	5YR4/6	2,c,SBK	SiL	fr	c,w	ve	Cn, f + m, roots; Cn, m, $CaCO_3$ soft bodies + nodules.
CB1b	159-211	5YR4/6	1,c,PR	SiL	vfi	c,w	ve	Cn, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules; Cn, dt, clay skins on ped faces.
CBk2b	211-234	2.5YR3/6	3,c,PR	C	exfi	c,w	ve	Cn, f, roots; Cn, c, $CaCO_3$ nodules + soft bodies; My, pt, clay skins on ped faces.
CBk3b	234-262	2.5YR4/6	2,c,SBK	SiL	vfi	c,w	ve	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies + nodules; Cn, ft, clay skins on ped faces.
CBk4b	262-328	2.5YR4/6	1,c,SBK	VFSL	fi	c,w	ve	Fw, f, roots; Fw, c, $CaCO_3$ soft bodies + nodules.
CB5b	328-394+	2.5YR4/6	1,c,SBK	LVFS	fr		ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules.

Table 6.2 (cont.). Soil Profile Descriptions for Burnham Site 1991 and 1992 Soil Borings and Excavations.

Horizon	Depth (cm)	Color Moist	Structure	Texture	Consistence	Boundary	Reaction	Special Features
Profile descriptions for Bulldozer Trench D, Burnham site 103.00 m (Fig. 6.6)								
A	0-21	5YR3/4	3,c,GR	SiCL	fr	a,w	ve	My, f + m, roots.
Bk1	21-44	2.5YR4/6	2,f,SBK	SiCL	fr	c,w	ve	Cn, f + m, roots.
Btk2	44-95	2.5YR4/6	2,c,PR	SiCL	fr	c,w	ve	Cn, f + m, roots; Cn, m, $CaCO_3$ soft bodies + nodules; Cn, pt, clay skins on ped faces; fly stratified.
BC1	95-150	2.5YR4/6	1,c,PR	SiL	fi	c,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules; Cn, dt, clay skins on ped faces; fly stratified.
BC2	150-218	5YR5/6	1,c,SBK	SiL	fr	c,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules at top of horizon; Cn, ft, clay skins on ped faces; fly stratified.
CB1	218-246	5YR5/6	1,c,SBK	SiL	fr	c,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules at base; Fw, ft, clay skins on ped faces; fly stratified.
CBk2	246-294	5YR5/8	1,c,SBK	SiL	fr	c,w	ve	Fw, f, roots; Cn, c, $CaCO_3$ soft bodies + nodules; fly stratified.
CB3	294-334	5YR5/8	1,c,SBK	SiL	fr	c,w	ve	Fw, f, roots; Fw, m, $CaCO_3$ soft bodies + nodules; fly stratified.
CB4	334-350+	2.5YR4/6	1,c,SBK	SiL	fr		ve	Fw, f, roots; Fw, m + c, $CaCO_3$ nodules; fly stratified.

† color; (moist): structure; 1 – weak, 2 – moderate, 3 – strong, f – fine, m – medium, c – coarse, PL – platty, SBK – subangular blocky, ABK – angular blocky, PR – prismatic, M – massive, SG – single grain: texture; V – very, F – fine, S – sand, Si – silt, C – clay, L – loam, G – gravel: consistence; v – very, fr – friable, l – loose, fi – firm, h – hard: boundary; a – abrupt, c – clear, g – gradual, d – diffuse, s – smooth, w – wary, i – irregular: reaction; e – effervescence, sl – slight, st strong, v – violent: special features; My – many, Cn – common, Fw – Few, f – fine, m – medium, c – coarse, redox – redoximorphic features (mottles), ft – faint, dt, distinct, pt – prominent.

Chapter 7
Introduction to the Burnham Biological Studies

Don G. Wyckoff

The initial impetus for the Burnham site research was the observed presence of snails and bones of diverse mammals. Their presence indicated the site could yield substantial information on the setting and environment in which they lived. Even though the research at this site eventually took on the hints of an ancient human presence too, all of the ensuing excavations were conducted in ways that emphasized recovery of all kinds of biological evidence. For example, all deposits excavated by hand were washed through 2 mm mesh screen to assure maximum recovery of snails, seeds, charcoal, and bones of all sizes. Moreover, whenever it appeared that other fossil forms might be present, matrix samples were collected so that they could be processed by appropriate scholars. As the following chapters attest, much was recovered that enhances our understanding of the site's age, ecological setting, and the environment at that time.

During the first visit in 1986 bone fragments were seen strewn over all three of the gleyed deposits exposed by the bulldozer during construction of the small, modern pond. Dr. Larry Martin, paleontologist with the University of Kansas Museum of Natural History, was a member of that first visiting party. Throughout the excavations Larry accepted the responsibility for identifying and interpreting the recovered vertebrate remains. Assisting him was Ph.D. candidate T.J. Meehan. In 2001, bones of a dire wolf eroded out of the site's east exposure, and Dr. Nick Czaplewski (Sam Noble Oklahoma Museum of Natural History) supervised their recovery and analysis.

Especially abundant during the first visit to the site were thousands of snails scattered over the gleyed deposits. Dr. Jim Theler (University of Wisconsin-LaCrosse) had been a colleague during the Hajny mammoth site research (Wyckoff et al. 1992), and, thankfully, he was willing to plan, recover, and study the aquatic and terrestrial gastropods preserved in the Burnham deposits. His findings add much insight to the character of the setting. Notably, Jim's interest in refining the interpretive value of fossil gastropods led him, Brian Carter, and me on systematic collecting expeditions for live land snails across the Southern Plains, north to the Canadian border (Theler et al. 2002; Wyckoff et al. 1997), and even to Colorado's highest mountain!

During the first fieldwork, samples from the diverse red or gray sandy sediments were collected for pollen extraction. Their submission to the Palynology Lab at Washington State University failed to yield any pollen. Thanks do go to Dr. Peter Mehringer and Peter Wigand for trying. After the 1989 excavations, a sample of a thin silt lens above the horse bone bed was submitted to Peter Wigand, who at that time was with the Desert Research Institute, Reno, Nevada, and he did succeed in recovering some poorly preserved grains. Dr. Paul Minnis (University of Oklahoma) and student Barbara Keener kindly undertook analysis of seeds recovered during water screening. The only charcoal large enough for reasonable identification was part of a charred log found in the paleosol exposed in the North 3 backhoe trench in 1989. Dr. Julio Betancourt (U.S. Geological Survey) was contacted about trying to identify the wood before a sample was submitted for radiocarbon dating. Although personally unable to do the analysis, Dr. Betancourt did enlist graduate intern Peter van der Water who did complete a detailed study of the sample.

Included in this section is the description of the flint flakes and other chipped stone objects recovered at the Burnham site. We all were surprised when the first examples of these artifacts were found while sorting through the debris left after waterscreening sediments during the 1986 work. Our surprise continued as more flakes were found during the 1988 and 1989 excavations. Again, if we had not waterscreened with the fine mesh, we never would have found the majority of these tantilizing hints of the presence of people. Kent Buehler completed the analyses of these material clues to people working flint. Besides thoroughly describing and illustrating each of the artifacts, Kent has undertaken detailed studies of the vertical and horizontal distributions of these items and compared these distributions with those of what are clearly natural pebbles and flinty lithics found at the site. The objects we believe to be of human origin do have a restricted distribution, but it is of secondary origin because the artifacts were redeposited in one of the earliest ponds that stood at this location.

Collectively, the efforts of all these individuals, and often their colleagues, contribute significant information on the animals and plants that lived around the ancient pond that eventually became the Burnham site. Their findings are presented in the following chapters and comprise a major contribution to our knowledge of the late Pleistocene in this part of the Plains. All specimens are now curated at the Sam Noble Oklahoma Museum of Natural History and are available for father studies. In fact, teeth of the Southern bog lemming have been loaned to Dr. Eileen Johnson at Texas Tech University for comparative studies, and several horse teeth are on loan to Dr. Bruce McFadden (Florida Museum of Natural History) who is attempting to recover plant remains indicative of the prehistoric ecology and climate.

References Cited

Theler, J.L., D.G Wyckoff, and B.J. Carter. 2002. The Southern Plains Gastropod Survey: The Distribution of Land Snail Populations in an American Grassland Environment. *American Malacological Bulletin* 18: in press.

Wyckoff, D.G., B.J. Carter, P. Flynn, L.D. Martin, B.A. Branson, and J.L. Theler. 1992. *Interdisciplinary Studies of the Hajny Mammoth Site, Dewey County, Oklahoma.* Oklahoma Archeological Survey, Studies in Oklahoma's Past 17. Norman.

Wyckoff, D.G., J.L. Theler, and B.J. Carter. 1997. Southern Plains Gastropods: Modern Occurrences, Prehistoric Implications. Final report on Grant #5477-95 to the National Geographic Society. Report on file at the Sam Noble Okalhoma Museum of Natural History, University of Oklahoma, Norman.

Chapter 8
Vertebrate Fauna of the Burnham Site

Larry D. Martin and T. J. Meehan

Introduction

Over seven hundred bones and bone fragments have been recovered from the Burnham site (Tables 8.1, 8.2, and 8.3), yielding the largest and most diverse late Pleistocene fauna from Oklahoma. The site closely resembles sites to the south in Texas. Co-occurrence of *Alligator* and *Synaptomys* (bog lemming) at Burnham is unusual and lends further support for higher equability of Pleistocene climates. A small portion of the bones appear burned, and there is limited evidence of human modification.

Located close to the Burnham site, but younger in age, is the Bar M local fauna in Harper County, Oklahoma (Fig. 8.1). The Bar M local fauna has been dated at 17,750 ± 360 ybp by Wells and Stewart (1987). This makes it full glacial, even though it includes a cold intolerant species, *Dasypus bellus* (beautiful armadillo). The Cragin site in Meade County, Kansas, has a similar fauna to Burnham, but is older.

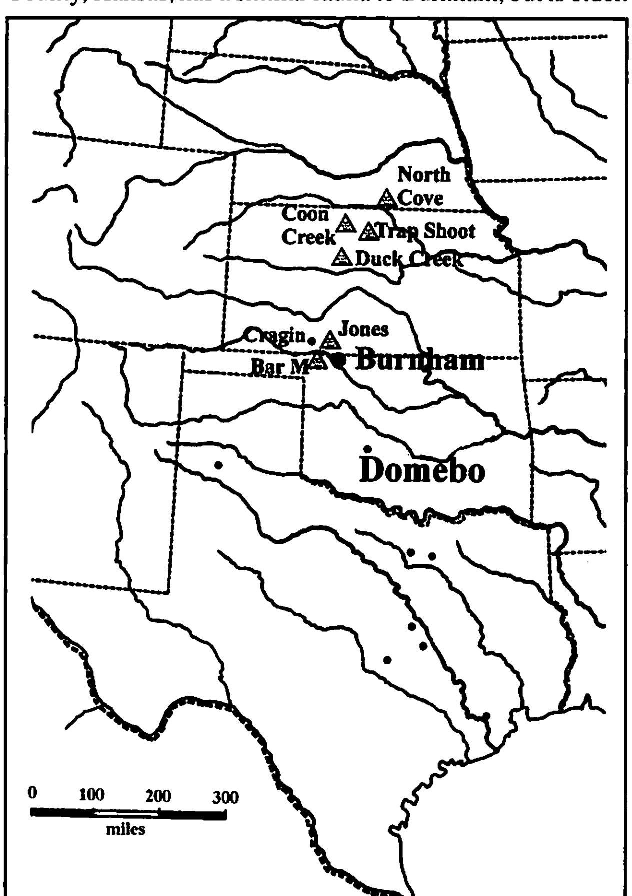


Figure 8.1. Some notable Pleistocene sites near the Burnham site of Oklahoma. Those with triangles lack Alligator *and* Hesperotestudo.

The Cragin site was associated with active springs and may have formed an isolated oasis in a semi-arid region (Hibbard and Taylor 1960). In both Cragin and Burnham, there are no beavers, muskrats, or water rats, and the fish are small and have a very low diversity (minnow and small bullhead in Cragin; sunfish in Burnham). The Cragin local fauna includes the large *Terrapene*, *Hesperotestudo*, and *Alligator* found in the Burnham local fauna. They also share *Glossotherium*, *Cynomys*, *Geomys*, *Neotoma*, *Microtus* (*Pedomys*), *Canis*, *Mammuthus*, *Lepus*, *Sylvilagus*, *Hemiauchenia*, and *Equus*.

The Jones fauna is closer in age (radiocarbon dates of 26, 700 ± 1500 and 29,000 ± 1300 ybp; Martin 1977) to the Burnham fauna and is closer geographically to the Cragin fauna, but, unlike either, it has a northern faunal character. The Jones fauna differs in having *Sorex arcticus*, *S. cinereus*, *Microtus pennsylvanicus*, and *M. montanus*. The character of the Jones fauna is maintained further north in the Trapshoot local fauna (Stewart 1987), and the character of the Burnham site is maintained southward into Texas. During the Sangamon interglacial, faunas of the Burnham type extended further northward, at least as far as southwestern Kansas. During the Wisconsinan glacial, their northern border was close to the present Oklahoma/Kansas border.

Due to the possibility of a human context, all bones were examined for modification, and the occurrence of burned bone was noted. The collection resides at the Sam Noble Oklahoma Museum of Natural History, and the identification numbers cited below were assigned by us.

Faunal Analysis

Fish (Pisces)

Fish are notable by their rarity and low diversity. Almost all specimens can be referred to a single species of sunfish, *Lepomis* cf. *cyanellus*. This sunfish is particularly good at colonizing semi-isolated bodies of water. A second fish (not a sunfish) is indicated by a single vertebra (#247), but the overall diversity is amazingly low and would not be typical of either normal pond or stream assemblages. All of the fish so far recovered were probably less than 20cm in length.

Amphibians (Amphibia)

Salamanders. Both the plains tiger salamander, *Ambystoma tigrinum* (#122, #193, #277, #294, #317, #54, #392, #435, #482, #532), and the Texas salamander, *Ambystoma texanum* (#390, #454), are present according to the vertebral characters given by Tihen (1958). The vertebrae indicate adult animals of normal size.

Frogs. No toads have been recognized, and frogs are restricted to the leopard frog, *Rana pipiens* (#395, #457), and the bullfrog, *Rana catesbiana* (#412).

Reptiles (*Reptilia*)

Turtles. A variety of turtles are represented in the Burnham collection. Two of the forms, *Chelydra* sp. and *Trionyx* sp., are characteristic of aquatic environments. Both of these forms are based on very fragmentary remains. The identification of *Chelydra* sp. is based on a fragmentary portion (#243) of the second costal and neural. This fragment is from a thin-shelled turtle with a low-arched carapace, large flat neurals, and a short interval between the scute lines and the neural-costal suture. The specimen does not have a rib base across from the junction of the scutes, but it otherwise conforms with *Chelydra* sp. Three specimens (#103, #403, #443) of the soft-shelled turtle, *Trionyx* sp., can be identified on the basis of fragments with the characteristic shell ornamentation. The occurrence of pond turtles (*Clemys*, *Chrysemys*) is presently doubtful although a number of very small shell fragments are open to a variety of interpretations. *Chelydra* and *Trionyx* require permanent water, and *Trionyx* specifically requires a stream environment. With only four occurrences, the aquatic turtles must be considered rare members of the fauna.

The box turtle, *Terrapene*, is much more common and may account for the bulk of the unidentified turtle fragments. Identification can be made on: a hypoplastron fragment (Fig. 8.2) showing the characteristic hinge (#705); a neural fragment showing ornamentation (#685); a xiphiplastron fragment (#717); and the right anterior margin of a carapace (#678; Fig. 8.2). All of these are from a large (carapace length greater than 200mm) *Terrapene* and may be referred to one of the large Pleistocene forms of *Terrapene carolina*. A similar *Terrapene* occurs at the nearby Hajny site, but that site is thought to be of greater age than the Burnham site (Martin 1992).

Two specimens (Fig. 8.2), a plastron fragment (#677) and a peripheral (#708), are from a very large turtle with a thick shell. We think that these fragments are from a relatively smooth-shelled example of *Hesperotestudo* sp. (see Preston 1979 for a discussion of late Pleistocene *Hesperotestudo*). This is the most northern late Pleistocene record of this genus. *Hesperotestudo* is not thought to have been able to tolerate freezing temperatures.

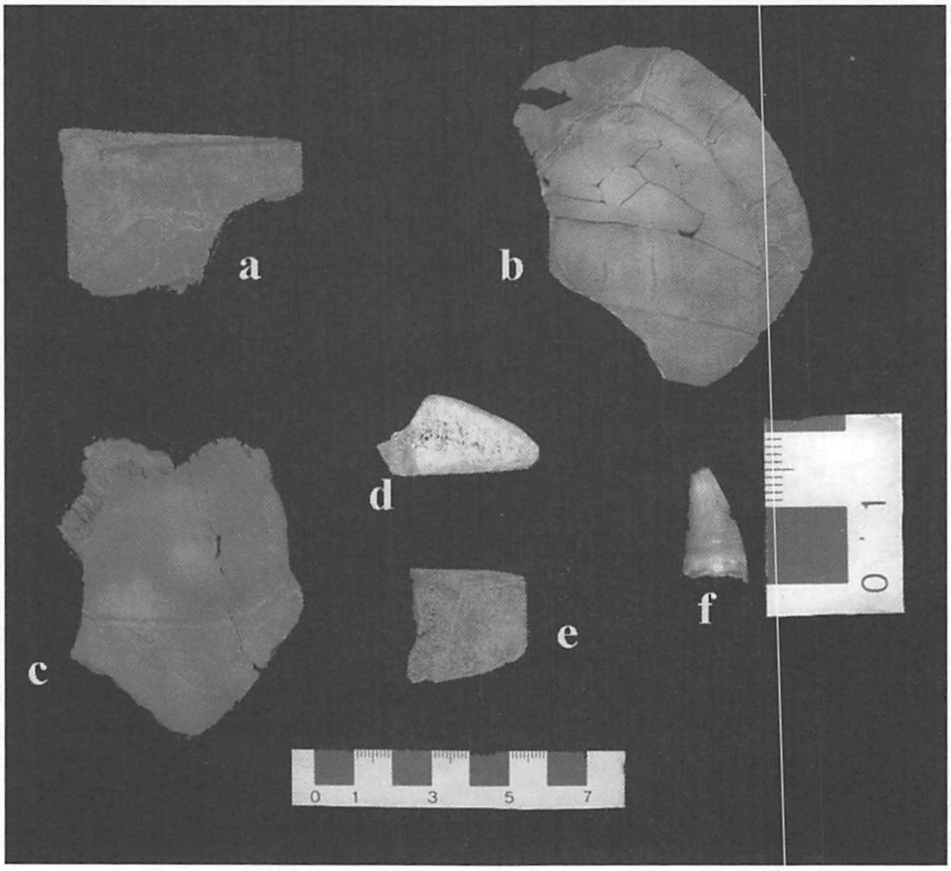


Figure 8.2. Terrapene carolina*: a, hypoplastron fragment with hinge (#705); b, right anterior carapace margin (#678).* Hesperotestudo sp.*: c, plastron fragment (#677); d, peripheral fragment, cross section view (#708); e, peripheral fragment, dorsal view (#708).* Alligator cf. mississippiensis *tooth (#491). Lower scale in cm is for items a-e, whereas the right scale is for item f.*

Snakes. A small number of identifiable snake vertebrae have been recovered. None of the taxa would be considered exceptional in the modern fauna around the Burnham site. They include: a racer, *Coluber constrictor* (#255); kingsnakes, *Lampropeltis* sp. (#209, #343, #380); water snakes, *Natrix* sp. (#117, #170, #213, #216, #375, #407, #457); and a rattlesnake, *Crotalus* sp. (#113, #200, #231, #376, #455, #697).

Lizards. An unidentified lizard is represented by two vertebrae (#123, #150).

Alligators. The most surprising faunal element at the Burnham site is a single, probably shed tooth (#491) of a fairly large (over one meter) alligator, *Alligator* cf *mississippiensis* (Fig. 8.2). Preston (1979) reports a single tooth from the slightly further north and older Cragin Quarry local fauna (late Illinoian to Sangamonian of Meade County, Kansas). The Burnham occurrence is the furthest northern record for its age (late Wisconsinan), although Herculaneum, Missouri, also yielded a late Wisconsinan record. Alligators require deep, permanent water and would not tolerate severe freezing winters. They generally feed on fish, turtles, and snakes. It is unlikely that the known fish fauna at Burnham could support an alligator. Turtles and snakes along with an occasional mammal may have supported an individual, but we doubt that there was a sustained population.

Birds (Aves)

Two unidentifial bones (#144, #149), a duck (#261), and unidentified passeriforms (songbirds; #483, #733) are the only bird remains so far found at the site. The absence of greater numbers of birds or small mammals may be due to the absence of a suitable owl roost over the pond, as raptorial birds are important sources of small vertebrate remains in most Pleistocene faunas.

Mammals (Mammalia)

Edentata. Two ground sloths appear to be present. The larger form (Fig. 8.3) is represented by a hyoid bone (#739) identified by G. MacDonald (1991, personal communication) as "*Glossotherium sp.*" The smaller form, represented by a tooth (#514), probably represents *Nothrotheriops shastensis* (Fig. 8.3).

Insectivora. Two insectivores are present in the Burnham site collection. One (Fig. 8.3) is a shrew, *Cryptotis parva*, which is represented by a mandible (#722). According to Bee et al. (1981), it prefers grasslands and successional growth around ponds. The other insectivore is the eastern mole, *Scalopus aquaticus*, which is represented by a humerus (#406). In western Kansas it is only found in valleys where the soil is soft and moist (Bee et al. 1981), and this restriction should also apply to northwestern Oklahoma. Both species can be found today in the vicinity of the Burnham site.

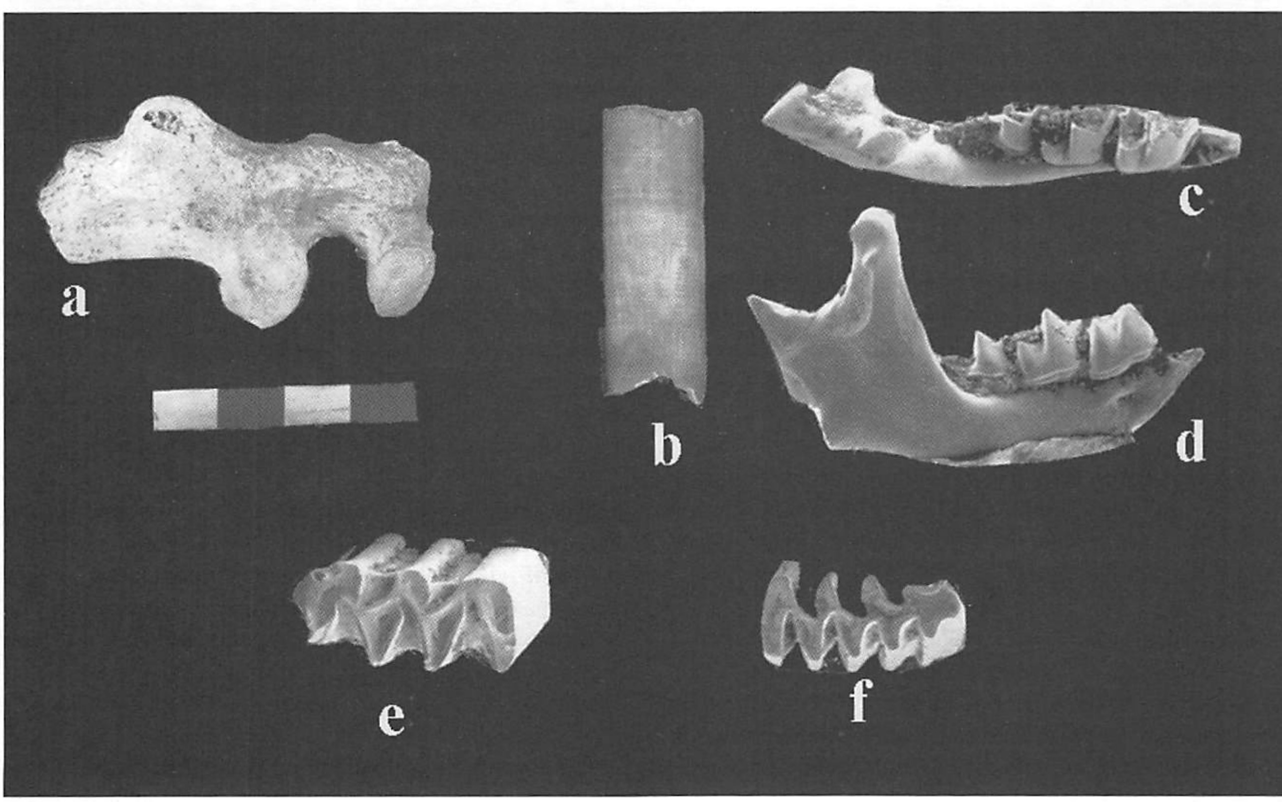


Figure 8.3. Ground sloth, Glossotherium sp.*: a, hyoid (#739). Ground sloth,* Nothrotheriops shastensis*: b, tooth (#514). Shrew,* Cryptotis parva*: c, occlusal view of mandible (#722); d, lateral view of mandible (#722). Bog lemming,* Synaptomys cooperi*: e, occlusal view of M_1 (#379). Prairie vole,* Microtus ochrogaster*: f, occlusal view of M_1 (#226). Items a-b scale in cm; items c-f scale is 10X.*

Leporidae. The jackrabbit, *Lepus* sp., is represented by a single tooth (#194), and the cottontail rabbit, *Sylvilagus* sp., by some isolated incisors (#120, #169, #438, #480) and a cheek tooth (#600).

Rodentia. The blacktailed prairie dog, *Cynomys ludovicianus*, is present (#168, #227, #265, #266, #332, #410, #410, #477, #488). It requires open areas of short or mixed-grass habitat and apparently cannot tolerate tall-grass (Goodwin 1990). Prairie dogs are accomplished burrowers, but make burrows of greater diameter than those observed in the Burnham excavations. The presence of prairie dogs indicates the absence of continuous forest and the probable absence of tall-grass prairie (Goodwin 1990).

Vole specimens are common at the site (#145, #155, #167, #181, #196, #207, #226, #229, #253, #308, #323, #328, #358, #371, #389, #393, #439, #461, #468, #471, #569, #578, #582, #616, #617). The prairie vole, *Microtus ochrogaster*, is hard to distinguish from the woodland vole, *Microtus pinetorum*. The M1 specimens have a broadly open connection between the anterior loop and the alternating triangles (Fig. 8.3f). This feature along with biogeographic considerations favor an identification of prairie vole. Prairie voles construct underground tunnels and can live in drier grasslands than some of the other arvicoline rodents.

The only other arvicoline present at the site is the southern bog lemming, *Synaptomys cooperi* (Fig. 8.3e). The form present is unusually large as indicated by two isolated teeth and a mandible (#355, #379, #415). Southern bog lemmings still occur with the prairie vole in southeastern Kansas, and this is presently the southernmost limit of their range. They favor damp to wet grassland surrounding springs (Bee et al. 1981).

Several wood rat molars (#348, #540, #575, #583, #673) were found at Burnham and assigned to *Neotoma* cf *floridana*. The wood rat normally requires a few trees and prefers rock outcrops for shelter. It presently occurs in the vicinity of the Burnham site.

A pocket gopher, *Geomys* sp., is represented at Burnham by teeth, mandibles, and a few limb bones. The pocket gopher has a wide modern distribution and prefers deep, sandy soils with few trees (Bee et al. 1981).

Carnivora. *Canis latrans* (coyote) is identified on the basis of a radius (#737) and an enamel fragment (#172) from the labial side of the left M-1. The only other carnivore represented is a large bear for which there is a third metatarsal (#736). This bone is smaller than the third metatarsal of a female short-faced bear (*Arctodus simus*) from Natural Trap Cave, but is larger than any black bear (*Ursus americanus*) in the University of Kansas collection. The Pleistocene *Ursus americanus* was larger than the modern form (Kurten and Anderson 1980), and assignment to the large Pleistocene form is reasonable.

Artiodactyla. A fragment of a camelid metatarsal (#267/#268), as well as a vertebral fragment and incisor (#111, #573), can be referred to the llamine camel, *Hemiauchenia* sp. *Hemiauchenia* was a highly cursorial llama that is common in late Pleistocene sediments of the southern states.

A large (elk-sized) cervid is represented by the posterior margin of a lower jaw and some tooth fragments (#285, #456, #466, #626).

The bison (Figs. 8.4 and 8.5j) is the most completely represented artiodactyl at the site. It consists of a skull, jaw, teeth, horn core fragments, scapula, scaphoid, and various vertebrae and ribs (#258, #280, #284, #493, #494, #495, #496, #497, #498, #499, #500, #501, #504, #511, #512, #603, #634, #637, #660, #661, #730, #731, #732). The teeth of the Burnham bison are completely worn out and the horns are large, indicating that this individual was a bull at the extreme range of old age.

This bison is a long or "straight-horned" bison of the group that includes *Bison latifrons* and *B. alleni*. The identification of North American long-horned bison is chaotic. McDonald (1981) assigns some taxa to hybrids between species, for instance, *B. willistoni* is considered a hybrid between *B. latifrons* and *B. priscus*, and *B. crassicornis* is considered a hybrid population of Eurasian and North American species (McDonald 1981:120). It is difficult to evaluate the biological reality of such schemes, and the assignment of very dissimilar specimens from Texas and Oklahoma to the expected range of variation of Alaskan species is biogeographically risky. Because of this we have decided to use *Bison chaneyi* (Cook 1928). If *B. chaneyi* is a junior synonym, we think it is more likely to be included in *B. alleni* than in *B. alaskensis*, a species whose separation from *B. priscus* and *B. crassicornis* is uncertain. According to McDonald (1981:126), "*B. alaskensis* is usually undifferentiated from *B. priscus* by European writers." The most striking difference between *B. chaneyi* and *B. alleni* is the somewhat less recurved horn cores of the latter.

The taxonomy of this group is so unsettled that Kurten and Anderson (1980) included all of the straight-horned bison in *B. latifrons*, while others recognize *B. willistoni* and *B. chaneyi* as separate species. Schultz (1968) restricts this general type of bison to pre-Sangamonian deposits. The Burnham bison is important as it shows unequivocally that this type of bison persisted into the late Wisconsinan.

The horn core length of the Burnham bison (Table 8.1) is too short for typical *Bison latifrons*, although its basal diameter is well within the range of that species (Skinner and Kaisen 1947). The high curvature of the horns is not typical of *B. alleni* and compares well with *B. chaneyi*. We postulate the existence of a long-horned bison population

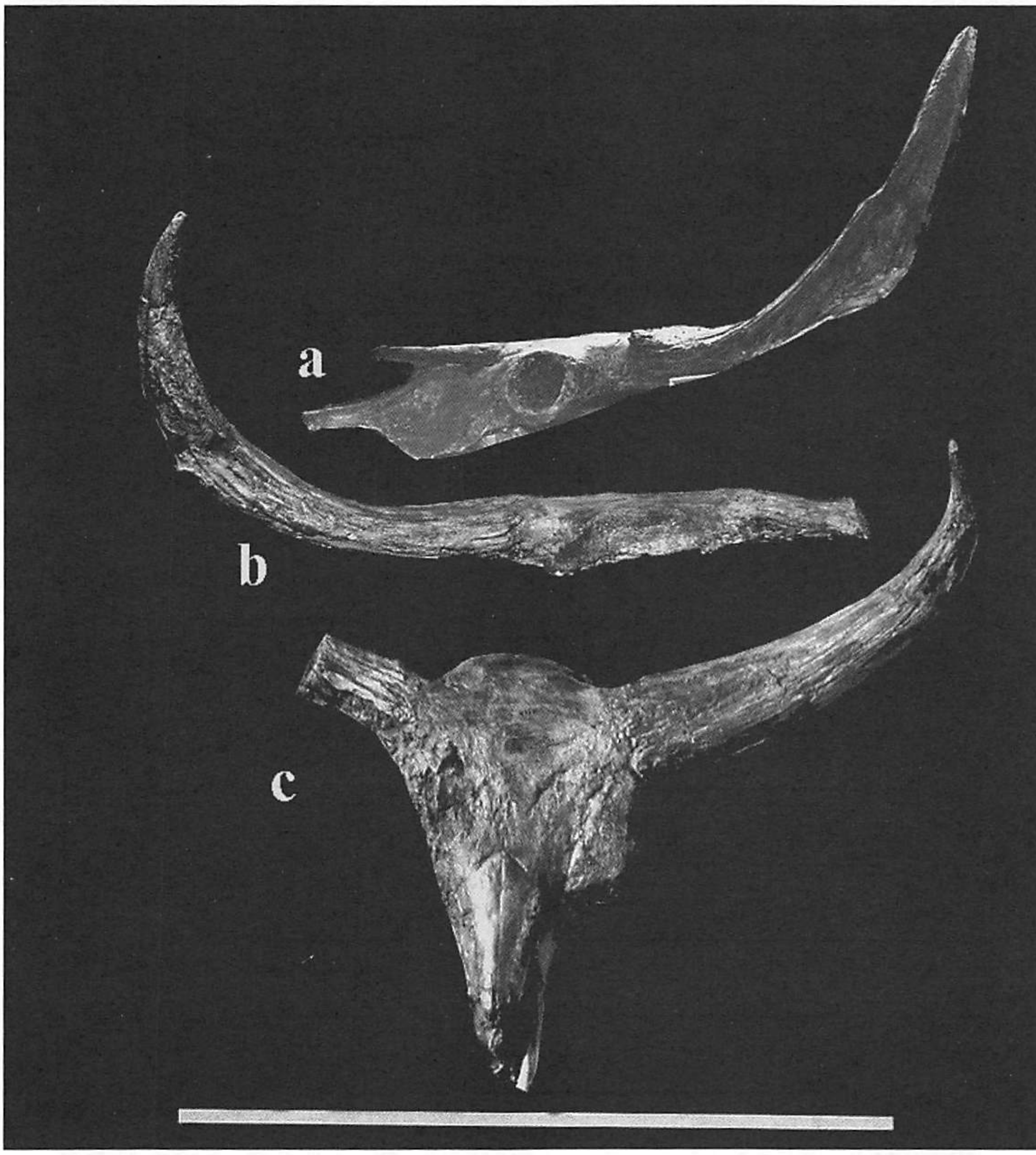


Figure 8.4. Views of Bison chaneyi *skull (#730): a, lateral view; b, posterior view; and c, dorsal view. Scale bar is one meter.*

Table 8.1. Comparative Horncore Measurements of Bison

Horncore Measurement in millimeters	Burnham *Bison*	*Bison chaneyi* Holotype	*B. alleni* Holotype	*B. alaskensis* Holotype
Tip to burr on the upper curve	558	545	640	475
Tip to burr on the lower curve	660	630	750	528
Tip to tip	1002*	1071	?	1115
Transverse diameter	147	142	143	129
Width between horncores and orbits	325*	320	?	339

Non-Burnham bison measurements from Skinner and Kaisen (1947) who also describe methods.
*Measured to the midline and doubled.

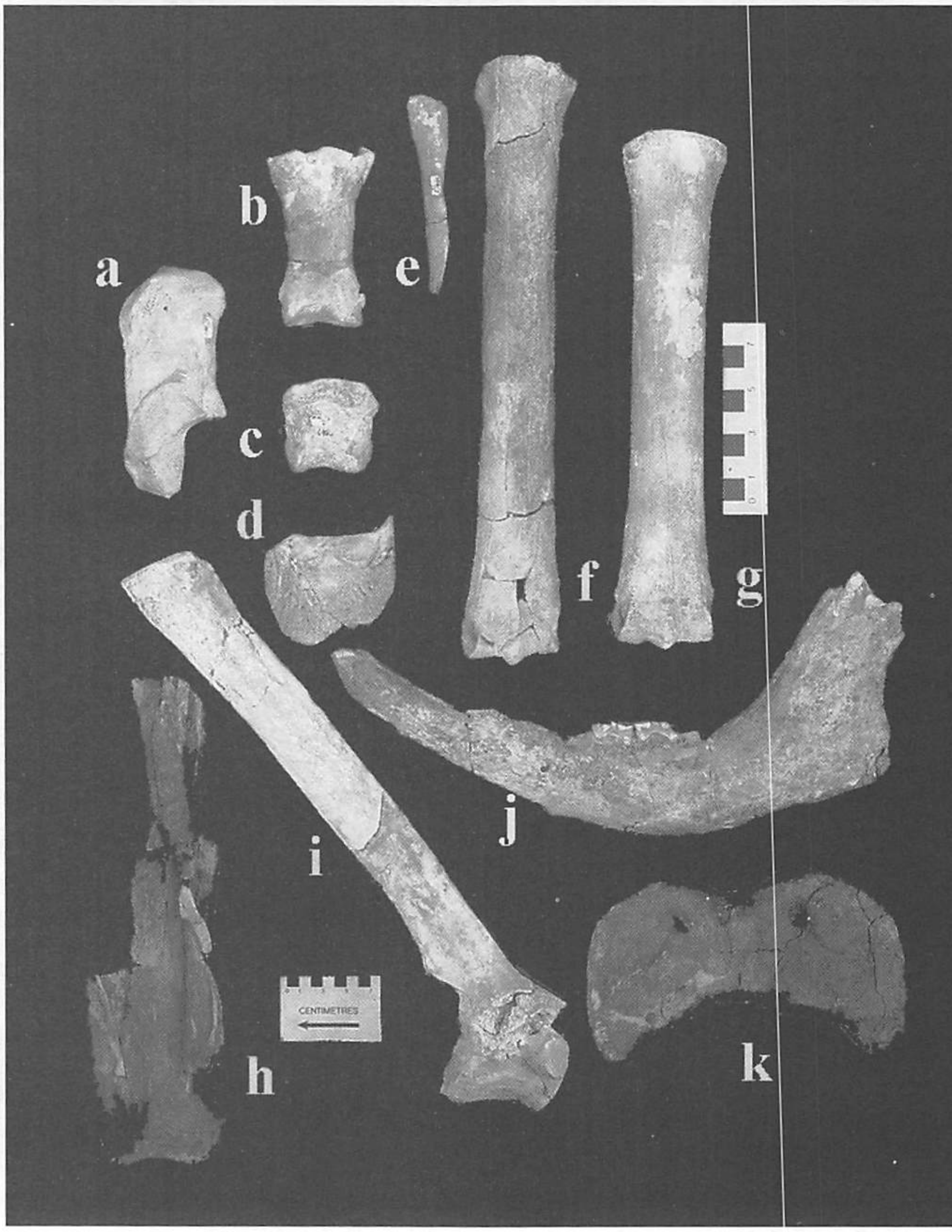


Figure 8.5. Equus (Hemionus) sp.*: a, calcaneum (#650); b, first phalanx (#642); c, second phalanx (#642); d, third phalanx (#642); e, vestigial metacarpal (#738); f, metatarsal III (#502); g, metacarpal III (#744).* Bison chaneyi*: h, scapula (#496); i, thoracic vertebra (#501/660); j, left mandible (#493); k, atlas vertebra (#495). Items a-g, right cm scale; items h-k, lower cm scale.*

assignable to *B. chaneyi* in the very late Pleistocene of the southern United States. The Burnham site is the only co-occurrence of possible lithic artifacts with a long-horned bison.

Proboscidea. A number of ivory scraps and two bone fragments (#505, #636) demonstrate the presence of a proboscidean, and two tooth fragments (#137, #219) identify it as *Mammuthus*.

Perissodactyla. Two kinds of horses are present. There is a large (draft horse-sized) form (Fig. 8.6b), *Equus* sp. (#503), and a small wild ass (Figs. 8.5a-g and 8.6a-e), *Equus (Hemionus)* sp. (#101, #108, #109, #156, #157, #158, #159, #161, #162, #166, #177, #259, #262, #263, #264, #269, #270, #271, #272, #281, #283, #339, #489, #502, #513, #515, #517, #519, #520, #521, #522, #525, #527, #555, #556, #557, #593, #604, #605, #606, #607, #608, #609, #610, #611, #613, #614, #621, #622, #623, #624, #625,

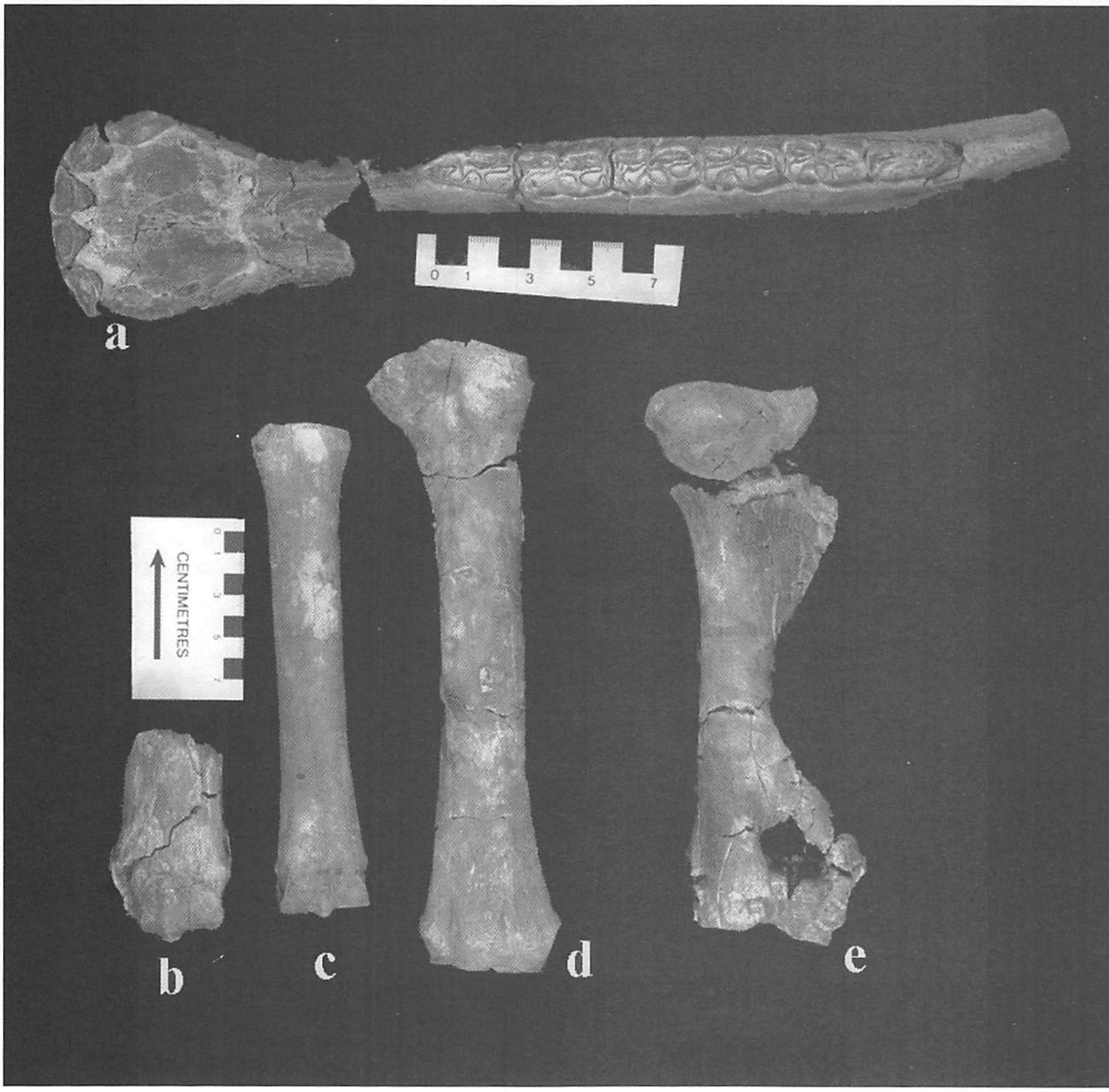


Figure 8.6. Equus (Hemionus) *sp.: a, partial mandible (#504).* Equus *sp.: b, distal metapodial fragment (#503).* Equus (Hemionus) *sp.: c, metacarpal III (#744; same as in Fig. 8.5g); d, radius (#745); e, humerus (#740). Item a, top cm scale; items b-e, left cm scale.*

#638, #639, #640, #641, #642, #643, #644, #645, #646, #647, #648, #649, #650, #651, #652, #653, #654, #655, #656, #657, #658, #659, #668, #680, #720, #721, #723, #724, #725, #728, #729, #738, #740, #741, #743, #744, #745). The ass is probably the most common and best represented animal at the Burnham site and seems to be identical to 17,000 year-old specimens from Natural Trap Cave in Wyoming. Natural Trap also contains a large equid (Wang and Martin 1993)..

Bone Distribution

The distribution of vertebrate remains within the site is not very informative. Plots comparing sunfish (Figs. 8.7 and 8.8) to arvicolids (Figs. 8.9 and 8.10) show essentially the same distributions. The burned bones are concentrated in the same squares as the lithic artifacts, but so are the fish occurrences (Figure 8.11). Ivory flakes are also more abundant in those squares (Figs. 8.12 and 8.13), but no fragments found were culturally modified. There is a tendency for the vertebrate remains to form a band running northeast, and this may reflect a relationship with the pond's margin.

Conclusions

The snails, alligator, and fine-grained sediments of the Burnham site all indicate permanent ponded water, but many

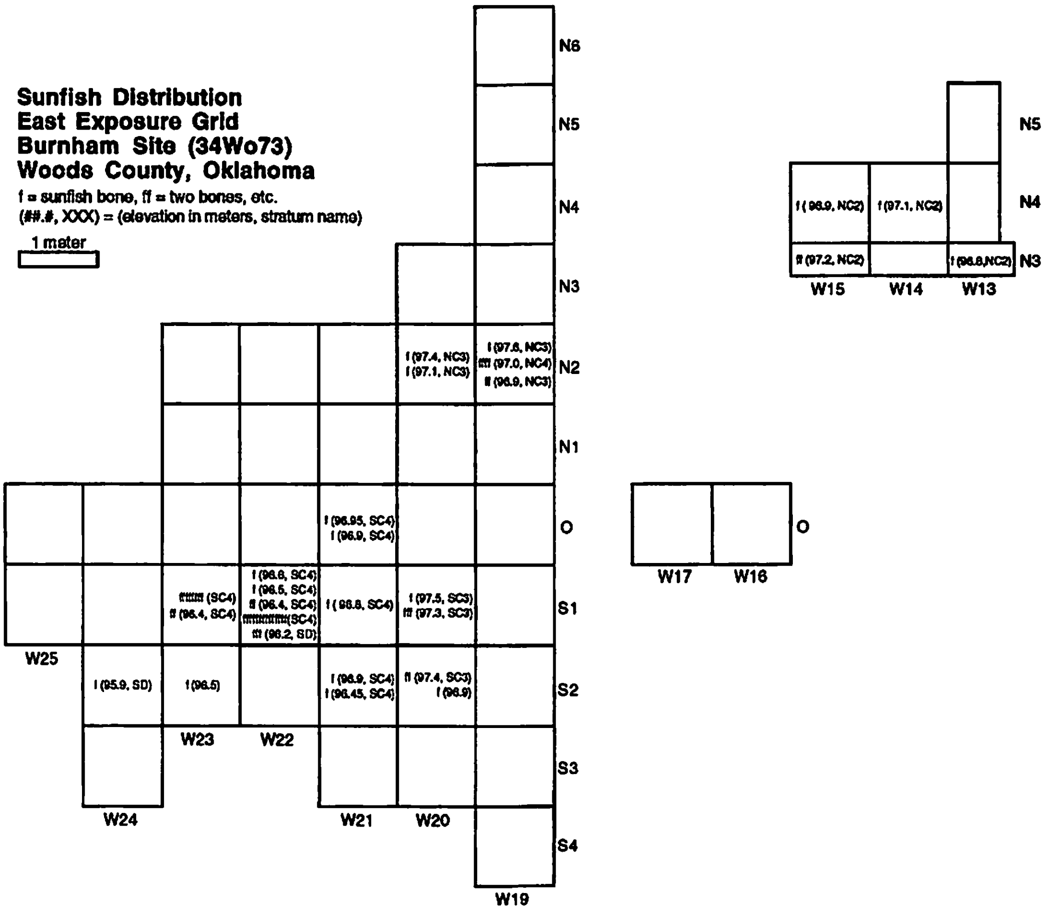


Figure 8.7. Distribution of sunfish bones in the East Exposure at the Burnham Site.

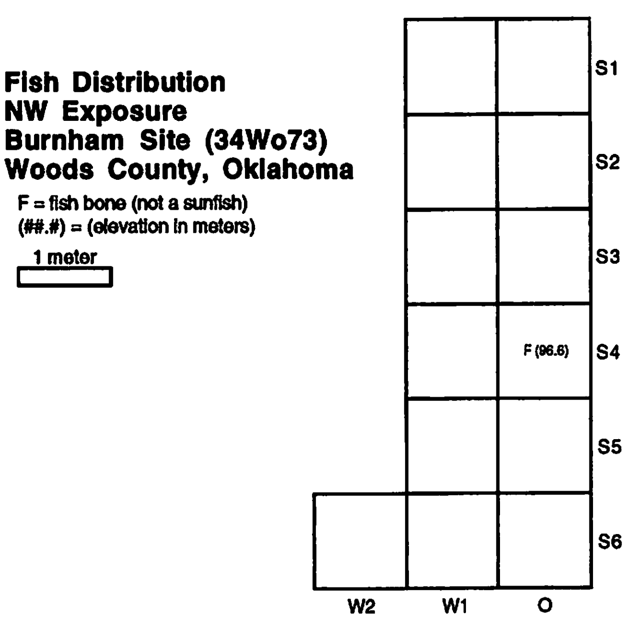


Figure 8.8. Distribution of fish bones in the Northwest Exposure at the Burnham Site.

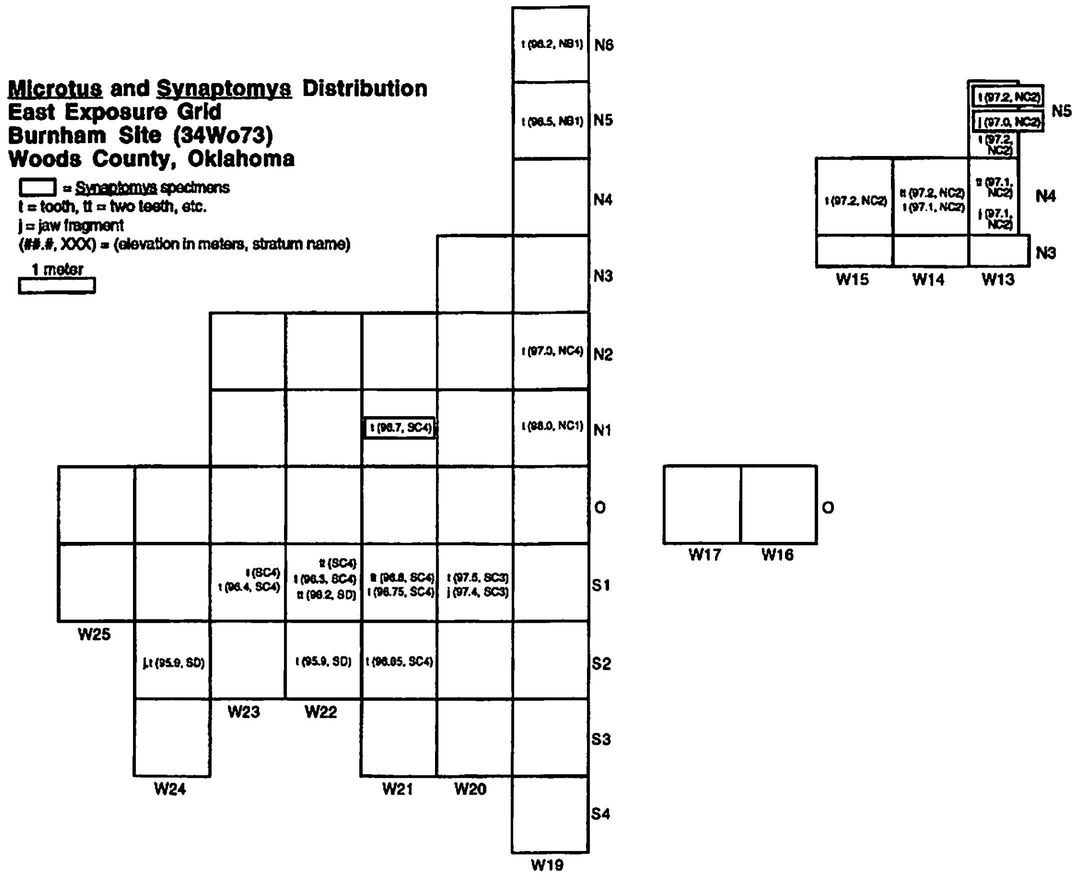


Figure 8.9. Distribution of bones of Microtus *and* Synaptomys *in the East Exposure at the Burnham Site.*

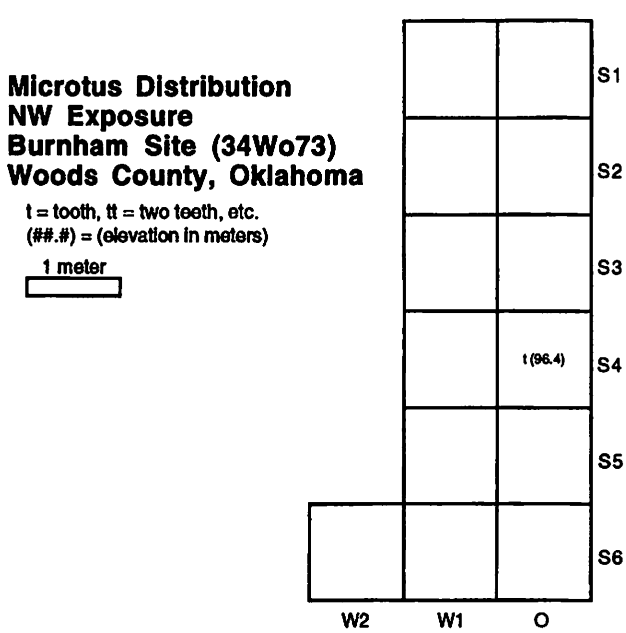


Figure 8.10. Distribution of Microtus *bones in the Northwest Exposure at the Burnham Site.*

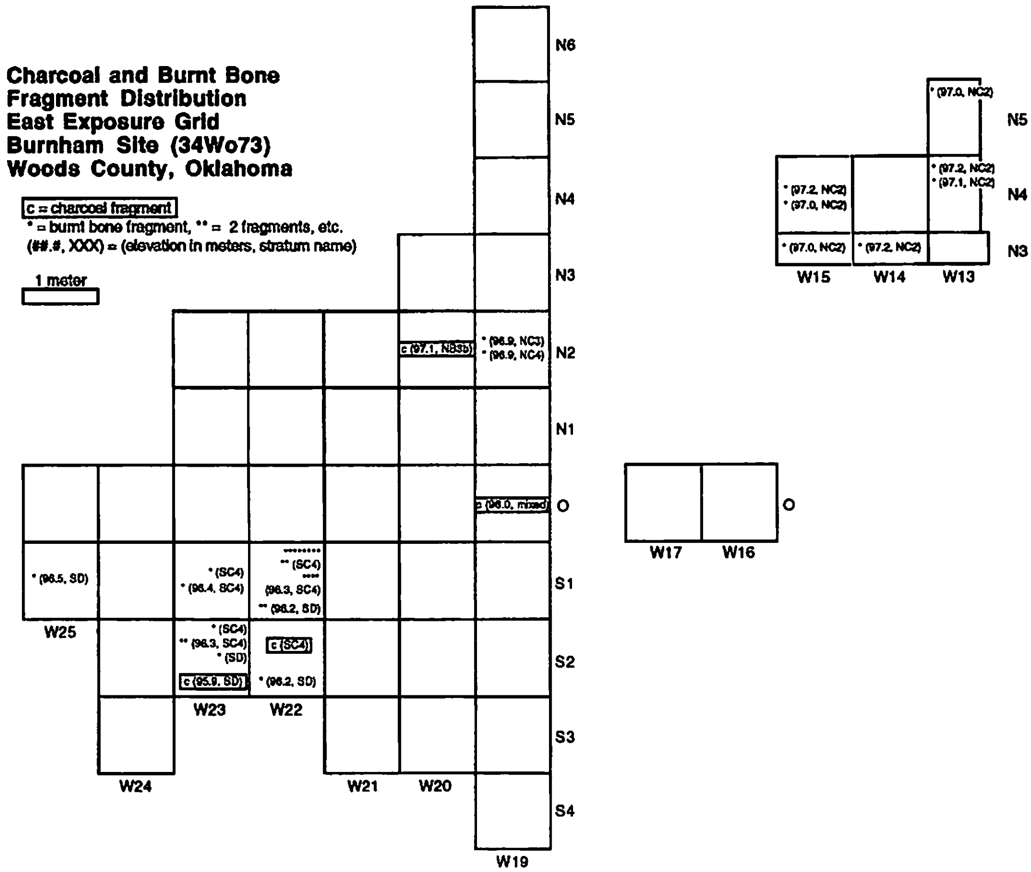


Figure 8.11. Distribution of charcoal and burned bone in the East Exposure at the Burnham Site.

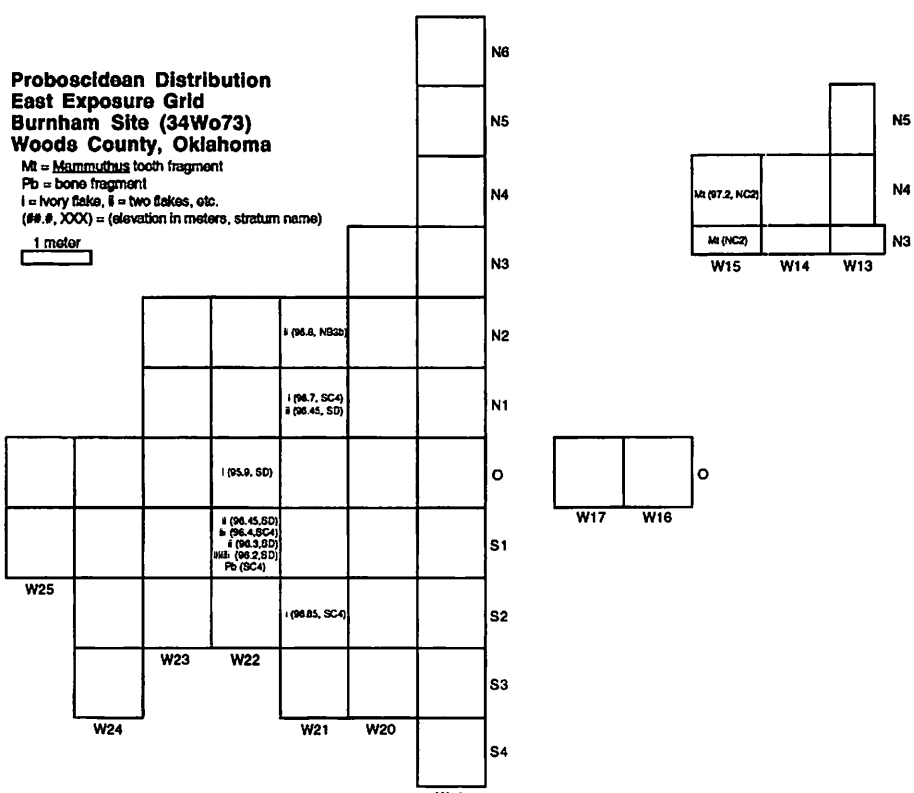


Figure 8.12. Distribution of proboscidean bones in the East Exposure at the Burnham Site.

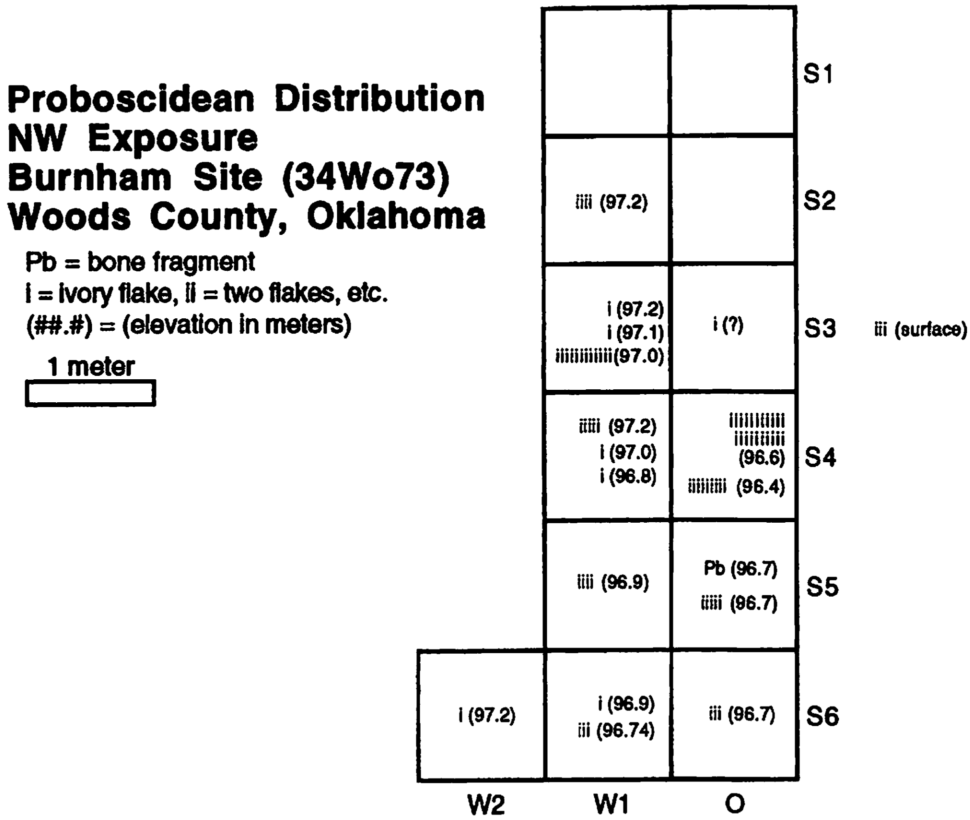


Figure 8.13. Distribution of proboscidean bones in the Northwest Exposure at the Burnham Site.

paleoecological indicators of such an environment are absent, including most of the commonly found species of fish, pond turtles, muskrats, water rats, and beavers. Only a single species of small sunfish is present, and it belongs to a species with notable dispersal abilities. It seems impossible that the pond could have been associated with a permanent stream of any size, and it seems likely that the Burnham site was semi-isolated from other bodies of water, except during the highest water in the springtime when an occasional fish or soft-shelled turtle was able to enter it. On other hand, the alligator would require relatively deep, permanent water. We think this situation could best be explained by a spring fed sinkhole that was drained by a small creek, one that would not have been large, even in flood periods.

During drought periods, the spring would have reduced flow, and the pond margin would have retreated. Many of the bones show etching from roots, indicating that a surface with terrestrial vegetation had developed soon after their burial. In a few cases the bones show etching on only one side. In these cases, the pond retreated before the bone was completely buried, and roots acted on the buried portion. When the pond level rose, the upper part of the pond was buried by normal lacustrine sediments, and root action ceased. Coupled with these changes in water level are zones of bioturbation. Judging from the size and shape of the burrows, crayfish may be the most important bioturbators with occasional rodent burrowing. The putative crayfish burrows appear to be penecontemporaneous with the infilling of the pond.

Spring turbation is indicated by the development of a high polish on limited areas of some bones and by indications of sediment and oxidation boils. The discovery of the bison skull resting nearly vertically on one horn core indicates that it must have come in at a high angle off of a steep slope and became imbedded in a soft bottom.

Small vertebrates are not common in the Burnham sediments, and those that have been found probably lived in or adjacent to the site. In many Pleistocene small vertebrate assemblages, raptorial birds are thought to have accumulated much of the collections. It may be that adequate roosts for such birds were not available in the portion of the deposit that was excavated. The presence of hackberry (*Celtis* sp.) fruits and paw paw wood in the deposit indicate that at least some trees were locally present.

The entire vertebrate fauna has a very southern aspect, showing a much greater affinity with Gulf Coast faunas than with the well-known late Pleistocene faunas of Kansas and Nebraska. Especially southern in aspect are the alligator, large terrapene, and the giant tortoise (*Hesperotestudo*). The alligator and giant turtoise are not thought to have been able to tolerate extended periods of freezing temperatures. Somewhat greater or more effective precipitation than today is also indicated. The only animal of northern aspect is the southern bog lemming, and a relic population of this animal still persists in spring fed marshes and adjacent meadows less than a hundred miles north in Kansas.

Acknowledgments

This study would not have been possible without the generous support of the Oklahoma Archaeological Survey and Dr. Don Wyckoff who made the collection available. We also thank the Burnham family for their cooperation. K. Shaw identified the fish remains; N. Woodman identified the shrew; and G. MacDonald identified the sloth hyoid. We have benefited from conversations with J. Howe on Pleistocene horse taxonomy. J. Chorn and C. Burres read the manuscript and made helpful comments.

References Cited

Bee, J.W., G.E. Glass, R.S. Hoffman, and R.R. Patterson. 1981. *Mammals in Kansas.* University of Kansas Publication, Museum of Natural History, Series No.7. Lawrence.

Goodwin, T. 1990. *Systematics, Biogeography, and Evolution of Fossil Prairie Dogs* (Genus *Cynomys*). Ph.D. dissertation, University of Kansas. Lawrence.

Hibbard, C.W. and D.W. Taylor. 1960. *Two Late Pleistocene Faunas from Southwestern Kansas.* University of Michigan, Museum of Paleontology, Contributions 16(1). Ann Arbor.

Kurten, B. and E. Anderson. 1980. *Pleistocene Mammals of North America.* Columbia University Press, New York.

Martin, L.D. 1977. A Whooping Crane from the late Pleistocene of Kansas. *Kansas Ornithological Society Bulletin* 28:22-23.

Martin, L.D. 1992. Hajny Local Fauna. Oklahoma Archeological Survey, *Studies of Oklahoma's Past* 17:97-100. Norman.

McDonald, J.N. 1981. *North American Bison.* University of California Press. Berkeley.

Preston, R.E. 1979. Late Pleistocene Cold-Blooded Vertebrate Faunas from the Mid-Continental United States, I: Reptilia; Testudines, Crocodilia. *Claude Hibbard Memorial Papers on Paleontology*, 6:19. University of Michigan, Ann Arbor.

Schultz, C.B. 1968. The Stratigraphic Distribution of Vertebrate Fossils in Quaternary Eolian Deposits in the Midcontinent Region of North America. *Loess and Related Eolian Deposits of the World*, edited by C.B. Schultz and J.C.Frye, pp.369. University of Nebraska Press, Lincoln.

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.

Stewart, J.D. 1987. Latitudinal Effects in Wisconsinan Mammalian Faunas of the Plains.*Kansas Geological Survey, Guidebook Series* 5:153-158.

Tihen, J.A. 1958. Comments on the Osteology and Phylogeny of Ambystomatid Salamanders.*Bulletin of the Florida State Museum* 3:1-50.

Wang, X. and L.D. Martin. 1993. Natural Trap Cave. *Research and Exploration* 9(4):422-435.

Wells, P.V. and J.D. Stewart. 1987. Spruce Charcoal, Conifer Macrofossils, and Landsnail and Small-Vertebrate Faunas in Wisconsinan Sediments on the High Plains of Kansas. *KansasGeological Survey, Guidebook Series* 5:129-140.

Table 8.2. Faunal Identification Summary for the Burnham Site.

University of Kansas Temporary #	Provenience	Identification
	Mammuthus	
137	East Grid, N4-15, NE ¼ level 97.2	*Mammuthus* tooth fragment
219	East Grid, N3-W15, North Balk, NC2 stratum	*Mammuthus* tooth fragment
505	East Grid, S1-W22, bone concentration, SC4 stratum	*Proboscidian* bone fragment
636	NW Exposure, 0-S5, level 96.7, mapped item #1	*Proboscidian* bone fragment
	Ivory, probably Mammuthus	
104	NW Exposure, surface, west side of modern pond	2 flakes of ivory
242	NW Exposure, surface, just east of 0-S3	Ivory flake
274	NW Exposure, 0-S4, level 96.4	9 flakes of ivory
275	NW Exposure, 0-S5, level 96.7	5 flakes of ivory
276	NW Exposure, 0-S4, level 96.6	16 flakes of ivory
278	NW Exposure, 0-S4, level 96.6	5 flakes of ivory
279	NW Exposure, 0-S6, 96.7	3 flakes of ivory
314	East Grid, S1-W22, level 96.4, SC4 stratum	3 flakes of ivory
316	East Grid, S1-W22, level 96.2, SD stratum	1 flake of ivory
319	East Grid, S1-W22, level 96.3, SD stratum	2 flakes of ivory
326	East Grid, S1-W22, level 96.2, SD stratum	7 flakes of ivory
341	East Grid, 0-W22, level 95.9, NE ¼, SD stratum	1 flake of ivory
364	East Grid, N2-W21, level 96.8, NC3 stratum	2 flakes of ivory
366	East Grid, N1-W21, level 96.7, SE ¼, SC4 stratum	1 flake of ivory
367	East Grid, N1-W21, level 96.45, NW ¼, SD stratum	2 flakes of ivory
369	East Grid, S2-W21, level 96.85, NW &SE 1/4s, SC4	1 large flake of ivory
561	NW Exposure, 0-S3	1 flake of ivory
664	NW Exposure, S6-W1, level 96.9	1 flake of ivory
667	NW Exposure, S6-W1, level 96.74	3 flakes of ivory
675	NW Exposure, S4-W1, level 97.2	5 flakes of ivory
676	NW Exposure, S4-W1, level 96.8	1 flake of ivory
682	NW Exposure, S6-W2, level 97.2	1 flake of ivory
687	NW Exposure, S3-W1, level 97.1	1 flake of ivory
689	NW Exposure, S3-W1, level 97.2	1 flake of ivory
690	NW Exposure, S3-W1, level 97.0	5 flakes of ivory
693	NW Exposure, S3-W1, level 97.0	7 flakes of ivory
699	NW Exposure, S2-W1, level 97.2	4 flakes of ivory
711	NW Exposure, S4-W1, level 97.0	1 flake of ivory
716	NW Exposure, S5-W1, level 96.9	4 flakes of ivoiry
'	***Bison chaneyi***	
258	NW Exposure, surface of gully exposure	Tooth
280	NW Exposure, W#5 item mapped	Tooth fragment
284	SW Exposure, near horse bone fragments	Horn core fragments
493	East Grid, S2-W22, stratum SC4	mandible
494	East Grid, S2-W23, Bones #1 and #3	4 rib fragments
495	East Grid, S2-W23, stratum SD	Atlas
496	East Grid, S1-W22, stratum SD	Scapula
497	East Grid, S2-W22, stratum SD	Thoracic vertebra
498	East Grid, S1-W22, Bone #3, stratum SD	Scapula fragment
499	East Grid, S3-W21, Bone #1, stratum SD	Rib fragment
500	East Grid, S1-W22, 75 cm below surface, stratum SD	Thoracic vertebra
501	East Grid, S2-W22, Bone #5, stratum SD	Thoracic vertebra
504	East Grid, S2-W24	Mandible
511	Northwest Exposure, 0-S4, mapped bone #9	Upper third molar
512	Northwest Exposure, 0-S4, mapped item	Polished mandible fragment
603	East Grid, S1-W23, level 8, 25cm north and 20cm west of SE corner	Scaphoid
634	East Grid, N5-W13, NC2 stratum	Partial tooth root
637	East Grid, N3-W13, Bone labeled TT, NC2 stratum	Horn section
660	East Grid, bone labeled 34Wo73/42	Vertebral spine
661	East Grid, S1-W21, mapped bone A	Vertebral spine
730	East Grid, S2-W22, stratum SC4	Skull
731	East Grid, S3-W20, level 97.2	Horn core and skull fragments
732	East Grid, S2-W24, mapped bone B	Rib fragments

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations

University of Kansas Temporary #	Provenience	Identification
	Cervids (Deer, Elk)	
285	Southwest Exposure, Surface	Large mandible fragment (coronoid and condyloid)
456	East Grid, S2-W21, level 96.5, SC4 stratum, waterscreen	Third molar fragment
466	East Grid, S2-W24, SW ¼, level 96.0, SD stratum waterscreen	Lower incisor or canine
626	East Grid, S1-W23, level 96.2, SD stratum	Lower incisor or canine
	***Hemiauchenia* (Llama)**	
111	East Exposure, surface mapped item #16	Posterior zygapophysis
267	Southwest Exposure, surface at base of channel fill	Metapodial fragment
268	Southwest Exposure, surface at north side of channel fill (#267 and 268 fit together)	Metapodial fragment
573	East Grid, S1-W23, level 8 (70-80 cm), 3 cm west of mapped carpal	Incisor
	Artiodactyls unspeciated	
618	East Grid, N4-W13, SE ¼ , level 96.9, stratum NC2	1 tooth fragment
635	East Grid, S2-W23, at end of nasal bones of *B. chaneyi*, stratum SC4	1 tooth fragment
	***Equus (Hemionus)* sp. (Small wild ass)**	
101	Northwest Exposure, surface	3 teeth fragments
108	East Exposure, surface, uncertain stratum	Transverse process of Vertebra
109	Northwest Exposure, eroded slope	3 teeth fragments
156	East Grid, N4-W14, level 97.0, NE ¼, NC2 stratum	Sesamoid
157	East Grid, N4-W14, Level 97.1, SW ¼ , NC2 stratum	Carpal
158	East Grid, N4-W14, Level 97.1, SW ¼ , NC2 stratum	Sesamoid
159	East Grid, N4-W14, Level 97.1, SW ¼ , NC2 stratum	Tooth fragment
161	East Grid, N4-W14, Level 97.0, SW ¼ , NC2 stratum	Sesamoid
162	East Grid, N4-W14, Level 97.0, SW ¼ , NC2 stratum	Carpal
166	East Grid, N4-W14, Level 97.0, NW ¼ , NC2 stratum	Sesamoid
177	East Grid, N4-W14, Level 97.2, NW ¼ , NC2 stratum	Tooth fragment
259	Southwest Exposure, surface	Metapodial
262	East Exposure, surface, uncertain stratum	Phalanx
263	East Exposure, surface, uncertain stratum	Phalanx
264	East Exposure, surface, uncertain stratum	Tooth fragment
269	East Grid, S2-W19, surface, SC3 stratum	2 teeth fragments
270	Southwest Exposure, surface at west end of gleyed material	Vertebra
271	East Grid, S2-W23, eroding from SW corner, SD stratum	2 rib fragments
272	East Grid, S2-W20, surface of SC3 stratum	Caudal vertebra
281	Southwest Exposure, surface	Tooth
283	Southwest Exposure, surface	Phalanx
339	East Grid, 0-W22, SE ¼ , Level 96.0, SD stratum	Tooth
489	East Grid, S2-W24, SW ¼ , level 95.9, SD stratum	Tooth fragment
502	Southwest Exposure, surface	Metapodial #2
503	Southwest Exposure, surface	Distal metapodial (larger than other horse metapodials)
513	East Grid, 0-W22, level 96.52, mapped item #3, SC4 stratum	Tooth
515	East Grid, 0-W22, Level 96.9, SC4 stratum	Tooth fragment
517	East Grid, S1-W23, Level 96.4, mapped item, SC4 stratum	Tooth
519	East Grid, 0-W22, mapped item #2, SD stratum	Ulna distal tip
520	East Grid, N4-W14 and N3-W14, Bone block A, NC2 stratum	Metapodial proximal end
521	East Grid, N3-W14, Bone block E, NC2 stratum	Metapodial proximal end
522	East Grid, S3-W19, Level 96.9, SC3 stratum	Tooth fragment
525	Southwest Exposure, uncertain elevation, north side of exposure	Tooth
527	East Grid, N1-W19, Level 97.8, mapped item B, NC1 stratum	Tooth
555	Southwest Exposure, surface	T1 incisor
556	Southwest Exposure, surface	T2 incisor
557	Southwest Exposure, surface	T3 incisor
593	East Grid, S2-W22, level 6 (50-60 cm) waterscreen fill around skull, SC4 stratum	Tooth fragment
604	East Grid, N3-W14, mapped bone KK, NC2 stratum	Tooth
605	East Grid, N4-W13, mapped bone XX, NC2 stratum	Tooth
606	East Grid, N3-W15, mapped bone JJ, NC2 stratum	Tooth

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Equus (cont)	
607	East Grid, N3-W14, mapped bone P, stratum NC2	1 tooth fragment
608	East Grid, N5-W13, mapped bone UU, stratum NC2	1 tooth
609	East Grid, N3-W14, mapped bone QQ, NC2 stratum	Tooth-mandible section
610	East Grid, uncertain stratum but probably "Horse Bone Bed"	2 teeth
611	East Grid, N4-W15, mapped bone K, NC2 stratum	Tooth
613	Southwest Exposure, surface	Tooth
614	Southwest Exposure, surface	Terminal phalanx
622	East Grid, S1-W19, level 97.8, NC1 (?) stratum	Tooth fragment
623	East Grid, S4-W19, level 97.0, SC3 stratum	Vertebra fragment
624	East Grid, S3-W19, level 97.0, SC3 stratum	Tooth fragment
625	East Grid, S3-W19, level 96.9, SC3 stratum	Tooth fragment
638	East Grid, N3-W14 and N4-W14, mapped Block D, NC2 stratum	4 vertebrae
639	East Grid, N3-W14 and N4-W14, mapped Block D, NC2 stratum	Metapodial distal end
640	East Grid, N3-W14, mapped Block C, NC2 stratum	4 vertebrae
641	East Grid, N3-W14, mapped Block C, NC2 stratum	2 ulna fragments
642	East Grid, N3-W14, mapped Block C, NC2 stratum	Phalanges I-III
643	East Grid, North 3 backhoe trench, uncertain provenience	Distal radius
644	East Grid, North 3 backhoe trench, uncertain provenience	Vertebra fragment
645	East Grid, N4-W13, level 96.8, mapped bone K, NC2 stratum	Ulna fragment
646	East Grid, N4-W14 and N3-W14, level 96.8, mapped bone block A, NC2 stratum	Ulna fragment
647	East Grid, N4-W14 and N3-W14, level 96.8, mapped bone block A, NC2 stratum	2 rib fragments
648	East Grid, N4-W14 and N3-W14, level 96.8, mapped bone block A, NC2 stratum	3 carpal bones
649	East Grid, N3-W14, mapped bone WW, NC2 stratum	Distal radius
650	East Grid, N3-W14, mapped bone DD, NC2 stratum	Calcaneum
651	East Grid, N3-W14, mapped Block F, NC2 stratum	Femur
652	East Grid, N3-W14, mapped bone FF, NC2 stratum	Phalanx
653	East Grid, N4-W14, mapped bone BB, NC2 stratum	Mandible
654	East Grid, N4-W14, mapped bone CC, NC2 stratum	Scapula fragment
655	East Grid, mapped bone 34Wo73/31	Proximal femur
656	East Grid, S2-W24, mapped bone C	Proximal ulna and radius
657	East Grid, surface of backfill from North 3 backhoe trench	Partial tooth
658	East Grid, S1-W19, level 97.4	Tooth fragments
659	East Grid, North 3 backhoe trench, from backfill	Tooth fragment
668	Northwest Exposure, S6-W1, level 97.4, plotted in profile	Rib fragments
680	Northwest Exposure, S6-W2, level 97.3	6 tooth fragments
720	Southwest Exposure, found near horse mandible fragments	Astragalus and Calcaneum
721	Southwest Exposure, mapped bone 91F	Vertebra fragment
723	Southwest Exposure, mapped bone 91G	Partial incisor
724	Southwest Exposure, mapped bone 91D	Phalanx
725	Southwest Exposure, eroded from uncertain elevation	Distal radius
728	Southwest Exposure, mapped bone 91B	Mandible fragment
729	East Grid, S2-W20, level 96.75	Petrosal
738	East Grid, N3-W14 and N4-W14, NC2 stratum	Metacarpal
740	Southwest Exposure, eroded on exposed surface	Humerus
741	East Grid, S2-W20, level 96.75	Tooth fragment
743	East Grid, S2-W24, mapped bone E	2 rib fragments
744	Southwest Exposure, eroded surface	Metapodial
745	Southwest Exposure, eroded surface	Radius
	***Ursus* cf *americanus* (Black bear)**	
736	East Grid, 0-W24, level 96.5	3rd metatarsal
	***Canis latrans* (Coyote)**	
737	East Grid, N3-W15, mapped in "Horse Bone Bed", stratum NC2	1 radius
	***Felis catus* (Domestic cat)**	
110	East Grid, mapped on surface, recent deposition	1 mandible
	Carnivores unspeciated	
151	East Grid, N4-W14, NE ¼, level 96.9. stratum NC2	1 manubrium ?
172	East Grid, N3-W14, NW ¼, level 97.05, stratum NC2, likely canid	1 m1 fragment
398	East Grid, S2-W21, level 96.9, stratum SC4	1 canine fragment

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Paramylodon (Harlan's ground sloth)	
739	Northwest Exposure, surface of gleyed deposit	1 hyoid
	Nothrotheriops shastensis **(Shasta ground sloth)**	
514	East Grid, 0-W23, level 96.7, mapped item #3, stratum SC4	1 tooth
	Cryptotis parva **(Least shrew)**	
722	Southwest Exposure, eroding from gleyed sediment	1 mandible
	Scalopus aquaticus **(Eastern mole)**	
406	East Grid, N5-W13, SE ¼, level 97.1, stratum NC2	1 humerus
	Sylvilagus **and** ***Lepus*** **(Rabbits and Hares)**	
120	East Grid, S2-W20, level 97.2, SC3 stratum	1 incisor (*Sylvilagus*)
169	East Grid, N4-W14, SW ¼, level 96.9, stratum NC2	1 incisor (*Sylvilagus*)
194	East Grid, N6-W19, level 98.5, stratum NB1	1 tooth (*Lepus*)
438	East Grid, N2-W19, level 97.0, stratum SD	1 incisor (*Sylvilagus*)
480	East Grid, S2-W24, NW ¼, level 95.9, stratum SD	1 incisor (*Sylvilagus*)
600	East Grid, S1-W22, level 8 (70-80 cm) waterscreened fill around bison skull	1 tooth (*Sylvilagus*)
	Cynomys ludovicianus **(Blacktailed prairie dog)**	
168	East Grid, N4-W14, SW ¼ , level 96.9, NC2 stratum	Astragalus
227	East Grid, N4-W13, SW ¼ , level 97.1, NC2 stratum	Tooth
265	East Grid, eroding from first carbonate layer above the bison bones	2 mandibles
266	Northwest Exposure, eroding surface	1 upper molar
332	East Grid, S1-W22, level 96.4, SC4 stratum	Tooth fragment
410	East Grid, N5-W13, SW ¼ , level 97.9, NC2 stratum	Tooth
477	East Grid, S2-W24, NW ¼ , level 95.9, SD stratum	Tooth root
488	East Grid, S1-W20, level 97.5, SC3 stratum	molar 3
	Geomys bursarius **(Plains pocket gopher)**	
114	East Grid, N1-W21, SW ¼, level 96.8, stratum SC3	1 tooth
118	East Grid, S3-W20, level 97.1, stratum SC3	1 incisor
129	East Grid, N4-W15, SE ¼, level 96.9, stratum NC2	2 incisor fragments
138	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 tooth
142	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	2 teeth
148	East Grid, N4-W14, SE ¼, level 97.2, stratum NC2	1 incisor
163	East Grid, N4-W14, SW ¼, level 97.0, stratum NC2	1 incisor
165	East Grid, N4-W14, NW ¼, level 97.1, stratum NC2	1 incisor
173	East Grid, N3-W14, NW ¼, level 97.05, stratum NC2	2 ungual phalanges
175	East Grid, N4-W14, NE ¼, level 97.2, stratum NC2	1 tooth
176	East Grid, N4-W14, NE ¼, level 97.2, stratum NC2	1 tooth
184	East Grid, N3-W14, NW ¼, level 96.9, stratum NC2	1 incisor
195	East Grid, N6-W19, level 98.2, stratum NB1	1 proximal ulna
197	East Grid, N6-W19, level 98.2, stratum NB1	1 proximal femur
201	East Grid, N3-W13, north wall, stratum NC2	1 incisor
205	East Grid, N5-W19, level 98.4, stratum NB1	1 tooth
208	East Grid, N5-W19, level 98.2, stratum NB1	1 proximal ulna and radius
282	Southwest Exposure, surface	2 mandibles and upper teeth
288	East Grid, S2-W23, under bison rib, stratum SD	1 tooth
293	East Grid, S2-W22, level 96.5, waterscreened material, stratum SC4	1 tooth
297	East Grid, S2-W22, level 96.3, waterscreened material, stratum SC4	1 tooth
298	East Grid, S2-W22, level 96.2, waterscreened material, stratum SC4	1 tooth
299	East Grid, S1-W23, level 96.3, waterscreened material, stratum SC4	3 teeth
302	East Grid, S2-W23, level 96.3, waterscreened material, stratum SC4	1 incisor
304	East Grid, S2-W23, level 96.5, waterscreened material, stratum SC4	1 tooth
315	East Grid, S1-W22, level 96.4, waterscreened material, stratum SC4	1 proximal ulna
333	East Grid, S1-W22, level 96.7, waterscreened material, stratum SC4	1 tooth
337	East Grid, S1-W22, level 96.7, waterscreened material, stratum SC4	1 tooth
338	East Grid, 0-W22, NW ¼, level 96.0, stratum SD	2 teeth
365	East Grid, N1-W21, SW ¼, level 96.5	1 tooth
370	East Grid, S2-W21, NW ¼, level 96.6, stratum SC4	1 distal humerus
372	East Grid, S2-W21, SE ¼, level 96.85, stratum SC4	1 proximal femur
373	East Grid, S2-W21, SE ¼, level 96.75, stratum SC4	1 proximal femur
378	East Grid, N1-W21, NE ¼, level 96.7, stratum SC4	1 incisor
384	East Grid, N5-W13, SW ¼, level 97.0, stratum NC2	1 tooth

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Geomys bursarius (cont.)	
386	East Grid, N5-W13, NW ¼, level 97.1, stratum NC2	1 incisor
396	East Grid, S2-W23, level 96.3, stratum SC4	1 vertebra
404	East Grid, S2-W21, NE ¼, level 96.7, stratum SC4	1 tooth
414	East Grid, N5-W13, SW ¼ , level 97.3, "Horse bone bed", stratum NC2	1 distal humerus
429	East Grid, N2-W19, level 97.2, waterscreened material, stratum NC3	1 partial mandible and lower incisor
433	East Grid, N2-W19, level 97.9, waterscreened material, stratum NC1	3 teeth fragments
475	East Grid, S2-W21, SE ¼, level 96.45, stratum SC4	1 tooth
478	East Grid, S2-W24, NW ¼, level 95.9, waterscreened material, stratum SD	1 distal humerus
524	East Grid, 0-W19, level 96.0, mixed strata	1 tooth
547	East Grid, S1-W22, level 96.5, waterscreened material, stratum SC4	Upper and lower incisor fragments
548	East Grid, N6-W19, level 98.7, waterscreened material, stratum NB1	1 upper incisor fragment
562	East Grid, S2-W23, level 7 (60-70 cm), stratum SC4	1 tooth
570	East Grid, S1-W23, under left horn core of *B. chaneyi* , stratum SC4	1 tooth
628	East Grid, 0-W21, NW ¼, level 96.75, stratum SC4	Lower set of teeth
735	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	Incisor fragment
	Neotoma cf *floridana* (Eastern woodrat)	
348	East Grid, S1-W21, NW ¼ , level 96.45, SC4 stratum	molar 1
540	East Grid, N2-W20, level 97.4, NC3 stratum	molar 2
575	East Grid, S1-W22, level 3 (20-30 cm) waterscreened fill from around bison skull.	Molar 2
583	East Grid, S1-W22, level 8 (70-80 cm) waterscreened fill from around bison skull	Molar 1
673	East Grid, 0-W19, level 97.5	molar
	Synaptomys cooperi (Southern bog lemming)	
167	East Grid, N4-W14, SW ¼ , level 97.2, NC2 stratum	Molar 1
355	East Grid, N1-W21, NW ¼ , level 96.7, SC4 stratum	Partial incisor
379	East Grid, N5-W13, NE ¼ , level 97.2, NC2 stratum	molar 1
415	East Grid, N5-W13, SE ¼ , level 97.0, NC2 stratum	Mandible and 3 teeth
	Microtus cf *ochrogaster* (Prairie vole)	
145	East Grid, N4-W15, NE ¼ , level 97.2, NC2 stratum	molar
155	East Grid, N4-W14, NE ¼ , level 97.1, NC2 stratum	molar
181	East Grid, N4-W14, NW ¼ , level 97.2, NC2 stratum	molar
196	East Grid, N6-W19, level 98.2, NB1 stratum	molar
207	East Grid, N5-W19, level 98.5, NB1 stratum	molar
226	East Grid, N4-W13, SW ¼ , level 97.1, NC2 stratum	molar
229	East Grid, N4-W13, SW ¼ , level 97.1, NC2 stratum	Partial mandible
253	Northwest Exposure, square 0-S4, level 96.4	molar
308	East Grid, S1-W23, level 96.4, SC4 stratum	molar
323	East Grid, S1-W22, level 96.3, SC4 stratum	molar
328	East Grid, S1-W22, level 96.2, SD stratum	2 molars
358	East Grid, S1-W22, NE ¼ , level 96.75, SC4 stratum	molar
371	East Grid, S2-W21, NW ¼ , level 96.85, SC4 stratum	molar
389	East Grid, N5-W13, SE ¼ , level 97.2, NC2 stratum	molar
393	East Grid, N4-W13, NE ¼ , level 97.1, NC2 stratum	molar
439	East Grid, N2-W19, level 97.0, NC4 stratum	molar 2
461	East Grid, S1-W20, level 97.5, SC3 stratum	Molar 1
464	East Grid, N1-W19, level 98.0, NC1 stratum	molar
468	East Grid, S2-W22, level 95.9, SD stratum	Molar 1
471	East Grid, S1-W20, level 97.4, SC3 stratum	Partial mandible with m1 and m2
479	East Grid, S2-W24, NW ¼ , level 95.9, SD stratum	Lower incisor & Partial mandible
481	East Grid, S2-W24, NW ¼ , level 95.9, SD stratum	molar 2
569	East Grid, S1-W23, level 5 (40-50 cm), SC4 stratum	molar
578	East Grid, S1-W22, level 4 (30-40 cm) waterscreened fill around bison skull	molar

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Microtus cf *ochrogastor* (cont.)	
616	East Grid, S1-W21, NE ¼, level 96.8, stratum SC4	1 molar (lost)
617	East Grid, S1-W21, NE ¼, level 96.8, stratum SC4	1 molar
	Unspeciated Rodent Bones	
115	East Grid, N1-W21, SW ¼, level 96.8, stratum SC3	1 humerus
154	East Grid, N4-W14, NE ¼, level 97.1, stratum NC2	1 incisor
174	East Grid, N3-W14, NW ¼, level 97.05, stratum NC2	1 calcaneum
190	East Grid, N6-W19, level 98.1, stratum NB1	1 ulna
198	East Grid, N6-W19, level 98.2, statum NB1	1 caudal vertebra
206	East Grid, N5-W19, level 95.5, stratum NB1	1 incisor
228	East Grid, N4-W13, SW ¼, level 97.1, stratum NC2	1 incisor
233	East Grid, N4-W13, SW ¼, level 96.9, stratum NC2	1 proximal ulna
234	East Grid, N3-W13, NE ¼, level 97.2, stratum NC2	1 cranial fragment
296	East Grid, S2-W22, level 96.3, waterscreened material, stratum SC4	1 radius
311	East Grid, S1-W23, level 96.6, waterscreened material, stratum SC4	1 humerus
322	East Grid, S1-W22, level 96.3, waterscreened material, stratum SC4	1 incisor
324	East Grid, S1-W22, level 96.3, waterscreened material, stratum SC4	1 astragalus
327	East Grid, S1-W22, level 96.2, waterscreened material, stratum SD	1 radius
356	East Grid. S1-W21, SE ¼, level 96.8, stratum SC4	1 tibia
408	East Grid, N5-W13, SE ¼, level 97.1, stratum NC2	1 ulna
424	East Grid, washed-in fill in N2-W22, S2-W22, N2-W23, and S2-W23, waterscreened material	1 mandible (recent)
427	East Grid, N2-W20, level 96.8, waterscreened, stratum NC4	1 innominate and 1 rib
473	East Grid, S1-W20, level 97.4, waterscreened, stratum SC3	1 incisor
485	East Grid, S2-W24, SE ¼, level 95.9, waterscreened, stratum SD	1 incisor
535	East Grid, N2-W20, level 97.2, stratum NB3	2 humeri
580	East Grid, S1-W22, level 4 (30-40 cm), waterscreened, stratum SC4	1 vertebra
691	Northwest Exposure, S3-W1, level 97.0	1 proximal femur
719	Northwest Exposure, S5-W1, level 96.8	1 innominate
	Passeriform (Perching birds)	
483	East Grid, N1-W19, level 97.8, waterscreened material, stratum NC1	1 partial humerus
733	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 scapula fragment
	Unspeciated bird	
144	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 scapula
149	East Grid, N4-W14, SE ¼, level 97.2, stratum NC2	1 radius
	***Rana* sp. (Frog)**	
131	East Grid, N4-W15, NE ¼, level 96.9, stratum NC2	2 mandibles
395	East Grid, S1-W22, level 96.4, waterscreened material, stratum SC4, *Rana pipiens* (Northern leopard frog)	1 vertebra
412	East Grid, 0-W21, SE ¼, level 96.95, stratum SC4, *Rana catesbeiana* (bullfrog)	1 vertebra
426	East Grid, N2-W20, level 97.7, waterscreened material, stratum NC1	2 fragments
428	East Grid, N2-W19, level 97.0, waterscreened material, stratum NC4	1 vertebra
451	East Grid, N3-W19, level 98.2, waterscreened material, stratum NB1, *Rana pipiens* (Northern leopard frog)	1 vertebra
452	East Grid, N3-W19, level 98.2, waterscreened material, stratum NB1	1 vertebra
453	East Grid, N3-W19, level 98.2, waterscreened material, stratum NB1	2 tibia fragments and 3 phalanges
462	East Grid, S2-W22, level 96.0, waterscreened material, stratum SD	1 vertebra
467	East Grid, N3-W19, level 98.2, waterscreened material, stratum NB1	2 pelvis fragments
492	East Grid, N5-W19, level 98.6, waterscreened material, stratum NB1	1 vertebra fragment
	Unspeciated frog	
121	East Grid, S2-W20, level 97.2, stratum SC3	1 frontal
128	East Grid, N4-W15, SE ¼, level 96.9, stratum NC2	1 scapula
134	East Grid, N4-W15, NE ¼, level 96.9, stratum NC2	1 basicranial fragment
147	East Grid, N4-W14, SE ¼, level 97.2, stratum NC2	1 tibia
171	East Grid, N4-W14, NE ¼, level 97.1, stratum NC2	1 vertebra
178	East Grid, N4-W14, NW ¼, level 97.2, stratum NC2	1 vertebra
188	East Grid, N3-W14, NE ¼, level 97.2, stratum NC2	1 humerus
210	East Grid, N3-W15, level 97.2, stratum NC2	1 cranial fragment
215	East Grid, N5-W19, level 98.1, stratum NB1	1 cranial fragment

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Unspeciated frog (cont.)	
218	East Grid, N4-W13, NW ¼, level 97.2, stratum NC2	2 humeri
237	East Grid, N3-W13, NW ¼, level 96.8, stratum NC2	1 humerus
240	East Grid, N3-W13, NW ¼, level 97.0, stratum NC2	1 mandible
300	East Grid, S1-W23, level 96.3, waterscreened material, stratum SC4	1 humerus
313	East Grid, S1-W23, level 96.4, waterscreened material, stratum SC4	1 frontal
387	East Grid, N5-W13, NW ¼, level 97.1, stratum NC2	1 humerus
391	East Grid, N5-W13, SW ¼, level 97.2, stratum NC2	1 humerus
401	East Grid, N5-W13, NW ¼, level 97.2, stratum NC2	1 vertebra
411	East Grid, N5-W13, SW ¼, level 97.9, stratum NC2	1 mandible
418	East Grid, N5-W13, SE ¼, level 97.1, stratum NC2	1 coracoid
458	East Grid, S3-W19, level 97.1, waterscreened material, stratum SC3	1 humerus framents
469	East Grid, S1-W20, level 97.2, waterscreened material, stratum SC3	1 ilium frag.
470	East Grid, S1-W20, level 97.4, waterscreened material, stratum SC3	1 humerus fragments
472	East Grid, S1-W20, level 97.4, waterscreened material, stratum SC3	Limb bone shaft
601	East Grid, S1-W22, level 8 (70-80 cm), waterscreened, stratum SC4	1 humerus
631	East Grid, N2-W19, level 96.7, stratum NC4	1 vertebra
	***Ambystoma tigrinum* (Tiger salamander)**	
122	East Grid, S2-W20, level 97.2, stratum SC3	1 vertebra
191	East Grid, N6-W19, level 98.3, stratum NB1	1 femur
193	East Grid, N6-W19, level 98.5, stratum NB1	1 vertebra
277	Northwest Exposure, square 0-S4, level 96.6	1 vertebra
294	East Grid, S2-W22, level 96.5, waterscreened material, stratum SC4	1 vertebra
317	East Grid, S1-W22, level 96.6, waterscreened material, stratum SC4	1 vertebra
336	East Grid, S1-W22, level 96.7, waterscreened material, stratum SC4	1 vertebra
354	East Grid, S1-W21, SE ¼, level 97.0, stratum SC3	1 vertebra
390	East Grid, N5-W13, SE ¼, level 97.2, stratum NC2	1 vertebra
392	East Grid, N4-W13, SW ¼, level 97.0, stratum NC2	1 vertebra
431	East Grid, N2-W19, level 97.6, waterscreened material, stratum NC1	Limb bone shaft
435	East Grid, N2-W20, level 97.7, waterscreened material, stratum NC3	1 vertebra
454	East Grid, S1-W19, level 97.6, waterscreened material, stratum NC1	1 vertebra
482	East Grid, S2-W24, NW ¼, level 95.9, stratum SD	1 vertebra
532	East Grid, N2-W20, level 96.9, stratum NC4	1 vertebra
	Unspeciated lizard	
123	East Grid, S2-W20, level 97.4, stratum SC3	1 vertebra
150	East Grid, N4-W14, NW ¼, level 96.9, stratum NC2	1 vertebra
	***Hesperotestudo* (Giant turtle)**	
677	Northwest Exposure, S40W1, level 96.7	Epiplastron fragment
708	Northwest Exposure, S4-W1, level 97.1	1 shell fragment
	Chelydridae (Snapping turtle)	
243	Northwest Exposure, surface of gleyed deposit	1 shell fragment
	***Chrysemys* sp. (Painted turtle)**	
405	East Grid, N1-W21, NE ¼, level 96.7, stratum SC4	3 shell fragments
	***Clemmys* sp. (Pond turtle)**	
245	East Grid, S4-W20, surface of gleyed stratum SC3	1 shell fragment
	***Terrapene carolina* (Box turtle)**	
678	Northwest Exposure, S4-W1, level 96.7	Posterior carapace frag.
685	Northwest Exposure, S6-W2, level 97.0	1 shell fragment
703	Northwest Exposure, S2-W1, level 97.2	1 shell fragment
705	Northwest Exposure, S4-W1, level 96.9	1 shell fragment
717	Northwest Exposure, S5-W1, level 96.9	4 shell fragments
	***Trionyx* sp. (Softshell turtle)**	
103	Northwest Exposure, surface of gleyed deposit	1 shell fragment
403	East Grid, S1-W21, SW ¼, level 96.8, stratum SC4	1 shell fragment
443	East Grid, waterscreened fill redeposited in N2-W22, S2-W22, N2-W23, and S2-W23	1 shell fragment

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Unspeciated Turtle	
102	Northwest Exposure, surface of gleyed deposit	3 shell fragments
105	Northwest Exposure, surface of gleyed deposit	2 shell fragments
126	East Grid, S2-W20, level 97.4, stratum SC3	1 shell fragment
146	East Grid, N4-W14, SE ¼, level 97.2, stratum NC2	1 shell fragment
180	East Grid, N4-W14, NW ¼, level 97.2, stratum NC2	1 shell fragment
192	East Grid, N3-W15, level 96.9, stratum NC2	1 shell fragment
244	Northwest Exposure, surface of gleyed deposit	1 shell fragment
249	Northwest Exposure, 0-S5, level 96.6	1 shell fragment
250	Northwest Exposure, 0-S5, level 96.8	3 shell fragments
251	Northwest Exposure, 0-S5, level 96.7	8 shell fragments
252	Northwest Exposure, 0-S4, level 96.9	6 shell fragments
256	Northwest Exposure, 0-S4, level 96.6	1 shell fragment
260	Southwest Exposure, surface of gleyed deposit	1 shell fragment
290	East Grid, S2-W23, level 96.2, waterscreened material, stratum SD	1 shell fragment
292	East Grid, S2-W22, level 96.3, waterscreened material, stratum SC4	1 shell fragment
295	East Grid, S2-W22, level 96.3, waterscreened material, stratum SC4	1 shell fragment
306	East Grid, S2-W23, level 96.5, waterscreened material, stratum SC4	1 shell fragment
325	East Grid, S1-W22, level 96.3, waterscreened material, stratum SC4	1 shell fragment
335	East Grid, S1-W22, level 96.7, waterscreened material, stratum SC4	1 shell fragment
340	East Grid, 0-W22, NE ¼, level 95.8, stratum SD	1 shell fragment
345	East Grid, N1-W21, NE ¼, level 97.05, stratum SC3	1 shell fragment
346	East Grid, 0-W21, level 97.6, stratum SC3	1 shell fragment
352	East Grid, S1-W21, level 97.1, stratum SC3	1 shell fragment
374	East Grid, S2-W21, SE ¼, level 96.75, stratum SC4	2 shell fragments
383	East Grid, N5-W13, SE ¼, level 97.0, stratum NC2	1 shell fragment
394	East Grid, N1-W21, level 97.4, stratum NC2	1 ulna
400	East Grid, N5-W13, NW ¼, level 97.2, stratum NC2	1 shell fragment
417	East Grid, S4-W20, surface of gleyed stratum SC3	1 shell fragment
419	East Grid, N5-W13, SE ¼, level 97.0, stratum NC2	1 shell fragment
420	Northwest Exposure, surface of gleyed layer	1 shell fragment
421	East Grid, S2-W23, level 96.5, waterscreened material, stratum SC4	1 shell fragment
422	Northwest Exposure, 0-S5, level 96.8	1 shell fragment
442	East Grid, fill washed into squares N2-W22, S2-W22, N2-W23, And S2-W23	1 shell fragment
490	East Grid, S2-W24, SW ¼, level 95.9, stratum SD	1 shell fragment
518	East Grid, S1-W23, level 96.68, mapped item in stratum SC4	1 shell fragment
528	East Grid, S1-W21, level 97.5, stratum SC3	1 shell fragment
542	East Grid, S2-W22, mapped items #2 and #3 in stratum SD	2 shell fragments
543	East Grid, 0-W24, surface of gray stratum SC4	1 shell fragment
550	Northwest Exposure, 0-S5, plotted in west wall	2 shell fragments
554	Northwest Exposure, 0-S2, plotted in west wall	14 shell fragments
559	East Grid, S1-W22, level 96.2, stratum SD	1 shell fragment
560	East Grid, S1-W22, level 96.3, stratum SC4	1 shell fragment
576	East Grid, S1-W22, level 7 (60-70 cm), stratum SC4	2 shell fragments
619	East Grid, N3-W14, NW ¼, "horse bone bed", stratum NC2	1 shell fragment
627	East Grid, 0-W21, NW ¼, level 96.75, stratum SC4	1 shell fragment
662	Northwest Exposure, S6-W1, level 96.8	2 shell fragments
663	Northwest Exposure, S6-W1, level 96.9	2 shell fragments
666	Northwest Exposure, S6-W1, level 96.74	4 shell fragments
669	Northwest Exposure, S7-W1, level 96.7	1 shell fragment
674	Northwest Exposure, S4-W1, level 97.2	1 shell fragment
683	Northwest Exposure, S6-W2, level 97.2	1 shell fragment
684	Northwest Exposure, S6-W2, level 97.18	1 shell fragment
686	Northwest Exposure, S3-W1, level 97.1	1 shell fragment
688	Northwest Exposure, S3-W1, level 96.6	1 shell fragment
692	Northwest Exposure, S3-W1, level 97.0	14 shell fragments

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
694	Northwest Exposure, S3-W1, level 97.0	2 shell fragments
696	Northwest Exposure, S2-W1, level 96.89	1 shell fragment
698	Northwest Exposure, S2-W1, level 96.9	1 shell fragment
700	Northwest Exposure, S2-W1, level 97.2	2 shell fragments
701	Northwest Exposure, S2-W1, level 96.8	1 ulna
702	Northwest Exposure, S2-W1, level 96.8	6 shell fragments
706	Northwest Exposure, S4-W1, level 96.8	1 shell fragment
707	Northwest Exposure, S4-W1, level 96.8	2 shell fragments
709	Northwest Exposure, S4-W1, level 97.1	1 shell fragment
710	Northwest Exposure, S4-W1, level 97.0	1 vertebra
712	Northwest Exposure, S4-W1, surface of gleyed sediment	4 shell fragments
718	Northwest Exposure, S5-W1, level 96.8	1 shell fragment
727	Northwest Exposure, S6-W2, level 97.4	1 dentary
734	East Grid, N4-W15, NE ¼, level 97.2, stratum NC1	1 tibia shaft
742	Northwest Exposure, S6-W1, mapped item	1 large shell fragment
	***Coluber constrictor* (Racer)**	
255	Northwest Exposure, 0-S4, level 96.6	1 vertebra
	Unspeciated Colubrid Snake	
179	East Grid, N4-W14, NW ¼, level 97.2, stratum NC2	2 vertebrae
	***Elaphe obsolete* (Rat snake)**	
589	East Grid, S1-W22, level 1 (0-10 cm) around bison skull, stratum SC4	1 vertebra
	***Lampropeltis* sp. (Kingsnake/ Milk snake)**	
209	East Grid, N3-W15, level 97.2, stratum NC2	1 vertebra
343	East Grid, 0-W21, NW ¼, level 96.9, stratum SC4	1 vertebra
380	East Grid, N5-W13, NE ¼, level 97.0, stratum NC2	1 vertebra
	***Thamnophis* sp. (Garter/Ribbon snake)**	
239	East Grid, N3-W13, NW ¼, level 97.0, stratum NC2	1 vertebra *T. radix*
385	East Grid, N5-W13, NW ¼, level 97.1, stratum NC2	1 vertebra *T. proximus* ?
685	East Grid, 0-W21, SW ¼, level 96.45	1 vertebra *T. radix*
	***Nerodia* sp. (Water snake)**	
117	East Grid, S3-W20, level 97.3, stratum SC3	1 vertebra
170	East Grid, N4-W14, SW ¼, level 96.9, stratum NC2	1 vertebra
213	East Grid, N3-W15, level 97.0, stratum NC2	1 vertebra
216	East Grid, S3-W21, NW ¼, surface	1 vertebra
375	East Grid, S2-W21, NW ¼, level 96.5, stratum SC4	1 vertebra
407	East Grid, N5-W13, SE ¼, level 97.1, stratum NC2	2 vertebrae
457	East Grid, S2-W23, level 95.9, stratum SD	1 vertebra
	***Crotalus* sp. (Rattlesnake)**	
113	East Grid, N1-W21, SW ¼, level 96.8, stratum SC3	1 vertebra
200	East Grid, N3-W15, north wall, level 97.05, stratum NC2	1 vertebra
231	East Grid, N4-W13, SW ¼, level 97.2, stratum NC2	1 vertebra
376	East Grid, S2-W23, SW ¼, level 96.0, stratum SD	1 vertebra
455	East Grid, S2-W21, level 96.5, stratum SC4	1 vertebra
697	Northwest Exposure, S2-W1, level 97.0	1 vertebra
	Unspeciated Snake	
119	East Grid, S3-W20, level 97.1, stratum SC3	1 vertebra
125	East Grid, S2-W20, level 97.4, stratum SC3	1 vertebra
132	East Grid, N4-W15, NE ¼, level 96.9, stratum NC2	1 vertebra
133	East Grid, N4-W15, NE ¼, level 96.9, stratum NC2	1 vertebra
140	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 vertebra
153	East Grid, N4-W14, NE ¼, level 97.1, stratum NC2	1 vertebra
183	East Grid, N3-W14, NW ¼, level 96.9, stratun NC2	1 vertebra
186	East Grid, N3-W14, NW ¼, level 97.0, stratum NC2	1 vertebra
202	East Grid, N3-W13, north wall, stratum NC2	2 vertebra

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	Unspeciated snake	
222	East Grid, S2-W22, level 96.2, stratum SD	3 vertebrae
232	East Grid, N4-W13, NE ¼, level 96.9, stratum NC2	3 vertebrae
238	East Grid, N3-W13, NW ¼, level 96.8, stratum NC2	1 vertebra
246	Northwest Exposure, 0-S4, level 96.6	1 vertebra
248	Northwest Exposure, 0-S4, level 96.7	1 vertebra
301	East Grid, S1-W23, level 96.3, waterscreen material, stratum SC4	1 vertebra
312	East Grid, S1-W23, level 96.5, waterscreen material, stratum SC4	1 vertebra
321	East Grid, S1-W22, level 96.3, stratum SC4	1 vertebra
334	East Grid, S1-W22, level 96.4, stratum SC4	1 vertebra
347	East Grid, 0-W21, level 97.2, stratum SC3	1 vertebra
350	East Grid, N1-W21, level 97.4, stratum SC3	1 vertebra
359	East Grid, S1-W21, NW ¼, level 96.7, stratum SC4	1 vertebra
360	East Grid, S1-W21, NW ¼, level 96.5, stratum SC4	1 vertebra
361	East Grid, S1-W21, SW ¼, level 96.5, stratum SC4	1 vertebra
362	East Grid, N2-W21, level 97.3, stratum NC3	1 vertebra
363	East Grid, S1-W20, level 97.3, stratum SC3	1 vertebra
377	East Grid, N1-W21, NE ¼, level 96.7, stratum SC4	1 vertebra
381	East Grid, N5-W13, NE ¼, level 97.1, stratum NC2	1 vertebra
388	East Grid, N5-W13, NE ¼, level 97.0, stratum NC2	1 vertebra
409	East Grid, N5-W13, SE ¼, level 97.1, stratum NC2	1 vertebra
416	East Grid, N3-W15, level 97.0, stratum NC2	1 vertebra
425	East Grid, 0-W24, level 96.5, stratum SD	1 vertebra
430	East Grid, N2-W19, level 97.7, stratum NC1	8 vertebrae
432	East Grid, N2-W19, level 97.8, stratum NC1	5 vertebrae
436	East Grid, N2-W20, level 97.7, stratum NC1	3 vertebrae
441	East Grid, N2-W19, level 97.6, stratum NC3	9 vertebrae
445	East Grid, S1-W19, level 97.4, stratum SC3	1 vertebra
446	East Grid, N5-W19, level 98.6, stratum NB1	2 vertebrae
447	East Grid, S1-W19, level 97.4, stratum SC3	1 vertebra
449	East Grid, S1-W19, level 97.3, stratum SC3	1 vertebra
450	East Grid, N2-W19, level 97.3, stratum NC3	1 vertebra
460	East Grid, S1-W20, level 97.5, stratum SC3	1 vertebra
463	East Grid, N1-W19, level 98.0, stratum NC1	1 vertebra
484	East Grid, N1-W19, level 97.8, stratum NC1	1 vertebra
526	East Grid, 0-W19, level 98.0, stratum NC1	1 vertebra
533	East Grid, N2-W20, level 97.2, stratum NB3	1 vertebra
534	East Grid, N2-W20, level 97.5, stratum NC3	1 vertebra
536	East Grid, N2-W20, level 97.5, stratum NC3	1 vertebra
537	East Grid, N2-W20, level 97.4, stratum NC3	1 vertebra
538	East Grid, N2-W20, level 97.4, stratum NC3	1 vertebra
571	East Grid, S1-W22, under left horn core of *B. chaneyi*, stratum SC4	1 vertebra
586	East Grid, S1-W22, level 3 (20-30 cm), stratum SC4	3 vertebrae
587	East Grid, S1-W22, level 3 (20-30 cm), stratum SC4	1 vertebra
592	East Grid, S1-W22, level 2 (10-20 cm), stratum SC4	1 vertebra
596	East Grid, S1-W22, NW ¼, material waterscreened from around *B. chaneyi* skull, stratum SC4	1 vertebra
598	East Grid, S1-W22, level 3 (20-30 cm), stratum SC4	1 vertebra
602	East Grid, S1-W22, level 8 (70-80 cm), stratum SC4	1 vertebra
715	Northwest Exposure, S5-W1, level 96.9	1 vertebra
	***Alligator* cf *mississippiensis* (Alligator)**	
491	East Grid, 0-W24, level 96.4, stratum SD	1 tooth
	***Lepomis* cf *cyanellus* (Sunfish-Centrarchidae)**	
124	East Grid, S2-W20, level 97.4, stratum SC3	2 vertebrae
130	East Grid, N4-W15, SE ¼, level 96.9, stratum NC2	1 vertebra
164	East Grid, N4-W14, NW ¼, level 97.1, stratum NC2	1 vertebra
211	East Grid, N3-W14, level 97.2, stratum NC2	1 vertebra
212	East Grid, N3-W15, level 97.2, stratum NC2	1 vertebra
225	East Grid, N2-W20, level 97.1, stratum NC3	1 vertebra
236	East Grid, N3-W13, NW ¼, level 96.8, stratum NC2	1 vertebra

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
	***Lepomis* cf. *cyanellus* (Sunfish-Centrarchidae) cont.**	
303	East Grid, S2-W23, level 96.5, waterscreened material	1 vertebra
309	East Grid, S1-W23, level 96.4, stratum SC4, waterscreened material	1 vertebra
318	East Grid, S2-W22, level 96.6, stratum SC4, waterscreened material	1 vertebra
329	East Grid, S1-W22, level 96.2, stratum SD, waterscreened material	3 vertebrae
331	East Grid, S1-W22, level 96.4, stratum SC4, waterscreened material	2 vertebrae
344	East Grid, 0-W21, NE ¼, level 96.9, stratum SC4	1 vertebra
357	East Grid, S1-W21, NW ¼, level 96.8, stratum SC4	1 vertebra
397	East Grid, S1-W23, level 96.4, stratum SC4	1 dentary
413	East Grid, 0-W21, SE ¼, level 96.95, stratum SC4	1 maxilla
437	East Grid, N2-W19, level 97.0, stratum NC4, waterscreened material	4 vertebrae
440	East Grid, N2-W19, level 97.6, stratum NC3, waterscreened material	1 vertebra
459	East Grid, S1-W20, level 97.6, stratum SC3, waterscreened material	1 supracleithrum
474	East Grid, S2-W21, SE ¼, level 96.45, stratum SC4, waterscreened material	1 median spine
476	East Grid, S2-W24, NW ¼, level 95.9, stratum SD, waterscreened material	1 median spine
486	East Grid, S1-W20, level 97.3, stratum SC3, waterscreened material	3 vertebrae
539	East Grid, N2-W20, level 97.4, stratum NC3	1 pterotic bone
546	East Grid, S1-W22, level 96.5, stratum SC4, waterscreened material	1 vertebra
564	East Grid, S1-W23, level 7 (60-70 cm), stratum SC4	1 spine (anal?)
565	East Grid, S1-W23, level 7 (60-70 cm), stratum SC4	1 vertebra
567	East Grid, S1-W23, level 5 (40-50 cm), stratum SC4	5 vertebrae
568	East Grid, S1-W23, level 5 (40-50 cm), stratum SC4	1 medial spine
572	East Grid, S1-W22, waterscreened material from under bison left horn core, stratum SC4	1 spine
574	East Grid, S1-W22, level 3 (20-30 cm), waterscreened material around bison skull, stratum SC4	2 vertebrae
577	East Grid, S1-W22, level 4 (30-40 cm), waterscreend material around bison skull, stratum SC4	5 vertebrae
585	East Grid, S1-W22, level 3 (20-30 cm), waterscreened material around bison skull, stratum SC4	1 basioccipital
590	East Grid, S1-W22, level 2 (10-20 cm), waterscreened material around bison skull, stratum SC4	3 vertebrae
594	East Grid, S1-W22, level 7 (60-70 cm), waterscreened material around bison skull, stratum SC4	1 vertebra
599	East Grid, S1-W22, NW ¼, waterscreened material from around bison skull, stratum SC4	2 vertebrae
632	East Grid, N2-W19, level 96.9, stratum NC3	2 vertebrae
726	East Grid, S2-W20, level 96.9	1 dentary
	Unidentified Fish	
247	Northwest Exposure, 0-S4, level 96.6, definitely not sunfish	1 vertebra
399	East Grid, S2-W21, level 96.9, stratum SC4	1 bone
	Unidentified Bone	
106	East Grid, S1-W14, surface	1 phalanx fragment
112	East Grid, N1-W21, NE ¼, level 96.8, stratum SC3	1 distal tibia
116	East Grid, N1-W21, NE ¼, level 96.8, stratum SC3	1 claw
135	East Grid, N4-W15, level 97.1, stratum NC2	3 fragments
143	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 fragment
160	East Grid, N4-W14, SE ¼, level 97.1, stratum NC2	1 scratched fragment
185	East Grid, N3-W14, NE ¼, level 97.0, stratum NC2	1 fragment
189	East Grid, N6-W19, level 97.9, stratum NB1	1 scratched fragment
203	East Grid, N4-W13, level 97.1, stratum NC2	1 vertebra
204	East Grid, N5-W19, level 98.4, stratum NB1	1 fragment
217	East Grid, S3-W21, NW ¼, surface of gleyed deposit	1 fragment
223	East Grid, S2-W23, level 96.6, stratum SC4	2 fragments
224	East Grid, N2-W20, level 98.0, stratum NC1	3 fragments
235	East Grid, N3-W13, NE ¼, level 96.8, stratum NC2	1 rib section
286	Southwest Exposure, surface of gleyed deposit	1 mandible fragment
287	East Grid, S2-W23, SW ¼, surface of stratum SC4	1 radius fragment
423	East Grid, N5-W13, NW ¼, level 97.2, stratum NC2	1 polished fragment

Table 8.2 (cont.). Faunal Identification Summary for the Burnham Site, 1986-1991 Investigations.

University of Kansas Temporary #	Provenience	Identification
506	East Grid, S1-W22, eroding surface of stratum SD	1 vertebra fragment
508	Northwest Exposure, 0-S4, mapped item #8	1 polished bone fragment
509	Northwest Exposure, 0-S4, mapped item #5	1 polished bone fragment
510	Northwest Exposure, 0-S4, mapped item #4	1 polished bone fragment
516	East Grid, 0-W23, level 96.7, stratum SC4	1 centrum fragment
530	East Grid, N2-W20, level 97.5, stratum NC3	1 fragment
541	East Grid, S1-W21, level 97.46, stratum SC3	1 scapula fragment
545	East Grid, N1-W22, from east wall in stratum NC3	1 polished bone fragment
549	East Grid, N4-W14, mapped item in stratum NC2	1 polished rib fragment
551	East Grid, N3-W14, Bone Block A, stratum NC2	3 polished rib fragments
552	East Grid, N3-W14, Bone Block C, stratum NC2	1 polished bone fragment
558	Northwest Exposure, 0-S5, level 96.7	1 polished bone fragment
591	East Grid, S1-W22, level 2 (10-20 cm) around bison skull	2 fragments
612	East Grid, S1-W21, level 97.46, stratum SC3	1 vertebra fragment
620	East Grid, N3-W15, level 97.1, stratum NC2	1 tooth fragment
629	East Grid, N2-W19, level 96.7, stratum NC4	1 bone fragment
	Burned Bone Fragments	
135	East Grid, N4-W15, NE ¼, level 97.0, stratum NC3	1 fragment
139	East Grid, N4-W15, NE ¼, level 97.2, stratum NC2	1 fragment
187	East Grid, N3-W14, NE ¼, level 97.2, stratum NC2	1 fragment
199	East Grid, 0-W25, level 96.5, stratum SD	1 fragment
214	East Grid, N3-W15, level 97.0, stratum NC2	1 fragment
220	East Grid, S2-W23, level 96.3, stratum SC4	1 fragment
221	East Grid, S2-W22, level 96.2, stratum SD	1 fragment
230	East Grid, N4-W13, SW ¼, level 97.2, stratum NC2	1 fragment
241	East Grid, N4-W13, SW ¼, level 97.1, stratum NC2	1 fragment
289	East Grid, S2-W23, red sandy clay (stratum SD) below Rib #1	1 fragment
291	East Grid, S2-W23, level 96.3, stratum SC4	1 fragment
310	East Grid, S1-W23, level 96.4, stratum SC4	1 fragments
320	East Grid, S1-W22, level 96.3, stratum SC4	4 fragments
330	East Grid, S1-W22, level 96.2, stratum SD	2 fragments
382	East Grid, N5-W13, SE ¼, level 97.0, stratum NC2	1 fragment
563	East Grid, S2-W23, level 7 (60-70 cm), stratum SC4	1 fragment
566	East Grid, S1-W23, level 5 (40-50 cm), stratum SC4	1 fragment
579	East Grid, S1-W22, level 4 (30-40 cm) waterscreened fill around bison skull, stratum SC4	3 fragments
584	East Grid, S1-W22, level 3 (20-30 cm) waterscreened fill around bison skull, stratum SC4	3 fragments
588	East Grid, S1-W22, level 8 (70-80 cm) waterscreened fill around bison skull, stratum SC4	3 fragments
597	East Grid, S1-W22, NW ¼, waterscreened fill of stratum SC4 around bison skull	1 fragment
630	East Grid, N2-W19, level 96.9, stratum NC4	1 fragment
633	East Grid, N2-W19, level 96.9, stratum NC4	1 fragment

Chapter 9
Vertebrate Fauna from the 1992 Excavations

Larry D. Martin, T.J. Meehan, and Don G. Wyckoff

With partial funding from the National Science Foundation, a month-long field session was spent at the Burnham site in June of 1992. The primary goal of this fieldwork was to expose the soils and sediments around the artifact-bearing stratum in order to determine the likely source(s) of the artifacts redeposited in the second lowest gleyed sediment. Consequently, most of the actual digging that month was done with a coring rig, a backhoe, and a bulldozer. While these machines great facilitated exposing stratigraphy that clarified the formation and age of the site (Carter, this volume), they weren't conducive to recovering many fossil bones. Fortunately, numerous volunteers from the Oklahoma Anthropological Society were present to manually dig and waterscreen wherever such effort was merited.

While the mechanical excavations were underway, the volunteers were supervised in excavating a series of meter squares in the Northwest Exposure and a couple in the Southwest Exposure. Controlled excavations there offered the opportunity to add to the number and variety of animal remains from these sediments, and we wanted to waterscreen a larger sample of those deposits to see if human artifacts might be recovered.

As the backhoe and bulldozer excavations continued, a few opportunities arose to establish and manually dig 1x1 m squares to sample interesting deposits uncovered by these machines. Specifically, a series of three squares were set on gleyed deposits uncovered at the east end of Backhoe Trench A dug in 1992. These units allowed us to cross-section a distinct segment of the gleyed pond sediment (Fig. 9.1). Also, squares were established and dug in paleosols exposed in Bulldozer Trenches B and C. The fill from all such work was waterscreened through 2 mm mesh hardware cloth, and some small vertebrate bones were recovered. Finally, a few identifiable bones were found during the bulldozer scraping in Trench B (Fig. 9.2). All vertebrate remains from the 1992 excavations were taken to the University of Kansas Museum of Natural History where the senior authors compared and identified skeletal elements with that museum's extensive Pleistocene holdings.

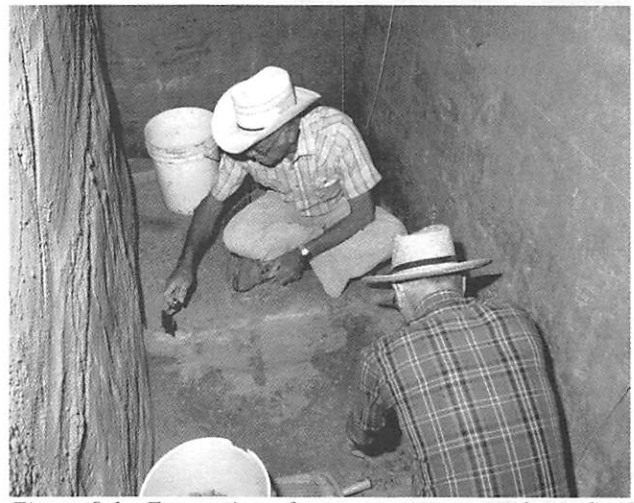


Figure 9.1. Excavation of a narrow segment (channel) of gleyed sediment in squares #2 and #3 of Backhoe Trench 92-A. Photo taken June 22, 1992, by Bill Thompson.

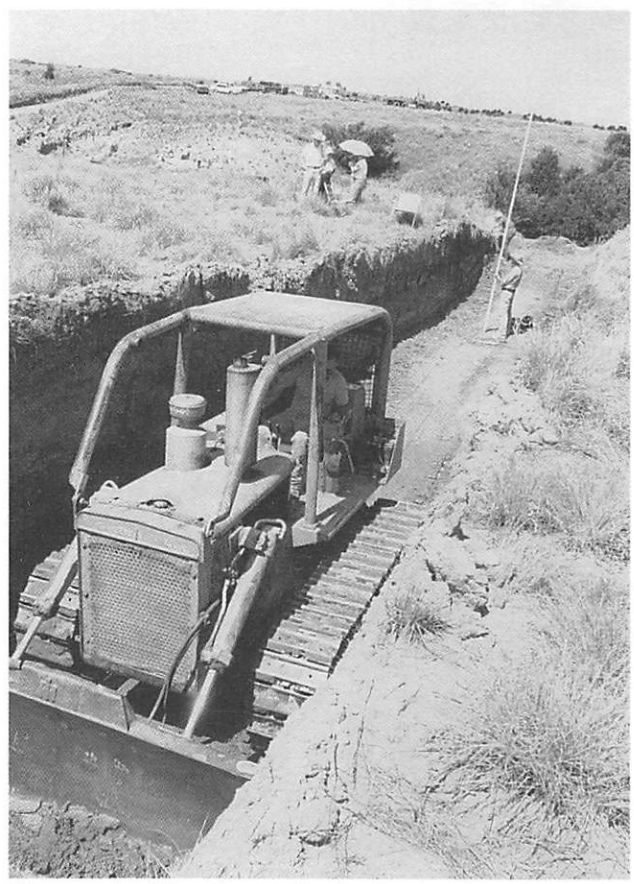


Figure 9.2. Mapping in the Gopherus *carapace section found in Bulldozer Trench 92-B. Photo taken June 17, 1992, by Bill Thompson.*

The Findings

A total of 226 teeth, bones, and identifiable bone fragments were recovered during the 1992 excavations. These specimens and their proveniences are listed in Table 9.1. Most are from species already recorded for the Burnham site's late Pleistocene deposits (compare Table 9.1 with Table 8.2). For example, *Geomys* cf. *bursarius* (Plains pocket gopher), *Neotoma floridana* (eastern wood rat), *Microtus ochrogaster* (prairie vole), *Cynomys ludovicianus* (black-tailed prairie dog), *Ambystoma tigrinum* (tiger salamander), and Centrarchidae (sunfish family) have been reported before. Carolina box turtle (*Terrapene* cf. *carolina*), horse (*Equus* sp.), and mammoth (*Mammuthus)* have also been reported previously, but among the elements found in 1992 are larger segments of shells and bones than found before. In particular, the sizeable segment of *Terrapene* cf. *carolina* shell was found adjacent split sections of a mammoth femur near the bottom of the gleyed sediment in the Northwest Exposure (Figs. 9.3, 9.4, and 9.5). Both sections of a *Terrapene* cf. *carolina* plastron were found in the manually dug squares in Backhoe Trench 92-A (Fig. 9.6). Also, a well preserved horse sacrum (Fig. 9.7) was recovered from the base of the Southwest Exposure.

A few bones were recovered in 1992 that are attributable to species not previously recognized for the Burnham inventory. Brief descriptions and discussions of these finds are presented below.

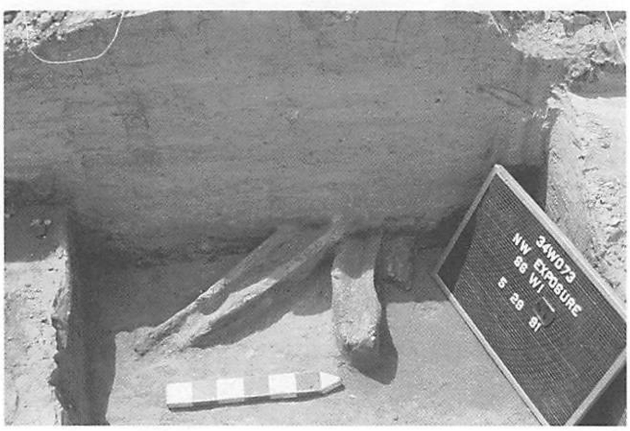


Figure 9.3. Looking west at split femur of mammoth at base of gleyed sediment, Square S6-W1, Northwest Exposure. These bones were not removed until the 1992 excavations. Photo taken May 21, 1991, by Don Wyckoff.

Figure 9.4. Uncovering the Terrapene *cf.* carolina *carapace in square S6-W2 of the Northwest Exposure. Photo taken June 17, 1992, by Bill Thompson.*

***Peromyscus* cf. *leucopus* (White-footed mouse).**

Represented by a maxilla with dentition (item #750 in Table 9.1), this occurrence of the white-footed mouse was recovered from gleyed sediment waterscreened from Square 2 dug in Backhoe Trench 92-A. Historically, this species is recorded throughout Oklahoma where it is commonly associated with brushy or woodland settings (Caire et al. 1989:231-232). Historic occurrences just south (in Woodward County) of the Burnham site include plum-sage, sumac-grama, and brushy slopes with juniper (ibid.)

***Chaetodipus* cf. *hispidus* (Hispid pocket mouse).**

A first lower molar (item #860 in Table 9.1) of this species was recovered from the gleyed pond sediments exposed in Backhoe Trench 92-A. The hispid pocket mouse is common throughout central and western Oklahoma where it is usually in grassland settings (Caire et al. 1989:201-204). This species is a frequent inhabitant of grassy settings near salt plains and canyons in western Oklahoma (Jackson and Warfel 1933).

***Gopherus* sp. (Gopher tortoise).**

Part of the carapace of this kind of turtle was uncovered in the Burnham paleosol near the west end of Bulldozer Trench 92-B (Fig. 9.8). This genus no longer inhabits Oklahoma but is represented by forms found in Florida, southern Texas, and the Colorado River basin in western Arizona and adjacent Sonora (Olsen 1968:97). Those living in this latter

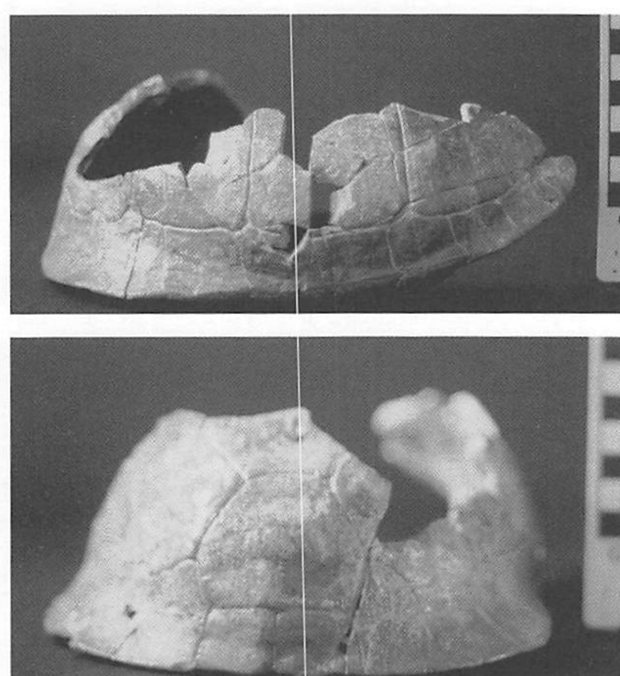


Figure 9.5. Right lateral and rear views of Terrapene *cf.* carolina *carapace recovered from square S6-W2 of the Northwest Exposure.*

Table 9.1. Faunal Remains from the 1992 Excavations at the Burnham Site.

University of Kansas Temporary #	**Provenience**	**Element**
	***Mammuthus* (Mammoth)**	
757	Backhoe Trench 92-A, Square #2, level 96.9	2 ivory flakes
776	Backhoe Trench 92-A, Square #2, level 97.1	2 ivory flakes
798	Backhoe Trench 92-A, Square #1, level 97.2	1 ivory flake
839	Southwest Exposure, Square S24-W1, level 98.9	1 ivory flake
849	Northwest Exposure, Square S1-W2, level 98.2	1 ivory flake
850	Northwest Exposure, Square S1-W2, level 98.3	1 ivory flake
854	Northwest Exposure, Square S1-W2, level 98.4	2 ivory flakes
862	Northwest Exposure, Square S2-W2, level 98.4	2 ivory flakes
866	Northwest Exposure, Square S3-W2, level 98.0	2 ivory flakes
867	Northwest Exposure, Square S3-W2, level 98.1	7 ivory flakes
878	Northwest Exposure, Square S3-W2, level 98.3	2 ivory flakes
889	Northwest Exposure, Square S4-W2, level 98.3	1 ivory flake
892	Northwest Exposure, Square S4-W2, level 98.3	2 ivory flakes
908	Northwest Exposure, Square S5-W2, level 98.1	3 ivory flakes
916	Northwest Exposure, Square S5-W2, level 98.3	1 ivory flake
925	Northwest Exposure, Square S6-W2, level 97.885	1 femur ball, 3 sections of proximal right femur shaft
	***Equus* sp. (Horse)**	
926	Southwest Exposure, mapped near deposit base	1 sacrum
	Artiodactyla unspeciated	
785	Backhoe Trench 92-A, Square #2, level 97.2	1 tooth fragment
	Canidae (Coyotes, Wolves, Foxes)	
833	Bulldozer Trench 92-B, Square B1	1 fox-size p3
	***Sylvilagus* or *Lepus* (Hares, Rabbits)**	
747	Backhoe Trench 92-A, Square 2, level 96.9	1 incisor
	***Geomys* cf. *bursarius* (Plains Pocket Gopher)**	
815	Backhoe Trench 92-A, Square 3, level 96.9	1 premolar
831	Backhoe Trench 92-A, Square 3, level 97.2	1 premolar
835	Bulldozer Trench 92-C, Square C3, level 1	1 lower incisor
836	Bulldozer Trench 92-C, Square C4, level 2	1 premolar
840	Southwest Exposure, Square S24-W1, level 98.9	1 humerus
884	Northwest Exposure, Square S3-W2, level 98.4	
	***Geomys* unspeciated**	
748	Backhoe Trench 92-A, Square 2, level 96.9	2 upper incisors
770	Backhoe Trench 92-A, Square 2, level 97.0	1 upper incisor
799	Backhoe Trench 92-A, Square 1, level 97.2	3 upper incisors
806	Backhoe Trench 92-A, Square 3, level 96.8	1 upper incisor
	***Neotoma* cf. *floridana* (Eastern Wood Rat)**	
834	Bulldozer Trench 92-B, Square B1	1 partial m2
913	Northwest Exposure, Square S5-W2, level 98.1	1 M2
922	Northwest Exposure, Square S5-W2, level 98.5	1 M2
	***Microtus* cf. *ochrogaster* (Prairie Vole)**	
792	Backhoe Trench 92-A, Square 2, level 97.3	1 m1
820	Backhoe Trench 92-A, Square 3, level 97.0	1 M2
829	Backhoe Trench 92-A, Square 3, level 97.1	1 m1
847	Northwest Exposure, Square S1-W1, level 98.2	1 m1

Table 9.1 (cont.). Faunal Remains from the 1992 Excavations at the Burnham Site.

University of Kansas Temporary #	Provenience	Element
	***Microtus* cf. *ochrogaster* (Prairie Vole)**	
902	Northwest Exposure, Square S5-W2, level 97.8	1 m1
903	Northwest Exposure, Square S5-W2, level 97.8	1 M2
904	Northwest Exposure, Square S5-W2, level 97.8	1 m2
917	Northwest Exposure, Square S5-W2, level 98.3	1 partial m1
918	Northwest Exposure, Square S5-W2, level 98.3	1 m3
	***Peromyscus* cf. *leucopus* (Woods Mouse)**	
750	Backhoe Trench 92-A, Square 2, level 96.9	1 m1
	***Chaetodipus* cf. *hispidus* (Hispid Pocket Mouse)**	
860	Northwest Exposure, Square S2-W2, level 98.4	Maxilla with P4, M1, M3
	***Cynomys ludovicianus* (Blacktailed Prairie Dog)**	
848	Northwest Exposure, Square S2-W2, level 98.3	Heavily worn m3
	Unspeciated rodent	
749	Backhoe Trench 92-A, Square 2, level 97.0	1 femur
	***Rana pipiens* (Northern Leopard Frog)**	
827	Backhoe Trench 92-A, Square 3, level 97.1	1 sacral vertebra
	Unspeciated frog	
758	Backhoe Trench 92-A, Square 2, level 96.9	1 vertebra
759	Backhoe Trench 92-A, Square 2, level 96.9	1 ilium fragment
794	Backhoe Trench 92-A, Square 1, level 97.0	1 ilium fragment
797	Backhoe Trench 92-A, Square 1, level 97.2	1 vertebra
805	Backhoe Trench 92-A, Square 1, level 97.3	1 vertebra
812	Backhoe Trench 92-A, Square 3, level 96.9	1 vertebrae
821	Backhoe Trench 92-A, Square 3, level 97.0	1 urostyle (fused tail vertebrae)
841	Southwest Exposure, Square S24-W1, level 98.9	1 humerus
869	Northwest Exposure, Square S3-W2, level 98.1	1 vertebra
874	Northwest Exposure, Square S3-W2, level 98.1	1 vertebra
875	Northwest Exposure, Square S3-W2, level 98.2	1 ilium
895	Northwest Exposure, Square S5-W2, level 98.3	1 vertebra
	***Ambystoma tigrinum* (Tiger Salamander)**	
837	Southwest Exposure, Square S24-W1, level 98.8	2 vertebra
845	Southwest Exposure, Square 0-S24, level 98.5	1 vertebra
883	Northwest Exposure, Square S3-W2, level 98.4	1 vertebra
885	Northwest Exposure, Square S3-W2, level 98.5	1 vertebra
	***Ambystoma* cf. *texanum* (Smallmouth Salamander)**	
888	Northwest Exposure, Square S4-W2, level 98.1	1 vertebra
	Unspeciated salamander	
856	Northwest Exposure, Square S2-W2, level 98.3	1 partial vertebra
	Unspeciated lizard	
786	Backhoe Trench 92-A, Square 2, level 97.2	Mandible fragment
796	Backhoe Trench 92-A, Square 1, level 97.0	Mandible fragment
872	Northwest Exposure, Square S3-W2, level 98.1	Mandible fragment
881	Northwest Exposure, Square S3-W2, level 98.4	Mandible fragment
	***Gopherus* sp. (Gopher turtle)**	
Not assigned	Bulldozer Trench 92-B, mapped bone, ele. 97.67	Carapace section
	***Terrapene* cf. *carolina* (Eastern Box Turtle)**	
923	Backhoe Trench 92-A, Squares 2 and 3	Anterior plastron section
924	Backhoe Trench 92-A, Squares 2 and 3	Posterior plastron section
Not assigned	Northwest Exposure, Square S5-W2, level 97.88	Partial carapace

Table 9.1 (cont.). Faunal Remains from the 1992 Excavations at the Burnham Site.

University of Kansas Temporary #	Provenience	Element
	Unspeciated turtle	
789	Backhoe Trench 92-A, Square 2, level 97.3	2 limb bone fragments
814	Backhoe Trench 92-A, Square 3, level 96.9	1 shell fragment
865	Northwest Exposure, Square S3-W2, level 98.0	1 shell fragment
868	Northwest Exposure, Square S3-W2, level 98.1	1 shell fragment
898	Northwest Exposure, Square S6-W2, plotted bone ff	3 shell sections
899	Northwest Exposure, Square S5-W3, level 97.7	1 shell fragment
	***Nerodia rhombifera* (Diamondback Water Snake)**	
819	Backhoe Trench 92-A, Square 3, level 97.0	1 vertebra
	Unspeciated snake	
761	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
764	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
765	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
772	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
775	Backhoe Trench 92-A, Square 2, level 97.1	1 vertebra
781	Backhoe Trench 92-A, Square 2, level 97.2	2 vertebrae
793	Backhoe Trench 92-A, Square 2, level 97.3	1 vertebra
800	Backhoe Trench 92-A, Square 1, level 97.2	1 vertebra
801	Backhoe Trench 92-A, Square 1, level 97.2	1 vertebra
802	Backhoe Trench 92-A, Square 1, level 97.2	1 vertebra
807	Backhoe Trench 92-A, Square 3, level 96.9	1 vertebra
808	Backhoe Trench 92-A, Square 3, level 96.9	1 vertebra
816	Backhoe Trench 92-A, Square 3, level 96.9	1 vertebra
825	Backhoe Trench 92-A, Square 3, level 97.0	1 vertebra
828	Backhoe Trench 92-A, Square 3, level 97.1	1 vertebra
838	Southwest Exposure, Square S24-W1, level 98.8	2 vertebrae
842	Southwest Exposure, Square S24-W1, level 98.9	2 vertebrae
843	Southwest Exposure, Square 0-S24, level 98.4	1 vertebra
844	Southwest Exposure, Square 0-S24, level 98.5	1 vertebra
846	Southwest Exposure, Square 0-S24, level 98.6	1 vertebra
851	Northwest Exposure, Square S1-W2, level 98.3	1 vertebra
853	Northwest Exposure, Square S1-W2, level 98.4	1 vertebra
858	Northwest Exposure, Square S2-W2, level 98.4	2 vertebrae
873	Northwest Exposure, Square S2-W2, level 98.1	1 vertebra
890	Northwest Exposure, Square S4-W2, level 98.2	2 vertebrae
897	Northwest Exposure, Square S4-W2, level 98.4	1 vertebra
900	Northwest Exposure, Square S5-W2, misc. debris	1 vertebra
907	Northwest Exposure, Square S5-W2, level 98.0	1 vertebra
910	Northwest Exposure, Square S5-W2, level 98.1	1 vertebra
921	Northwest Exposure, Square S5-W2, level 98.4	1 vertebra

Table 9.1 (cont.). Faunal Remains from the 1992 Excavations at the Burnham Site.

University of Kansas Temporary #	Provenience	Element
	Centrarchidae (Sunfish)	
746	Backhoe Trench 92-A, Square 2, level 96.9	1 spine
752	Backhoe Trench 92-A, Square 2, level 96.9	1 spine
755	Backhoe Trench 92-A, Square 2, level 96.9	1 spine
767	Backhoe Trench 92-A, Square 2, level 97.0	1 spine
773	Backhoe Trench 92-A, Square 2, level 97.0	3 spines
783	Backhoe Trench 92-A, Square 2, level 97.2	1 spine
788	Backhoe Trench 92-A, Square 2, level 97.2	3 spines
791	Backhoe Trench 92-A, Square 2, level 97.3	1 spine
804	Backhoe Trench 92-A, Square 1, level 97.2	2 spines
810	Backhoe Trench 92-A, Square 3, level 96.9	1 spine
824	Backhoe Trench 92-A, Square 3, level 97.0	1 spine
826	Backhoe Trench 92-A, Square 3, level 97.1	2 spines
855	Northwest Exposure, Square S2-W2, level 98.3	1 spine
871	Northwest Exposure, Square S3-W2, level 98.1	1 spine
893	Northwest Exposure, Square S4-W2, level 98.3	1 spine
905	Northwest Exposure, Square S5-W2, level 98.0	1 spine
911	Northwest Exposure, Square S5-W2, level 98.1	1 spine
919	Northwest Exposure, Square S5-W2, level 98.4	1 spine
	Unidentified fish	
753	Backhoe Trench 92-A, Square 2, level 96.9	3 spines
756	Backhoe Trench 92-A, Square 2, level 96.9	3 vertebrae
762	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
763	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
768	Backhoe Trench 92-A, Square 2, level 97.0	1 vertebra
771	Backhoe Trench 92-A, Square 2, level 97.0	2 vertebrae
777	Backhoe Trench 92-A, Square 2, level 97.1	1 operculum
778	Backhoe Trench 92-A, Square 2, level 97.1	1 vertebra
782	Backhoe Trench 92-A, Square 2, level 97.2	2 vertebrae
787	Backhoe Trench 92-A, Square 2, level 97.2	2 vertebrae
790	Backhoe Trench 92-A, Square 2, level 97.3	1 vertebra
795	Backhoe Trench 92-A, Square 1, level 97.0	1 vertebra
803	Backhoe Trench 92-A, Square 1, level 97.2	2 vertebrae
809	Backhoe Trench 92-A, Square 3, level 96.9	1 vertebra
811	Backhoe Trench 92-A, Square 3, level 96.9	1 bone fragment
818	Backhoe Trench 92-A, Square 3, level 97.0	1 vertebra
822	Backhoe Trench 92-A, Square 3, level 97.0	3 vertebrae
823	Backhoe Trench 92-A, Square 3 , level 97.0	1 vertebra
830	Backhoe Trench 92-A, Square 3, level 97.1	2 vertebrae
852	Northwest Exposure, Square S1-W2, level 98.4	1 vertebra
857	Northwest Exposure, Square S2-W2, level 98.3	2 vertebrae
859	Northwest Exposure, Square S2-W2, level 98.4	2 vertebrae
861	Northwest Exposure, Square S2-W2, level 98.4	1 vertebra
863	Northwest Exposure, Square S2-W2, level 98.76	1 vertebra

Table 9.1 (cont.). Faunal Remains from the 1992 Excavations at the Burnham Site.

University of Kansas Temporary #	Provenience	Element
	Unidentified fish	
864	Northwest Exposure, Square S2-W2, level 98.6	1 vertebra
870	Northwest Exposure, Square S3-W2, level 98.1	1 vertebra
882	Northwest Exposure, Square S3-W2, level 98.4	3 vertebrae
886	Northwest Exposure, Square S3-W2, level 98.5	1 vertebra
891	Northwest Exposure, Square S4-W2, level 98.2	3 vertebrae
896	Northwest Exposure, Square S4-W2, level 98.4	1 vertebra
901	Northwest Exposure, Square S5-W2, level 97.8	7 vertebrae
909	Northwest Exposure, Square S5-W2, level 98.0	4 vertebrae
912	Northwest Exposure, Square S5-W2, level 98.1	1 fragment
915	Northwest Exposure, Square S5-W2, level 98.3	1 vertebra
920	Northwest Exposure, Square S5-W2, level 98.4	3 vertebrae

Note: All specimens are at the Sam Noble Oklahoma Museum of Natural History.

Figure 9.6. Terrapene *cf.* carolina *plastron from Squares 2 and 3 in Backhoe Trench 92-A. Scale is 6.0 cm. long.*

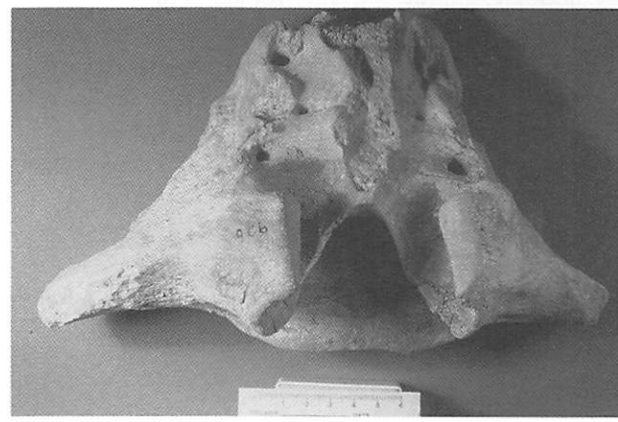
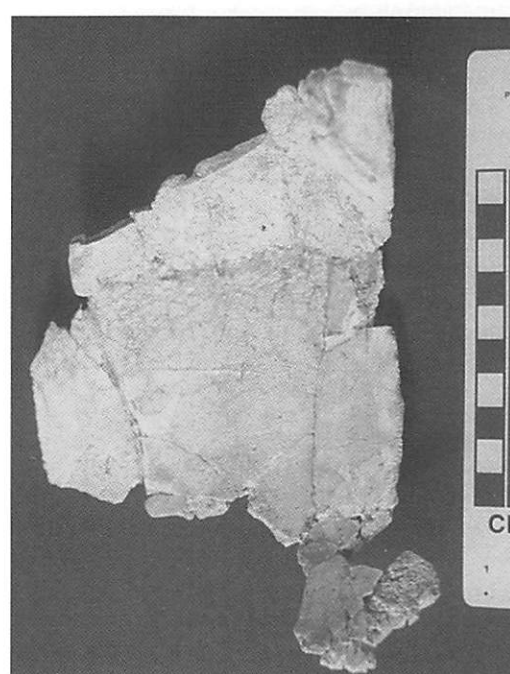


*Figure 9.7. Horse (*Equus *sp.) sacrum from Southwest Exposure. Scale is 6.0 cm. long.*

Figure 9.8. Exterior (above) and interior (right) views of Gopherus *sp. carapace recovered from Burnham paleosol in Bulldozer Trench 92-B.*



area are the closest living relatives to Southern Plains Pleistocene forms, and they have adapted to the desert's heat and water loss by burrowing below the surface during the most stressful times of the day and foraging in early mornimg or later afternoons (Vitt 1999:564).

Comments on the Fauna Recovered in 1992

Three new taxa were added to the Burnham fossil inventory by the faunal remains recovered during the 1992 excavations. Of the three new taxa, *Peromyscus* cf. *leucopus* and *Chaetodipus* cf. *hispidus* are small mammals still extant in Kansas and Oklahoma grasslands and brushy areas near the Burnham site. On this basis, these fossil finds suggest the setting was not greatly different over 30,000 years ago.

The third new taxon for the Burnham fossil record is *Gopherus* sp., a tortoise whose historic range is considerably south of the Burnham site. *Gopherus* sp. has a long, widespread fossil record on the Southern Plains. According to Preston (1979:38-40), fossils of *Gopherus* sp. occur in Texas and Kansas deposits dating back to early Pleistocene, perhaps even the Pliocene. The late Pleistocene fossils manifest attributes that seem to link them to *G. polyphemus*, the living gopher tortoise of Florida and the Gulf Coast (ibid.). Preston (1979:40) suggests that *Gopherus* sp. may have become extinct on the Southern Plains by 50,000 years ago, but the Burnham example, which was recovered from the Burnham paleosol, would indicate the species was still present 38,000 years ago.

First uncovered in 1991, but not actually recovered until 1992, large pieces of a mammoth (*Mammuthus*) femur come from the base of the gleyed sediments in the Northwest Exposure (Fig. 9.3). Although small fragments of ivory and teeth were found elsewhere, the Northwest Exposure of the Burnham site has been the location where the largest mammoth elements occur. When the Burnham site was first visited, a tusk segment was observed crushed (by machinery) and exfoliating at the east edge of the Northwest Exposure. This context appears to be the remnant of a northwestern arm of the ancient pond, and the large segments of femur recovered in 1992 imply that the Northwest Exposure contains the disarticulated, widely scattered remains of at least one mammoth. Consistently occurring near the bottom of the gleyed deposit, these remains must have been washed into this context early in the history of ponding events.

Numerous fish bones are represented among the bones recovered in 1992 (Table 9.1). About half of the fish elements come from manually dug squares in the Northwest Exposure. Notably, however, the other half come from the three 1x1 m squares excavated in a narrow deposit of gleyed sediment at the east end of Backhoe Trench 92-A (Fig. 9.1; Table 9.1). Forty-six fish bones come from this context,and their presence in this thin, narrow deposit indicates that it was an active part of the pond setting.

Conclusions

Rather modest amounts of identifiable bone were found during the geoarchaeological investigations at the Burnham site in 1992. Despite their low numbers, the identified elements attest mainly to species already recorded for the late Pleistocene deposits at this location. Of the three new taxa added to the Burnham fossil inventory, two are small mammals still present in the region. The third, gopher tortoise (*Gopherus* sp.) is a form common to the area throughout the Pleistocene. Its occurrence at Burnham, however, is one of the most recent ever radiocarbon dated.

References Cited

Caire, W., J.D. Tyler, B.P. Glass, and M.A. Mares. 1989. *Mammals of Oklahoma.* University of Oklahoma Press, Norman.

Jackson, H.H.T. and H.E. Warfel. 1933. Notes on the Occurrence of Mammals in the Regions Adjacent to the Salt Plains of Northwestern Oklahoma. *Publication of the University of Oklahoma Biological Survey* 5:65-72.

Olsen, S.J. 1968. *Fish, Amphibian, and Reptile Remains from Archaeological Sites, Part I: Southeastern and Southwestern United States.* Harvard University, Papers of the Peabody Museum of Archaeology and Ethnology 56(2).

Preston, R.E. 1979. *Late Pleistocene Cold-Blooded Vertebrate Faunas from the Mid-Continental United States.* University of Michigan, Museum of Paleontology, Papers in Paleontology 19.

Vitt, L.J. 1999. Tortoise. *Encyclopedia of Deserts*, edited by M.A. Mares, pp. 563-564. University of Oklahoma Press, Norman.

Chapter 10
A Pleistocene Dire Wolf from the Burnham Site

Nicholas J. Czaplewski

Introduction

The dire wolf, *Canis dirus*, is a well known large canid in the late Pleistocene fauna. The species was wide-ranging, as evidenced by the occurrence of its remains at over 135 localities in North and South America (Dundas 1999). Dire wolf fossils have been found at sites extending from near sea level in Florida to 2255 m (7400 feet) elevation in the Rocky Mountains. Despite its widespread distribution, very few records of the species are associated with reliable radiometric dates. All records appear to be of late Pleistocene age (Rancholabrean land mammal age; Dundas 1999). *Canis dirus* is an autochthonous North American canid, derived from the Eurasian immigrant *Canis armbrusteri* near the end of the Irvingtonian land mammal age (Tedford et al. 2001).

Although the dire wolf inhabited North America from coast to coast and from southwestern Canada throughout the United States and Mexico, the species has been reported previously at only one locality in Oklahoma (Nowak 1979; Kurtén 1984; Dundas 1999; Cifelli et al., in press). I report herein a second Oklahoma record of *C. dirus* at the Burnham site below an alluviation surface and calcic paleosol layer dated at about 37,500-40,100 yr bp.

The Find and Its Recovery

In June of 2001, landowner Vic Burnham noticed bones eroding from red dirt that was below and just north of the Burnham site's east exposure (Figs. 10.1 and 10.2). Thinking they were small and human-like, Mr. Burnham notified Don Wyckoff to arrange for their inspection and recovery. Due to previous commitments out-of-state, Wyckoff could not visit the site until July 22. At that time he and Mr. Burnham recovered metapodial bones which were brought back to the Sam Noble Oklahoma Museum of Natural History. There, the bones were identified as canid. Meanwhile, continued erosion uncovered teeth which Mr. Burnham recognized and reported to Wyckoff. On July 30, 2001, Wyckoff and Czaplewski went to the site and exposed and collected the remaider of the skeleton. This was done primarily with

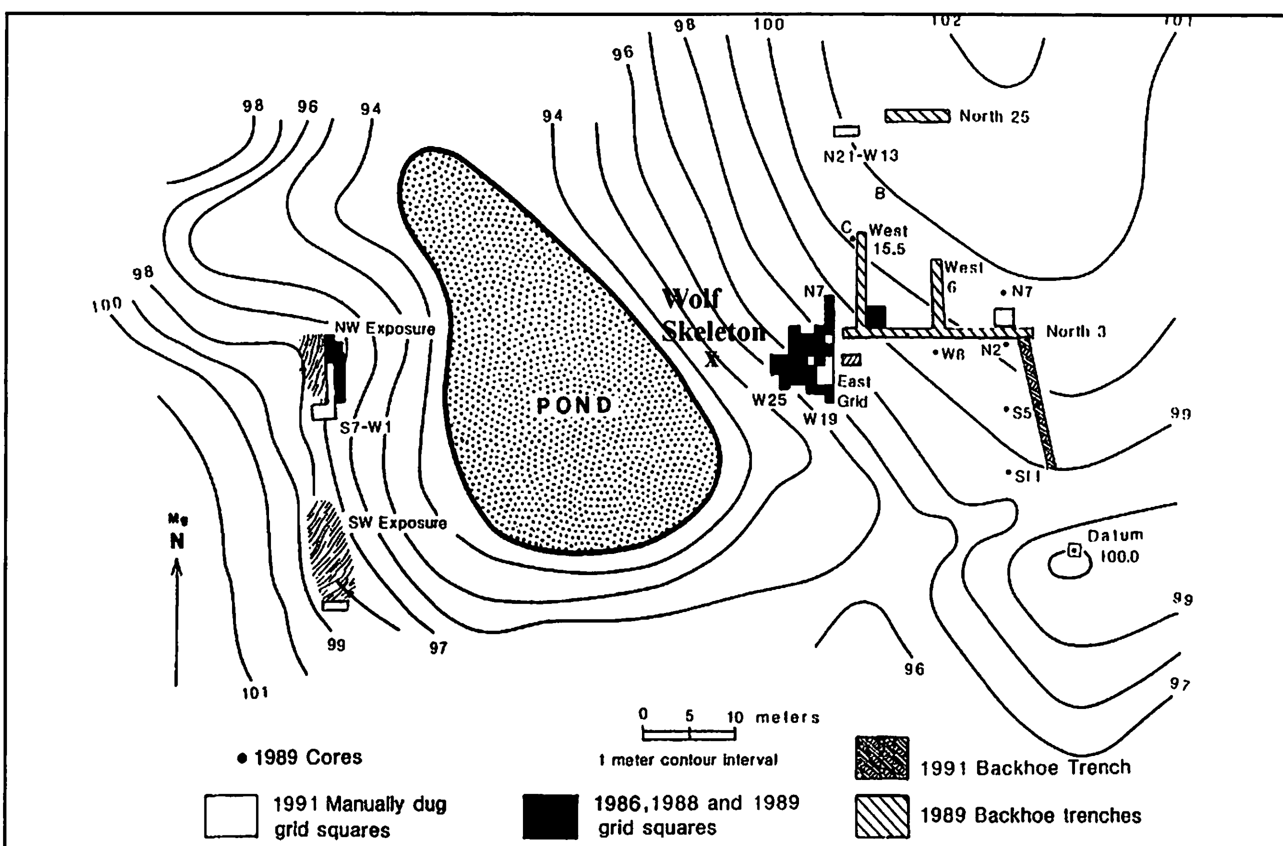


Figure 10.1. Map of the Burnham site and location of the dire wolf find of July 2001.

Figure 10.2. View north of Burnham site's East Exposure slope where Vic Burnham (with hat and back to camera) found the dire wolf remains. Photo taken July 30, 2001.

Figure 10.3. Using a water sprayer to expose the dire wolf cranium and associated bones. Photo taken July 30, 2001.

a hand-operated spray-pump filled with water (Fig. 10.3). After uncovering and trenching around the cranium and long bones with the spray pump, the specimen was pedestaled and jacketed with orthopedic bandages for transport to the OMNH (Figs. 10.4 and 10.5). A few hand or foot bones were immediately beneath the cranium. Several more hand and foot bones were picked up separately about 40 cm northeast of the skull and long bones.

The dire wolf was at elevation 94.5 (relative to datum of 100.0 m; Fig. 10.1) in the red alluvium which Brian Carter (this volume) has designated as the Group I sediment layer at the Burnham site. Composed of stratified gravel and sand, the Group I deposit is continuous across the site and underlies the stratified, gleyed/redoximorphic pond deposits that yield the site's Pleistocene fauna. The dire wolf remains occurred about 20.0 m north-northwest and 2.0 m below the level of the large-horned bison (*Bison chaneyi*) skull and several postcranial bones that stimulated research at this site. Extensive evidence from excavation of this bison and from subsequent coring, backhoe trenches, and bulldozer trenches indicate that the Burnham vertebrate and invertebrate fauna occurred in or at the edges of ponds that existed between approximately 32,000 and 26,000 years ago. Moreover, these ponds formed after erosion created a channel in a paleosol that is some 36,000 years old. The dire wolf occurred below this paleosol and is lower than any fossils previously found at this site. Thus, the wolf relates to the middle Wisconsinan glacial period or earlier.

Figure 10.4. Close-up of dire wolf cranium and associated femur during excavation. The zygomatic arch and right side of shattered rostrum are partially exposed. Roots of upper incisors are visible in top center of picture. Photo taken July 30, 2001.

Notes on the Specimen

The Burnham dire wolf specimen, a partial skeleton, appears to be an isolated find of an aged individual judging from the wear on the teeth. The only other fossil remains found in association with the dire wolf skeleton were two osteoderms which probably represent part of the dermal armor from the limbs of a tortoise (Fig. 10.6). The osteoderms likely pertain to a giant tortoise (*Hesperotestudo* sp.).

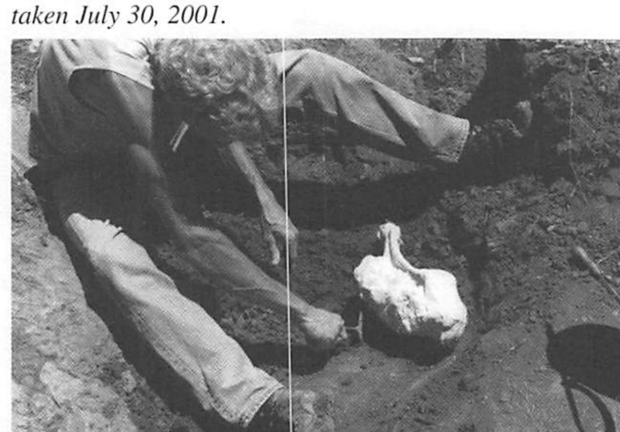


Figure 10.5. Cleaning away from the dire wolf cranium after jacketing it with orthopedic bandages. Photo taken July 30, 2001.

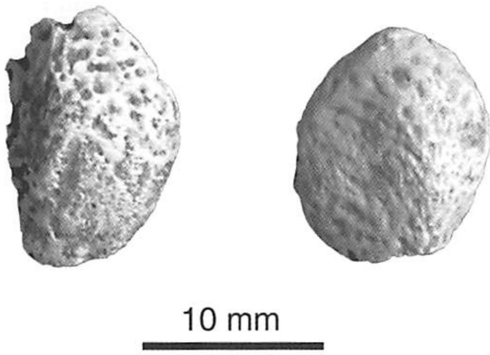


Figure 10.6. Tortoise osteoderms (dermal-bone armor) associated with Canis dirus *skeleton at the Burnham site East Exposure.*

The wolf skeleton is deposited in the vertebrate paleontology collection of the Oklahoma Museum of Natural History (OMNH) as specimen no. OMNH 71119 (Figs. 10.7 and 10.8). It consists of the following: a partly crushed cranium with all upper teeth; condyloid process of left dentary; root of a lower canine; rib blade; magnum; right metacarpal II; proximal portion of right metacarpal III; right metacarpal IV (distal end is broken); small fragment of pelvis; right femur damaged at both ends; left tibia lacking proximal end; right entocuneiform; right and left ?mesocuneiforms; right metatarsal II missing distal end; distal half of indeterminate metapodial; shaft of indeterminate metapodial; 4 proximal phalanges; 1 medial phalanx; 1 ungual phalanx; and miscellaneous fragments.

The specimen is readily identifiable as *Canis dirus* following Kurtén (1984): the preserved portions of its cranium are very large and the teeth, especially the upper carnassials, are massive. The postpalatine foramina open opposite of the posterior ends of the P4s; the P4 protocone is slightly reduced; and the hypocone on the M1 is reduced.

The posterior portions of the cranium, especially the basicranium and occiput, are shattered and the pieces are relatively poorly preserved and partly disarticulated. Anteriorly the cranium is in better condition, yet it shows shearing breakage and displacement of the right and left sides of the rostrum and palate (Fig. 10.7). All the upper teeth are very worn, but less so (especially the canines) than in the only known other Oklahoma dire wolf from Marlow, Stephens County (Cifelli et al., in press).

Kurtén (1984) split the North American dire wolves into two subspecies. The smaller western *Canis dirus guildayi* of California and Mexico contrasts with the larger *C. d. dirus* found east of the continental divide in the United States and southern Canada. Dimensions of the teeth and measurable parts of the muzzle in the Burnham specimen are within the range of variation exhibited by both subspecies, although they tend toward the larger end of the range of most available measurements (Table 10.1), in keeping with the geographic position of this find within the range of *C. d. dirus* (Kurtén 1984). The only two long bones associated with the cranium, a partial femur and partial tibia, are missing their ends (Fig. 10.8). As a result, their length measurements cannot be made nor compared with those of the two subspecies.

In contrast to the large size of the teeth, the two metacarpals (MC) that are complete are unusually small in the Burnham specimen (Table 10.1). The MC II length is equal to the low end of the observed range for this element in *C. d. dirus* (80-98 mm) and the MC IV length is less than any other *C. dirus* specimen (observed range: 95-110 mm) measured by Kurtén (1984:Table 1). This contrasts with Kurtén's (1984) characterization of *C. d. dirus* as larger in size with relatively longer distal limb elements than *C. d. guildayi*. The unusually short metacarpals of the Burnham wolf might simply reflect individual variation. Moreover, as Kurtén himself admitted, the available samples of *C. dirus* comprise a mixture from different time periods within the Rancholabrean land mammal age. This temporal variation could account for the unusual pattern of mensural variation as seen in the Burnham specimen.

Three of the skeletal elements, the femur, tibia, and the distal half of an indeterminate metapodial, have what appear to be tooth marks on them (Fig. 10.9). The femur has only a narrow, centimeter-long, longitudinal incision on the anterolateral surface distal to the greater trochanter. The distal metapodial has a relatively deep, 7-mm-long incision on the anterior surface at about midshaft. The tibia has five deep and longer marks, all on the posterior surface (Fig. 10,9). The significance of the tooth marks is uncertain in the absence of other taphonomic evidence, but steep edges on the marks suggest they could have been made by a saber-toothed cat or other carnivcre with sharp-edged teeth rather than by the tips of conical teeth.

Discussion

Previous late Quaternary records of wolves in Oklahoma are rare. They include a few representing the extant gray wolf, *Canis lupus*, and one previous record of the extinct dire wolf. The gray wolf records consist of one probable Pleistocene specimen, an ulna fragment from Cooper Creek, Tillman Co. (Midwestern State University 12469; Goetze 1989), a late Pleistocene or Holocene occurrence at Afton, Ottawa County (Holmes 1902; Smith and Cifelli 2000), and two finds probably of Holocene age from the Selman Cave System, Woodward Co. (which is some 16 km from the Burnham site). The Selman Cave specimens are a right dentary (Black 1970; Black and Best 1972) and a partial cranium (Caire et. al. 1989:p. 284). In addition, there are unpublished records of *Canis lupus* in the OMNH VP collection (uncataloged) consisting of three dentaries (and origi-

Table 10.1. Measurements of the Burnham *Canis dirus* (OMNH71119) Cranium.

Description	Measurement (mm)
Anterior edge of palatal notch to anterior edge of upper incisors (palatal length)	152
Palatine-maxillae suture on midline to anterior edge of premaxillae	93
Muzzle breadth across P4-M1, inclusive	102*
Breadth across upper molars (M2-M2)	96*
Braincase width	100**
Zygomatic breadth	150**
Least interorbital constriction	40**
Upper premolar row length (P1-P4)	Right-83.2 Left-87.7
Maxillary tooth row length (C1-M2)	Right-133.1 Left-134.2

*Estimated measurements of broken element.
**Doubled measurement from one side of broken specimen.

Table 10.2. Measurements of the Teeth of the Burnham *Canis dirus* (OMNH71119).

Tooth	Anteroposterior Length (mm)	Transverse Width (mm)
I1	7.5	4.4
I2	9.4	7.5
I3	12.4	10.1
C1	17.0	11.6
P1	10.3	8.4
P2	16.1	7.6
P3	19.3	8.2
P4	32.7	15.0
Blade of P4	-	13.9
M1	20.6	25.5
M2	10.6	14.7
c1	18.2	12.8

Table 10.3. Measurements of Leg Elements of the Burnham *Canis dirus* (OMNH 71119).

Description	Measurement (mm)
Anteroposterior diameter of femur shaft at midpoint	20.0
Transverse diameter of femur shaft at midpoint	20.5
Diameter of femur head	29.0
Transverse width of tibia at distal end	30.0

Table 10.4. Measurements of the Hand and Foot bones of the Burnham *Canis dirus*.

Skeletal element	Length (mm)	Proximal end depth (mm)	Proximal articular surface width (mm)	Distal articular surface width (mm)
Metacarpal II	80.0	16.7	10.0	12.9
Metacarpal III	-	16.1	11.8	-
Metacarpal IV	91.4	18.0	9.1	12.0
Metatarsal II	-	18.7	7.9	-
Proximal phalanges (mean)	30.4 (n=3)	11.0 (n=3)	12.3 (n=3)	10.1 (n=4)
Medial phalanx	25.6	9.2	10.7	10.0
Ungual phalanx	24 (est.)	14.3	9.8	-

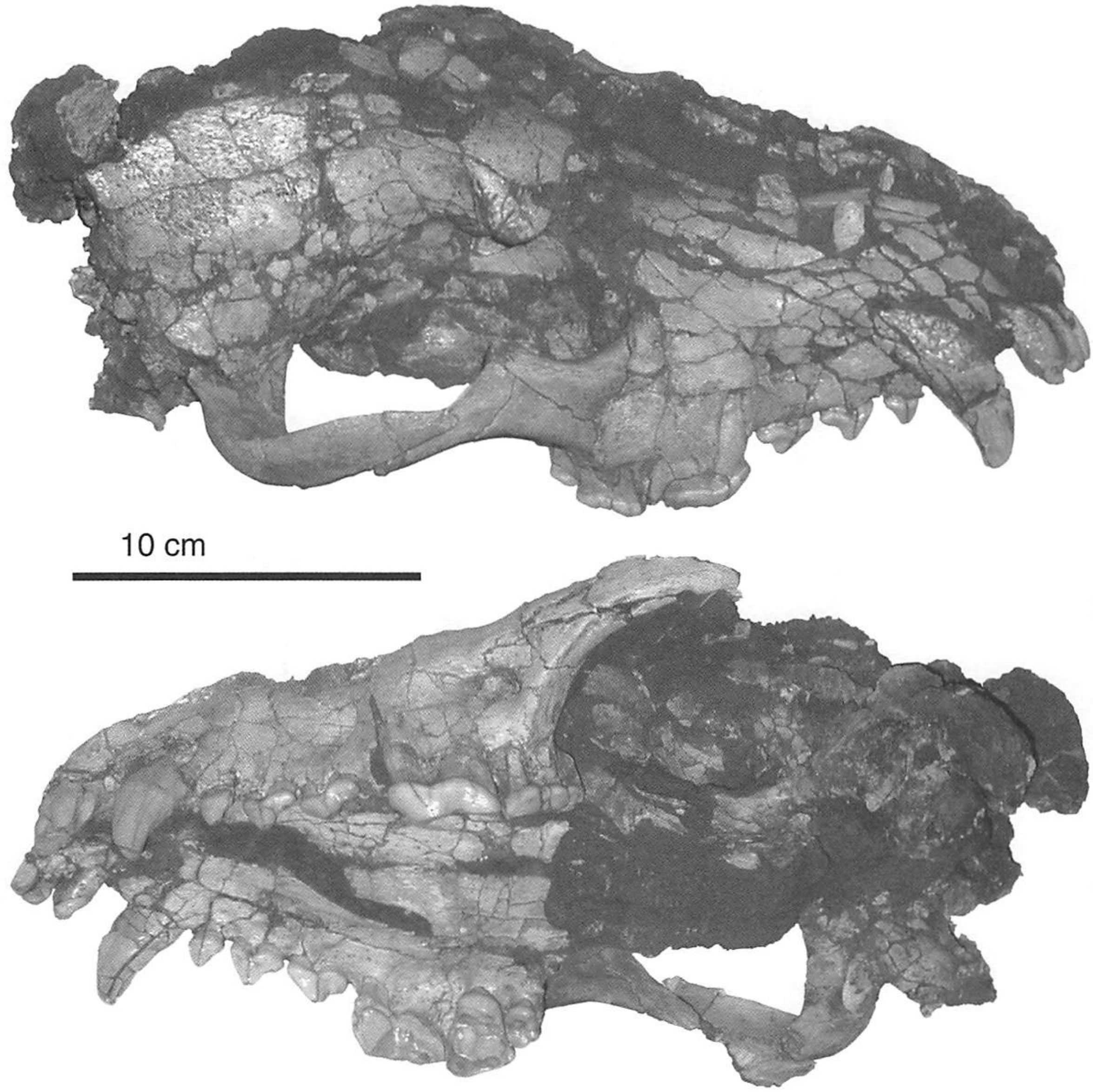


Figure 10.7. Canis dirus *cranium (OMNH 71119) in dorsolateral and ventrolateral views.*

nally a cranium, now lost; old catalog nos. S-478 and 40-4-S14) collected by W. E. Salter in 1937 at Payne's Canyon near Hydro, Oklahoma; a partial cranium "found with Indian material 12′ deep" near Foss, Oklahoma; and a mounted skeleton that was a "Gift of Roy C. Gardner of Devol, Oklahoma. Mounted April 1936. No. 97". No further provenance data accompany these specimens; all three are undated but probably late Holocene in age. No Oklahoma fossils are as yet identified as pertaining to the red wolf, *Canis rufus*.

The one previous find identified as *Canis dirus* (Nowak 1979; Cifelli et al., in press) consists of a partial skeleton including cranium and mandible from the town of Marlow, Stephens Co. (National Museum of Natural History, specimen no. USNM 10278). In view of the widespread occurrence of *C. dirus* in the Great Plains during the late Pleistocene, further records are likely to be found in Oklahoma in the future.

Acknowledgments

I offer my sincere thanks to Vic Burnham for discovering the specimen, bringing it to our attention, giving permission to excavate it, and donating it to the OMNH. Thanks also to Don G. Wyckoff for help in field work, and to Dennis Erfourth, Kyle Davies, and Richard Morris for preparing the specimen.

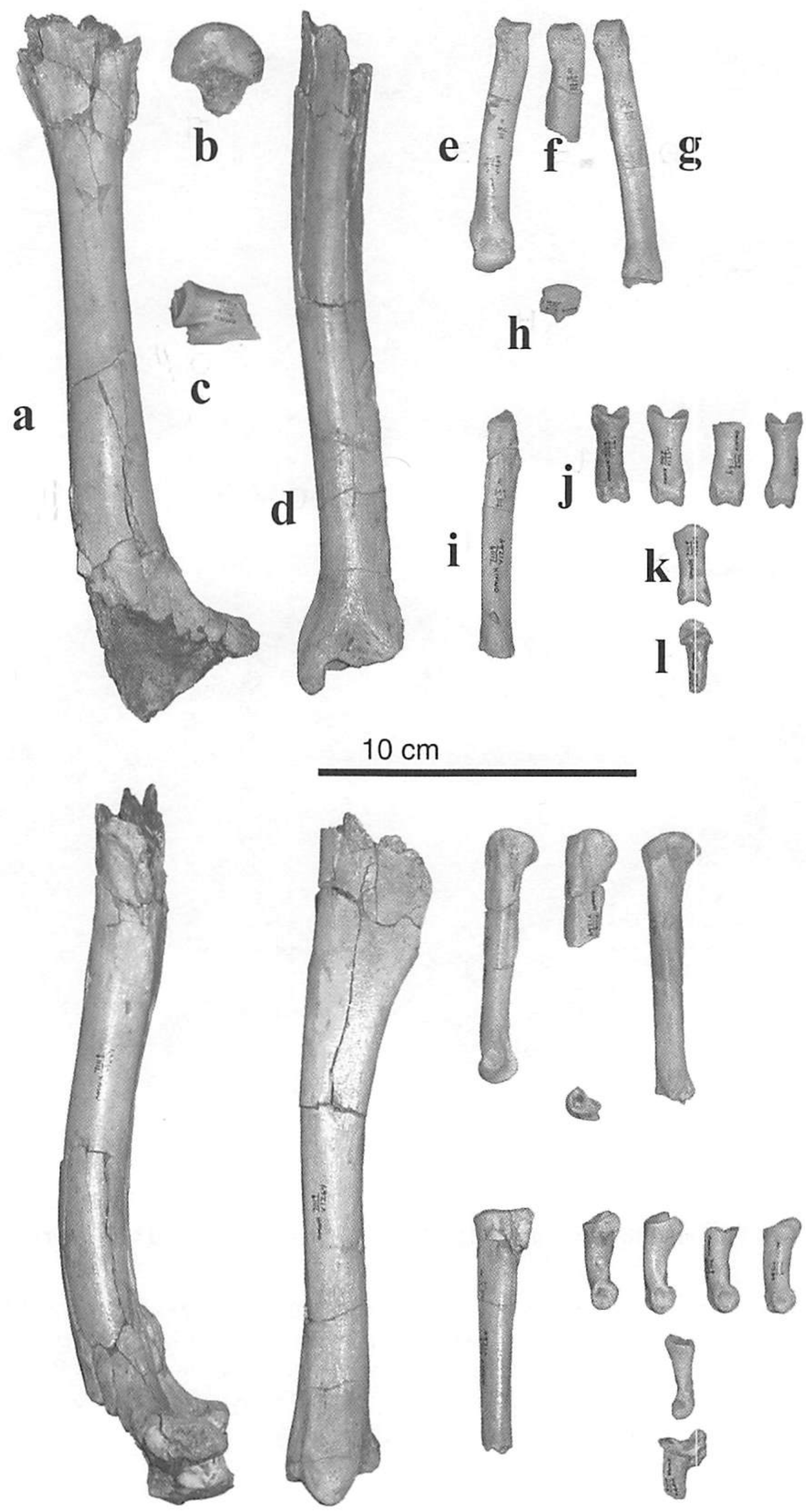


Figure 10.8. Canis dirus *postcranial bones (OMNH 71119) in anterior views (top) and lateral views (bottom: a, femur; b, ball of femur; c, small fragment of pelvis; d, tibia; e, metacarpal II; f, metacarpal III; g, metacarpal IV; h, distal tip of metapodial; i, proximal portion of metatarsal II; j, four proximal phalanges; k, medial phalanx; and, l, ungual phalanx.*

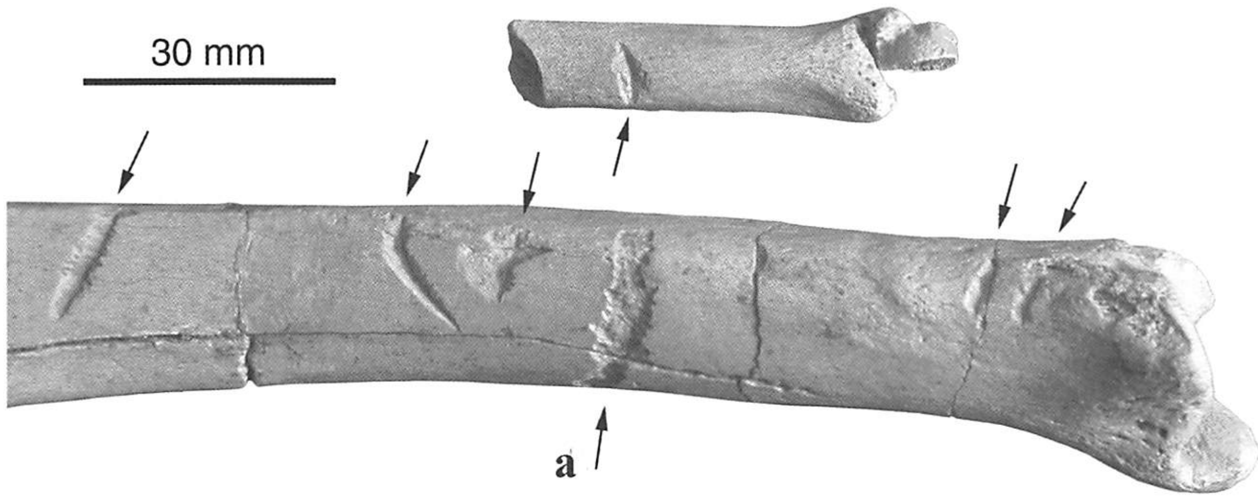


Figure 10.9. Probable tooth marks (indicated by arrows) on dire wolf metapodial fragment and tibia. Mark at "a" resembles modern carnivore gnawing marks described by Haynes (1980:Figs. 1 and 2).

References Cited

Black, J. 1970. Wolf Bone in Gypsum Cave. *Oklahoma Underground* 3(2):49-50.

Black, J. H., and T. L. Best. 1972. Remains of a Gray Wolf (*Canis lupus*) from Northwestern Oklahoma. *Proceedings of the Oklahoma Academy of Science* 52:120.

Caire, W., J. D. Tyler, B. P. Glass, and M. A. Mares. 1989. *Mammals of Oklahoma*. Norman, University of Oklahoma Press, 567 pp.

Cifelli, R. L., K. S. Smith, and F. v. H. Grady. In press. Dire Wolf (*Canis dirus*) in the Pleistocene of Oklahoma. *Oklahoma Geology Notes* v., pp.???.

Dundas, R. G. 1999. Quaternary Records of the Dire Wolf, *Canis dirus*, in North and South America. *Boreas* 28:375-385.

Gillette, D. D. 1979. The Largest Dire Wolf: Late Pleistocene of Northern Florida. *Florida Scientist* 42:17-21.

Goetze, J. R. 1989. Mammalian Faunas of a Late Pleistocene-Holocene Terrace of the Red River, Tillman County, Oklahoma. *Texas Journal of Science* 41:205-209.

Haynes, G. 1980. Evidence of Carnivore Gnawing on Pleistocene and Recent Mammalian Bones. *Paleobiology* 6:341-351.

Holmes, W. H. 1902. Flint Implements and Fossil Remains from a Sulphur Spring at Afton, Indian Territory. *American Anthropologist* 4:108-129.

Kurtén, B. 1984. Geographic Differentiation in the Rancholabrean Dire Wolf (*Canis dirus* Leidy) in North America. Carnegie Museum of Natural History, *Special Publication* 8:218-227.

Nowak, R. M. 1979. *North American Quaternary* Canis. Monograph of the Museum of Natural History, University of Kansas 6:1-153.

Smith, K. S., and R. L. Cifelli. 2000. A Synopsis of the Pleistocene Vertebrates of Oklahoma. *Oklahoma Geological Survey Bulletin* 147:1-36.

Tedford, R. H., X. Wang, and B. E. Taylor. 2001. History of the Caninae (Canidae). *Journal of Vertebrate Paleontology* 21(supplement to 3):107A.

Wang, X. 1990. Pleistocene Dire Wolf Remains from the Kansas River with Notes on Dire Wolves in Kansas. *Occasional Papers of the Museum of Natural History*, University of Kansas 137:1-7.

Wyckoff, D. G. 1999. The Burnham Site and Pleistocene Human Occupations of the Southern Plains of the United States. *Ice Age Peoples of North America: Environments, Origins, and Adaptations of the First Americans*, edited by R. Bonnichsen and K.L. Turnmire, pp. 340-361. Oregon State University Press, Corvallis.

Chapter 11
Paleoenvironmental Interpretation from Burnham Site Gastropods: 1989 Results

James L. Theler

Introduction

This report considers the Pleistocene subfossil snail (gastropod) shells recovered from the Burnham site (34Wo73) in Woods County, Oklahoma. Mollusk shells are abundant in many Pleistocene age deposits on the Great Plains and Midwest, where they have been used by many researchers since the early part of the 20th century as indicators of past environmental conditions (DeVore 1975; Drake 1975; A.B. Leonard 1952; Leonard and Frye 1960; Miller 1966; Ruhe 1969:38-40, 1983:135; Shimek 1913, 1930; Wayne 1967; Wells and Steward 1987). The use of subfossil snail assemblages to characterize certain components of paleoenvironments involves the assumption that a species' habitat preference has remained constant through time (LaRocque 1966:17). This assumes "that species have been influenced in former periods by the same limiting factors and to the same degree as now" (Taylor 1960:4). Researchers working with subfossil gastropods generally agree that the factors exerting the greatest influence on the distribution and abundance of gastropods on the Great Plains during the Quaternary are temperature and moisture (Miller 1975:13; Taylor 1965:601-603). The majority of gastropod taxa found in Pleistocene deposits are identifiable to species on the basis of shell morphology and are referable to living species. Habitat and range distribution data derived from living gastropod species are used as a source of proxy information to interpret subfossils of the same species in the reconstruction of paleoenvironments (Hibbard and Taylor 1960; Miller 1975; Taylor 1960; Wells and Steward 1987). The available data on living snail taxa is often limited, a factor diluting the potential interpretation of environmental reconstruction (Jaehnig 1971:296; Taylor 1965:598-599). Studies that document the habitats of living snails in northwestern Oklahoma are few (Wyckoff et al. 1997) but are useful when combined with those in nearby southwestern Kansas and the Texas panhandle (A.E. Leonard 1943; Leonard 1959; Neck 1984, 1990).

Methods

Subfossil Material

A total of 23 sediment samples were taken at four locations at the Burnham site for the recovery of subfossil gastropod shells. Sampling locations were chosen to evaluate the gastropod content within the range of sediment bodies filling the Pleistocene pond basin at Burnham. Sediment samples were dried, their volumes measured and then water-screened with material larger than .425 mm retained in a Tyler #40 geologic sieve. All complete and potentially identifiable shell fragments were isolated from waterscreen residue under a low power binocular microscope. All vertebrate remains and carbonized plant material from the sediment sample were recovered and transmitted to the appropriate specialists. Additional classes of biotic material, such as Sphaeriidae clams, Ostracoda, and *Chara*, were also segregated; they await future analysis. All subfossil gastropods are deposited at the Sam Noble Oklahoma Museum of Natural History.

Modern Material

Ten vegetation detritus ("litter") samples were taken in the vicinity of the Burnham site to evaluate the modern terrestrial snail community. Each modern sample location was photographed and plotted on a U.S.G.S. topographic map with information recorded on the vegetation at the sample site. Each sample was waterscreened to remove detritus particles <.425 mm and then dried. Samples were stored in glass containers until sorted under a binocular microscope. In the case of two large samples having abundant gastropods, a Humbolt sample splitter was employed to obtain an unbiased 50% sample of the vegetation detritus prior to sorting and removal of gastropod shells.

The gastropod shells from prehistoric and modern samples were sorted to taxon with reference to Baker 1928; Burch 1962, 1982, 1988; Burch and Tottenham 1980; Clarke 1981; Franzen and Leonard 1947; Hibbard and Taylor 1960; Pilsbry 1948; Taylor 1960; and others. Following identification, shells were counted, catalogued by taxa, and stored in glass vials containing individual labels with pertinent taxonomic and provenience information. The taxonomic nomenclature used here is that presented by Turgeon et al. (1988). A series of voucher specimens has been deposited at the Sam Noble Oklahoma Museum of Natural History.

Results

The Burnham sediment sample taken at the base of the North 3 trench (described below) did not contain mollusk shells. The remaining 22 fossiliferous samples, having a total sediment sample volume of 25.75 liters, contained 5220 gastropod shells. This averages 203 individuals per liter. A total of 1976 aquatic shells of at least 9 taxa and 3244 terrestrial shells representing 17 taxa (Table 11.1) were present in the Burnham samples. The gastropod assemblages from incremental column samples were found to exhibit a shift in the relative abundance of numerically important taxa, changes that are interpreted to indicate responses to changing local conditions. The more abundant gastropod taxa occur

Table 11.1. Subfossil Gastropods from All Contexts at the Burnham Site Ordered by Abundance.

	Number	Percentage
Terrestrial Taxa		
Hawaiia minuscula (A. Binney)	996	35.8
Vallonia perspectiva Sterki	129	4.6
Vallonia juveniles	610	21.9
Helicodiscus singleyanus (Pilsbry)	539	19.4
Gastrocopta pellucida (Pfeiffer)	127	4.6
Gastrocopta cristata (Pilsbry and Vanatta)	106	3.8
Succineidae	81	2.9
Deroceras laeve (Muller)	58	2.1
Gastrocopta procera (Gould)	51	1.8
Helicodiscus parallelus (Say)	26	0.9
Pupoides albilabris (C.B. Adams)	25	0.9
Gastrocopta armifera (Say)	17	0.6
Gastrocopta pentodon (Say)	5	0.2
Deroceras aenigma Leonard	5	0.2
Carychium exiguum (Say)	4	0.1
Vertigo ovata Say	3	0.1
Glyphyalinia indentata (Say)	2	<0.1
Gastrocopta holzingeri (Sterki)	1	<0.1
Subtotal	2785	100
Unidentified Terrestrial Juveniles	459	
Total of Terrestrials	3244	100
Aquatic Taxa		
Physidae Juveniles and Damaged	780	39.5
Physella virgata (Gould)	7	0.4
Gyraulus parvus (Say)	276	14.0
Gyraulus circumstriatus (Tryon)	1	0.1
Gyraulus Juveniles	324	16.4
Planorbella trivolvis (Say)	13	0.7
Planorbella Juveniles and Damaged	177	9.0
Valvata tricarinata (Say)	136	6.9
Hydrobiidae/Lymnaeidae	91	4.6
Ferrissia fragilis (Tryon)	59	3.0
Ferrissia walkeri (Pilsbry and Ferriss)	46	2.3
Ferrissia sp. Juveniles	39	2.0
Promenetus exacuous (Say)	21	1.1
Subtotal	1971	100
Unidentified Aquatic Juveniles	5	
Total of Aquatics	1976	100

throughout the sampled sequence, indicating little change in the regional environment during the deposition of the sampled strata.

Prehistoric Gastropod Assemblages

Unit S1-W22: Adjacent the *Bison chaneyi* Skull

In 1986, Wyckoff took three 10 cm thick sediment samples at 20 cm intervals from square S1-W22 (Fig. 11.1) adjacent the big horned bison skull for the recovery of snail shells. Two samples were taken in stratum SC4 at 96.91 to 96.8 m (=96.86m) and at 96.61 to 96.51m (=96.56m), a gray to light brownish silt loam that held the bison skull. A third sample was taken at the contact of stratum SC4 and the underlying brown loam stratum (SD) at 96.31 to 96.21m (=96.26m). The gastropod assemblage composition and individual sample volumes are presented in Table 11.2. The three S1-W22 samples totaled 2.8 liters of sediment and contained 1314 individual gastropod shells. The combined samples' snail density was 469 individuals per liter (ind/l), with a range from a low of 404 ind/l for sample SD-SC4 (96.26m) to a high of 541 ind/l for sample SC4 (96.86m).

Aquatic gastropods are represented by 859 specimens (7 taxa) in the three combined S1-W22 samples. The lower

Table 11.2. Gastropod Density (Individuals/Liter) and Number of Identified Species (NISP) in East Grid Square S1-W22, Burnham Site.

	Stratum SC4 Ele. 96.86 0.95 liters		Stratum SC4 Ele. 96.56 0.95 liters		Stratum SD Ele. 96.26 0.90 liters	
	Ind/L	NSIP	Ind/L	NSIP	Ind/L	NSIP
Aquatic Taxa						
Valvata tricarinata	24	23	24	23	23	21
Hydrobiidae/Lymnaeidae	6	6	5	5	10	9
Physidae	182	173	103	98	91	82
Gyraulus parvus	77	73	51	48	88	79
Gyraulus sp.	65	62	42	40	26	23
Planorbella trivolvis	3	3	-	-	3	3
Planorbella sp.	30	28	12	11	3	3
Promenetus exacuous	3	3	3	3	2	2
Ferrissia frigilis	-	-	1	1	3	3
Ferrissia sp.	20	19	4	4	12	11
Subtotal		390		233		236
Terrestrial Taxa						
Gastrocopta armifera	1	1	-	-	2	2
Gastrocopta cristata	9	9	11	10	12	11
Gastrocopta pellucida	5	5	10	9	2	2
Gastrocopta pentodon	1	1	-	-	-	-
Gastrocopta procera	7	7	8	8	3	3
Pupoides albilabris	4	4	2	2	3	3
Vertigo ovata	1	1	-	-	1	1
Vallonia perspectiva	3	3	6	6	3	3
Vallonia sp.	16	15	18	17	20	18
Helicodiscus parallelus	-	-	2	2	-	-
Helicodiscus singleyanus	11	10	17	16	20	18
Succineidae	6	6	8	8	9	8
Hawaiia minuscula	38	36	70	66	82	74
Deroceras laeve	3	3	4	4	3	3
Juveniles - unidentified	24	23	24	23	16	14
Subtotal		124		171		160

from a low of 2 ind/l (NC4, 96.53-96.59m) to a high of 46 ind/l (NC4, 97.11-97.21m). A similar trend is evident for *Vallonia* and *Helicodiscus singleyanus* (Table 11.3; Figure 11.3). The land snail *Gastrocopta pellucida*, a typical associate of xeric vegetation communities, while not particularly common in the sequence is the most abundant in the lower eight samples where *H. minuscula*, *Vallonia*, and *H. singleyanus* are least abundant.

The gastropod samples taken from the North 3 trench were deposited in a basin or at a basin margin that experienced several episodes of ponding and subsequent drying. The most distinct change in the North 3 trench sequence is the cessation of ponding in the upper sampled sediments and the establishment of a mesic vegetation community with associated *Hawaiia minuscula*, *Vallonia*, and *Helicodiscus singleyanus*. *Gastrocopta pellucida*, while never common, is most frequent in the lower portion of the North 3 incremental column. This may have to do with local changes in the vegetation community or, more simply, the upper mesic vegetation may have acted to filter out the xeric community snails that previously washed or blew into the basin.

West 6 Trench (Fig. 11.1)

In October of 1989, six incremental sediment samples were collected from the east face of the West 6 backhoe trench (Figure 11.1). Samples were taken over a 1.3 m vertical profile in 10 cm (5 samples) or 3 cm (1 sample) thick intervals. Sample location, interval, and thickness were controlled by observed changes in sediment color and texture. The incremental samples were positioned immediately south of the location selected for detailed profile description (see Carter, this volume).

The West 6 sample elevations ranged from a high of 98.91 to a low of 97.56m. The six samples totaled 6.8 liters of sediment, and they yielded 725 individual mollusk shells, with 185 (26%) being aquatic and 540 (74%) being terrestrial taxa. The combined sample snail density was 98 ind/l, but the density ranged (Table 11.4) from a low of 24 ind/l in stratum Btk2 (98.86m) to a high of 245 ind/l in stratum AB,2b (97.96m).

The West 6 samples contained shells of eight aquatic gastropod taxa. The aquatic snail density ranged from a low of 0 ind/l (Bky,2b; 97.61m) to a high of 102 ind/l (Btk2b; 97.96m). Aquatic snails were abundant only in stratum Btk2b (98.01-97.91m), a setting adjacent to gleyed sediment deposited in ponded waters. The majority of aquatic snails are small individuals that may have accumulated as riparian drift. The other five samples yielded 12 or fewer ind/l, virtually all of which are minute, pulmonate snails easily moved by wind or water.

The most common aquatic snails in the West 6 column are juvenile Physidae with only one identified species, *Physella virgata*. Next in abundance is the freshwater limpet *Ferrissia fragilis*, a pulmonate of shallow, low energy waters usually found on emergent aquatic vegetation such as cattail (*Typha*) bases. All of the *Ferrissia* were recovered in the riparian stratum Btk2b, where 83% of the aquatic snails were found in the West 6 sequence. Third in abundance are specifically unidentified *Gyraulus* juveniles and four individual *Gyraulus parvus*. These three taxa (Physidae, *Ferrissia*, and *Gyraulus*) account for 83% (154 of 183 individuals) of the West 6 aquatics. If the *Planorbella*, with only one identified species (*Planorbella trivolvis*), is added, these four represent 92% of the aquatic snails. Notably, only three shells of *Valvata tricarinata* (representing less than 2% of the aquatics) were recovered in the West 6 sequence.

The West 6 samples yielded 540 land snails, and these represent 12 of the 17 taxa found in all of the Burnham sediments. The density of terrestrial snails ranges from a low of 18 ind/l (in stratum Btk2; 98.86m) to a high of 152 ind/l (stratum Bkl,b; 98.31m), and the mean is 98 ind/l. The density of land snails is greatest in stratum Bk1,b (98.31m) that appears to represent sedimentation in a post-ponding period, one preceded by the riparian stratum Btk2b (below Bkl,b) with the highest density of aquatic snails. These two strata (Bkl,b and Btk2b) would presumably represent periods of high local moisture availability with the mesic community associates like *Hawaiia minuscula* being most abundant in the riparian strata. The density of land snails declines as one goes higher in elevation or to the lowest sample in stratum Bky,2b (at 97.81m in Figure 11.3).

Table 11.3. Gastropod Density (Individuals/Liter) and Number of Identified Specimens (NISP) in the North 3 Trench Samples, Burnham Site.

Stratum	NB1		NB1		NB1		NC2		NC2		NCE	
Elevation	98.26		98.06		97.77		97.60		97.43		97.32	
Sample Volume	2.2 liters		2.4 liters		1.8 liters		1.0 liters		1.0 liters		0.6 liters	
Aquatic Taxa	Ind/L	NSIP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP
Valvata tricarinata	-	-	1	2	2	3	1	1	11	11	12	7
Hydrobiidae/Lymnaeidae	-	-	1	2	17	31	16	16	4	4	-	-
Physidae	14	31	5	13	20	36	32	32	44	44	62	37
Physella virgata	-	-	-	-	-	-	-	-	-	-	2	1
Gyraulus parvus	<1	1	<1	1	1	2	1	1	8	8	12	7
Gyraulus sp.	1	2	2	5	5	9	2	2	20	20	20	12
Planorbella trivolvis	-	-	-	-	-	-	-	-	1	1	3	2
Planorbella sp.	1	3	3	6	5	9	16	16	31	31	20	12
Promenetus exacuous	-	-	-	-	-	-	-	-	4	4	-	-
Ferrissia frigilis	-	-	2	4	-	-	-	-	1	1	2	1
Ferrissia walkeri	-	-	-	-	-	-	-	-	37	37	15	9
Ferrissia sp.	<1	1	-	-	1	1	-	-	-	-	-	-
Juveniles-unidentified	-	-	-	-	-	-	-	-	2	2	-	-
Subtotal		38		33		91		68		163		88
Terrestrial Taxa												
Carychium exiguum	-	-	-	-	-	-	1	1	-	-	-	-
Gastrocopta armifera	1	2	-	-	1	1	-	-	-	-	2	1
Gastrocopta cristata	4	9	1	3	1	2	1	1	2	2	10	6
Gastrocopta holzingeri	-	-	-	-	1	1	-	-	-	-	-	-
Gastrocopta pellucida	-	-	1	2	1	1	-	-	5	5	3	2
Gastrocopta pentodon	-	-	-	-	1	1	1	1	-	-	2	1
Gastrocopta procera	6	14	-	-	1	1	-	-	-	-	-	-
Pupoides albilabris	-	-	1	3	1	1	-	-	-	-	-	-
Vertigo ovata	-	-	-	-	-	-	1	1	-	-	-	-
Vallonia perspectiva	7	16	11	27	18	11	1	1	2	2	3	2
Vallonia sp.	26	56	52	124	40	72	15	15	15	15	12	7
Helicodiscus parallelus	1	3	1	3	2	4	3	3	3	3	3	2
Helicodiscus singleyanus	46	102	67	160								
Succineidae	-	-	1	3	11	20	5	5	4	4	3	2
Hawaiia minuscula	66	145	62	148	62	112	29	29	33	33	43	26
Deroceras laeve	4	8	3	8	4	8	1	1	2	2	3	2
Deroceras aenigma	-	-	1	3	1	1	1	1	-	-	-	-
Juveniles-unidentified	32	71	25	61	27	49	13	13	18	18	22	13
Subtotal		426		545		340		88		95		71

Table 11.3 (cont.). Gastropod Density and Number of Identified Specimens in the North 3 Trench Samples, Burnham Site.

Stratum	NC4		NC4		NC4		NC4		BC,2b	
Elevation	97.16		96.96		96.80		96.56		96.37	
Sample Volume	1.0		1.7		0.6		1.5		1.0	
Aquatic Taxa	**Ind/L**	**NISP**	**Ind/L**	**NISP**	**Ind/L**	**NISP**	**Ind/L**	**NISP**	**Ind/L**	**NISP**
Valvata tricarinata	8	8	15	26	-	-	5	7	1	1
Hydrobiidae/Lymnaeidae	2	2	4	6	-	-	4	6	2	2
Physidae	43	43	48	82	-	-	17	26	8	8
Physella virgata	2	2	1	2	-	-	1	1	-	-
Gyraulus parvus	9	9	20	34	-	-	3	4	5	5
Gyraulus sp.	39	39	39	67	2	1	8	12	2	2
Planorbella trivolvis	1	1	-	-	-	-	1	1	-	-
Planorbella sp.	15	15	11	19	-	-	5	8	2	2
Promenetus exacuous	2	2	2	4	-	-	1	1	-	-
Ferrissia frigilis	-	-	-	-	-	-	-	-	-	-
Ferrissia walkeri	-	-	-	-	-	-	-	-	-	-
Ferrissia sp.	-	-	1	2	-	-	1	1	-	-
Juveniles-unidentified	-	-	-	-	-	-	-	-	-	-
Subtotal		121		242		1		67		20
Terrestrial Taxa										
Carychium exiguum	-	-	1	1	-	-	-	-	2	2
Gastrocopta armifera	1	1	-	-	-	-	1	1	-	-
Gastrocopta cristata	5	5	5	8	5	3	2	3	5	5
Gastrocopta holzingeri	-	-	-	-	-	-	-	-	-	-
Gastrocopta pellucida	4	4	2	3	5	3	3	5	4	4
Gastrocopta pentodon	-	-	-	-	-	-	1	1	-	-
Gastrocopta procera	2	2	-	-	-	-	1	1	1	1
Pupoides albilabris	4	4	1	2	-	-	-	-	1	1
Vertigo ovata	-	-	-	-	-	-	-	-	-	-
Vallonia perspectiva	4	4	2	4	2	1	-	-	6	6
Vallonia sp.	14	14	14	23	10	6	8	12	14	14
Helicodiscus parallelus	-	-	-	-	-	-	1	1	1	1
Helicodiscus singleyanus	12	12	6	10	-	-	3	4	6	6
Succineidae	4	4	2	4	-	-	1	2	2	2
Hawaiia minuscula	46	46	31	53	2	1	16	24	5	5
Deroceras laeve	3	3	5	8	-	-	1	1	-	-
Deroceras aenigma	-	-	-	-	-	-	-	-	-	-
Juveniles-unidentified	10	10	12	20	12	7	-	-	9	9
Subtotal		109		136		21		55		56

Note:All densities rounded to nearest whole number with< 0.5=1.

Table 11.4. Gastropod Density (Individuals/Liter) and Number of Identified Specimens (NISP) in the West 6 Trench Samples at 34Wo73.

Stratum	Btk2		Btk2		Bk1,b		Bk1, b		Btk2b		Bky,2b	
Elevation	98.86		98.65		98.41		98.31		97.96		97.61	
Sample Volume	1.2 liters		1.3 liters		0.5 liters		1.1 liters		1.5 liters		1.2 liters	
Aquatic Taxa	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP
Valvata tricarinata	-	-	2	2	-	-	1	1	-	-	-	-
Hydrobiidae/Lymnaeidae	-	-	-	-	-	-	2	2	-	-	-	-
Physidae	2	2	5	6	-	-	4	4	43	63	-	-
Physella virgata	-	-	-	-	-	-	-	-	1	1	-	-
Gyraulus circumstriatus	-	-	1	1	-	-	-	-	-	-	-	-
Gyraulus parvus	1	1	-	-	-	-	-	-	2	3	-	-
Gyraulus sp.	3	3	2	3	-	-	1	1	15	22	-	-
Planorbella trivolvis	-	-	-	-	-	-	1	1	1	1	-	-
Planorbella sp.	-	-	-	-	2	1	-	-	9	13	-	-
Promenetus exacuous	1	1	-	-	-	-	-	-	1	1	-	-
Ferrissia frigilis	-	-	-	-	-	-	-	-	33	49	-	-
Juveniles-unidentified	-	-	2	3	-	-	-	-	-	-	-	-
Subtotal		7		15		1		9		153		0
Terrestrial Taxa												
Gastrocopta armifera	-	-	-	-	-	-	1	1	2	2	-	-
Gastrocopta cristata	-	-	6	8	-	-	4	4	3	3	-	-
Gastrocopta pellucida	-	-	-	-	-	-	1	1	1	1	2	2
Gastrocopta procera	-	-	1	1	2	1	4	4	2	2	1	1
Pupoides albilabris	-	-	-	-	-	-	2	2	-	-	1	1
Vallonia perspectiva	1	1	2	2	-	-	9	10	2	3	1	1
Vallonia sp.	3	3	5	6	12	6	61	67	11	17	4	5
Helicodiscus parallelus	-	-	-	-	-	-	-	-	2	3	1	1
Helicodiscus singleyanus	5	6	12	16	18	9	22	24	28	42	11	13
Succineidae	-	-	-	-	4	2	6	7	2	3	1	1
Hawaiia minuscula	9	11	5	7	14	7	25	27	64	96	7	8
Glyphyalinia indentata	-	-	-	-	2	1	1	1	-	-	-	-
Deroceras laeve	-	-	-	-	-	-	2	2	3	3	-	-
Juveniles-unidentified	-	1	-	28	-	5	-	17	-	41	-	3
Subtotal		22		68		31		167		216		36

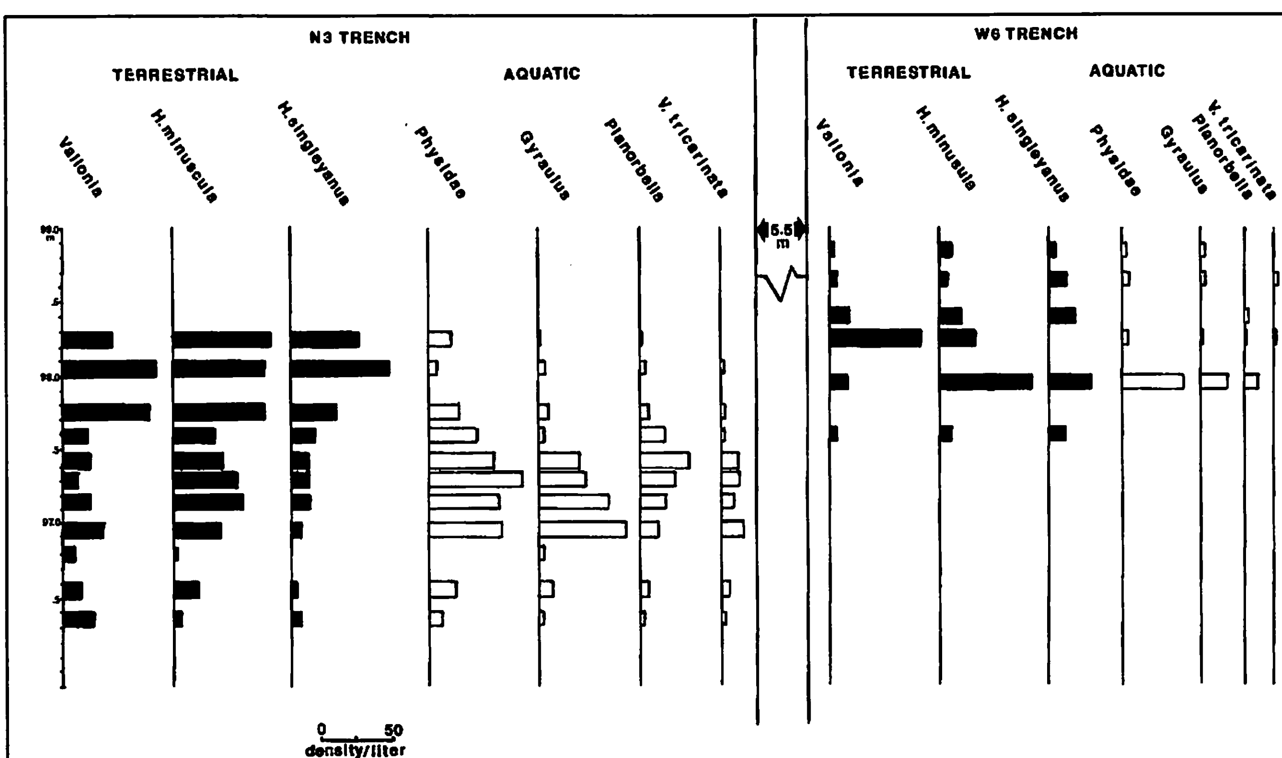


Figure 11.3. Density (individuals/liter) for selected snail species from samples in the North 3 and West 6 backhoe trenches at the Burnham site.

Table 11.5. Gastropod Density (Individuals/Liter) and Number of Identified Specimens (NISP) in the Sample from North 3-West 5 at the Burnham Site.

Stratum	BC,2b		BC,2b	
Elevation	97.29		97.37	
Sample Volume	0.65		0.70	
Terrestrial Taxa	Ind/L	NISP	Ind/L	NISP
Gastrocopta armifera	8	5	-	-
Gastrocopta cristata	6	4	14	10
Gastrocopta pellucida	100	65	19	13
Gastrocopta procera	5	3	3	2
Pupoides albilabris	-	-	3	2
Vallonia perspectiva	26	17	13	9
Vallonia sp.	135	88	14	10
Helicodiscus singleyanus	-	-	3	2
Hawaiia minuscula	43	28	20	14
Deroceras laeve	3	2	-	-
Juveniles-unidentified	45	29	6	4
Total		**241**		**66**

Note: No aquatic taxa were present.

The most common terrestrial snail in the West 6 samples is *Hawaiia minuscula* that reaches its highest density (64 ind/l) in riparian stratum Btk2b, followed by the post-riparian stratum of Bkl,b (25 ind/l). *Hawaiia minuscula* represents 29% (156 specimens) of all terrestrials in the sequence, being followed by *Vallonia perspectiva* and juvenile *Vallonia* with 121 individuals or 22% of the combined assemblage. Third in abundance is *Helicodiscus singleyanus* with 110 individuals contributing 20% of the total land taxa. These three taxa represent 72% (387 specimens) of the terrestrial snail shells from the West 6 incremental samples.

The most distinct trend in the West 6 samples is the abundance of aquatic pulmonate snails and mesic land snails in the riparian sample of Btk2b. The densities of both aquatic and terrestrials decline in samples taken at higher elevations.

North 3-West 5 (Fig. 11.1)

In October 1989, Wyckoff took two sediment samples in the North 3 trench at grid coordinate N3-W5. These samples came from stratum BC,2b at elevations 97.40 to 97.30 and 97.33 to 97.25 which correspond to a dark organically enriched stratum that has been dated at more than 34,000 years old. The two samples totaled 1.35 liters of sediment and yielded 307 terrestrial and no aquatic snails (Table 11.5). The mean density of these two samples was 233 ind/l, whereas the range was 371 ind/l (stratum BC,2b at 97.37m) to 94 ind/l (stratum BC,2b at 97.29m). The two samples contained 9 of the 17 terrestrial taxa recovered in the Burnham sediments.

The most common land snails in the N3-W5 samples are *Vallonia perspectiva* and juvenile *Vallonia*, probably assignable to *V. perspectiva* with 40% (124 individuals), followed by *Gastrocopta pellucida* (25%; 78 individuals) and *Hawaiia minuscula* (14%; 42 individuals). These samples appear to represent a drier habitat than the assemblage from the West 6 trench, S1-W22, or N3.75-W11.5. *Vallonia perspectiva* is a stress tolerant gastropod found in dry or seasonally dry habitats. *Gastrocopta pellucida* is second in abundance but has a low density while being a persistent element in the Burnham site sequence. *Gastrocopta pellucida* is more common in the N3-W5 samples than elsewhere at the site. It has a density of 100 ind/l in stratum BC,2b (97.37m), ten times more than the next highest density (in S1-W22, stratum SC4 at 96.56m) for this species. The marked difference in the density of certain land snails in the N3-W5 samples probably reflects the former presence of a rather xeric vegetation community at the BC,2b location. The density for *G. pellucida* is similar to some modern sampled xeric habitats in the Burnham site vicinity (see discussion of modern gastropod fauna). The *G. pellucida* found in many of the site samples are perhaps individuals carried from nearby xeric vegetation communities by wind or water runoff into the prehistoric Burnham pond basin. A somewhat drier local setting is indicated at BC,2b sample sites by the lowest density of *Hawaiia minuscula* in any sampled area and a near absence of *Helicodiscus singleyanus*, both being numerous terrestrial elements at other sampled locations.

Discussion

Aquatic Gastropods

The Burnham matrix samples yielded 1976 aquatic snail shells that represent at least nine taxa (Table 11.6; some examples shown in Fig. 11.4). The aquatic shells were most abundant in the water-deposited gleyed strata (SC4, SD, NC2, NC3, and NC4) or in sediments adjacent gleyed strata (Btk2b in the West 6 trench). Riparian habitats may have supported aquatic snails during high water periods or received accumulations of shells through windrowing or other abiotic mechanisms. Three taxa, Physidae, *Gyraulus*, and *Planorbella*, together represent 80%of all aquatic gastropods in the combined Burnham assemblage. These

Table 11.6. The Number of Identified Specimens (NISP) and the Projected Individuals Per Liter of Sediment (Ind/L) for Sphaeriidae Clams, Ostracoda, *Chara*, Aquatic Snails, and Terrestrial Snails in the Sampled Deposits at the Burnham Site.

Provenience	Elevation	Sample Volume (Liters)	Sphaeriidae NISP	Sphaeriidae Ind/L	Ostracoda NISP	Ostracoda Ind/L	*Chara* NISP	*Chara* Ind/L	Aquatic Snails NISP	Aquatic Snails Ind/L	Terrestrial Snails NISP	Terrestrial Snails Ind/L
S1W22	96.86	0.95	5	5	167	176	88	93	390	411	124	130
	96.56	0.95	9	9	134	141	7	7	233	245	171	180
	96.26	0.90	10	11	49	54	2	2	236	262	160	178
North 3 Trench	98.26	2.20	2	1	16	7	-	-	38	17	426	194
	98.06	2.40	2	1	10	4	-	-	33	18	545	227
	97.77	1.80	-	-	1	1	-	-	91	51	340	187
	97.60	1.00	2	2	67	34	-	-	68	68	88	88
	97.43	1.00	3	3	196	196	-	-	163	163	95	95
	97.32	0.60	2	3	202	336	-	-	88	147	71	118
	97.16	1.00	1	1	104	104	-	-	121	121	109	109
	96.96	1.70	9	5	308	181	3	2	242	142	136	80
	96.80	0.60	-	-	1	2	-	-	1	2	21	35
	96.56	1.50	1	1	68	45	2	1	67	45	55	37
	96.37	1.00	-	-	7	7	-	-	20	20	56	56
West 6 Trench	98.86	1.20	-	-	3	3	-	-	7	6	22	18
	98.65	1.30	-	-	5	4	-	-	15	12	68	52
	98.41	0.50	-	-	3	6	-	-	1	2	31	62
	98.31	1.10	-	-	4	4	-	-	9	9	167	152
	97.96	1.50	-	-	64	43	-	-	153	102	216	144
	97.61	1.20	-	-	1	1	-	-	-	-	36	30
North 3-West 5	97.37	0.65	-	-	1	2	-	-	-	-	241	371
	97.29	0.70	-	-	-	-	-	-	-	-	66	94
Total NISP			46		1411		102		1976		3244	

pulmonate snails are found most abundantly on emergent or floating vegetation in the quiet areas of shallow waters.

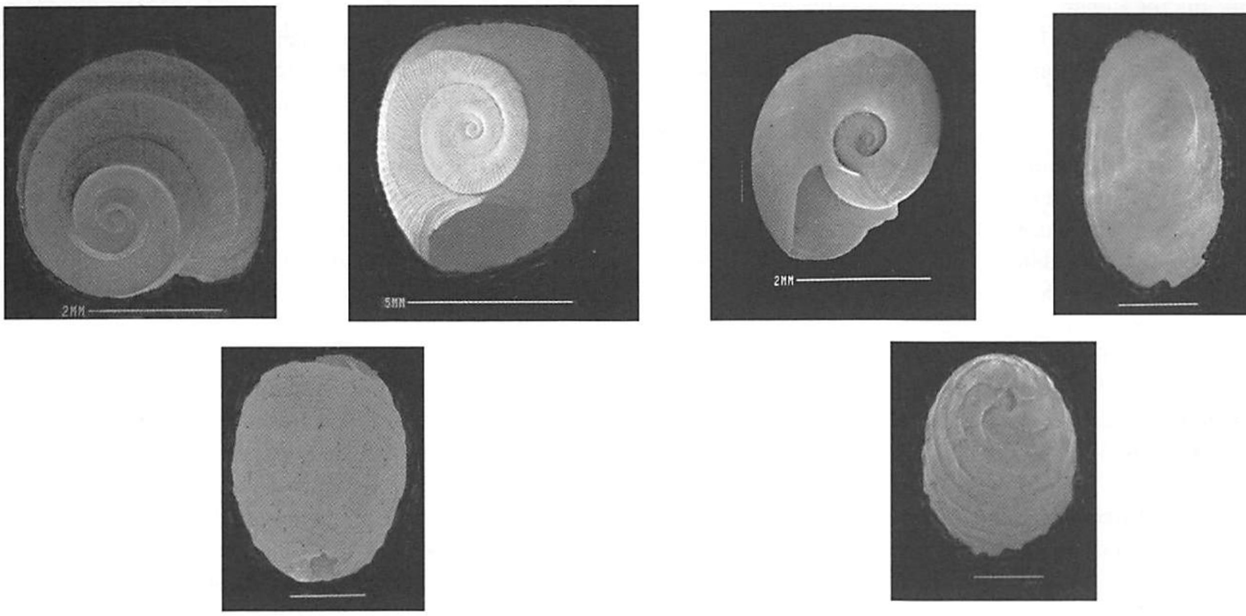
The most common taxa in the Burnham sediments are individuals of the family Physidae. The 787 specimens represent 40% of all aquatic snails. The majority of the Physidae shells are subadult or damaged specimens that make species identification difficult (see comments by Baker 1928:418-419; Leonard 1959:53; Taylor 1960:115-116). The specifically identified Physidae at Burnham is *Physella virgata* which is represented by 7 individuals. *Physella virgata* has been referred to the synonym *Physa anatina* Lea and *Physa hawnii* Lea in the ecological and paleoecological literature of the Great Plains prior to about 1970 (e.g., Leonard 1959:46-47; Hibbard and Taylor 1960:115-116; Taylor 1960:62).

Physella virgata is a widespread species found living today throughout central North America, including Kansas, Oklahoma, and Texas (Bequaert and Miller 1973:201-203; Leonard 1959:46-47; Fullington 1982:63; Neck 1990:14; Branson 1961a:46-47). The Physidae in general, and *Physella virgata* specifically, have a wide tolerance for habitat types and may be found in ephemeral ponds, water-filled ditches, stream pools, and lakes. This species may occur on a mud substrate or on aquatic vegetation and seems to prefer perennial waters and spring-fed ponds in the Great Plains region (Leonard 1959:46-47; Hibbard and Taylor 1960:117; Taylor 1960:62). The Physidae snails have one of the widest tolerance ranges for temperature extremes (Van der Schalie and Berry 1973).

Next in abundance at Burnham are *Gyraulus parvus* (276 specimens) and specifically unidentified juvenile *Gyraulus* (325 specimens) that are probably assignable to *G. parvus*. One additional *Gyraulus* species, *G. circumstriatus*, is represented at Burnham by a single shell. The 602 *Gyraulus* comprise 30.5% of the combined aquatic assemblage. *Gyraulus parvus* is a species typically found living on submerged aquatic vegetation rooted in a mud substrate in the quiet, shallow (<1m) waters of stream pools, ponds, and lakes. This species can be found in temporary or permanent waters (Baker 1928:376-377; Clarke 1981:180; Hibbard and Taylor 1960:101; Taylor 1960:58). *Gyraulus parvus* is a widespread species that today occurs in Kansas, Texas, and Oklahoma (Leonard 1959:60-61, 64, Fig. 28; Fullington 1982:63; Neck 1990:11, Table 1; Branson 1961). The one specimen of *G. circumstriatus* was found rather high (at 98.65m in stratum Btk2) on the West 6 trench samples and may be a contaminant washed into the depositional sequence from an older deposit. *Gyraulus circumstriatus* appear restricted to temporary water habitats (Clarke 1979:14).

The genus *Planorbella* with 13 *Planorbella trivolvis* and 177 juvenile *Planorbella*, all probably assignable to *P. trivolvis*, represents the third ranking (10% of the combined assemblage) aquatic taxon. The preferred habitat of *P. trivolvis* is shallow (<1m), well vegetated, low energy waters of stream pools, ponds, and lakes where it may be found on the mud substrate or adhering to submerged vegetation or detritus. This species is usually attributed to perennial waters (Baker 1928:332; Clarke 1981:212; Leonard 1959:58-59; Taylor 1960:59), although some researchers indicate it can withstand seasonal drying (A.E. Leonard 1943:235). An in-depth study of aquatic snails in central Canada found *Planorbella trivolvis* to be the most widespread species, one with the broadest ecological tolerance. The adaptability of *P. trivolvis* allows it to be a highly successful colonizer of

Aquatic Species



Terrestrial Species

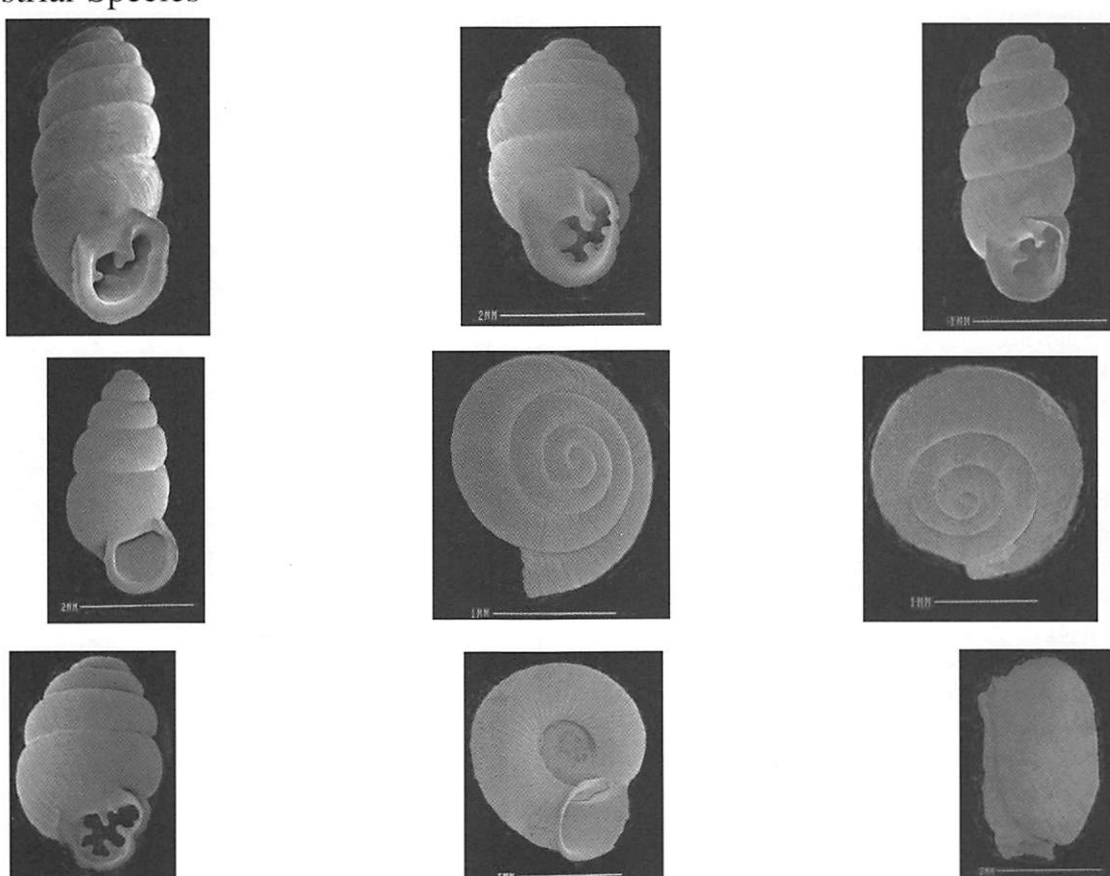


Figure 11.4. Illustrations of Burnham site gastropods and Chara. *Top row (left to right):* Valvata tricarinata, Planorbella trivolvis, Promenetus exacuous, *and* Ferrissia walkeri. *Second row (left to right):* Chara. *Third row (left to right):* Gastrocopta procera, Gastrocopta armifera, *and* Gastrocopta pellucida. *Fourth row (left to right):* Pupoides albilabris, Hawaiia minuscula, *and* Helicodiscus singleyanus. *Bottom row (left to right):*. Vertigo ovata, Vallonia perspectiva, *and* Deroceras laeve.

new habitats (Pip 1986:41). A study of water temperature parameters for aquatic snails indicates a range between 22 and 30 degrees Celcius (72 to 86 degrees F) is necessary for growth and reproduction of *P. trivolvis* (Van der Schalie and Berry 1973:51-52).

In contrast to the pulmonates, the gill-breathing species *Valvata tricarinata* represent only 7% of all Burnham aquatic snails. Living populations of *V. tricarinata* are found in cool perennial water habitats, usually on submerged aquatic vegetation (Clarke 1981:9; Taylor 1960:48), such as the rooted macrophytic algae *Chara*. The remains of *Chara* were recovered in Burnham's gleyed strata (Table 11.6). This algae grows beyond the depths tolerated by emergent vegetation in well oxygenated littoral zones of ponds and lakes (Smith 1966:174-175; Odum 1971:303).

Valvata tricarinata is not known to be living today in Kansas, Oklahoma, Texas, or the arid Southwest (Hibbard and Taylor 1960:79-80; Fullington 1982:63; Neck 1990; Bequaert and Miller 1973:213). The nearest population of *V. tricarinata* to Burnham is located 400 miles (640km) to the north at the Fort Niobrara National Wildlife Refuge in Cherry County, Nebraska. This represents a disjunct population that is south of *V. tricarinata*'s modern range (Fig. 11.5). The Cherry County population is found in one spring-fed pond having a water temperature of 15 degrees Celcius (59 degrees F). It is stated that *V. tricarinata*'s existence at this locality is considered possible because of the insulating effect of the cool spring water. This northern species is probably able to live here because the pond is warmed little if at all during summer hot spells. Other permanent ponds in Cherry County, apparently similar except that they lack spring sources, were examined without finding this species (Taylor 1960:48).

Valvata tricarinata has sometimes been employed in the Southern Plains as a proxy indicator of cooler temperatures during the Pleistocene (Wendorf 1961:110-111; DeVore 1975:28). This initially seems reasonable as water temperature in the littoral zone is closely coupled with seasonal changes in air temperature (Odum 1971:303). However, caution has been urged by some researchers in using aquatic snails such as *Valvata* as a climatic indicator (Hibbard and Taylor 1960:51-52) because of the cooling effects of spring water. *Valvata tricarinata*, requiring a cool (circa 15 degrees C) summer water temperature for its existence, seems inconsistent with species such as *Planorbella trivolvis* which require warmer (22 to 30 degrees C) for growth and reproduction. This is an example of a "disharmonious" Pleistocene assemblage with warm water and cool water species present in the same depositional context.

A number of natural, spring-fed ponds and lakes are known on the Southern Plains today. Springs are a concentrated flow of ground water that issues from a ground opening. The temperature of spring water is constant throughout the year. Examples of cool water temperature, spring-fed ponds and lakes include the Roswell Artesian Basin in eastern New Mexico (Navarre 1959; Cole 1963:420) and the Meade Artesian Basin in Meade County, Kansas (Fig. 11.5). The Meade Artesian Basin is 100 km northwest of Burnham and is known for its numerous spring-fed "sink-hole" ponds and lakes (Schultz 1969). One of these spring-fed ponds contains a disjunct population of the cool water pulmonate snail *Promenetus exacuous*, but not *Valvata tricarinata* (A.E. Leonard 1943:235; Leonard 1959:67).

Recently, Caran and Baumgardner (1990) have defined the Lingos Formation, which covers more than 9000 sq. km in the Rolling Plains of Texas southwest of the Burnham site (Fig. 11.5). The Lingos Formation includes evidence of subsidence basins that formed during the late Pleistocene as a result of dissolution of Permian evaporites by emergent ground water and that later filled with sediments. Given the gypsum-rich Permian bedrock in the Burnham locality, it seemed feasible that the late Pleistocene Burnham pond was a spring-fed basin somewhat similar to those of the Meade or Roswell artesian basins. That this type of pond was widespread over the Southern Plains seems enhanced by the susceptibility of the bedrock to dissolution and a Pluvial period water table 10 m (30 ft.) higher than that of today in the adjacent Southwest (Smith and Street-Perrott 1983:208).

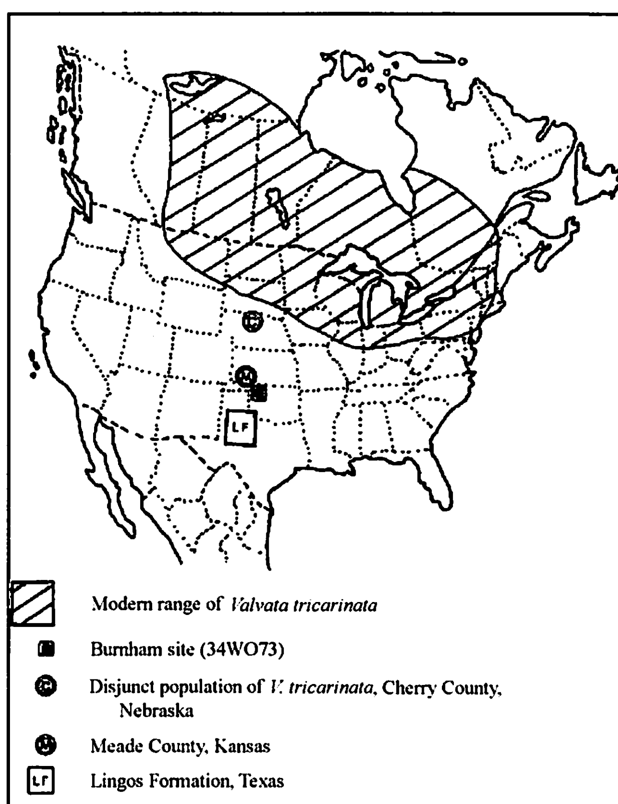


Figure 11.5. Modern range of Valvata tricarinata *in realtion to the Burnham sites and other discussed locations.*

However, examination of rock strata in the vicinity of the Burnham site failed to reveal a subsidence basin. The most probable origin for the Burnham pond is a dam constructed by beavers.

Aquatic gastropods, including *Valvata tricarinata*, along with riparian terrestrial taxa would be readily introduced into isolated ponds through avian dispersal, often as eggs in mud adhering to the feet of birds (Pratt 1983:74; Bequaert and Miller 1973:47). During late Pleistocene periods having relatively warm summer temperatures, the cool water, gill-breathing *Valvata* would be thermally segregated into deeper, spring-cooled waters, whereas the seasonally warmed pond margins would maintain populations of pulmonates such as *Planorbella trivolvis*.

One cool water pulmonate snail, *Promenetus exacuous*, is represented by less than 1% (21 individuals) in the Burnham aquatic snail assemblages. This species is generally not found living today south of 39° North Latitude, but it is known from disjunct populations in eastern Oklahoma, Kansas, and Texas (Branson 1961a:57; A.E. Leonard 1943:235; Pratt 1983). The warm water margins of the Pleistocene Burnham pond may not have favored reproduction and increase of this species.

Three additional aquatic mollusks in the Burnham assemblage include 91 specimens of the families Hydrobiidae/Lymnaeidae, 59 individuals of the tiny limpet *Ferrissia fragilis*, 46 individuals of *Ferrissia walkeri*, and 39 specimens of specifically unidentified juvenile *Ferrissia*. These 233 shells collectively represent 12% of all aquatic snails.

Terrestrial Gastropods

The Burnham sediment samples yielded 3244 land snails that represent 17 taxa (Table 11.6; some examples shown in Fig. 11.4). The shells of terrestrial species were most common in the colluvial soil horizons, but they were also numerous in the gleyed soil horizons (Tables 11.1 and 11.6; Fig. 11.3). The shells of most land snails are easily carried by water run-off or wind, and thus they are readily incorporated into pond sediments. Three land snail species, *Hawaiia minuscula, Helicodiscus singleyanus*, and *Vallonia perspectiva*, plus *Vallonia* juveniles, collectively represent 82% of the identified terrestrial taxa. Although *H. minuscula* and *H. singleyanus* tend to be most abundant in mesic vegetation communities, all three are notable for their tolerance of drought conditions and temperature stress.

Hawaiia minuscula, with 996 individuals (36% of the identified land snails), was the most abundant terrestrial species and was recovered in each of the 22 Burnham samples. *Hawaiia minuscula* is adaptable to a wide range of habitats, ranging from moist deciduous woodlands to xeric grasslands, and it occurs throughout the Midwest, Plains, and Southwest (Bequaert and Miller 1973:76-77, 145; Leonard 1959:117; Taylor 1960:81). *Hawaiia minuscula* may be found in xeric settings, but it is most abundant in moist woodlands (A.E. Leonärd 1943:238; Leonard and Goble 1952:1042; Basch et al. 1961:196). The modern distribution of *H. minuscula* populations in Kansas and Oklahoma indicates that they are most widespread in the eastern portions of those states and that they generally decrease towards the west, a fact that is assumed to be related to a corresponding decrease in rainfall (Hubricht 1985:130, Map 289; Sutherland 1977:47-48, Figs. 13-14). In his survey of gastropods in the Texas panhandle, Neck (1990:13) found living *H. minuscula* at only one mesic stream bank location in Ochiltree County, which is about 125 miles west-southwest of the Burnham site. Modern vegetation litter samples from the Burnham vicinity recovered fresh shells or living *H. minuscula* in 8 of 10 sample locations. The Burnham locale receives about 4.0 inches more annual precipitation than Ochiltree County, Texas, and this increase may provide more habitats suitable for *H. minuscula.* The modern Burnham samples having the largest number of *H. minuscula* were those at the most mesic locations (see discussion of the modern snail fauna).

The second most abundant land snail was *Vallonia perspectiva* (129 individuals) combined with the specifically unidentified juvenile *Vallonia* (610 individuals) that are probably attributable to *V. perspectiva.* The 739 *Vallonia* comprise 27% of the Burnham terrestrial assemblage. The *Vallonia*, like *Hawaiia minuscula*, are a persistent member of the land snail community, being recovered from each of the 22 Burnham sediment samples. The highest densities of *Vallonia* appear in post-gleyed (pond derived) sediments, whereas *Hawaiia minuscula* seem more abundant in gleyed or riparian associated sediments. The record of modern *Vallonia perspectiva* distribution and habitat preference is not extensively reported. No modern populations of this species are reported in Kansas or Oklahoma (Leonard 1959; Hubricht 1985:67, Map 33). *Vallonia perspectiva* is recorded in relict mesic habitats of the trans-Pecos area of southwestern Texas (Fullington and Pratt 1974:29, Fig. 17). In the Southwest, it lives at 3500 to 8700 feet above sea level in Arizona and New Mexico (Bequaert and Miller 1973:96-97). In western Wisconsin, I have found living *V. perspectiva* at several locations, most commonly inhabiting the detritus of xeric to mesic vegetation communities adjacent to, or on, dolomite outcrops (Theler 1997). It is more abundant in locations that experience sharp seasonal extremes than in either thick stands of prairie vegetation or in moist woodlands.

Helicodiscus singleyanus is the third most common species in the Burnham sediments. Its 539 specimens comprise 19% of the identified terrestrial snails. Like *H. minuscula* and *Vallonia, Helicodiscus singleyanus* can withstand the frequently dry conditions of xeric vegetation communities, but it is most common in mesic or transitional mesic to xeric settings (Basch et al. 1961:195). It is not found in any numbers in the same high stress Wisconsin location that *Vallonia* seems to occupy (Theler 1997). *Helicodiscus singleyanus* was recovered from 4 of the 10 modern samples collected in the Burnham locale.

Next in abundance in the Burnham sediments are two pupillids, *Gastrocopta pellucida* with 127 individuals (4.6% of all land snails) and *Gastrocopta cristata* with 106 individuals (3.8%). These species characteristically inhabit the moisture-retaining vegetation detritus in brushland and grassland settings. Both taxa live today in portions of Texas, Oklahoma, and Kansas (A.E. Leonard 1943:239; Leonard 1959:180; Cheatum and Fullington 1973:13-14, 16-17; Neck 1990; Branson 1961b; Hubricht 1985:72, Maps 47, 49, and 73). The modern ranges for some species retain an element of ambiguity due to published records that have included riparian drift shells of possible Pleistocene origin. The failure to document if specimens were collected living or as fresh shells can contribute to dramatic differences in the mapped ranges of species such as *G. cristata*; for example, compare the maps of Leonard (1959:178, Fig. 77) with those of Hubricht (1985:72, Map 47).

Gastrocopta pellucida (Fig. 11.6) and perhaps *G. cristata* appear at their modern northern limit in southern Kansas, just north of the Burnham site. The presence of both species throughout the sampled Burnham sediments suggests that they lived in the site's vicinity during the period of ponding and sediment deposition. This is interpreted to indicate xeric vegetation communities were adjacent to the Pleistocene Burnham pond and that summers were as warm and winters as mild as those of modern northwestern Oklahoma. *Gastrocopta pellucida* is the most abundant land snail now living in the Burnham site vicinity (see discussion of modern snail fauna), whereas *G. cristata* has not yet been found living there (Wyckoff et al. 1997). It is recorded to be living in nearby Meade County, Kansas, and in the Texas panhandle (A.E. Leonard 1943:239; Neck 1990:11, Table 1).

The presence of *Gastrocopta pellucida* and *G. cristata* indicate a relatively warm mean summer temperature. This is supported by the complete absence of northern or Rocky Mountain alpine associated terrestrial snails (discussed below), which indicate that all of the sampled strata predate the cooler summer temperatures of the Wisconsinan maximum (Pilsbry 1948:XLII; Miller 1975:13; Taylor 1965:601; Hibbard and Taylor 1960:16; Follmer 1983:141-142).

Three additional land species found at Burnham are: *Gastrocopta procera* (51 individuals; 1.8% of all land snails), *G. armifera* (17 individuals; 0.6%), and *Pupoides albilabris* (25 specimens; 0.9%), and all are characteristic of arid grassland and brushland communities (Leonard and Goble 1952:1030, 1034-1035; Basch et al. 1961:192-193; Fitch and Lokke 1956:450). These three species are also widespread on the Southern Plains today (Hubricht 1985:69,

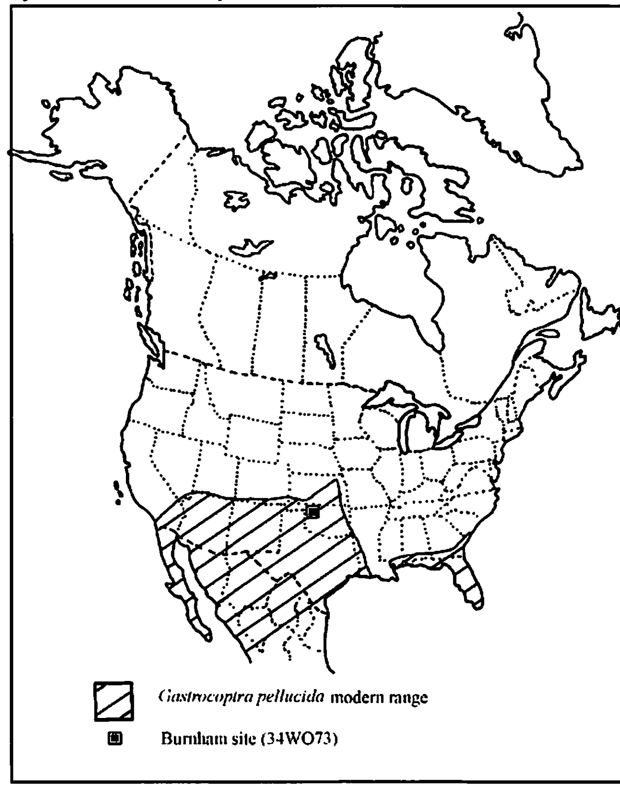


Figure 11.6. The modern range of Gastrocopta pellucida *in relation to the Burnham site.*

Maps 38, 44, 46, 72, and 72; Leonard 1959:169-170, 178-182). *Gastrocopta procera* and *P. albilabris* co-occur with *G. pellucida* in most of the modern gastropod samples collected near the Burnham site. All three species are distinct from *G. pellucida* and *G. cristata* in having more northern range distributions. *Gastrocopta procera* and *P. albilabris* populations extend into the north central Midwest (Baerreis 1980:108-109; Reigle 1963:16-17; Hubricht 1985:69, Map 38; Theler 1997), and *G. armifera* is found into Canada (Bequaert and Miller 1973:79; Hubricht 1985:71, Map 44).

The shells of Succineidae are fairly common in the Burnham sediments; 81 individuals (2.9% of the terrestrials) were recovered. The shells alone are generally unreliable for species identification (Leonard 1959:139), leaving this family of snails valueless for habitat and climatic interpretations.

Two slug species, *Deroceras laeve* and *D. aenigma*, are represented at Burnham by their scale-like internal shell. *Deroceras laeve* is represented by 58 shells (equaling 2.1% of the terrestrial assemblage) and is widespread (in small numbers in 15 of 22 samples) at Burnham. This slug is found today over much of North America, including Texas, Oklahoma, and Kansas where it is well adapted to locations having seasonally moist conditions (Hubricht 1985:115, Map 202; Leonard 1959:126-127; Bequaert and Miller 1973:68; Neck 1990:15). The other slug species manifest in the Burnham deposits is *Deroceras aenigma* with 5 shells (0.2% of the terrestrial assemblage). This species became extinct at the end of the Pleistocene (Taylor 1965:605) and is the only extinct snail recovered at Burnham. The taxonomic validity of *D. aenigma* has been questioned (Bequaert and Miller 1973:68-69), but the few shells in the Burnham collection do not intergrade with *D. laeve* and appear distinct. *Deroceras aenigma* was found only in three adjacent samples (between elevations 97.60 and 98.06m) in the North 3 trench.

Helicodiscus parallelus is represented by 26 shells (0.9% of total land snails) at Burnham, and it is sparsely manifest in 11 of the 22 samples. This species can survive in arid grasslands but is most abundant in mesic settings (Leonard and Goble 1952:1039; Fitch and Lokke 1956:451). This species is widespread on the eastern Plains, reaching its western distributional range margin in Oklahoma and the Texas panhandle (Hubricht 1985:11, Map 185). *Helicodiscus parallelus* is found living in a few protected locations around the Burnham site today.

The final five terrestrial gastropod species, each with five or fewer individuals in the sampled Burnham sediments, together contribute less than 1% of all identified land snails. Even though uncommon, these species offer some insight to our understanding of the local and regional environmental setting. *Gastrocopta pentodon*, with five individuals, comprises 0.2% of the terrestrial assemblage. This species occurs today in eastern Kansas and Oklahoma and portions of Texas (Leonard 1959:175, Fig. 75; Hubricht 1985:77, Map 61; Wyckoff et al. 1997), a distribution that seems controlled by available moisture. *Gastrocopta pentodon* appears to thrive where 30 inches or more precipitation occurs annually, but other factors, such as ground cover and vegetation detritus, may play a role at the western margins of this species' range.

Carychium exiguum is represented at Burnham by four individuals (0.1% of identified land snails). Today, this species is not found living closer to the site than easternmost Kansas and Oklahoma (Hubricht 1985:89, Map 17). *Carychium exiguum* is typically found in riparian habitats such as spring seeps or at stable pond margins and in moist deciduous woodlands (Taylor 1960:51; Leonard 1959:194; Harry 1951:17-20; Burch and Van Devender 1980:61).

Vertigo ovata is represented by only three individuals (0.1% of identified land species). This is a riparian species that is widespread but sporadic on the Plains today (Hubricht 1985:79, Map 67). *Vertigo ovata* occurs at spring seeps and on detritus in marshy areas (Leonard 1959:186; Franzen and Leonard 1947:355).

Two individuals representative of *Glyphyalinia indentata* were recovered at Burnham. The two shells were found in adjacent samples at N3-W5 of the North 3 backhoe trench (Table 12.5), and they probably represent a brief introduction of the species at Burnham. *Glyphyalinia indentata* is found today in the eastern parts of Oklahoma and Kansas (Hubricht 1985:119, Map 222; Leonard 1959:113, Fig. 45). The sharp east-west distributional limit of this species is most likely the result of moisture availability that inhibits its spread westward. The western range margin of *G. indentata* is closely associated with the 30 to 32 inches isohyets (Sutherland 1977:48, Figs. 13-14).

Gastrocopta holzingeri is the rarest snail species (1 individual) at Burnham. *Gastrocopta holzingeri* is found in dry to moist habitats and is reportedly widespread in Kansas and Oklahoma (Hubricht 1985:73, Map 48; Leonard 1959:174-175). No examples were recovered in the modern samples taken from around the Burnham site, and it was not found by Neck (1990:14) in the Texas panhandle. Metcalf (1984, cited in Neck 1990) has reported living *G. holzingeri* among basaltic talus in northwestern Cimarron County, Oklahoma. Neck (1990:14) suggests this species arrived in

Table 11.7. Modern Terrestrial Snail Quanities from the Vicinity of the Burnham Site, Woods County, Oklahoma.

	Drier Open									Moister Protected
Site Number	3	10	2	1	5	4	9	8	7	6
Vegetation	Sage	Juniper	Juniper	Dead Yucca	Live Yucca	Dead Yucca	Living/Dead Yucca	Grass	Grass	Grass
Site Aspect	SW	W	SW	S	N	N	WSW	S	E	N
Taxon	#	#	#	#	#	#	#	#	#	#
Gastrocopta armifera	-	-	-	-	1	1	-	-	-	25
Gastrocopta pellucida	54	121	21	149	63	154	436	79	381	576
Gastrocopta procera	7	12	12	23	46	66	272	40	157	141
Pupoides albilabris	2	-	1	22	31	35	17	12	4	22
Helicodiscus parallelus	-	-	1	-	-	-	-	-	31	6
Helicodiscus singleyanus	-	-	1	-	-	-	-	2	11	4
Helicodiscus nummus	-	-	-	-	-	-	-	-	108	31
Hawaiia minuscula	-	2	-	1	1	1	6	13	58	40
Deroceras laeve	-	-	-	-	-	-	-	-	1	-
Subtotal	63	135	36	195	142	257	731	146	751	845
Juveniles	61	271	16	166	132	187	448	99	654	883
Total	124	406	52	361	274	444	1179	245	1405	1728
Sample Volume (Liters)	0.6	0.7	1.0	0.4	0.6	0.8	0.9	0.8	0.6	0.7
Number of Taxa	3	3	5	4	5	5	4	5	8	8
Individuals / Liter	207	580	52	903	457	555	1310	306	2342	2469

western Oklahoma through immigration from populations upstream in New Mexico and Colorado.

The Modern Land Snail Fauna

Prior to the present study, no attempt has been made to assess the living gastropod fauna of Woods County, Oklahoma. A number of regional and statewide studies have listed gastropod species recovered in western Oklahoma (Lutz 1949; Wallen 1951; Branson and Wallen 1956), including Woods County (Wallen and Dunlap 1954), but these studies do not indicate if specimens were represented by fresh shells or living individuals when collected. The many headward working stream and arroyo systems in Woods County have cut through numerous Pleistocene deposits. Flash floods in this region will carry modern and subfossil snail shells and deposit them in concentrated detritus pockets along stream courses as floodwaters subside. These riparian drifts often contain great concentrations of shells. Some researchers (Branson and Wallen 1956:34) focused collection efforts on these accumulations with the prospect of surveying an entire drainage basin from a single location (Frest and Dickson 1986:132). The disadvantage of riparian drift collection is that most specimens are empty shells, with modern and subfossils brought together in a single depositional context. Any assessment of habitat association and relative abundance is not possible. As a number of researchers have pointed out, gastropods recovered from riparian drift are practically worthless (Pratt 1983; Neck 1990:10).

During October 1989, I collected five modern vegetation detritus samples in the immediate vicinity of the Burnham site (Fig. 11.7). This was done to assess the modern land snail fauna. Sampling stations were chosen at locations where vegetation detritus had accumulated and where historic disturbance, such as livestock grazing or erosion, appeared minimal. Each location was also evaluated to insure that contamination from sources like riparian drift and colluvial deposits was improbable. Samples were taken under sagebrush, juniper trees, and yucca, all of which provided some protection from sunlight and thus reduced desiccation. Vegetation detritus was collected along with a 5 to 10 mm thick zone of underlying soil. Methods employed in processing and identifying snail taxa are described in the methods portion of this report.

In June of 1991, five additional vegetational detritus samples were collected at the margins of a mesa located just to the northeast of the Burnham site (Fig. 11.7). Three samples were taken at the mesa edge, along the base of detached dolomite caprock blocks, two of which (samples #6 and #7) had adjacent, thick, ungrazed stands of grasses and herbaceous plants. The final two samples included litter taken from under yucca and juniper on the western talus slope of the mesa, some distance below the caprock.

The 10 modern samples are loosely organized in Table 11.7 using the combined factors of number of taxa represented, the number of individual specimens (NISP) per liter (ind/l) of detritus and the species present. The lowest species diversity and density were encountered at the most xeric sites in samples taken under sagebrush and juniper trees facing west or south. Slightly higher taxa diversity and individual density numbers were found in the accumulation of vegetation litter under the protection of mature or dead yucca plants. The number of taxa and individuals dramatically increase in protected settings along the mesa's caprock margin. The two richest samples were taken at north and east facing stations, and each yielded eight of the nine species represented in the modern snail community. These samples included living or fresh shells of each taxa in addition to what is interpreted to be several generations of empty shells.

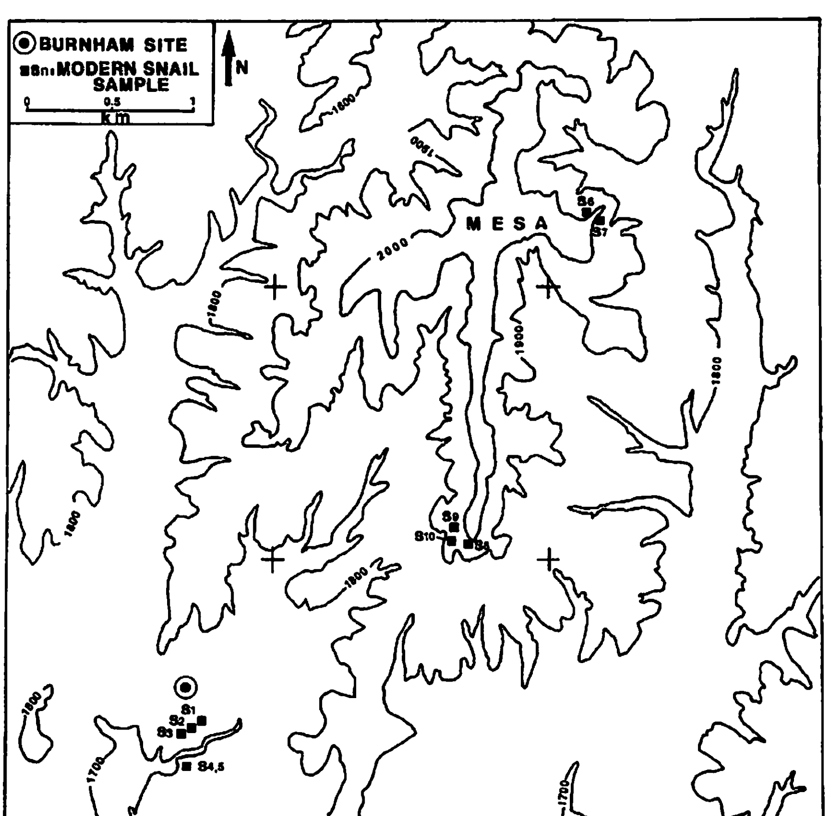


Figure 11.7. Locations of modern snail samples collected in 1989 and 1991 in the vicinity of the Burnham site.

Discussion of Modern Species

The 10 modern vegetation litter samples totaled 7.1 liters of detritus and yielded 6218 gastropod shells. There were 3301 individuals that represent 9 species in addition to 2917 individuals that were subadult shells, virtually all pupillids of the genus *Gastrocopta*.

Gastrocopta pellucida and *G. procera* were present in all 10 samples and together comprise 85% (2810 specimens) of the identifiable shells. *Pupoides albilabris* was not particularly abundant at any one location but was recovered in nine of the modern samples. Neck (1990:14) has included these three species in a group "characteristic (but not restricted to) upland, well-drained microhabitats that represent the most extreme xeric conditions that are tolerated by terrestrial gastropods in the Texas Panhandle". All three taxa are widespread, but of low density, in the Pleistocene sediments of the Burnham site. The single exception is the large number of *Gastrocopta pellucida* recovered from sediment samples taken at North 3-West 5, perhaps representing an in-place accumulation.

In terms of sample occurrence, *Hawaiia minuscula* was next in abundance, being present in eight modern samples (with a total of 122 individual shells). *Helicodiscus singleyanus* (18 individuals) was found in four modern samples, followed by *Helicodiscus parallelus* and *Gastrocopta armifera*, each species recovered in 3 of the 10 modern samples with a total of 38 and 27 individuals, respectively. *Hawaiia minuscula* and *Helicodiscus singleyanus* were widespread and abundant in the Burnham site sediments. The modern samples clearly indicate that while these taxa, along with *H. parallelus* and *G. armifera*, can survive dry conditions, they are found today in some abundance only in the near-mesic, protected setting of the mesa margin.

Finally, *Helicodiscus nummus* (Vanatta) occurred at two locations with 139 individuals. The slug *Deroceras laeve* was found in one modern sample; it was represented by an internal shell that still retained traces of soft tissue that confirms it was of modern origin. *Helicodiscus nummus* was found alive at sample locations #6 and #7. This species does not occur in the Burnham subfossil assemblage and does not appear to have been recovered alive prior to 1991, known only from subfossil and riparian drift specimens (Hubricht 1985:22). The distribution of modern (?) specimens and subfossil shells of *H. nummus* tends to be south of the Woods County, Oklahoma, occurrence reported here (Branson 1960:152-153; Branson, Taylor, and Taylor 1982:239-240; Hubricht 1985:112, Map 188), but shells of this species were reported by Wallen and Dunlap (1954:77) for Woods County.

In the 10 modern detritus samples, species diversity and individual density are found to increase with the degree of protection and potential for moisture retention. In terms of number of individuals and taxa, the richest samples were from the protected, near-mesic locations at the north and east mesa margin at a caprock/grass interface. These were the only locations that produced *Helicodiscus nummus* and *Deroceras laeve*, and they yielded the highest densities of *Hawaiia minuscula*, *Helicodiscus singleyanus*, and *Helicodiscus parallelus* (Table 11.7).

Summary and Conclusions

Aquatic gastropods are dominant in the gleyed, Pleistocene pond-origin strata at the Burnham site. The taxa Physidae, *Planorbella trivolvis*, plus *Planorbella* juveniles, and *Gyraulus parvus* with *Gyraulus* juveniles, together comprise 80% of the Burnham aquatic snails. These are pulmonate gastropods that surface frequently to obtain air. They are usually found living on emergent or floating vegetation in the shallower portions of ponds or lakes where summer water temperatures reach the 22° to 30°C (72° to 86°F) necessary for their physiological maintenance and reproduction. In contrast to these warm water pulmonates, the gill breathing *Valvata tricarinata* represented 7% of all Burnham aquatic snails and indicate a cool, perhaps not exceeding 15°C (59°F) water temperature. This "disharmonious" aquatic snail assemblage is interpreted to be the result of a sharp temperature gradient in a pond fed by cool, emergent ground water. *Valvata* would have been thermally segregated into deeper, cool waters on submerged aquatic vegetation such as the macrophytic algae *Chara*, the remains of which were found in Burnham's gleyed strata. The abundant pulmonates would have lived in the pond's shallower waters, seasonally warmed by solar radiation. *Valvata, Planorbella trivolvis*, and *Chara* all indicate a perennial body of water, but one that may have fluctuated seasonally, resulting in poor recruitment opportunities for cool water pulmonates such as *Promenetus exacuous*, a species that comprised less than 1% of the Burnham aquatic snails. Assuming that the Pleistocene Burnham pond was an isolated basin for much of its existence, it would have been colonized by aquatic gastropods primarily arriving by avian transport, although other dispersal mechanisms are feasible.

Terrestrial snails were most abundant in the colluvial soil horizons at Burnham, but they were common in alluvial strata. The land snail species *Hawaiia minuscula*, *Helicodiscus singleyanus*, and *Vallonia perspectiva*, plus the *Vallonia* juveniles, collectively represent 80% of the terrestrial taxa. These three species are notable for their tolerance of drought and temperature stress, and they would be well adapted to reoccurring mesic meadow habitats that might be fostered by a fluctuating water table associated with the Burnham Pleistocene pond. Support for this may be reflected in the rarity of the riparian terrestrial *Vertigo ovata* and the moist habitat loving *Carychium exiguum*. If the Burnham Pleistocene pond's water had been rather stable, these moisture associated terrestrials would be expected to have been more common, and the species composition of the gastropod community in the hypothesized nearby mesic meadows would have been considerably different and richer from that reflected by the depauperate assemblage of stress tolerant species represented. The terrestrial snails *Gastrocopta pellucida* and *Gastrocopta procera* attest to xeric vegetation communities in close proximity to the Burnham locality. Figure 11.8 provides a schematic representation of the proposed aquatic and terrestrial habitats evident at the Burnham Pleistocene pond locale.

The presence of *Gastrocopta pellucida* and *G. cristata* additionally indicates that winters were not more severe than those of the region today and that summers were as warm as those at present. A growing season of at least 160 days is evidenced by *Gastrocopta procera.* A relatively warm mean summer temperature is supported by the complete absence in the Burnham sequence of terrestrial species found living today at higher elevations of the Rocky Mountains or at the northern portions of the Great Plains. These northern and alpine species include *Discus cronkhitei* (Newcomb), *Pupilla muscorum* (Linneaus), *Pupilla blandi* Morse, *Vallonia gracilicosta* Reinhardt, among other taxa (Wells and Steward 1987; Taylor 1965; Hoff 1962; Karlin 1961). The absence of these cool summer temperature associated land snails is believed to indicate that all of the Burnham strata samples predate the local effects of the coolest summer temperatures of the Wisconsinan maximum of circa 18,000-22,000 B.P. Evidence for this is present in the gastropod assemblage from the Bar M local fauna reported (Taylor and Hibbard 1955) for Harper County, Oklahoma, a location only 20 miles west of Burnham. Radiocarbon dated at 17,750 B.P., the Bar M location contains 11 northern Plains or Rocky Mountain snail species while lacking some taxa, such as *Gastrocopta procera* and *G. pellucida*, that thrive in xeric vegetation communities.

Acknowledgments

Financial support for this study was provided by the National Geographic Society and the Oklahoma Archaeological Survey. Individuals deserving special thanks include Don G. Wyckoff and Kent Buehler; the Keith, Gene, and Vic Burnham families of Freedom, Oklahoma; and John Flick of Hammon, Oklahoma. Dr. Arthur E. Bogan (The Academy of Natural Sciences, Philadelphia) provided assistance with gastropod identification. Mike Scott and Susan Skinner both assisted in report preparation.

References Cited

Baerreis, David A. 1980. Habitat and Climatic Interpretation from Terrestrial Gastropods at the Cherokee Site. *The Cherokee Excavations: Holocene Paleoecology and Human Adaptation in Northwestern Iowa*, edited by D.C. Anderson and H.S. Semken, Jr., pp. 101-122. Academic Press, New York.

Baker, Frank C. 1928. *The Fresh Water Mollusca of Wisconsin.* Wisconsin Geological and Natural History Survey, Bulletin 70, Part I, Gastropoda, pp. 1-507. Madison.

Bequaert, Joseph C. and Walter B. Miller. 1973. *The Mollusks of the Arid Southwest: with an Arizona Check List.* University of Arizona Press, Tucson.

Basch, Paul F., Philip Bainer, and Jerry Wilhm. 1961. Some Ecological Characteristics of the Molluscan Fauna of a Typical Grassland Situation in East Central Kansas. *American Midland Naturalist* 66:178-199.

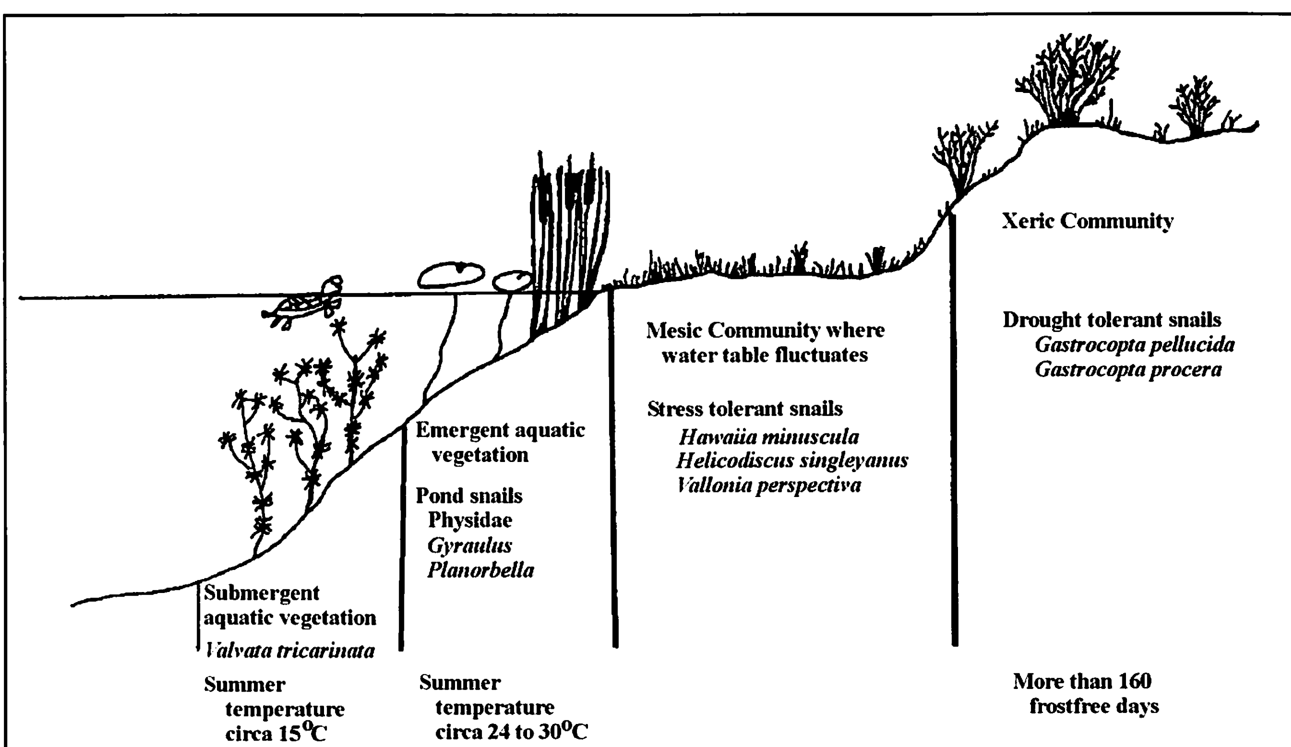


Figure 12.8. Schematic representation of the proposed aquatic and terrestrial habitats at the Pleistocene Burnham pond.

Branson, Branley A. 1960. Gastropoda of the Rob and Bessie Welder Wildlife Foundation Refuge, San Patricio County, Texas. *Southwestern Naturalist* 5(3):143-159.

Branson, Branley A. 1961a. *Recent Gastropoda of Oklahoma, Part 2, Distribution, Ecology, and Taxonomy of Fresh-water Species, with Description of* Helisoma travertine *sp nov.* Oklahoma state University, Publications in Biological Studies, Series (6) 58(17):1-72.

Branson, Branley A. 1961b. The Recent Gastropoda of Oklahoma, III. Terrestrial Species: Pupillidae, Carychiidae, Strobilopsidae, and Oligyridae. *Proceedings of the Oklahoma Academy of Science* 41:45-69.

Branson, Branley A., John Taylor, and Constance Taylor. 1982. Additional Collections of Mollusks from Pleistocene Local Faunas in Caddo and Canadian Counties, Oklahoma. *Southwestern Naturalist* 27(2):238-240.

Branson, Branley A. and I. Eugene Wallen. 1957. Some Further Records of Snail Distribution by Counties in Oklahoma. *Proceedings of the Oklahoma Academy of Science* 36:34-37.

Burch, John B. 1962. *How to Know the Eastern Land Snails.* W.C. Brown Company Publishers, Dubuque.

Burch, John B. 1982. North American Freshwater Snails: Identification Keys, Generic Synonymy, Supplemental Notes. *Walkerana* 4:217-365.

Burch, John B. 1988. North American Freshwater Snails: Introduction, Systematics, Nomenclature, Identification, Morphology, Habitats, Distribution. *Walkerana* 2(6):1-80.

Burch, John B. and John L. Tottenham. 1980. North American Freshwater Snails: Species List, Ranges, and Illustrations. *Walkerana* 1(3):81-215.

Burch, John B. and Amy S. VanDevender. 1980. Identification of Eastern North American Land Snails: the Prosobranchia, Opisthobranchia and Pulmonata (Actophila). *Transactions of the Poets Society*, No. 2.

Caran, S. Christopher and Robert W. Baumgardner. 1990. Quaternary Stratigraphy and Paleoenvironments of the Texas Rolling Plains. *Geological Society of America Bulletin* 102:768-785.

Cheatum, Elmer P. and Richard W. Fullington. 1973. *The Aquatic and Land Mollusca of Texas.* The Recent and Pleistocene Members of the Pupillidae and Urocoptidae (Gastropoda). Dallas Museum of Natural History, Bulletin 1, Part 2.

Clarke, Arthur H. 1979. Gastropods as Indicators of Trophic Lake Stages. *Nautilus* 94(4):138-142.

Clarke, Arthur H. 1981. *The Freshwater Molluscs of Canada.* National Museum of Natural Sciences and National Museums of Canada, Ottawa.

Cole, Gerald A. 1963. The American Southwest and Middle America. *Limnology in North America*, edited by D.G. Frey, pp. 393-434. University of Wisconsin Press, Madison.

Devore, Cynthia H. 1975. The Molluscan Fauna of the Illinoian Butler Spring Sloth Locality from Meade County, Kansas. *Studies on Cenozoic Paleontology and Stratigraphy in Honor of Claude W. Hibbard*, edited by G.R. Smith and N.E. Friedland, pp. 19-28. University of Michigan, Museum of Paleontology, Ann Arbor.

Drake, Robert J. 1975. Fossil Nonmarine Molluscs of the 1961-1963 Llano Estacado Paleoecological Study. *Late Pleistocene Environments of the Southern High Plains*, edited by F. Wendorf and J.J. Hester, pp. 201-245. Fort Burgwin Research Center, Publication 9. Ranchos de Taos, New Mexico.

Fitch, Henry S. and Donald H. Lokke. 1956. The Molluscan Record of Succession on the University of Kansas Natural History Reservation. *Transactions of the Kansas Academy of Science* 59(4):442-455.

Follmer, Leon R. 1983. Sangamon and Wisconsinan Pedogenesis in the Midwestern United States. *Late-Quaternary Environments of the United States*, edited by H.E. Wright, Jr., Vol. 1, The Late Pleistocene, edited by S.C. Porter, pp. 138-144. University of Minnesota Press, Minneapolis.

Fullington, Richard W. 1982. The Recent and Fossil Freshwater Gastropod Fauna of Texas. *Proceedings of the Symposium on Recent Benthological Investigations in Texas and Adjacent States*, edited by J.R. Davis, pp. 61-67.

Fullington, Richard W. and William L. Pratt, Jr. 1974. *The Aquatic and Land Mollusca of Texas.* Dallas Museum of Natural History, Bulletin 1, Part 3: The Helicinidae, Carychiidae, Achatinidae, Bradybaenidae, Bulmulidae, Cionellidae, Haplotrematidae, Helicidae, Oreohelicidae, Spiraxidae, Strobilopsidae, Thysanophoridae, Valloniidae (Gastropoda) in Texas.

Franzen, Dorothea S. and A. Byron Leonard. 1947. Fossil and Living Pupillidae (Gastropoda:Pulmonata) in Kansas. *University of Kansas Science Bulletin* 31, Part 2, 15:311-411.

Frest, Terrence J. and Jeffrey R. Dickson. 1986. Land Snails (Pleistocene-Recent) of the Loess Hills: A Preliminary Survey. *Proceedings of the Iowa Academy of Science* 93(3):130-157.

Harry, Harold W. 1951. Carychium exiguum *(Say) of Lower Michigan: Morphology, Ecology, Variation and Life History (Gastropoda Pulmonata).* Ph. D. dissertation, University of Michigan, Ann Arbor.

Hibbard, Claude W. and Dwight W. Taylor. 1960. *Two Late Pleistocene Faunas from Southwestern Kansas.* University of Michigan, Museum of Paleontology, Contributions 16(1). Ann Arbon.

Hoff, C. Clayton. 1962. Some Terrestrial Gastopoda from New Mexico. *Southwestern Naturalist* 7(1):51-63.

Hubricht, Leslie. 1985. *The Distributions of the Native Land Mollusks of the Eastern United States.* Field Museum of Natural History, Fieldiana Zoology N.S. 24. Chicago.

Jaehnig, Manfred E.W. 1971. The Study of Gastropods:

Methodology. *Plains Anthropologist* 16(54):289-297.

Karlin, Edward J. 1961. Ecological Relationships between Vegetation and the Distribution of Land Snails in Montana, Colorado, and New Mexico. *American Midland Naturalist* 65(1):60-66.

LaRocque, Aurele. 1966. *Pleistocene Mollusca of Ohio.* Ohio Geological Survey Bulletin 62 (pt. 1):1-112.

Leonard, A. Byron. 1952. *Illinoian and Wisconsinan Molluscan Faunas in Kansas.* University of Kansas Paleontological Contributions, Mollusca (4).

Leonard, A. Byron. 1959. *Handbook of Gastropods in Kansas.* University of Kansas Museum of Natural History, Miscellaneous Publication 20.

Leonard, A. Byron and John C. Frye. 1960. *Wisconsinan Molluscan Faunas of the Illinois Valley Region.* Illinois State Geological Survey, Circular 304.

Leonard, A. Byron and C. Raymond Goble. 1952. Mollusca on the University of Kansas Natural History Reservation. *University of Kansas Science Bulletin* 34 (16):1013-1055. Lawrence.

Leonard, Alice E. 1943. The Mollusca of Meade and Clark Counties, Kansas. *Transactions of the Kansas Academy of Science* 46:226-240.

Lutz, Louis. 1949. A Check List of the Land Snails of Oklahoma. *Proceedings of the Oklahoma Academy of Science* 30:32-35.

Metcalf, Artie L. 1984. Land Snails (Gastropoda: Pulmonata) from Cimarron County, Oklahoma. *Texas Journal of Science* 36:53-64.

Miller, Barry B. 1966. Five Illinoian Molluscan Faunas from the Southern Great Plains. *Malacologia* 4(1):173-260.

Miller, Barry B. 1975. A Sequence of Radiocarbon-dated Wisconsinan Nonmarine Molluscan Faunas from Southwestern Kansas-Northwestern Oklahoma. *Studies on Cenozoic Paleontology and Stratigraphy in Honor of Claude W. Hibbard*, edited by G.R. Smith and N.E. Friedland, pp. 9-18. University of Michigan, Museum of Paleontology. Ann Arbor.

Navarre, Richard J. 1959. *Basic Survey of the Bottomless Lakes.* New Mexico Department of Game and Fish, Job Completion Report, Federal Aid Project F-10-R-4, Job No. A-2-2.

Neck, Raymond W. 1984. Living Terrestrial Gastropods from the Eastern Caprock Escarpment, Texas. *Nautilus* 98(2):68-74.

Neck, Raymond W. 1990. Ecological Analysis of the Living Molluscs of the Texas Panhandle. *American Malacological Bulletin* 8(1):9-18.

Odum, Eugene P. 1971. *Fundamentals of Ecology.* W.B. Saunders Company, Philadelphia.

Pilsbry, Henry A. 1948. *Land Mollusca of North America (North of Mexico).* Philadelphia Academy of Natural Sciences, Monographs 3, II(2).

Pip, Eva. 1986. The Ecology of Freshwater Gastropods in the Central Canadian Region. *Nautilus* 100(2):56-66.

Pratt, William L. 1983. Living *Promenetus exacuosus* (Pulmonata: Planorbidae) from North Central Texas. *Nautilus* 97(2):73-74.

Reigle, Norman J. 1963. Northern Records of *Gastrocopta procera. Nautilus* 77(1):16-18.

Ruhe, Robert V. 1969. *Quaternary Landscapes in Iowa.* Iowa State University Press, Ames.

Ruhe, Robert V. 1983. Depositional Environment of Late Wisconsinan Loess in the Midcontinental United States. *Late-Quaternary Environments of the United States*, edited by H.E. Wright, Jr., Vol. 1: The Late Pleistocene, edited by S.C. Porter, pp. 130-137. University of Minnesota Press, Minneapolis.

Schultz, Gerald E. 1969. *Geology and Paleontology of a Late Pleistocene Basin in Southwest Kansas.* Geological Society of America, Special Paper 105.

Shimek, Bobhumil. 1913. The Significance of Pleistocene Mollusks. *Science* 37:501-509.

Shimek, Bobhumil. 1930. Land Snails as Indicators of Ecological Conditions. *Ecology* 11(4):673-686.

Smith, George I. and F. Alayne Street-Perrott. 1983. Pluvial Lakes of the Western United States. *Late-Quaternary Environments of the United States*, edited by H.E. Wright, Jr., Vol. 1, The Late Pleistocene, edited by S.C. Porter, pp. 190-212. University of Minnesota, Minneapolis.

Smith, Robert L. 1966. *Ecology and Field Biology.* Harper and Row, New York.

Sutherland, Stephen M. 1977. Climate of Oklahoma. *Geography of Oklahoma*, edited by J.W. Morris, pp. 40-53. The Oklahoma Series, Oklahoma Historical Society, Oklahoma City.

Taylor, Dwight W. 1960. *Late Cenozoic Molluscan Faunas from the High Plains.* U.S. Geological Suvery, Professional Paper 337. Washington, D.C.

Taylor, Dwight W. 1965. The Study of Pleistocene Nonmarine Mollusks in North America. *The Quaternary of the United States*, edited by H.E. Wright, Jr. and D.G. Frey, pp. 597-611. Princeton University Press, New Jersey.

Taylor, Dwight W. and Claude W. Hibbard. 1955. *A New Pleistocene Fauna from Harper County, Oklahoma.* Oklahoma Geological Survey, Circular 37. Norman.

Turgeon, Donna D., Arthur E. Bogan, Eugene V. Coan, William K. Emerson, William G. Lyons, William L. Pratt, Clyde F.E. Roper, Amelie Scheltema, Fred G. Thompson, and James D. Williams. 1988. *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks.* American Fisheries Society, Special Publication 16.

Theler, James L. 1997. The Modern Terrestrial Gastropod (Land Snail) Fauna of Wester Wisconsin's Hill Prairies. *Nautilus* 110(4):111-121.

Van Der Schalie, Henry and Elmer G. Berry. 1973. The Effects of Temperature on Groth and Production of Aquatic Snails. *Sterkiana* 50.

Wallen, I. Eugene. 1951. Additions to "A Check List of the Land Snails of Oklahoma". *Proceedings of the Oklahoma Academy of Science* 32:27-30.

Wallen, I. Eugene and Paul Dunlap. 1954. Further Additions to the Snail Fauna of Oklahoma. *Proceedings of the Oklahoma Academy of Science* 34:76-80.

Wayne, William J. 1967. Periglacial Features and Climatic Gradients in Illinois, Indiana, and Western Ohio, East-Central United States. *Quaternary Paleoecology*, edited by E.J. Cushing and H.E. Wright, Jr., pp. 393-414. Yale University Press, New Haven.

Wells, P.V. and J.D. Stewart. 1987. Cordilleran-boreal Taiga and Fauna on the Central Great Plains of North America, 14,000 - 18,000 Years Ago. *American Midland Naturalist* 118(1):94-106.

Wendorf, Fred. 1961. Invertebrate Collections. *Paleoecology of the Llano Estacado*, assembled by F. Wendorf, pp. 105-114. Fort Burgwin Research Center, Publication No. 1. Museum of New Mexico Press, Santa Fe.

Wyckoff, Don G., James L. Theler, and Brian J. Carter. 1997. Southern Plains Gastropods: Modern Occurrences, Prehistoric Implications. Final Report on Grant #5477-95 to the National Geographic Society. Oklahoma Archeological Survey, University of Oklahoma, Norman.

Chapter 12
Gastropods from the 1992 Excavations at the Northwest Exposure

James L. Theler

Introduction

The preceding chapter, "Paleoenvironmental Interpretation from Burnham Site Gastropods: 1989 Results", discussed more than 5000 snails recovered from 22 sediment samples at the Pleistocene age Burnham site as well as some 6000 snails from 10 modern vegetation detritus samples collected in the vicinity of the Burnham site. The analysis of the Pleistocene and modern snail assemblages allowed a partial reconstruction of the environmental setting at and adjacent to the Pleistocene pond at this site.

Not considered in this initial analysis was material from that portion of the Burnham site known as the Northwest Exposure. Marked by deposits of gray (gleyed) loamy fine sand that contains Proboscidea and other animal bone fragments and abundant gastropods, this Northwest Exposure was subjected to controlled manual excavations in 1988, 1991, and 1992. This work was undertaken to provide data on the exposure's strata, fossils, their ages, and the possible occurrences of artifacts. Such data could then be compared with what was being found in the East Exposure. Although the Northwest Exposure's grey sediments occur at similar elevations with the East Exposure and its large-horned bison (*Bison chaneyi*) and the horse (*Equus*) beds, the depositional and habitat association of these two exposures remained in question. It appeared reasonable to assume that the Northwest and East exposures of grey sediments were part of the same prehistoric ponding event, their complete physical separation by erosion and the modern pond building activity, as well as rather distinct clusters of macrofauna, resulted in a degree of uncertainty about these two areas being contemporary deposits.

In order to help resolve some of this uncertainty, Don Wyckoff took a sediment sample from the Northwest Exposure grid at square S5-W2 (Fig. 12.1) during the NSF-supported 1992 excavations. The sample was taken between 40 and 60cm below the surface of the square's west wall. This sample of 4kgs of gray loamy fine sand was processed for recovery of gastropods. The gastropods from a portion of the S5-W2 sample were analyzed to assess the similarity of Northwest Exposure snail assemblage with those from East Exposure, especially the assemblages from around the "Horse Bone Bed" and adjacent the *Bison chaneyi* find. Also, selected species of aquatic and terrestrial snails from the Northwest Exposure sample were submitted for accelerator mass spectrometry (AMS) dating.

The Results

The analyzed snails from Square S5-W2 of the Northwest Exposure came from 1.0kg (0.75 liter) of gray loamy fine sand. No other strata were manifest in this square. The sample yielded 716 aquatic and 133 terrestrial snails (Table 12.1). In addition, shells of Sphaeriidae clams and Ostracoda and the remains of the macrophytic algae *Chara* were recovered.

The assemblage of aquatic and terrestrial snails from the Northwest Exposure looks entirely consistent with those from the gleyed ponded sediments of the East Exposure. The predominant aquatic snails from the Northwest Exposure are the shallow, warm water taxa: Physidae, *Planorbella*, and *Gyraulus* (Table 13.1). These were taxa prevalent in the gleyed ponded sediments of the East Exposure. Also, *Valvata tricarinata*, the aquatic species indicative of cool water, is well represented in both the Northwest Exposure

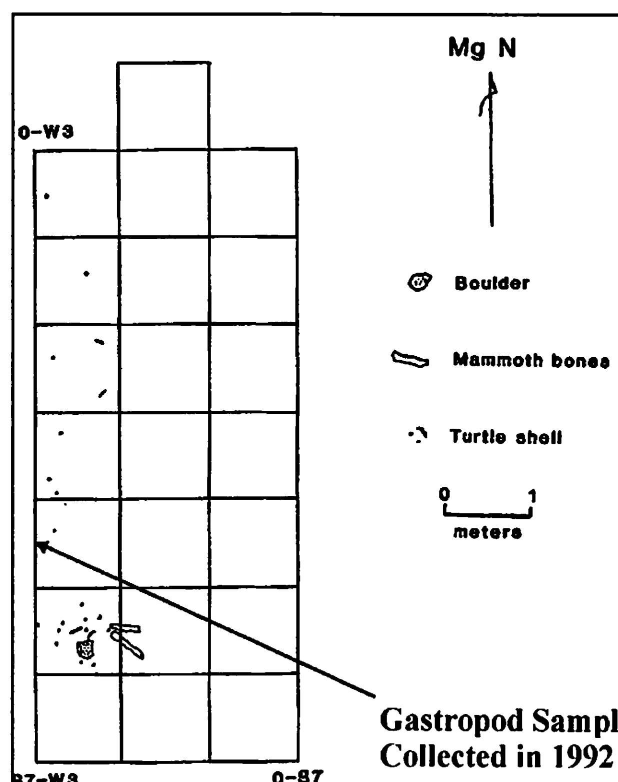


Figure 12.1. Location of the gastropod sample collected in 1992 from excavations in the Northwest Exposure of the Burnham site.

Table 12.1. Inventory and Density (Individuals/Liter) Comparisons of Gastropods the Northwest and East Exposures, Burnham Site.

	Northwest Exposure Sq. S5-W2 0.75 liter Ind./Liter	East Exposure "Equus Bed" 0.60 liter Ind./Liter	East Exposure "Bison Bed" 0.95 liter Ind./Liter
Aquatic Taxa			
Valvata tricarinata	93	12	24
Lymnaeidae/Hydrobiidae	37	0	6
Physidae	365	62	182
Physella virgata	21	2	0
Gyraulus parvus	183	12	77
Gyraulus sp.	67	20	65
Planorbella trivolvis	8	3	3
Planorbella sp.	48	20	30
Promenetus exacuous	72	0	2
Ferrisia frigilis	1	2	0
Ferrissia walkeri	7	15	0
Ferrissia sp.	0	0	20
Ostracoda	423	336	176
Sphaeriidae	31	3	5
Chara	27	0	93
Terrestrial Taxa			
Carychium exiguum	1	0	0
Gastrocopta armifera	0	2	1
Gastrocopta pentodon	5	2	1
Gastrocopta cristata	5	10	9
Gastrocopta pellucida	1	3	5
Gastrocopta procera	1	0	7
Pupoides albilabris	1	0	4
Vertigo ovata	4	0	1
Vallonia perspectiva	5	3	3
Vallonia sp.	13	12	16
Helicodiscus parallelus	1	3	0
Helicodiscus singleyanus	4	12	11
Succineidae	8	3	6
Hawaiia minuscula	85	43	38
Deroceras laeve	5	3	3
Juveniles	26	22	2

and East Exposure gleyed deposits (Table 12.1). Overall, the prevailing aquatic snails from the Northwest Exposure bear witness to the same kinds of aquatic habitats interpreted from the East Exposure aquatic snails.

From the Northwest Exposure, the terrestrial snail species *Hawaiia minuscula*, *Vallonia perspectiva*, *Helicodiscus singleyanus*, and *Vertigo ovata* implicate a mesic meadow adjoining the ponded waters. A nearby xeric vegetation community is indicated by a few other terrestrials, namely *Gastrocopta cristata*, *G. pellucida*, and *G. procera*. These same species occurred in the East Exposure deposits (Table 12.1). Consequently, the terrestrial species recovered from the Northwest Exposure sample are believed to mirror the kinds manifest among the East Exposure samples.

Dating the Northwest Exposure Gastropods

Although recognized as a problem material for obtaining reliable radiocarbon dates (Taylor 1987), gastropods were used initially to develop some idea of the age of the Burnham site's deposits (Wyckoff 1999; Wyckoff et al. 1990, 1991). This was done because snail shells were so plentiful, and charcoal fragments so rare, in the site's diverse strata, and especially in the East Exposure stratum that yielded the artifacts. Not only was charcoal hard to find during the early excavations but when it was recovered the pieces were so small and so carbonate laden that they created some laboratory procedure problems when they were submitted for accelerator dating. Eventually, most of these chemical treatment problems were resolved, and most dates for the Burnham site were obtained from charred wood fragments. However, because of their prevalence at Burnham and dozens of other intriguing Pleistocene deposits in northwestern Oklahoma, Burnham site researchers wondered how unreliable snail shells were for radiocarbon dating.

In particular, as work progressed on identifying and counting the numerous snail species recovered at Burnham, it seemed reasonable that dating at the species level, rather than by volumes or weights of mixed shells, might yield compatible results. Accordingly, discussions with Don Wyckoff focused on selecting paired samples of specific terrestrial and specific aquatic taxa from the same context for accelerator dating. We first tried this for the Bouziden Exposure, a Pleistocene pond deposit located a quarter mile south of the Burnham site. There, the assemblage of snails included species indicative of Wisconsinan full glacial times here on the Southern Plains. And, accelerator dates on a terrestrial species and an aquatic species fell within that time (although the two dates were some 1500 years apart).

With the Bouziden Exposure's results in mind, we decided to submit a paired sample of terrestrial and aquatic snail shells from the as yet undated Northwest Exposure at the Burnham site. So, from the identified snails collected from 40 to 60cm below the surface in square W2-S5 of the Northwest Exposure I selected 0.2g of *Hawaiia minuscula* shells and 0.5g of *Physella virgata* shells for radiocarbon dating. These samples were sent to Don Wyckoff who, in turn, submitted them to the University of Arizona Radiocarbon Laboratory for tandem mass accelerator dating.

The terrestrial species *Hawaiia minuscula* yielded a date of 42,785 $\pm$ 1800 years ago (AA-11688). In contrast, the aquatic species *Physella virgata* was dated at 37,215 $\pm$ 940 years ago (AA-11687). These are uncorrected dates. Although the results do not have overlapping one-sigma factors, they are roughly compatible in the sense that they implicate the Northwest Exposure is around 40,000 years old.

Summary

Gastropods from the single stratum evidenced in the Northwest Exposure of the Burnham site indicate the same kinds of aquatic and adjacent habitats interpreted from gastropods recovered from East Exposure sediments. Moreover, radiocarbon dates on an aquatic and a terrestrial species from the Northwest Exposure show that this pond deposit is contemporaneous with the East Exposure. For this reason, and because the deposits are at essentially the same elevation, the Northwest Exposure more than likely is a cutoff (by later erosion) remnant of the pond sequence of the East Exposure.

References Cited

Taylor, R.E. 1987. *Radiocarbon Dating, An Archaeological Perspective.* Academic Press, Orlando.

Wyckoff, D.G. 1999. The Burnham Site and Pleistocene Human Occupations on the Southern Plains. *Ice Age Peoples of North America*, edited by R. Bonnichsen and K. Turnmire, pp,. 340-361. Oregon State University, Center for the Study of the First Americans, Corvallis.

Wyckoff, D.G., G.R. Brakenridge, K. Buehler, B.J. Carter, W. Dort, Jr., L.D. Martin, J.L. Theler, and L.C. Todd. 1991. Interdisciplinary Research at the Burnham Site (34WO73), Woods County, Oklahoma. *A Prehistory of the Plains Border Region: Guidebook of the 9th Annual Meeting of the South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 82-121. Oklahoma State University, Department of Agronomy, Stillwater.

Wyckoff, D.G., B.J. Carter, W. Dort, Jr., G.R. Brakenridge, L.D. Martin, J.L. Theler, and L.C. Todd. 1990. Northwestern Oklahoma's Burnham Site: Glimpses Beyond Clovis? *Current Research in the Pleistocene* 7:60-63.

Chapter 13
Seeds from the Burnham Site (34Wo73), Woods County, Oklahoma

Paul E. Minnis and Barbara M. Keener

Introduction

Numerous plant remains were recovered during the excavation of the Burnham site in northwestern Oklahoma. For example, pawpaw (*Asimina triloba*) wood charcoal and hackberry (*Celtis* sp.) seeds were identified (Wyckoff et al. 1991).

It was hoped that the analysis of more macroplant remains might highlight the prehistoric environment. The presence of pawpaw indicates significantly different environmental conditions from those now present, since Woods County is outside the current distribution of pawpaw. Pawpaw is currently found no closer than Kay County, approximately 180km east of Burnham (Little 1981). Additionally, we hoped to further clarify the nature of the stratigraphic processes responsible for this site. Understanding micro and macro scale geomorphological processes is, of course, especially essential in order to assess the integrity of pre-Paleoindian deposits.

With these goals in mind, the University of Oklahoma Ethnobotanical Laboratory was given both wood charcoal and "seed" remains for analyses.[1] Unfortunately, all wood charcoal specimens were too small for identification using the facilities available at the laboratory. A total of 1524 seeds were identified from the 90 samples containing seeds. In addition to the samples directly from Burnham site contexts, five off-site flotation samples were studied. These samples provide a comparison to evaluate the significance of the uncharred seed from the Burnham deposits. We would normally assume that the uncharred seeds are relatively recent remains. Therefore, there should be some correspondence between the on-site and off-site seed assemblages. A total of 1785 seeds were recovered from the five off-site samples.

All excavated soils were waterscreened through a 2mm mesh in the field and then hand sorted under magnification. Soils from around the bison skull were waterscreened in the laboratory through 1mm mesh and then hand sorted. Even though most of the samples were passed through 2mm screening, some smaller seeds, such as pigweed (*Amaranthus*), which are approximately 1 mm in diameter, were recovered, although probably not in the numbers present in the soil.

The off-site flotation samples were handled differently. These samples were floated at the Oklahoma Archeological Survey laboratory in Norman. Instead of the 2mm window screening used at Burnham, the lab system used a cloth with approximately .3mm openings.

To facilitate analysis, Burnham plant remains from two provenience categories were studied. SC4 is the artifact-bearing stratum (Brian Carter's Unit IIB), and SD (Carter's Unit IIC) is the stratum directly above SC4. By comparing the remains from these two categories, we may be able to determine the uniqueness of the artifact-bearing provenience. If SC4 proveniences contained different seed assemblages than the other stratum, this could be evidence for its unique stratigraphic history.

Seeds were identified with the aid of an extensive comparative collection and various reference works (Martin and Barkley 1961; Montgomery 1977; U.S. Department of Agriculture 1974). For example, the smartweed (*Polygonum*) seeds were segregated from morphologically similar seeds in the Cyperaceae family by their lack of striated inner seed coat and peripheral, not basal, embryo (Martin 1954).

Results

Table 13.1 summarizes the Burnham site seed assemblages, and Tables 13.2 and 13.3 provide the raw counts by sample. A total of 1524 seeds were examined, with 26 remaining unidentified. Most seeds (1256, or 82.4%) were from the 46 SC4 samples, and 268 (17.6%) were from the 44 SD samples. While SC4 proveniences have much greater numbers of seeds, some of this is due to a few SC4 samples with extremely large numbers of seeds. Of special note is one sample, from level 96.6 of square S1W22, that contained 67.7% of the smartweed seeds and 51.4% of the pigweed seeds recovered from all samples. It is quite likely that this concentration represents a cache of some graniverous animal.

The five off-site flotation samples yielded 1785 seeds, all of which were uncharred and four which remain unidentified. Table 13.4 enumerates the seeds from off-site samples.

In addition to seeds, some uncharred vegetative tissue (leaf and stem fragments), rocks, and insect chitin fragments were often found in the seed samples. Their presence was noted on the original laboratory worksheets, but this information is not included in the tables.

Seeds were placed in 23 taxa: 5 identified to species, 15 to genus, 2 to family, and an unknown category. Below is a

Table 13.1. Summary of the Burnham Seed Assemblage.

Taxon	Stratum SC4 Number Seeds	Stratum SC4 Number Samples	Ranking	Stratum SD Number Seeds	Stratum SD Number Samples
Celtis sp.	483	41	1	125	26
Polygonum sp.	167	16	2	70	19
Juniperus sp.	1	1	-	-	-
Croton sp.	54	15	3	36	17
Euphorbia sp.	19	10	4	4	3
Amaranthus sp.	498	6	5	16	3
Chenopodium sp.	1	1	-	-	-
Helianthus sp.	3	3	-	1	1
Ambrosia sp.	4	2	-	-	-
Ambrosia artimesiifolia	2	1	-	2	1
Cirsium sp.	-	-	-	2	2
Mentzelia sp.	1	1	-	-	-
Proboscidea louisianica	-	-	-	1	1
Solanum sp.	1	1	-	-	-
Solanum rostratum	2	2	-	-	-
Gramineae	2	1	-	1	1
Solanaceae	1	1	-	1	1
Unknown	17	10	-	9	9

short summary of the taxa.

***Amaranthus* (Pigweed)**

This genus is dominated by herbaceous annuals adapted to disturbed soils. It is very common and enormous quantities of pigweed seeds are produced. The *Amaranthus* seeds recovered here appear to be quite recent; most often the seed coat was still shiny.

***Ambrosia* (Ragweed)**

Ragweed is a common weed in western Oklahoma. The distinctive tubercle projects are diagnostic. These specimens most likely are *A. trifolia*, the giant ragweed, but their fragmentary condition precluded this level of identification.

***Ambrosia artimesiifolia* (Short Ragweed)**

This plant is very commonly found on disturbed soils. It is possible that these specimens are *A. psilostachya*, the western ragweed, but the morphological match is not as good as for the short ragweed.

***Celtis* (Hackberry, Sugarberry)**

Hackberry is a very common tree/shrub in Oklahoma. (Examples are growing less than 75 m up the draw from the Burnham site.) Today, the netleaf hackberry (*C. reticula*) is most common in Woods County, although two other species (*C. laevigata* and *C. occidentalis*) are present. The two obvious seed characteristics, size and surface venation, intergrade between species. Therefore, a species level identification was not made.

***Cenchrus* (Sandbur)**

These annual weedy grasses produce well known and unappreciated spiny fruits.

***Chenopodium* (Goosefoot)**

Goosefoot plants are very similar to pigweed, as are the seeds from both, and goosefoot, too, is most abundant on disturbed soils. The identified goosefoot seed was distinctive because of the presence of its adherent papery perianth as well as other distinguishing characteristics.

***Cirsium* (Thistle)**

Many thistles are present in western Oklahoma, and these seeds could not be identified to species. Thistles are more frequent on disturbed soils.

***Croton* (Croton)**

This genus has more than one species and is common to western Oklahoma.

***Euphorbia* (Spurge)**

Plants in this genus are usually weeds, plants adapted to disturbed habitats. A more specific identification was not possible because of the large number of spurges with similar morphological characteristics and the inadequate number of Oklahoma spurges in the comparative collection. Of the seeds in our comparative collection, these specimens most closely resemble *E. hexagona.*

Gramineae **(Grass Family)**

Of course, the grass family is one of the most common and important plant families in western Oklahoma. These specimens could be identified more precisely. This was not done because it would have taken a great deal of time and because it was not felt that this information would have had

Table 13. 2. Propagules from Stratum SC4 Proveniences, Burnham Site (34Wo73).

Provenience*	*Celtis* sp.	*Polygonum* sp.	*Juniperus* sp.	*Croton* sp.	*Euphorbia* sp.	*Amaranthus* sp.	*Chenopodium* sp.	*Helianthus* sp.	*Ambrosia* sp.
0-W1, SE1/4, 96.75 cm	1								
0-W23, SW1/4, 96.3 cm	2								
S1-W21, 96.4 cm	1								
S1-W22, 70-80 cm	18			1					
S1-W22, 96.4 cm	86	4		2		21			
S1-W22, 96.5 cm	19	3		1	5	65	1	1	
S1-W22, 96.6 cm	20	113	1	11	7	256		1	1
S1-W22, 96.7 cm	3					11			
S1-W23, 96.4 cm	61	15							
S1-W23, 96.5 cm	67	7		2	3	143			
S1-W23, 96.6 cm	46	2		3	2	2			
S1-W23, 60-70 cm	37								
S2-W21, SE1/4, 96.4 cm	1								
S2-W22, 30-40 cm	15			9					
S2-W22, 50-60 cm	14			6					
S2-W22, 60-70 cm	9								
S2-W22, 70-80 cm	11								
S2-W22, 96.4 cm	4	14		15	1			1	3
S2-W22, NW1/4, Bison Skull	48			1					
S2-W23, 60-70 cm	8			1					
S2-W23, 96.4 cm		3		1					
S2-W23, 96.5 cm	3	8		1					
S3-W21, 96.5 cm	4	3			1				

Table 13. 2 (cont.). Propagules from Stratum SC4 Proveniences, Burnham Site (34Wo73).

Provenience*	*Ambrosia artimesiifolia*	*Cirsium* sp.	*Mentzelia* sp.	*Proboscidea louisianica*	*Solanum* sp.	*Solanum rostratum*	Gramineae	Solanaceae	Unknown
0-W1, SE1/4, 96.75 cm									
0-W23, SW1/4, 96.3 cm									
S1-W21, 96.4 cm									
S1-W22, 70-80 cm									
S1-W22, 96.4 cm									
S1-W22, 96.5 cm									
S1-W22, 96.6 cm					1				
S1-W22, 96.7 cm									
S1-W23, 96.4 cm	2								3
S1-W23, 96.5 cm									3
S1-W23, 96.6 cm			1						1
S1-W23, 60-70 cm									
S2-W21, SE1/4, 96.4 cm									1
S2-W22, 30-40 cm									2
S2-W22, 50-60 cm									
S2-W22, 60-70 cm									
S2-W22, 70-80 cm									
S2-W22, 96.4 cm						1	2	1	1
S2-W22, NW1/4, Bison Skull									
S2-W23, 60-70 cm									
S2-W23, 96.4 cm									
S2-W23, 96.5 cm						1			
S3-W21, 96.5 cm									

*Provenience includes excavation square, quarter (where applicable), and depth.

much interpretive value.

Helianthus (Sunflower)

Several sunflower species are present in western Oklahoma, and they are most abundant on disturbed soils.

Juniperus (Cedar, Juniper)

Juniper is a common plant in western Oklahoma, and it is becoming more abundant. While the Burnham specimen is fragmentary, it is likely that it is *J. virginiana*, the most common cedar in Woods County today.

Lappula (Stickseed)

This genus is a common weed, often with seeds that stick to clothing and hair.

Mentzelia (Blazing Star, Stickleaf)

This plant is common on disturbed soils. The stickleaf seed was of the type with a pronounced marginal wing, a characteristic shared by several *Mentzelia* species present in

Table 13.3. Propagules from Stratum SD Proveniences, Burnham Site (34Wo73).

Provenience*	*Celtis* sp.	*Polygonum* sp.	*Juniperus* sp.	*Croton* sp.	*Euphorbia* sp.	*Amaranthus* sp.	*Chenopodium* sp.	*Helianthus* sp.	*Ambrosia* sp.
0-W22, NW1/4, 96.0 cm	1								
0-W24, 96.4 cm									
0-W25, 96.1 cm	2								
0-W25, 96.2 cm				2		16			
0-W25, 96.3 cm				1					
0-W25, 96.4 cm				6					
0-W25, 96.5 cm	1			3					
S1-W22, 96.2 cm	59	41		1					
S1-W23, 96.1 cm	2	1							
S1-W23, 96.2 cm	3	7			1				
S1-W23, 96.3 cm	12								
S2-W22, 96.2 cm	12	4			3				
S2-W23, 96.2 cm		9							
S2-W23, 96.3 cm	2	6		3					
S2-W23, Bison Rib	2	1						1	
S2-W24, NE1/4, 95.9 cm				1					
S2-W24, NW1/4, 95.9 cm				5					
S2-W24, NW1/4, 96.0 cm				4					
S2-W24, NE1/4, 96.0 cm				2					
S2-W24, 96.0 cm	1			2					
S2-W24, SW1/4, 96.0 cm	4			4					
S3-W24, NW1/4, 96.0 cm	7			2					
S3-W24, NE1/4, 96.0 cm	2								

Table 13.3 (cont.). Propagules from Stratum SD Proveniences, Burnham Site (34Wo73).

Provenience*	*Ambrosia artimesiifolia*	*Cirsium* sp.	*Mentzelia* sp.	*Proboscidea louisianica*	*Solanum* sp.	*Solanum rostratum*	Gramineae	Solanaceae	Unknown
0-W22, NW1/4, 96.0 cm									
0-W24, 96.4 cm									1
0-W25, 96.1 cm									1
0-W25, 96.2 cm		2							1
0-W25, 96.3 cm									
0-W25, 96.4 cm									
0-W25, 96.5 cm									
S1-W22, 96.2 cm									
S1-W23, 96.1 cm									
S1-W23, 96.2 cm									1
S1-W23, 96.3 cm									1
S2-W22, 96.2 cm							1		
S2-W23, 96.2 cm									3
S2-W23, 96.3 cm	2								1
S2-W23, Bison Rib									
S2-W24, NE1/4, 95.9 cm									
S2-W24, NW1/4, 95.9 cm									
S2-W24, NW1/4, 96.0 cm									
S2-W24, NE1/4, 96.0 cm									
S2-W24, 96.0 cm									
S2-W24, SW1/4, 96.0 cm									
S3-W24, SW1/4, 96.0 cm									
S3-W24, NW1/4, 96.0 cm				1					
S3-W24, NE1/4, 96.0 cm									

*Provenience includes excavation square, quarter (where applicable), and depth.

western Oklahoma.

***Mollugo verticillata* (Carpetweed)**
This plant is a common weed throughout Oklahoma.

***Monarda* cf. *clinopodioides* (Basil Beebalm)**
This annual is present on sandy soils.

Monarda ckubioiduiudes
This annual is present on sandy soils.

***Polygonum* (Smartweed)**
Plants of this genus tend to be found in well watered locations. The majority of the recovered *Polygonum* seeds are two sided, although a few triangular examples were present.

***Proboscidea louisianica* (Devil's Claw)**
This plant with its oddly shaped fruits is common in western Oklahoma. The one specimen of this species appears to have geminated.

***Salvia* (Sage)**
This the common genus in the mint family.

Table 13. 4. Summary of Modern Seed Assemblage Collected near Burnham Site.

	Samples					
	Gully Floor			*Fallow Field*		
Taxon	*1*	*2*	*3*	*4*	*5*	*Total*
Amaranthus sp.	361	209	297	162	296	1325
Chenopodium sp.	15	25	-	65	52	157
Polygonum sp.	6	6	12	5	9	38
Ambrosia sp.	4	-	-	-	-	4
Euphorbia sp.	3	21	23	-	21	68
Gramineae	3	20	-	-	23	46
Salvia sp.	1	26	-	-	-	27
Solanum rostratum	1	2	7	1	-	11
Celtis sp.	-	1	-	-	-	1
Cenchrus sp.	-	5	-	-	-	5
Croton sp.	-	14	20	-	-	34
Helianthus sp.	-	5	2	-	-	7
Lappula sp.	-	2	-	3	-	5
Mollugo sp.	-	-	-	-	17	17
Monarda clinopodioides	-	8	19	-	-	27
Ambrosia artimesiifolia	-	-	8	-	-	8
Trifolium sp.	-	-	-	-	1	1
Unknown	-	-	4	-	-	4

Solanaceae (Nightshade Family)

This is a large and important family. Due to the condition of the seeds, a more specific identification was not possible.

***Solanum* (Nightshade)**

This genus contains many species found in western Oklahoma. It is rarely possible to identify these seeds to species.

***Solanum rostratum* (Buffalobur)**

This plant is common on disturbed soils.

***Trifolium* (Clover)**

This is a commonly planted cultigen.

Unknown

This category includes a number of seeds that were not identified. Some are sufficiently intact that additional study could confirm an identification.

Interpretation

Soils have large numbers of naturally dispersed seeds (a "seed bank"). Fenner (1985), for example, estimates that grassland soils contain a range of 10^3 to 10^6 seeds per m^2 with a greater number present in arable lands with enormous numbers of weed seeds. Archaeological sites also have a natural seed assemblage. No seeds in the Burnham assemblage were obviously prehistoric, and, in fact, there are several reasons to conclude that all of these seeds are part of the natural seed bank and are quite recent, somewhere on the order of less than one hundred years old. All seeds were uncharred, and some were gnawed, evidence of natural predation. Some were fresh, whereas others were quite degraded with decomposing seed coats. Very few seeds remain viable for more than century in soils (Bewley and Black 1985; Fenner 1985), and, presumably, most decompose quite rapidly after loss of viability. It is generally agreed that charring is the primary process resulting in the preservation of ancient and archaeological relevant seeds in sites (Minnis 1981). Because of their bony nutlet, hackberry seeds probably have the greatest resistance to decay of all seed types recovered. However, many of the Burnham specimens appear to be from a relatively recent population. Less than half of the hackberry seeds were gray with rounded (worn) edges, rather than white with sharp edges, and this probably is evidence of initial decomposition.

All plant taxa recovered in the Burnham excavations are now present in Woods County. Additionally, the majority of the seed types are from weedy plants, those that thrive best on disturbed soils. The excavation of the Burnham site as well as the recent and extensive field plowing on the ridge above the site has increased the population of weedy plants. These two observations are most consistent with the conclusion that this assemblage represents the modern seed bank.

The relative ubiquity of seed types can further help us determine the biological processes affecting the Burnham site. Table 13.1 summarizes the number of seeds of each type and the number of samples containing each taxon. The ranking provided is based on the number of samples containing each type. Only the most common types are ranked. For example, hackberry is ranked first, because it is the most common plant. In descending order of ubiquity are hackberry, smartweed, croton, spurge, and pigweed. The fact that the same seed types are found in the same relative ubiquity order in both SC4 and SD assemblages is strong evidence that the basic processes of seed deposition are nearly identical. That is, the artifact bearing stratum appears little different from the overlying stratum that lacks artifacts.

Comparison of the off-site samples with the on-site samples provides a useful approach to help determine if the uncharred on-site seeds are recent or prehistoric. As can be seen in Table 13.4, the most common seeds from the off-site flotation samples are pigweed, goosefoot, and spurge. In contrast, the most commonly recovered taxa from on-site waterscreened samples are hackberry, smartweed, croton, spurge, and pigweed. Most of the differences between the two assemblages can be most easily explained by the fact that the off-site samples were floated using a smaller screen compared with the waterscreen on-site samples. Clearly, the small screening was recovereing seeds smaller than 2mm (such as goosefoot, pigweed, and spurge) in large numbers. One other characteristic of the remains points toward a similarity between on-site and off-site seeds. With a few exceptions, the types of seeds found in one assemblage were also present in the other. The majority of exceptions are *Salvia* and *Monarda* cf. *clinopodioides*, most of which were found in only sample each.

To our mind, the one taxon whose representation is significantly different between the two sets of data is hackberry. Hackberry seeds were the most common seed from on-site samples, yet only one was recovered from the five off-site samples. This observation combined with the fact that the bony nutlet is quite resistant to decay leads us to conclude that many of the on-site hackberry seeds could be quite old. Recently, Wang, Jahren, and Amundson (1997) dated hackberry seeds from Burnham and confirm that some are very old, up to 40,000 years old.

Summary

To summarize, it is best concluded that this assemblage represents the seed bank naturally found in soils for the following reasons:

1. none of the seeds were charred;
2. all seeds come from plants now present in the area around the site;
3. the large number of seeds from weedy plants reflects the recent soil disturbance in and immediately around the site;
4. there is a complete range of decay as one would expect with a natural population;
5. the ubiquity ranking of seeds from strata SC4 and SD proveniences are similar, suggesting similar processes of seed dispersal and deposition; and
6. there is a general similarity between the seeds recovered from the on-site waterscreened samples and those from the off-site flotation samples.

End Notes

1. In order to simplify terminology, the word "seed" as used here includes all propagules, both seeds and fruits.

2. The original laboratory worksheets are available at the University of Oklahoma Ethnobotanical Laboratory.

References Cited

Bewley, J.D. and M. Black. 1985. *Seeds: Physiology, Development, and Germination.* Plenum Press, New York.

Fenner, M. 1985. *Seed Ecology.* Chapman and Hall, London.

Little, E.L., Jr. 1981. *Forest Trees of Oklahoma: How to Know Them.* Revised edition No. 12. Oklahoma Department of Agriculture, Forestry Division. Oklahoma City.

Martin, A.C. 1954. Identifying Polygonum Seeds. *Journal of Wildlife Management* 18:515-520.

Martin, A.C. and W. Barkley. 1961. *Seed Identification Manual.* University of California Press, Berkeley.

Minnis, P.E. 1981. Seeds in Archaeological Sites: Sources and Some Interpretive Problems. *American Antiquity* 46:143-152.

Montgomery, F.H. 1977. *Seeds and Fruits of Plants of Eastern Canada and Northeastern United States.* University of Toronto Press, Toronto.

United States Department of Agriculture. 1974. *Seeds of Woody Plants in the United States.* U.S. Government Printing Office, Washington, D.C.

Wang, Y., A.H. Jahren, and R. Amundson. 1997. Potential for ^{14}C Dating of Biogenic Carbonate in Hackberry (*Celtis*) Endocarps. *Quaternary Research* 14:337-343.

Wyckoff, D.G., G.R. Brakenridge, K. Buehler, B.J. Carter, W. Dort, Jr., L.D. Martin, J.L. Theler, and L.C. Todd. 1991. Interdisciplinary Research at the Burnham Site (34WO73), Woods County, Oklahoma. *Prehistory of the Plains Border Region: Guidebook for the 9th Annual South-Central Friends of the Pleistocene*, edited by B.J. Carter and P.A. Ward III, pp. 81-121. Oklahoma State University, Department of Agronomy, Stillwater.

Chapter 14
Identified Charred Wood from the 1989 Excavations

Peter Van de Water

Introduction

During the 1989 excavations, a large section of charred wood was discovered buried deep in a soil profile some 20 m east of the bison skull. Because this charcoal was determined to originate in the deepest, oldest paleosol discerned for the site, a portion of the charcoal was submitted for radiocarbon dating. Also, because the charcoal was large enough to retain some cellular structure, a portion was subjected to microscopic study to see if the plant species could be determined.

The Find

On October 2, 1989, Brian Carter supervised the start of a long, east-west backhoe trench about 25m east of where the *Bison chaneyi* skull was uncovered. The purpose of the trench was to create a long, deep, continuous profile from which to study the soil and geologic contexts away from the gleyed, fossil-bearing deposit. Earlier coring had revealed that the gleyed deposit did not extend 25m east of the skull. So, with the backhoe aligned along the North 3 line of the East Grid, the trenching was begun. As the backhoe worked its way west, Brian and several helpers worked feverishly to scrape and clean the north wall of the 2 to 3m deep trench in order to study and record the stratigraphy. As they began clearing this profile, one of the workers discovered that the backhoe had exposed a 15cm long section of a charred log near the bottom of the trench. Quickly photographed (Fig. 14.1), this find was collected, wrapped in aluminum foil, and its find spot marked with nail and flagging tape.

Subsequent profile studies by Carter, Brakenridge, and Dort have this charred log plotted at an elevation of 98.1 (relative to site datum) which is 2.2 m below the west sloping graded surface (Fig. 14.2). Carter and Brakenridge record that the charcoal was in a paleosol, a buried B horizon noted by its clay and carbonate content. This horizon also contained occasional fragments of bone and charcoal. In 1991, six 1x1m squares were manually dug through this

Figure 14.1 . View northeast of charred wood exposed in the North 2 Backhoe Trench dug October 2, 1989. Photo by Kent Buehler.

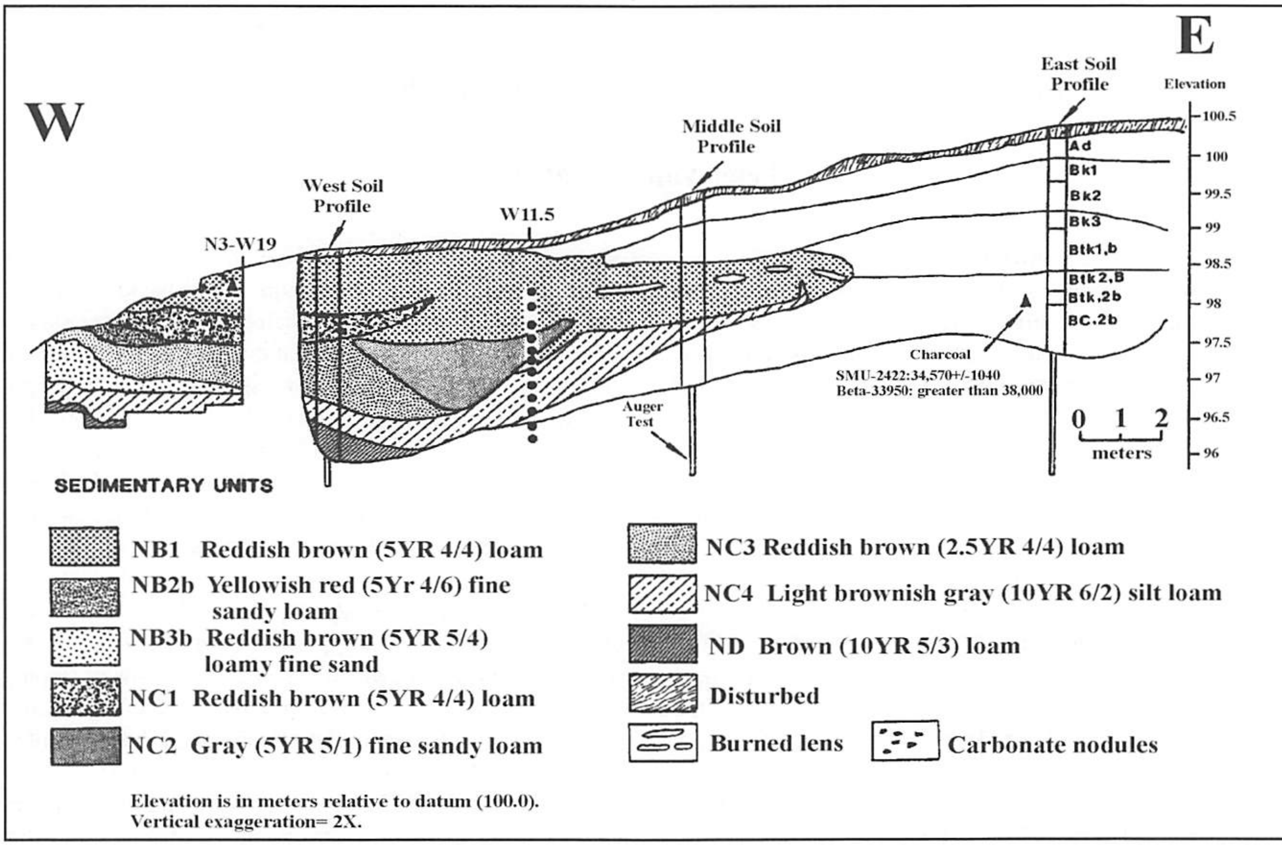


Figure 14.2. Location of charred wood in the N3 backhoe trench dug in 1989. Adapted from profile prepared by Brian Carter.

horizon. This work uncovered scattered bits of charcoal and occasional deteriorated pieces of bone, but no evidence of people. Backhoe trenching in 1991 and bulldozer trenching in 1992 uncovered this paleosol 5m south and 60m north of its initial exposure. Based on coring done over the site, no deeper paleosol exists here.

Two fragments of the charred log were submitted for radiocarbon dating. A result of "greater than 38,000 years" was obtained from one sample (Beta-33950). A second sample was sent to the radiocarbon dating laboratory at Southern Methodist University, and it yielded an uncorrected age of 34,750 ± 1040 years (SMU-2422). Being associated with the earliest paleosol found at the site, the charred log merited further study.

Species Identification

Unequivocal identification of the Burnham sample was hampered for two reasons: 1) the poor quality of the charcoal sample; and 2) the observation of characteristics not associated with those species commonly found in the collection at the Desert Laboratory in Tucson. Determination of characteristics was accomplished using both light and scanning electron microscopy.

The Burnham charcoal sample exhibits large springwood vessels grading to smaller summerwood vessels. These vessels form a sharp yearly demarcation. Thus, the charcoal comes from a ring-porous hardwood species (Figs. 14.3, 14.4, and 14.5). Springwood vessels are elliptical in cross section, averaging 200 to 300 microns along the long axis and are stacked (crowded) 2 to 3 deep at each ring boundary (Figs. 14.3, 14.4, and 14.5). Springwood vessel elements grade into the smaller summerwood vessel elements (100-150 microns) along the long axis. Summerwood vessels occur in distinctive nests or clusters with parenchyma sheaths enclosing them (Figs 14.6 and 14.7). Internal vessel microscopic features are undetermined due to the presence of tylosis, a structure formed when living parenchyma protoplast grows into vessel elements (Fig. 14.8). The tylosis obscures any vessel wall features.

Other features noted include longitudinal parenchyma, located around springwood and summerwood vessels as sheaths, growing in cambiform strands along the grain of the wood. Rays occur as unstoried (not occurring in any kind of alignment), homogeneous (the top and bottommost cells are similar to the remaining cells), and strands of 2 to 6 seriate cells (2 to 6 cells wide; Fig. 14.9).

Using these diagnostic features, veneer slices were examined from Harrar (1957) looking for the best match. The species most resembling the Burnham sample include *Celtis* (hackberry), *Fraxinus* (ash), and *Asimina* (pawpaw).

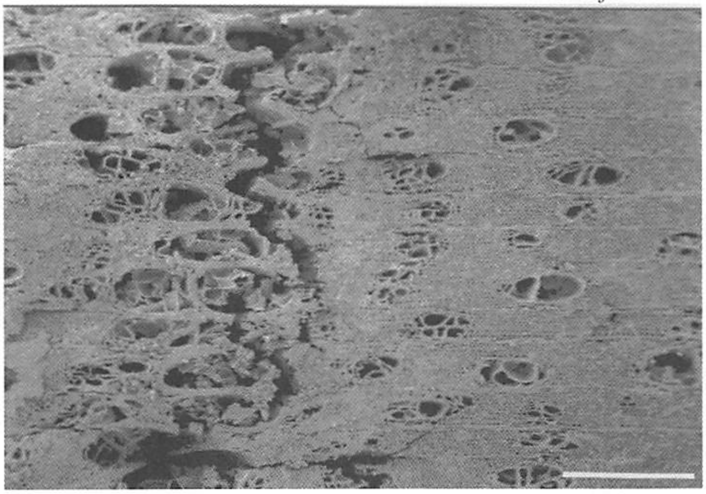


Figure 14.3. Photomicrograph of charred wood from Burnham North 3 Backhoe Trench. View shows large elliptical spring-wood vessel elements grading to smaller summerwood vessel elements. Bar equals 200 microns.

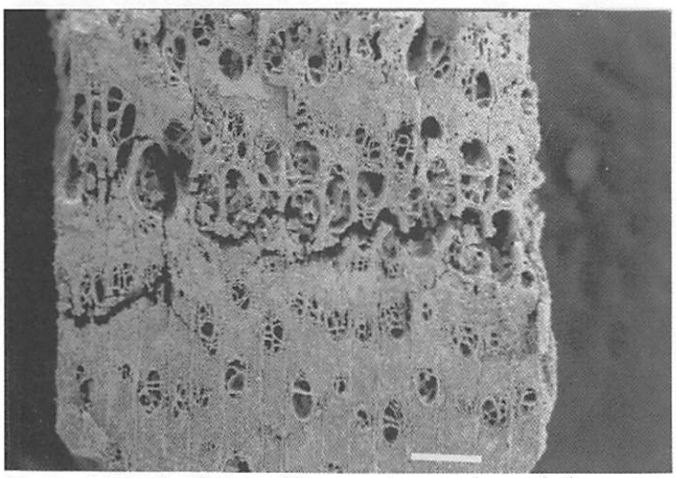


Figure 14.4. Gradation of large springwood vessel elements to smaller summerwood vessel elements on charred wood from N3 Backhoe Trench at Burnham site. Bar equals 100 microns.

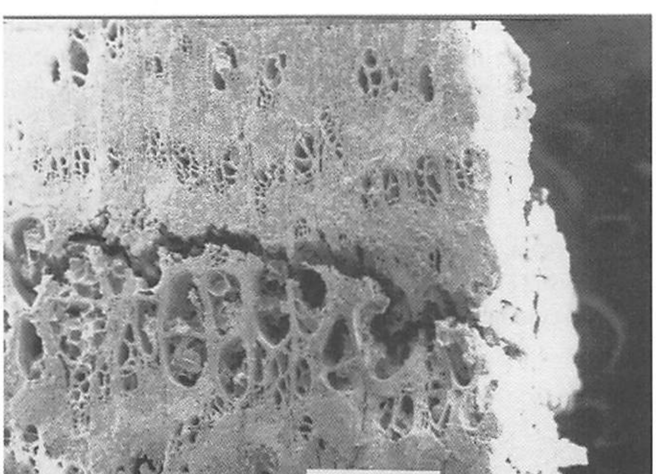


Figure 14.5. Another view of gradation of large to smaller vessel elements in charred wood from N3 Backhoe Trench at the Burnham site. Bar equals 200 microns.

Celtis characteristically has unstoried rays that are 1 to 10 cells wide and heterogeneous (meaning the top and bottommost cells differ in shape from the rest). Since the Burnham sample displays homogeneous cells, this latter characteristic would seem to eliminate *Celtis* as a possibility. *Fraxinus* and *Asimina*, on the other hand, have homogeneous unstoried rays similar to the Burnham sample. In *Fraxinus*, however, the transition from springwood vessels to summerwood vessels is very abrupt, unlike the gradual transition characteristic of the Burnham sample. In addition, a sheath of parenchyma cells surrounding the summerwood vessels in *Fraxinus* is poorly developed. *Asimina* (pawpaw), however, displays a gradual transition of springwood to summerwood vessels, as well as forming a well-developed sheath.

The assignment of the Burnham charcoal sample to *Asimina* cannot be absolute at this time. The most explicit features for species determination, such as the

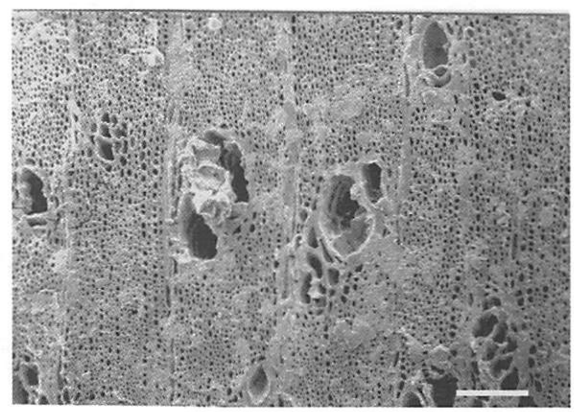


Figure 14.6. Photomicrograph of nested summerwood vessels with enclosing parenchyma sheaths. Bar equals 100 microns.

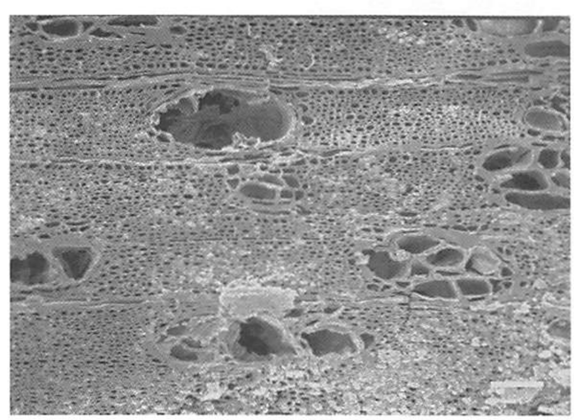


Figure 14.7. Clustered summerwood vessels with enclosed parenchyma sheathing on charred wood sample from N3 Backhoe Trench at Burnham site. Bar equals 50 microns.

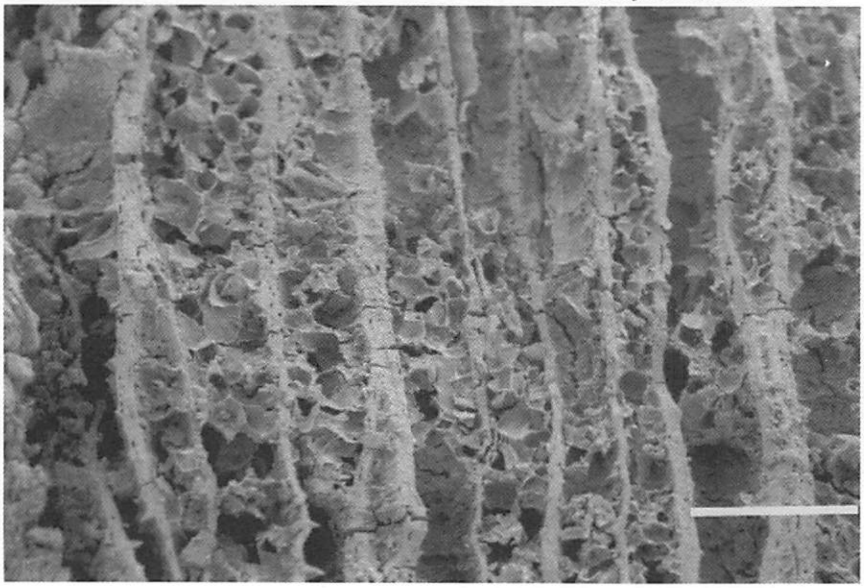


Figure 14.8. Photomicrograph of tylosis structures that mask internal microscopic features of charred wood from N3 Backhoe Trench at the Burnham site. Bar equals 200 microns.

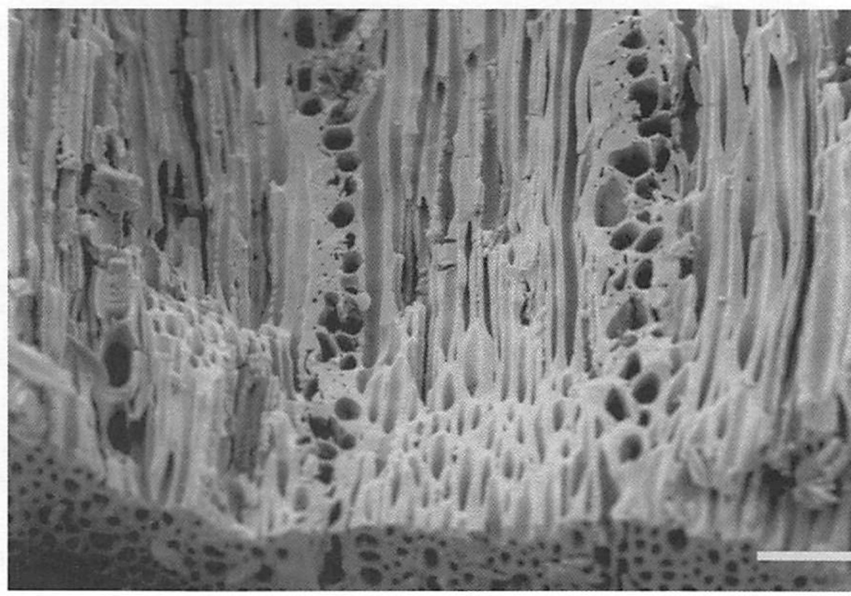


Figure 14.9. Photograph of unstoried, homogeneous strands of cells 2 to 6 seriate on charred wood from N3 Backhoe Trench at the Burnham site. Bar equals 100 microns.

size and shape of intervessel pits and distinctive thickening in the ends of vessels, are either obscured or indeterminate in the Burnham sample. Features which disqualify *Fraxinus* and *Celtis*, however, are relatively major morphological characteristics. Thus, while the assignment of the Burnham charcoal sample to *Asimina* is not unequivocal, the morphological features noted for this sample are closer to *Asimina* than any other species available for comparison.

Asimina triloba is presently distributed throughout the eastern United States. The westernmost occurrences are in eastern Kansas, Oklahoma, and Texas, whereas northern Illinois, southern Michigan, and western New York mark the northern boundary. The largest trees are reported from deep, rich, moist soils of the lower Ohio drainage basin and river bottoms in central and southern Arkansas. Large specimens reach 35 to 40 feet in height and 8 to 16 inches in diameter. Pure stands are known from the lower Mississippi River valley, but in most cases it grows as common understory in mixed hardwood forests (Harrar 1957). If the charcoal sample from Burnham is indeed *Asimina*, this would indicate a limited westward expansion of its range 35,000 to 40,000 years ago and climatic conditions broadly similar to those today.

Acknowledgments

I thank Mary J. Adair (University of Kansas) and Debbie Pearsall (Washington University, St. Louis) for their review and comments on ths study.

References Cited

Harrar, E.S. (editor). 1957. *Hough's Encyclopedia of American Woods.* R. Speller, Publisher, New York.

Chapter 15
Palynology of the Burnham Site

Peter Wigand

Introduction

Sediment samples from several strata at the Burnham site were submitted for pollen extraction and evaluation of palynological potential. Of interest was the development of a pollen record for the stratified pond sediments, especially the one that yielded the bison skull and artifacts. Unfortunately, most of the pond sediments were too sandy and gleyed (characteristics of an unstable depositional environment in which pollen preserves poorly), and despite attempting several careful extraction methods, no pollen was recovered.

Briefly reported here, however, are the pollen extraction results from a 3.0 to 5.0cm thick lens of reddish brown silt loam exposed in the profile adjacent the "Horse Bone Bed" or "Equus Bed" (Figure 15.1). Uncovered during the 1989 backhoe trenching, the "Horse Bone Bed" was in squares N5-W13, N4-W13, N4-W14, N4-W15, N3-W13, N3-W14, and N3-W15. The thin lens of reddish brown silt loam was at elevation 97.6 and directly east of the excavated portion of square N5-W13 (Figure 15.1). At this location, the lens was slightly above the gleyed sediment that contained the partially articulated, fossil horse bones. With a lateral extension of nearly 2.0m, this silt loam had a fine laminated structure. Overall, the lens appeared to represent sediment that had settled in a small pool of water. Because it was one of the few occurrences of non-sandy, non-gleyed, water-deposited, very fine textured strata found at the site, this lens seemed worthy of testing for pollen. At the very least, pollen extracted from this lens might represent a seasonal pollen rain dating sometime between 34,000 and 26,000 years ago.

Sample Collection

Approximately half a liter of the reddish brown silt loam was collected from a freshly trowelled face of the lens as it was expressed directly east of square N5-W13. The material was collected in a large lumps as possible, and these were placed in a clean plastic bag labeled with all appropriate provenience information. This bag was then double-

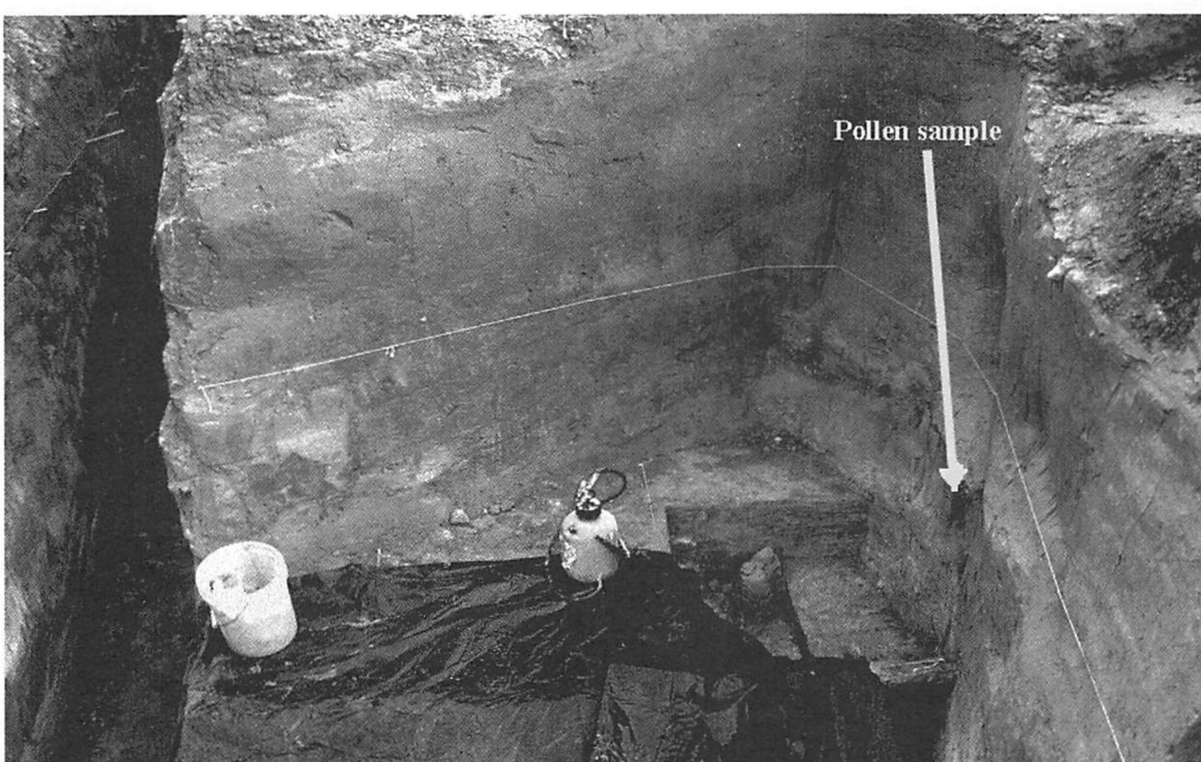


Figure 15.1. View north of pollen sample location in profile by square N3-W13 at the "Horse Bone Bed" of the East Grid, Burnham site. Photo taken October 16, 1989, by Don G. Wyckoff.

bagged and sent to the author.

Extraction Methodology

The sample was extracted two different ways. Only one produced a result in which pollen was recovered. The first attempt, run on December 2, 1989, followed the normal procedures of the Washington State University Pollen Lab, with the addition of an initial swirl step to concentrate the pollen. Two tablespoons of sediment were taken and five *Lycopodium* tablets (13,500 spores per tablet) were added as tracer pollen (Stockmarr 1977) for a total of 978 spores per cubic centimeter. This sample was run as normally with all acid treatments and acetolysis (Mehringer 1967). The extraction yielded no identifiable pollen.

In May of 1990, a second extraction was undertaken. Two tablespoons (138 cubic centimeters) of sediment were processed. Treatment differed in that it was attempted to concentrate pollen by employing sediment swirls to separate sand grains from the silt and clay. Then, the fine sediment was processed by timed centrifuge to precipitate the silt while leaving the clay in suspension. At each step both the reserved material and the material being poured off were checked for pollen. This was done to ensure that the fraction containing pollen was retained. Ten *Lycopodium* tracer spore tablets were introduced into the sample for a total of 135,000 tracers (or about 978 tracers per cubic centimeter). The final extraction was counted in June of 1990, but despite these efforts little well preserved pollen was in the sample.

The Results

The existing pollen count (Table 15.1) is the result of counting 28 rows on three separate slides. From doing this, the total pollen count is only 173 grains, 130 (81.8%) of which are unidentifiable. The 124 recovered *Lycopodium* tracers (Table 15.1) suggest that only 188,346 pollen grains

Table 15. 1. Pollen Sample results from the Burnham Site (34Wo73).

Pollen Type	*Raw Count*	*Relative %*
Pinus (pine)	2	1.1
Juniperus (cedar)	8	4.6
Acer (maple)	1	0.5
Ribes (currants)	1	0.5
Asteroideae (daisy/sunflower)	2	1.1
Poaceae (grass)	13	7.5
Cyperaceae (sedge)	14	8.0
Undetermined	2	1.1
Unidentifiable	130	75.1
Pollen Total	173	
Lycopodium tracer pollen	124	

were in the whole sample that was processed. That equates to less than 1365 grains per cubic centimeter.

If it were not for the fact that the little pollen recovered was in such poor shape, one might suggest that the pollen was modern contaminant. Again, pollen preservation was terrible. Of the 173 prehistoric grains recovered, essentially 82% were unidentifiable. these grains were so corroded that often their morphology could not be determined.

Of those grains that were identified, grass and sedge make up the majority. This suggests that the local environment was dominated by sedge to such an extent that the regional pollen rain, except for grass, was effectively screened out. The few juniper grains may have come from nearby or may represent some longer distant transport. The few pine are probably long distance transport. Otherwise, if local, they would have been more abundant.

Summary

Pollen preservation at the Burnham site is obviously so poor that it is doubtful that the extant pollen spectra is representative of the real environment around the site. Sedge grains are most numerous among the few identifiable pollen, and they attest to a marshy niche as is already indicated by recovered fossil gastropods. Grass pollen is next most frequent and could bear witness to nearby meadows or grasslands.

References Cited

Mehringer, P.J., Jr. 1967. Pollen Analysis of the Tule Springs Site Area, Nevada. *Pleistocene Studies in Southern Nevada*, edited by H.M. Wormington and D. Ellis, pp. 129-200. Nevada State Museum, Anthropological Papers 13.

Stockmarr, J. 1971. Tablets with Spores Used in Absolute Pollen Analysis. *Pollen et Spores* 13(4):615-621.

Chapter 16
Human and Naturally Modified Chipped Stone Items from the Burnham Site

Kent Buehler

Introduction

A primary reason for the existence of the Burnham project concerned the possibility of pre-Clovis human activities. Excavations recovered what appeared to be flaked stone artifacts in association with the bones of an extinct form of bison. Two questions immediately come to mind: 1) are the artifacts actually the result of human activity; and 2) if so, is their association with the bison bones valid, i.e., are the artifacts as old as the bones?

The first question can be answered through the techniques and methodology of lithic technology analysis. The second question requires input from other research avenues in the project, namely geomorphology, taphonomy, pedology, and radiocarbon dating. This chapter will present descriptions and interpretations of the recovered lithic materials and their spatial contexts in an attempt to address the above two questions.

Recovery, Initial Assessment and Descriptive Procedures

From the beginning, excavated sediments at Burnham were water screened through 1.6mm mesh window screen. This was done initially to recover small faunal material which might provide environmental data. However, it also resulted in the recovery of several small flakes. These were found in the winter of 1986 and spring of 1987 during laboratory sorting of recovered debris by former Lab Manager Peggy (Flynn) Rubenstein and students under her direction.

Approximately 50 m^3 of sediment and paleosols were water screened for the site between 1986 and 1992. All debris recovered from this manually dug and screened material was sorted. A few soil samples from select squares were water-screened in the lab. All sorting of washed matrix was done by student lab assistants at the Oklahoma Archeological Survey, and this work was done by hand with the aid of magnifier lamps. Student helpers were instructed to save all pieces of cryptocrystalline material, in addition to faunal and floral remains.

As bags of debris were sorted, I examined each potential stone artifact under a Bausch and Lomb stereoscopic microscope (10-70X Zoom) and made an initial determination as to whether it was of probably natural or cultural origin. My determinations were based on morphological features (Table 16.1) considered indicative of humanly made flakes (Crabtree 1972; Faulkner 1972; Cotterell and Kamminga 1979, 1987; Fladmark 1982). This was done "blind" with respect to provenience to avoid being influenced by possible associations or distributional patterns. The characteristics associated with each lithic item from the Burnham site are presented in Tables 16.2 through 16.5.

Table 16.1. Attributes of Humanly Produced Flakes.

Morphological attributes of flakes	Selected references
Platform	Crabtree 1972:84
Platform flaking	Crabtree 1972:84
Ventral lip	Crabtree 1972:74
Bulb of force	Crabtree 1972:48
Eraillure	Faulkner 1972:159-161; 1973
Radial striation	Crabtree 97; Faulkner 1972:152
Gull wings	Faulkner 1972:152
Feather termination	Crabtree 1972:64; Hayden 1979:133
Step termination	Cotterell and Kamminga 1979:105-106; Crabtree 1972:93
Hinge termination	Cotterell and Kamminga 1979:105; Crabtree 1972:68
Dorsal flake scars	Patterson 1983:302.
Dorsal edge flaking	Patterson 1983:302.

Five categories of lithic items were subjected to analysis. Four of these are considered to be of possible human origin: debitage, a modified flake tool, a biface fragment, and a large, flaked chert cobble. The fifth category consisted of unmodified, natural pieces of cryptocrystalline stone. Each of these is discussed below.

The Data: "Cultural Debitage"

Residue sorting resulted in the recovery of 52 pieces of cryptocrystalline material which, based on initial microscopic examination, were considered to be of possible human production (Tables 16.2-16.5; Figs. 16.1-16.51). Each item was further classified as a flake (or flake fragment) or as a piece of shatter. The latter are angular, blocky fragments which lack platforms and bulbs of force and usually are multifaceted (as opposed to the dual dorsal/ventral faces of flakes). Eleven items have been classified as shatter.

The remaining 41 items are flakes and flake fragments. Specimens #1 and #46 are the distal and proximal ends, respectively, of a single flake. Consequently, they are counted as one item unless otherwise noted. In summary, there are 9 complete flakes, 12 proximal fragments, 10 distal fragments, and 9 midsections for a total of 40 flakes and flake fragments (Table 16.2).

Table 16.2. Classification of Cultural Debitage from the Burnham Site.

Debitage class	Number	Percentage
Complete flakes	9	17.6
Proximal fragments	12	23.5
Distal fragments	10	19.6
Midsections	9	17.6
Shatter	11	21.6

Table 16.3. Provenience, Measurements, and Material Type of Flakes and Shatter from the Burnham Site.

Specimen Number	*Figure*	*Provenience Square*	*Level*	*Condition*	*Raw Material*	*Length*	*Width*	*Thickness*
1/46*	16.1	S1-W22	96.2	Complete Flake	Brown agate	10.3 mm	11.6 mm	1.9 mm
2	16.2	S2-W23	96.3	Distal Fragment	Unidentified	5.3	5.4	0.6
3	16.3	S2-W23	96.3	Distal Fragment	Day Creek	7.5	6.9	2.1
4	16.4	S2-W23	96.5	Distal Fragment	Day Creek	3.9	2.6	0.6
5	16.5	S2-W23	96.7	Complete Flake	Unidentified	2.9	1.7	0.7
6	16.6	S2-W22	96.7	Complete Flake	Day Creek	3.6	4.5	0.8
7	16.7	S2-W22	96.7	Proximal Fragment	Unidentified	1.6	2.3	0.7
8	16.8	S2-W22	96.7	Proximal Fragment	Day Creek	2.6	4.5	0.5
9	16.9	S2-W22	96.7	Proximal Fragment	Day Creek	2.4	2.5	0.6
10	16.1	S2-W22	96.7	Midsection	Probably Day Creek	1.8	2.2	0.3
11	16.11	S2-W22	96.7	Proximal Fragment	Probably Day Creek	2.1	2.3	0.3
12	16.12	S1-W22	97.0	Distal Fragment	Probably Day Creek	2.6	2.1	0.5
13	16.13	S1-W22	97.1	Proximal Fragment	Day Creek	2.4	1.4	0.5
14	16.14	S2-W22	96.2	Distal Fragment	Ogallala quartzite	10.5	19.2	4.1
15	16.15	N2-W21	96.6	Complete Flake	Day Creek	5.3	9.6	3.3
16	16.16	S2-W22	96.7	Complete Flake	Day Creek	5.6	5.9	1.7
17	16.17	S2-W23	96.5	Proximal Flake	Day Creek	5.4	5.1	1.4
18	16.18	S2-W22	96.8	Distal Fragment	Day Creek	6.5	4.9	0.9
19	16.19	S2-W22	96.6	Proximal Fragment	Day Creek	7.3	6.4	1
20	16.2	S1-W23	96.6	Distal Fragment	Unidentified	6.6	6	1
21	16.21	S2-W22	96.7	Edge of a Midsection	Edwards	7.8	7.5	2.6
22	16.22	S2-W22	96.7	Proximal Fragment	Unidentified	5.3	6.6	0.8
23	16.23	S2-W22	96.7	Proximal Fragment	Possibly Day Creek	4.5	7.4	1.6
24	16.24	S2-W22	96.7	Edge of a Midsection	Possibly Day Creek	6	2.5	0.6
25	16.25	S2-W22	96.7	Shatter	Day Creek	9.2	5.4	2.7
26	16.26	S2-W23	96.3	Shatter	Day Creek	6.2	5.7	5.5
27	16.27	S2-W22	96.7	Shatter	Day Creek	6.2	3.1	2.8
28	16.28	S2-W22	96.7	Shatter	Day Creek	7	4	2.5
29	16.29	S2-W22	96.7	Midsection	Day Creek/ Alibates	6	3.8	1.7
30	16.3	S2-W22	96.7	Midsection	Day Creek/Alibates	5.7	7.8	1.3
31	17.31	S1-W23	96.4	Shatter	Day Creek/Alibates	3.3	2.6	1.5
32	16.32	S1-W23	96.4	Shatter	Day Creek	4.9	3.5	2.3
33	16.33	S2-W23	96.6	Midsection	Day Creek	5.1	4.9	1.2
34	16.34	S2-W22	96.7	Midsection	Unidentified	3.7	4.9	1.3
35	16.35	S2-W22	96.3	Distal Fragment	Day Creek	6.2	7.9	1.6
36	16.36	S1-W23	96.4	Proximal Fragment	Day Creek	4.2	10.7	1.3
37	16.37	S1-W22	96.4	Complete Flake	Day Creek	5.7	6.7	1.7
38	16.38	S1-W22	96.2	Shatter	Day Creek	2.1	5.9	1.7
39	17.39	S2-W23	96.2	Shatter	Unidentified	5.2	4.5	0.8
40	16.4	S2-W23	96.3	Shatter	Day Creek	3.5	2.6	1.6
41	16.41	S2-W23	96.5	Shatter	Day Creek	3.2	1.7	0.7
42	16.42	S2-W23	96.5	Shatter	Day Creek	4.8	1.9	1.2
43	16.43	S1-W23	96.4	Distal Fragment	Unidentified	4.1	4.1	0.6
44	16.44	S1-W23	96.4	Midsection	Unidentified	2.5	4.8	0.7
45	16.45	S1-W22	96.2	Proximal Fragment	Day Creek	4.5	7.5	1.9
47	16.46	S1-W20	97.3	Midsection	Day Creek	5.7	13.2	1.6
48	16.47	S2-W22	96.7	Complete Flake	Day Creek	2.7	6	2.1
49	16.48	N1-W21	96.9	Distal Fragment	Day Creek	19.2	26.4	6
50	16.49	S2-W22	96.7	Complete Flake	Day Creek	5.3	9.1	2.1
51	16.5	S2-W21	96.8	Complete Flake	Unidentified	18.1	25.4	3.8
52	16.51	S2-W22	96.7	Proximal Section	Day Creek	7.2	6.3	1.1

*Specimens #1 and #46 refit and are counted as one complete flake.
Note: All artifact measurements are in millimeters.

Size

Dimensions were recorded to the nearest 0.1mm and are summarized in Table 16.6. One of the most obvious characteristics of the Burnham debitage is its small size. Given the field recovery techniques used, it is not surprising that small debitage was recovered. What is surprising is that it dominates the assemblage. The complete flakes average only 6.6mm in length, 8.24mm in width, and 1.9mm in thickness. The largest complete flake recovered is only 18.1mm long. The shatter averages only 4.46mm in its longest dimension. While larger than the 1.0mm cutoff suggested by Fladmark (1982:205) as defining microdebitage, we are clearly dealing with small-scale debitage at the Burnham site.

It is interesting to note that the flakes average greater in width than in length. Luedtke (1986:57) noted this same tendency in two assemblages of naturally produced flakes. This characteristic most likely results from low velocity fracture. Unfortunately, the few flakes in these samples (only 9 in the Burnham case) tends to preclude such metric analyses as comparing length to width ratios, etc. between the sampels.

Cortex

Most researchers agree that humanly produced flake assemblages should be dominated by non-decortication flakes, whereas natural assemblages should show high percentages of cortex covered specimens (Barnes 1939:10;Luedkte 1986:58; Patterson 1983:302; Peacock

Table 16.4 . Platform and Dorsal Attributes of Cultural Flakes and Shatter.

Specimen Number	*Figure*	*Flake Type****	*Platform*	*Platform Flaking*	*Biface Edge Platform*	*Dorsal Edge Flaking*	*Dorsal Flake Scars*
1/46*	16.1	PD	X	X			
2	16.2	ND					X
3	16.3	ND	X	X		X	X
4	16.4	ND					X
5	16.5	ND	X	X		X	X
6	16.6	ND	X	X			X
7	16.7	ND					X
8	16.8	ND	X	X	X	X	X
9	16.9	ND	X	X			X
10	16.10	ND					X
11	16.11	ND	X	X	X	X	X
12	16.12	ND					X
13	16.13	ND	X	X		X	X
14	16.14	SD					X
15	16.15	ND	X	X			X
16	16.16	ND	X	X		X	X
17	16.17	SD	X	X			X
18	16.18	ND					X
19	16.19	ND	X	X	X	X	X
20	16.20	ND					X
21	16.21	ND					X
22	16.22	ND	X	X	X	X	X
23	16.23	ND	X	X	X	X	X
24	16.24	ND					X
25**	16.25	SD					
26**	16.26	SD					
27**	16.27	ND					
28**	16.28	ND					
29	16.29	ND					X
30	16.30	ND					X
31**	16.31	ND					
32**	16.32	ND					
33	16.33	SD					X
34	16.34	ND					X
35	16.35	ND					X
36	16.36	ND	X	X		X	X
37	16.37	ND	X	X		X	X
38**	16.38	ND					
39**	16.39	ND					
40**	16.40	ND					
41**	16.41	ND					
42**	16.42	ND					
43	16.43	ND					X
44	16.44	ND					X
45	16.45	ND	X	X		X	X
47	16.46	ND					X
48	16.47	ND	X	X		X	X
49	16.48	ND					X
50	16.49	ND	X	X	X		X
51	16.50	PD	X				
52	16.51	ND	X	X	X	X	X

*Specimens 1 and 46 refit, counted as one complete flake.
**Indicates Shatter
***PD=Primary Decortication Flake, SD=Secondary Decortication Flake, ND=Non-Decortication Flake

1991:353). Among the proposed cultural debitage from the Burnham site, 87.5% (n=35) of the 40 flakes are non-decortication forms, and 5% (n=2) are primary cortex flakes while 7.5% (n=3) are secondary decortication flakes (Table 16.7). Of the 11 shatter pieces, 81.9% (n=9) have no cortex, and 18.1% (n=2) have some cortex present. Clearly, the Burnham assemblage is dominated by non-decortication debitage, and, on this basis, it appears to have a human origin. This agrees with Peacock's (1991:352-353) results, which showed a significant difference between natural and human flakes, with the latter having high percentages of non-cortex flakes.

Platforms, Platform Flaking, and Dorsal Edge Flaking

All of the 21 complete flakes and proximal fragments retain their platforms. This is in rather marked contrast to Luedtke's two natural flake groups in which only 30% and 48% retained the platforms (Luedtke 1986:57). Of the 21 platforms 20 (95.2%) are flaked showing from 1 to as many

Table 16.5. Ventral Face and Termination Attributes of Cultural Flakes and Shatter.

Specimen Number	*Figure*	*Ventral Lip*	*Bulb*	*Radial Striations*	*Undulations*	*Gull Wings*	*Wallner Lines*	*Termination****
1/46*	16.1	X	X	X		X	X	HT
2	16.2			X			X	FT
3	16.3			X				HT
4	16.4	X					X	FT
5	16.5	X	X	X			X	FT
6	16.6		X					FT
7	16.7							ST
8	16.8							ST
9	16.9		X					ST
10	16.10			X		X		ST
11	16.11			X	X			ST
12	16.12							FT
13	16.13	X	X		X			ST
14	16.14				X			FT
15	16.15	X	X					FT
16	16.16							HT
17	16.17	X	X				X	ST
18	16.18			X				FT
19	16.19	X	X	X				ST
20	16.20			X				ST
21	16.21			X			X	ST
22	16.22	X	X	X				ST
23	16.23	X	X	X		X		ST
24	16.24			X				ST
25**	16.25							
26**	16.26							
27**	16.27							
28**	16.28							
29	16.29							ST
30	16.30							ST
31**	16.31							
32**	16.32							
33	16.33							ST
34	16.34							ST
35	16.35			X				ST
36	16.36		X		X			ST
37	16.37		X					FT
38**	16.38							
39**	16.39							
40**	16.40							
41**	16.41							
42**	16.42							
43	16.43							FT
44	16.44							ST
45	16.45	X	X					ST
47	16.46							ST
48	16.47		X	X				FT
49	16.48							FT
50	16.49	X	X	X				FT
51	16.50		X					FT
52	16.51	X	X	X				FT

*Specimens 1 and 46 refit, counted as one complete flake.
**Indicates Shatter
***FT=Feather Termination, ST=Step Termination, HT=Hinge Termination

as 4 flake removals. Only one specimen has an unmodified, cortex-covered platform. Additionally, 58.3% (n=14) of the complete or proximal end flakes show minute flaking of the dorsal face immediately below the platform, suggesting additional platform preparation.

Consistent indications of prepared platforms are usually taken as evidence of human-controlled flaking, done to produce acute platform angles suitable for controlled removal of flakes. However, as Patterson (1983:301) points out, nature also produces flakes with angles of less than 90 degrees simply because flakes detach much more easily than when angles are more obtuse. Therefore, acute platform angles are not by themselves necessarily indicative of human-controlled flaking. However, the steps which create such platform angles or otherwise prepare platforms usually are. As Patterson (1983:302) notes, "Evidence of the preparation of a striking platform is therefore a key indication of manufacturing by man".

Peacock (1991:352), however, reached a different conclusion. In his comparison of cultural vs. natural flakes, 41% of the artifact flakes had flaked platforms as opposed to 31% of the natural flakes. A chi-square test showed no significant difference between the two flake groups at the .01 level. He concluded, "it would seem then, that faceted platforms ....are not a characteristic that would consistently distinguish artifacts from geofacts" (Peacock 1991:352).

Table 16.6. Summary of Burnham Site Cultural Debitage Dimensions.

Attributes	Number	Mean(cm)	Range(cm)
Flake length			
Complete	9	6.6	2.7 - 18.1
Incomplete	31	5.44	1.6 - 19.2
All Flakes	40	5.57	1.6 - 19.2
Flake Width	40	8.24	1.4 - 26.4
Flake Thickness	40	1.90	.3 - 6.0
Shatter			
Length	11	5.05	2.1 - 9.2
Width	11	3.71	1.7 - 5.4
Thickness	11	2.10	0.7 - 5.5

Table 16.7. Summary of Burnham Site Cultural Debitage Attributes

Attributes	Number of examples	Percentage
Primary Decortication		
Flakes	2	5.0*
Shatter	0	0
Secondary Decortication		
Flakes	3	7.5*
Shatter	2	18.2**
Non-Decortication		
Flakes	35	87.5*
Shatter	9	81.8**
Platform	21	100***
Platform Flaking	20	95.2***
Platform is Biface Edge	7	33.3***
Dorsal Edge Flaking	14	66.6***
Bulb	17	80.9***
Erailure	0	0
Ventral Lip	12	57.1***
Radial Striations	17	42.5*
Undulations	4	10.0*
Dorsal Flake Scars	38	95.0*
Termination		
Feather	15	37.5*
Hinge	3	7.5*
Step/Broken	22	55.0*

* Percentage of all flakes (n=40)
**Percentage of all shatter (n=11)
***Percentage of complete flakes and proximal fragments (n=21)

Notably, the Burnham flakes show a much higher percentage of flaked platforms than Peacock's artifact sample. Additionally, the Burnham flakes have a high percentage with dorsal flaking below the platform, suggesting platform angle preparation.

Seven Burnham flakes (specimens #8, #11, #19, #22, #23, #50, and #52) have platforms which appear to be remnants of biface edges (Figs. 16.8, 16.11, 16.19, 16.22, 16.23, 16.49 and 16.51). It would seem unlikely that natural forces would repeatedly produce the multifaceted, bifacially flaked morphology necessary to imitate a biface edge platform. Although Peacock (1991:352) cautions that forms mimicking biface thinning flakes can be produced naturally, he does not support his caveat with examples. Despite such warnings, the high proportions of platform and dorsal face flaking, combined with the presence of several biface edge platforms, strongly suggest that the Burnham flakes are of human origin.

Dorsal Flake Scars

Natural and cultural assemblages of flakes are often expected to differ with respect to the number, orientations, and character of scars on their dorsal surfaces resulting from previously removed flakes. According to Patterson (1983:302),

> "Man-made flakes are more likely to have multiple flake scars on dorsal surfaces, indicating prior flake removals from the core. In addition, man-made flakes should have all dorsal-face flake scars of the same apparent age, with no uneven surface weathering of separate flakes scars".

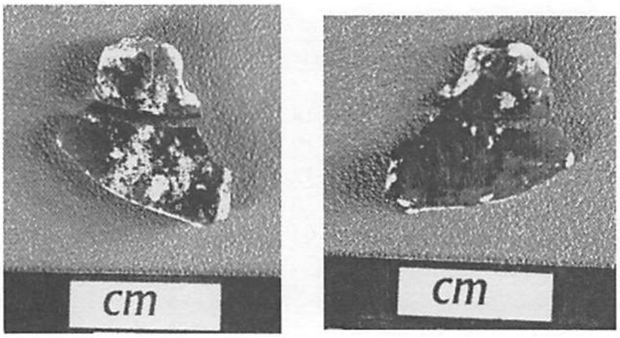


Figure 16.1. Artifact #1 & 46. Dorsal (left) and ventral views of refitted flake of a brown agate. White interval is 1.0cm.

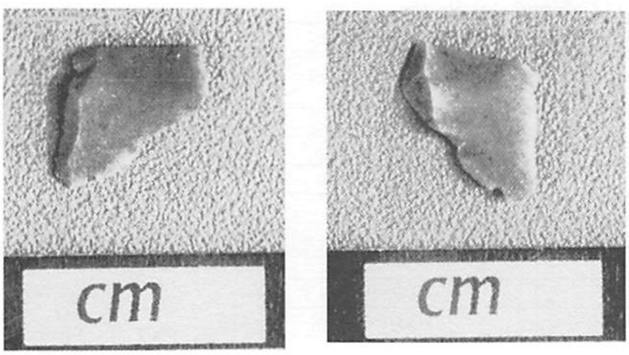


Figure 16.2. Artifact #2. Dorsal (left) and ventral views of distal end of retouched flake of unidentified chert. White interval is 1.0cm.

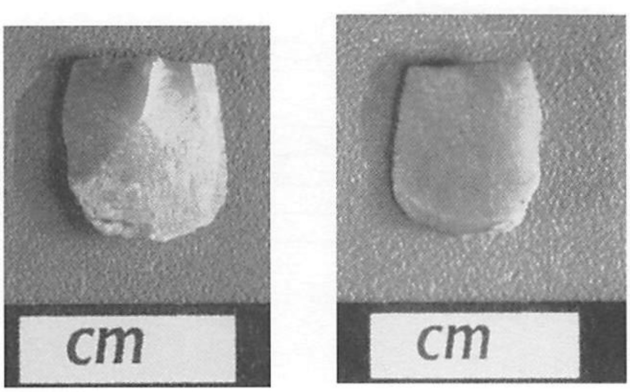


Figure 16.3. Artifact #3, Dorsal (left) and ventral views of distal end of a flake of Day Creek chert. Note the hinge termination. White interval is 1.0cm.

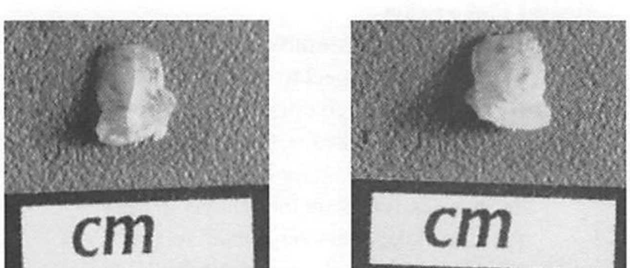


Figure 16.4. Artifact #4. Dorsal (left) and ventral face of the distal end of a flake of Day Creek chert. White interval is 1.0cm.

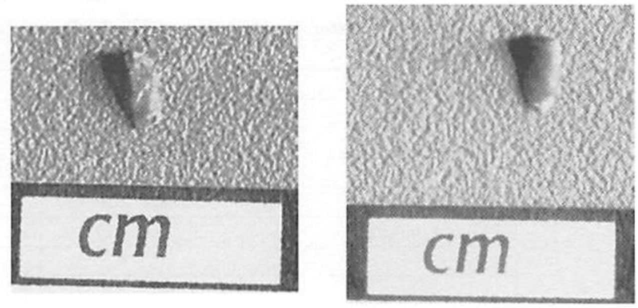


Figure 16.5. Artifact #5. Dorsal (left) and ventral faces of a flake of unidentified flint. White interval is 1.0cm.

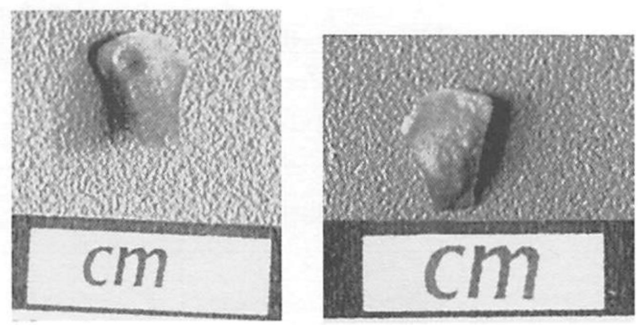


Figure 16.6. Artifact #6. Dorsal (left) and ventral faces of a flake of Day Creek chert. Note potlidding on dorsal face. White interval is 1.0cm.

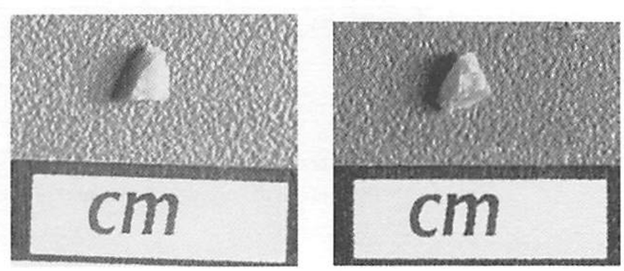


Figure 16.7. Artifact #7. Dorsal and ventral faces of a proximal fragment of unidentified flint. White interval is 1.0cm.

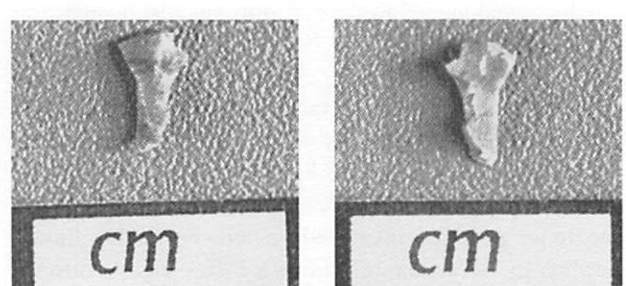


Figure 16.8. Artifact #8. Dorsal (left) and ventral faces of longitudinally split proximal part of a flake of Day Creek chert. White interval is 1.0cm.

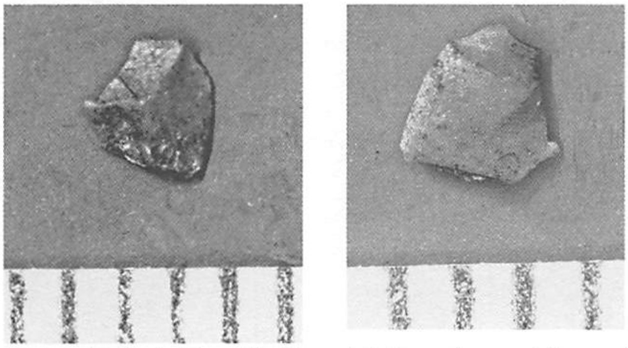


Figure 16.9. Artifact #9. Dorsal (left) and ventral faces of a proximal fragment of Day Creek chert. Intervals are 1.0mm.

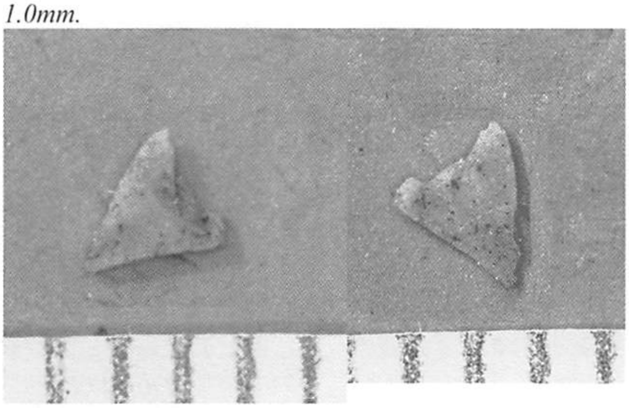


Figure 16.10. Artifact #10. Dorsal (left) and ventral faces of a midsection of unidentified (possibly Day Creek) flint. Intervals are 1.0mm.

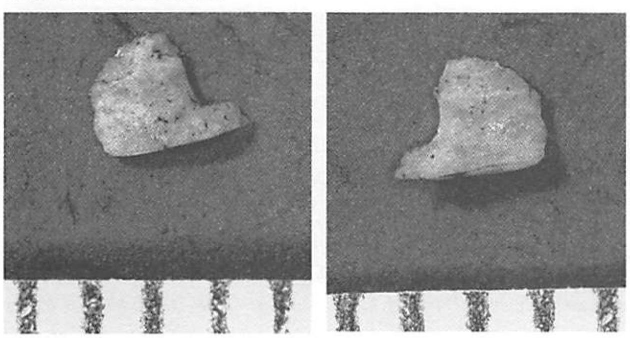


Figure 16.11. Artifact #11. Dorsal (left) and ventral faces of a proximal fragment of a flake of unidentified (possibly Day Creek) chert. Intervals are 1.0mm.

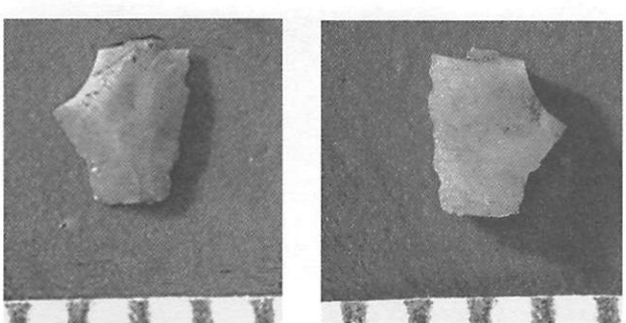


Figure 16.12. Artifact #12. Dorsal (left) and ventral faces of a distal fragment of a flake of unidentified (possibly Day Creek flint. Intervals are 1.0mm.

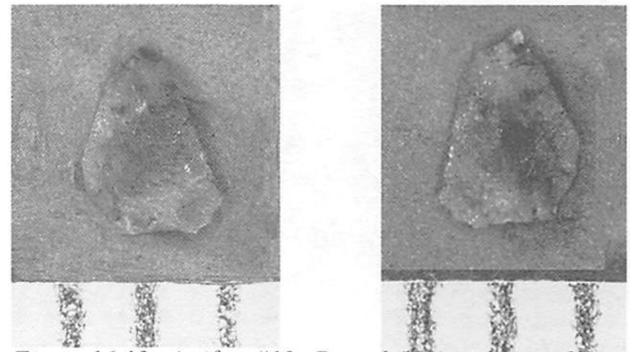


Figure 16.13. Artifact #13. Dorsal (left) and ventral faces of a proximal fragment of a flake of Day Creek chert. Intervals are 1.0mm.

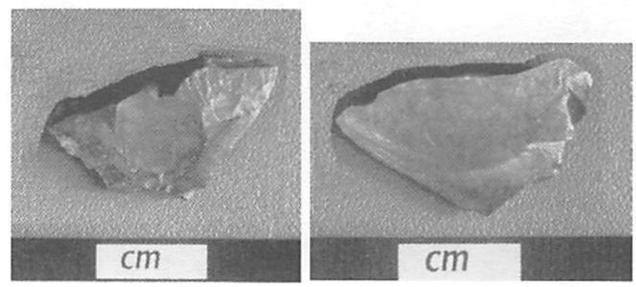


Figure 16.14. Artifact #14. Dorsal (left) and ventral faces of the distal end of a flake of Ogallala quartzite. White interval is 1.0cm.

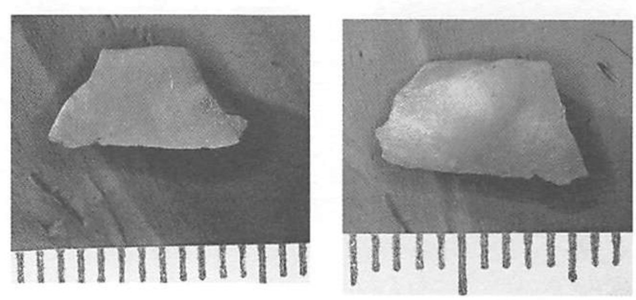


Figure 16.15. Artifact #15. Dorsal (left) and ventral faces of a complete flake of Day Creek chert. Intervals are 1.0mm.

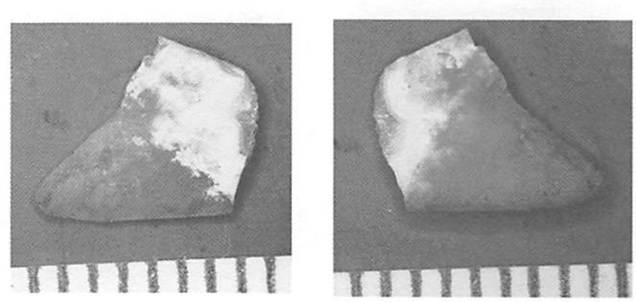


Figure 16.16. Artifact #16. Dorsal (left) and ventral faces of a complete flake of Day Creek chert. Intervals are 1.0mm.

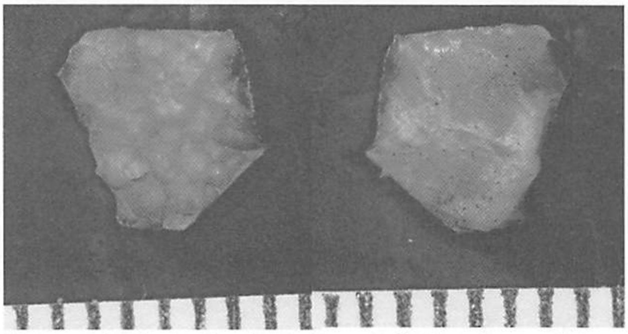


Figure 16.17. Artifact #17. Dorsal (left) and ventral faces of a proximal section of a Day Creek chert flake. Intervals are 1.0mm.

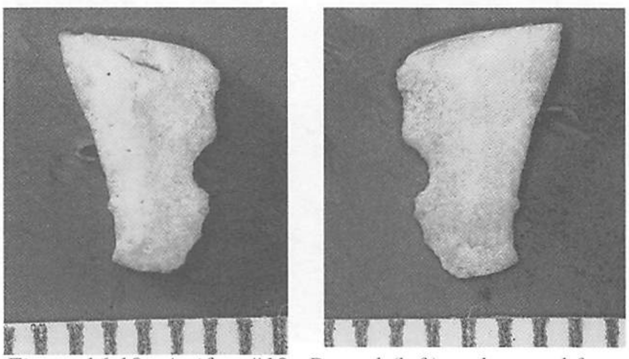


Figure 16.18. Artifact #18. Dorsal (left) and ventral faces of the distal end of a Day Creek chert flake. Intervals are 1.0mm.

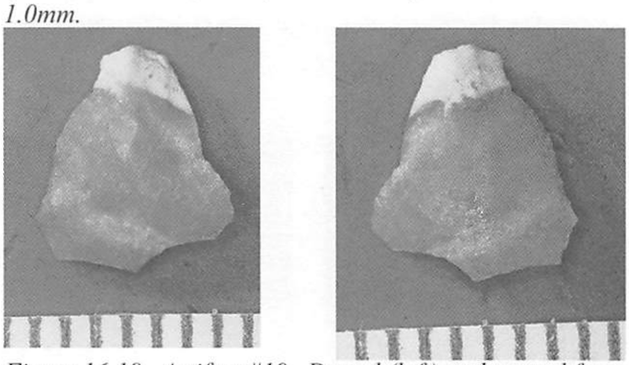


Figure 16.19. Artifact #19. Dorsal (left) and ventral faces of the proximal end of a Day Creek chert flake. Intervals are 1.0mm.

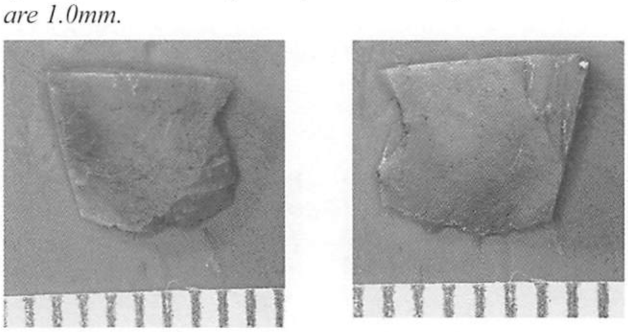


Figure 16.20. Artifact #20. Dorsal (left) and ventral faces of a distal fragment of an unidentified chert flake. Intervals are 1.0mm.

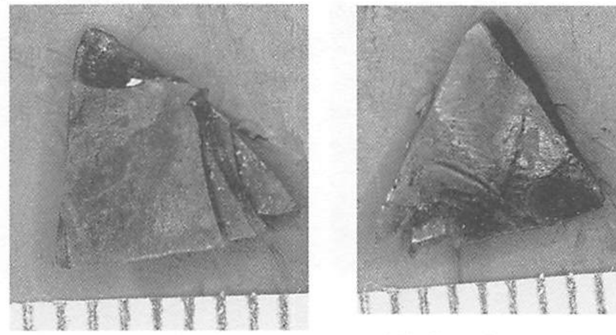


Figure 16.21. Artifact #21. Dorsal (left) and ventral faces of edge of a midsection of Edwards ('Root Beer' variety) chert flake. Intervals are 1.0mm.

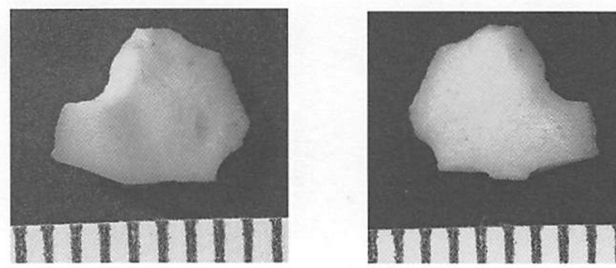


Figure 16.22. Artifact #22. Dorsal (left) and ventral faces of the proximal end of an unidentified chert flake. Note faceted platform (right). Intervals are 1.0mm.

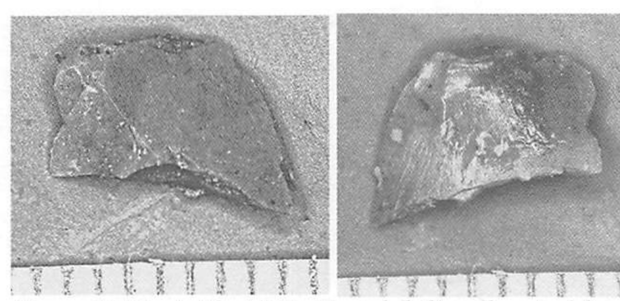


Figure 16.23. Artifact #23. Dorsal (left) and ventral faces of proximal end of a flake of possibly Day Creek chert. Intervals are 1.0mm.

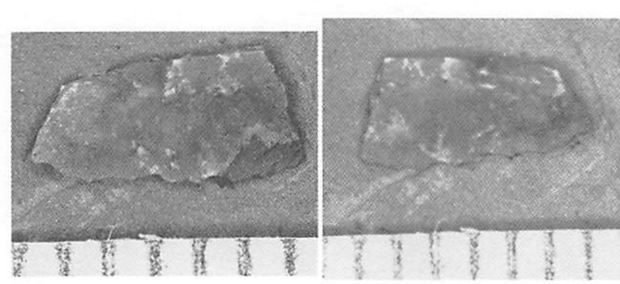


Figure 16.24. Artifact #24. Dorsal (left) and ventral faces of a flake's midsection and edge. Material is possibly Day Creek chert. Intervals are 1.0mm.

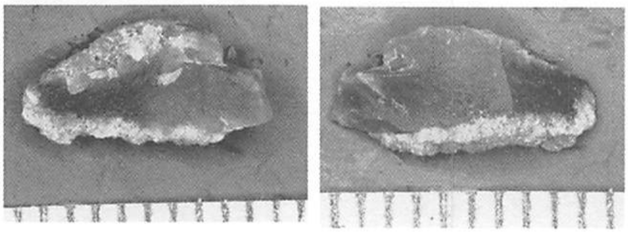


Figure 16.25. Artifact #25. Two faces of shatter debris of Day Creek chert. Intervals are 1.0mm.

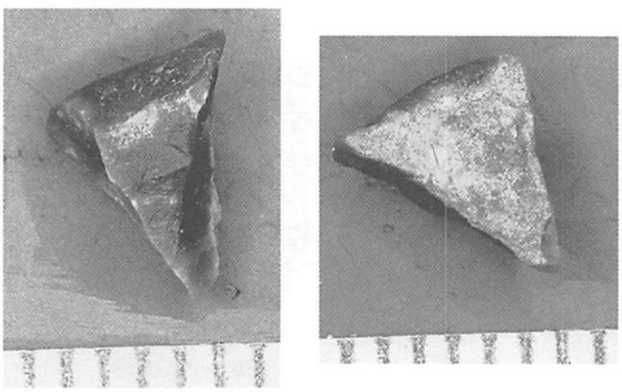


Figure 16.26. Artifact #26. Two faces of a piece of shatter debris of Day Creek chert. Intervals are 1.0mm.

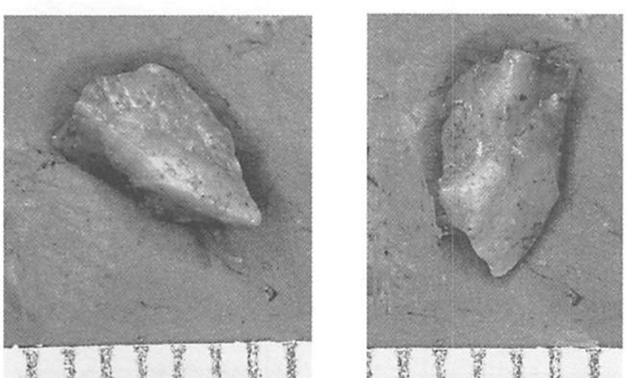


Figure 16.27. Artifact #27. Two faces of a piece of shatter debris of Day Creek chert. Intervals are 1.0mm.

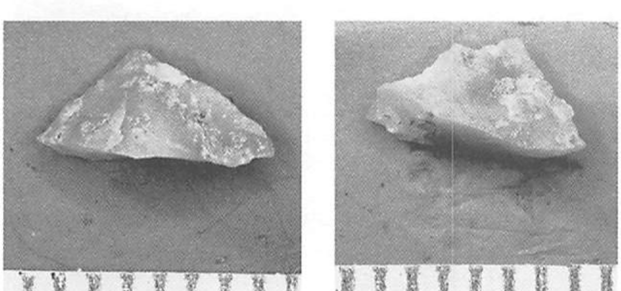


Figure 16.28. Artifact #28. Two faces of Day Creek chert shatter debris. Intervals are 1.0mm.

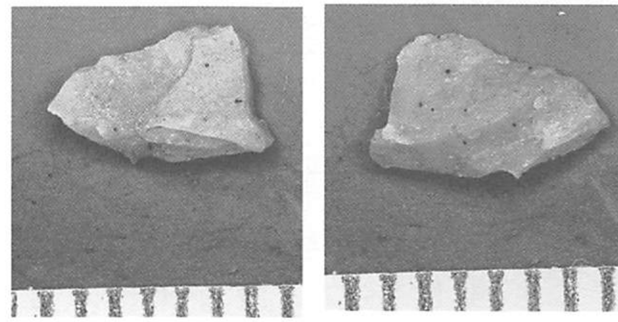


Figure 16.29. Artifact #29. Dorsal (left) and ventral faces of a midsection of a flake of Day Creek or Alibates flint. Intervals are 1.0mm.

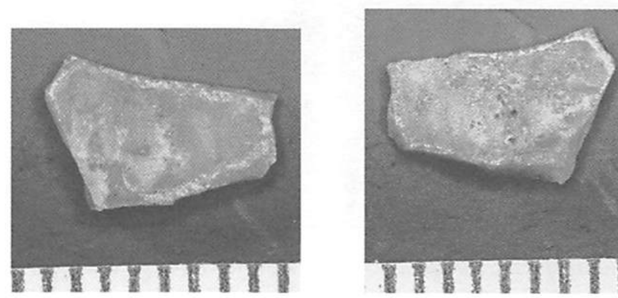


Figure 16.30. Artifact #30. Dorsal (left) and ventral faces of the midsection of a flake of Day Creek or Alibates flint. Intervals are 1.0mm.

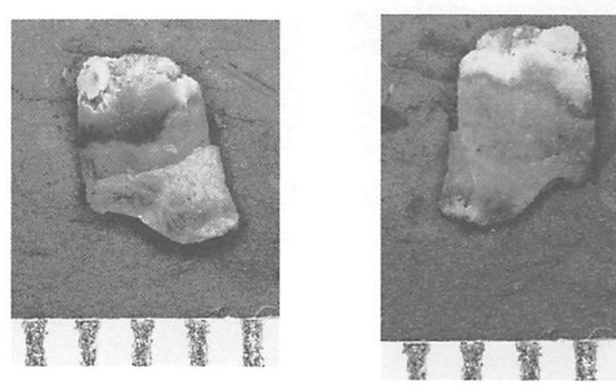


Figure 16.31. Artifact #31. Two facets of a piece of Day Creek or Alibates flint shatter debris. Intervals are 1.0mm.

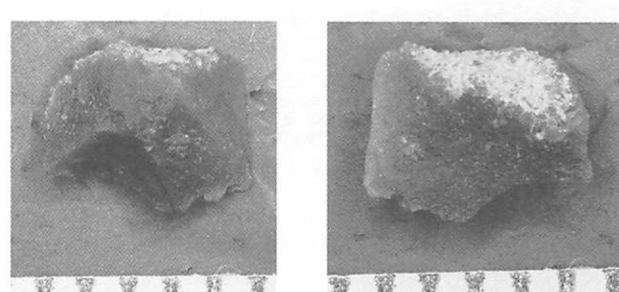


Figure 16.32. Artifact #32. Two facets of a piece of Day Creek chert shatter debris. Intervals are 1.0mm.

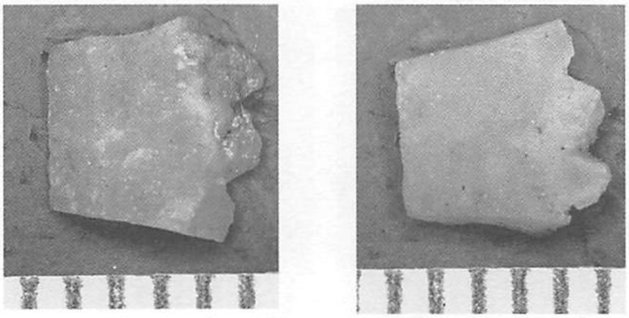


Figure 16.33. Artifact #33. Dorsal (left) and ventral faces of a midsection of a flake of Day Creek chert. Intervals are 1.0mm.

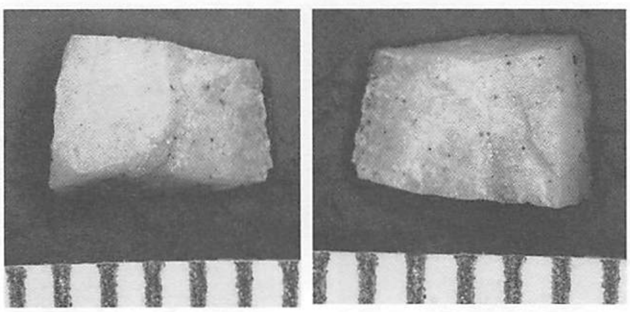


Figure 16.34. Artifact #34. Dorsal (left) and ventral faces of the midsection of a flake of unidentified flint. Intervals are 1.0mm.

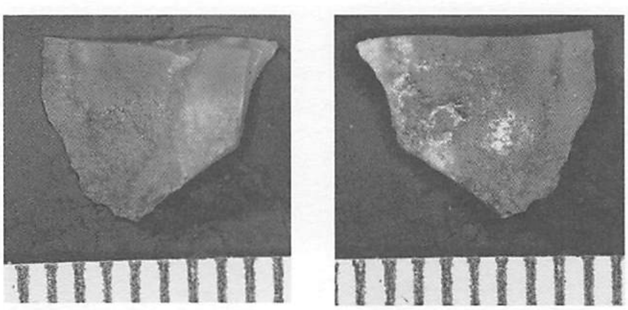


Figure 16.35. Artifact #35. Dorsal (left) and ventral faces of the distal end of a flake of Day Creek chert. Intervals are 1.0mm.

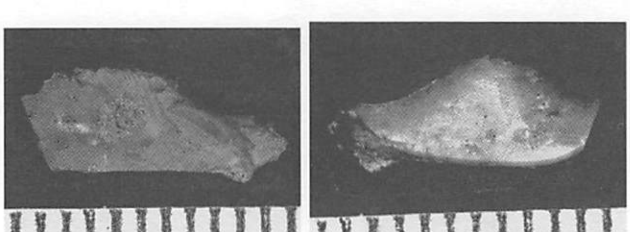


Figure 16.36. Dorsal (left) and ventral faces of the proximal end of a flake of Day Creek chert. Intervals are 1.0mm.

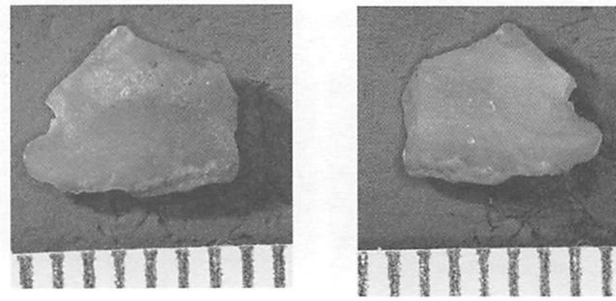


Figure 16.37. Artifact #37. Dorsal (left) and ventral faces of a flake of Day Creek chert. Intervals are 1.0mm.

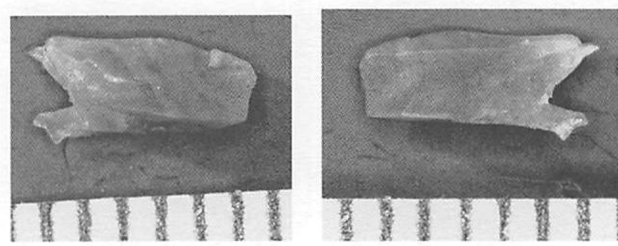


Figure 16.38. Artifact #38. Both faces of a piece of Day Creek chert shatter debris. Intervals are 1.0mm.

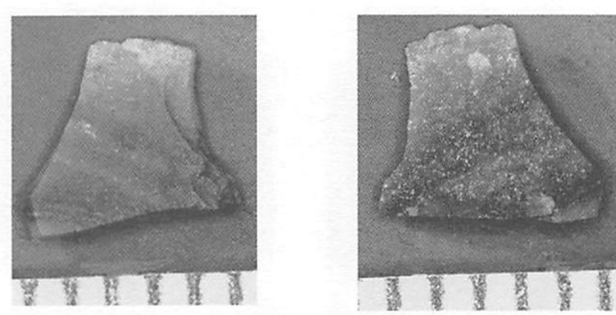


Figure 16.39. Artifact #39. Dorsal (left) and ventral faces of shatter debris of unidentified chert. Intervals are 1.0mm.

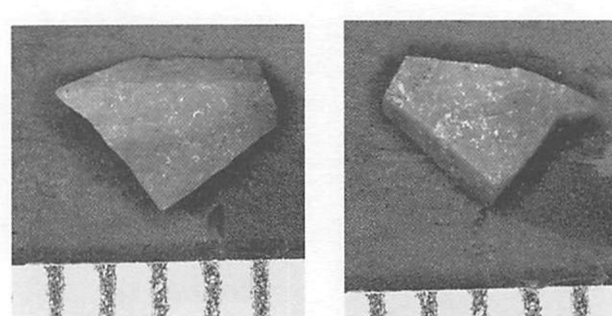


Figure 16.40. Artifact #40. Two facets of a piece of shatter debris of Day Creek chert. Intervals are 1.0mm.

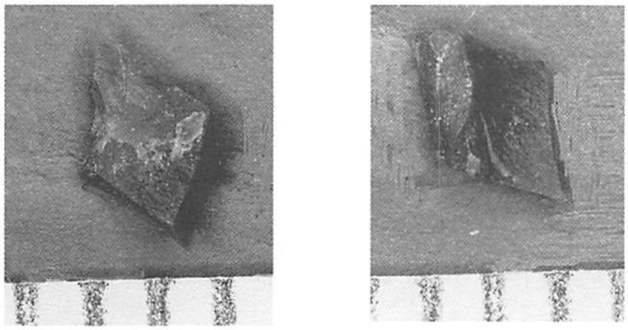


Figure 16.41. Artifact #41. Two facets of Day Creek chert shatter debris. Intervals are 1.0mm.

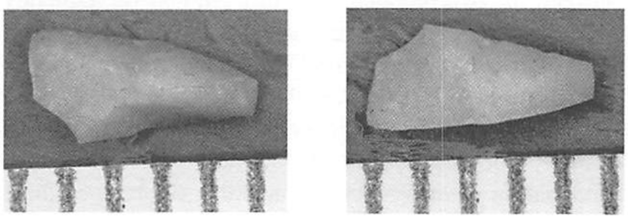


Figure 16.42. Artifact #42. Two facets of Day Creek chert shatter debris. Intervals are 1.0mm.

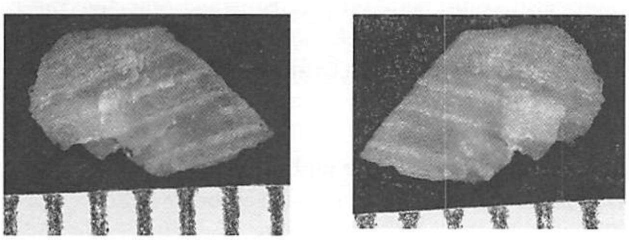


Figure 16.43. Artifact #43. Dorsal (left) and ventral faces of the distal end of a flake of unidentified chert. Intervals are 1.0mm.

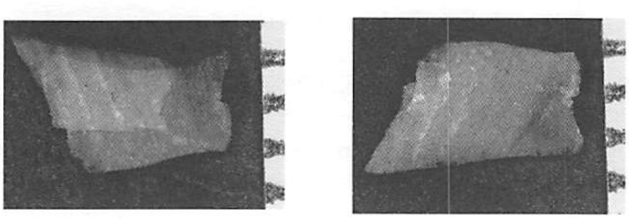


Figure 16.44. Artifact #44. Dorsal (left) and ventral faces of the midsection of a flake of unidentified chert. Intervals are 1.0mm.

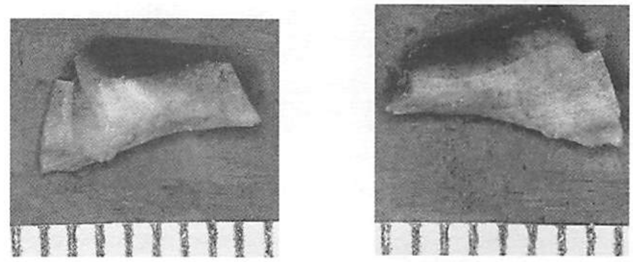


Figure 16.45. Artifact #45. Dorsal (left) and ventral faces of the proximal end of a flake of Day Creek chert. Intervals are 1.0mm.

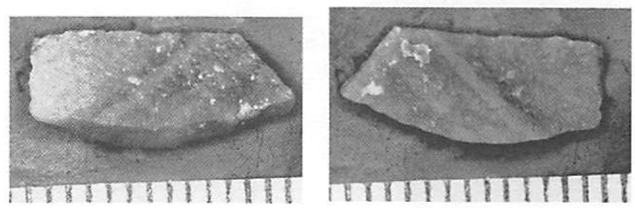


Figure 16.46. Artifact #47. Dorsal (left) and ventral faces of the midsection of a flake of Day Creek chert. Intervals are 1.0mm.

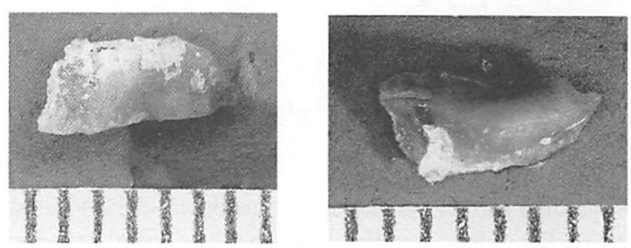


Figure 16.47. Artifact #48. Dorsal (left) and ventral faces of a flake of Day Creek chert. Intervals are 1.0mm.

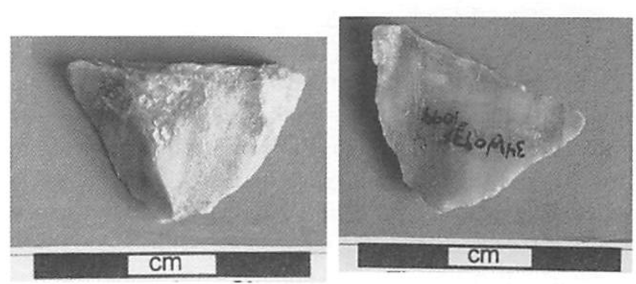


Figure 16.48. Artifact #49. Dorsal (left) and ventral faces of the distal end of a flake of Day Creek chert. Intervals are 1.0mm.

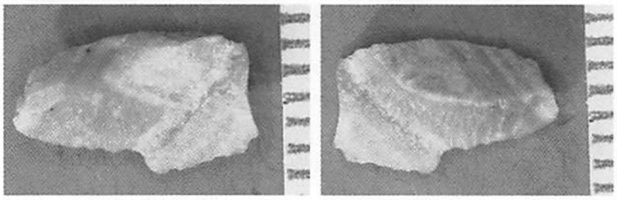


Figure 16.49. Artifact #50. Dorsal (left) and ventral faces of a flake of Day Creek chert. Intervals are 1.0mm.

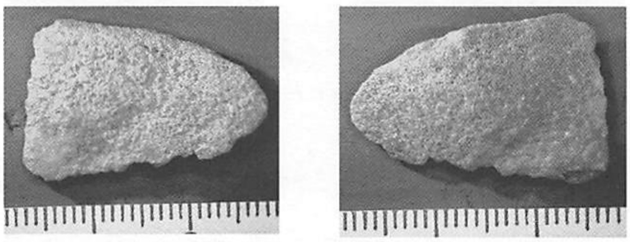


Figure 16.50. Artifact #51. Dorsal (left) and ventral faces of a flake of unidentified quartzite. Intervals are 1.0mm.

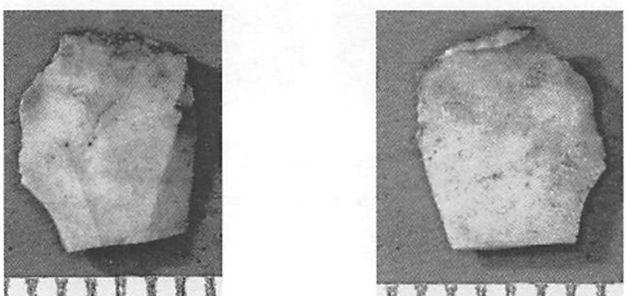


Figure 16.51. Artifact #52. Dorsal (left) and ventral faces of the proximal end of a flake of Day Creek chert. Note overhanging lip and faceted platform(right). Interval is 1.0mm.

Regarding natural assemblages, Luedtke (1986:58) states, "these flakes have few flake scars on their dorsal surfaces, and those that do have are often not oriented parallel to the medial axis of the flake, another sign of random rather than intentional flaking".

Among the proposed Burnham cultural material, 95% (n=38) of the flakes have at least one dorsal flake scar, with some having as many as six (Table 16.8). It should be noted that these are not the same as the minute dorsal face flaking found adjacent the platform (and discussed above). The number of directions of removal of dorsal flakes ranges from one to four, with the former being far more dominant (Table 16.9). The majority (65%, n=26) has dorsal scars oriented in the same direction as the medial axis, with 17.5% (n=5) being both perpendicular and obliquely oriented to the axis (Table 16.10). This is in agreement with Peacock's (1991:353) finding that humanly produced flakes showed a significantly higher proportion of dorsal flake scars than did natural flakes, and that such scars were significantly more likely to be oriented parallel to the medial axis on cultural debitage. Thus, the high percentage and characteristics of dorsal flake scars in the Burnham assemblage would seem to be representative of humanly made, rather than natural, flakes.

Additional support for this conclusion stems from the fact that none of the Burnham flakes have dorsal scars of apparently different ages, such as might be indicated by differential patination. Such multi-generational flaking is more commonly associated with naturally produced flakes (Oakley 1972:18; Patterson 1983:302; Peacock 1991:352).

Bulbs of Force

It has long been recognized (Warren 1914) that both human and naturally produced flakes may exhibit bulbs of force (also called bulbs of percussion). However, numerous researchers have used bulb saliency to attempt to distinguish between the two production modes. In general, humanly made flakes are deemed to have a higher percentage of salient bulbs of force, whereas natural flakes tend to have flatter or more diffuse bulbs (Luedtke 1986; Oakley and Newcomer 1978; Patterson 1983; Peacock 1991; Watson 1968). Actually, the degree of bulb saliency is the result of a combination of many factors, including the type of force application (dynamic vs. static), velocity of applied force, type of percussor, and the fracture characteristics of the material being worked. The manner in which a flint knapper combines, applies, or controls these factors will influence bulb saliency. In general, it is believed that salient bulbs tend to be more common in high velocity fracture with a high elastic ratio between percussor and objective piece. Diffuse bulbs tend to result more from lower velocity/low elastic ratio scenarios (Crabtree 1972:44; Patterson 1983:300).

Among the complete and proximal end flakes from Burnham, 42.8% (n=9) have salient bulbs, 38.1% (n=8) have diffuse bulbs, and 19% (n=4) show no bulbs (Table 16.7). In his comparison of humanly produced vs. naturally produced flakes, Peacock (1991:350-351) showed 65% prominent bulbs among the cultural debitage and only 7% among the natural flakes. Additionally, fully 75% of the natural flakes had no bulbs at all. Peacock concluded that prominent bulbs are characteristic of man-made flakes.

Although Luedtke's (1986:58-59) experiments did not include human-produced debitage, her two naturally fractured assemblages showed 7% and 25% prominent bulbs. The first figure agrees precisely with Peacock's results, whereas the second is considerably higher. The Burnham sample falls between Peacock's natural and cultural assemblages but is much closer to the latter. It also is greater than both of Luedtke's natural samples for this trait. As for flakes lacking bulbs completely, Luedtke (1986:58-59) showed 38% and 41% for her two natural samples as compared to 19% for Burnham. While these figures are in contrast to the aforementioned 75% reported by Peacock, the Burnham sample shows a closer affinity to the cultural samples than the natural flakes.

Table 16.8. Number of Dorsal Flake Scars on Burnham Cultural Flakes.

Number of Scars	Number	Percentage
0	2	5.0
1	10	25.0
2	15	37.5
3	4	10.0
4	6	12.5
5	3	7.5
6	1	2.5

Table 16.9. Number of Orientations of Dorsal Flake on Burnham Cultural Flakes.

Orientations	Number	Percentage
0	2	5.0
1	32	80.0
2	5	12.5
3	0	0
4	1	2.5

Table 16.10. Orientation of Dorsal Flake Scars Relative to Medial Axis.

Orientations	Number	Percentage
None	2	5.0
Same as Medial Axis	26	65.0
Oblique or Perpendicular	7	17.5
Oblique and Perpendicular	5	12.5

Because bulb saliency reflects many technical factors, one must be cautious in using this attribute to distinguish between humanly and naturally made flakes. It is likely that natural flakes have a lesser tendency to have prominent bulbs. However, the same can be true of man-made flakes, depending on the technology available, its specific application, and the lithology of the material being flaked. Hard-hammer percussion, soft-hammer percussion, and pressure flakes, all of human production, can and do vary regarding this attribute. Unless one knows or can reliably infer the production mode of the cultural sample (which most of the researchers cited above did not), one must be cautious using bulb saliency as an indicator. The production mode of the Burnham flakes is thus inconclusive when this attribute is considered. However, a high percentage of bulb presence suggests human-made flakes.

Radial Striations, Eraillures, Undulations, and Gull Wings.

Among the 40 flakes from the Burnham site, 42.5% (n=17) have radial striations. In Peacock's (1991:351) two cultural samples, 94% and 66% had radial striations (radial lines in his terminology) for an average of 80%. By comparison, his natural samples had 8% and 24% (for an average of 16%). Based on a chi-square test, Peacock concluded that a significant difference existed between natural and man-made flakes, and those with high proportions of radial striations were indicative of human manufacture.

The Burnham sample falls between Peacock's group averages for natural and cultural flakes, the 42.5% radial striations for Burnham being much higher than either of the percentages for Peacock's two samples of natural flakes. The lower percentage for Burnham as compared to Peacock's cultural assemblages again probably reflects low velocity detachment at Burnham.

Although occurring on bulbs, eraillures are closely related to the formation of radial striations (Faulkner 1973). They can and do appear on flakes produced by any method of force application, but may be less common in low velocity situations (Faulkner 1973:4). Whether eraillures can be used to distinguish between percussion vs. pressure flaking is debatable. Crabtree (1968:457), Patterson (1983:300), and Watson (1968:28) believe eraillures are more common on percussion flakes than on pressure flakes. Faulkner (1972:159; 1973:4) is not so sure, stating that eraillures are common in pressure flaking and other low velocity situations.

Peacock's (1991:Table 1) cultural and natural flake assemblages had 42% and 4% eraillures, respectively. His chi-square test results showed a significant difference between the two populations. At Burnham, none of the flakes had eraillures, thus more closely approximating Peacock's naturally created assemblage. Conversely, if Patterson (1983:300) is correct that eraillures rarely occur on pressure flakes, the Burnham debitage could be the result of that technique.

Undulations do not seem to be of significant value in distinguishing between naturally and humanly produced debitage. Peacock (1991:351) concluded that they are nearly equally produced by both agencies. What they do seem to reflect is the velocity of the fracture front as it moves through the material (Cotterell and Kamminga 1987:680; Patterson 1983:300). They are also affected by material type, tending to be less prominent on coarse-grained lithics, even when high velocity was used to produce flakes (Patterson 1983:301). Peacock's (1991:Table 1) cultural and natural flakes showed undulations (ripple lines in his terminology) present 70% and 56% of the time, respectively. By contrast, the Burnham flakes have undulations on only 10% (n=4) of the specimens. This is markedly different than either of Peacock's studied assemblages. The relative lack of this feature in the Burnham debitage is suggestive of low velocity loading, possibly pressure flaking (Patterson 1983:300).

Gull wings also reflect the velocity of the fracture front. They are formed as the front bends around a flaw in the stone. The angle of the intersection of the "wings" reflects the front's speed, i.e., the more acute the angle, the higher the velocity (Faulkner 1972:156). The angles on the three Burnham flakes (specimens #1/46, 10, and 43; Table 16.5) that have gull wings are not particularly acute, suggesting low velocity. Again, this could be consistent with the flakes have been produced by pressure flaking.

Ventral Lipping

Although this feature can occur with many knapping techniques, it is considered to be more indicative of soft hammer percussion and pressure flaking (Crabtree 1972:74). Of the 21 complete and proximal-end flakes from Burnham, 57.1% (n=12) manifests a ventral lip (Table 16.5). This would suggest that the flakes most likely were the result of pressure flaking, or if by percussion, that the percussor had a low elastic ratio relative to the knapped stone.

Terminations

The majority (55%, n=22) of the Burnham flakes are broken (55%) while 37.5%(n=15) end in feather terminations and the remainder (7.5%, n=3) have hinge terminations (Table 16.5). Luedtke (1986:Tables 1 and 2) found 21% and 20% broken flakes and 14% and 20% hinge terminations in her studied samples of naturally produced debitage. Feather terminations dominated these samples with 52% and 43%. She also has a termination type that she describes as "fracture extends on free cortex" with no further definition or discussion. Just what this termination type refers to is unclear.

Feather terminations are normally considered to be successful terminations. Step and hinge fractures arenormally considered undesirable by most knappers. Crabtree (1968:466) describes step fractures as the result of insufficient force. The high percentage of broken, presumably step-fractured flakes at Burnham could, again, be the result of low velocity fracture initiation and propagation. Conversely, my personal observation is that some forms of pressure flaking result in high rates of broken flakes. These are not actually step fractures because a complete flake is successfully detached. The fracture occurs post-detachment as a result of the flake being driven into a supporting surface such as the knapper's hand. It is also possible that the Burnham flakes were broken after detachment by some other means such as trampling or redeposition processes, but there is no way to demonstrate this other than their occurrence in deposits believed representative of ponding.

Lithology

The identification of the type of stone used to make tools can be important for any archaeological site. At a place like Burnham, such determinations assume even greater importance, primarily regarding the presence of non-local lithic materials. Because humans are the only animals that transport stone across major drainages, the presence of exotic stone types among the Burnham debitage has direct bearing on the question of whether people were responsible for this debitage.

Determination of the type of lithic material is often a difficult task given the range of variation present in many cherts. Such difficulty is compounded when studying small-scale debitage like that from the Burnham site. The small size of the flakes often limits the number of attributes useful for identification. Color, which is often of questionable identification value even in large flakes, is even less useful with small debitage. Not only is the color range not adequately represented, the thinness of small flakes often makes them translucent, thus washing out the color. For example, small flakes detached from the edge of a dark grey Edwards (Georgetown variety) chert biface appear translucent with a slight yellowish tinge under a microscope.

Grain size can vary from one specimen to another within a single chert type. A small flake will not usually reflect such variation, and, when coupled with overlapping grain size between different lithic materials, identification can be difficult. Fossil inclusions, vugs, and the like are not apt to be present in small flakes unless they are very densely distributed throughout the rock.

All of this is not to say that small-scale debitage cannot be identified as to lithic type, just that one must be cautious when doing so. For this project, specimens were examined macroscopically and microscopically under incandescent polarized white light and under long and short wave ultra-violet light. The use of ultra-violet light follows previous work by Collins and Headrick (1992), Hofman et al. (1991), and Hillsman (1992) who have shown U-V analysis to be reliable for at least some chert types, when used with caution. The concept is based on the principle that different materials often display distinguishable florescent colors which may be used to separate lithic types. The process requires known control samples that cover at least the majority of the range of variation for each type. Specimens in this study were exposed separately to both long and short wave U-V in a darkened room in the presence of control samples to which they were compared.

Table 16.11 gives the results of the white light and U-V examinations. The local Day Creek chert is in the majority in both white and ultra-violet applications. Unidentified cherts comprise the second largest category in each test situation. Day Creek and Alibates agatized dolomite have similar, often overlapping, responses to U-V light. Therefore, it is often not possible to distinguish between the two when studying very small pieces.

Of interest is the failure of the U-V test to substantiate the tentative white light identifications of eight or nine flakes as Edwards chert from central Texas. In each case, the flake in question showed no reaction to long wave U-V, which normally produces a yellow-brown to orange reaction in Edwards. This reaction, however, is substantially reduced or eliminated by patination of the rock's surface. The smaller the piece and the heavier the patina, the less the fluorescence. Even patina not particularly noticeable to the eye appears go be enough to inhibit florescence; several Burnham flakes which are undoubtedly of Day Creek chert failed to fluoresce.

It is also sometimes the case that fluorescence is not consistent within a single specimen. Some areas fluoresce while others do not. While this is no problem for large specimens, and may in fact be characteristic of them, very small pieces are more problematic. It is entirely possible to produce two small flakes from the same parent piece, one of which fluoresces under U-V light, and one, which does not.

These factors point out that identification of lithic types using ultra-violet fluorescence must be done with caution,

Table 16.11. Lithological Study of Burnham Cultural Debitage.

Flake #	Figure	White Light	U-V Light	Identification
#1/46	16.1	Unidentified	Day Creek/Alibates	Day Creek ?
#2	16.2	Edwards chert	No reaction	Unidentified
#3	16.3	Day Creek chert	Day Creek/Alibates	Day Creek
#4	16.4	Day Creek chert	Day Creek/Alibates	Day Creek
#5	16.5	Edwards chert	No reaction	Unidentified
#6	16.6	Day Creek chert	Day Creek/Alibates	Day Creek
#7	16.7	Edwards chert	No reaction	Unidentified
#8	16.8	Edwards chert	No reaction	Unidentified
#9	16.9	Unidentified chert	No reaction	Unidentified
#10	16.10	Edwards chert	No reaction	Unidentified
#11	16.11	Unidentified chert	No reaction	Unidentified
#12	16.12	Unidentified chert	No reaction	Unidentified
#13	16.13	Day Creek chert	Day Creek/Alibates	Day Creek
#14	16.14	Ogallala quartzite	No reaction	Ogallala quartzite
#15	16.15	Day Creek chert	Day Creek/Alibates	Day Creek
#16	16.16	Day Creek chert	Day Creek/Alibates	Day Creek
#17	16.17	Day Creek chert	Day Creek/Alibates	Day Creek
#18	16.18	Unidentified chert	Day Creek/Alibates	Day Creek ?
#19	16.19	Unidentified chert	Day Creek/Alibates	Day Creek ?
#20	16.20	Edwards chert	No reaction	Unidentified
#21	16.21	Edwards chert	Edwards chert	Edwards
#22	16.22	Unidentified chert	No reaction	Unidentified
#23	16.23	Edwards chert	No reaction	Unidentified
#24	16.24	Edwards chert	No reaction	Unidentified
#25	16.25	Day Creek chert	Day Creek/Alibates	Day Creek
#26	16.26	Day Creek chert	Day Creek/Alibates	Day Creek
#27	16.27	Day Creek chert	Day Creek/Alibates	Day Creek
#28	16.28	Day Creek chert	Day Creek/Alibates	Day Creek
#29	16.29	Day Creek chert	Day Creek/Alibates	Day Creek or Alibates
#30	16.30	Day Creek chert	Day Creek/Alibates	Day Creek or Alibates
#31	16.31	Day Creek chert	Day Creek/Alibates	Day Creek or Alibates
#32	16.32	Day Creek chert	Day Creek/Alibates	Day Creek
#33	16.33	Day Creek chert	Day Creek/Alibates	Day Creek
#34	16.34	Unidentified cherrt	No reaction	Unidentified
#35	16.35	Day Creek chert	Day Creek/Alibates	Day Creek
#36	16.36	Day Creek chert	Day Creek/Alibates	Day Creek
#37	16.37	Day Creek chert	Day Creek/Alibates	Day Creek
#38	16.38	Day Creek chert	Day Creek/Alibates	Day Creek
#39	16.39	Unidentified chert	No reaction	Unidentified
#40	16.40	Day Creek chert	Day Creek/Alibates	Day Creek
#41	16.41	Day Creek chert	Day Creek/Alibates	Day Creek
#42	16.42	Day Creek chert	Day Creek/Alibates	Day Creek
#43	16.43	Unidentified chert	No reaction	Unidentified
#44	16.44	Unidentified chert	No reaction	Unidentified
#45	16.45	Day Creek chert	Day Creek/Alibates	Day Creek
#47	16.46	Day Creek chert	Day Creek/Alibates	Day Creek
#48	16.47	Day Creek chert	Day Creek/Alibates	Day Creek
#49	16.48	Day Creek chert	Day Creek/Alibates	Day Creek
#50	16.49	Day Creek chert	Day Creek/Alibates	Day Creek
#51	16.50	Unidentified quartzite	No reaction	Unidentified
#52	16.51	Day Creek chert	Day Creek/Alibates	Day Creek

particularly in the case of very small specimens. In the case of the eight possible Edwards chert flakes from the Burnham site, the U-V test is inconclusive for the reasons outlined above. The test certainly does not demonstrate that these items are the non-local Edwards chert, but it does not rule it out either.

The ninth flake (specimen #21) did respond with a faint, yellow-brown fluorescence under long-wave U-V light. Moreover, this piece is entirely consistent macroscopically and microscopically with a sample of so-called "root beer brown" Edwards chert in the lithic comparative collection housed at the Oklahoma Archeological Survey. As a result of the agreement of these three lines of identification, this specimen is considered to be Edwards chert. It is the only Burnham flake that appears to be of non-local origin. Although it is possible that some of the other flakes could be Edwards, their identifications are inconclusive.

The Data: Chipped Stone Tools

Flake Tool (Fig.16.52)

This is a flake fragment that is 34mm long, 23.5mm in maximum width, and 7mm in maximum thickness. It has been broken diagonally by a bending break, and the proximal end is missing. The dorsal surface is strongly convex, whereas the ventral face is relatively flat. Both faces are heavily patinated. A large hinge scar is on the dorsal face, and it was detached before the flake was broken by the diagonal break. The hinge scar shows less patination that the remainder of the ventral face. This difference is especially noticeable under ultra-violet light.

This specimen's lateral edges show nearly continuous bifacial flaking. Most scars are steep and shallow, although larger, deeper scars are present (Fig. 16.52). These scars are consistent with "snap fractures" described by Cotterell and Kamminaga (1987:691 and Fig. 14). They consider such fractures to be "common in use wear" and produced them in one experiment by using a flake with an acute edge angle to saw antler (Cotterell and Kamminga 1987:691). However, I have experimentally produced snap fractures along flake edges by trampling and by banging flakes together by placing them in a bag and shaking it. The flake scars produced by these two activities were discontinuous around the flake's edge, whereas the scars on the specimen used by Cotterell and Kamminga were continuous around the utilized edge. I replicated their antler-sawing experiment and obtained the same results (Fig. 16.53). The Burnham flake edge snap fractures are nearly continuous and resemble the utilized flakes more than the trampled or shaken specimens.

Close examination of the flake scars on the edge of the Burnham specimen shows they are less patinated than the main dorsal and ventral faces. These differences are even more apparent under ultra-violet light. This suggests the possibility of multi-generational flaking, i.e., that the flake

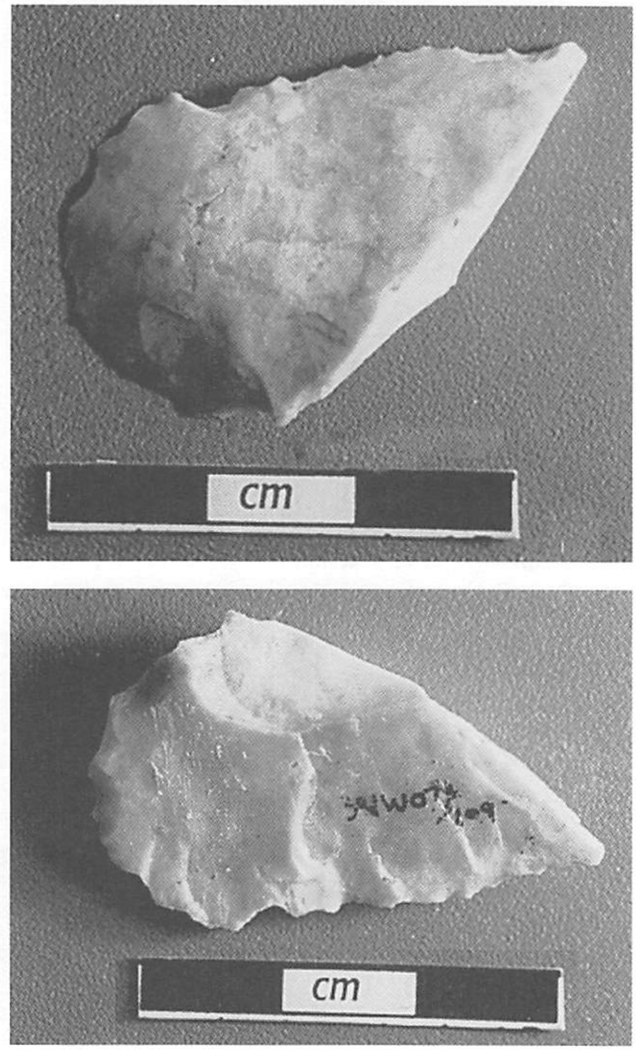


Figure 16.52. Flake tool of likely Alibates agatized dolomite recovered in level 96.4 of East Grid square 0-W23. Top shows convex face with sinuous incidentally flaked edge on top while bottom edge has overlapping scalar scars. Bottom view shows hinge scar on face; the sinuous cutting edge is on the bottom. Scale is in centimeters.

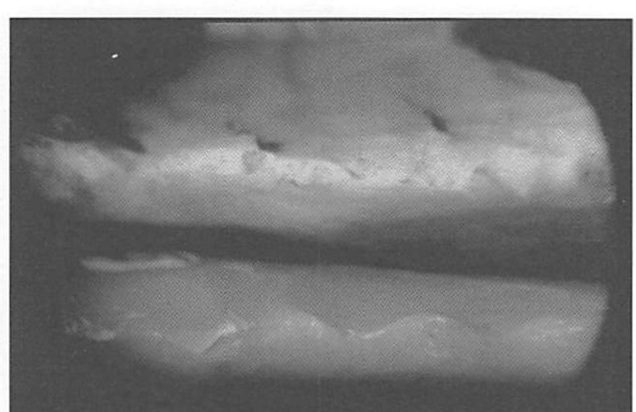


Figure 16.53. Comparison of flake tool's worn sinuous cutting edge (top) with fresh bifacially flaked edge (bottom) on a flake of Alibates agatized dolomite.

scars may be more recent than the dorsal and ventral faces. Multi-generational flaking is often taken to be the work of nature, not people. However, the edge scars are consistent with one another in this regard, suggesting that the edge flaking occurred simultaneously. The possibility that the edge modification occurred as a single event on an old flake is consistent with the evidence.

Under the microscope, rounding of the edges and flake scar arrises is evident. Also, minor micro-crushing occurs on some of the more prominent points between flake scars.

Examination under both white and ultra-violet lights suggests this item is Alibates agatized dolomite. While Alibates and Day Creek cherts have similar responses to long-and short-wave U-V, subtle differences often can be detected in larger pieces. Under short-wave U-V, Day Creek chert tends to fluoresce a bright lime-green, whereas Alibates tends to be darker and less intense. However, both hues may be present in each type. The Burnham specimen reacts to short-wave U-V in a manner more similar to Alibates than to Day Creek. Under long-wave U-V, Day Creek becomes more mottled and the green is darker than under short-wave U-V. In Alibates, the green tends to disappear altogether, and control pieces show a mottled purple, darker black-purple, and white. Again, the Burnham specimen reacts in a manner more similar to Alibates than to Day Creek. At this time, although I cannot conclusively identify the lithic type of this specimen, the evidence suggests that it is Alibates.

Biface Fragment (Fig. 16.54)

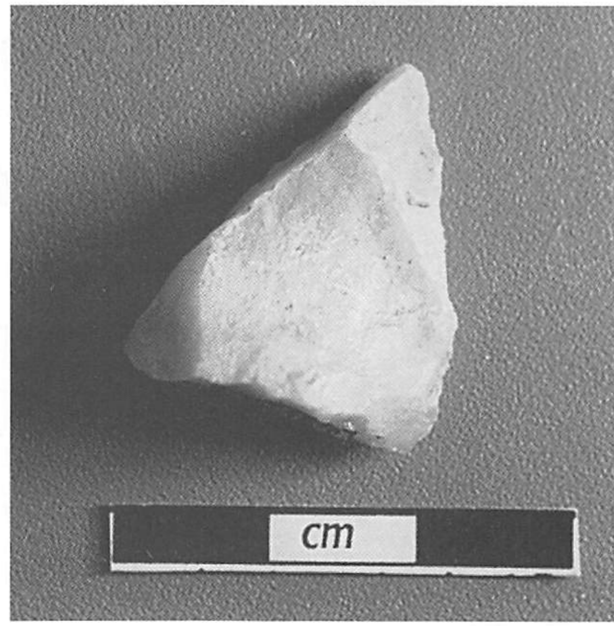
This specimen is a triangular, wedge-shaped fragment that appears to have been broken out of a biface. A very similar fragment (Figure 16.55) was produced experimentally by striking an Edwards chert biface in its center, the resulting radiating fractures producing several fragments much like the Burnham specimen.

The Burnham fragment shows one moderate and two larger flake scars on one face with more numerous, smaller scars on the opposite face. This reverse face also shows a rough area that appears to have been just below the original cortical surface. Minute bending flake scars are visible under 10x magnification along the unbroken edge on both faces. The broken edges also show a few minor, intermittent flake scars and one fairly large step scar. This would seem to suggest post-breakage damage and the possibility that some of the other flake scars are fortuitous or natural, and that the fragment is not really a man-made biface at all. However, the experimentally produced biface fragments mentioned above also showed the same flaking along broken edges. Thus, such edge damage can occur at the time a biface is broken.

This specimen appears to have come from a biface produced by percussion with little, if any, deliberate pressure flaking along the edges. No obvious signs of use-wear were detected up to 70x magnification. The Burnham piece is made from Day Creek chert. Under long-wave ultra-violet light, the broken edges fluoresce somewhat more strongly than the obverse and reverse faces due to slight differences in patina. This suggests the broken edges are younger than the faces.

Chert Cobble (Fig. 16.55)

The final lithic item of possible cultural origin is a large



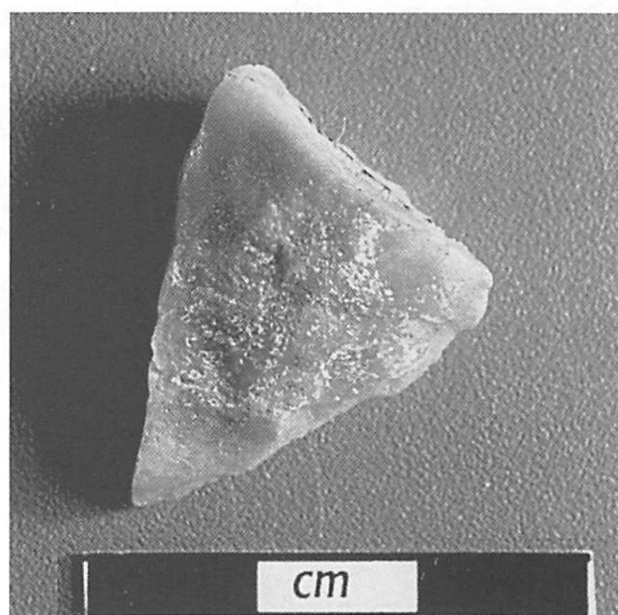


Figure 16.54. Both faces of a biface edge fragment of Day Creek chert. The edge is to the right in the top view and to the lower right in the bottom view. Minute scaler retouch occurs along both faces. Specimen was found in level 96.6 of East Grid square 0-W22. Scale is in centimeters.

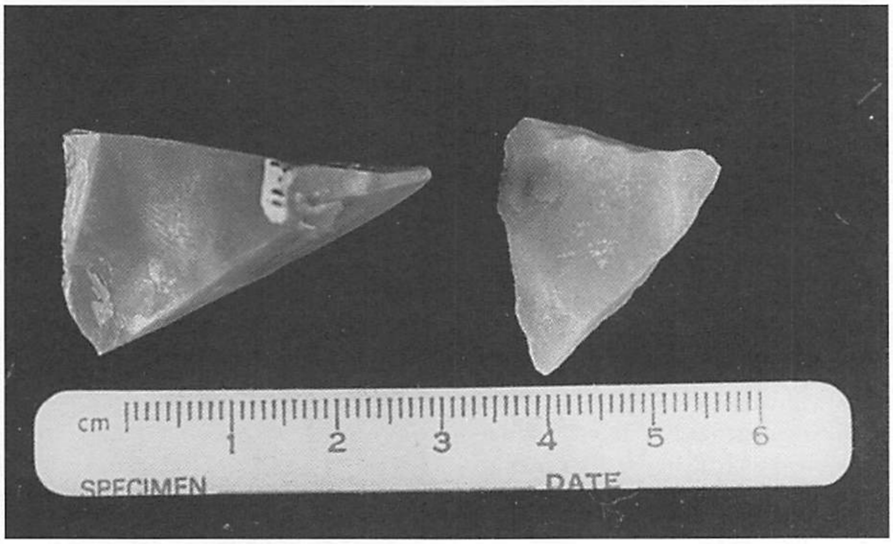


Figure 16.55. Comparison of a replicated radially fractured biface edge(left) with the one (right) recovered from the Burnham site.

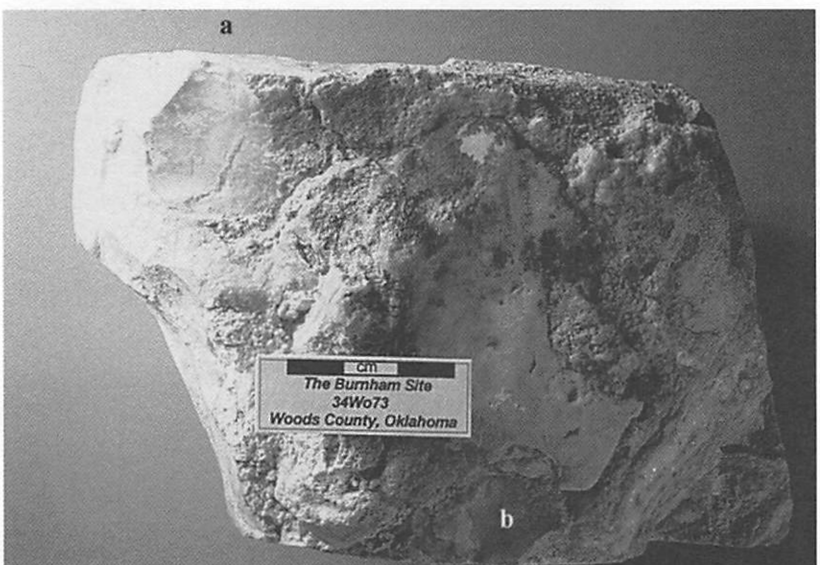


Figure 16.56. Above: Side view of Day Creek chert cobble showing two flake scars (a and b) potentially removed by people. Right: View of another facet of this cobble showing waterworn scars from stream tumbling. The scales are in centimeters.

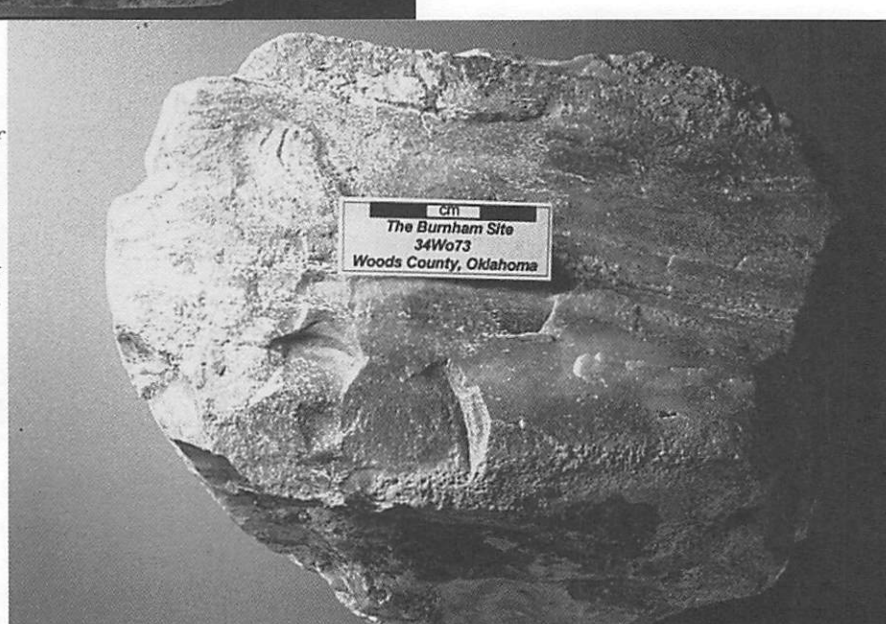


Figure 16.57. View south of Day Creek chert cobble in situ in red sediment under the Bison chaneyi *skull. Find was in East Grid square S2-W22 at a depth of 96.07. Scale is in 5.0cm increments.*

cobble of Day Creek chert (Fig. 16.55). It is 14.74cm in maximum length, 11.64cm in maximum width, and 9.88cm in maximum thickness. It weighs 2.7kg. The cobble is subangular in shape, exhibits large areas of cortex on its upper and lower faces, and is heavily patinated. Two flake scars occur on opposite edges of one face (Fig. 16.55). One scar is 19.9mm long by 29.9mm wide. The other is 30.4mm long and 31.6mm wide. These scars show much less patina than the rest of the cobble. Each shows minor crushing at the point of impact.

This cobble was found immediately adjacent to and slightly below the bison skull in square S2-W22 of the East Exposure (Fig. 16.56). Its size and weight are inconsistent with the clast sizes of the sediment containing it, making it unlikely that it was deposited by the same fluvial activity as the sediment itself. It is therefore possible that it was transported as the result of human activity, although this cannot be proven with any certainty. Likewise, it is not possible to say whether the two flake removals had anything to do with people.

The Data: "Non-Cultural Debitage"

Residue sorting resulted in the recovery of 120 pieces of cryptocrystalline material which appear to be of wholly natural origin and show no evidence of human modification. These pieces are primarily small, rounded or subangular, tabular gravels. They are covered with cortex or heavily patinated. They range from 3.4mm to 37.5mm in maximum dimension, but the majority average less than 1.0cm in length.

An attempt was made to identify the material of each item in order to determine their probable sources. Each piece was examined under white light and under long- and short-wave ultra-violet light. Under white light, the majority (60.8%, n=73) of these pieces were identified as Day Creek chert, but a substantial number of specimens (n=43, 35.8%) were unidentified. The remaining four specimens (3.4%) are fragments of quartz. Under ultra-violet light, the majority (51.7%, n=62) showed no response, whereas the remainder (48.3%, n=58) displayed short-wave responses typical of Day Creek chert. The high proportion of non-response is largely due to the heavy cortex and patina on most specimens. The unidentified specimens are typical of the varieties of small chert gravels which can be found in the Ogallala Formation in the area. None of the natural lithics were reminiscent of any recognizable non-local materials such as Edwards or Alibates chert.

Spatial Distributions

Here, the horizontal and vertical distributions of all the lithic items recovered at Burnham are examined. This includes spatial relationships within and between lithic categories, with stratigraphic units, and with the bison remains. Note that for the purposes of examining spatial distributions and taphonomic factors, the two refitted flake sections (specimens #1 and 46) are counted separately so that the total number of cultural debitage specimes is 52, not 51.

Looking first at the bison bone, we find the *Bison chaneyi* skull and related bones are concentrated in four East Exposure squares: S1-W22, S2-W22, S2-W23, and S2-W24 (Fig. 16.58). The cultural debitage shows a very similar

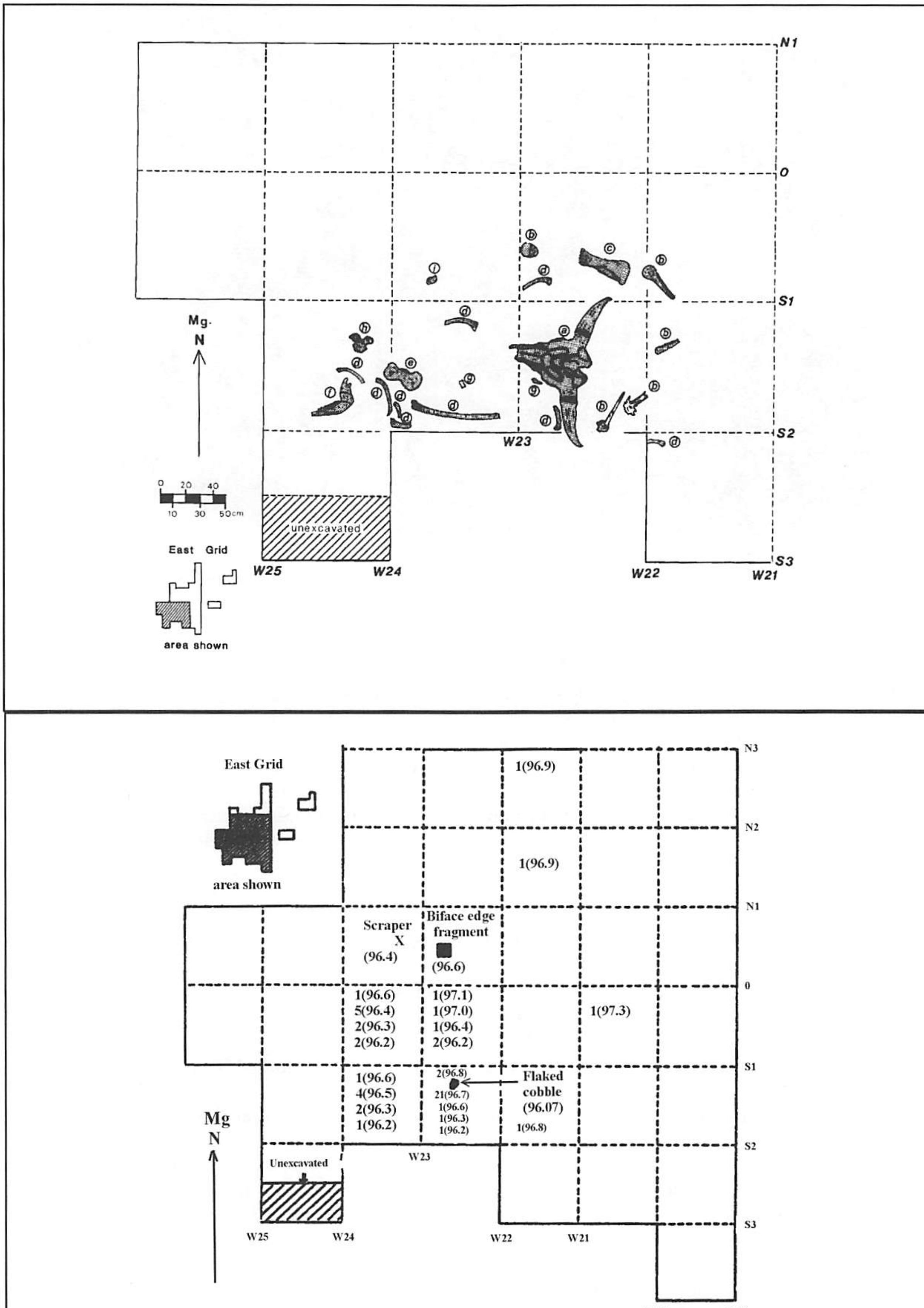


Figure 16.58. Comparison of bison and horse bones distributions in East Grid with the distributions of flakes and chipped stone artifacts. Flakes cluster where the bison skull and other bones occur. In the lithic distributions the numbers outside the parentheses are the numbers of flakes, whereas those in parentheses are the elevations where recovered.

pattern; 73% (n=38) of the debitage, plus the cobble, are concentrated in three of the same squares (S1-W22, S2-W22, and S2-W23). Adding the count from the adjacent square S1-W23 (n=10) puts 92.3% (n=25) of the debitage, plus the cobble, within a two meter square block among and immediately adjacent to the concentration of bison bones (Fig. 16.58). One square in particular, S2-W22, contains 48.1% (n=25) of the debitage, the bison skull, and the cobble (Fig. 16.58).

Vertically, the bison bones range from elevation 97 to 96.2, a spread of 80 cm (Fig. 16.59). The majority of the bones occur in levels 96.7 to 96.6. From the 97.0 to 96.2 zone where the bison bone prevails, 96% (n=50) of the debitage as well as the tool fragments and the cobble originate. Forty-one percent (n=21) of the debitage is in level 96.7 alone. Thus the debitage, tool fragments, and cobble show a very tight association with horizontal and vertical distributions of the *Bison chaneyi* bones (Fig. 16.59).

The natural lithics show a similar but less marked distribution with the bison-bearing levels (Figure 16.59). Ninety-four naturally formed pieces (78%) of cryptocrystalline material occur in these levels. The four squares containing the bulk of the bison bone account for 34% (n=32) of this. The four squares having 92% of the cultural lithics contain 50% (n=60) of the natural pieces (Fig. 16.60). Vertically, the latter peak in level 96.4 (18.3%, n=22), whereas the cultural debitage peaks (40%, n=21) in level 96.7 (Fig. 16.59).

While sharing areas of concentration, the natural lithics are more widely dispersed horizontally and vertically than the cultural lithics (Figs. 16.58 and 16.60). Natural pieces have been recovered from nearly all excavated levels above and below those yielding the bison bones. Only two cultural flakes occurred above these levels (one each in 97.3 and 97.1), and none come from below these levels. None-the-less, within the zone containing the bison bones cultural and natural lithic materials show similar distribution patterns. However, a difference of percentages test (Leabo 1968) on the proportions of cultural vs. non-cultural lithics within these levels was significant at the .05 level, suggesting the distribution difference between the two is not random. Because the majority of the bison bones *and* the tool fragments and cobble co-occur both horizontally and vertically, there exists the possibility of a relationship between them. It is tempting to suggest that this tight association was the result of a bison being butchered with stone tools during which the latter were resharpened, producing the debitage. While this scenario would account for the close proximity of the bison remains and the artifacts, it doesn't explain the *broad* pattern of spatial distribution all of these objects share with the non-cultural lithics.

To reiterate, all of the bison bone, 96% (n=50) of the

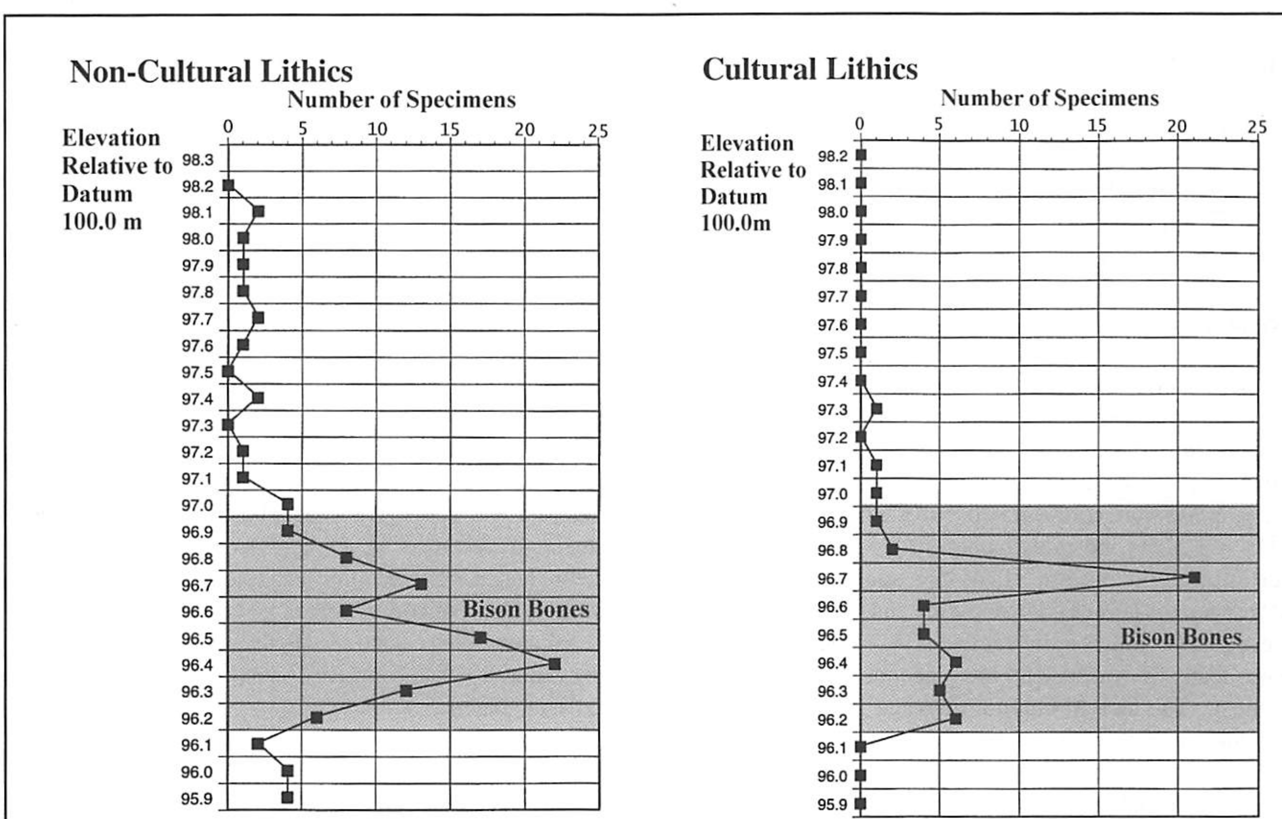


Figure 16.59. Comparison of the vertical distributions for the bison bones, non-cultural lithics, and cultural lithics found in the East Grid at the Burnham site.

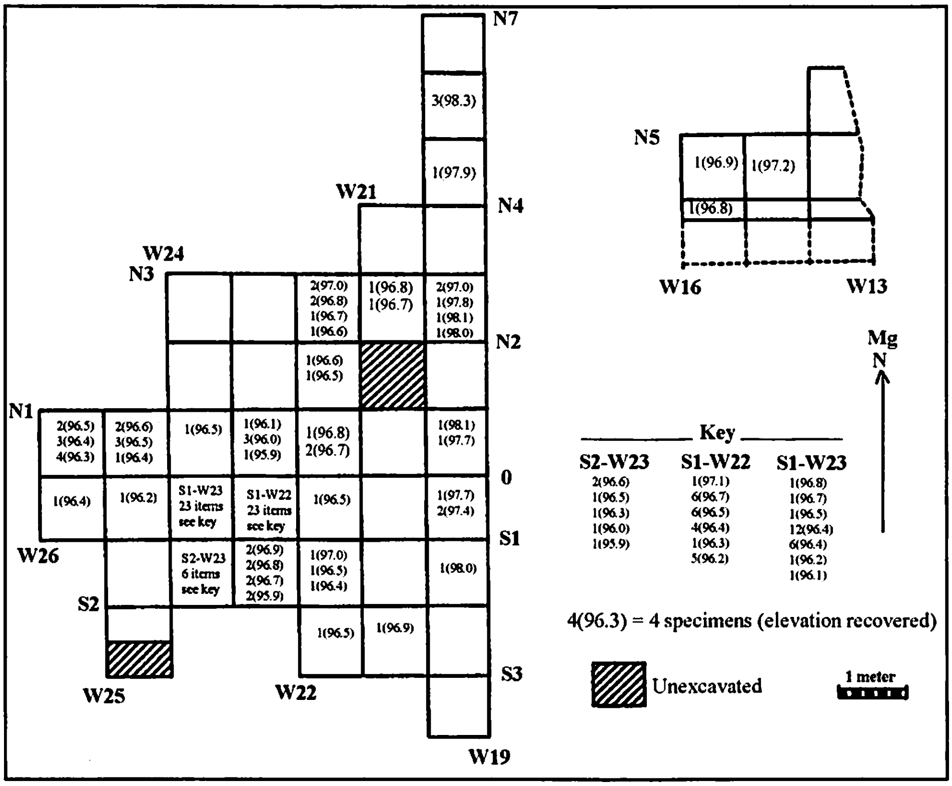


Figure 16.60. Distribution of the natural siliceous pebbles recovered in waterscreened debris from East Grid squares.

cultural lithics, and 78% (n=94) of the non-cultural lithics occur between levels 97.0 and 96.2. The four squares containing the majority of the bison bones and 92% (n=48) of the cultural debitage also contain 50% (n=60) of the non-cultural debitage. While 50% is not quite a majority, when one considers that the non-cultural debitage is distributed across nearly 30 excavation squares, half of it being concentrated in just 4 squares is significant. Moreover, two of those squares, S1W22 and S1W23 each contain 23 pieces of non-cultural debitage, far more than any other units. In other words, the largest concentration of non-cultural lithics occurs in the same area as the bison bone and the cultural debitage.

This co-occurrence suggests the possibility that all of these objects were acted upon by the same taphonomic process that resulted in all of them being concentrated in the same small area. However, the fact that the cultural lithics are so *much more* concentrated than the non-cultural lithics (92% vs. 50%) indicates taphomic processes like fluvial action cannot explain all of the spatial distribution. Moreover, the lack of edge rounding and water polishing on these cultural lithics indicates that if they have been moved, it was likely from nearby, probably no more than a few meters at most. The lack of cultural debitage from layers above indicates that if there was any displacement of cultural materials, it was horizontal in direction and not vertical. Based on the nature of the lithic samples there is absolutely no evidence of younger cultural materials being redeposited in lower, older pond deposits containing the *Bison chaneyi* bones.

Discussion

At the start of this chapter I posed two questions:

1. Are the Burnham lithics of human or natural origin; and
2. If man-made, are they really as old as the bison bones with whichthey were found?

Since the answer to the first question influences how much we care about the second, I will deal with the human vs. the natural origin query first.

Among the vast literature pertaining to archaeological lithics are numerous articles which attempt to identify characteristics useful for distinguishing naturally flaked stone from that done by people. Many such studies were done in the late 19th and early 20th centuries, often with mixed results (Barnes 1939; Breuil 1943; Moir 1911; Warren 1905, 1919, 1921, 1923). More recently, archaeologists turned again to this subject (Grayson 1986; Luedtke 1986; Patterson 1983; Peacock 1991; Schnurrenberger and Bryan 1985). Despite tremendous advances in our knowledge of brittle fracture, fracture mechanics, and lithic technology, the results of such studies are still mixed. There is no cut and dried checklist of attributes which can be used to distinguish humanly made from naturally flaked objects. Instead, there are general trends and patterns.

Many archaeologists seem to assume they know the differences between natural and cultural lithics without giving the matter much thought. Many knowingly or otherwise use the context of the finds as the determining factor. If the object was found on an archaeological site, it must be man-made. Such "reasoning" obviously breaks down when one is dealing with the pre-Clovis question of whether or not you actually have an archaeological site in the first place. The picture is further complicated when the debitage is very small. While debitage studies are not rare, few focus on very small flakes. Of those that do, most actually deal with "microdebitage", defined as less than 1 mm (Fladmark 1982; Vance 1987), or with specimens larger than ¼ inch, 6 mm, or some other arbitrary figure (cf., Clark 1986; Luedtke 1986; Patterson 1983; Patterson and Sollberger 1978; Stahle and Dunn 1984). Additionally, very few studies deal with the technological and fracture mechanics of small debitage. A valid question is, does small-scale debitage show the same attributes in the same proportions as its larger counterpart? At the Burnham site, the vast majority of the flakes fall into this relatively unstudied category. The analysis of these flakes shows that, in terms of their attributes, they are indeed quite similar to their larger counterparts (Tables 16.3, 16.4, and 16.5).

Even a casual reading of the previously cited studies shows one fact quite clearly: there is a certain degree of shared characteristics between humanly fractured and naturally flaked lithics. Both agencies can, under certain circumstances, produce nearly identical individual specimens. Therefore, one must look at overall morphological patterning throughout the entire assemblage. Patterson (1983:298) observed, "Production of numerous lithic specimens with consistent morphology is certainly not a habit of nature". Luedtke (1986) suggested a three-step procedure for distinguishing natural from cultural assemblages:

1. Quantify characteristics of entire assemblages, not just selected examples or stray finds;
2. Study combinations of attributes rather than focusing on only one or two "diagnostic criteria".
3. Consider and evaluate carefully the context and distribution of the finds.

I will follow this procedure in summing my evaluation of the Burnham lithics.

The attributes of man-made flakes can be divided into those that directly reflect decisions made by human knappers, such as whether and how to prepare a platform, and those that indirectly reflect such decisions. The latter include characteristics indicative of percussor type, amount of force application, etc. Obviously, those attributes that directly reflect decisions are more powerful in identifying human flaking.

The proposed cultural debitage at Burnham is almost certainly the result of low velocity fracture initiation and propagation. This is indicated by these factors:

1. small size,
2. flakes have widths greater than length,
3. predominance of diffuse, flake bulbar areas,
4. radial striations that are weakly developed,
5. eraillures are absent (relates to #4),
6. undulations are weakly developed, and
7. high angles on gull wings.

These characteristics could be produced by low velocity, soft-hammer percussion or by pressure flaking, most likely the latter. This conclusion is also supported by the high proportion of ventral lips and the low percentage of crushed platforms.

So, the Burnham flakes were likely the result of pressure flaking, or at least low velocity fracture. But both people and nature produce flakes by pressure. We must, then, look at those attributes that (if present) would directly reflect human decision making. First of all, the Burnham assemblage is dominated by non-cortical flakes. Nearly all researchers of the human vs. nature question agree that this is characteristic of humanly produced flakes. Secondly, the Burnham flakes show a very high percentage of platform flaking and dorsal face flaking. These two attributes, particularly in combination, are usually interpreted as platform preparation. Additionally, six flakes (25% of the complete flakes or proximal fragments of flakes) have platforms which appear to be remnants of biface edges. These also strongly indicate the flakes are of human origin. Finally, almost all of the flakes have dorsal scars from previous flake removals. The majority of these scars run parallel to the medial axis, suggesting non-random flaking, and are more likely the result of human behavior than nature. These scars do not show differential patination or other evidence of multi-generational flaking. Again, this is indicative of human flaking.

There is an additional factor that suggest the Burnham debitage is the result of human activity. One flake shows every indication of being of Edwards chert, a non-local stone with a primary source in central Texas. Several other flakes could also be of Edwards chert, but I was unable to substantiate this so they must remain neutral in this regard.

The majority of the Burnham flakes' attributes suggest a human production origin. The exception is their proportions (width to length ratios) which are quite similar to the natural flakes studied by Luedtke (1986:58). She suggests that short, wide flakes are often produced in nature because the parent piece may be free to give and shift under pressure/impact. This, coupled with the low velocity of the impact, produces short, wide flakes. Given the nature of the matrix at Burnham this situation would likely have applied there.

However, if we assert that the Burnham flakes were produced naturally, we must then have a mechanism for their production. The sediments containing the flakes were deposited in a very low energy environment. While the

Burnham flakes appear to have been the result of low velocity fracture, it is questionable that the depositional environment had sufficient energy to produce flakes. It certainly does not appear to have been capable of knocking rocks together to produce flakes. But even if we concede this possibility or that sufficient force was available to detach flakes by pressure, we still must have suitable parent material from which the flakes could have come. Such pieces are essentially lacking in the immediate area. The only other chert specimens recovered, the natural debitage discussed above, are very small pieces of gravel. Moreover, they do not show evidence of flake removals. In short, suitable candidates for parent pieces are lacking within the excavated area. Is it possible, then, that such pieces existed some distance away from the excavations? Certainly, but none of the flakes show any evidence of long distance water transport.

Given all of the above, the most logical conclusion is that the Burnham flakes are of human origin. But what about the remaining three items: the "flake tool", the "biface fragment", and the cobble?

The proposed flake tool is certainly not a formal, carefully prepared artifact. Rather, it appears to be a flake fragment whose edges were apparently modified through use, not through deliberate retouch. Use-wear is apparent along the modified edges and edge scar arrises. Such rounding is not apparent on the broken edges. Finally, the items appears to be made from Alibates, a non-local lithic. All of these factors indicate the specimen is an artifact rather than a geofact.

The same is true of the biface fragment. In experimenting with the radial fracture of bifaces, I was able to produce numerous, nearly identical specimens.

The cobble is more problematic. The primary factors suggesting a connection with human activity are that it is out of place in terms of size and weight with the surrounding sediments and that it is closely associated with the skull and other bones of *Bison chaneyi*, as are most of the flakes. Neither of these observations can be taken as conclusive evidence that the item is an artifact. Nor does the removal of two small flakes from opposite margins of one face prove a human connection. This item remains only a possible artifact.

Concluding that humanly produced lithics exist in context with a pre-Clovis species of bison says nothing about the validity of that context. Thus, we must turn to our second major inquiry, asking if the association is valid.

We have seen that the cultural material is tightly concentrated in the same area as the bones of *Bison chaneyi*. Larry Todd's taphonomic study (this volume) of the bison bones indicates that these bones have been dispersed and otherwise moved a short distance, although he cannot identify the specific agencies responsible for this movement. The lithics do not show evidence of prolonged water transport. Nonetheless, taphonomic agencies sufficient to move large bison bones would certainly be capable of moving small tool fragments and even smaller flakes.

The distribution *pattern* of the natural, small, chert gravels is similar to the flakes, suggesting the possibility that both were acted on by the same taphonomic agenices. Although both have concentrations in close association with the bison bones, the cultural lithics are much more concentrated there than the non-cultural lithics. The natural pieces have a broader distribution both horizontally and vertically than the flakes. They occur in 29 excavated squares as opposed to only 8 squares for the cultural items. Those eight yielded 100% of the cultural material but only 59% (n=71) of the non-cultural.

The same is true of their vertical distribution. The non-cultural lithics are found in all levels, whereas the cultural itmes are primarily confined to the levels containing the bison bones. Thus, the flakes have a closer association with the bison remains than do the natural cherty pieces, even though they share a similar pattern. Put another way, it is significant where the flakes are *not*, as much as where they are. The non-cultural lithics are widely distributed both horizontally and vertically while the bison bones and cultural lithics are not. Significantly, they are concentrated in the third lowest of four stratified pond deposits manifest in the East Exposure of the Burnham site.

Conclusions

Taking all of the above factors into consideration, I conclude that the most plausible and most parsimonious explanation is that the Burnham lithics are the result of human activities associated with the processing of a bison carcass. The bison bones, the flakes and tool fragments, and the non-cultural chert pieces have likely all been acted upon by low velocity fluvial forces which resulted in very short distance movement of the objects from their original positions.

Our research at the Burnham site has driven home an important point: if Burnham were a Folsom site, the association of the artifacts and bison bones would likely be taken at face value. But given the site's age and the lack of "smoking gun" artifacts, everything is brought into question, including whether the flakes truly *are* artifacts in the first place. This is as it should be. But it shows us that when we deal with possible pre-Clovis sites, we cannot take anything for granted. Much of what we would presume to "know" about a younger site must first be demonstrated for sites of this age. We need to increase our knowledge of geomorphology, taphonomy, lithic technology, etc., because these sites will not allow us the luxury of presumption.

Whether Burnham withstands the scrutiny of the scientific community and becomes accepted as a pre-Clovis site is, on one level, irrelevant. What is important is that questions were asked, analysis was done, and knowledge was gained. In the end, that is more important than the status of any individual site.

References Cited

Barnes, A. S. 1939. The Difference between Natural and Human Flaking on Prehistoric Flint Implements. *American Anthropologist* 41:99-113.

Breuil, H. 1943. On the Presence of Quartzites Mechanically Broken (Sometimes Simulating Human Workmanship) in the Dwyka Tillites and Their Derivation in the Older Gravels of the Vaal. *South African Journal of Science* 40:285-286.

Clark, J. E. 1986. Another Look at Small Debitage and Microdebitage. *Lithic Technology* 15(1):21-33.

Collins, M.B. and P. Headrick. 1992. Fluorescent Properties of "Edwards" and Related Cherts of Central Texas. *Journal of Field Archaeology*

Cotterell, B. and J. Kamminga. 1979. The Mechanics of Flaking. *Lithic Use-Wear Analysis*, edited by B. Hayden, pp. 97-112. Academic Press, New York.

Cotterell, B. and J. Kamminga. 1987. The Formation of Flakes. *American Antiquity* 52(4):675-708.

Crabtree, D.E. 1968. Mesoamerican Polyhedral Cores and Prismatic Blades. *American Antiquity* 33(4):446-478.

Crabtree, D.E. 1972. *An Introduction to Flintworking.* Idaho State University Museum, Occasional Papers 28. Pocatello.

Faulkner, A. 1972. *Mechanical Principles of Flintworking.* Ph.D. dissertation, Department of Anthropology, Washington State University. Pullman,.

Faulkner, A. 1973. Mechanics of Eraillure Formation. *Lithic Technology* 2(3):4-11.

Fladmark, K.R. 1982. Microdebitage Analysis: Initial Consideration. *Journal of Archaeological Science* 9:205-220.

Grayson, D.K. 1986. Eoliths, Archaeological Ambiguity, and the Generation of "Middle-Range" Research. *American Archaeology Past and Future*, edited by D.J. Meltzer, D.D. Fowler, and J.A. Sabloff, pp. 77-133. Smithsonian Institution Press, Washington.

Hayden, B. 1979. Snap, Shatter, and Superfractures: Use-Wear of Stone Skin Scrapers. *Lithic Use-Wear Analysis*, edited by B. Hayden, pp. 207-229. Academic Press, New York.

Hillsman, M.J. 1992. *Evaluation of Visible and Ultraviolet-Excited Attributes of Some Texas and Macroscopically Similar New Mexico Cherts.* M.A. thesis, Department of Anthropology, Eastern New Mexico University. Portales.

Hofman, J.L., L.C. Todd, and M.B. Collins. 1991. Identification of Central Texas Edwards Chert at the Folsom and Lindenmeier Sites. *Plains Anthropologist* 36 (137):297-308.

Leabo, D.A. 1968. *Basic Statistics.* Richard Irwin, Inc., Homewood, Illinois.

Luedtke, B. 1986. An Experiment in Natural Fracture. *Lithic Technology* 15(2):55-60.

Moir, R. 1911. The Natural Fracture of Flint and Its Bearing upon Rudimentary Flint Implements. *Proceedings of the Prehistoric Society of East Anglia* 1:171-184.

Oakley, K.P. 1972. *Man the Tool-Maker.* University of Chicago Press, Chicago.

Oakley, K.P. and M.H. Newcomer. 1978. Notes on Paleolithic Flakes from Ilford. *Proceedings of the Prehistoric Society* 44:435-439.

Patterson, L.W. 1983. Criterial for Determining the Attributes of Man-Made Lithics. *Journal of Field Archaeology* 10:297-387.

Patterson, L.W. and J.B. Sollberger. 1978. Replication and Classification of Small Size Lithic Debitage. *Plains Anthropologist* 23(80):103-112.

Peacock, E. 1991. Distinguishing between Artifacts and Geofacts: a Test Case from Eastern England. *Journal of Field Archaeology* 18(3):345-361.

Schnurrenberger, D. and A.L. Bryan. 1985. A Contribution to the Study of the Naturefact/Artifact Controversy. *Stone Tool Analysis: Essays in Honor of Donald E. Crabtree*, edited by M.G. Plew, J.C. Woods, and M.G. Pavesic, pp. 133-159. University of New Mexico Press, Albuquerque.

Stahle, D.W. and J.E. Dunn. 1984. *An Experimental Analysis of the Size Distribution of Waste Flakes from Biface Reduction.* Arkansas Archaeological Survey, Technical Paper 2. Fayetteville.

Vance, E.D. 1987. Microdebitage and Archaeological Activity Analysis. *Archaeology* 40(4):58-59.

Warren, S.H. 1905. On the Origin of Eolithic Flints by Natural Causes, Especially by Foundering of Drifts. *Journal of the Royal Anthropological Institute* 35:337-364.

Warren, S.H. 1914. The Experimental Investigation of Flint Fracture and Its Application to Problems of Human Implements. *Journal of the Royal Anthropological Institute* 44:412-450.

Warren, S.H. 1921. A Natural "Eolith" Factory beneath the Thanet Sand. *Quarterly Journal of the Geological Society* 76:238-253.

Warren, S.H. 1923. Sub-Soil Flint Flaking Sites at Grays. *Proceedings of the Geologists Association* 34:38. London

Watson, W. 1968. *Flint Implements.* Trustees of the British Museum, London.

Chapter 17
Examining the Integrity, Chronology, and Significance of the Burnham Site Findings

Don G. Wyckoff

An array of mammals, amphibians, reptiles, fish, snails, seeds, wood, pollen, and apparent human artifacts are described in the preceding chapters. These finds would have little significance if detailed notes and measurements had not been made about the exact locations where these things were found. Recording finds in three dimensions as sites are dug is what archaeologists do to establish the provenience or context for these finds. For the Burnham site, several different contexts were discerned for the recovered paleontological and archaeological materials. Earth scientists Brian Carter, Wakefield Dort, and Bob Brakenridge studied, mapped, profiled, and recorded details on the diverse soils and sediments exposed during the field work. Their observations, records, and interpretations are contained in earlier chapters. As fossils and artifacts were found, they were carefully plotted according to their locations and positions within specific soils and sediments. Consequently, the interpretive value of each find was enhanced appreciably because each fossil or artifact could be demonstrably linked to a particular provenience or context.

Understanding the integrity of the contexts is critical. As mentioned above, three different earth scientists studied, described, and interpreted the soils and sediments at the site. However, another means to examining those contexts is to study the nature of the fossil bones found within them. By nature, reference is made specifically of the kinds of bones, their amount of articulation, and the angles and directions individual bones were lying. Such research is a part of the field of taphonomy, the study of what fossils get preserved and the processes involved in their preservation (Lyman 1994). Although not often considered by archaeologists, taphonomy has proven a most useful approach in studying Paleoindian game kills on the Plains. There, the findings from such study help discern the extent and kinds of butchering practiced long ago as well as the potential length of time carcasses were exposed to natural weathering processes and the possibility that multiple kills were undertaken over a period at one favored hunting location. A leader in this research is Dr. Larry Todd (1987, Todd and Hofman 1992), an anthropology faculty member at Colorado State University. We were fortunate to have Larry as a member of the Burnham site research team. He was able to visit the site during the 1989 excavations and to supervise mapping the "horse bone bed" as well as newly exposed bison bones believed related to the *Bison chaneyi* skull. With this information, plus several ancillary studies, Larry was able to assess diverse preservation processes of these fossil-bearing deposits. These findings also have implications for the chipped stone objects recovered in these deposits. While his chapter could easily have been presented with the chapters covering the site's geology and soils, Larry's findings are most important for understanding the processes affecting two bone beds, one of which yielded chipped stone materials. Consequently, Larry's chapter is included in this section of the Burnham site monograph.

As is the case with all archaeological and paleontological finds, the importance of their contexts is increased greatly when these deposits are well dated. This is especially the case at the Burnham site. The soils and sediments here are complexly interfingered and stratified contexts created by different landscape-forming processes over some length of time. These contexts look very old. The vertebrate fossils from these contexts include species known to have existed during late Pleistocene times. But exactily when during late Pleistocene times? It does make a difference whether we are talking about 15,000, 30,000, 75,000, or even 150,000 years ago. Unlike many other Pleistocene paleontological sites reported for the Southern Plains, the Burnham deposits yielded a variety of organic materials amenable for radiocarbon dating. Consequently, opportunities existed for obtaining dates on diverse materials. These results not only are useful for defining the age of the Burnham deposits and the things recovered from them, they also help clarify when particular forms of Pleistocene plants and animals existed. Ultimately, because some of these organisms are believed very sensitive to certain temperature and precipitation regimes, the chronological assessments help us refine understanding of the timing and character of late Pleistocene climatic fluctuations and changes on the Southern Plains. Finally, because potentially human artifacts come from a few Burnham contexts, chronological assessment of those proveniences help address the question of human antiquity in North America.

In Chapter 19, all of the Burnham site's chronological assessments are presented and discussed. As will be obvious upon reading this chapter, a variety of techniques and materials were used to try to develop a chronology for the Burnham site's contexts. Early in the research, difficulties were encountered in obtaining dates through conventional radiocarbon dating. Some of these problems were resolved eventually through modified lab processing and by dating with tandem mass accelerator. Yet, because varied materials were available, other techniques were attempted, as much to offer other researchers opportunities to test newly developed techniques as to firm up a chronology for the Burnham site. Once all of the Burnham dates are presented in Chapter 19, they are related to the specific soils and sediments from which they were derived. On this basis a site chronology is developed.

In the last chapter, all of the Burnham site findings are synthesized in order to answer important questions about the site. In particular, the authors of the last chapter examine the evidence for the geomorphic setting in which the Burnham site occurs. They then compile the site's clues to the processes and timing by which the site's soils and sediments were deposited. These clues also provide a framework that is useful for integrating the vertebrate and invertebrate fossils found in each of the diverse deposits. Many of these fossils represent proxy records of distinct ecological niches, certain temperature and precipitation regimes, and, as a result, the climate and environment at the time the soils and sediments accumulated at the Burnham site. Overall, the deposits and fossils from Burnham offer us snapshots of the Southern Plains between 40,000 and 30,000 years ago.

Most controversial will be the claim that people are faintly visible in these snapshots. Small flakes of flint and quartzite and three flaked objects come from the lowest of a series of stratified pond deposits. Found anywhere else, these chipped stone specimens would be readily accepted as evidence that people were using and resharpening stone tools. Because they come from one of the oldest contexts manifest at the Burnham site, they represent clues to humans being on the Southern Plains much longer ago than most archaeologists are willing to accept. For this reason, the last chapter ends with an evaluation of the Burnham artifacts using three criteria standard to resolving controversies about the antiquity of humans in North America.

References Cited

Lyman, R.L. 1994. *Vertebrate Taphonomy*. Cambridge University Press, New York.

Todd, L.C. 1987. Taphonomy of the Horner II Bone Bed. *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., J.L. Hofman, and C.B. Schultz. 1992. Faunal Analysis and Paleoindian Studies: A Reexamination of the Lipscomb Bison Bonebed. *Plains Anthropologist* 37(139):137-165.

Chapter 18
1989 Taphonomic Investigations of the Burnham Site Bison and Equid Bone Beds

Lawrence C. Todd

Introduction

The taphonomic analysis of two concentrations of bones investigated at the Burnham site (Fig. 18.1) must address a series of formational problems that can only be partially answered from the small sizes of the collections. Many basic taphonomic analytical methods are based on the sue of relative representation of skeletal elements within multi-animal deposits. The extremely wide range of variation that can be reflected in the remains of a single carcass makes the interpretation of the Burnham collections difficult. The possibility of human activity associated with the bison carcass is neither supported nor refuted by the evidence at hand.

A second, related problem is also within the methodological realm, but of a different sort. Many types of taphonomic analysis are still in the developmental stage. For example, Lyman and Fox (1989) have discussed some difficulties with the use of bone weathering stage in the interpretation of assemblage formation. Behrensmeyer's (1978) initial paper on the use of weathering was a very significant contribution to the field, but it was clearly not the final statement on the problem associated with documenting and interpreting differences in surface condition of faunal assemblages. Similarly, Voorhies's (1969) and Hanson's (1980) flume experiments and Behrensmeyer's (1975) hydraulic equivalence values provide the basis for nearly all operational approaches to the investigation of fluvial transport/sorting of bones. As with the weathering data, additional research at the basic methodological level is required to develop more refined interpretations of fluvial modification of archaeological deposits, and this has been a goal of the present investigation.

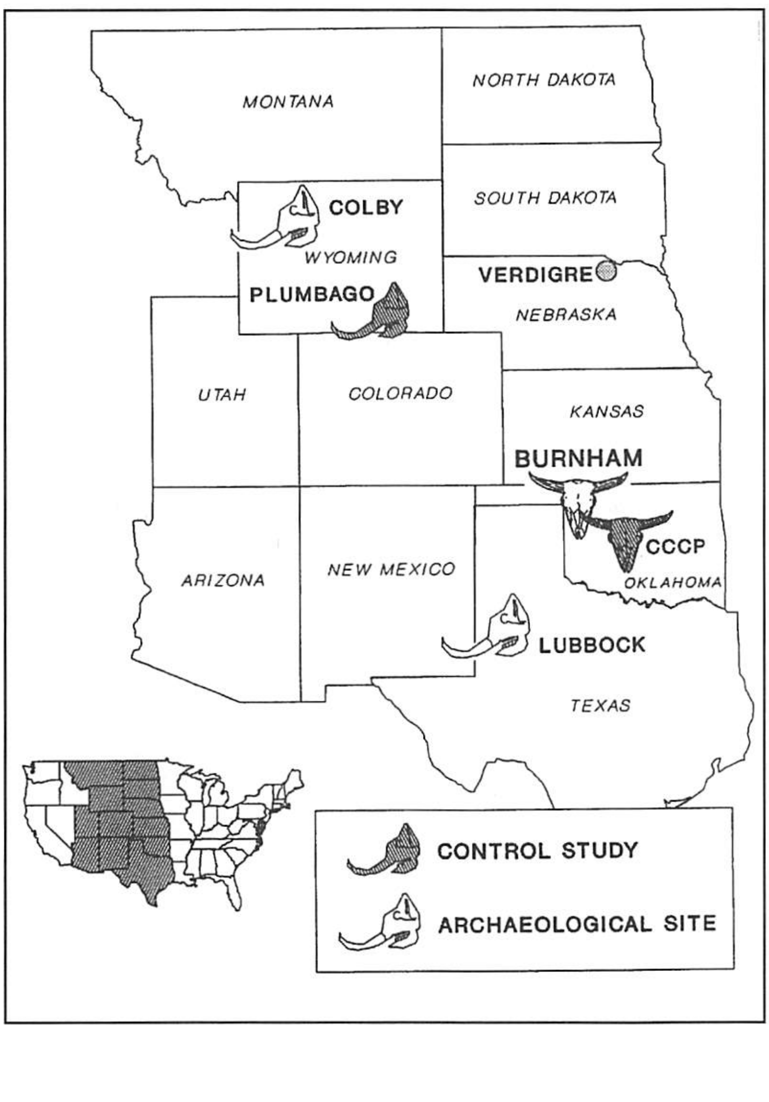


Figure 18.1. Location of the Burnham site and other selected Plains faunal assemblages where fluvial transport studies have been conducted: Colby (Frison and Todd 1986), Plumbago (Frison and Todd 1986), Verdigre (Voorhies 1969), Caddo County Canyon Project (CCCP; Hill 1989), and Lubbock Lake (Kreutzer 1988).

Several classes of information derived from this preliminary analysis of the Burnham assemblages do, however, have relevance to the more general interpretation of the deposit. Both the bison and horse bone beds may have been subjected to some type of post-depositional bioturbation, possibly trampling. Prior to being encased in sediments, the bison bones were exposed on the ground surface for several years, and at least some of them (including the crania) were moved or repositioned at least once years after the animal's death, and perhaps even sorted at least once by flowing water. Spatial associations within the deposit are probably not snapshots of moments in remote time.

It must be stressed that the following discussion of the taphonomy of the Burnham bone beds is preliminary and by no means comprehensive or complete. Many bones have not been fully cleaned and prepared for study, and a detailed examination of bone surfaces has

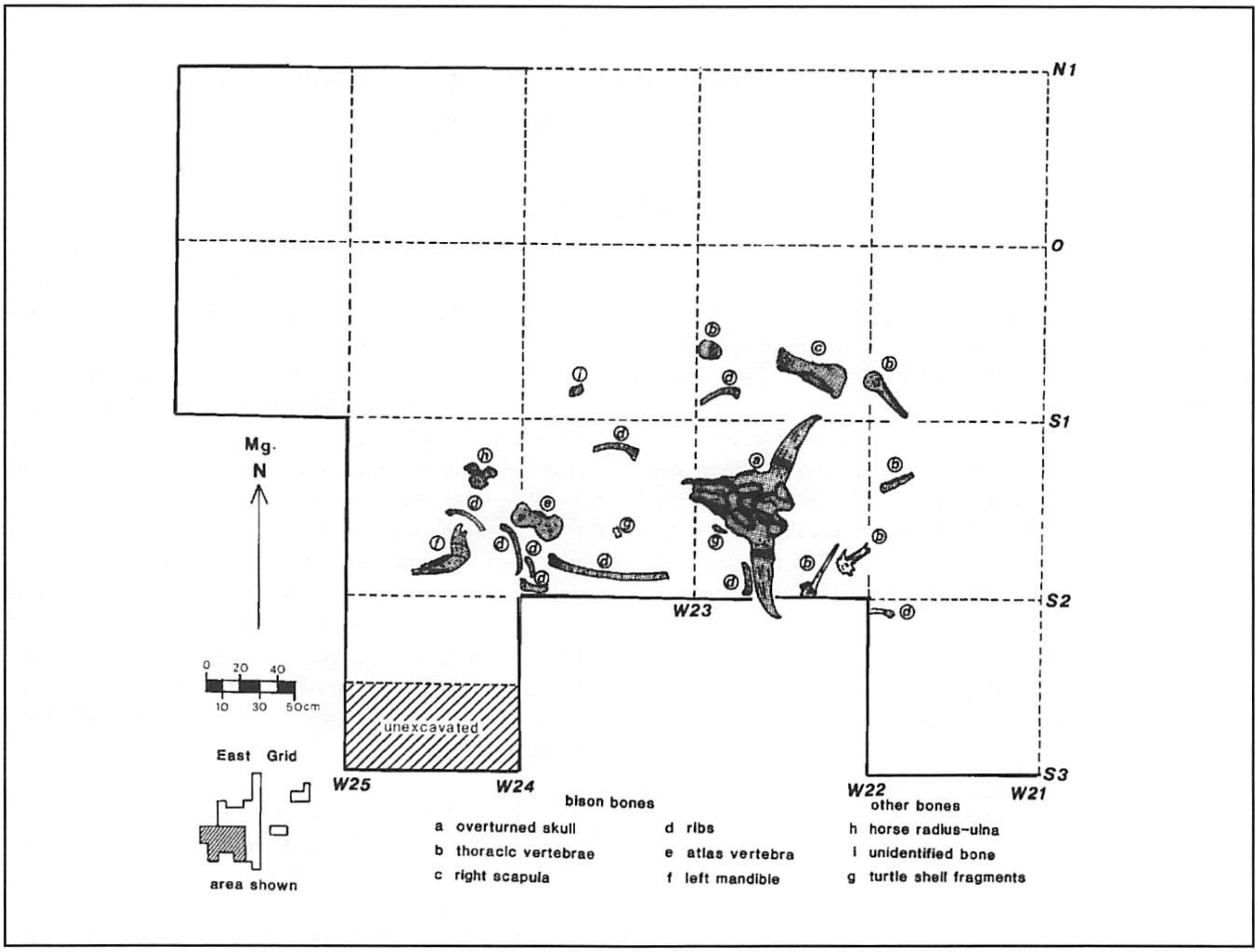


Figure 18.2. Plan view of the bison bone bed in the East Grid of the Burnham site.

not been possible.

Element Frequencies, Surface Conditions, Articulation, and Modification

The Bison Bone Bed

The bison bone bed (Figs.18. 2, 18.3, 18.4, and 18.5) consists of the scattered remains of a single, old adult male bison (Table 18.1). One horse bone, a proximal left radius-ulna, was also recovered from this area in 1989. The bison bones include a pair of mandibles, with extreme wear to the molars—the fossetes on the M3s have been obliterated by wear. The left mandible was recovered from immediately beneath the cranium, the right found about 1.5 m to the west (Fig. 18.2). Other elements include a complete right scapula, an atlas vertebra, 2 complete thoracic vertebrae, 2 thoracic dorsal spines, and several ribs and rib blade fragments. No limb bones have been found, and, as shown in Figure 3, the anterior segments of the axial skeleton predominate.

The cranium, mandibles, and atlas vertebra are a group of elements that could have formed an articulated unit, although unless hide-bound, these elements may disarticulate rapidly (Burgett 1990:Fig. 4.3). No other potential articulations were noted; one thoracic was a first, whereas the other is clearly a more posterior thoracic vertebra. Comparison of the Burnham skeletal element frequencies with element frequencies from large body-size (>800 kg) modern bison bull mortality sites (Burgett 1990:104-105) that had been scavenged by coyotes provides some interesting results. The most common post-cranial elements recorded at the modern bull bison death sites are thoracic and lumbar vertebrae and innominates. The most frequent forelimb element is the scapula, and ribs are slightly more common than any of the forelimb bones

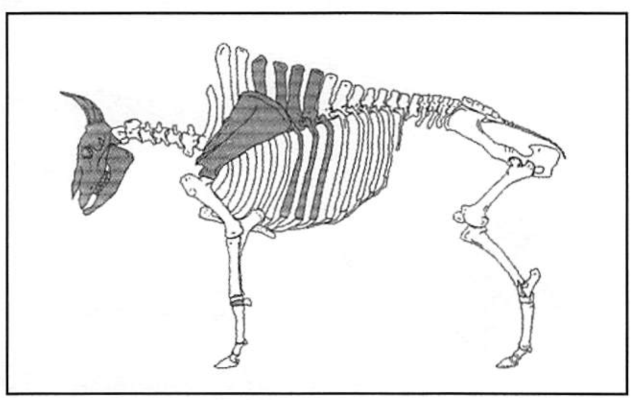


Figure 18.3. Bison bones recovered from the Burnham bison bone bed.

Figure 18.4. View southeast of the bison skull while it was being uncovered in the East Grid of the Burnham site.

distal to the scapula (Burgett 1990:Fig. 3.9).

No carnivore or rodent modification has been observed on any of the Burnham bison bones. Some have a slight amount of root etching. There is limited subaerial weathering with most surfaces being either unweathered or at Behrensmeyer's (1978) Stage 1. Of particular interest is the left mandible, which was found below the cranium. The lateral surface is more extensively weathered (Stage 2/3) than the medial surface (Stage 0/1). This suggests that the defleshed mandible lay exposed on the ground surface in a stable position with the lateral portion upward, perhaps for several years. After weathering of the lateral surface had begun, the cranium came to rest in its recovery position on top of the mandible. This shows that movement of the bones occurred well after the skeleton had been defleshed and disarticulated.

Green bone breaks are present on at least two of the bison bones: one proximal blade rib-blade fragment and one thoracic spine. The left mandible was fractured in situ with the symphysis broken off and displaced about 1 cm from the rest of the element. This breakage is possibly the result of trampling.

Figure 18.5. View south of bison thoracic vertebrae, ribs, and scapula blade, East Grid, Burnham site. Photo taken September 26, 1988.

Although not microscopic examination of bone surfaces for striations or cut marks has been completed, no obvious

Table 18.1. Skeletal Element Counts for Bison Bone Bed, Strata SC4 and SD, Burnham Site East Grid.

Skeletal element	Left side	Right side	Axial	Unsided	MNE	MAU
Cranium			1		1.0	1.0
Mandible	1	1			2.0	1.0
Atlas			1		1.0	1.0
Thoracic vertebrae			4		4.0	0.29
Rib, proximal				3	3.0	0.17
Scapula		1			1.0	0.50
Carpals				1	1.0	0.08

Table 18.2. Orientation of Elements in Bison Bone Bed, 1989 Excavations at the Burnham Site.

Skeletal element	Long Axis Orientation	Long Axis Plunge
Right mandible	70 degrees	21 degrees
Rib blade	329	61
Rib blade	285	14
Horse radius-ulna	287	28

examples of either have been observed in the initial visual inspections of the bison bones. Linear marks/striations can be produced on bones in several ways, including humanly inflicted cut marks and trampling related scratches (Behrensmeyer et al. 1986; Fiorillo 1988b). Various lines of evidence can be used to evaluate the role of trampling versus human butchery in the production of striations on bones. Fiorillo (1988b:78) suggests that "the percentage of marks caused by trampling is probably related to either the amount of trampling activity at a site or the amount of sand grains present in the trampled substrate or to both." Amount of trampling can, in part, be evaluated by both the nature of bone breakage and position of bones within the sediment. Hunt (1990:101) notes that at the Agate Quarry a clear correlation exists between evidence of trampling bioturbations and areas "where unstable bone orientations are observed to be particularly common." Given the potential significance of the interpretation of any linear striations on the Burnham site bones, several lines of evidence have been collected. First, information on the long axis orientation and plunge has been recorded. These data can be used for a variety of analyses, including evaluation of the likely causes of any striations. A correlation between frequency of striations and steeply plunging long axes could be used to support an inference of treadage-induced modification. The converse, however, is not necessarily the case—large numbers of striation on bones in stable orientation, does not directly point to a cause other than trampling since trampling on a hard, somewhat impenetrable substrate could produce striations without producing unstable orientations. Of the bones recorded in 1989, most (Table 18.2) exhibit long axis plunges in excess of 10 degrees, which is the value Hunt (1990) uses in his investigation of treadage bioturbation at the Agate Bone bed. This, together with the breakage noted on the mandible, suggests that trampling by other large mammals may well have resulted in movement of at least some bones within the soft substrate.

A second class of information collected from the Burnham bison bone bed to aid in the assessment of any marks on the bones is data on substrate particle size. During the 1989 excavations, a sediment sample from the deposits encasing each bone was collected. These are being described in terms of both particle size and particle angularity. The goal of this type of paired bone/sediment sampling is to allow analysis of relationships between specific stubstrate characteristics and individual bone attributes. The results of this investigation are pending.

The other large mammal bone from the bison bone bed area is a proximal left radius-ulna from a horse. The distal end of this element plunges to the northwest (Table 18.2) at an angle of 28 degrees. The bone is fractured in mid-shaft, with the break surface exhibiting a spiral fracture. In addition, a flake approximately 1.5 by 2.0 cm originates from the fracture surface and extends in a proximal direction on the lateral surface of the shaft. The margins of the breaks have been abraded and rounded. Rounding and polishing of some bones within the assemblage, especially if some deformation of surrounding sediments occurred, is not unexpected. Fiorillo (1988:Table 7) reports that 6% of the Hazard Homestead Quarry (Miocene) exhibit slight abrasion, and Hunt (1990:99) states that within the lower Miocene deposits "many bones in the Agate bone bed show moderate to strong surface abrasion" and notes the presence of "numerous selectively abraded bones (especially astragali) in which one face exhibits significant wear while the opposite side is nearly unworn." Therefore, it would be difficult to support a suggestion that the abrasion on the horse bone was evidence of its use as a tool.

In summary, the bison bone bed contains the remains of an old male bison. The molars were heavily worn, indicating an animal past its prime and perhaps in relatively poor physical condition. Although it cannot be determined if the discovery location corresponds to the mortality site, the presence of the large, heavy cranium suggests that death occurred nearby. After death, the carcass became dispersed, although the agents of dispersal cannot be determined. Scavengers, human butchery, trampling/kicking, or fluvial movement may have been involved, either singularly or in concert, in the movement of the bones. Given that only a small area has been excavated to the depth of the carcass remnant, it cannot be determined if bones have been removed or simply scattered over a wider area. The bones were exposed on the ground surface for several years, with movement continuing until the cranium came to rest on one of the weathered mandibles. The question of human involvement in dispersal/butchering of the carcass cannot be resolved at this time.

The Equid Bone bed

Unlike the bison bone bed, where the bones of a single individual comprise most of the remains, at least three individual horses are represented in the equid bone bed (Figs. 18.6, 18.7, and 18.8). This estimate is based on the presence of two complete right radium-ulnae (field label designations "R" and "V") with a right distal radius ("WW"). Although not all the casts removed in 1989 have been completely cleaned (as discussed below, most of the horse bones are coated with a 1-5 mm carbonate crust, making cleaning and identification difficult), and there may be a few additional small bones identified later. Table 18.3 presents a tabulation of most bones from the equid bone bed. Except for the radius-ulnae, there is little duplication of elements and the bones are generally scattered and dispersed within

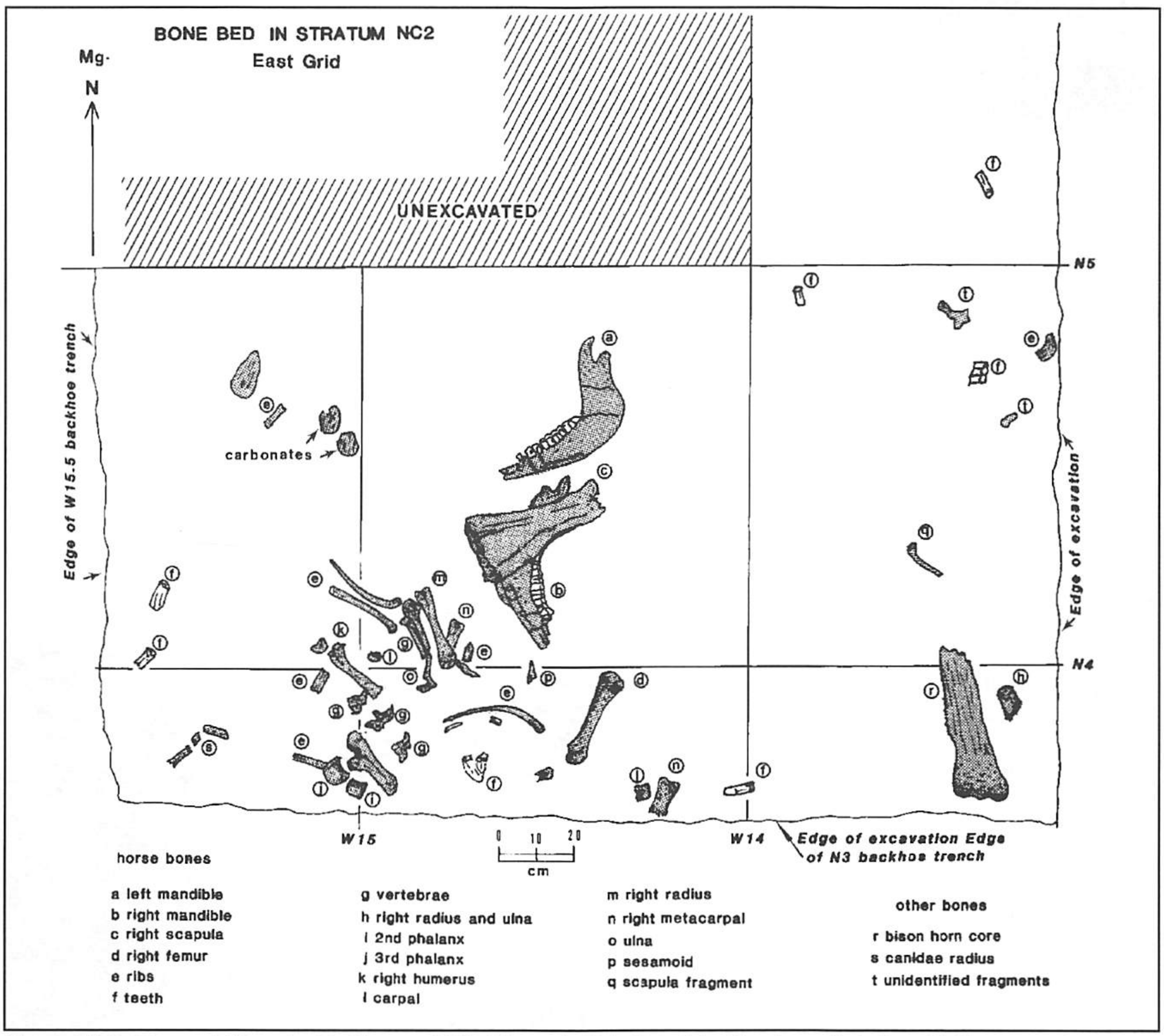


Figure 18.6. The equid bone bed in Stratum NC2 (Carter's Unit IIc) of the Burnham site's East Grid.

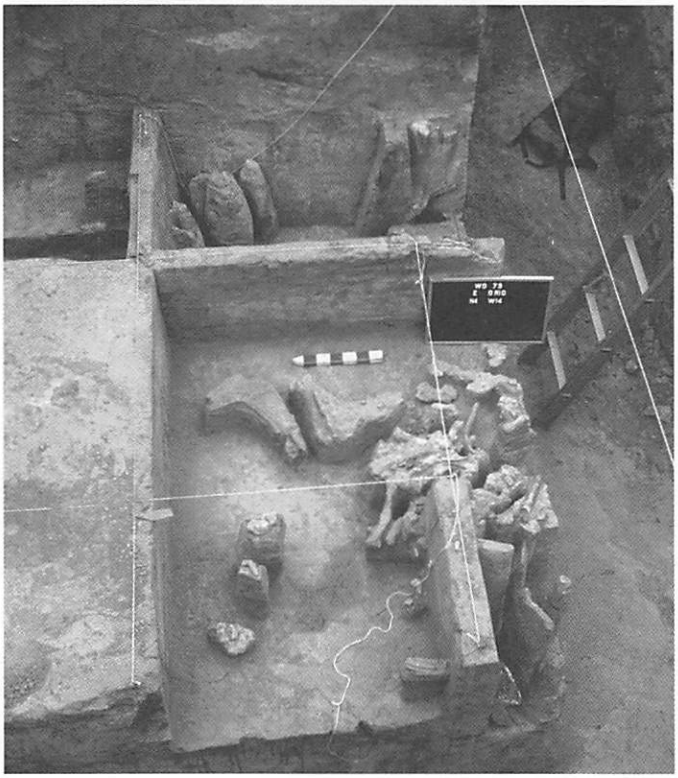


Figure 18.7. View east of equid bone bed as exposed in gleyed sediments in Burnham site's East Grid. Photo taken October 16, 1989.

a limited elevation zone. There is a wider range of skeletal elements represented in the horse bone bed (Fig. 18.6) than in the bison bone bed with elements of the axial skeleton and both front and hind limbs being present. The mandibles show that at least one horse was a young, prime-age adult. The complete ephiyseal union of each distal radius also points to all the horses being skeletally mature at time of death.

Besides the mandibles, this bone bed contains a series of loose teeth and mandible fragments (Table 18.3). These indicate that more intensive fragmentation of some elements occurred, suggesting that perhaps several events or episodes of accumulation may be represented.

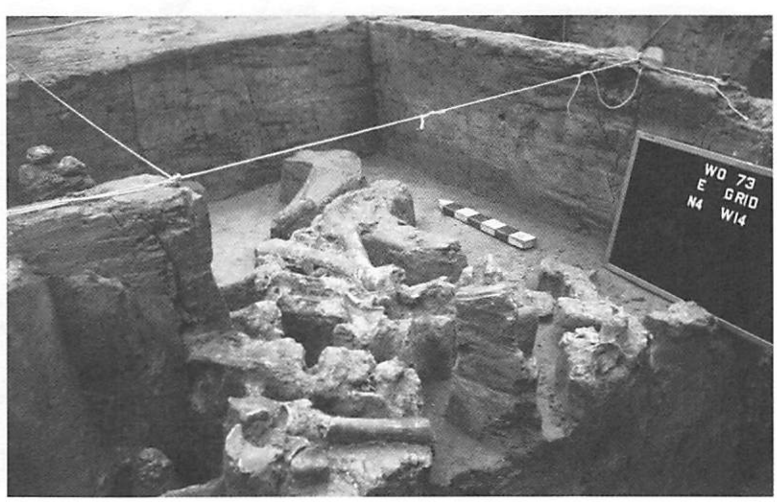
While no bones were found in articulation, there are several groupings that are in near articulation (Figs. 18.8 and 18.9) and probably were together when buried. These include 2 thoracic vertebrae with 2 proximal ribs and a group of at least 3 lumbars (and perhaps a sacrum, but these are still encased in carbonates). The presence of the right scapula, right humerus, right radius-ulna, and right metacarpals in proximity and of similar body-size range, suggests a once-articulated forelimb. Besides the horse bones, a single bison bone, a horn core of comparable size to that of the specimen from the bison bone bed area, was recovered.

The two half mandibles are part of a single element that was fractured prior to burial. In addition, the anterior portion of the right mandible was fractured in situ with the incisors displaced about 2.5 cm to the southwest.

Although the initial fracture of the mandible has an irregular dry-bone-like break, all the bones in the assemblage show little evidence of subaerial weathering. Most elements are either unweathered or in Behrensmeyer's (1978) Stage 1, which indicates a very limited exposure on the ground surface. Another source of information on the depositional setting is provided by the accumulation of carbonates and the fill of long bone marrow cavities. Several long bones were fractured by the backhoe excavations that led to the initial discovery of the bone bed. In all cases, the inner walls of marrow cavities were encased in a layer of carbonate, but otherwise empty—no sediments had entered the cavities. This may be the result of the bones being constantly water-saturated with the carbonate accumulation beginning soon enough to seal the inner cavities and prevent subsequent sediment in-filling. The carbonate accumulation continued on many bones until a coating up to 5 mm covered the outer surfaces. These carbonates are yet to be completely removed, so the surfaces of most bones have not been examined, but no indications of either carnivore or rodent gnawing have been observed on the surfaces exposed so far.

The orientation data from the equid bone bed suggests that a variety of processes has played a role in its formation. First, the data on plunge of the long axis (Fig. 18.10) indicates that over 60% of the bones have long axes plunging in excess

Figure 18.8. View northeast across the equid bone bed, showing the relatively horizontal poisitions and carbonate encrustations common to these bones.



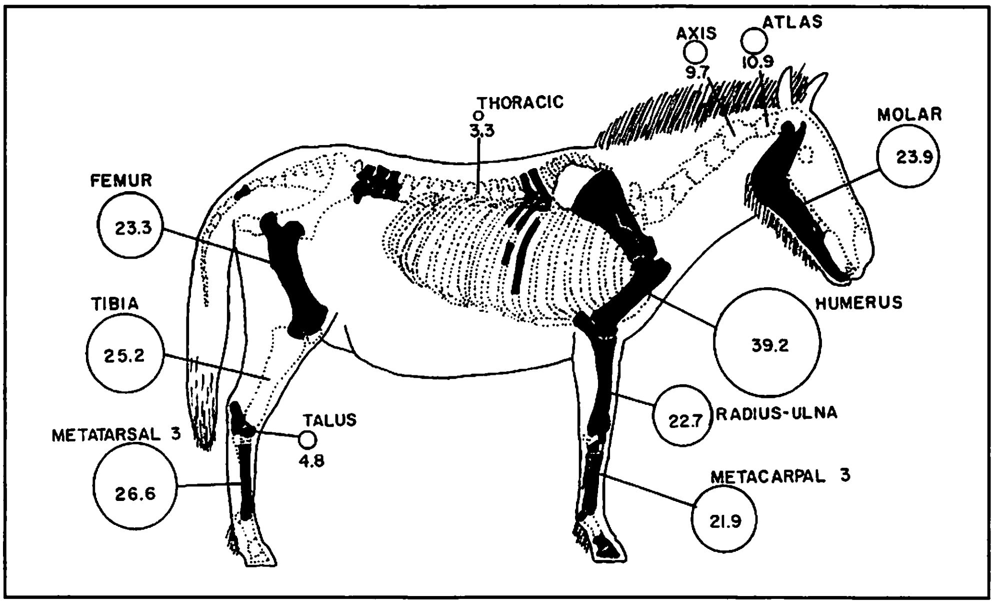


Figure 18.9. Horse bones from the Burnham equid bone bed shown with hydraulic equivalents (dq) illustrated for selected elements.

Table 18.3. Skeletal Element Counts for Equid Bone Bed, Stratum NC2, East Grid, Burnham Site.

Skeletal element	Left side	Right side	Axial	Unsided	MNE	MAU
Mandible	1	2			3.00	1.50
Isolated molar/premolar				6	6.00	-
Isolated incisor				1	1.00	-
Thoracic vertebrae			2		2.00	0.11
Lumbar vertebrae			3		3.00	0.60
Caudal vertebrae			1		1.00	0.06
Rib, proximal	2				2.00	0.05
Scapula		1			1.00	0.50
Humerus		1			1.00	0.50
Radius/ulna		3			3.00	1.50
Carpals		1		1	2.00	0.13
Metacarpal, third		1			1.00	0.50
Metacarpal, second		1			1.00	0.50
Femur		1			1.00	0.50
Talus				1	1.00	0.50
Calcaneus	1				1.00	0.50
Metatarsal, third		1			1.00	0.50
Phalanx, second				2	2.00	0.50
Phalanx, third				1	1.00	0.25
Sesamoid, proximal				1	1.00	0.25

of 10 degrees, but only 255 plunging more than 20 degrees. As illustrated in Figure 18.6, the long axes tend to be oriented to the southeast (see Fiorillo 1988a, 1988b for a discussion of the use of this type of orientation data). This could be an indication of form of the paleo-landsurface. The possibility that trampling, or some other form of post-depositional turbation, has modified the position of some smaller bones is suggested by the relationship illustrated in Figure 18.7. All bones with a long axis plunging in excess of 15 degrees are small, less than 120 mm in maximum length. The smaller bones would be more susceptible to movement and repositioning than the larger elements.

Several bone fragments with localized polish were recovered. These tend to be smaller pieces, found above the level of most of the horse bones. Given the potential for movement within soft sediments, or exposure to flowing water, the presence of polish and rounding on some bones is not unexpected.

As with the bison bone bed, a series of modifying processes are indicated as having played a role in the formation of the equid bone bed. There is no indication of cause of death, nor is there evidence of extensive modification by carnivores. Indications of subaerial weathering are limited and attest to a very brief exposure prior to burial or inundation. There are some indications of patterned orientations and element frequencies that suggest some fluvial modification of the assemblage. Plunge of long axis data suggest that some trampling into a soft substrate may have occurred. A scatter of loose bones and bone fragments may be indicative of several mortality events or episodes of deposition.

Fluvial Sorting, Settling Velocity, and Hydraulic Equivalence

Given the setting of both bone beds in, or next to, pond sediments, a major concern in taphonomic analysis is the role that fluvial processes have played in the formation of these assemblages. There have been several studies of fluvial modification to faunal assemblages. Several approaches have been used, primarily transport experiments (Frison and Todd 1986; Hanson 1980; Voorhies 1969) and development of various measures of hydraulic equivalences to quartz grains (Behrensmeyer 1975; Fiorillo 1988; Hanson 1980; Korth 1979), which have been studied in numerous sedimentological investigations.

As an initial pattern recognition tool for study of the Burnham equid bone bed, the hydraulic equivalents (d_q) of horse bones were calculated from data on zebra bone density (p_b) and volume (V) presented by Behrensmeyer (1975:Appendix I). The basic equation for quartz grain equivalents is (Behrensmeyer 1975:493):

$$d_q = \frac{(p_b-1)d_b}{1.65}$$

where d_b, the nominal diameter of a bone is calculated as:

$$d_b = \sqrt[3]{1.91*V}$$

Table 18.4 lists Behrensmeyer's volume and density values and the calculated equivalent diameters of quartz spheres (d_b). As illustrated in Figure 18.5, based on these hydraulic equivalence estimates, many horse bones at Burnham are those with the lowest fluvial transport potential, whereas many of the more transportable elements are missing (e.g., the vertebrae). However, these bones are clearly the largest clasts in the sediments and are considerably larger than the associated sediment particles (Carter 1990).

Behrensmeyer's work showed, however, that although volume and density can be used to calculate an expected settling velocity there can be significant differences between the expected velocity (V_p) and the measured settling velocity (V_s) for a sample of vertebrate bones. In particular, Behrensmeyer (1975:493) noted specific differences between flume experiments and hydraulic equivalence estimates for the scapula.

Prompted by the Burnham project, I began a series of bone settling velocity experiments similar to those described by Behrensmeyer's (1975:492-493) for a small sample of vertebrate bones. As with Behrensmeyer's experiments, settling velocities were measured using a stop watch and Plexiglas tank. Unlike Behrensmeyer's study, I have concentrated on the bones of a single species and, to date, have used only a single adult female bison skeleton. Also, unlike Behrensmeyer's studies, bones were dry rather than saturated at the beginning of each experiment. Settling velocity was measured each minute for the first 20 minutes of immersion time, and periodically after that for up to two to three days. After initial immersion, each bone remained submerged either in the Plexiglas tank or an adjacent immersion tank until the experiments were completed. Bones

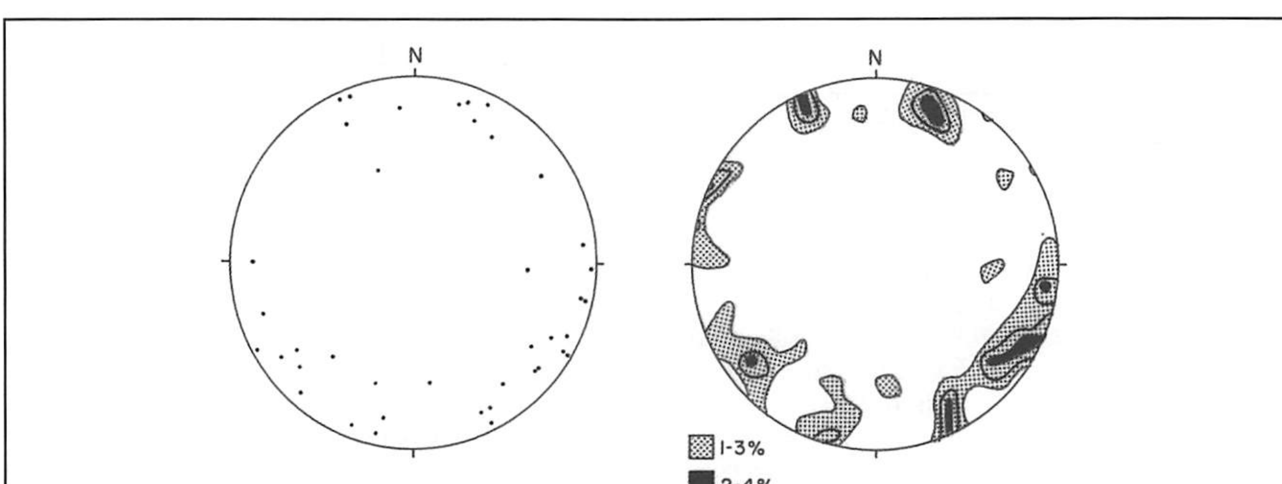


Figure 18.10. Synopic projection and contour diagram for orientation data (long axis orientation and plunge) for the Equid Bone Bed (N=40) at the Burnham site.

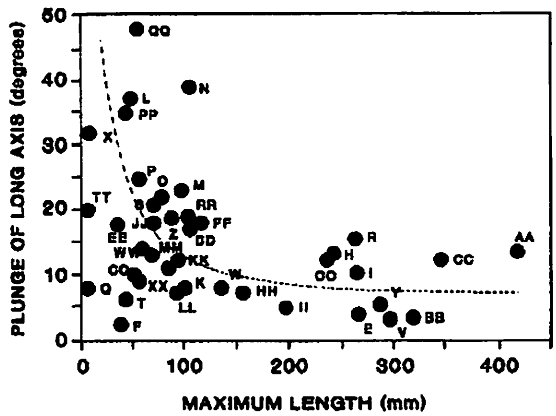


Figure 18.11. Plunge of long axis and maximum length of bones from equid bone bed at the Burnham site.

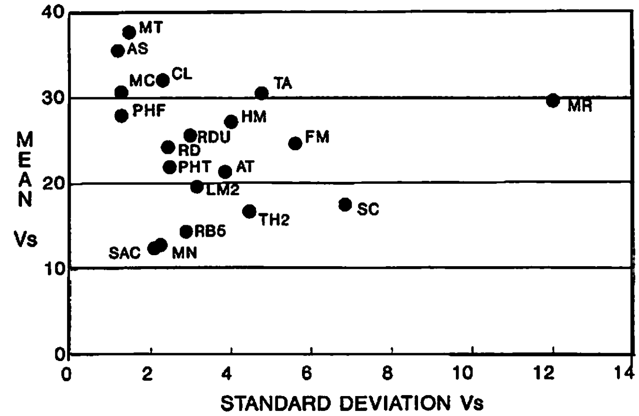


Figure 18.12. Mean settling velocity (Vs) and standard deviation of settling velocity from bison bone settling experiments. For element codes, see Table 11.6.

Table 18.4. Volume, Density, and Calculated Quartz Grain Equivalents for Equid Bones, Burnham Site.

Skeletal elements	V	Pd	dq	Burnham MNE
Mandible	-	-	-	3.0
Molar	25.4	2.08	23.87	6.0
Atlas	139.0	1.28	10.91	0.0
Axis	155.0	1.24	9.70	0.0
Cervical	170.0	0.98	-0.83	0.0
Thoracic	64.0	1.11	3.31	2.0
Lumbar	49.0	0.99	-0.28	3.0
Humerus, complete	310.0	1.77	39.19	1.0
Humerus, proximal	168.0	1.63	26.14	0.0
Humerus, distal	150.0	1.83	33.16	0.0
Radius-ulna, complete	303.0	1.45	22.73	2.0
Radius-ulna, proximal	170.0	1.29	12.08	0.0
Radius-ulna, distal	147.0	1.50	19.84	1.0
Metacarpal 3, complete	176.0	1.52	21.91	1.0
Metacarpal 3, proximal	82.0	1.40	13.07	0.0
Metacarpal 3, distal	90.0	1.40	13.48	0.0
Femur, complete	635.0	1.36	23.27	1.0
Femur, proximal	325.0	1.33	17.06	0.0
Femur, distal	299.0	1.45	22.63	0.0
Patella	45.0	0.64	-9.63	0.0
Tibia, complete	411.0	1.45	25.16	0.0
Tibia, proximal	235.0	1.27	12.53	0.0
Tibia, distal	168.0	1.77	31.95	0.0
Metatarsal 3, complete	140.0	1.68	26.55	1.0
Metatarsal 3, proximal	68.0	1.49	15.04	0.0
Metatarsal 3, distal	68.0	1.36	11.05	0.0
Talus	63.0	1.16	4.79	1.0
Calcaneus	87.0	1.00	0.00	1.00
Rib #1	26.5	1.22	4.93	-
Rib #2	25.0	1.84	18.47	-
Phalanx 1	48.0	1.00	0.00	0.0
Phalanx 2	-	1.02	-	2.0
Phalanx 3	20.0	1.05	1.02	1.0

Table 18.5. Summary of 1990 Bison Bone Settling Velocity Experiments and Skeletal Element Frequencies from the Verdigre Quarry.

Element	Vs	N	STD DEV	STD Vs	Verdigre
Sacrum	12.63	36	2.13	33.5	0.6
Manubrium	12.97	24	2.22	34.4	-
Rib 5	14.45	33	2.85	38.3	1.0
Thoracic 2	16.82	36	4.46	44.6	2.0
Scapula	17.65	38	6.84	46.8	16.0
Lumbar 2	19.75	34	3.16	52.3	7.0
Atlas	21.54	38	3.85	57.1	4.0
Phalanx 3	21.85	32	2.43	57.9	-
Radius	24.39	44	2.43	64.6	29.0
Femur	24.87	20	5.61	65.9	13.0
Radius-ulna	25.69	38	2.96	68.1	-
Humerus	27.29	53	4.04	72.3	46.0
Phalanx 1	28.12	34	1.26	74.5	-
Mandible	29.69	38	11.96	78.7	100.0
Tibia	30.43	36	4.76	80.6	55.0
Metacarpal	30.53	46	1.27	80.9	50.0
Calcaneus	31.91	32	2.30	84.6	42.0
Astragalus	35.49	17	1.20	94.0	41.0
Metatarsal	37.74	11	1.47	100.0	67.0

Note: All bison bones are from a fully mature, female *Bison bison* specimen. Verdigre data are from Voorhies 1969:Table 2.

Vs Mean settling velocity (cm/sec), based on series of 5-case sliding means.

N Number of 5-case, sliding mean velocities averaged.

STN DEV Standard deviation of settling velocity.

STD Vs Standardized settling velocity (in reference to maximum observed velocity of 37.74 for metatarsal.

Verdigre MAU% values for *Merycodus* from the Early Pliocene, Verdigre Quarry (Fig. 1).

were dropped from a constant depth with the entire element submerged, and each element was dropped from a standard position or positions. A series of settling velocity estimates (cm/sec) were derived using a 5-trial sliding mean to calculate an average velocity for each minute of immersion. The preliminary results of this on-going study are presented in Table 18.5. It should be noted that further studies are underway using additional elements, dropping bones from a greater variety of initial orientations, using bones of other species, and using bones in a variety of weathering stages. Consequently, the values presented in Table 18.5 may change slightly with further experimentation.

An initial observation is that the settling velocity data for bison bones compares favorably with the results of the Voorhies flume experiments. Voorhies's Group I, or the first group of bones to be moved by flowing water, corresponds to the bones with the lowest settling velocity, whereas Groups II and III bones have higher settling velocities.

Also illustrated in Figure 18.8, where mean settling velocity is plotted against the settling velocity standard deviation, is the observation that the velocity of some elements is much more consistent than that of others. The manubrium (MN) and sacrum's (SAC) velocities are always low, whereas the velocities for the astragalus (AS) and metatarsal (MT) are always high. The standard deviation for other elements, such as the mandible, scapula, and the major limb bones, is much greater.

The two major reasons for this variation are:

1. body shape, and
2. bone structure.

As shown in Figure 18.9, for bones like the mandible or scapula, settling velocity can be very different depending on the element's initial position in the water. Several studies have indicated this factor—that bone shape can play a significant role in its transport potential. A scapula dropped with the flat medial surface down "floats" to the bottom, whereas if dropped with the heavy caudal border downward it falls directly and rapidly. One advantage of settling velocity data or flume data over hydraulic equivalence estimates is that the former give a much better indication of how a bone's shape will influence its transport potential. The settling velocity values (V_s) in Table 18.5 are derived from a combination of all experimental data from each element. For example, the value for the scapula of 17.65 cm/sec is derived from the velocities of all trials despite the initial position of the bone and, as shown in comparison to Figure 18.9, is different from the average values for either lateral surface

Table 18.6. Quartz Grain Equivalents for Selected Bison Bones.

Skeletal element	Quartz Sphere Equivalents (dq) mm
Sacrum (SAC)	1.5
Manubrium (MN)	1.6
5th Rib (RB5)	1.9
2nd Thoracic (TH2)	2.6
Scapula (SC)	2.9
2nd Lumbar (LM2)	3.6
Atlas (AT)	4.3
3rd Phalanx (PHT)	4.4
Radius (RD)	5.5
Femur (FM)	5.7
Radius-ulna (RDU)	6.1
Humerus (HM)	6.9
1st Phalanx (PHF)	7.3
Mandible (MR)	8.2
Tibia (TA)	8.6
Metacarpal (MC)	8.6
Calcaneus (CL)	9.4
Astragalus (AS)	11.7
Metatarsal (MT)	13.2

Note: The equation presented by Behrensmeyer (1975:492) to calculate quartz grain equivalents from Observed bone settling velocity is $dq=.00928*V_s^2$.

upward or caudal border upward initial placement. This orientation/shape factor was noted Behrensmeyer (1975:573) who suggested that:

> The orientation of a bone may have great effects on settling velocity and quartz equivalence. Thus, a metapodial dropped parallel to its long axis may fall faster than a sphere of equivalent volume, but the same bone dropped with its long axis horizontal could settle at a rate slower than that of a sphere. The same bone can alter for equivalence to small or large quartz grain by slight changes in orientation.

The second cause of variation in settling velocities, bone structure, is illustrated by Figure 18.10. This factor has not been considered in previous settling velocity studies. The femur exhibits a very different settling velocity depending on the amount of time it has been immersed and consequently how saturated it has become. When dry, the femur contains many air pockets and is quite buoyant. As it becomes saturated, its velocity increases dramatically. This is true of most of the major limb bones. Bones such as the astragalus, on the other hand, are much more compact, and their internal structure does not contain as many air pockets. The settling velocity of such bones is relatively constant regardless of immersion duration. This observation has several implications for the evaluation of fluvial transport characteristics of bones.

It should be clear the fluvial transport potential of certain bones is not a constant. Due either to shape or structure, certain bones (i.e., those with the largest standard deviations, Fig. 18. 12) may respond very differently to fluvial processes under different conditions. Frequencies of elements, such as the scapula, in fluvially modified assemblages may exhibit a greater departure from transport models than bones with lower standard deviations. Voorhies (1969) noted that sometimes a scapula would transport with the Group I bones whereas in others it corresponded to the Group II's.

As an initial evaluation of the usefulness of the bison bone settling velocity values for the analysis of fossil assemblages, data on the relative percentage representation of bones from Voorhies's Verdigre Quarry are plotted against the V_s values from Table 18.5. Based on several lines of evidence, the Verdigre Quarry has been interpreted as a classic example of a fluvially modified assemblage. Figure 18.11 shows a strong positive relationship between element representation at Verdigre and the standardized bison bone settling velocity (V_s)—the bones with the lowest settling velocity are the least well represented, and as settling velocity increases so does element frequency. This suggests that the settling velocity data developed here are a useful additional tool for a wider range of taphonomic analyses.

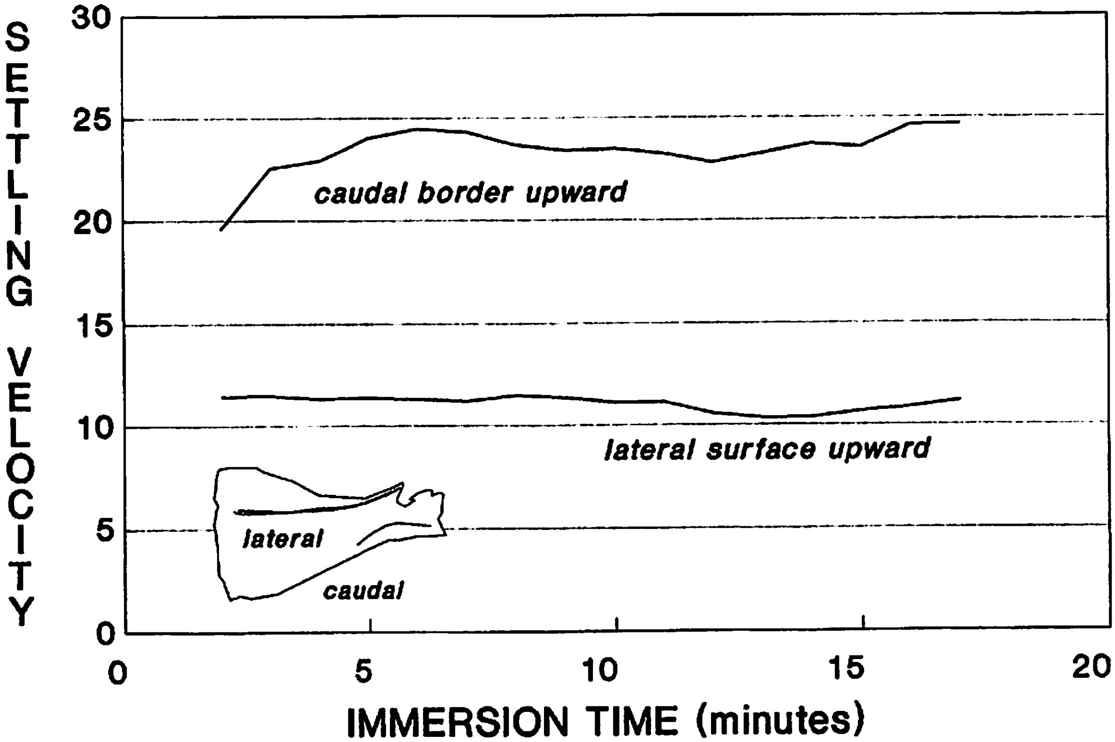


Figure 18.13. Differences in settling velocity (Vs) of a bison scapula as a function of initial position (either with caudal border upward or lateral surface upward) and cumulative immersion time.

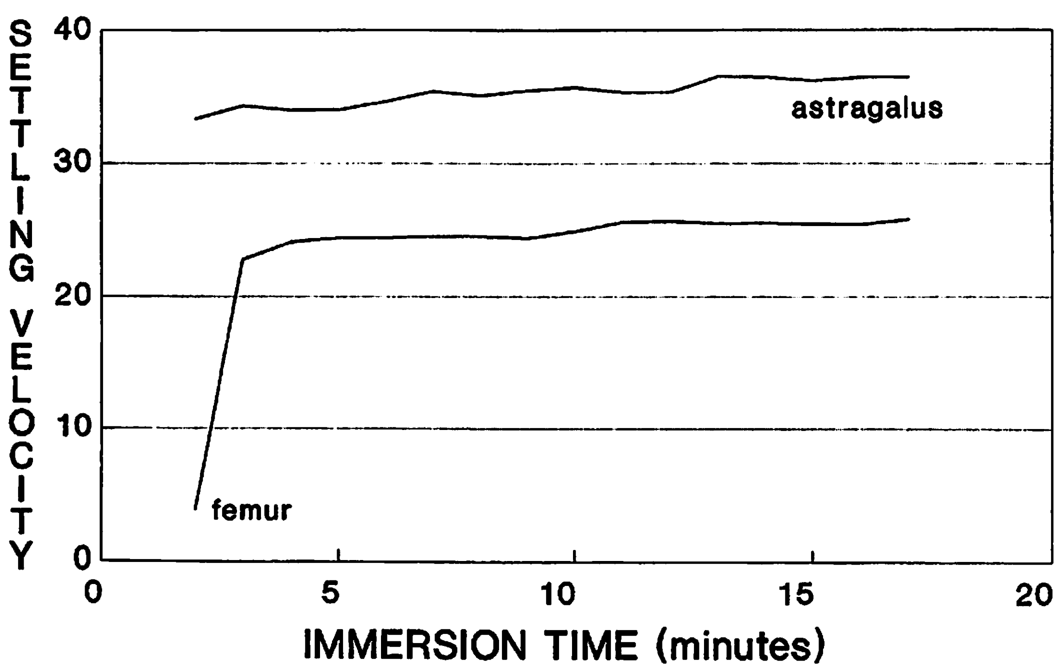


Figure 18.14. Differences in settling velocity (Vs) of bison femur and astragalus as a function of cumulative immersion time.

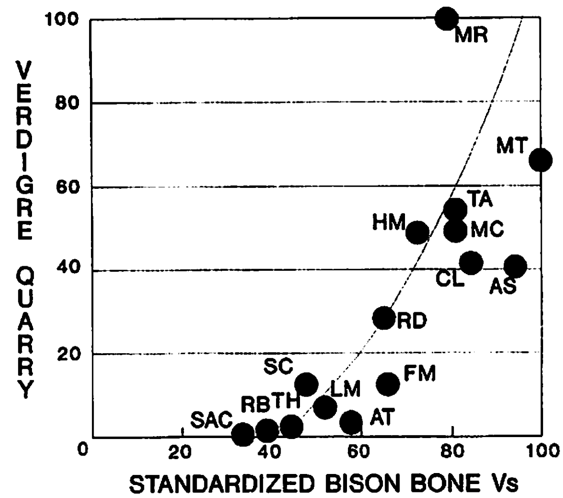


Figure 18.15. Relationship of skeletal element frequencies (MAU%) from the fluvially sorted Verdigre Quarry (Voorhies 1969) and a standardized bison bone settling velocity index.

In terms of the Burnham site bison bone bed, the assemblage contains elements that probably have very low transport potential (the cranium), some elements with high transport potential (vertebrae and ribs), as well as elements that can be highly variable in transport potential (mandibles and scapula). This may indicate that fluvial transport may not have occurred. However, if the standardized MAU values are examined, clearly most of the elements with higher transport potentials (i.e., lower settling velocities) are underrepresented or missing, and so fluvial sorting should not be discounted at this time. The question of fluvial modification of the Burnham bones is important not only in the interpretation of the skeletal element frequencies and evaluation of possible agents of bone deletion, it also is important in the interpretation of the apparent spatial association of bones and the stones recovered from the deposits. Examination of relationships between stones, bones (Table 18.6), and other clasts with the immediate vicinity of the bison cranium needs to be continued.

Conclusions

Initial taphonomic analysis of the bison and horse bone beds at the Burnham site suggests that both have complex formational histories. On this basis the possibility of human involvement in the creation of these bone beds cannot be supported or denied. The study has, however, indicated several important points about the formational analysis of deposits.

First, and of major significance, is that the interdisciplinary nature of the Burnham project included the incorporation of documentation techniques to allow tapahonomic investigations at an early stage in the project. Thus, information on bone orientation, inclination, side upward, etc., is available for analysis. Although the results of analysis to date are inconclusive, without the commitment to record the data sets in the field, the potential for ***any*** meaningful formational analysis would have been diminished. This highlights the first important aspect of taphonomic research (or any form of interdisciplinary research) as illustrated by the Burnham project—input and consultation must be an integral part of all aspects of project design and implementation.

A second important point about taphonomic studies that can be highlighted by this preliminary analysis is the need for constant interplay between analysis, fieldwork, and controlled investigations. There is, as yet, no comprehensive body of taphonomic analytical techniques that can be brought to bear on all sites. Investigation of each new site often emphasizes the need for better understanding of certain formational processes, ones which require additional ancillary study. For the Burnham study, I have chosen to begin by taking a closer look at fluvial transport properties of bison bones. Other types of investigation are clearly needed: studies of the processes resulting in polish and abrasion; studies of trampling and movement of bones in soft sediments; and studies of inundation and saturation on bone preservation. All are lines of inquiry that need to be pursued with additional actualistic or experimental research. Investigations of this sort, although often initiated in the context of a limited set of problems faced when dealing with a single site, often have much more general applicability. For example, study of settling velocities and transport potentials for bison bones at the Burnham site has relevance to any site containing bison or other large bovids where the effects of fluvial modification need to be considered.

Finally, the research potential of additional work at Burnham needs to be stressed. Fieldwork so far has opened several very limited windows on the record of the late Pleistocene pond at Burnham. Setting aside the question of human involvement for the moment, these windows have revealed a rich and intricate record of late Pleistocene environments. The results of paleoecological research derived from sites such as Burnham are of ***central*** importance to studies of the earliest occupation of the continent, despite the specifics of human involvement at any one locality. If we really want to address questions of late Pleistocene human adaptations in the Americas, we clearly need a better understanding of the environmental factors influencing those adaptations. Continued research at the Burnham site is essential, since the question of human activity in excess of 20 kyr is still ambiguous and of equal if not greater importance, the site provides a setting that can become a key locality for reconstructing Southern Plains Pleistocene environments.

References Cited

Behrensmeyer, A.K. 1975. The Taphonomy and Paleoecology of Plio-Pleistocene Vertebrate Assemblages East of Lake

Rudolf, Kenya. *Bulletin of the Museum of Comparative Zoology* 146(10):473-578.

Behrensmeyer, A.K. 1978. Taphonomic and Ecologic Information from Bone Weathering. *Paleobiology* 4:150-162.

Burgett, G.R. 1990. *The Bones of the Beast: Resolving Questions of Faunal Assemblage Formation Processes through Actualistic Research.* Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

Fiorillo, A.R. 1988a. A Proposal for Graphic Presentation of Orientation Data from Fossils. *Wyoming Contributions to Geology* 26(1):1-4. University of Wyoming, Laramie.

Fiorillo, A.R. 1988b. Taphonomy of Hazard Homestead Quarry (Ogallala Group), Hitchcock County, Nebraska. *Wyoming Contributions to Geology* 26(2):57-97. University of Wyoming, Laramie.

Frison, G.C. and L.C. Todd. 1986. *The Colby Mammoth Site: Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming.* University of New Mexico Press, Albuquerque.

Hanson, C.B. 1989. Fluvial Taphonomic Processes: Models and Experiments. *Fossils in the Making: Vertebrate Taphonomy and Paleoecology*, edited by A.K. Behrensmeyer and A.P. Hill, pp. 156-181. University of Chicago Press, Chicago.

Hill, M. 1989. Untitled manuscript in possession of the author.

Hunt, R.M., Jr. 1978. Depositional Setting of a Miocene Mammal Assemblage, Sioux County, Nebraska. *Palaeogeography, Palaeoclimatology, and Palaeoecology* 24:1-52.

Hunt, R.M., Jr. 1990. Taphonomy and Sedimentology of Arikaree (Lower Miocene) Fluvial, Eolian, and Lacustrian Paleoenvironments, Nebraska and Wyoming: A Paleobiota Entombed in Fine-grained Volcaniclastic Rocks. Volcanism and Fossil Biotas, edited by M.G. Lockley and A. Rice, pp. 69-111. *Geological Society of America Special Paper* 24. Boulder, Colorado.

Korth, W.W. 1979. Taphonomy of Microvertebrate Fossil Assemblage. *Annals of the Carnegie Museum* 48:235-285.

Kreutzer, L.A. 1988. Megafaunal Butchering at Lubbock Lake, Texas: A Taphonomic Perspective. *Quaternary Research* 30:211-231.

Lyman, R.L. and G.L. Fox. 1989. A Critical Evaluation of Bone Weathering as an Indication of Bone Assemblage Formation. *Journal of Archaeological Science* 16:293-317.

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

Voorhies, M.R. 1969. *Taphonomy and Population Dynamics of an Early Pliocene Vertebrate Fauna, Knox County, Nebraska.* Wyoming Contributions to Geology, Special Paper No. 1. University of Wyoming, Laramie.

Chapter 19
Dating the Burnham Site

Don G. Wyckoff and Brian J. Carter

From northwestern Texas to southwestern Kansas nearly 50 reported locations have yielded paleontological records believed to represent middle to late (Wisconsinan) Pleistocene faunal assemblages (Caran et al. 1985; Dalquest and Schultz 1992; Hibbard 1970; Johnson 1987; Miller 1975; Stephens 1960; Taylor and Hibbard 1955). Extensive vertebrate and/or invertebrate faunal lists are available for these sites, but few can be considered well dated. In fact, there are 25 radiocarbon dates from only 20 of these sites. Consequently, as we began investigations at the Burnham site we knew that dating the several fossil-bearing deposits was very important if the site's contents were going to be useful for developing a local and regional paleoenvironmental record. Because the skull of a rare form of bison was the focus of our initial work, it was only natural that we wanted to establish the skull's age. So a sample of the adjacent bison scapula was sent to the Radiocarbon Laboratory at Washington State University soon after the October 1986 excavation. Several months later Lab Assistant Peter Wigand reported the bone was not suitable for obtaining a radiocarbon date. By that time two of the flint flakes had been found while sorting residue from waterscreening gleyed sediment around the bison skull. With clues to the possible presence of humans it became even more imperative that we get some idea of the age of the deposit. We finally decided to submit a bulk sample of the snail shells from two of the 10 cm thick levels of gray loamy sand removed from around the skull. We knew that snail shells often yielded imprecise, if not suspect, results, but they were numerous in the stratum that had contained the flakes and the bison skull, so we hoped that they would yield a date relevant for a bison form thought to be a precursor to *Bison antiquus*. We were expecting a date of around 20,000 years ago. The result came back 31,150 $\pm$ 700 years ago (Beta-23045, uncorrected age) with a note that the sample was given triple the normal counting time because of its age. A date of even 20,000 years ago was going to be hard to accept given the few material hints for the presence of people. The date of 31,000 left us incredulous.

During all ensuing fieldwork at the Burnham site we endeavored to find datable materials and to submit samples, no matter what dating process was required, that would help establish the age of the fossil and artifact bearing deposits there. All excavators were coached and encouraged to watch for charcoal of any size or amount as they manually dug anywhere at the site. From 1988 to 1992, dozens of pieces of charcoal were uncovered and carefully plotted horizontally and vertically (elevation relative to datum and stratigraphic unit). Twenty-six samples were eventually submitted for radiocarbon dating. These came from the several strata of gleyed sediment, and a few were from intervening red, calcic paleosols. Charcoal fragments were regularly recovered from the few squares manually dug in what became recognized as the lowest paleosol at the site. Rarely was any charcoal piece of substantial size. Most were of wood match-head size or smaller.

Because of the small charcoal fragments, we realized that dating them would entail use of a tandem mass accelerator (Haynes et al. 1984). Though AMS dating was costly, we were prepared to spend the money in order to generate a suite of dates that would span the age of the deposits, especially those yielding the fossils and artifacts. However, upon submitting examples of Burnham charcoal, the respective laboratories encountered problems pretreating pieces before actually dating them. Thus, other treatment techniques were tried. Once we began to get dates from important stratigraphic units, these results were sometimes so different that they were hard to reconcile. Overall we learned a lot about the application of AMS dating and also much about the movement of minute pieces of charcoal over an ancient landscape.

In addition to radiocarbon dating, a few opportunities arose to try other dating techniques on Burnham site materials. A graduate student at the Southern Methodist University dating facility offered to run uranium series tests on a tooth from the *Bison chaneyi* mandible as part of his training in that technique. The results were disappointing. Finally, a horse tooth and sediment sample from the bison and artifact stratum were submitted for electronic spin resonance dating at the ESR Lab of McMaster University at Hamilton, Ontario. These results seem compatible with the radiocarbon-based chronology for the deposit.

Because of the interest in the age of the Burnham deposits, each of the dating techniques and their results are presented in sequence below. Following this presentation, the resultant ages are combined and plotted stratigraphically in order to show the chronology for the Burnham site. Throughout this report all Burnham radiocarbon and AMS dates are cited and discussed as uncorrected determinations except where noted. Most Burnham dates are older than extant correction scales. Until such scales are reliably extended back into mid-Wisconsinan times, it seems most appropriate to report the Burnham results as they were given to us by the respective dating facilities.

A very special thanks must be given to the many interested people who helped with dating Burnham site samples. At the University of Arizona, Vance Haynes, Austin Long, A.T.J. Jull, and Doug Donahue supported dating this site and endeavored in many ways to get results. At Southern Methodist University, Herbert Haas and Curtis McKinney were interested and most helpful. Joseph McKee and Rodger Sparks always were diligent and communicative at the New Zealand Institute of Geological and Nuclear Sciences. Bonnie Blackwell and Ann Skinner of the Department of Chemistry at Williams College followed through with obtaining ESR results. Finally, Michael Mares, former Director of the Oklahoma Museum of Natural History, graciously provided the funds for the first dates on Burnham site material.

Radiocarbon Dating

As noted above, the initial effort to date the Burnham site consisted of submitting bison bone for routine radiocarbon dating at Washington State University. Unfortunately, the scapula pieces that were submitted were too weathered to yield a date. We then decided to submit an unsorted batch of snail shells for routine radiocarbon dating. Because their shells can absorb dissolved old carbon from groundwater, and because their shells can be leached of amino acids needed for reliable dating, fossil gastropods are considered poor material for developing a reliable chronology (Evin et al. 1980; Goodfriend and Stipp 1983; Rubin and Taylor 1963; Taylor 1987:52-53; Yates 1986). Despite these long recognized problems, fossil land and aquatic snail shells are the primary material that has been radiocarbon dated at most late Pleistocene (Wisconsinan) paleontological sites in northwestern Texas (Dalquest and Schultz 1992:42-61), and they are the basis for some of the dating of paleontological sites in southwestern Kansas (Miller 1975). Lacking any other datable material at the time, one sample of Burnham's fossil shells was sent to Beta Analytic (#23045 in Table 19.1).

As fieldwork continued at the Burnham site in 1988 and 1989, it became obvious that we weren't going to recover many samples of plant material suitable for regular radiocarbon dating. In fact, only two other Burnham samples were submitted for such processing. This sample was a large fragment of the deeply buried, charred wood exposed near the east end of the North 3 backhoe trench dug during the National Geographic Society supported fieldwork in 1989. A part of this charred wood was sent to Beta Analytic (#33950 in Table 19.1). Later, because of interest expressed by Dr. Herbert Hass in problems of dating material from carbonate-rich deposits, a second part of this wood was submitted to the radiocarbon dating lab at Southern Methodist University's Institute for the Study of Earth and Man (#2422 in Table 19.1).

Accelerator Dating

All fieldworkers during the 1988, 1989, 1991, and 1992 excavations were instructed to dig by scraping with trowels. In this way they could carefully uncover and plot artifacts, bones, and charcoal. This latter was commonly 2 to 4mm fragments. These were regularly recovered from all manual excavations in the East and Northwest Exposures. The Southwest Exposure never received the amount of controlled excavations it merited. Several gullies were cutting through the Southwest Exposure and isolated bones of Pleistocene horse were uncovered as this erosion continued. A 1x2 meter excavation unit was staked out on the Southwest Exposure during the 1991 fieldwork, but excavation in these squares was terminated by heavy rain before getting very deep. As a result the few charcoal fragments from the Southwest Exposure come mainly from a nearly three meter long profile created when we cleaned and troweled a gully wall that was providing a cross section of the gleyed sediment. Two such samples were eventually submitted for accelerator dating, but no results were forthcoming because both samples disintegrated during pretreatment.

Table 19.1. Conventional Radiocarbon Dates from the Burnham Site.

Lab #	Material, provenience, and comments	Uncorrected age and 1 sigma factor
Beta 23045	Aquatic and terrestrial snail shells (75 g) water screened from East Grid, square S1-W22, levels 6 and 7 (3.5 to 3.7 m below datum elevation of 100). Sample given triple normal counting time.	31,150 ± 700 years B.P.
Beta 33950	Charred wood (0.6 g) identified as *Asimina triloba* recovered at elevation 98.0 (2.0 m below datum) in Horizon Btk,2b at N3-E1.5 in the North 3 backhoe trench. Horizon also contains bone fragments. Sample given quadruple normal counting time.	>38,000 years B.P.
SMU-2422	Charred wood (0.5 g) identified as *Asimina triloba* recovered at elevation 98.0 (2.0 m below datum) in Horizon Btk,2b at Na3-E1.5 in the North 3 backhoe trench. Sample was given acid treatment for 13 days, but base treatments for humate extraction were limited to two because sample showed rapid decay during treatment in weak NaOH solutions. δ 13/12C was –24.8 permil.	34,570 ± 1040 years B.P.* (*corrected 14C age)

With numerous minute fragments of charcoal being found during the 1988 excavations, arrangements were begun to get some dated by tandem mass accelerator. Upon hearing of the Burnham project, researchers with the University of Arizona NSF Accelerator Facility for Isotope Dating expressed interest in helping date bone or other organic material. After contacting them about the small charcoal fragments, that facility's steering committee graciously recommended processing Burnham site samples. Once the extensive excavations in 1989 were done, we had so many piece-plotted charcoal fragments that it was impossible for the University of Arizona lab to handle all of those deemed useful for dating important contexts. Learning of the New Zealand Institute of Geological and Nuclear Sciences' conscientious treatment and handling of AMS samples, Kent Buehler, Lab Manager of the Oklahoma Archeological Survey, contacted them in November of 1989 and asked if they would consider dating a series of Burnham samples. They, too, accepted.

Between 1989 and 1993, 24 charcoal fragments from the Burnham site were submitted for accelerator dating. Thirteen samples were sent to the University of Arizona and the remaining 11 went to New Zealand. Eleven dates were obtained from these 24 charcoal samples (Table 19.2). A few of the remaining 13 samples were too small for even accelerator dating. More serious was a problem encountered by both labs. During pretreatment to remove contaminants, the small pieces of charcoal decreased in size and became too small to make enough graphite for processing in the tandem mass accelerator.

To see how comparable the results would be, Joseph McKee at the New Zealand Institute of Geological and Nuclear Sciences undertook to date treated and untreated segments of the same piece of charcoal. He selected a remnant of charcoal, one part of which had been chemically treated and successfully dated (NZA-2823; Table 19.2). The untreated part of this charcoal was processed and yielded a date of 45,000 $\pm$ 1900 years before present. Quoting Dr. McKee (letter of February 18, 1993), "This compares well with the determination on the treated charcoal of 46,203 $\pm$ 1613 years BP. The two dates statistically overlap and indicate little contamination of this sample." Because of this finding, Dr. McKee proceeded to accelerator date one other Burnham charcoal sample (NZA-3009) without doing all of the chemical pretreatment.

Among the accelerator dates in Table 19.2, three were run because of an interest in studying the reliability of snail shells as datable material. The Arizona staff ran one shell sample in an effort to replicate the age determined from regular radiocarbon dating unsorted snail shells from the artifact-bearing stratum. Using a sample of mixed terrestrial and aquatic snail shells from the same 20cm thick zone where Beta-23045 originated, the University of Arizona reported an accelerator date (AA-3837) nearly 4500 years older! Two other samples of snail shells were submitted to the Arizona facility to compare the accelerator result on one aquatic species with the result on one terrestrial species from the same provenience. The results (AA-11687 and AA-11688) revealed the terrestrial species was some 5000 years older! Factors behind this discrepancy could involve the vegetation and carbonate enriched soil where the terrestrial species lived (Goodfriend 1987). The older date on the land snails could also indicate that they are older and that they represent detrital material washed into the pond from nearby, older soils. Clearly, given its younger assessment, the aquatic species was not acquiring old carbon from the water.

In 1994, two years after the last fieldwork at the Burnham site, University of California Ph.D. candidate Hope Jahren contacted Don Wyckoff about the availability of Burnham hackberry (*Celtis* sp.) seeds for accelerator dating. Ms. Jahren and Dr. Yang Wang of the University of California Division of Ecosystem Sciences were undertaking research on the suitability of hackberry seed endocarp as a reliable material for radiocarbon dating (Wang et al. 1997). We had recovered numerous hackberry seeds from several of the Burnham site strata, so it was easy to comply with Jahren and Wang's request, especially because their results would enhance the site's chronology. Eventually, eleven samples of single hackberry seeds were sent to them, and six of these were dated at the Lawrence Livermore National Laboratory (Table 19.2).

The 17 accelerator results (Table 19.2) comprise the majority of the dates available for establishing the Burnham site's age. Except for sample RA-C0289, these results provide a reasonable, though not always consistent, assessment of this site's antiquity. Fifteen of these results fall between 22,000 and 46,000 years ago. Preceding the Wisconsinan full glacial (21,000 years ago; Bard et al. 1990), this period seems plausible given the presence of skeletal elements of a bison form that appears to be a precursor to *Bison antiquus*, the late Wisconsinan form known to have been hunted by Paleoindians using Clovis and Folsom style spearpoints. Nearly a dozen radiocarbon dates are available for *B. antiquus* paleontological finds on the Southern Plains (Wyckoff and Dalquest 1997:Appendix 3), and these dates support the conclusion that *Bison antiquus* was the shorthorn species present during and after the Wisconsinan full glacial.

Uranium Series Dating

The first excavations at the Burnham site occurred just a few months after fieldwork was completed at the Hajny site, a Pleistocene paleontological site located some 50 miles southeast of Burnham (Wyckoff et al. 1992). At Hajny some major issues developed regarding the age of the deeply buried spring deposits with mammoth remains, all being in a terrace high above the South Canadian River's present course. To try to resolve the chronology of the Hajny site, Dr. Herbert Hass, Southern Methodist University coordina-

Table 19.2. Acceleator Dates from the Burnham Site.

Lab #	Material, provenience, and comments	Uncorrected age and 1 sigma range
AA-3838	Charcoal (<1.0g) from East Grid, square S1-W22, elevation 96.26, from red sandy stratum below that yielding artifacts.	26,820 ± 350 years B.P.
AA-3840	Charcoal (<1.0g) from East Grid, square 0-W22 at elevation 97.06, from gray loamy fine sand above stratum containing artifacts.	40,900 ± 1600 years B.P.
NZA-1090	Charcoal (<1.0g) from East Grid, square N5-W19, elevation 98.2, from red sandy unit below the highest gleyed deposit. δ13C:-33.99; D14C:-763.6±9.3.	11,580 ± 320 years B.P.
NZA-1416	Charcoal (<1.0g) from East Grid, square 0-W25, elevation 96.2, from red loamy fine sand below stratum containing artifacts. δ13C: -24.35; D14C: -989.1.	36,300 ± 1700 years B.P.
NZA-2823	Charcoal (1.5g) from East Grid, 1992 Backhoe Trench A, square 3, elevation 96.72, from gray loamy sand sediment of early pond accumulation. δ13C: -24.2; D14C: -996.8 ± 0.6. Sample split with one being pretreated and dated while the other was not pretreated.	46,200 ± 1600 years B.P. (45,000±1900 on untreated part)
NZA-2824	Charcoal (<1.0g) from 1992 Bulldozer Trench B, Feature #1 (rodent burrow with charred hackberry seeds) exposed at elevation 99.0, earliest paleosol found at site. δ13C: -26; D14C: -990.9 ± 0.8.	37,790 ± 680 years B.P.
NZA-3009	Charcoal (<1.0g) from Northwest Exposure, square S5-W2, elevation 97.89. Charcoal not pretreated before dating. δ13C: -25.0; D14C: -976.6 ± 1.1.	30,160 ± 390 years B.P.
NZA-4381	Charcoal (<1.0g) from East Grid, square S1-W22, elevation 96.35. Initially thought from gray loamy sand, but review implicates from fill washed into square between 1986 excavations and those of 1988.	10,210 ± 270 years B.P.
AA-3837	Mixed aquatic and terrestrial snail shells (34.1g) from East Grid, square S1-W22, levels 6 and 7. Remaining part of sample previously dated by Beta-23045 (31,150 ± 700 years B.P.).	35,890 ± 850 years B.P.
AA-11687	Aquatic snail shells (0.5g) of the species *Physella virgata* from column of gray sediment in Northwest Exposure square S5-W2. Fraction of modern carbon: 0.0097 ± 0.0011.	37,215 ± 940 years B.P.
AA-11688	Terrestrial snail shells (0.2g) of the species *Hawaiia minuscula* from column of gray sediment in Northwest Exposure square S5-W2. Fraction of modern carbon: 0.0040 ± 0.0011.	42,785 ± 1800 years B.P.
RA-C0289	Hackberry (*Celtis* sp.) seed from Feature #1 (rodent burrow) exposed in paleosol at elevation 99.0 in Bulldozer Trench B. Result indicates modern seed introduced while feature was uncovered in open bulldozer trench.	30 ± 60 years B.P.
RA-C0291	Hackberry (*Celtis* sp.) seed from top of red sediment under artifact bearing stratum, East Grid, square S3-W24, elevation 96.1	37,590 ± 820 years B.P.
RA-C0352	Hackberry (*Celtis* sp.) seed from East Grid, square S1-W23, elevation 96.3, near bottom of gleyed layer containing artifacts.	22,670 ± 330 years B.P.
RA-C0353	Hackberry (*Celtis* sp.) seed from Feature #1 (rodent burrow) exposed in paleosol at elevation 99.0 in Bulldozer Trench B.	40,130 ± 1280 years B.P.
RA-C0354	Hackberry (*Celtis* sp.) seed from East Grid, square N2-W20, level 96.8, the upper part of the gleyed layer containing artifacts.	35,680 ± 710 years B.P.
RA-C0419	Hackberry (*Celtis* sp.) seed from East Grid, square S1-W22, level 5 (dug in 1986) in gleyed stratum containing artifacts.	40,190 ± 870 years B.P.

tor of the dating facility, asked Ph.D. candidate Curtis McKinney to run uranium/thorium ratio assessments on the molars from the two mammoths uncovered there. The resulting determinations seemed reasonable given the geological context of the Hajny site. Consequently, after Washington State University radiocarbon lab was unable to date Burnham bison bone, Dr. Haas agreed to allow Mr. McKinney to try uranium/thorium dating on a tooth from the *Bison chaneyi* mandible.

The result of the uranium series testing of the Burnham bison molar is shown in Table 19.3. The chemical analyses focused on the tooth's enamel. The inferred age is 98,000 ± 4500 years ago (Sample SMU-217E1). In his November 29, 1988, letter reporting this result, Mr. McKinney noted that bison molars were more troublesome to date, perhaps because their enamel is more porous than that of horses or elephants.

In essence, this dating process resulted in an age almost three times older than that assessed by routine radiocarbon and accelerator dating for the Burnham deposits. Given the many radiocarbon dates, it seems likely that the uranium/thorium result is not directly relevant to the Burnham geological context.

Electronic Spin Resonance Dating

In the interest of obtaining as much chronological information on the Burnham site as possible, in December of 1990, a response was made to a note in the American Quaternary Association newsletter regarding electronic spin resonance dating in collaboration with researchers at McMasters University, Hamilton, Ontario. Communications with Dr. Bonnie Blackwell of McMasters' Department of Geology resulted in our sending three samples of fossil horse teeth. These came from three different strata at the Burnham site.

Due to changes in residence and institutional affiliation, Dr. Blackwell did not finish processing any of the Burnham samples until 2000. At that time, a single horse tooth (from East Grid square S1-W23, elevation 96.4, the gleyed deposit with the *Bison chaneyi* skull) was analyzed along with sediment from the Burnham site. Actually, this tooth was divided into six samples, and each was independently dated by electronic spin resonance (ESR). This tooth's standard ESR ages averaged:

Early Uptake Age: 37,000 ± 4000
Linear Uptake Age: 67,000 ± 7000
Recent Uptake Age; 583,000 ± 167,000.

Because isochron analysis suggests that the tooth underwent some minor uranium leaching, the tooth is believed to date ≥ 37,000 ± 4000 years ago whereas the pond deposit dates at 35,000 ± 9000 years ago.

A Burnham Site Chronology

In a preceding chapter, soils scientist-geomorphologist Brian Carter has used most of the Burnham dates to develop and interpret a mean age for the prehistoric ponds at the site. At the risk of some redundancy, the following pages review all of the dates, where the samples originated, and their significance for the site's overall antiquity. Particular attention is paid to those dates above, below, and from the stratum yielding the flint flakes and chipped stone tool fragments.

The Earliest Paleosol

The earliest paleosol was observed first at elevation 98.0 (2.0m below site datum) at the east end of the North 3 backhoe trench dug in the East Grid in 1989 (Figs. 19.1, 19.2, and 19.3). Described as Btk,2b, this thin argillic-calcic horizon was discovered to extend 13.0m south when the 1991 backhoe trench was dug from the North 3 trench. At its southernmost expression this paleosol merged with the top of a gravel lens draped over a near vertical (at least 2.0m high) sidewall of Marlow sandstone. In 1992, this paleosol was found some 50.0m north of the North 3 backhoe trench exposure. This 1992 occurrence was near site elevation 98.0 in Bulldozer Trench B where the paleosol was almost 5.0m below the modern ground surface. From these findings, the earliest paleosol at Burnham is known to have a north-south extent of at least 60.0m, but its east-west extent is uncertain. Importantly, this paleosol is within aggraded sediments (Carter's Unit III) but lower than the gleyed sediments of pond IIB (Chapter 6, this volume)

As noted above, this paleosol developed after a prehistoric drainage had aggraded near the top of its bedrock wall. Notably, this paleosol was a context for considerable biological activity. From it was recovered pieces of charred wood (Fig. 19.2) identified as paw paw (*Asimina triloba*), a

Table 19.3. Uranium Series Dating Results for the Burnham Site.

Sample #	Material, provenience and comments	Inferred age and error factor
SMU-217E1	*Bison chaneyi* molar from mandible recovered under bison skull in East Grid, square S2-W22. Uranium concentration ppm: 10.5 ± .2; U234/U238: 1.63 ± .04; Th230/Th234: >1000; Th230/U234: .623 ± .018.	98,000 ± 4500 years B.P.

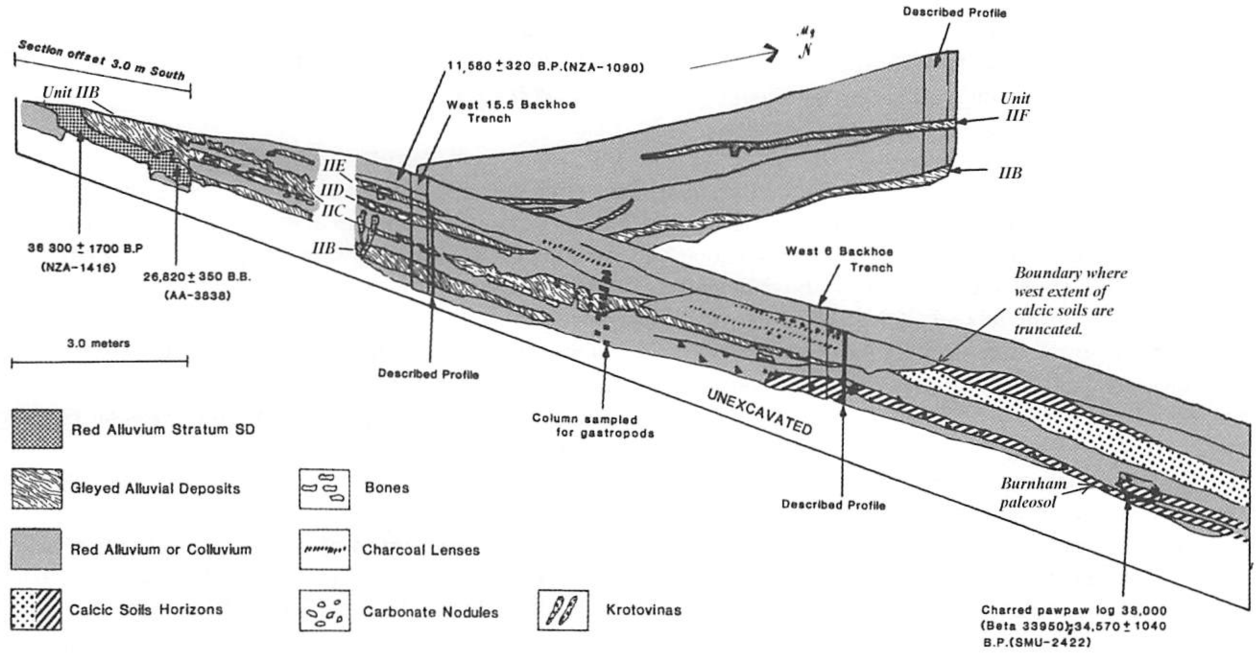


Figure 19.1. Profile of East Exposure sediments and soil as recorded during 1989 excavations. Sedimentary units are designated according to Brian Carter's synthesis of findings (this volume). Modified from a profile created by G. Robert Brakenridge.

Figure 19.2. The first clue to the Burnham paleosol was the charred section of pawpaw wood exposed near the east end of the North 3 backhoe trench dug in 1989. Photo taken by Kent Buehler in October 1989.

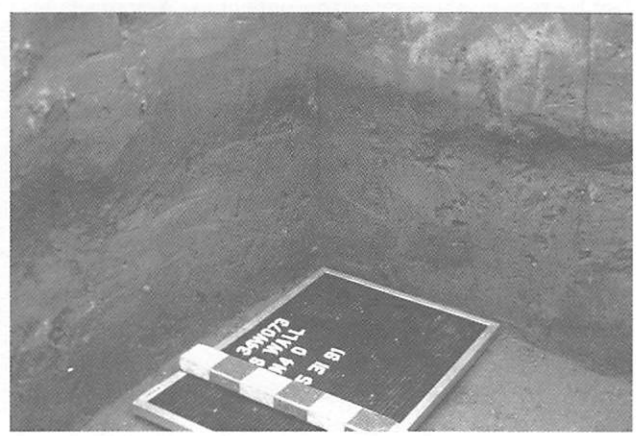


Figure 19.3. View of the Burnham paleosol exposed in East Grind square 0-N4. Scale is in 5cm increments. Photo taken May 31, 1991, by Don Wyckoff

species which grows today some 120 miles east of the Burnham site. In 1991, six 1x1m squares were manually dug adjacent the pawpaw find. This work recovered numerous charcoal fragments and occasional pieces of bone. These latter were deteriorated enough that they couldn't be identified as to element or species. Finally, in Bulldozer Trench B, this paleosol was disturbed by a large rodent burrow that contained charcoal flecks and charred hackberry seeds.

Because it represents the earliest evidence for stability of Pleistocene sediments, and because it contains clues to plants and animals living on it, the Burnham site's deepest paleosol merited dating. Five samples (Beta-33950, SMU-2422, NZA-2824, RA-C0289, and RA-C0533 in Tables 19.1 and 19.2) were submitted from this context. Except for RA-C0289, the dates on these samples fall between 34,500 and 40,000 years ago.

Sample RA-C0289 yielded essentially a modern date (Table 19.2). This sample was a hackberry seed thought associated with the ancient rodent burrow found nearly 5.0m below the ground surface in Bulldozer Trench B. This bioturbation feature was left uncovered several days before and during its excavation, and a recent seed could easily have been dropped there. Clearly, we weren't careful enough in examining all hackberry seeds before sending samples for accelerator dating to the University of California.

This earliest paleosol is thin, has some clay accumulation and carbonate enrichment, but has little structural development. This paleosol probably formed over several hundred to a few thousand years before being buried by additional alluvial sediments. Because these dates derive from plants that grew on or above this paleosol, then the dates must be younger than the paleosol. We would put its age at around 40,000 years ago, whereas the plant and animal activity appears to date mainly around 36,000 or 37,000 years ago.

Soil Accumulation and Truncation

After its development at site elevation 98.0, the Burnham paleosol was buried by nearly 2.0m of fine textured sediments that also underwent soil forming processes. These sediments are red, calcium carbonate enriched, loamy fine sand and fine sandy loam (Table 5.2). In these formed multiple, discontinuous layers of soft to slightly hard calcium carbonate nodules (Figs. 19.4 and 19.5). Each carbonate layer formed as wetting fronts moved down through the profile and deposited calcium carbonate ions at depths where the wetting fronts were no longer mobile. There, the mineral ions bonded with each other and with silt and/or sand particles. In essence, these are caliche layers, each having formed at a particular depth below a different, relatively stable, ground surface. On this basis, the profile above the Burnham paleosol is demonstrating that it accumulated with parent materials, depositional processes, and moisture regimes that were not too different from those evident today in northwestern Oklahoma.

Unfortunately, few chronological controls exist for determining when and how long these red, fine sediments accumulated. In the North 3 and the West 6 backhoe trenches, these red calcic fine sediments manifest at least two discontinuous, thin (1 to 2cm) lenses of blackened sediment. Speculated to be traces of ancient grass fires, neither lens was dated (a sample from one failed to yield enough carbon). Further laboratory study revealed these lenses were manganese coated grains, the result of chemical processes due to the lenses' original location relative to the ground surface and lateral water seeping from an adjacent pond.

After accumulating some 80cm of carbonate enriched, red, fine sediments above the Burnham paleosol, the depositional sequence was partially disrupted. At grid point West 5 in the North 3 backhoe trench a distinct break occurs in the sequence of red, calcic, fine sediments that comprise Carter's (this volume) Group III deposits (Figs. 19.4 and 19.5). To these east the Group III deposits continue, but to the west the profile is composed of stratified, sometimes nested, lenses of waterlaid, fine sandy material (Carter's Group II deposits).

The discontinuity evidenced in the North 3 trench profile is a boundary created by the change from pond deposits (to the west) to floodplain and toeslope settings of terrestrial (upland) soil environments (to the east). The ponds were likely created in the axis of this incised valley by beaver dams (Dalquest et al. 1990). The ponds collected detrital organic matter which formed gley and redoximorphic soil features in and adjacent the pond deposits. The axis (channel) of this prehistoric stream valley was 2.5m below the paleosol. That elevation (95.6 relative to the site datum) is the bottom of the fossil-bearing, red, sandy alluvium found below the *Bison chaneyi* skull, which was some 17.0m west

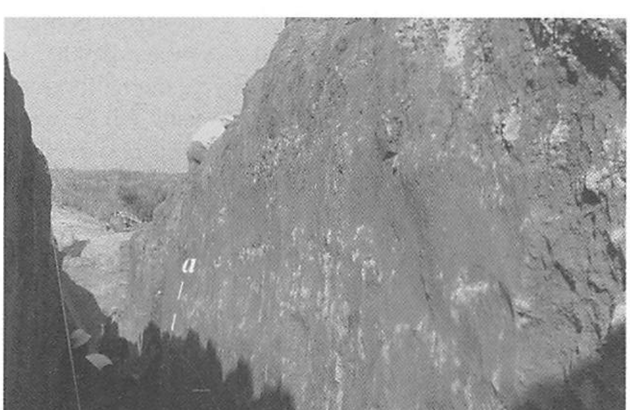


Figure 19.4. View west in the North 3 backhoe trench showing layer-like occurrences of calcium carbonate nodules in soil above the Burnham paleosol. At point "a" this layering is truncated. Photo taken by Don Wyckoff in October of 1989.

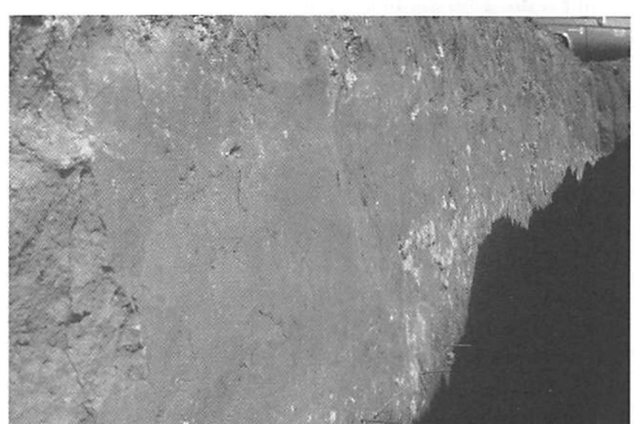


Figure 19.5. View northeast of near vertical boundary in layered carbonate-bearing soils exposed in the North 3 backhoe trench in the East Exposure of the Burnham site. Photo taken by Kent Buehler in October of 1989.

of the pond-upland boundary. The western edge of this channel was discerned in profile some 2.0m northwest of the bison skull. Measured from there to its eastern edge in the North 3 backhoe trench, the channel's width was some 20.0m. Partially cross-sectioned in Backhoe Trench 92A, this channel has a northeast-southwest orientation with a narrow finger that extended 60.0m northeast where a meter wide gleyed deposit (with gastropods) was observed to terminate in the eastern part of Bulldozer Trench B. Here, too, the channel was adjacent the Burnham paleosol.

East Exposure Pond Sediments

There are 11 AMS, 2 ESR, and 1 regular radiocarbon dates that come from the colorful pond sediments. These deposits are stratified, partially nested lenses of gray or red loamy fine sand, and they contain many aquatic gastropods indicative of the former presence of spring-fed small ponds. Manifest at elevation 98.5, the highest such lens (a gleyed example) lacks any fossils. The alternating red and gray sediments below it yielded both invertebrate and vertebrate fossils. The next to the lowest lens is gray (gleyed) and yielded the *Bison chaneyi* bones, the flint flakes, and the broken chipped stone tools.

The 14 dates for the East Exposure alluvial deposits represent a majority of the chronological results for the Burnham site. Despite this, these stratified diverse sediments should not be considered well dated. The gleyed loamy fine sand with the bison skull and artifacts has only six dates. Three accelerator results are from the red alluvium that underlies the bison skull and artifacts, and a single accelerator date is from the sediment overlying the skull and artifacts. Two other dated samples come from other strata in the sequence of ponds and channel fills. The remaining dated sample (NZA-4381) is the poorly selected charcoal fragment that washed out and was redeposited sometime between the 1986 and the 1988 excavations.

In Figure 19.6 all dates from the East Exposure channel fills are plotted according to their ages and their depths (elevation relative to site datum). In such a chart, if there has been no mixing, the older samples would be expected to occur deeper (earlier) within the channel fills. Even just a glance at Figure 19.6 reveals some inconsistent correlations of age with depth. Most notably, the three oldest dates (AA-3840, NZA-2823, and RA-C0419) occur at least a meter above the channel's base. Below these three dates occur nine samples that yielded younger results. These nine samples include the one (NZA-4381) recognized as having been redeposited by erosion between the 1986 and 1988 excavation seasons. Two others (AA-3838 and RA-C0352), dating respectively 26,820 ± 350 and 22,670 ± 330 years ago, are substantially younger than the other six samples from comparable depths (Fig. 19.6).

Two explanations are possible for the diverse ages of dated samples from similar depths in the East Exposure alluvial sediments. One explanation is that the samples come from mixed deposits. Several spots in the East Exposure fluvial deposits manifested clues to bioturbation and some kind of soft sediment deformation. The most obvious clues to bioturbation are the vertical krotovinas that typically extend from red sediments down into grey (gleyed) sediments. These krotovinas are 3 to 5 cm wide and resemble crayfish burrows. A few yielded carapace fragments believed to come from crayfish. These krotovinas were easy to spot in plan view (Fig. 19.6) as well as in vertical section (Plate 4a; Fig. 19.8). For this reason, everyone manually digging East Grid squares was told to plot charcoal finds carefully and to pay special attention to charcoal plotted within krotovinas. Consequently, when selecting charcoal or hackberry seeds for radiocarbon dating, no samples were submitted if they came from recorded krotovinas or from squares riddled with krotovinas. Another clue to bioturbation was the unusual "flare" of red sediment (Plate 3a) some 3.0m north of where the bison skull and artifacts were found. The origin of this unusual boundary feature is still not determined although the explanation that it resulted from a large mammal walking in the pond seems plausible. Not observed elsewhere, this kind of disturbance doesn't appear to be a likely cause for moving more recent charcoal or hackberry seeds into older deposits. Finally, soft sediment deformation may be indicated by distorted boundaries between grey and red alluvial deposits observed along segments of the North 3 and West 15.5 backhoe trenches (Fig. 19.9). While the visible traces of such disturbances are obvious, they don't really demonstrate how more recent charcoal or seeds could be moved downward in the profiles.

Bioturbation may have moved some datable organics in the East Exposure, but it is more likely that the sediments washing into the ancient ponds contained organic material of different ages. The dated samples attest to four different periods. This is best demonstrated by plotting the samples according to their individual results (Fig. 19.10). Two samples date between 12,000 and 10,000 years ago; 2 others fall between 27,000 and 22,000 years ago; 8 between 40,000 and 30,000 years ago; and 2 between 48,000 and 42,000 years ago. Clearly, a majority of the radiocarbon dated samples from the ponded sediments fall between 40,000 and 30,000 years ago. Because this period overlaps with that (40,000 to 34,500 years ago) for the Burnham paleosol, the dates could indicate that the ponds were essentially contemporaneous with the paleosol. But the noticeable boundary (Fig. 19.5) between the sediments and the paleosol truncates the western extent of the latter and indicates that some of the sediments accumulated in a depression or channel that was younger than the paleosol. In fact, the alluvium in the two lowest gleyed deposits (Carter's Units IIB and IIC; Fig. 19.1) occurs below the paleosol (which was at elevation 98.0). From these lowest sediments come 9 of 10 radiocarbon dates on charcoal or hackberry seeds. Of these 9 dates, 6 (samples AA-3840, NZA01416, NZA02823; RA-C0291, RA-C0353, and RA-C0419; Table

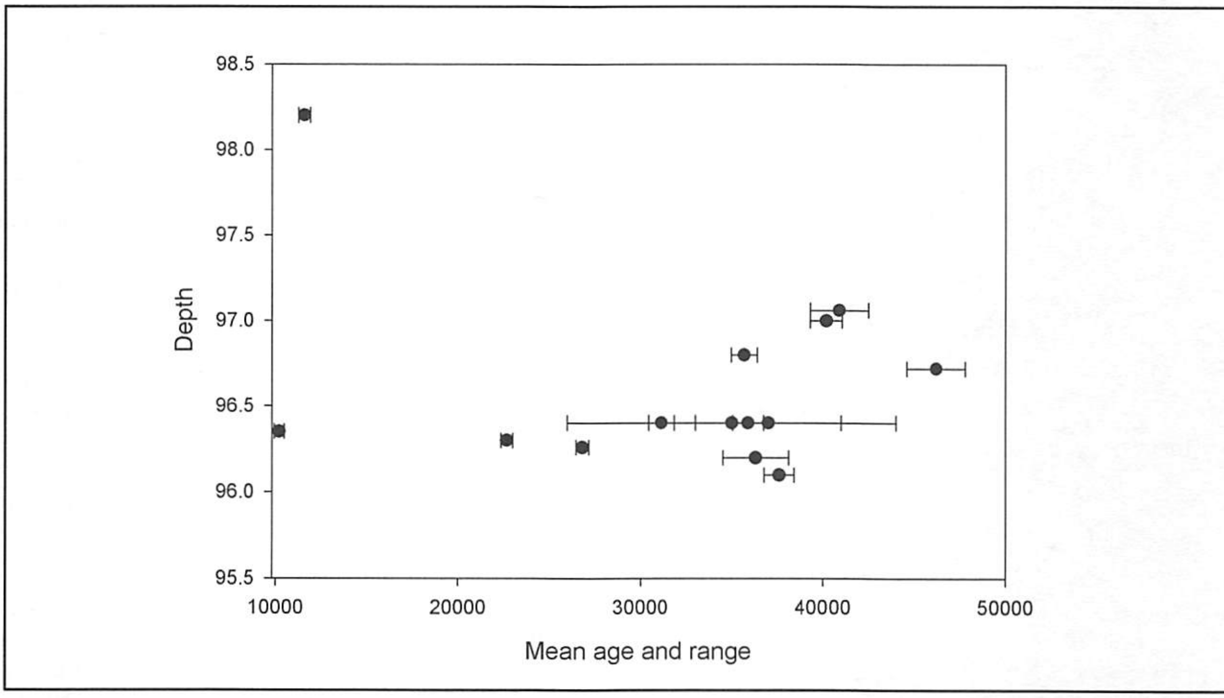


Figure 19.6. Plot of uncorrected radiocarbon and accelerator dates and their respective depths in fluvial sediments from the East Exposure of the Burnham site.

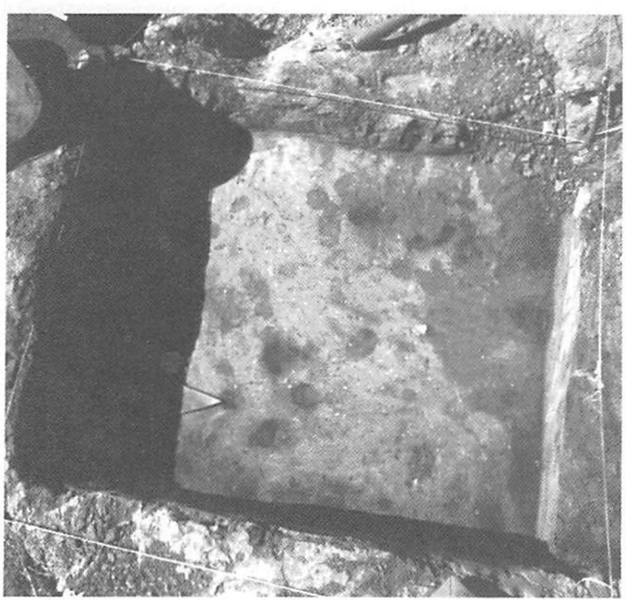


Figure 19.7 (above). Plan view of krotovinas in East Grid square N1-W19 at elevation 98.0. Photo taken October 7, 1989, by Don Wyckoff

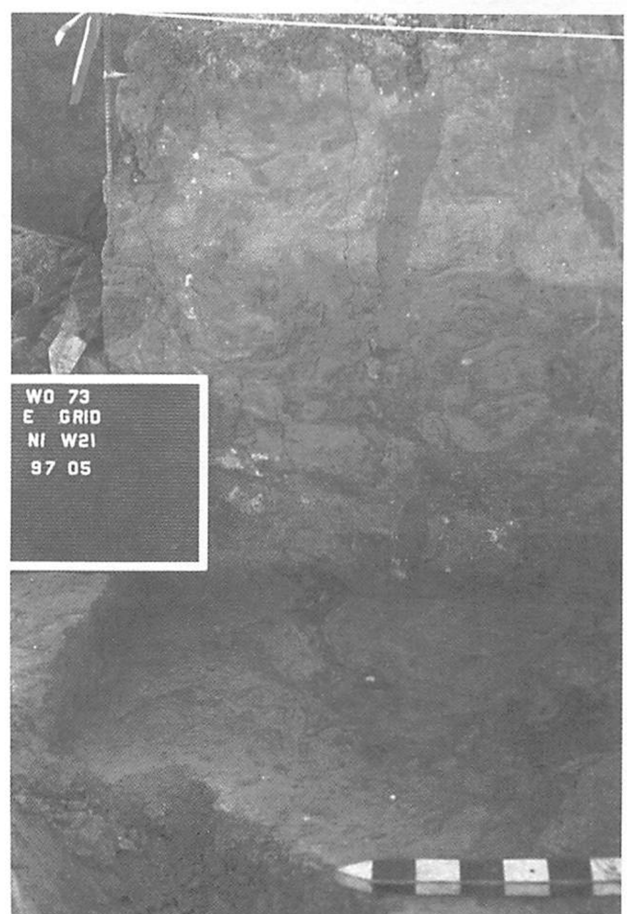


Figure 19.8 (right). View east of krotovina profile in east side of East Grid square N1-W21. Floor is at elevation 97.05. Photo taken October 15, 1989, by Byron Sudbury.

Figure 19.9. View northwest of deformed sediments in East Exposure where West 15.5 and North 3 backhoe trenches intersect. Photo taken October 11, 1989, by Don Wyckoff.

19.2) are as old as, or older than, those from the Burnham paleosol. Given their lower elevations than the paleosol, these six dated samples could easily be detrital organics eroded from the Burnham paleosol or an older one nearby.

So, when did the ponds exist? They could be slightly younger than the Burnham paleosol. Two dates (Beta-33950 and RA-C0353) from this paleosol have one-sigma ranges that overlap around 38,500 years ago (Fig. 19.11). Sample SMU-2422 (Table 19.1) implicates the Burnham paleosol might be as much as 4000 years younger.

Five dates from East Exposure alluvium indicate these sediments are younger than the Burnham paleosol. One such date is the electronic spin resonance (ESR) result obtained on sediment adjacent the *Bison chaneyi* skull. Although it has a very large one-sigma range, this ESR date is 35,000 years ago. Because they are derived from carbon of shells of snails living in and adjacent the ancient ponds, two radiocarbon dates on snails from the East Exposure are perhaps most relevant for establishing the antiquity of the ponds. One batch of mixed aquatic and terrestrial snail shells was dated by routine radiocarbon assessment at 31,150 ± 700 years ago (Beta-23045). Another sample of unsorted shells from the same context was accelerator dated at 35,890 ± 850 years ago (AA-3837). On the basis of these results the lowest prehistoric pond deposits (Units IIB and IIC) were present some 35,000 to 31,000 years ago. They were either contemporary with the formation of the Burnham paleosol or a couple of thousand years later than its formation.

Two other dated samples (AA-3838 and RA-C0352) of

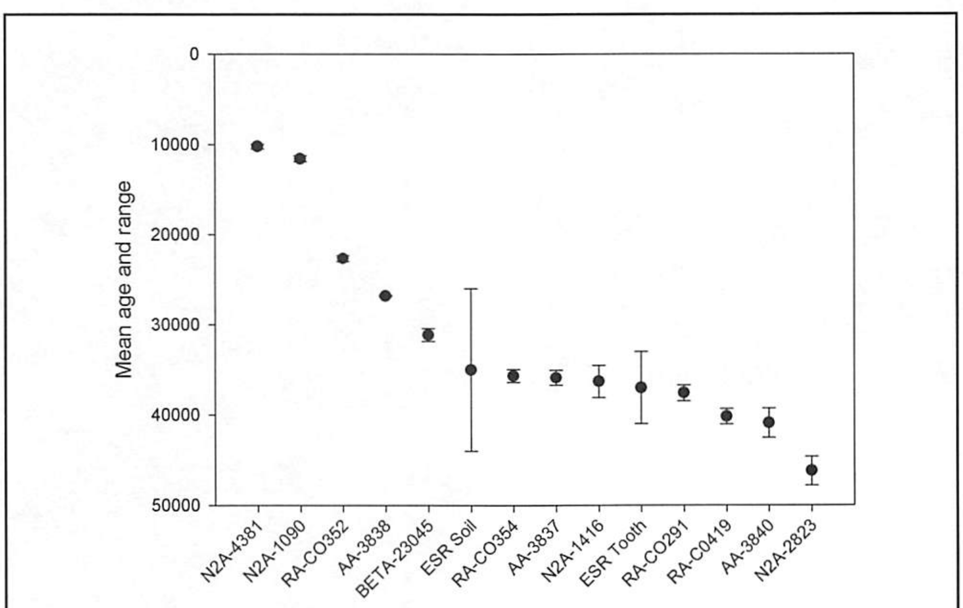


Figure 19.10. Radiocarbon dates (one sigma range) from the fluvial sediments in the East Exposure plotted by age.

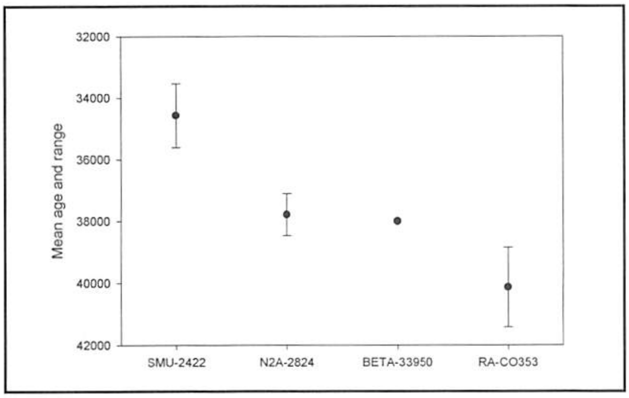


Figure 19.11. Radiocarbon dates (with one sigma factor) for the Burnham paleosol.

charred organics come from strata (and elevations) lower than the Burnham paleosol but indicate that these lower pond deposits may have formed between 27,000 and 22,000 years ago. The dates on these two samples are in stratigraphic order, the oldest being from (at elevation 96.26) the red sediment under the artifact-bearing stratum, the youngest from (at elevation 96.3) near the bottom of the artifact-bearing stratum (Table 18.2). In contrast to sample NZA-4381, neither of these two samples appears to come from recently redeposited sediment, so they comprise evidence the lower pond sediments (Units IIB and IIC) might be 10,000 to 12,000 years more recent than the Burnham paleosol.

Pond Sediments in the Northwest and Southwest Exposures

Occurring at comparable elevations and yielding similar vertebrate fossils, the Northwest and Southwest exposures of gleyed sediments undoubtedly are part of the same ponding events that created the lower alluvial deposits in the East Exposure. The Northwest Exposure is also known to contain the same gastropod assemblage as the East Exposure alluvium (Theler, this volume), and selected species of aquatic and terrestrial gastropods were accelerator dated (Table 19.2) to establish a chronology for the Northwest Exposure. Unfortunately, no materials were radiocarbon dated from the Southwest Exposure.

The dating of selected terrestrial and aquatic snail species from the Northwest Exposure partially supports the age of the East Exposure's lower alluvial deposits. Shells of the aquatic species *Physella virgata* yielded an accelerator date of 37,215 ± 940 years ago (AA-11687). This result does overlap the 35,800 year-old date (AA-3837) obtained from a mixture of land and water snails from the East Exposure gleyed sediments.

Disappointingly, the accelerator date (42,785 ± 1800 years ago; AA-11688) on the terrestrial species *Hawaiia minuscula* from the Northwest Exposure does not overlap with either the other accelerator date from that exposure or the 35,800 year-old result on unsorted snails from the East Exposure pond sediments. Since the 1980s, extensive research has been conducted on the chemical isotopes of snails and their relevance for reliable dating or indicating past environments (e.g., Goodfriend 1987, 1989; Goodfriend and Magaritz 1987; Goodfriend and Stipp 1983; Goslar and Pazdur 1985; Vita-Finzi and Roberts 1984). Land snails can date older than expected because they ingest old carbonate from alga and lichens growing on carbonate rocks;

Figure 19.12. Gray sediments of Unit IID overlain by red sediments with carbonate nodules and occasional bones in East Grid square N3-W19 at elevation 98.1. A radiocarbon sample from these red sediments was dated at 11,580 ± 320 years ago. Photo taken by Don Wyckoff on October 20, 1989.

they also ingest old carbonate by just moving across such rocks (Goodfriend 1987). While it may eventually be possible to develop correction factors when dating fossil land snails, such correction factors are not now available for the dated land species from the Burnham site's Northwest Exposure.

Final Ponding and Soil Development

We see little evidence that the lowest pond deposits resulted from standing water that was present very long. That these ponds existed more than a decade or two would be surprising. The soils at this location erode easily with running water. The usual vertical walls from such erosion dissolve at water's edge when they are adjacent standing water. This results in gully walls collapsing into the pool, eventually to nearly fill it. Red sediment from such a process may be represented at elevation 98.0 in the East Exposure. A radiocarbon date of 11,580 ± 320 years ago (NZA-1090) at elevation 98.2 in this exposure bears witness to carbonate-rich sediment and occasional bones collecting in a shallow depression after the Wisconsinan full glacial.

Surprisingly, nowhere in the Burnham site profiles was any horizon or stratum identified that could be attributed to Wisconsinan full glacial times. Elsewhere on the Southern Plains this period (21,000 to 16,000 years ago) is well represented by sediments and vertebrate and invertebrate fossils indicative of a cooler climate with more effective precipitation than today (Caran and Baumgardner 1990; Dalquest and Schultz 1992; Gustavson et al. 1991). A quarter mile south of the Burnham site does occur an extensive, thick, black, silty deposit (the Bouziden Exposure; Wyckoff 2000) with aquatic and terrestrial gastropods dated to the Wisconsinan full glacial. Yet nowhere in the Burnham sequence is such a time and climatic condition manifest.

As noted above, a shallow depression was apparently present at Burnham around 11,500 years ago. In it accumulated a thin, narrow stratum of gleyed silty sand that lacked fossils. This deposit attests to ephemeral standing water of short duration. After this ponding event, the location was blanketed with carbonate-rich, red, silty sediment of likely aeolian origin. Subsequently, the modern arroyo was eroded into the landscape to eventually expose the Burnham site's Pleistocene sequence. We have no chronological results to ascertain when this last erosion occurred, but in all likelihood it was during mid-Holocene times.

Summary

Twenty-three chronological assessments indicate the Burnham site deposits date from around 40,000 to nearly 10,000 years ago. Notably, however, the depositional sequence doesn't have a stratum or horizon that can be pinpointed as being representative of the full glacial times of 21,000 to 16,000 years ago. The Burnham site's significant depositional contexts include a paleosol and four pond deposits. These latter are stratified and nearly fill a depression or channel adjacent the paleosol. Diverse kinds of fossils occur with the paleosol and the three lowest pond deposits. Chipped stone artifacts were recovered from the second lowest pond deposit and appear to have washed into that setting from somewhere immediately east of the deposit.

The paleosol is thin, argillic, and calcic. From it come seeds and plant remains indicating it was a viable habitat for plants and animals around 36,000 or 37,000 years ago. This paleosol was adjacent wetlands and ponds probably created by beaver activity. Calcium carbonate enriched the soils through translocation and water saturation in this paleosol before it was buried. In the low stream channel adjacent the paleosol, red and gray (gleyed) sediments accumulated during a period when a sequence of ponds existed. Fourteen chronological assessments were obtained from snails, hackberry seeds, charcoal fragments, sediments, and animal teeth recovered from these fluvial sediments. A majority of the dates from these contexts fall between 40,000 and 30,000 years ago. Snails living in or adjacent to these ponds yielded dates implicating these lacustrine settings are 35,000 to 36,000 years old. Because virtually all of the artifacts were recovered from the second lowest pond deposit, these items are believed to be equally old. Subsequent filling of the ancient depression was by carbonate rich, red sediment of probable fluvial origin and by a thin, gray, sandy sediment that collected in a shallow, ephemeral pond some 11,000 years ago. This last setting failed to yield fossils of any kind or any signs of the presence of humans.

References Cited

Bard, E., B. Hamelin, R.G. Fairbanks, and A. Zindler. 1990. Calibration of the 14C Timescale over the Past 30,000 Years Using Mass Spectrometric U-Th Ages for the Barbados Corals. *Nature* 345:405-410.

Caran, S.C. and R.W. Baumgardner, Jr. 1990. Quaternary Stratigraphy and Paleoenvironments of the Texas Rolling Plains. *Geological Society of America Bulletin* 102:768-785.

Caran, S.C., R.W. Neck, and R.W. Fullington. 1985. Paleoclimatic Reconstruction Based on Molluscan (Gastropoda; Pelecypoda) Environmental Indicators—Late Quaternary of Northwestern Texas. University of Texas at Austin, Bureau of Economic Geology, unpublished file report OF-WTWI-1985-27. Austin.

Dalquest, W.W. and G.E. Schultz. 1992. *Ice Age Mammals of Northwestern Texas.* Midwestern State University Press, Wichita Falls.

Dalquest, W.W., F.B. Stangl, Jr., and M.J. Kocurko. 1990. Zoogeographic Implications of Holocene Mammal Remains from Ancient Beaver Ponds in Oklahoma and New Mexico. *The Southwestern Naturalist* 35:105-110.

Evin, J., G. Marechal, C. Pachiaudi, and J.J. Puissegur. 1980. Conditions Involved in Dating Terrestrial Shells. *Radiocarbon* 22(2):545-555.

Goodfriend, G.A. 1987. Radiocarbon Age Anomalies in Shell Carbonate of Land Snails from Semi-Arid Areas.

Radiocarbon 29(2):159-167.

Goodfriend, G.A. and M. Magaritz. 1987. Carbon and Oxygen Isotope Composition of Shell Carbonate of Desert Land Snails. *Earth and Planetary Science Letters* 86:377-388.

Goodfriend, G.A. and J.J. Stipp. 1983. Limestone and the Problem of Radiocarbon Dating of Land-Snail Shell Carbonate. *Geology* 11:575-577.

Goslar, T. and M.F. Pazdur. 1985. Contamination Studies on Mollusk Shell Samples. *Radiocarbon* 27(1):33-42.

Gustavson, T.C., R.W. Baumgardner, Jr., S.C. Caran, V.T. Holliday, H.H. Mehnert, J.M. O'Neill, and C.C. Reeves, jr. 1991. Quaternary Geology of the Southern Great Plains and an Adjacent Segment of the Rolling Plains. *Quaternary Nonglacial Geology, Conterminous United States*, edited by R.B. Morrison, pp. 477-501. Geological Society of America, The Geology of North America, Vol. K-2. Boulder, Colorado.

Haynes, C.V., Jr., D.J. Donahue, A.J.T. Jull, and T.H. Zabel. 1984. Application of Accelerator Dating to Fluted Point Paleoindian Sites. *Archaeology of Eastern North America* 12:184-191.

Hibbard, C.W. 1970. Pleistocene Mammalian Local Faunas from the Great Plains and Central Lowland Provinces of the United States. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Knox, Jr., pp. 395-433. University of Kansas, Department of Geology, Special Publication 3.

Johnson, W.C. (editor). 1987. *Quaternary Environments of Kansas.* Kansas Geological Survey, Guidebook Series 5. Lawrence.

Miller, B.B. 1975. A Sequence of Radiocarbon-Dated Wisconsinan Nonmarine Molluscan Faunas from Southwestern Kansas-Northwestern Oklahoma. *Studies in Cenozoic Paleontology and Stratigraphy*, edited by G.R. Smith and N.E. Friedlund, pp. 9-18. University of Michigan, Museum of Paleontology, Ann Arbor.

Rubin, M. and D.W. Taylor. 1963. Radiocarbon Activity of Shells from Living Clams and Snails. *Science* 141:637.

Stephens, J.J. 1960. Stratigraphy and Paleontology of a Late Pleistocene Basin, Harper County, Oklahoma. *Bulletin of the Geological Society of America* 71:1675-1702.

Taylor, D.W. and C.W. Hibbard. 1955. *A New Pleistocene Fauna from Harper County, Oklahoma.* Oklahoma Geological Survey, Circular 37. Norman.

Taylor, R.E. 1987. *Radiocarbon Datin, An Archaeological Perspective.* Academic Press, New York.

Wang, Y., A.H. Jahren, and R. Amundson. 1997. Potential for 14C Dating of Biogenic Carbonate in Hackberry (*Celtis*) Endocarps. *Quaternary Research* 47:337-343.

Wyckoff, D.G. 2000. Geoarchaeology and Past Environments in the West Moccasin Creek Drainage, Northwestern Oklahoma. Unpublished paper given at the 65th Annual Meeting of the Society for American Archaeology, Philadelphia, Pennsylvania.

Wyckoff, D.G., B.J. Carter, P. Flynn, L.D. Martin, B.A. Branson, and J.L. Theler. 1992. *Interdisciplinary Studies of the Hajny Mammoth Site, Dewey County, Oklahoma.* Oklahoma Archeological Survey, Studies in Oklahoma's Past 17. Norman.

Wyckoff, D.G. and W.W. Dalquest. 1992. From Whence They Came: The Paleontology of Southern Plains Bison. *Plains Anthropologist Memoir* 29:5-32.

Yates, T. 1986. Studies of Non-Marine Mollusks for the Selection of Shell Samples for Radiocarbon Dating. *Radiocarbon* 28(2A):457-463.

Chapter 20
Looking Back on an Odyssey: Summarizing the Findings at the Burnham Site

Don G. Wyckoff, Brian J. Carter, and James L. Theler

Ten years after the last major fieldwork at the Burnham site should be enough time to have gained a perspective on what we did, what we found, and what we learned. One thing is certain. What started out as a brief, simple evaluation of ice-age paleontological materials turned into much, much more. Accordingly, we present here our understanding of the diverse findings. We start by summarizing the geological and pedological evidence and the chronology for the site. The soils and sediments represent the contexts in which the paleontological and archaeological findings gain significance. We then summarize the paleontological findings and their associations with the specific deposits at the Burnham site. Last, we examine the archaeological finds, where they occur, and the clues to their age. Because these chipped stone objects appear to be so old, we review these finds with long established criteria for evaluating purported ancient archaeological finds in North America. Throughout this synthesis we refer to figures and tables in previous chapters.

The Geomorphic Setting: Now and Then

The Burnham site is on gently south-sloping ground that lies between the Cimarron River to the south and a high east-west oriented ridge to the north (Figs. 20.1 and 20.2). Given the site's location relative to these two prominent geomorphic features, what processes created a situation in which late Pleistocene fauna could be preserved in this landscape? Was the slope formed by erosion of the ridge? By valley cutting by the river? By some other process?

A Collapse Basin?

Geologist W. Dort and colleague L. Martin (this volume) offer that the Burnham site might have formed in a collapse basin. This idea was a viable explanation based on the modest geological findings available to Drs. Dort and Martin in 1989. Dissolution of underground salt and gypsum is a common geomorphic process in this part of Oklahoma (Fay 1965:14). That it happened at the Burnham site seems unlikely. Good exposures of horizontal bedrock are visible less than a quarter mile west, northwest, east, and south of the site. Nowhere is there any hint of dip attributable to localized basin development due to dissolution of underlying mineral beds and the collapse of overlying terrain.

A River Terrace?

The Burnham site appears positioned on an ancient terrace of the Cimarron River. An orthographic projection for westernmost Woods County depicts a series of bench-like

Figure 20.1. A view east showing the terrain in which the Burnham site occurs. To the left is the high ridge capped with the Ogallala Formation, and to the right is the south-sloping land underlain by the Permian Marlow Formation. The Burnham site is exposed in the draw running through the center of the picture. Photo taken in 1998 by Don Wyckoff.

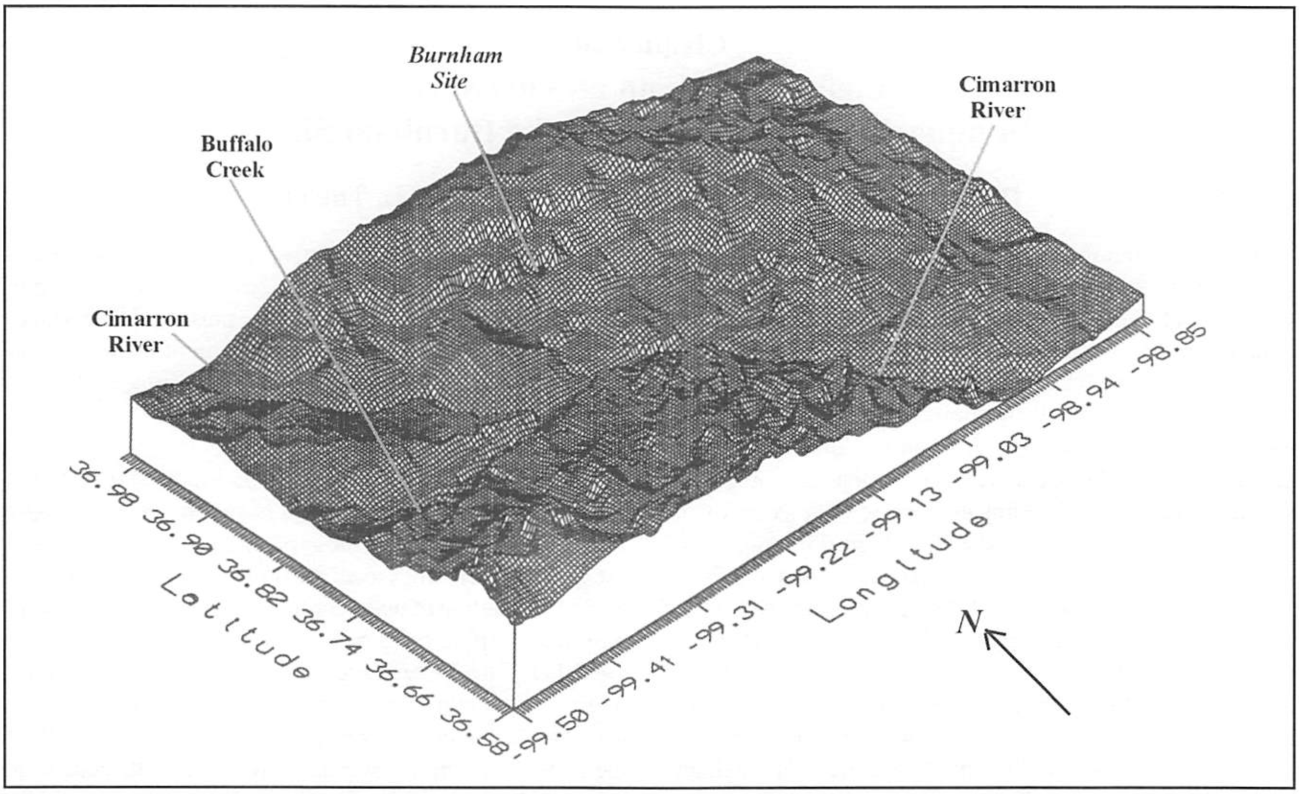


Figure 20.2. An orthographic projection (looking northeast) of western Woods County, the historic course of the Cimarron River, and the location of the Burnham site. Illustration courtesy of J. Peter Thurmond.

settings (Fig. 20.2) north of the river, and the Burnham site is plotted on the second (or middle) of three such benches. Geologist R.O. Fay (1965:87) reports that at least three terrace levels are traceable north of the Cimarron River. Fay (1965:Plate I) mapped Cimarron River sand and gravel as close as three-quarters of a mile west and one mile south of the site.

Although the Cimarron River could have created the original setting for the Burnham site, several factors seem to mitigate against such an interpretation. One such factor is that our surveys of creek and gully walls within a half-mile of the site failed to reveal any clues that the Cimarron River flowed here. We did observe gravel deposits here and there, but their alignments (usually north-south or northeast-southwest) and their lithologies seem more compatible with them being Ogallala Formation pebbles and cobbles redeposited by streams draining off the high ridge north of the site. Notably lacking in these deposits are clasts of scoria and basalt, two materials incorporated into Cimarron River gravels as this stream drains the volcanic fields of northeastern New Mexico and adjacent Colorado.

The Burnham site is about 60 m above the present bed of the Cimarron River. Relative to the terrace sequences recognized by Fay (1959, 1965), such an elevation would correlate with Middle Pleistocene times. Elsewhere, such an age is borne out by fission track dates on volcanic ash buried in terraces along major streams draining this region. Extensive contructional terraces are known along the Arkansas River and its tributaries such as the Cimarron, North Canadian, and Canadian (Carter et al. 1990). Terraces found 40 to nearly 70 m above these rivers contain beds of ash identifiable as Lava Creek B, and this ash yields fission track dates of around 600,000 years ago (Carter et al. 1990). The fossils and radiocarbon dates for the Burnham site indicate its deposits are much younger, so, despite its elevation above the Cimarron River, the Burnham site is not the result of this river's flow and deposition.

The Burnham site itself is much younger than when the river flowed nearby (a mile to the south). Instead, the Burnham site is believed contemporaneous with deposits along the current course of the river. The basis for this belief is Fay's (1965:87-88) observations that the river's oldest fluvial deposits occur at high elevations north and east of the present course and that successively younger river deposits occur at lower and lower elevations nearer the present flood plain. This northeast-southwest successive distribution occurs because the river has been shifting southwestward through the Pleistocene due to its channel cutting down along the southwest dipping bedrock common to this region (ibid.). The 30 to 50 feet of sand and gravel present in the modern channel is believed (Fay 1965:88) to represent what the river built up in its flood plain since early Wisconsinan time. Most radiocarbon dates for the Burnham site indicate its deposits are middle to late Wisconsinan in age.

A Late Pleistocene Tributary to the Cimarron?

After four seasons of fieldwork, diverse clues support the conclusion that the Burnham site was part of a former incised stream draining the high ridge to the north. Moreover, the available radiocarbon dates and the site's stratigraphy indicate that this stream was mainly active before Wisconsinan full glacial times (also called the Last Glacial Maximum, beginning about 21,000 years ago).

The first clues that this was some kind of fluvial setting were several beds of fossil-bearing, gray, fine sediment uncovered on both sides of a short, deep draw. What we have called the East, Northwest, and Southwest exposures consist of gleyed loamy fine sands and fine sandy loams marked by swirling and linearly variegated reds and yellows. These characteristics attest to aggrading alluvium and anaerobic decomposition of organic matter under water. Common to these fine sediments are bones of fish (representing very few species) and shells of aquatic snails indicative of different water conditions. One snail species (*Valvata tricarinata*) bears witness to this stream being spring-fed at one time during its existence.

Systematic, widespread coring at the site revealed that the near-surface gray (redoximorphic soil features) sediments that initially attracted our interest were actually underlain by 4.0 to nearly 7.0 m of reddish brown alluvium. Cores taken deeper than 4.0 m typically penetrated stratified clay and some fine sandy textured sediments. Frequently, these cores included and were terminated by gravel lenses (Tables 5.2 and 6.2). Clasts recovered from these lenses included calcite, quartzite, and red sandstone along with manganese-blackened pebbles. These lowest lenses may well be basal gravels resting in a gully or canyon cut into the Marlow sandstone bedrock that underlies the gently sloping terrain south of the high ridge.

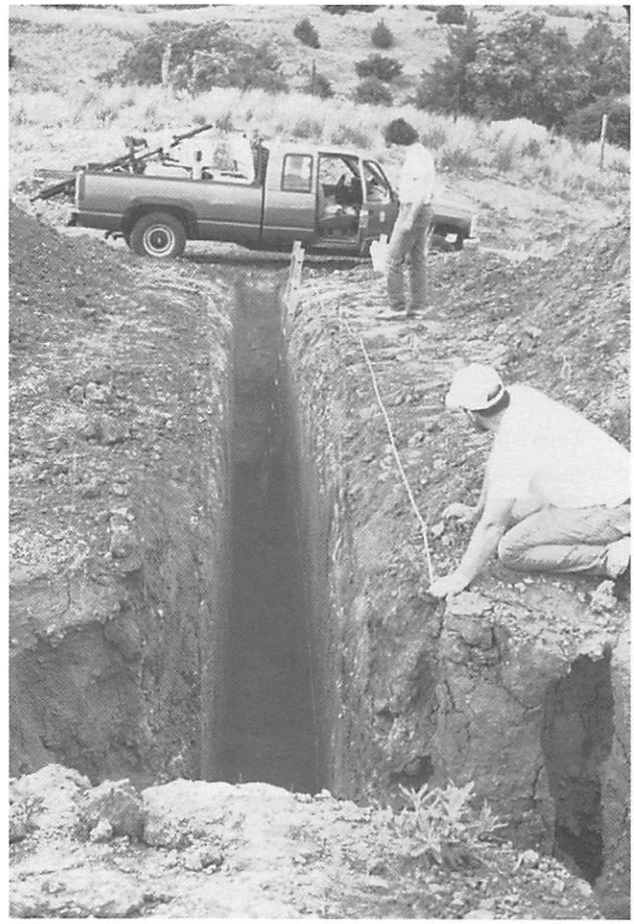


Figure 20.4. Looking south at the 1991 backhoe trench and the gravel covered exposure of Marlow sandstone at the trench's south end (beyond ladder). Photo taken in May of 1991 by Don Wyckoff.

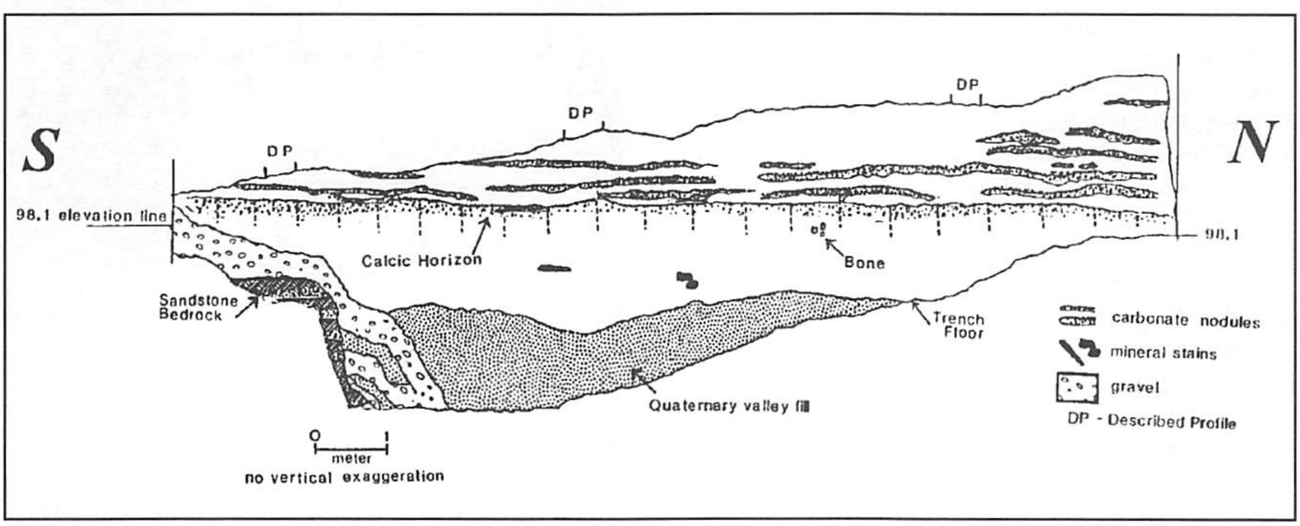


Figure 20.3. Profile of the calcic paleosol, underlying sediments, and gravel drapped over Marlow Formation sandstone as exposed in the 1991 backhoe trench dug at the East Exposure. Depths are in meters and are relative to elevation of 100 assigned to the site's datum. Profile by Don Wyckoff.

That a watercourse was cut into the underlying Marlow Formation sandstone was surprisingly revealed in 1991. At that time, a short trench was dug with backhoe to further trace the site's earliest paleosol from its initial exposure in the East Exposure's North 3 backhoe trench. As expected, the earliest paleosol was found as well as more than a meter of fine textured, reddish brown alluvium underneath it (Figure 20.3). Unexpected, however, was the discovery of a nearly vertical wall of Marlow sandstone at the trench's south end (Figs. 20.3 and 20.4). Over 2.0 m high, this wall was mantled and draped with gravel, the pebbles and cobbles of which resemble Ogallala Formation clasts. Their presence attests to rapid water flow and channel scouring into the Marlow Formation as well as to redeposition of Ogallala Formation gravels washed from their original context on the high ridge north of the site.

Figure 20.5. View north of a single boulder of Day Creek dolomite protruding from gray sediment of the Southwest Exposure. Photo taken in 1990 by Don Wyckoff.

Figure 20.6. View east of a single boulder of Day Creek dolomite in square S6-W2 of the Northwest Exposure. Photo taken June 1, 1991, by Don Wyckoff.

Figure 20.7. View south of the calcic, argillic Burnham paleosol as exposed in East Grid square 0-N4. Photo taken May 31,1991, by Don Wyckoff.

Waterworn, angular to subangular clasts of Day Creek dolomite comprise additional evidence that the paleostream was draining the ridge north of the site. Day Creek dolomite is the ledge-forming member in this ridge (Fay 1965:77-78). Pebbles and cobbles of this dolomite are common components in gravels at the site. Especially noteworthy are the occasional dolomite boulders found in the gray sediments of all three exposures at the site (Figs. 2.13, 20.5, and 20.6).

Based on these findings, we believe that the lowest part of the Burnham sequence is a thick (4 to 7 m) deposit of fluvial sediments that accumulated in a stream-cut gully or canyon. Many details about this setting are lacking. We don't know its width, and we aren't sure of its orientation. We suspect the latter is northeast to southwest, roughly paralleling the modern tributary, West Moccasin Creek, south of the site. Although coring and bulldozer trenching were undertaken, respectively, 210 and 140 m north of the East Exposure, neither excavation got deep enough to ascertain a north edge for the stream-cut setting.

Accumulating Sediments and Soils

All manually dug squares, backhoe trenches, bulldozer trenches, and machine-recovered cores reveal that water-carried sediments accumulated in an incised watercourse at the Burnham site. Among the last such aggrading sediments are yellowish red (Munsell 5YR 4/6), reddish brown (2.5YR 4/4) to red (2.5YR 4/6) loamy very fine sands and very fine sandy loams (Tables 5.2 and 6.2). Once these had accumulated to nearly the top of the gravel-draped bedrock wall, fluvial sedimentation (overbank deposition) outside the stream's channel slowed appreciably and soil development began. This latter involved formation of a thin, calcic, argillic soil horizon (Fig. 20.7). We have referred occasionally to this as the Burnham paleosol, a name which we formally adopt at this time.

Our knowledge of the Burnham paleosol's expanse is limited. We know it has a north-south extent of at least 60 m. Within this distance, it slopes about a meter. In Bulldozer Trench B this paleosol occurs around elevation 99.0, and it is just below 98.0 in the 1991 backhoe trench. Its largest east-west extent was in Bulldozer Trench B where nearly 20 m could be traced.

The Burnham paleosol represents an horizon wherein calcium carbonate-enriched clay was concentrated after having been moved downward in the extant soil profile. This calcium carbonate and clay concentration in a thin horizon implicates that the environment at that time did not provide much more precipitation than today's. That is, enough precipitation was dissolving and translocating calcium carbonate and free clay particles for movement to the subsoil, but there wasn't such an abundance of moisture that it could move this mineral-clay combination deep or out of the existing profile. The thinness of the Burnham paleosol may indicate a relatively short time for its development. As part of a soil profile, however, this now deeply buried horizon was formerly a medium that supported plants and animals. In and directly above it were recovered occasional bones (usually badly deteriorated) as well as charred wood and snails. Also, one extensive rodent burrow (Feature #1 in Bulldozer Trench B) was found extending into this horizon.

The Burnham paleosol's age has been assessed by four radiocarbon dates. Two are on charred wood (identified as pawpaw, *Asimina triloba*) found with the horizon where it was first exposed near the east end of the North 3 backhoe trench in the East Exposure. These two dates are: >38,000 years B.P. (Beta-33950) and 34,570 + 1040 years B.P. (corrected ^{14}C age; SMU-2422). The other two dates are on a hackberry (*Celtis*) seed and a piece of charcoal recovered from the rodent burrow (Feature #1) in Bulldozer Trench B: 40,130 + 1289 years B.P. (RA-C0353) and 37,790 + 680 years B.P. (NZA-2824). All of these dated samples are plant remains or, in essence, things that grew on the former soil. Consequently, the soil's age is most likely older than the radiocarbon dates. We estimate the Burnham paleosol to be around 42,000 or 43,000 years old.

An A soil horizon was not recognizable directly above the Burnham paleosol. Instead, this paleosol was covered with more sediment. Sandy clay loam to very fine sandy loam in texture (Table 5.2), this overlying material was yellowish red (5YR 5/8) to reddish brown (5YR 4/4) and was enriched with calcium carbonate. Slightly more than 80 cm of this material accumulated, from some overbank as well as aeolian deposition, and underwent pedogenesis that resulted in the formation of several discontinuous layers of soft to slightly hardened calcium carbonate nodules. We believe these calcium carbonate-rich soil horizonst formed as the ground surface increased in height from accumulating sediments. This created a cumulic soil.

Where the Burnham paleosol was plotted, the development of the Burnham site locality was due to the steady accumulation of fine sandy sediments and to the stability for sufficient time for calcium carbonate (caliche) layers to form. Almost 2.0 m of such profiles are recorded at the Burnham East Exposure, over 5.0 m in Bulldozer Trench B, and over 3.0 m in Bulldozer Trench A some 200 m north of the East Exposure (Fig. 20.8). The parent material for these silts and fine sands forming these profiles is believed to be windblown and washed downslope from the base of the high ridge to the north. Regrettably, we were unable to follow up with adequate dating of these thick exposures of cumulic, calcic soils. Datable organic material was sparse in the recorded profiles, and even when recovered it was given low

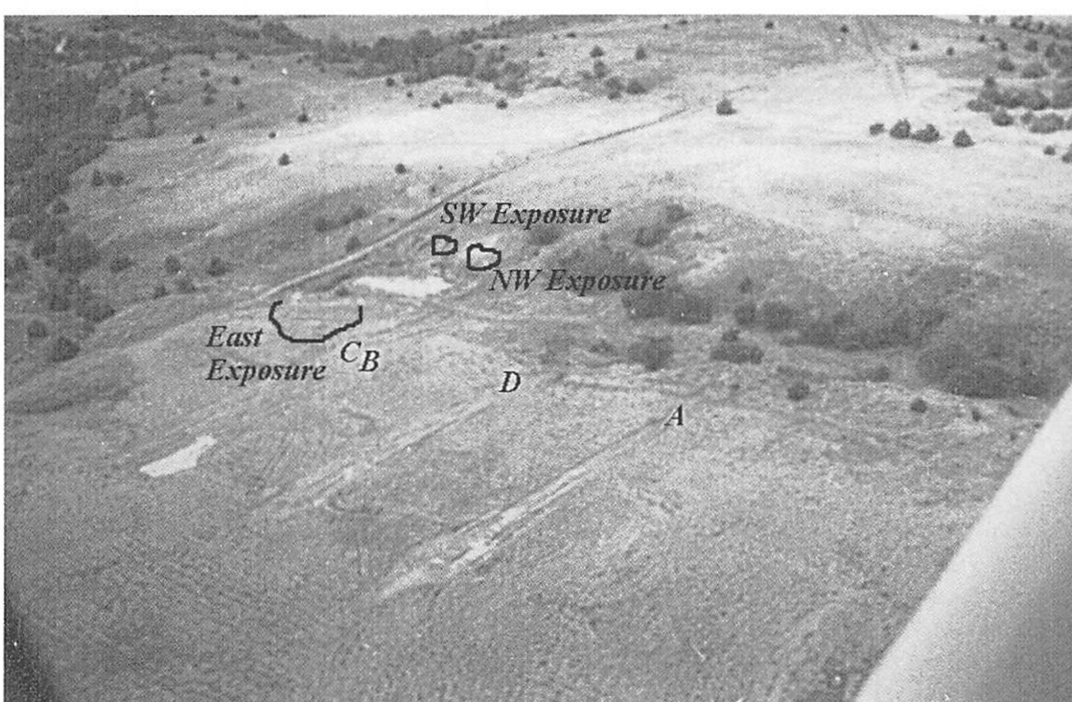


Figure 20.8. Aerial view southwest of the Burnham site and the four refilled bulldozer trenches(A, B, C, and D). In the upper left corner can be seen the junction of the West Moccasin Creek with the draw in which the Burnham site occurs. Photo taken August 4, 1992, by Don Wyckoff.

Figure 20.9. Aerial view east of West Moccasin Creek, the major southwest tributary's confluence with West Moccasin Creek, and the Wisconsinan full glacial pond deposit known as the Bouziden Exposure (marked a). The draw marked "b" above West Moccasin Creek is the one in which the Burnham site occurs. Photo taken August 4, 1992, by Don Wyckoff.

priority because of the greater concern to date samples from the fossil- and artifact-bearing strata. Most disappointing in the soil profiles is the lack of visible clues to Wisconsinan full glacial times. Presumably, this region was under the influence of a cooler, more moisture-effective climate. But we see nothing at the Burnham site that is comparable to the thick lacustrine deposits observed at the Bouziden exposure a quarter mile south of the Burnham site (Fig. 20.9). Radiocarbon dates on snail shells from the Bouziden sediments indicate they were deposited during Wisconsinan full glacial times.

A Pond Sequence at the Burnham Site

The Burnham site's accumulating calcic (calcium carbonate-rich) soils were disrupted at least once by stream incision and overbank deposition. So, the site contains a record of accumulating soils and aggrading alluvium. Each later (higher) accumulation of alluvial sediments rests in a bed whose eastern edges are farther west than preceding beds (Fig. 20.10). Clearly, the stream channel was aggrading and becoming narrower through time. Meanwhile, the calcium carbonate-rich soil continued to thicken as well as develop farther and farther west (Fig. 20.10). Because the colorful alluvial sediments interfinger with, and are overlapped by, the calcic soils, we believe the two processes of filling in and building up the landscape occurred in cycles and essentially contemporaneously. However, as the calcic soils appear to have accumulated continuously, the forma-

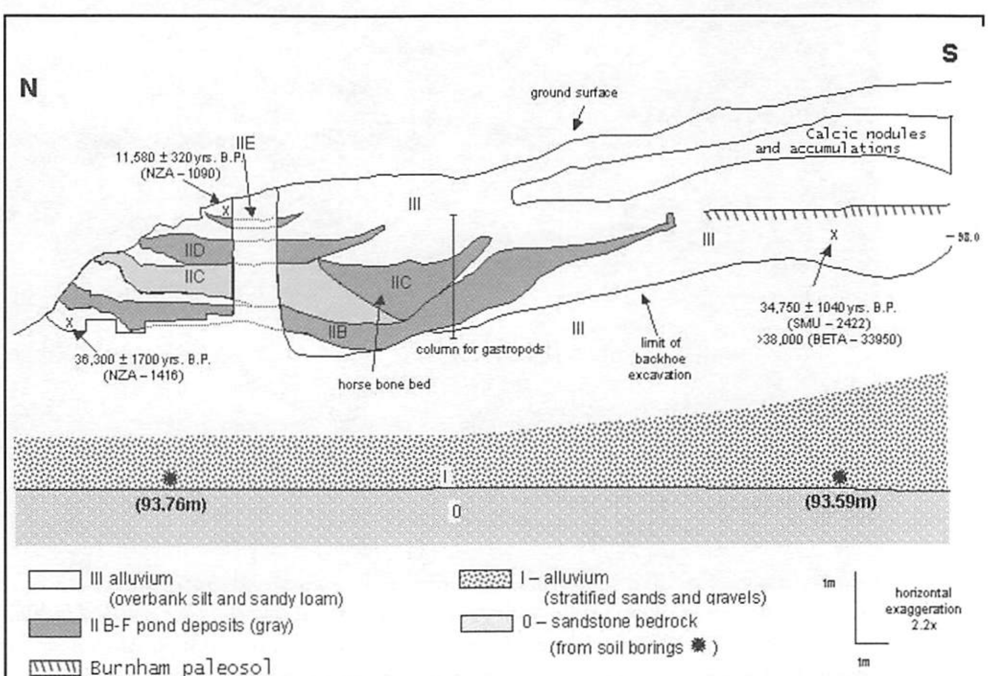


Figure 20.10. East-west profile through the East Exposure showing the stratified alluvial sediments (units IIB-IIE) and the adjacent alluvium in which calcic soils developed. Depths are in meters relative to 100 assigned to the site's datum. Profile prepared by Brian Carter.

tion of ponds are easily recognized as cyclic or sporadic intervals (Fig. 20.10). Extending from the ponds-wetlands (west) to well drained soils (east), this soil catena regressed and transgressed apparently in repsonse to the periodic activities of beavers.

Direct clues for explaining the origins of the several ponds are lacking. Their colorful (gley and redoximorphic-rich) sediments now are perched two to four meters above the modern draw's floor, and the original dams for these ponds were south (and even higher above the modern floor) of where we worked. The slopes of the draw in that direction are thickly covered with grass (Fig. 20.8), and that property's owner did not want the area disturbed. Thus, we undertook no coring or mechanical trenching where the prehistoric dams potentially were located.

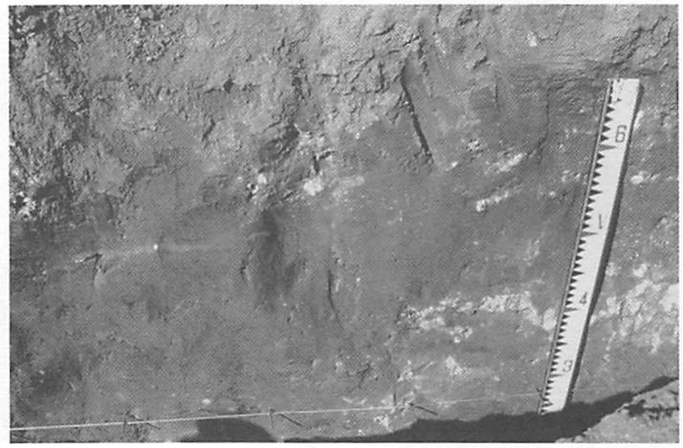


Figure 20.11. Looking north at east boundary between calcic soils (right) and ponded sediments(left) as exposed in East Exposure North 3 backhoe trench. Photo taken October 4, 1989, by Byron Sudbury.

Pleistocene lacustrine deposits abound in upland settings in northwestern Oklahoma and adjacent parts of Texas and Kansas (e.g., Dalquest and Baskin 1992; Dalquest and Stangl 1989; Dalquest and Schultz 1992; Hibbard 1970). After years of recovering late Cenozoic fossils from such settings, paleontologist W.W. Dalquest became convinced that beavers (*Castor canadensis*) were the main creators of the ponds in which the distinctive sediments and fossils accumulated (Dalquest et al. 1990). Although remains of beavers are frequently reported for these settings, not one beaver bone has been recovered from the Burnham site. Despite this, we are inclined to believe that beavers were responsible for the ponding events represented in the Burnham stratigraphic record rather than ponding in a collapse basin or a fault-formed impounded setting.

Figure 20.12. Looking north at west boundary of ponded sediments in East Grid squares 0-W24 and 0-W25. White dashed lines is boundary; scale is in 5 cm increments. Photo taken October 20, 1989, by Brian Carter.

The Drainage Channel

The dynamic nature of the Burnham site's stratigraphy was nowhere better evidenced than the lateral truncation of the Burnham paleosol and the approximately 80 cm of overlying calcic soils (Fig. 20.11). First found in the North 3 backhoe trench of the East Exposure, this diagonal boundary dipped west and was traceable for some 3 m. East of this boundary, the paleosol and overlying calcic soils were manifest (Fig. 20.11). But to the west were intricately combined, stratified, but often only partially nested, lenses of gray or reddish yellow alluvium (Fig. 20.12). Displaying gleying and redoximorphic characteristics, these alluvial sediments also contain discontinuous layers of hard calcite nodules and sometimes even bone with calcite encrustations. Aquatic snails and traces of the aquatic plant *Chara* are common to these sediments, and in some places vertical krotovinas are evident. These biotic traces are clues useful to identifying various niches associated with slow moving water of diverse depths.

In the East Exposure, ponded sediments are stacked in a channel or depression that is some 17.0 m wide (east-west; Fig. 20.10). The depression's east edge is the diagonal boundary that truncates the Burnham paleosol (Fig. 20.11). The west edge was clearly defined in East Grid squares 0-W24 and 0-W25 (Fig. 20.12). The lowest plotted point in this depression was 95.6 (relative to site datum), which is 2.4 m below the Burnham paleosol.

The Northwest and Southwest exposures are unquestionably remnants of one or more of the ponding episodes represented by the East Exposure's gleyed sediments. But unlike the East Exposure, the Northwest and Southwest exposures are composed predominantly of gray, loamy fine sandy sediment that has occasional streaks of red to yellow loamy fine sand. The Southwest Exposure is slightly more than a meter thick, 6.0 m wide (east-west), and nearly 10.0 m in north-south extent (Fig. 20.13). This deposit's western edge has not been ascertained. In 1992, coring was undertaken 10.0 m west (and upslope) of the visible gleyed sediment. Although the retrieved core was 8.15 m long it did not intersect the pond sediment observed in theSouthwest Expo-

Figure 20.13. Looking south at a partial east-west profile of the Southwest Exposure. Photo taken May 27, 1991, by Don Wyckoff.

Figure 20.14. Looking west at the Northwest Exposure while staking out the grid for the first manual excavations there. Photo taken September 23, 1988, by Don Wyckoff.

sure. Consequently, the west boundary must lie somewhere between that core and the gray sediments visible in the short gulleys leading to the modern draw.

In contrast, the Northwest Exposure is gray sediment that fills a wide, shallow, U-shaped channel observed in the west slope of the modern gulley (Fig. 20.14). Twenty-two 1x1 m squares were manually dug in the Northwest Exposure. Fifteen of these squares were dug through the gray sediment and were terminated where that sediment was underlain by reddish brown alluvium (Carter's Group III material).

The Northwest Exposure's lowest boundary was at 96.4 (relative to datum 100.0 m). The base of the Southwest Exposure was plotted at 96.6. These lowest points in the westernmost occurrences of ponded sediments correspond closely with the lowest sediments in the East Exposure. On this basis we are inclined to believe that the Northwest and Southwest exposures accumulated during the early part of

The Pond Sequence

Gray to red sediments intricately fill the channel discerned in the East Exposure excavations. These stratified, partially nested sediments are believed to result from five different episodes of slow moving to standing water that accumulated the respective fine sandy loams and loamy fine sands. Given the associated occurrences of vadose carbonates; aquatic gastropods; bones of salamanders, frogs, and fish; crayfish (Decapoda) burrows; and *Chara* remains, these deposits are representative of diverse pond settings. Consequently, they are lacustrine rather than fluvial or alluvial sediments. In periodic consultation with G.R. Brakenridge, Brian Carter (this volume) has studied and recorded profiles of all of these deposits (Figs. 20.10, 20.15, and 20.16), and so his designations and nomenclature for these strata are adopted here. Table 20.1 summarizes key characteristics of each of the five strata believed associated with the ponding episodes. Additional brief comments on each of these strata are provided below.

Table 20.1. Summary of Ponded Sediment Strata in the East Exposure, Burnham Site.

Final Stratum Designation	Previous Names or Labels[1]	Elevation	Thickness	Color and Texture	Other Characteristics	Relevant Illustrations
Unit IIF	NA Uppermost Pond Deposit	Top: 98.5 Bottom: 98.19	25 to 31 cm	Brown (10YR 5/3) to Yellowish brown (5YR 5/8) clay loam	East-west profile (7.3 m long) exposed in 92A and 92B backhoe trenches. Partial north-south profile in West 15.5 backhoe trench; perched high, this stratum or lens doesn't extend far enough south to merge with other gleyed strata. No vertebrate remains and few gastropods observed; column collected for gastropod extraction but not processed due to few specimens. Occasional vertical krotovinas (crayfish?) recorded. No charcoal collected for radiocarbon dating. None of stratum manually dug or waterscreened.	Figs. 2.18, 2.30, 2.31, 2.32, 4.10, 5.12, 6.7, 6.9, 6.12, and 19.1.
Unit IIE	Layer D	Top: 98.7-98.8 Bottom: 98.25 – 98.5	12 to 25 cm	Gray (10YR 5/1) to reddish gray (10 YR 5/2) fine sandy loam	Narrow, thin lens with remnants traceable in north-south profile along east sides of squares N7-W19 to N3-W19 and in east-west profile along North 3 backhoe trench where most of Unit IIE was cut away to uncover "horse bone bed" (Unit IICb). Approximately 0.4 m^3 were manually dug and waterscreened from squares N5-W19, N4-W19, 0-W16, and 0-W17. Few fossils recovered. Charcoal sample NZA-1090 (11,580 ± 350 years B.P.) came just below this unit in square N5-W19.	Fig. 19.12.
Unit IID	NC1	Top: 98.0 – 98.4 Bottom: 97.8	40 – 50 cm	Reddish brown (5YR 4/4) loam	North-south profiles exposed in West 15.5 backhoe trench and along east sides of squares N6-W19 to S2-W19. Partial east-west profile exposed in North 3 backhoe trench where unit was destroyed to uncover "horse bone bed" (Unit IICb). It is marked by many vertical krotovinas (crayfish?) and considerable soft sediment deformation. This stratum underlies and does not extend north to Unit IIF. Approximately .65 m^3 of this stratum was manually dug and waterscreened, yielding a few fossil bones and fragments. A few charcoal flecks were recovered from unit, but they have not been radiocarbon dated. Notable calcium carbonate concretions were mapped in unit in squares N3-W19, N3-W20, and N4-W20.	Figs. 2.18, 2.20, 2.32, 4.5, 5. 11, 6.7, 6.9, 6.10, 19.1, 19.9; and 19.12. Plate 4b.
Unit IIC					Stratum may contain one deposit (IICb) inset in another (IICa).	
IICa	SC3, NC3	Top:97.7 Bottom: 97.0 to 97.5	40 cm	Reddish brown (2.5YR 4/4) loam	This prevalent gleyed deposit was exposed in the 92A, West 15.5, and North 3 backhoe trenches where it dips south slightly and appears nested in the western half of the underlying Unit IIB. Approximately 4.02 m^3 of IICa was manually dug from squares such as N1-W19, N2-W19, 0-W21, N2-W20, S1-W20, N1-W21, N2-W21, N1-W22,0-W22, and 0-W23. Yielded numerous fossil bones, many gastropods, and 1 flake. Radiocarbon date of 40,900 ± 1600 years B.P. (AA-3840) came from this stratum.	Figs. 2.2, 2.3, 2.4, 2.5, 2.14, 4.10, 5.11, 5.12, 5.13, 5.19, 6.7, 6.9, 6.10, 19.1, 19.9, and 19.12. Plate 2a.
IICb	NC2	Top: 97.5 Bottom: 96.9	40-45 cm	Gray (5YR 5/1) fine sandy loam	East part of Unit IIC where hints observed of a separate ponding event. Unfortunately, excavation of West 15.5 backhoe trench ruined location where boundary could be reverified. May extend to Backhoe Trench 92A. This subunit contained the "horse bone bed". Approximately 1.0 m^3 of sediment was manually dug and waterscreened (squares N3-W13, N3-W14, N3-W15, N4-W13, N4-W14, N4-W15, and N5-W13). Yielded remains of Pleistocene horse and a few other animals. Numerous charcoal flecks were recovered, but no dates were obtained on those submitted.	Figs. 2.19, 2.20, 2.32, 4.5, 4.12, 5.12, 6.7, 6.9, 6.10, 11.2, 12.2, 15.1, 18.4, 18.5, and 19.1.
Unit IIB					Lowest ponding event represented by 2 substrata.	
IIBb	NC4, SC4	Top: 96.7 – 97.0 Bottom: 96.4 – 96.7	60-80 cm	Light brownish gray (10YR 6/2) silt loam	The principal fossil and artifact yielding gleyed deposit. Exposed at base of West 15.5 , North 3, and 1992A backhoe trenches and probably the thin narrow lens at east end of Bulldozer Trench B. Approximately 6.07 m^3 manually dug and waterscreened from squares 0-W24, N2-W23, N1-W23, 0-W23, S1-W23, S2-W23, N1-W22, 0-W22, S1-W22, S2-W22, N2-W21, N1-W21, S1-W21, S2-W21, N2-W20, N1-W20, N1-W19, and 3 squares in 92A backhoe trench. Contained initial find of *Bison chaneyi* and yielded vast majority of chipped stone artifacts. Contains many gastropods and numerous bones of other animals. Pre-Wisconsinan full glacial age indicated by dates on samples Beta-23045, NZA-2823, AA-3837, RA-C0352, RA-C0354, and RA-C0419.	Figs. 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.14, 2.32, 2.33, 5.11, 5.12, 5.13, 5.17, 5.18, 5.19, 6.7, 6.9, 6.10, 6.13, 11.2, 16.57, 18.4, 18.5, 19.1, and 19.8. Plates 1a, 2a, 2b, and 3a.
IIBa	SD, ND	Top: 96.4 – 96.7 Bottom: 95.6	50-80 cm	Brown (10YR 5/3) loam	Red to reddish yellow loam to fine sandy loam that forms basal sediment in the ancient channel adjacent Burnham paleosol. Tip of *Bison chaneyi* horn core in this sediment; also yielded flaked cobble, numerous gastropods, and some bones of diverse animals. Approximately 5.21 m^3 was manually dug and waterscreened from squares 0-W25, S1-W25, 0-W24, S2-W24, N2-W23, N1-W23, 0-W23, S1-W23, S2-W23, N1-W22, 0-W22, S1-W22, S2-W22, N2-W21, N1-W21, S1-W21, S3-W21, N2-W20, and N2-W22. Dated samples AA-3838 and RA-C0291 indicate pre-Wisconsinan full glacial age.	Figs. 2.2, 2.7, 2.14, 5.11, 5.12, 5.13, 5.17, 6.9, 6.10, 6.13, 11.2, 16.57, 18.4, 18.5, 19.1, and 19.8. Plates 2b and 3a.

[1] G.R. Brakenridge profiles; Wyckoff et al. 1991, 1994.

Lacustrine Sedimentary Unit IIF. This is the highest gleyed deposit manifest in the East Exposure ponding sequence (Figs. 20.15 and 20.16). This unit was first observed in the West 15.5 backhoe trench (dug in 1989) where it clearly ended before extending south into the depositional sequence exposed in the East Grid manually dug squares. Its north-south extent is known only for some 8 m; it was not observed in the profile recorded in Bulldozer Trench C some 30 m north (Fig. 20.17). An east-west profile was manifest in the A and B backhoe trenches dug in 1992 (Figs. 20.16 and 20.17). There, the unit was only some 7 m wide and seldom 30 cm thick. Vadose carbonates had formed along its west edge (Fig. 20.16) at an elevation that corresponds closely with the indurated carbonates observed capping the East Exposure gleyed deposits (Fig. 2.11).

Although a few bone fragments were recovered from the indurated carbonate, none were found as Unit IIF was cleaned, profiled, and photographed. Occasional snail shells were seen during profile cleaning, and a column of sediment from the unit was collected for gastropod extraction during the 1992 field work. Due to the few observed snails, this column has not been processed. No charcoal was collected from this unit, so it is undated. It is above a radiocar-

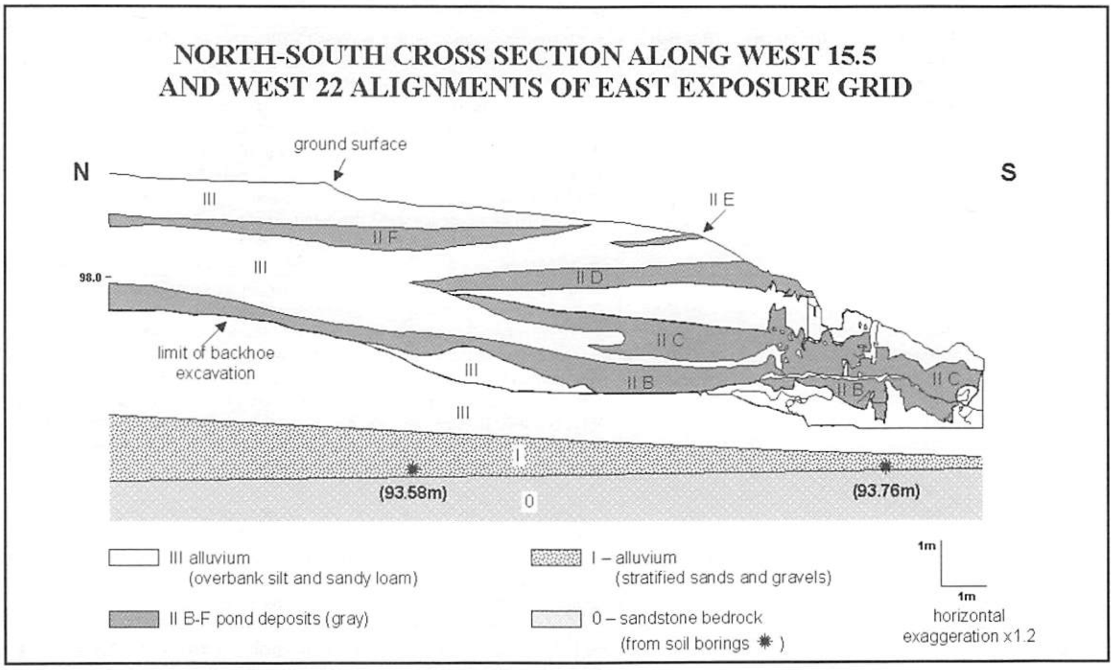


Figure 20.15. North-south profile of ponded sedimentary units in the East Exposure. Numbers are elevations in meters relative to 100 assigned to site datum. Profile by Brian Carter.

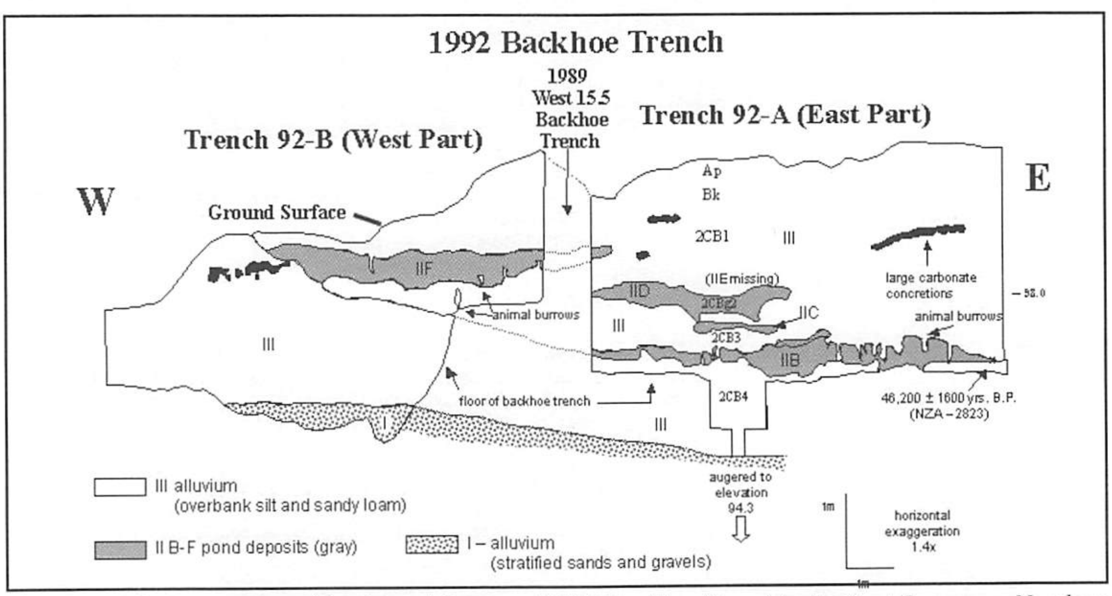


Figure 20.16. East-west profile of A and B parts of 1992 Backhoe Trench in the East Exposure. Numbers are elevations in meters relative to 100 assigned to site datum. Profile by Brian Carter.

bon date of 11,580 + 350 years B.P. (NZA-1090), so it is probably of late Pleistocene-early Holocene age.

Lacustrine Sedimentary Unit IIE. This is the least documented and most poorly understood gleyed unit in the East Exposure sequence. Portions were exposed in the North 3 backhoe trench, the West 15.5 backhoe trench, and a few hand-dug squares just west of these trenches (Table 20.1). Where observed, Unit IIE was usually less than 25 cm thick and not more than 5 m wide or long. Notable portions were lost when the West 15.5 trench was cut and when the soils and sediments overlying the "horse bone bed" were removed with a backhoe. Although it shares some elevation measurements with Unit IIF, its boundaries appeared separate from that more extensive deposit.

The radiocarbon date of 11,580 + 350 years B.P. (NZA-1090) was on a piece of charcoal collected below this deposit, so it, too, probably relates to a short ponding event during very late Pleistocene-early Holocene times. No ver-

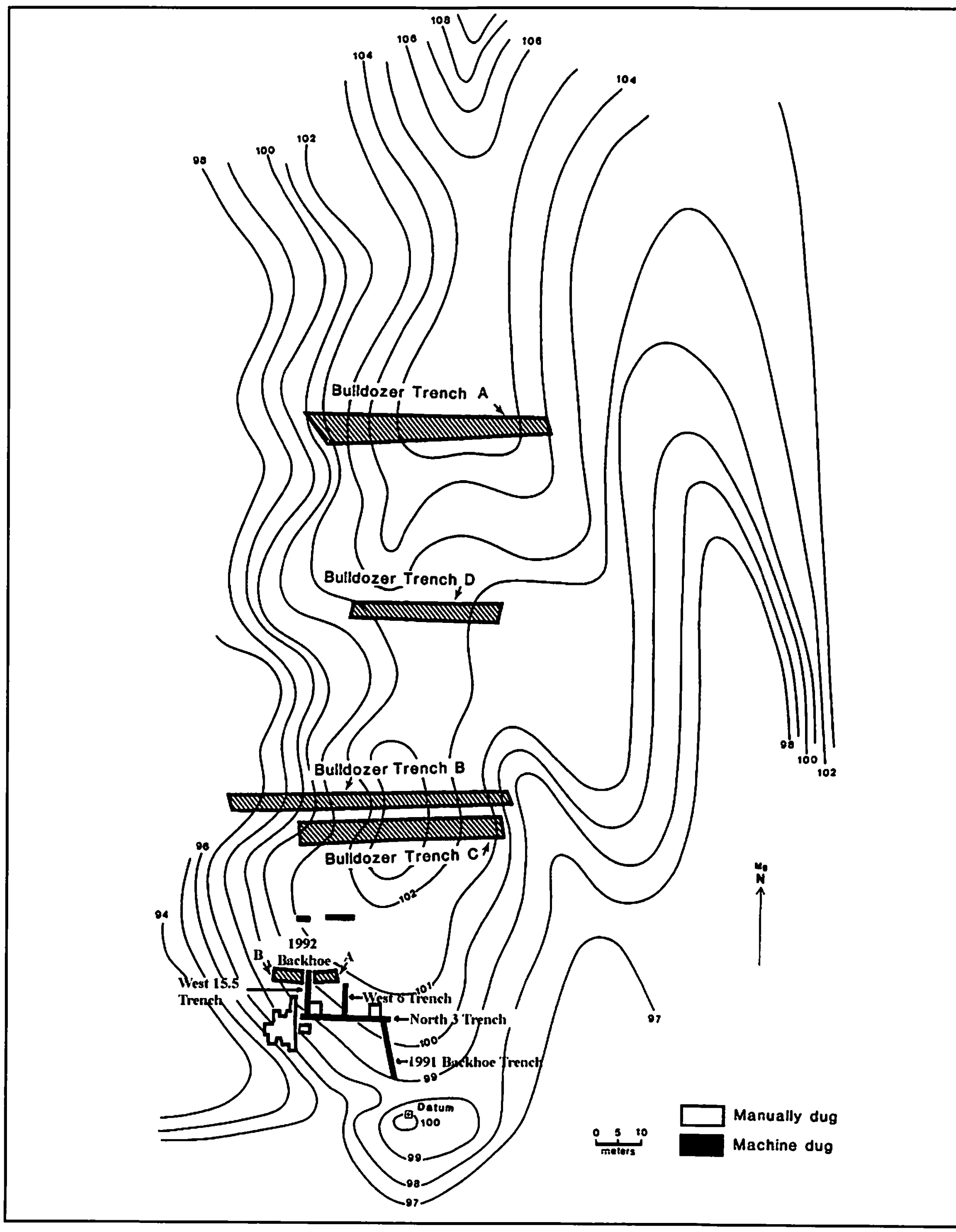


Figure 20.17. Excavated areas in the East Exposure of the Burnham Site.

tebrate or shell fossils were clearly associated with Unit IIE.

Lacustrine Sedimentary Unit IID. This rather extensive deposit was first seen in the North 3 and West 15.5 backhoe trenches, and it was eventually sampled by manually dug squares along the eastern edge of the main block of East Grid squares (Table 20.1; Figs. 20.10, 20.15, 20.16, and 20.17). Its north-south extent was slightly more than 11 m, whereas its east-west expanse was only 6.5 m. Varying from 40 to 50 cm in thickness, Unit IID was distinguished by a prevailing reddish brown color, by numerous red krotovinas that originate from red sediments above Unit IID (Plate 4a), and by areas (particularly in the West 15.5 trench; Fig. 19.9) where the boundaries are irregular and somewhat distorted by soft-sediment deformation.

Less than a cubic meter of Unit IID was dug and waterscreened. Consequently, few vertebrate and invertebrate fossils are recorded for this deposit. The radiocarbon date of 11,580 + 350 years B.P. (NZA-1090) came from the top of this unit.

Typically reddish brown, Unit IID appears to be composed of sediment that washed in from nearby terrain and that was less affected by the reduction and oxidation processes that created the gleyed sediments more common to the site. Concentrations of calcium carbonate nodules were recorded near the west edge of this unit and may be vadose deposits. Overall, Unit IID appears to have formed in shallow water that persisted for some time.

Lacustrine Sedimentary Unit IIC. This is one of the most extensive gleyed deposits in the East Exposure sequence. Given that its base is nearly a meter higher than the bottoms of the Southwest and Northwest exposures, Unit IIC is not believed to be preserved on the west side of the modern gulley. As Table 20.1 shows, two subunits are recognized for this deposit: Unit IICa and Unit IICb. This was done because of initial hints that the "horse bone bed" was actually a separate deposit (Unit IICb) inset in the main unit (IICa). Unfortunately, we are unable to resolve whether there was one continuous deposit or two separate ones because a critical segment of the profile was destroyed when the West 15.5 backhoe trench was dug. Regardless of whether there was one or two deposits, both are essentially equivalent stratigraphically and must be nearly the same age.

Unit IICa directly overlies the artifact-yielding stratum, so it was rather well sampled (4 m^3) by hand-dug levels that were waterscreened. Profiles of this gleyed stratum were exposed and recorded in the North 3, West 15.5, and 1992A-B backhoe trenches (Figs. 20.10, 20.15, 20.16, and 20.17). From these manifestations we can recognize that this 40 cm thick, gleyed stratum extends some 11 m north and south and nearly 13 m east and west. Many gastropods and numerous isolated bones and bone fragments were recovered from Unit IICa. Many pieces of charcoal also came from this unit, but only one has been radiocarbon dated (AA-3840; 40,900 + 1600 years B.P.).

Unit IICb occurs in the east part of the Unit IIC profile and contains what has been frequently mentioned in this volume as the "horse bone bed". This paleontological feature was discovered while excavating the North 3 backhoe trench. The backhoe bucket dumped out several well preserved bones eventually identified as Pleistocene horse (Martin and Meehan, this volume). Wishing to uncover the remaining bones and to study them taphonomically, the decision was made to have the backhoe dig a north-south trench (West 15.5) just west of the bone concentration and to remove the soil and sediments above the bone concentration. This allowed us to manually uncover the in situ bones and to record their arrangement and alignments (Todd, this volume). Many of these bones had carbonate encrustations on them, and several hollow bones had calcite crystals in them.

Our knowledge of Unit IICb comes primarily from the nearly cubic meter of sediment carefully removed from the several grid squares (or parts thereof) around the ancient horse bones (Fig. 2.19). Also, a sediment column (for recovering snails) was taken just east of the bone bed (Theler, this volume). And, the unit was profiled from the bone bed eastward for several meters along the lower wall of the North 3 backhoe trench (Plate 3b; Figs. 4.5, 5.11, 12.2, and 20.18).

Unit IICb varies from 40 to 45 cm in thickness, and it had an east-west extent of 5 m. Where manifest at the "horse bone bed", its north-south extent was at least 4 m. A small lens of what is believed to be Unit IIC was recorded in 1992 backhoe trench A (Fig. 20.16), but whether or not it is this subunit is uncertain. Several minute pieces of charcoal were found while uncovering the "horse bone bed", but problems when the submitted ones were processed hindered obtaining a radiocarbon date for the deposit. Because of the particular horse and bison (*Bison chaneyi*) bones recovered from

Figure 20.18. Looking northeast at east edge of "horse bone bed" or lacustrine unit IICb. A bison horn core is at lower right center. Gleyed sediments with occasional krotovinas in North 3 trench profile (right). Photo taken October 16, 1989, by Don Wyckoff.

the "horse bone bed", we believe Unit IICb is close in age to the underlying lacustrine deposit.

Lacustrine Sedimentary Unit IIB. Composed of two subunits, this is the lowest of the stratified pond deposits. It is also the most extensive. We believe it is represented by the gleyed sediments in the Southwest and Northwest exposures as well as by the lowest gleyed sediments in the East Exposure. This belief is based on the similar elevations of tops and bottoms of the gleyed sediments in all three exposures. Also, similar vertebrate fossils come from all three exposures (Table 8.2), and the aquatic gastropod assemblage studied for the Northwest Exposure is comparable to that recorded for the lowest gleyed deposit in the East Exposure (Theler, this volume). Manifest at the bottom of backhoe trench 1992A and as a narrow lens in Bulldozer Trench B, Unit IIB extends over 100 m from the Southwest Exposure. We estimate this unit's original expanse was at least a quarter hectare (slightly more than a half acre).

As noted above, two subunits are recognized: Unit IIBb and Unit IIBa (Table 20.1). Unit IIBb is the 60 to 80 cm thick, gray (gleyed) silt loam to fine sandy loam in which the overturned *Bison chaneyi* skull, other bones, and most chipped stone objects were found in the East Exposure. Unit IIBb as manifest in the East Exposure is believed to correlate with the gleyed sediments that comprise the Southwest and Northwest exposures. Using snails, charcoal, and hackberry seeds as sample material, nine radiocarbon dates were obtained for Unit IIBb (Table 20.2). These range from 22,600 to 46,200 years ago.

Underlying Unit IIBb in the manually dug area of the East Exposure is a brown loam deposit that also contained aquatic gastropods and bones of salamanders, frogs, and turtles. We have designated this lowest deposit Unit IIBa (Table 20.1) because it seems integrally related to Unit IIBb in the East Exposure. The boundary between these two deposits is clear and exhibits occasional bioturbation disturbances that mix small areas of both deposits. Nothing comparable to Unit IIBb was observed in the Southwest and Northwest exposures.

Unit IIBa varies from 50 to 80 cm in thickness. It did yield both terrestrial and aquatic gastropods as well as diverse bones. Notably, the atlas vertebra, left mandible, and several ribs of *Bison chaneyi* were in this reddish brown sediment, and bison ribs, a right scapula, and several thoracic vertebrae were found resting along the boundary between Unit IIBb and Unit IIBa (Fig. 20.19). The right horn core of the *Bison chaneyi* skull extended into Unit IIBa from Unit IIBb (Plate 2a). These occurrences attest to the close depositional relationship between these two sedimentary subunits. Such a relationship is further indicated by the three radiocarbon dates for Unit IIBa (Table 20.2). These results overlap the range of dates from Unit IIBa (Table 20.2).

Figure 20.19. Looking northeast at lacustrine units IIBb (gray) and underlying IIBa (dark) in square S2-W21(East Grid). Bison thoracic vertebra rests parallel to boundary. Photo taken October 21, 1989, by Don Wyckoff.

Table 20.2. Radiocarbon Dates for Lacustrine Sedimentary Units IIBa and IIBb.

Subunit Date years B.P.	Sample \#	Provenience and material
Unit IIBb		
22,670 ± 330	RA-C0352	East Grid square S1-W23, elevation 96.3, hackberry seed
30,160 ± 390	NZA-3009	Northwest Exposure square S5-W2, elevation 97.89, charcoal
31,150 ± 700	Beta-23045	East Grid square S1-W22, elevation 96.5 to 96.3, unsorted snail shells
35,680 ± 710	RA-C0354	East Grid square N2-W20, elevation 96.8, hackberry seed
35,890 ± 850	AA-3837	East Grid square S1-W22, elevation 96.5 to 96.3, unsorted snail shells
37,215 ± 940	AA-11687	Northwest Exposure square S5-W2, elevation 97.3 to 97.2, aquatic snail species
40,190 ± 870	RA-C0419	East Grid square S1-W22, elevation 96.6, hackberry seed
42,785 ± 1800	AA-11688	Northwest Exposure square S5-W2, elevation 97.3 to 97.2, terrestrial snail species
46,200 ± 1600	NZA-2823	East Exposure, square 3 in 1992A backhoe trench, elevation 96.72, charcoal
Unit IIBa		
26,820 ± 350	AA-3838	East Grid square S1-W22, elevation 96.26, charcoal
36,300 ± 1700	NZA-1416	East Grid square 0-W25, elevation 96.2, charcoal
37,590 ± 820	RA-C0291	East Grid square S3-W24, elevation 96.1, hackberry seed

Lacustrine Unit IIBa is reddish brown and prevailingly loamy in texture. These attributes are similar to those of the sediment that first aggraded in the canyon-like setting here. Unit IIBa was manifest only at the bottom of the pond sequence in the East Exposure. There, Unit IIBa appears to be the original bottom of the channel that had eroded through the Burnham paleosol and some of the overlying calcic soils. With development of the first pond, this part of the channel was shallowly flooded. This waterlogged the red sediment, and it was subsequently disturbed by vertebrate and invertebrate animals. Thus this sediment became Unit IIBa.

With deepening of the pond, organically enriched sandy sediments accumulated above Unit IIBa. These water saturated, organic-rich sediments anaerobically decomposed, resulting in the formation of Unit IIBb, the lowest gleyed deposit in the East Exposure sequence of ponded sediments.

Unit IIBa was not observed at the Southwest or Northwest exposures. This may be due to these places having been closer to the prehistoric dam and thus having deeper water over the channel bottom.

Paleontological and Paleobotanical Findings at the Burnham Site

As the preceding chapters by Martin and Meehan, Czaplewski, Theler, Wigand, Minnis and Keener, and van de Water attest, occasional plant fossils, hundreds of bones, and thousands of snails were recovered at the Burnham site. The numbers of recovered fossil remains are large in comparison to other Southern Plains paleontological sites that date prior to the Wisconsinan full glacial (see Dalquest and Schultz 1992; Hibbard 1970). The large quantities from the Burnham site are attributable to two factors: the dozens of volunteers who carefully dug and waterscreened large quantities of soil and sediment and the fact that all of this manually dug material was waterscreened through 2.0 mm mesh hardware cloth. Although the numbers are notable, the Burnham finds are additionally significant because they come from specific pedological and sedimentary contexts that are stratified and relatively well dated. When these plant and animal remains are synthesized with the dated deposits, the combined findings allow us to construct vignettes of the Burnham site's prehistoric setting and environs. And, when these findings are correlated with similar information from comparably old sites in the region, we have evidence for some of the temperature and precipitation regimes (i.e., climate) affecting this part of the Plains at that time. Therefore, in the following pages we will synthesize and summarize the Burnham biological findings according to their dated contexts. Following this summary we will compare the Burnham findings with other roughly contemporary fossil locations reported nearby in Oklahoma, Kansas, and Texas.

The Burnham Paleosol and the Underlying Alluvium

With one exception, the earliest fossils from the Burnham site are those associated with the Burnham paleosol. The exception is the partial skeleton of a dire wolf that was found in 2001 (Czaplewski, this volume). Although recovered at elevation 94.5, which is nearly 3.0 m below the paleosol, the dire wolf remains were in the reddish brown alluvium that aggraded in a bedrock-lined drainage and in which the Burnham paleosol formed. So, for the purpose of this summary, we are grouping the few fossils from the early alluvium (Carter's Group I sediments) with those from the Burnham paleosol that mantles this alluvium. Two conventional and two accelerator radiocarbon dates (samples Beta-33950, SMU-2422, NZA-2824, and RA-C0353 in Tables 19.1 and 19.2) indicate this paleosol is from 34,500 to 40,000 years old. We believe it was an active surface on which things grew, walked, or crawled around 36,000 to 37,000 years ago (see preceding chapter).

The list of organisms associated with (and under) the Burnham paleosol includes 2 species of plants, 2 varieties of land tortoise, 2 varieties of canids, 1 rodent, and 9 species of land snails (Table 20.3). Collectively, these attest to environmental conditions different from those of today.

Regarding the plants, hackberry (*Celtis* sp.) is still resident on the site. A small grove of hackberry trees thrive on the modern gully floor less than 100 m north of the site. Hackberry is a widespread genus and is capable of tolerating a wide range of temperature, precipitation, and soil conditions (Fowells 1965:140-142). Three varieties of hackberry are reported for Woods County, but the species *Celtis reticulata* is believed most common there today (Williams 1974:Maps 58, 59, and 60). Unfortunately, the fossil hack-

Table 20.3. Fossils Associated with the Burnham Paleosol and Underlying Alluvium.

Plants	Vertebrates	Invertebrates
Hackberry (*Celtis* sp.)	Giant tortoise (*Hesperotestudo* sp.)	*Gastrocopta armifera*
Pawpaw (*Asimina triloba*)	Gopher tortoise (*Gopherus* sp.)	*Gastrocopta cristata*
	Dire wolf (*Canis dirus*)	*Gastrocopta pellucida*
	Fox-size canid (Canidae)	*Gastrocopta procera*
	Eastern wood rat (*Neotoma* cf. *floridana*)	*Pupoides albilabris*
		Vallonia perspectiva
		Vallonia. sp.
		Helicodiscus singleyanus
		Hawaiia minuscula
		Deroceras laeve

berry seeds from the Burnham site are difficult to identify at the species level. The three varieties of hackberry currently found in Oklahoma occur primarily in the western half of the state where the precipitation is less than 36 in. a year while the annual lake evaporation is almost twice that (Williams 1974; Johnson and Duchon 1995). In contrast, pawpaw (*Asimina triloba*) no longer grows in Woods County. In fact, its closest modern record is Osage County, which is nearly 150 miles east of the Burnham site (Williams 1974:Map 25). Typically a small understory tree, pawpaw reportedly (Crawford et al. 1969:169) grows in thickets on deep soils in sheltered settings like ravines and wooded bottomlands. Its current distribution in Oklahoma is associated with areas receiving 36 to 44 in. of precipitation annually, having less than 52 in. of annual lake evaporation, and having more than 28 frost-free weeks (Johnson and Duchon 1995). Pawpaw now occurs sporadically in eastern Oklahoma, but its distribution does overlap with the hackberry variety *Celtis laevigata* (Williams 1974). The evidence for both hackberry and pawpaw being associated with the Burnham paleosol bears witness to different climatic conditions in western Woods County some 36,000 to 37,000 years ago. We estimate that the annual precipitation was as much as 20 to 30% more than today's while the evaporation rate may have been 20 to 30% less than it is today.

Further testimony of different climatic conditions is presented by the two fossil tortoises from these early contexts. *Hespertotestudo* is extinct and *Gopherus* no longer lives in this area. Both kinds of tortoises have long, spotty Pleistocene and earlier records for southwestern Kansas and nearby parts of Oklahoma and Texas (Czaplewski et al. 2001; Lundelius 1972; Preston 1979). Paleontologist C. Hibbard (1960, 1970) has frequently cited these animals, and especially *Hesperotestudo*, as indicators of frost-free climates. Unlike *Gopherus*, *Hesperotestudo* was unable to burrow and thus protect itself from prolonged sub-freezing temperatures. Existing varieties of *Gopherus* are associated with warm, moist, sandy lowlands far to the southwest of the Burnham site. In these settings *Gopherus* feeds on wildflowers, grasses, and cacti parts (Cohen 1992).

The remaining animals from the Burnham paleosol (and underlying alluvium) are what has been identified as eastern wood rat (*Neotoma* cf. *floridana*), dire wolf (*Canis dirus*), and some kind of fox-size canid (Table 20.3). Little can be said about this last since it can't be speciated. The wood rat is tentatively identified as the eastern variety, which still exists in the area today (Caire et al. 1989:248-250). Woods County comprises part of the boundary between distributions of the eastern wood rat and the southern plains wood rat (*N. micropus*), and individuals with attributes of both varieties are common (ibid.). Both build stick nests or houses and favor wooded areas along streams. The dire wolf was a large carnivore whose fossils have been found from southern Alberta well into South America (Dalquest and Schultz 1992:173; Dundas 1999). Notably, few have been reported from Plains states, and the Burnham specimen is one of only two from Oklahoma (Cifelli et al. 2002). Citing Nowak (1970), paleontologists Dalquest and Schultz (1992:173) suggest that dire wolves were more frequent in Pleistocene settings east of the Plains.

More than 300 snails were recovered from the two soil samples collected from the Burnham paleosol (Theler, this volume, Table 12.5). Nine different kinds of snails are represented (Tables 12.5 and 20.3), and all are terrestrial species. All have modern distributions that encompass northwestern Oklahoma (Hubricht 1985; Theler et al. 2003), although several (*Gastrocopta armifera*, *G. cristata*, *G. procera*, *Helicodiscus singleyanus*, and *Hawaiia minuscula*) are near the northern or western edges of their modern occurrences. *Vallonia perspectiva* (40%) and *Gastrocopta pellucida* (25%), are the two most numerous gastropods from the Burnham paleosol and are believed (Theler, this volume) to attest to dry or droughty conditions.

In summary, the few biological organisms associated with the Burnham paleosol (and the sediment it developed in) provide mixed messages about the environment some 36,000 to 37,000 years ago. The large land tortoises, the most common snails, and the hackberry plants attest to conditions warmer than today and almost as dry, whereas the pawpaw remains implicate more effective moisture than occurs in this region today.

The Calcic Soils above the Burnham Paleosol

Red, fine sandy loam soils lie above the Burnham paleosol. Characterized by discontinuous layers of soft to slightly hard calcium carbonate nodules, these deposits are representative of calcic soils (Birkeland 1999:127-129). Such soils are common to semiarid and arid regions of the southwestern United States (Birkeland 1999:201-215; Machette 1985). Calcic soils are prevalent in the western half of Oklahoma (Gray and Galloway 1969). There, calcium carbonate is common to soil-forming parent material and evaporation exceeds precipitation, thus allowing wetting fronts to concentrate calcium carbonate at particular zones in soil profiles (Gray and Galloway 1969; Gray and Roozitalab 1976). Given these factors, the calcic paleosols manifest above the Burnham paleosol bear witness to lengthy semiarid conditions similar to those of today.

Few controlled excavations, with accompanying waterscreening, were undertaken in the calcic paleosols at the Burnham site. A 1x2 m trench (East Grid squares N21-W13 and N21-W14) was dug in 1991 (Fig. 2.21), and several 1x1 m test squares were manually excavated at different elevations while grading Bulldozer Trench C (Fig. 2.40). No plant or animal remains were recovered from any of these excavations.

The only biological evidence we have for the calcic paleosols at Burnham are the gastropods that were carefully

Table 20.4. Gastropods (Individuals/Liter and Number of Identified Specimens) from West 6 Backhoe Trench.

Stratum	Btk2		Btk2		Bk1,b		Bk1, b		Btk2b		Bky,2b	
Elevation	98.86		98.65		98.41		98.31		97.96		97.61	
Sample Volume	1.2 liters		1.3 liters		0.5 liters		1.1 liters		1.5 liters		1.2 liters	
Aquatic Taxa	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP	Ind/L	NISP
Valvata tricarinata	-	-	2	2	-	-	1	1	-	-	-	-
Hydrobiidae/Lymnaeidae	-	-	-	-	-	-	2	2	-	-	-	-
Physidae	2	2	5	6	-	-	4	4	43	63	-	-
Physella virgata	-	-	-	-	-	-	-	-	1	1	-	-
Gyraulus circumstriatus	-	-	1	1	-	-	-	-	-	-	-	-
Gyraulus parvus	1	1	-	-	-	-	-	-	2	3	-	-
Gyraulus sp.	3	3	2	3	-	-	1	1	15	22	-	-
Planorbella trivolvis	-	-	-	-	-	-	1	1	1	1	-	-
Planorbella sp.	-	-	-	-	2	1	-	-	9	13	-	-
Promenetus exacuous	1	1	-	-	-	-	-	-	1	1	-	-
Ferrissia frigilis	-	-	-	-	-	-	-	-	33	49	-	-
Juveniles-unidentified	-	-	2	3	-	-	-	-	-	-	-	-
Subtotal		7		15		1		9		153		0
Terrestrial Taxa												
Gastrocopta armifera	-	-	-	-	-	-	1	1	2	2	-	-
Gastrocopta cristata	-	-	6	8	-	-	4	4	3	3	-	-
Gastrocopta pellucida	-	-	-	-	-	-	1	1	1	1	2	2
Gastrocopta procera	-	-	1	1	2	1	4	4	2	2	1	1
Pupoides albilabris	-	-	-	-	-	-	2	2	-	-	1	1
Vallonia perspectiva	1	1	2	2	-	-	9	10	2	3	1	1
Vallonia sp.	3	3	5	6	12	6	61	67	11	17	4	5
Helicodiscus parallelus	-	-	-	-	-	-	-	-	2	3	1	1
Helicodiscus singleyanus	5	6	12	16	18	9	22	24	28	42	11	13
Succineidae	-	-	-	-	4	2	6	7	2	3	1	1
Hawaiia minuscula	9	11	5	7	14	7	25	27	64	96	7	8
Glyphyalinia indentata	-	-	-	-	2	1	1	1	-	-	-	-
Deroceras laeve	-	-	-	-	-	-	2	2	3	3	-	-
Juveniles-unidentified	-	1	-	28	-	5	-	17	-	41	-	3
Subtotal		22		68		31		167		216		36

washed from six matrix samples taken from a 1.3 m vertical column in the West 6 backhoe trench dug in 1989. These matrix samples came from elevations 98.86, 98.65, 98.41, 98.31, 97.96, and 97.61 (Theler, this volume; Table 20.4). Nearly 7.0 liters of soil were washed for these six samples, but only 725 snails were found (Table 20.4). Land snails dominate (74%) the combined samples, but aquatic snails were very numerous (comprising 41%) in the sample taken at elevation 97.96 (Table 20.4). Described as a Btk2b soil horizon, the matrix at this elevation is directly east of the most extensive gleyed sediment (ponded Unit IIB) exposed in the North 3 backhoe trench. Theler (this volume) characterizes this horizon as being a "riparian stratum" coeval with the Unit IIB ponding event. Consequently, we minimize the gastropod assemblage from elevation 97.96 in this discussion of settings and past environments associated with the calcic paleosols.

Aquatic gastropods account for less than 1% of the snails recovered from the other five soil samples taken from the column in the West 6 backhoe trench (Table 20.4). The aquatic taxa from these soil samples are small with shell openings that allow them to be easily moved by wind or water. Their sparse presence in these soil samples is considered good evidence that these soils accumulated while ponded water was nearby and/or that overbank deposition provided the parent material in which these soils developed.

Twelve terrestrial taxa are represented in the five matrix samples from the calcic paleosols (Table 20.4). These 12 taxa comprise two-thirds of the prehistoric land snail taxa identifed for the Burnham site. Six of these terrestrial taxa still live in the Burnham site vicinity (Table 12.7). Within the column through the calcic paleosols, terrestrial gastropods peak in the "riparian" horizon (Ab,2b at elevation 97.96) and decline markedly below and above it (Table 20.4). The 12 terrestrial taxa from the column are mostly drought tolerant forms, but a few (e.g., *Gastrocopta armifera*, *G. procera*, *Hawaiia minuscula*, *Glyphyalinia indentata*, and *Deroceras laeve*) might be considered less drought tolerant. These five have modern distributions that are largely east of the Burnham site (Hubricht 1985).

After development of the Burnham paleosol, fine sandy parent material enriched with calcium carbonate accumulated. The material appears aeolian in origin but it may include sediment from overbank deposition. As this fine sandy material accumulated, precipitation dissolved calcium carbonate in the material, carried it downward, and concentrated it as discontinuous layers of soft caliche. This pedogenic process is ongoing in today's semiarid and arid settings on the Southern Plains, and we interpret the Burnham calcic soils to have formed under similar environmental conditions. Except for one interval when the calcic soils (or paleosols) were adjacent standing water, terrestrial snails prevail in the studied soil samples. Notably, the terrestrial taxa are primarily drought-tolerant forms. Thus, on the basis of the soil characteristics and the land snails from these soils, we conclude that a warm, dry environment existed when the calcic paleosols were formed. While we can't date these precisely, we believe these soils formed while the lower ponding events occurred at the Burnham site. We estimate this to be some 36,000 to 34,000 years ago.

The Lowest Pond Deposit (Unit IIB)

Earlier in this chapter, the lowest pond sediments (Unit

IIB in Table 20.1) in the East Exposure sequence were correlated with the unstratified gleyed deposits manifest in the Northwest and Southwest exposures. This correlation makes these deposits remnants of the largest prehistoric pond at the Burnham site. Radiocarbon dates from these three deposits indicate these lacustrine sediments accumulated sometime between 36,000 and 34,000 years ago (Wyckoff and Carter, this volume). Because the eastern extent of the Unit IIB sediments is adjacent red sediment (horizon Btk2b) containing many terrestrial and aquatic gastropods (Table 20.4), we believe this earliest pond was contemporaneous with some of the accumulation and development of the just discussed calcic paleosols.

This lowest lacustrine deposit was the focus of much of the Burnham site excavations. The *Bison chaneyi* skull lay in the gleyed upper part (IIBa; Table 20.1) of this deposit, and the initially discovered chipped stone objects came from gleyed sediment waterscreened from around the skull. Consequently, Unit IIB was extensively dug by hand (Table 20.1) and the fill from these excavations was thoroughly waterscreened. Not surprisingly, many of the identified bones and the vast majority of the studied gastropods were recovered from the squares carefully dug through this lowest gleyed sediment and into the fossil-bearing, red, fine sandy sediment below. Although not excavated as extensively, the Northwest Exposure received some attention as we tried to see if that unstratified, gleyed deposit contained fossil vertebrates, gastropods, and chipped stone objects like those found at the East Exposure. Over 100 identifiable bones and 800 identifiable gastropods were recovered from the Northwest Exposure (Tables 8.2, 9.1, and 13.1). Except for repeated troweling and a couple of levels removed from two 1x1 m squares, controlled excavations were minimal at the Southwest Exposure. As a result, only 28 identifiable bones (Table 8.2) and no gastropods were recovered there.

Table 20.5. Vertebrate Fauna Associated with the Lowest Ponded Deposits (Unit IIB) at the Burnham Site.

Species	East Exposure Unit IIBa*	East Exposure Unit IIBb*	Northwest Exposure	Southwest Exposure
Mammoth (*Mammuthus*)	+	+	+	
Bison (*Bison chaneyi*)	+	+	+	+
Deer/Elk (Unspeciated Cervid)	+	+		+
Llama (*Hemiauchenia*)	+			+
Small wild ass (*Equus [Hemionus]*) sp.	+	+	+	+
Unspeciated Artiodactyl	+			
Black bear (*Ursus* cf. *americanus*)	+			
Unspeciated Carnivore		+		
Shasta ground sloth (*Nothrotheriops shastensis*)		+		
Harlan's ground sloth (*Paramylodon*)			+	
Rabbit/Hare (*Sylvilagus/Lepus*)	+	+		
Least shrew (*Cryptotis parva*)				+
Prairie vole (*Microtus* cf. *ochrogaster*)	+	+	+	
Hispid pocket mouse (*Chaetodipus* cf. *hispidus*)			+	
White-footed mouse (*Peromyscus* cf. *leucopus*)		+		
Blacktailed prairie dog (*Cynomys ludovicianus*)	+	+	+	
Plains pocket gopher (*Geomys bursarius*)	+	+	+	+
Eastern woodrat (*Neotoma* cf. *floridana*)		+	+	
Southern bog lemming (*Synaptomys cooperi*)	+	+		
Unspeciated Rodent		+	+	
Northern leopard frog (*Rana pipiens*)		+		
Bullfrog (*Rana catesbeiana*)		+		
Frog (*Rana* sp.)	+	+		
Unspeciated Frog		+		
Smallmouth salamander (*Ambystoma* cf. *texanum*)			+	
Tiger salamander (*Ambystoma tigrinum*)	+	+	+	+
Alligator (*Alligator* cf. *mississippiensis*)	+			
Giant tortoise (*Hesperotestudo*)			+	
Snapping turtle (Chelydridae)			+	
Painted turtle (*Chrysemys* sp.)		+		
Softshell turtle (*Trionyx* sp.)		+	+	
Eastern box turtle (*Terrapene carolina*)			+	
Unspeciated Turtle	+	+	+	+
Rat snake (*Elaphe obsoleta*)		+		
Kingsnake/Milksnake (*Lampropeltis* sp.)		+		
Garter/Ribbon snake (*Thamnophis radix*)		+		
Diamondback water snake (*Nerodia rhombifera*)		+		
Water snake (*Nerodia* sp.)	+	+		
Rattlesnake (*Crotalus* sp.)	+	+	+	
Racer (*Coluber constrictor*)			+	
Unspeciated Snake	+	+		
Green sunfish (*Lepomis* cf. *cyanellus*)	+	+		
Unspeciated Fish		+	+	

*See Table 20.1

Thirty-five taxa are represented among the 363 bones identified for the lowest ponded sediment (Table 20.5). As might be expected, given the varying amounts of excavation and waterscreening at each exposure, the 35 taxa are not manifest at each exposure (Table 20.5). In fact, only four specific taxa were recovered from all three exposures: bison, small wild ass, Plains pocket gopher, and tiger salamander. Even units IIBa and IIBb that were stratified in the East Exposure only share 12 (33%) of the 35 taxa (Table 20.5).

Complete or nearly complete articulated skeletons were not found anywhere in these earliest lacustrine sediments. Instead, the 35 taxa are represented by one to many bones that were scattered through the respective deposits (Figs. 20.19 to 20.22). Paleontologists Larry Martin and T.J. Meehan (this volume) demonstrate these scattered distributions for several taxa (Figs. 8.7 through 8.13). Even the *Bison chaneyi* skull, which was the initial attraction for the site's research, had less than a dozen bison bones nearby. Some of these were in the gleyed upper unit (IIBb) where the overturned bison skull lay (Figs. 2.7, 2.8, and 20.22), but a few were

*Figure 20.20. Isolated horse (*Equus*) metacarpal in uppermost part of the Southwest Exposure. Scale in 5 cm increments.Photo taken 1990 by Don Wyckoff.*

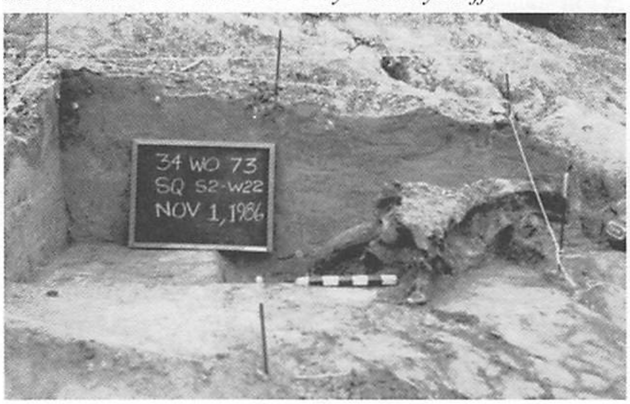


Figure 20.21. View east of Bison chaneyi *skull lying overturned in gleyed lacustrine sediment Unit IIBb. Its left horn core was in the underlying red Unit IIBa. Photo taken November 1, 1986, by Don Wyckoff.*

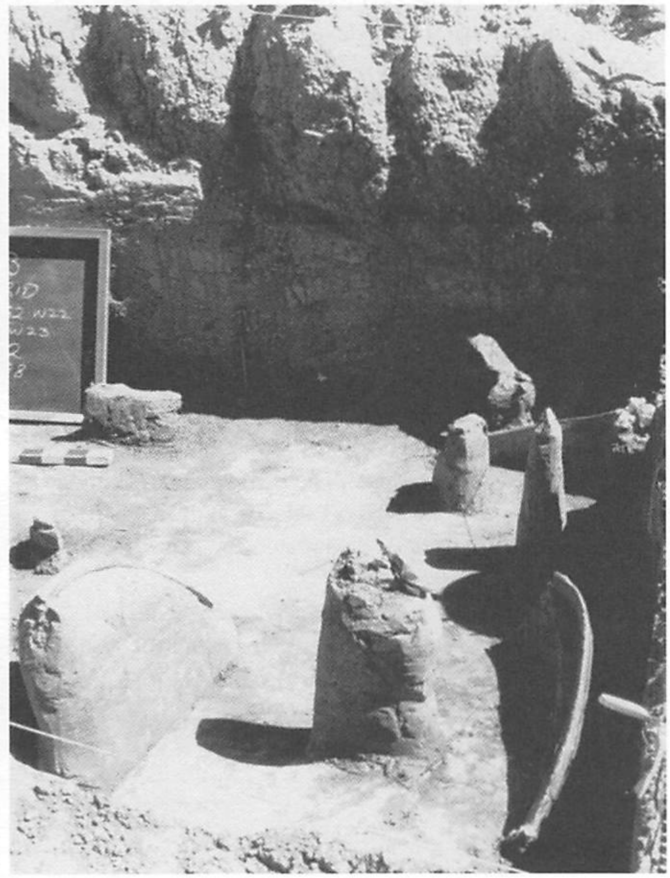


Figure 20.22. View east of bison ribs, thoracic vertebra spine, and scapula blade lying in Unit IIBa under where the bison skull was found. Photo taken in September of 1988 by Don Wyckoff.

along the lower boundary of this unit (Fig. 20.19), and a couple were resting entirely in the underlying red sediment (Fig. 20.22). Clearly, the taphonomic processes affecting the *Bison chaneyi* skull and the adjacent bison bones were different from those that left the horse, bison, and other bones lying essentially flat (and semi-articulated in the case of the horse) in the higher, and later, lacustrine Unit IIBa (Todd, this volume; Figs. 2.19, 11.7, and 11.8).

Lacking articulated skeletons, or even articulated parts of skeletons, some animals represented in the lowest ponded sediment obviously lived and died elsewhere. Subsequently, their skeletons became disarticulated and dispersed. Because many taxa are represented by few bones, their death sites must have been upstream or upslope. This especially would seem to be the case for such open grassland animals as mammoth, bison, horse, and llama (Table 20.5). Some length of time must be represented between the deaths of such animals , the disarticulation of their skeletal parts, the dispersal of these parts, and the eventual deposition of the few skeletal elements in the sediment that collected to become the Burnham site's lowest lacustrine deposits. The transportation of these large animals' bones, and those of grassland small species, was undoubtedly by flowing water. The occasional dolomite boulders found in the lowest sediments indicate the flow behind some of this initial sedimentation was very forceful. Convectional thunderstorms produce the kind of runoff that do this today. Notably, even animals that might be considered common to riparian or streamside niches are seldom represented by multiple skeletal parts found at one spot. An exception might be the *Terrapene carolina* shell found in the Northwest Exposure (Figs. 9.4 and 9.5) or the *T. carolina* plastron recovered from squares in the 92-A backhoe trench (Fig. 9.6). But even these examples are not complete. Based on the above observations, the lowest ponded sediments comprise a secondary taphonomic context (Steele 1990), one wherein the faunal remains have been well dispersed by flowing water.

The 35 taxa from the lowest ponded sediments comprise an interesting array of species still present in the region and species extinct since the end of the last ice age. Among these latter are *Mammuthus*, *Hemiauchenia*, *Equus* (*Hemionus*), *Northrotheriops*, *Paramylodon*, and *Hesperotestudo*. Except for the giant tortoise (*Hesperotestudo*), these are some of the Rancholabrean large mammals that did not survive the Pleistocene-Holocene transition in North America (Graham and Lundelius 1984). In contrast, many of the small mammals, amphibians, reptiles, and fish continue to live in Southern Plains settings near the Burnham site (Caire et al. 1989; Carpenter and Krupa 1989; Hall 1955).

Specific taxa that attest to prairie or grassland habitats include *Mammuthus*, *Hemiauchenia*, *Bison chaneyi*, *Equus*, *Synaptomys cooperi*, *Chaetodipus* cf. *hispidus*, *Geomys bursarius*, *Microtus* cf. *ochrogaster*, and *Cryptotis parva* (Table 20.5). Of these, several are at or just beyond their historic distributions. *Synaptomys cooperi* is common to the north in Kansas where it occurs at the edges of marshes as well as in dry upland stands of dense grass (Hall 1955:144). *Cryptotis parva* and *Microtus* cf. *ochrogaster* currently have distributions more to the east where they favor dense grass cover (Caire et al. 1989:255-257; Hall 1955:17-18). The presence of these three small mammals in the Burnham fossil record is interpreted to indicate some differences in the ancient temperature and precipitation regimes at this site. In particular, more effective moisture than that of today would have supported the lush, tall grass prairies favored by these small animals.

Not surprisingly, given the sedimentary record for flowing and ponded water, the vertebrate assemblage from these earliest lacustrine deposits includes taxa common to diverse riparian settings. Brushy and wooded areas along this prehistoric drainage would have provided niches for black bear, ground sloth, white-footed mouse, wood rat, and such reptiles as eastern box turtle, kingsnake, rat snake, garter snake, racers, and rattlesnake (Table 20.5) A few of these mammals and reptiles have living representatives that rarely inhabit northwestern Oklahoma today. For example, Woods County is at the western edge of the modern distribution of *Neotoma floridana* (Caire et al. 1989:248-250) and it is notably west of the usual range of *Terrapene carolina* (Conant and Collins 1998:160-161).

Frogs, salamanders, turtles, and fish comprise the fauna indicative of stream, pool, and marsh settings associated with the earliest lacustrine deposits. Among the specific taxa are *Rana catesbeiana*, *Ambystoma tigrinum*, Chelydridae, *Chrysemys* sp., *Trionyx* sp., *Nerodia* spp., and *Lepomis* cf. *cyanellus* (Table 20.5). These have late Pleistocene (but pre-Wisconsinan full glacial) records scattered from southwestern Kansas into northwestern Texas (Cross 1970; Hibbard 1955; Kasper 1989; Preston 1979; Stephens 1960), and they are still found along streams, springs, and marshes in this region. *Lepomis* cf. *cyanellus* is the only fish identified in the site's earliest lacustrine sediments, and this may be a clue that the prehistoric setting was at the uppermost part of the watershed. The green sunfish is a legendarily hardy, persevering species on the plains and prairies (Cross 1967; Walden 1964). In their study of historic fish distributions in Kansas, Smith and Fisher (1970:262-264) consider

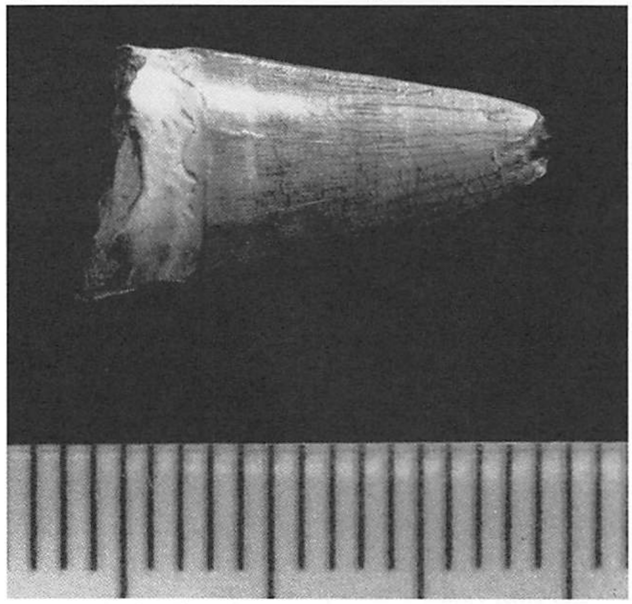


Figure 20.23. The alligator tooth recovered from sedimentary unit IIBb in the East Exposure. The battered tip and base may be clues to this tooth being redeposited from Ogallala Formation deposits on the ridge to the north. The scale is in millimeters.

Lepomis cyanellus to be one of the prairie and plains species often associated with springs and flowing cool water. In contrast, tiger salamanders (*Ambystoma tigrinum*) occur throughout the Plains today but require permanent ponds where they can lay eggs in deep water (Conant and Collins 1998:440-441; Klots 1966:318). They thrive if the ponds are isolated or far enough up the watershed that large fish haven't reached there to prey on them.

Of the fossil amphibians and reptiles in Burnham sedimentary Unit IIB (Table 20.5), three species no longer occur in northwestern Oklahoma. The northern leopard frog (*Rana pipiens*) does live on the plains today but to the north and west of the Burnham site (Thomas 2001). This frog prefers permanently wet marshes (ibid.). Such settings would also have been favored by the smallmouth salamander (*Ambystoma texanum*) which is found today southeast of Woods County (Conant and Collins 1998). Finally, the presence of one alligator tooth (Fig. 20.23) raises the question whether or not this reptile was this far north in late Pleistocene times. Comparably aged fossils are reported (Preston 1979) for Texas at points farther west than their historic distributions, but with one exception, alligators are not reported for middle to late Pleistocene deposits in southwestern Kansas or northwestern Texas. The exception is a reported, but never formally described, tooth from the Cragin fossil quarry in Meade County, Kansas (Preston 1979:25). We have personally collected alligator scutes from Ogallala Formation (Pliocene) deposits in northern Roger Mills County, Oklahoma, but not from any of the western Oklahoma Pleistocene deposits that we have examined. The battered nature of the Burnham example (Fig. 20.23) makes us wonder if it might not have been redeposited from Ogallala Formation sediments like those atop the high ridge north of the site. Lacking any other bones identifiable as alligator, and given the paucity of this species in the many Pleistocene fauna lists from nearby Meade County, Kansas, the existence of alligators in the late Pleistocene watercourse at Burnham remains questionable.

From the vertebrate fossils a picture begins to emerge of the settings associated with the Burnham site's earliest lacustrine sediments (Unit IIB). An upland stream, probably near its headwaters, with a deep pool and nearby marshes are inferred from the identified fish, frogs, salamanders, water snakes, and turtles. Brushy or wooded areas bordering this stream are implicated by such animals as the small ground sloth, black bear, eastern box turtle, eastern woodrat, white-footed mouse, rabbits, and several varieties of snakes. Nearby grasslands are evidenced by the large sloth, mammoth, large horned bison, llama, small horse or ass, and several other rodents. Significantly, these same settings are indicated by the snail assemblage associated with the Unit IIB deposits.

Jim Theler (this volume) has sorted and identified hundreds of snails from Unit IIB contexts. Nine different contexts were sampled (Table 20.6). These yielded 7 aquatic and 14 terrestrial taxa of gastropods (Table 20.6). Not unexpectedly, given that the sampled sediments represent different parts of the prehistoric pond, the 21 taxa weren't recovered from each of the nine contexts (Table 20.6). Still, the identified specimens bear witness to the varied aquatic and terrestrial niches implicated by the vertebrate fossils (Fig. 20.24). Because Theler (this volume) already has interpreted these findings, we only briefly summarize them here.

Among the aquatic gastropods (Table 20.6), *Valvata tricarinata* is important because it informs us about the water quality of the earliest pond at Burnham. This species has its closest modern occurrences in Nebraska where it lives in spring-fed ponds. To reproduce, *Valvata tricarinata* must have water that doesn't warm above 57°F. Its Nebraska occurrence may be a good clue to its Burnham site presence, namely with a cool, spring-fed aquatic niche. *Valvata tricarinata* was recovered from 7 of the 9 sampled contexts of lacustrine Unit IIB (Table 20.6). Although minimally represented, another cool water indicator is *Promenetus exacuous* which was recovered from 8 of the 9 sampled contexts. Found in only 6 of the 9 samples (Table 20.6), *Planorbella trivolvis* is representative of seasonally warm water such as might be found around the shallow, marshy edges of the Burnham site's prehistoric pond (Fig. 20.24).

Terrestrial snails are numerous in lacustrine Unit IIB. They show little damage, so they are believed to have washed into these ponded sediments from nearby locations. The 15 terrestrial taxa (Table 20.6) from Unit IIB include species historically common to cool, moist seeps (*Vertigo ovata and Carychium exiguum*), moist riparian zones affected by changing water tables (*Hawaiia minuscula, Helicodiscus singleyanus*, and *Vallonia perspectiva*), and drier, brushy to grassy settings (*Gastrocopta cristata, G. pellucida, G. procera, G. armifera*, and *Pupoides albilabris*). Historically, a few of the terrestrial species live some distance east or south of the Burnham site: *Gastrocopta pentodon, Helicodiscus parallelus*, and *Vallonia perspectiva* (Hubricht 1985). Their fossil presence at Burnham is believed indicative of less noticeable precipitation and temperature gradations than the zonal conditions prevalent today.

Table 20.6. Aquatic and Terrestrial Gastropods from the Burnham Site's Lowest Ponded Sediments.*

Aquatic taxa	East Grid S1-W22		North 3 Backhoe Trench					West 6 Backhoe Trench	Northwest Exposure
	IIBa	IIBb	NC4 97.16	NC4 96.96	NC4 96.80	NC4 96.56	BC2b 96.37	97.96	
Valvata tricarinata	+	+	+	+		+	+		+
Hydrobiidae/Lymnaeidae	+	+	+	+		+	+		+
Physidae	+	+	+	+		+	+	+	+
Physella virgata			+	+		+		+	+
Gyraulus parvus	+	+	+	+		+	+	+	+
Gyraulus sp.	+	+	+	+	+	+	+	+	+
Planorbella trivolvis	+	+	+			+		+	+
Planorbella sp.	+	+	+	+		+	+	+	+
Promenetus exacuous	+	+	+	+		+		+	+
Ferrissia fragilis	+	+						+	+
Ferrissia walkeri									+
Ferrissia sp.	+	+		+		+			
Terrestrial taxa									
Carychium exiguum				+			+		+
Gastrocopta armifera	+	+	+			+		+	+
Gastrocopta cristata	+	+	+	+	+	+	+	+	+
Gastrocopta pellucida	+	+	+	+	+	+	+	+	+
Gastrocopta pentodon		+				+			+
Gastrocopta procera	+	+	+			+	+	+	+
Pupoides albilabris	+	+	+	+			+		+
Vertigo ovata	+	+							+
Vallonia perspectiva	+	+	+	+	+		+	+	+
Vallonia sp.	+	+	+	+	+	+	+	+	+
Helicodiscus parallelus		+				+	+	+	+
Helicodiscus singleyanus	+	+	+	+		+	+	+	+
Succineidae	+	+	+	+		+	+	+	+
Hawaiia minuscula	+	+	+	+	+	+	+	+	+
Deroceras laeve	+	+	+	+		+		+	+

*See Tables 12.2, 12.3, 12.4, 13.1, and 20.1.

The cumulative evidence from the vertebrate and invertebrate fossils supports the interpretation for diverse spring, stream, pond, riparian, and open grassy settings at and around the Burnham site some 36,000 to 34,000 years ago. The site itself was most likely at the headwaters of the prehistoric drainage. There,

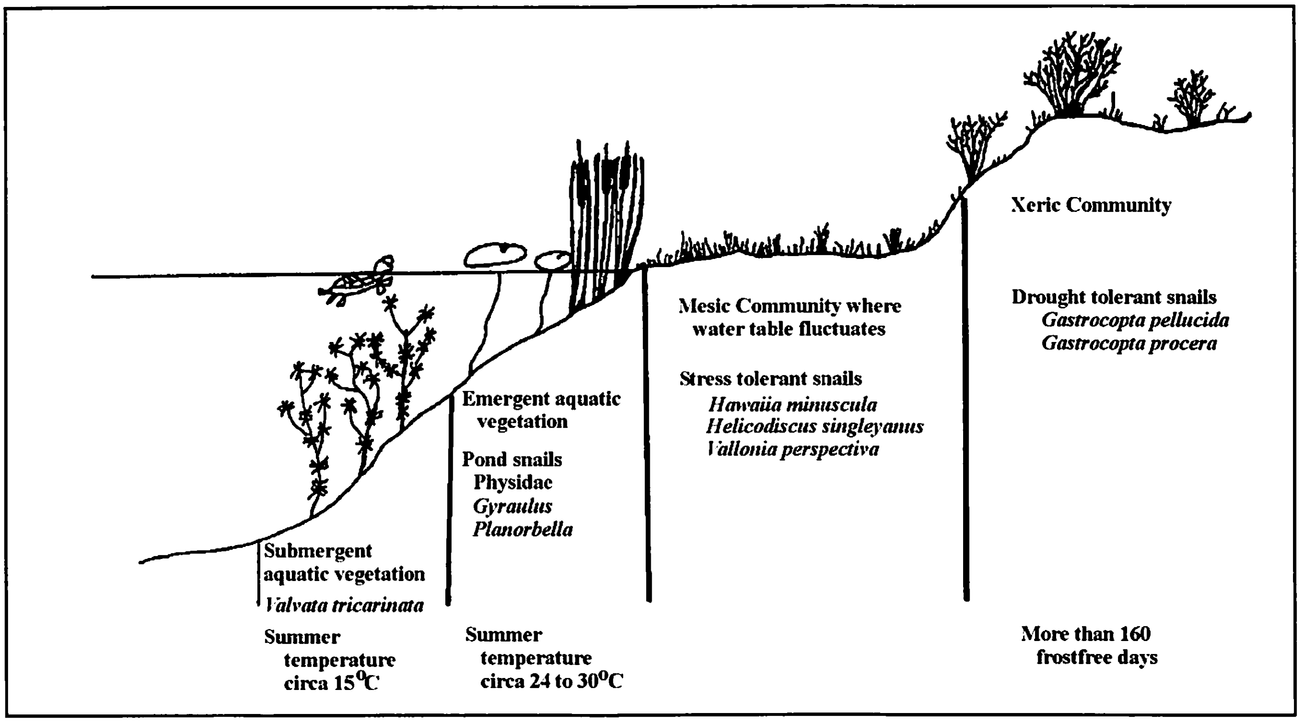


Figure 20.24. Habitat niches inferred from Burnham site snails recovered from prehistoric sedimentary units IIB and IIC. Illustration prepared by Jim Theler.

springs provided cold water that supported green sunfish and a cold water dependent species of aquatic gastropod. Water impounded (most likely by beavers) below this spring created a small (1/4 to 1/2 acre; <1 hectare) pond that was confined to diverging channels of the drainage at its uppermost end. Shallow edges of this pond provided warm water for select gastropods that thrive on emergent plants such as cattails. Trees (at least hackberry) grew along this drainage and provided moisture retentive to dry niches for a variety of terrestrial gastropods, reptiles, and different small and large mammals. Away from this riparian setting, dry but lush grasslands supported small horses, mammoths, llamas, occasional large horned bison, and an array of small mammals, tortoises, and terrestrial snails. Among the mammals and snails are a few species now found well to the north, east, and south. The co-occurrence of such species in the fossil record bears witness to ameliorating climatic conditions that were less cold and more moist than those of today. This kind of co-occuring fossil record is also recognized at such pre-Wisconsinan full glacial fossil localities as Doby Springs in Harper County, Oklahoma, Jones in southwestern Kansas, and Carrol Creek in northwestern Texas (Davis 1975; Kasper 1989; Stephens 1960).

The Second Lowest Pond Deposit (Unit IIC)

The second lowest lacustrine unit is known only for the East Exposure where it was stratigraphically above lacustrine Unit IIB (Table 20.1). This second lowest unit was composed of gleyed fine sandy loam that varied from 40 to 45 cm in thickness and was manifest between elevation 96.9 and 97.5. It had an irregularly convex bottom in east-west cross section (Fig. 20.10). This lower boundary was clear. Along its western exposure, this boundary was marked with discontinuous, almost tabular, carbonate nodules (Figs. 2.3, 2.4, and 5.19). These may have formed during a drying event while this sediment accumulated. In fact, Unit IIC consists of two separate, but nearly contemporaneous, sediment accumulations: Unit IICa, which is the western part of the East Exposure, and Unit IICb, which appears to be a cut-and-fill inset at the eastern extent of this deposit (Table 20.1; Fig. 20.10). This eastern segment held the so-called "horse bone bed" (e.g., Todd, this volume). None of Unit IIC is well dated. Because it yielded vertebrate and invertebrate fossils comparable to those from Unit IIB, Unit IIC is believed to be very close in age to the 36,000 to 34,000 years indicated for the directly underlying Unit IIB.

The second lowest pond deposit was subjected to quite a bit of controlled, manual excavations. In its western extent, Unit IICa was dug through in several squares north of the East Grid's east-west base line and also in a few squares south of that base line and east of the West 22 line. Slightly more than four cubic meters of Unit IICa fill was eventually dug by hand and waterscreened. In contrast, only a cubic meter was so excavated from Unit IICb, and this was done to uncover, taphonomically record, and recover bones in the "horse bone bed". A review of Martin and Meehan's faunal identification table (Table 8.2) reveals that more vertebrate fossils come from the minimally exposed "horse bone bed" than from the more extensive fill waterscreened from Unit IICa. We believe this reflects the fact that this bone bed was at the pond edge (where mammals drank and died) whereas Unit IICa was where the pond was deeper and not frequented by most mammals.

Twenty-one taxa are represented in the vertebrate remains identified for lacustrine sedimentary Unit IIC (Table 20.7). The two contexts associated with Unit IIC share only 11 (46%) taxa, but among these are mammoth, large horned bison, small ass, blacktailed prairie dog, Plains pocket gopher, prairie vole, several snakes, and sunfish (Table 20.7). Many of these shared animals are among the 16 (76%) taxa that Unit IIC holds in common with the underlying Unit IIB (compare Tables 20.5 and 20.7).

As we saw with the earliest pond deposit (Unit IIB), no animals in Unit IIC are represented by complete articulated skeletons. Even though the "horse bone bed" contained notable articulated parts of the vertebral column and some other elements of *Equus* (Figs. 20.25 and 20.26), it did not yield all of the bones of this animal. This is in spite of the observation that bones in the "horse bone bed" were taphonomically less disturbed than other plotted bones at the site (Todd, this volume). Consequently, like the fauna discussed for the underlying Unit IIB, the animals in the second lowest pond deposit are represented by dispersed, disarticulated bones. On this basis we again believe the death sites for most mammals and some reptiles found in Unit IIC were places away from the prehistoric pond. Flowing water is again considered the principal agency that moved, dispersed, and eventually deposited the vertebrate remains in Unit IIC.

As with the vertebrate fauna from the lowest pond deposit, those from the second lowest include species still present in the area and some extinct since 10,000 years ago. The latter include mammoth, small ass, and the large horned bison (Table 20.7). Bones of the southern bog lemming also were recovered from Unit IIC sediments; this small rodent now has its range north of Woods County (Hall 1955:143-144). The remainder of the speciated taxa in Table 20.7 are animals still resident on the eastern border of the Southern High Plains (Caire et al. 1989).

Lacustrine sedimentary Unit IIC vertebrate taxa bear witness to the grassland, riparian, and stream/pool settings first evidenced by the animals recovered from underlying Unit IIB. Unit IIC taxa indicative of nearby grasslands include mammoth, large horned bison, small ass, and coyote as well as such small creatures as blacktailed prairie dog, Plains pocket gopher, and prairie vole (Table 20.7). Rattlesnakes and the reptiles *Lampropeltis* sp. and *Thamnophis* sp. could also be appropriate associates. These three snakes might be equally at home in the riparian setting where rabbits, the eastern mole, eastern woodrat, and southern bog lemming (Table 20.7) would be expected. Although not as extensive as for Unit IIB, the Unit IIC animals associated with flowing and ponded water include the tiger salamander, frogs, pond turtles, water snakes, and sunfish (Table 20.7).

Table 20.7. Vertebrate Fauna Associated with the Second Lowest Ponded Deposits (Unit IIC)* at the Burnham Site.

Species	Lacustrine Unit IICa	Lacustrine Unit IICb
Mammoth (*Mammuthus*)	+	+
Large horned bison (*Bison chaneyi*)	+	+
Unspeciated Artiodactyl		+
Small wild ass (*Equus [Hemionus]*)	+	+
Coyote (*Canis latrans*)		+
Unspeciated Carnivore		+
Eastern mole (*Scalopus aquaticus*)		+
Rabbit (*Sylvilagus* sp.)	+	+
Blacktailed prairie dog (*Cynomys ludovicianus*)	+	+
Plains pocket gopher (*Geomys bursarius*)	+	+
Eastern woodrat (*Neotoma* cf. *floridana*)	+	
Southern bog lemming (*Synaptomis cooperi*)		+
Prairie vole (*Microtus* cf. *ochrogaster*)	+	+
Unspeciated Rodent	+	+
Perching birds (Passeriform)		+
Unspeciated Bird		+
Frog (*Rana* sp.)		+
Unspeciated Frog	+	+
Tiger salamander (*Ambystoma tigrinum*)	+	
Unspeciated Lizard	+	
Pond turtle (*Clemmys* sp.)	+	
Unspeciated Turtle	+	+
Kingsnake/Milksnake (*Lampropeltis* sp.)		+
Garter/Ribbon snake (*Thamnophis* sp.)		+
Water snake (*Nerodia* sp.)	+	+
Unspeciated Colubrid snake		+
Rattlesnake (*Crotalus* sp.)	+	+
Unspeciated Snake	+	+
Sunfish (*Lepomis* cf. *cyanellus*)	+	+

*Compiled from Table 8.2.

Table 20.8. Aquatic and Terrestrial Gastropods from the Burnham Site's Second Lowest Ponded Sediments.*

Aquatic taxa	North 3 Backhoe Trench Column 97.77	97.60	97.43	97.32
Valvata tricarinata	+	+	+	+
Hydrobiidae/Lymnaeidae	+	+	+	+
Physidae	+	+	+	+
Physella virgata				+
Gyraulus parvus	+	+	+	+
Gyraulus sp.	+	+	+	+
Planorbella trivolvis			+	+
Planorbella sp.	+	+	+	+
Ferrissia frigilis			+	+
Ferrissia walkeri			+	+
Ferrissia sp.	+			
Terrestrial taxa				
Carychium exiguum		+		
Gastrocopta armifera	+			+
Gastrocopta cristata	+	+	+	+
Gastrocopta holzingeri	+	+	+	+
Gastrocopta pellucida	+		+	+
Gastrocopta pentodon	+	+		+
Gastrocopta procera	+			
Pupoides albilabris	+			
Vertigo ovata		+		
Vallonia perspectiva	+	+	+	+
Vallonia sp.	+	+	+	+
Helicodiscus parallelus	+	+	+	+
Succineidae	+	+	+	+
Hawaiia minuscula	+	+	+	+
Deroceras laeve	+	+	+	+
Deroceras aenigma	+	+		

*See Table 12.3.

The aquatic, riparian, and grassy upland settings evidenced from Unit IIC vertebrates are also indicated by the gastropods from this unit (Theler, this volume). Relevant snails were identified in four stratified samples (Table 20.8) that were part of the column (Table 12.3) taken in the North 3 backhoe trench just east of the "horse bone bed" (Fig.

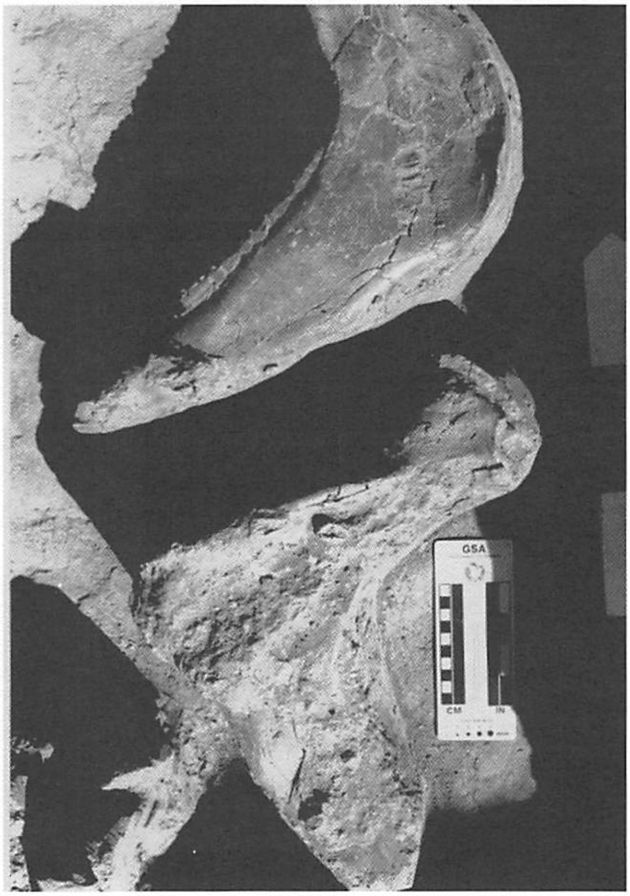


Figure 20.25. Equus *mandibles lying flat in pond Unit IICb of East Grid square N4-W14. Photo taken October 16, 1989, by Don Wyckoff.*

Figure 20.26. View east of the "horse bone bed" lying horizontal in East Grid square N4-W14. Note vertical krotovinas penetrating the gray sediment of Unit IICb. Photo taken October 16, 1989, by Don Wyckoff.

12.2). Consequently, the identified snails are pertinent to the Unit IICb part of this deposit. No snails have been studied for the Unit IICa segment. The four studied and identified samples come from elevations 97.32, 97.43, 97.60, and 97.77 (Table 20.8). Aquatic snails dominate the samples from elevations 97.32 (55%) and 97.43 (63%) and decline steadily from 97.60 (43%) to 97.77 (27%). We interpret these changing percentages to indicate that the stratified samples come from lacustrine Unit IICb sediment deposited during and immediately after this pond existed.

Six aquatic and 15 terrestrial gastropod taxa are in the four samples from lacustrine Unit IICb (Table 20.8). These taxa are essentially the same as those recovered from the lowest pond deposit (compare Tables 20.6 and 20.8). All of the aquatic taxa from Unit IICb occurred in Unit IIB (which also had one other minor aquatic species, *Promenetus exacuous*), and 14 of the 15 terrestrial taxa in Unit IICb were recovered from Unit IIB sediments (Tables 20.6 and 20.8). *Gastrocopta holzingeri* and the slug *Deroceras aenigma* are new additions to the terrestrial taxa for Unit IICb, but neither is numerous. All in all, the aquatic and terrestrial snails from the second lowest pond deposit basically replicate the taxa from the lowest pond deposit. We interpret these common occurrences to indicate that similar ecological niches were present (Fig. 20.24) and that little time lapsed between the two ponding events responsible for Unit IIC and the underlying Unit IIB.

As noted above, aquatic gastropods prevail in half of the four sediment samples taken for Unit IICb. Among the most numerous aquatic taxa in these two samples (elevations 97.32 and 97.43) are Physidae, *Gyraulus* sp., *Planorbella* sp., and *Ferrissia walkeri* (Tables 12.3 and 20.8). All of these would be species common to plant-rich, shallow pools (Theler, this volume). Although not numerous, *Valvata tricarinata*, a recognized indicator of cold, probably spring-flow, water occurs in the two samples where aquatic taxa dominate as well as in the uppermost two samples where aquatic taxa wane (Tables 12.3 and 20.8).

Terrestrial snails occur in the two lowest samples and dominate the uppermost two (Tables 12.3 and 20.8). Particularly numerous are the taxa *Hawaiia minuscula*, *Vallonia perspectiva*, and *Vallonia* sp. (Table 12.3). These are species common to mesic and increasingly drier habitats where deciduous detritus can accumulate and retain some moisture (Theler, this volume). The few recovered examples of *Helicodiscus parallelus* also probably bear witness to such mesic niches. Scattered through the four samples are occasional specimens of Succineidae and several varieties of *Gastrocopta* (Table 12.3). These terrestrial taxa generally are associated with dry, brushy to grassy settings. Finally, a few specimens of the extant slug *Deroceras laeve* and the extinct slug *D. aenigma* were recovered (Tables 12.3 and 20.8).

In summary, the vertebrate and invertebrate faunas from the second lowest pond deposit (Unit IIC) closely resemble those from the lowest pond deposit (Unit IIB). Besides implicating continuity of stream, pool, riparian, and grassland (prairie) habitats around the site, these shared taxa make it hard to believe that much climate change or time difference occurred between the two ponding events that created

Figure 20.27. Looking north at Unit IID sediment (dark) resting atop ponded sediment Unit IICa in East Grid squares N3-W19 and N3-W20. Photo taken October 20, 1989, by Don Wyckoff.

sedimentary Unit IIC and the underlying Unit IIB.

The Uppermost Pond Deposits (Units IID, IIE, and IIF)

The gleyed deposits lying above ponded sediment Unit IIC were minimally dug by hand. In part, this was because these deposits were preserved higher and farther away (northeast) from the stratum where fossils and artifacts were found. Also, even once exposed in backhoe profiles, these highest gleyed deposits were noticeably devoid of bones and snails. Because so little biological information comes from these uppermost lacustrine sediments, they are treated collectively here.

Ponded sediment Unit IID was a 40 to 50 cm thick, reddish brown loam that lay directly over Unit IIC (Table 20.1; Figs. 19.12 and 20.27). Manual excavations in four East Grid squares resulted in slightly more than a half cubic meter of Unit IID sediment being waterscreened (Table 20.1). This modest amount of waterscreened fill did yield 55 bone fragments attributable to 9 vertebrate taxa (Table 20.9). Although few Unit IID taxa are identified at the species level, this list is notable because Pleistocene large mammals are almost lacking (except for horse) and the remainder are mainly animals with representatives still living in the Burnham locality.

Unit IID was not sampled for gastropods. However, from the sediment column taken in the North 3 backhoe trench, samples at elevations 98.08 and 98.26 (Table 12.3) come from soil and sediment at nearly the same elevation as Unit IID. No pretense is made that snails from elevations 98.08 and 98.26 are from Unit IID sediments, but they appear coeval with the Unit IID ponding event. The taxa and their quantities for these two samples are summarized in Table 20.10. Aquatic taxa are present, but they comprise less than 10% of either sample. On this basis the sampled sediments were most likely adjacent the watery setting where these aquatic taxa lived. Two *Valvata tricarinata* shells may be evidence that cold, spring flow was still important to this setting. The terrestrial taxa include numerous *Hawaiia minuscula* and several varieties of *Gastrocopta* and *Vallonia* (Table 20.10). These terrestrial taxa attest to brushy and grassy niches with varying degrees of moisture retention. Many of these forms of land snails still live in the Burnham locality today (Theler, this volume). The presence of the slug *Deroceras aenigma* implicates that these sampled sediments/soils are Pleistocene in age. The only pollen recovered at the site came from an episodic deposit of silty clay just below, and a meter north of, these two snail samples. Among the recovered degraded pollen were grains identifiable as sedge, grass, and cedar (Wigand, this volume). These, too, are still common in the region.

Table 20.9. Vertebrate Fauna Associated with Ponded Sediment Unit IID, East Exposure of the Burnham Site.*

Identified Taxa	Number of Elements
Small horse or ass, *Equus (Hemionus)*	2 teeth
Rabbits/Hares, *Sylvilagus/Lepus*	1 tooth (*Lepus*)
Plains pocket gopher, *Geomys bursarius*	4 bone fragments and 5 teeth
Prairie vole, *Microtus* cf. *ochrogaster*	3 molars
Unspeciated rodent	2 bones and 1 tooth
Perching bird, Passeriform	1 bone section
Northern leopard frog, *Rana pipiens*	1 bone
Frog, *Rana* sp.	1 bone
Unspeciated frog	1 bone fragment
Tiger salamander, *Ambystoma tigrinum*	4 bones
Unspeciated turtle	1 bone
Unspeciated snake	20 vertebrae

*Compiled from Table 8.2.

Table 20.10. Aquatic and Terrestrial Gastropods from Two Samples Potentially Contemporaneous with Lacustrine Unit IID, Burnham Site.*

Aquatic taxa	North 3 Column Elevation 98.26	North 3 Column Elevation 98.06
Valvata tricarinata		2
Hydrobiidae/Lymnaeidae		2
Physidae	31	13
Gyraulus parva	1	1
Gyraulus sp.	2	5
Planorbella sp.	3	6
Ferrissia frigilis		4
Ferrissia sp.	1	
subtotal	38	33
Terrestrial taxa		
Gastrocopta armifera	2	
Gastrocopta cristata	9	3
Gastrocopta pellucida		2
Gastrocopta procera	14	
Pupoides albilabris		3
Vallonia perspectiva	16	27
Vallonia sp.	56	124
Helicodiscus parallelus	3	3
Helicodiscus singleyanus	102	160
Succineidae		3
Hawaiia minuscula	145	148
Deroceras laeve	8	8
Deroceras aenigma		3
subtotal	426	545

*Compiled from Table 12.3.

Lacustrine sedimentary Unit IIE is a thin, gleyed, fine sandy loam that was minimally excavated and waterscreened (Table 20.1). It did yield a piece of charcoal that was radiocarbon dated at 11,580 + 320 years ago (Sample NZA-1090). A few bone fragments were recovered but none retained enough attributes to allow species identification. No Unit IIE matrix samples were processed for gastropods, so we have no corresponding invertebrate record for this unit.

Ponded sediment Unit IIF was a distinct, isolated, gray

Figure 20.28. View north of the uppemost gleyed pond sediment Unit IIF. This exposure is in the north wall of the backhoe trench dug in 1992. Photo taken June 18, 1992, by Bill Thompson.

stratum perched high in the East Exposure stratigraphy (Table 20.1). Unit IIF was first observed in the northern part of the West 15.5 backhoe trench profile (Fig. 5.12). Its east-west cross section was nicely revealed in the 1992 backhoe trench (Fig. 20.28). These profiles provided access to nearly 10.0 m of Unit IIF, and these profiles were trowelled clean several times. This work failed to uncover any vertebrate remains in this uppermost gleyed sediment. Rare snail shells were observed during the trowelling, but they were often broken. A matrix column was taken through the gleyed sediment of Unit IIF, but because snails seemed so sparse these matrix samples were never processed.

Clearly, biological information for the three uppermost ponded sediments is minimal. The lowest of these is Unit IID, and the few vertebrate and invertebrate fossils recovered from it are essentially taxa evidenced for the two lowest ponded sediments. Thus, we are inclined to believe that Unit IID was the waning pond event in the sequence of Units IIB and IIC. Above Unit IID, the remaining two lacustrine units (IIE and IIF) are thin, cover little area, and seem much more ephemeral than the two lowest units. A radiocarbon date from Unit IIE indicates it is very late (post-Wisconsinan full glacial) Pleistocene. Perched even higher and more isolated than Unit IIE, lacustrine sediment Unit IIF is believed to be even more recent. Regrettably, neither of these two highest sediment accumulations yielded vertebrate or invertebrate fossils that would enhance understanding their ages or the environments in which they accumulated.

Regional Comparisons of the Burnham Paleontological Record

With its hundreds of identified bones and snails, the Burnham site's paleontological record is an important contribution to our understanding of late Pleistocene settings and environments on the Southern Plains. This record's significance is increased because the fossil-yielding deposits have more radiocarbon dates than any comparably aged Southern Plains location. Clustered between 40,000 and 30,000 years ago, these dates indicate that the Burnham site's soils, sediments, and fossils are evidence for Southern Plains situations at least 10,000 years before the peak of the last major glaciation. From southwestern Kansas to northern Texas, a few other fossil-yielding locations also appear to relate to these pre-full glacial times. So, to put the Burnham findings into a broader context, we briefly undertake some correlations and comparisons with other Southern Plains paleontological sites.

Vertebrate Faunal Comparisons

Nine reported sites in Kansas, Oklahoma, and Texas have vertebrate collections selected for comparison with those from Burnham (Fig. 20.29). Salient characteristics of these nine sites are summarized in Table 20.11. Seven have paleontological records that are roughly contemporaneous with Burnham: Jones, Carrol Creek, Little Sunday, Quitaque, Beaver Creek, Big Wichita River, and Canadian (Table 20.11). Their inclusion enables a regional comparison of vertebrate fauna during the Wisconsinan glacial period before the full glacial times that started around 21,000 years ago. To further appreciate the vertebrate faunal records from these 30,000 to 40,000 year old sites, we have also included the records from two sites dating to full glacial times. The Howard Ranch material is radiocarbon dated to the Wisconsinan full glacial of some 19,000 years ago (Table 20.11). In contrast, the Doby Springs fauna is believed (Stephens 1960) to relate to a middle Pleistocene glaciation of some 130,000 to 300,000 years ago.

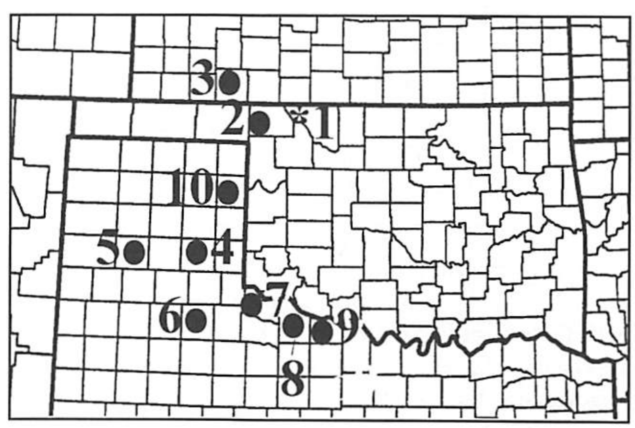


Figure 20.29. Locations of selected local faunas used to compare with the Burnham paleontological findings: 1, the Burnham site; 2, Doby Springs; 3, Jones; 4, Carrol Creek; 5, Little Sunday; 6, Quitaque; 7, Howard Ranch; 8, Beaver Creek; 9, Big Wichita River; and 10, Canadian.. See Table 20.11 for descriptions of these local fauna sites.

Table 20.11. Selected Pleistocene Paleontological Sites in Kansas, Oklahoma, and Texas.

Local Fauna Site	Description	References
Doby Springs, Harper County, Oklahoma	No. 2 in Figure 20.29. Large collapse basin that contains lake deposits believed to be middle Pleistocene in age. No radiocarbon dates. Varied vertebrate and invertebrate remains recovered from 10 ft. of deposits at 5 different locations. Twenty-four mammalian taxa identified along with less well identified frogs, salamanders, reptiles, birds, and gastropods.	Hibbard 1970; Stephens 1960.
Jones, Meade County, Kansas	No. 3 in Figure 20.29. Deep exposure of stratified sediments in a collapse basin on the edge of the High Plains. Of the two fossil-bearing strata, emphasis is on the "*Ambystoma*-zone" which was radiocarbon dated at 26,700 ± 1500 years ago (I-3461) and 29,000 ± 1300 years ago (I-3462); dates are on snail shells. Vertebrate and gastropod assemblages from the "*Ambystoma*-zone" are well reported.	Davis 1975; Miller 1975.
Carrol Creek, Donley County, Texas	No. 4 in Figure 20.29. Fluvial clay, sand, and gravel exposed along present creek and believed to be sediment washed into a sinkhole. A radiocarbon date of 32,400 ± 560 years ago (Beta-25354) obtained on snail shells. Over 3.0 kg of sandy clayey sediment washed, recovering many broken mammal bones. Mammalian remains thoroughly studied; recovered fish and gastropods not studied.	Dalquest and Schultz 1992:46-47; Kasper 1989; Kasper and Parmley 1990.
Little Sunday, Randall County, Texas	No. 5 in Figure 20.29. Greenish gray sands and clays comprise uppermost sediment in a basin believed half mile in diameter. Freshwater snails from deposit reportedly radiocarbon dated at 31,400 ± 3200 years ago. Nearly 6 tons of sediment waterscreened, yielding many mammals that have been studied. Also recovered fish, salamander, frog, snake, bird, and gastropod remains but these aren't studied in detail.	Dalquest and Schultz 1992:50-51; Johnston and Savage 1955.
Quitaque, Motley County, Texas	No. 6 in Figure 20.29. Fluvial sand and silty sand that comprise part of alluvial plain just east of High Plains caprock. Snail shells reportedly date to 31,400 ± 5600 and 31,400 ± 3200 years ago, but soil organics yielded dates of >38,260 (Beta-8969) and >35,000 (Tx-4900) years ago.. Small interesting assemblage of mammals recovered.	Caran and Baumgardner 1986; Dalquest 1964; Dalquest and Schultz 1992:39-40.
Howard Ranch, Hardeman County, Texas	No. 7 in Figure 20.29. Gray clayey sediments comprise valley or basin fill south of Red River. Snail shells radiocarbon dated at 16,775 ± 565 (unnumbered Socony Mobil sample) and 19,098 ± 1074 (SM-620). Waterscreening yielded one of largest late Pleistocene faunal assemblage for northern Texas; many diverse mammals.	Dalquest 1965; Dalquest and Schultz 1992:55-57.
Beaver Creek, Wilbarger County, Texas	No. 8 in Figure 20.29. Some 3.0 m of Pleistocene silty sand believed the result of local fluvial event. Shells reportedly yielded a radiocarbon date of 34,900 ± 700 years ago. Small assembage of mammalian remains, including traces of *Bison alleni*.	Dalquest 1957; Dalquest and Schultz 1992:42-43.
Big Wichita River, Wichita County, Texas	No. 9 in Figure 20.29. Numerous bones recovered from spoil piles left from commercial gravel quarrying. No radiocarbon dates, but recovered mammalian taxa believed to be 30,000 to 40,000 years old.	Dalquest and Schultz 1992:44-45; Jelinek 1960.
Canadian, Hemphill County, Texas	No. 10 in Figure 20.29. Organic rich sediment over gray clay in second terrace of Canadian River. Radiocarbon date of 34,900 ± 700 on shells. Small assemblage of mammals.	Dalquest and Schultz 1992:45-46.

Comparisons of the mammalian fossil lists are shown in Table 20.12. This table contains only the mammalian vertebrate finds identified for the sites. Although several of these sites (such as Jones and Little Sunday) yielded bones of frogs, salamanders, turtles, snakes, and fish, the respective paleontologists (Table 20.11) concentrated on identifying the mammals. So, for comparison's sake, we have listed only the mammal taxa (Table 20.12). Also, we show only the records for places where more than ten mammals were identified.

By comparing the percentages of shared taxa between sites, we attempted to examine the degree that these faunal lists (Table 20.12) were similar. No high correlations were observed between any of the sites. The highest correlation (26%) was between the faunal lists for the two pond deposits at the Burnham site. The range of correlations between Burnham and the other mid-Wisconsinan sites was from 6% (Burnham IIB with Quitaque) to a modest 15% (Burnham IIC with Carrol Creek). Even among the mid-Wisconsinan sites the degree of correlation was never higher than 24% (Jones and Carrol Creek). Notably, none of the Burnham contexts had a correlation exceeding 5% with the very ancient full glacial Doby Springs fauna, and the Burnham con-

Table 20.12. Comparison of Mammals from Burnham Early Pond Deposits with Other Middle to Late Pleistocene Paleontological Assemblages.

Taxa	Burnham Units IIC	IIB	Howard Ranch L.F.	Jones L.F.	Little Sunday L.F.	Quitaque L.F.	Carrol Creek L.F.	Doby Springs L.F.
Bison (*Bison antiquus*)			+					
Bison (*Bison chaneyi*)	+	+						
Bison (*Bison latifrons*)								+
Mammoth (*Mammuthus columbi*)			+		+	+	+	
Mammoth (*Mammuthus* sp.)	+	+		+				+
Whitetailed deer (*Odocoileus virginianus*)			+			+		
Unspeciated deer (Cervidae)		+						
Peccary (*Platygonus compressus*)				+				
Small camel (*Camelops minidoke*)						+		
Large-headed llama (*Hemiauchenia*)		+	+					
Unspeciated camel (*Camelops* sp.)			+		+			
Little pronghorn (*Capromeryx* cf. *furcifer*)						+		
Unspeciated antelope (Antilocapridae)								+
Little horse (*Equus* cf. *conversidens*)			+					
Noble horse (*Equus* cf. *excelsus*)						+		
Large horse (*Equus niobrarensis*)								+
Scott's horse (*Equus scotti*)			+					
Small ass (*Equus* [*Hemionus*])	+	+						
Unspeciated horse (*Equus*)				+	+	+	+	+
Gray fox (*Urocyon cinereoargenteus*)			+					
Coyote (*Canis latrans*)	+					+		
Unspeciated canid (Canidae)					+			
Black bear (*Ursus* cf. *americanus*)		+						
Raccoon (*Procyon lotor*)			+					
Skunk (*Mephitis mephitis*)			+					
Mink (*Mustela vison*)			+					
Badger (*Taxidea taxus*)				+				
Jaguar (*Panthera onca*)						+		
Unspeciated carnivore (Carnivora)	+	+						
Shasta ground sloth (*Nothrotheriops shastensis*)		+						
Ground sloth (*Megalonyx* sp.)						+		
Harlan's ground sloth (*Paramylodon*)		+						
Cottontail (*Sylvilagus* sp)	+		+	+			+	
Blacktailed jack rabbit (*Lepus californicus*)							+	+
Unspeciated rabbit/hare (*Sylvilagus/Lepus*)		+						
13-lined ground squirrel (*Spermophilus tridecemlineatus*)				+		+	+	+
Elegant ground squirrel (*Spermophilus* cf. *elegans*)					+			
Franklin's ground squirrel (*Spermophilus* cf. *franklini*)				+				
Richardson's ground squirrel (*Spermophilus richardsonii*)				+				
Blacktailed prairie dog (*Cynomys ludovicianus*)	+	+	+	+	+		+	
Bottae pocket gopher (*Thomomys bottae*)	+		+					
Northern pocket gopher (*Thomomys* cf. *talpoides*)					+			
Plains pocket gopher (*Geomys bursarius*)		+	+	+			+	+
Western pocket gopher (*Thomomys* sp.)				+				+
Pocket mouse (*Perognathus* sp.)			+	+				
Hispid pocket mouse (*Chaetodipus* cf. *hispidus*)		+	+				+	
Ord's kangaroo rat (*Dipodomys ordii*)			+					
Beaver (*Castor canadensis*)			+					+
Hibbard's rice rat (*Oryzomys fossilis*)			+					
Fulvous harvest mouse (*Reithrodontomys* cf. *fulvescens*)							+	
Western harvest mouse (*Reithrodontomys megalotis*)			+					
Cochran mouse (*Peromyscus cochrani*)								+
Oklahoma mouse (*Peromyscus oklahomensis*)								+
Common deer mouse (*Peromyscus* cf. *maniculatus*)			+	?	+			
Whitefooted deer mouse (*Peromyscus leucopus*)		+	+					
Shorttailed grasshopper mouse (*Onychomys leucogaster*)			+	+	+			
Hispid cotton rat (*Sigmodon hispidus*)			+					
Eastern woodrat (*Neotoma* cf. *floridana*)	+	+						
Plains woodrat (*Neotoma* cf. *micropus*)			+				+	
Prairie vole (*Microtus* cf. *ochrogaster*)	+	+	+	+	+	+	+	
Meadow vole (*Microtus pennsylvanicus*)			+	+	+	+	+	+
Florida bog lemming (*Synaptomys australis*)							+	
Southern bog lemming (*Synaptomys cooperi*)	+	+	+			+		
Muskrat (*Ondatra zibethicus*)			+					+
Unspeciated rodent (Rodentia)		+						
Arctic shrew (*Sorex arcticus*)				+			+	+
Masked shrew (*Sorex cinereus*)			+	+				+
Water shrew (*Sorex palustris*)			+					+
Shorttailed shrew (*Blarina brevicauda*)			+					+
Least shrew (*Cryptotis parva*)		+	+					
Eastern mole (*Scalopus aquaticus*)	+		+				+	

texts showed correlations of only 11 to 15% with the Wisconsinan full glacial fauna at Howard Ranch. Overall, these quantitative attempts to correlate diverse faunal assemblages fail for several reasons. For one, the respective assemblages are not identified to the same levels of species and varieties. Also, the assemblages are of diverse ages and from places several hundred miles apart north and south. In essence, they are not exactly contemporaneous and their faunas could reflect north-south clinal variations as well as temporal variations due to short-term climatic fluctuations. Finally, these lists come from different kinds of deposits, from different settings (fluvial margins vs. centers) within these deposits, and from different amounts of sediments that were processed in ways that weren't always comparable.

Although our quantitative comparisons don't reveal strong correlations among the mid-Wisconsinan sites, the animals reported for these locations attest to settings where grasslands were prevalent and adjacent well watered streams and substantial lakes. The principal grazers were Columbian mammoths and several forms of camels and horses (Table 20.12). These large mammals are reported for many of the sites listed in Table 20.12 as well as the Big Wichita, Canadian, and Beaver Creek localities where relatively few fossils were recovered (Dalquest and Schultz 1992). In contrast, bison have a spotty record at all of these sites (Table 20.12), and they are never represented by bone counts indicative of herds like those known for latest Wisconsinan and early Holocene times (Wyckoff and Dalquest 1997). Several bison varieties are implicated for the mid-Wisconsinan sites (Table 20.12), but concern has been continually expressed about their classification (Dalquest and Schultz 1992; Wyckoff and Dalquest 1997). *Bison antiquus* is well established in the fossil record by Wisconsinan full glacial times (Dalquest 1961; Dalquest and Schultz 1992:256-259), but bison variations for the preceding 80,000 years have been cause for concern. The Burnham examples are classified as *Bison chaneyi* because their horns curve more than such large-horned forms as *B. alleni* and *B. latifrons*. These straighter, large-horned bison are reported among the mid-Wisconsinan fauna at the Big Wichita and Beaver Creek locations in northern Texas (Fig. 20.29) where they were variously considered as *B. latifrons*, *B. alleni*, *B. chaneyi*, and even *B. priscus* (Dalquest and Schultz 1992). Similar, but as yet unstudied, large-horned skulls are known for northern Texas and southwestern Oklahoma (Wyckoff and Dalquest 1997). Unlike the small and large forms of camels and horses, which probably filled different niches in mid-Wisconsinan grasslands, these bison don't appear adaptively different. For this reason, they could well represent variations (age and/or sex) of one mid-Wisconsinan form.

Most large mammals listed for the mid-Wisconsinan sites did not survive the Pleistocene-Holocene transition of 12,000 to 10,000 years ago. But some of the small mammals from these sites (Table 20.12) are forms still living in the region or living just south, west, or north of the region. Those still extant on the Southern Plains include the blacktailed prairie dog, shorttailed grasshopper mouse, hispid pocket mouse, Plains pocket gopher, thirteen-lined ground squirrel, least shrew, eastern mole, and prairie vole (Table 20.12). These occur at several of the fossil sites in Table 20.12 as well as at the Big Wichita, Canadian, and Beaver Creek fossil localities (Dalquest and Schultz 1992). Among the fossil forms no longer common to all of the region today are the southern bog lemming, Florida bog lemming, eastern woodrat, and arctic shrew (Table 20.12 and the Canadian local fauna site; see Dalquest and Schultz 1992). The presence of all of these small critters in mid-Wisconsinan times is interpreted as evidence for more equable climatic conditions than occur today (Graham and Lundelius 1984; Lundelius 1967). Such conditions probably entailed warmer winters and cooler summers (with their concomitant effective moisture changes) than those of today.

Molluscan Faunal Comparisons

Fossil snails yielded exceptional information about the Burnham site's ancient setting (Theler, this volume). Since the 1930s, fossil mollusks have been recognized as components worthy of paleontological study in the region (Baker 1938; Leonard 1946, 1948), and, by the early 1950s, molluscan assemblages were being used to correlate deposits in different Kansas settings in order to discern Pleistocene landscape changes (Frye and Leonard 1952). By the late 1950s, paleontologists were realizing that fossil gastropods had more research potential than simply as aids in relative dating. Abundant in southwestern Kansas vertebrate fossil beds, the snails found there were primarily species that had living representatives with ranges associated with particular ecological niches, biotic districts, and, ultimately, such climatic factors as precipitation, temperature, and growing seasons. By knowing the climatic factors behind their modern distributions, paleontologists perceived that individual snail species could serve as clues to past environments when they were found in the fossil record. Consequently, numerous assemblages of fossil gastropods are now reported for Pleistocene deposits from southwestern Kansas, northwestern Oklahoma, and western Texas (Drake 1975; Hibbard and Taylor 1960; Taylor 1960, 1965; Wendorf 1961).

The accurate dating of fossil gastropod assemblages is an abiding concern for paleontologists working on the Plains and elsewhere. Although snail shell is a form of calcium carbonate, it is susceptible to leaching and contamination that can affect the carbon content and its reliablity for radiocarbon dating (e.g., Goodfriend 1987; Goslar and Pazdur 1985; Vita-Finzi and Roberts 1984). Despite such problems and concerns, unsorted fossil snail shells commonly have been submitted for radiocarbon dating in order to establish the late Pleistocene ages of Southern Plains vertebrate fossil beds and other deposits (Dalquest and Schultz 1992; Hibbard 1970; Wendorf 1961). Seven gastropod assemblages in southwestern Kansas and northwestern Oklahoma have been radiocarbon dated to the Wisconsinan glacial period (Miller 1975). Unfortunately, none of these assemblages is contemporaneous with those from the Burnham site. Thus, the following comparisons are not made with the expectation that the Burnham assemblages will mirror any nearby studied and dated snail assemblages. Instead, the comparisons are made to show how similar the Burnham assemblages are to other molluscan assemblages believed to date before the last glacial maximum (19,000 years ago). Also, these comparisons reveal some insights to settings and climate in this region before the last glacial maximum.

In Table 20.13, the gastropod assemblages from Burnham sedimentary Unit IIB and Unit IIC are compared with those from three nearby paleontological sites. One is Bar M I, a thick, snail-rich, pond deposit situated only 20 miles west of the Burnham site (Fig. 20.30). The Bar M I gastropods have been extensively described and analyzed (Miller 1975, 1976; Shaak and Franz 1978; Taylor and Hibbard 1955), and an unsorted collection of these shells was radiocarbon dated at 21,360 + 1250 years ago (SM-763; Myers 1965). This date places the assemblage near the start of the last glacial maximum. In contrast, gastropod assemblages from the Bird and Jones fossil localities are dated (conventional radiocarbon tests on snail shells) between 27,000 and 29,000 years ago (Miller 1975; Davis 1975). This age tends to place these two assemblages more near the warm, mid-Wisconsinan conditions believed evident at the Burnham site. Both the Bird and Jones localities are pond deposits in the Cimarron River drainage of nearby Meade County, Kansas (Fig. 20.30).

Like Burnham, the Bar M I, Bird, and Jones fossil localities are situated rather high in the landscape and away from the principal drainage, the Cimarron River. Bar M I is interpreted (Shaak and Franz 1978; Taylor and Hibbard 1955) to have been a small (a hectare or so) lake in which nearly four meters of sediment accumulated. Although suggested to have formed in a subsidence basin or as valley fill, the Bar M I deposit most likely is valley fill (like the Burnham deposits) because the underlying Permian beds are noted (Shaak and Franz 1978:177) to be lying horizontally (as opposed to tilted if they were in a collapse basin). In contrast, the Jones fossil locality does appear to have formed in a collapse basin (Davis 1975:3-7; Hibbard and Taylor 1960:66). The Jones gastropods compared here come from the "*Ambystoma* Zone", cross-bedded silts and sands manifest 11 to 15 ft. below the top of the studied exposure (Davis 1975:3-7). These sediments are interpreted (Davis 1975:3-5) as a delta-like deposit that formed in a lake occupying the collapse basin. Details on the setting at the Bird fossil locality are sketchy at best, but it apparently is a thin (12 in.) deposit of alluvial sand and silt exposed high (31 ft.) in a bluff adjacent the modern stream (Miller 1975:11; Stettenheim 1958:197).

The five fossil deposits compared in Table 20.13 have a total of 58 molluscan taxa. No single deposit yielded all 58

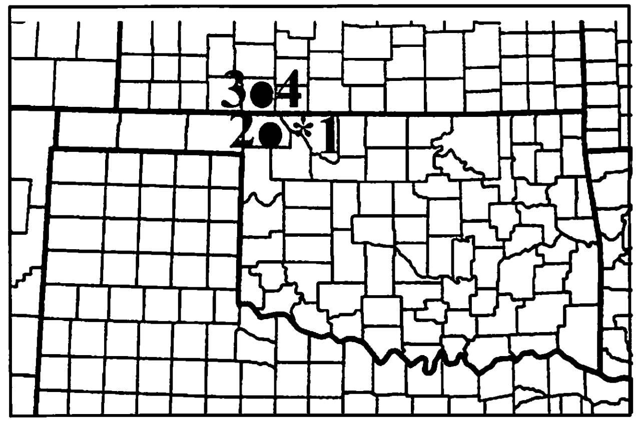


Figure 20.30. Locations of selected fossil localities with radiocarbon dated gastropod assemblages: 1, Burnham; 2, Bar M I ; 3, Bird; and 4, Jones.

species. The near-full glacial deposit at Bar M I yielded the most (n=40). In this region, glacial molluscan assemblages typically are more diverse than those from warmer, interglacial deposits (Miller 1975, 1976). This greater diversity is attributed to the presence of more northern and western species along with the southern forms that seem to persist in southwestern Kansas and northwestern Oklahoma (Miller 1976:83). Decreasing species diversity began around 10,500 years ago according to Miller's (1975) study of radiocarbon dated molluscan assemblages from the area, and the modern gastropods found in Meade County, Kansas, comprise the least diverse assemblage recorded since Pliocene times (Miller 1976). The extant species are predominantly those that can tolerate the seasonal climatic extremes common to the area today (ibid.).

The number of gastropod taxa at the Bar M I locality appears to be the culmination of increasing diversity since at least mid-Wisconsinan times. The two Burnham gastropod assemblages have about half the number of taxa reported for Bar M I (Table 20.13). The increase involves both aquatic (128% more, from 7 to 16 species) and terrestrial (78% more, from 14 to 24) taxa in the Bar M I assemblage over those of Burnham Unit IIB (Table 20.13). It should be noted, however, that 46% of the terrestrial species at Bar M I also occur in the Burnham IIB assemblage while only 19% of the aquatic species are the same. The Burnham IIB terrestrial species comprise 44% of the terrestrial taxa reported for the Bird locality and 73% of those reported for the Jones locality. From these findings, considerable continuity in terrestrial gastropods seems evident for the period leading up to the notable diversity found regionally during Wisconsinan full glacial times (Miller 1975, 1976).

Twenty-seven aquatic taxa are represented among the fossil localities compared in Table 20.13. Only three of these taxa occur in all five deposits: *Gyraulus parvus*, *Planorbella trivolvis*, and *Valvata tricarinata* (Table 20.13). The last is the cold water dependent snail, and its presence implicates that these four upland, aquatic settings may all have been

Table 20.13. Comparison of Fossil Gastropods from Selected Sites.

Aquatic Taxa	**Bar M I** **21,360± 1250 years ago**	**Jones** **29,000±1300** **26,700±1500 years ago**	**Bird** **29,300±1250 years ago**	**Burnham Unit IIC** **35,000± years ago**	**Burnham Unit IIB** **35,000± years ago**
Aplexa elongate	+	+			
Ferrissia fragilis				+	+
Ferrissia parallelus			+		
Ferrissia walkeri				+	+
Fossaria cockerelli	+	+			
Fossaria dalli	+	+			
Fossaria obrussa		+			
Gyraulus circumstriatus	+	+	+		
Gyraulus crista	+	+			
Gyraulus parvus	+	+	+	+	+
Laevapex fuscus		+			
Lymnaea stagnalis	+	+			
Physa skinneri	+				
Physella gyrina	+	+	+		
Physella virgata		+	+	+	+
Pisidium casertanum	+		+		
Pisidium compressum	+	+	+		
Pisidium ferrugineum		+			
Pisidium lilljeborgi		+			
Pisidium walkeri		+			
Planorbella trivolvis	+	+	+	+	+
Promenetus exacuous		+	+		+
Promenetus umbilicatellus	+	+	+		
Sphaerium nitidum		+			
Stagnicola caperata	+	+	+		
Stagnicola elodes	+	+	+		
Valvata tricarinata	+	+	+	+	+
Terrestrial Taxa					
Carychium exiguum	+			+	+
Deroceras aenigma				+	
Deroceras laeve	+			+	+
Discus whitneyi	+				
Euchemotrema leai	+		+		
Euconulus fulvus	+				
Gastrocopta armifera	+	+		+	+
Gastrocopta contracta	+				
Gastrocopta cristata	+	+	+	+	+
Gastrocopta holzingeri				+	
Gastrocopta pellucida				+	+
Gastrocopta pentodon				+	+
Gastrocopta procera	+	+		+	+
Gastrocopta tappaniana	+				
Hawaiia minuscula	+	+		+	+
Helicodiscus parallelus	+			+	+
Helicodiscus singleyanus	+	+			+
Nesovitrea electrina	+				
Oxyloma sp.	+		+		
Pupilla blandi			+		
Pupilla muscorum	+				
Pupilla sinistra	+				
Pupoides albilabris	+	+	+	+	+
Pupoides inornatus		+			
Strobilops labyrinthicus	+				
Succineidae	+	+	+	+	+
Vallonia gracilicosta	+	+	+		
Vallonia perspectiva				+	+
Vertigo elatior	+				
Vertigo milium	+	+	+		
Vertigo ovata	+	+	+	+	+

spring-fed. *Planorbella trivolvis* and *Gyraulus parvus* are species that indicate these settings had some protected shoreline where perennial water was quiet and where emergent aquatic plants grew and vegetal debris accumulated (Taylor 1960:44-65). The Jones, Bird, and Burnham assemblages also have *Physella virgata* and *Promenetus exacuous* in common. Both taxa attest to marshes and shallow permanent to semi-perminent water (Leonard 1959:67; Taylor 1960:59, 62).

Gyraulus circumstriatus, *G. crista*, *Physella gyrina*, *Pisidium casertanum*, *Promenetus umbilicatellus*, and *Stagnicola caperata* (Table 20.13) are aquatic taxa tolerant of seasonal drying like that common to prairie ponds and ephemeral streams today (Leonard 1959; Taylor 1960). Not recovered at Burnham, these six taxa are represented at the later Jones, Bird, and Bar M I localities (Table 20.13). Given their drought-tolerant adaptations, these six taxa seem incongruous with the permanent water inferred from the gastropods discussed in the preceding paragraph. However, the presence of the drought tolerant forms may result from their being washed into the Jones, Bird, and Bar M I sediments from less permanent or ephemeral pools upstream from these deposits.

Thirty-one terrestrial gastropod taxa are represented in the Bar M I, Jones, Bird, and Burnham deposits (Table 20.13). As noted above, the number of terrestrial taxa increases dramatically from the mid-Wisconsinan deposits at Burnham to the near-full glacial sediments at Bar M I. Although over 40% of the Burnham terrestrial taxa occur in the Bar M I assemblage, most Bar M I terrestrial taxa are species considered (Miller 1975, 1976) as having northern or eastern, not Southern Plains, origins. Today, such species as *Discus whitneyi*, *Gastrocopta holzingeri*, *Pupilla muscorum*, *Pupilla sinistra*, *Pupoides inornatus*, *Euchemotrema leai*, *Strobilops labyrinthica*, and *Vallonia gracilicosta* (Table 20.13) have ranges north and east where it is cooler and more moist than the plains of southwestern Kansas and northwestern Oklahoma (Hubricht 1985; Taylor 1960). The increased diversity of terrestrial snail taxa is believed due to a more equable climate prevailing on the Southern Plains during the last full glacial period (Miller 1976:83).

While some terrestrial taxa persist from mid-Wisconsinan to Wisconsinan full glacial times, clues do exist that suggest that diversity was variable before full glacial times. In particular, the Bar M I assemblage has more than double the number of taxa reported for the Jones and Bird localities (Table 20.13), and these two assemblages have nearly 30% fewer taxa than the older Burnham assemblages (Table 20.13). So what happened around 29,000 years ago? Is the observed decrease in taxa due to some ecological change, or is it the result of sampling and/or recovery vagaries?

Terrestrial snails of similar sizes are reported for the Burnham, Bird, and Jones localities. For this reason, the differences in numbers and kinds of terrestrial taxa among these assemblages don't appear entirely attributable to different recovery techniques. Climatically influenced ecological changes do seem to have been influencing the loss of taxa and the appearance of new taxa by 29,000 years ago. Gone are such Burnham taxa as *Carychium exiguum*, *Gastrocopta holzingeri*, *G. pellucida*, *G. pentodon*, and *Vallonia perspectiva* whose modern distributions are primarily east of the Southern Plains (Hubricht 1985). The modern distributions of these four species bear witness to a tolerance for summer heat and humidity, the last involving sufficient effective moisture to support a more varied plant cover than common to the High Plains and desert Southwest. These last two areas are mentioned because the new taxa that appear in the Bird and Jones assemblages include *Pupoides inornatus*, *Pupilla blandi*, and *Vallonia gracilicosta* (Table 20.13). Found today in the very dry grasslands of the western High Plains (Metcalf and Smartt 1997:27-28), *Pupoides inornatus* attests to more dry conditions than those implicated by species in the Burnham assemblage. Dry and seasonally longer, cold conditions are inferred from *Vallonia gracilicosta* and *Pupilla blandi*, species now found in the dry, cool, wooded foothills and Front Range of the Southern Rocky Mountains west of southwestern Kansas and northwestern Oklahoma (Metcalf and Smartt 1997). Dry conditions are also evinced by *Pupoides albilabris* and *Gastrocopta cristata* (Metcalf and Smartt 1997:27, 31), two terrestrial taxa that continue from Burnham times to those of the later Bird and Jones assemblages (Table 20.13).

Changes and continuities in land snail taxa among the Burnham, Bird, and Jones assemblages support the interpretation that drier conditions with longer cool seasons developed between 36,000 and 29,000 years ago. The loss of Burnham taxa usually associated with diverse woodland and prairie cover suggests that the dry conditions were occurring during the growing season. But conditions weren't so dry that there was a loss of all Burnham taxa (for example, *Vertigo ovata*) associated with damp, partially wooded places adjacent streams, marshes, and springs (Hubricht 1985; Metcalf and Smartt 1997:32). In fact, the 29,000 year-old Bird and Jones assemblages have new taxa (*Euchemotrema leai*, *Vertigo milium*, and *Oxyloma* sp.; Table 20.13) that also attest to the presence of damp to marshy settings (Hubricht 1985). On this basis, fall and winter precipitation may have increased somewhat to keep regional water tables at levels approaching those of 36,000 years ago. In summary, the Bird, and Jones terrestrial taxa may be representative of cooler, drier climate preceding the last glacial maximum that is represented by the Bar M I terrestrial snails.

So, what was happening that could create such unusual climatic conditions and support the intriguing combinations of gastropods and vertebrate fossils manifest at the Burnham site around 36,000 years ago? Notably, this time correlates with one of several rapid climatic fluctuations for which there is evidence between 60,000 and 12,000 years ago. Known as Heinrich events, these were millenial scale shifts in climate that involved notably colder atmospheric temperatures, significant surges of glacial ice south into the northern Atlantic Ocean, and ice-rafting of glacial-ground rock traceable to northeastern Canada (Bond et al. 1992, 1993; Chapman and Shackleton 1998; Heinrich 1988). The periodic occurrence of Heinrich events has been observed from fossil changes and the increased ice-rafted debris in the northern Atlantic as well as in changing chemical isotopes, particular those linked to received radiation and atmospheric CO_2 concentrations, measured in ice cores taken in interior Greenland (Broecker et al. 1992; Cortijo et al. 1999). What is identified as the fourth Heinrich event (H4) started around 37,000 years ago, had its maximum ice-rafting around 35,000 years ago, and was over by 33,000 years ago (Cortijo et al. 1999). Because the H4 event spans much of the dated deposits and fossils at the Burnham site, we believe the site provides a proxy record of the terrestrial effects of these dramatic climatic changes.

Archaeology at the Burnham Site

From the geological, pedological, and paleontological findings, the Burnham site emerges as a spring-fed, ponded stream with riparian brush and woods in a location where grasslands prevailed sometime between 36,000 and 34,000 years ago. The vertebrate and invertebrate fossils are compatible with southwestern Kansas, northwestern Oklahoma, and nearby Texas paleontological finds believed to date to middle Wisconsinan times. This was some 15,000 years before the Wisconsinan full glacial when the Cordilleran Ice Sheet had coalesced with the Laurentide Ice Sheet and the latter's ice front covered New England and extended south of where the Great Lakes are today (Dyke and Prest 1987; Dyke et al. 2002; Marshall et al. 2002). Middle Wisconsinan times, however, were a period of glacial retreat. Believed to have started around 65,000 years ago and to have persisted until some 23,000 years ago, Middle Wisconsinan times involved significant warming in northern latitudes, which, for North America, caused the Laurentide Ice Sheet to retreat northward to one of at least three greatly reduced scenarios (Dredge and Tharleifson 1987). As we have seen from Southern Plains findings, the Middle Wisconsinan involved warm conditions with less seasonal extremes and more effective moisture than today. Southern Plains grasslands during this period must have been fairly lush and quite capable of supporting mammoths, horses, camels and some bison. Recorded fossil predators of these grassland grazers included dire wolf, jaguar, and smaller carnivores. The question the Burnham findings raise is, "Were humans there too?"

Three-quarters of a century have passed since the first conclusive evidence was found for the antiquity of people occupying North America. It was 1927 when archaeologists confirmed the association of delicately chipped spearpoints with *Bison antiquus* skeletons at the Folsom site in the Cimarron River's headwaters of northeastern New Mexico (Cook 1927, 1928). Because *Bison antiquus* was known to occur in deposits of the last glacial period (the Wisconsinan), the presence of stone tools with these animals proved, for the first time, that people were here also then (Meltzer 1983, 1991). Since the Folsom find, archaeologists have discovered and studied numerous other sites that reaffirm the late Wisconsinan presence of people (Bonnichsen and Turnmire 1991, 1999). While this very late Pleistocene period is generally accepted for the arrival of humans in North and South America, the actual timing and routes by which humans arrived are very controversial (Adovasio and Page 2002; Adovasio and Pedler 1997; Anderson and Gillam 2000; Bryan 1978, 1986; Dillehay 1989, 1997, 2000; Dincauze 1984; Dixon 1993; Easton 1992; Fladmark 1979; Grayson 1988; Lynch 1990; Meltzer 1983, 1989, 1993, 1997; Meltzer et al. 1994; Meltzer et al. 1997; Rogers et al. 1992; Straus 2000; Whitley and Dorn 1993). The widespread Clovis material culture underlies cultural sequences in most North American regions and has been long accepted to date from around 11,500 to 10,900 years ago (Bonnichsen and Turnmire 1991, 1999). With that age, Clovis people became perceived as the first immigrants to come south from Alaska when an ice-free corridor opened as the Cordilleran and Laurentide ice sheets retreated. But new findings regarding carbon dioxide fluctuations since the end of the Wisconsinan enable corrections in radiocarbon dating, and now the Clovis sites appear to be 1000 to 2000 years older than previously thought (Taylor et al. 1996a, 1996b). If so, that raises questions whether the ice-free corridor was open, and passable, for Clovis band movements (Beaudoin et al. 1996; Mandryk 1996). Also complicating the "Clovis first" scenario are sites scattered from Alberta to Pennsylvania to Chile that are interpreted to be older than Clovis by at least a millennium (Adovasio and Page 2002; Adovasio and Pedler 1997;Bryan 1978, 1986; Chlachula 1996a, 1996b; Dillehay 1989, 1997, 2000).

Through the years that we have studied archaeology and soils-landscape development we have come to accept the late Wisconsinan arrival of people in North America. We have been impressed with the repeated discoveries demonstrating the early precedence of the Clovis material culture. Consequently, we find it ironic and incredible that we must cope with explaining chipped stone objects found at the Burnham site. The irony lies in the location of the Burnham site some 250 miles down the Cimarron Valley from the Folsom site. We are incredulous because 52 flakes, 2 broken objects that look like parts of chipped stone tools, and a flaked cobble were recovered close together from the lowest pond deposit at the Burnham site, and this deposit is mid-Wisconsinan age.

The Burnham objects and their horizontal and vertical distributions have been discussed and well illustrated by archaeologist Kent Buehler (this volume). Here, we repeat or reemphasize a few of Kent's observations, but we do so

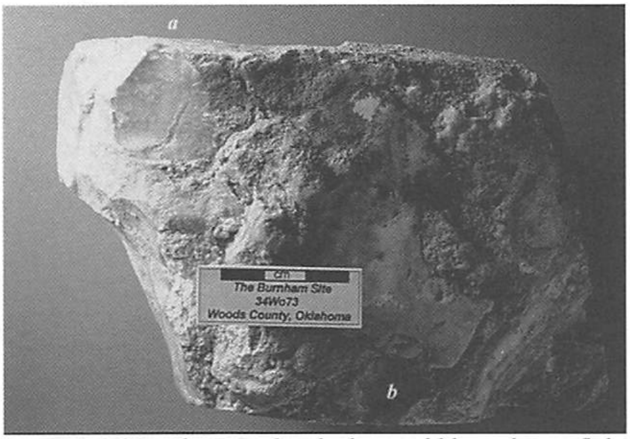


Figure 20.31. The Day Creek chert cobble with two flake scars (a and b) on it. Scale is in centimeters.

in order to examine these finds relative to three long-established critera for assessing sites and materials claimed to represent "pre-Clovis" occupations (Haynes 1969; Waters 1985; Wendorf 1966). We pose these criteria as questions:

1. are there artifacts or skeletal remains of unquestionable human origin;
2. are these artifacts or remains from undisturbed or unmixed stratigraphic contexts; and
3. are these contexts reliably dated?

Despite calls for new or different criteria by proponents of pre-Clovis occupations (e.g., Alsoszatai-Petheo 1986; Guidon and Arnaud 1991; Morlan 1988), we believe these three criteria have served archaeologists well as they grappled with issues of human antiquity in North America over the past 75 years. We use these criteria to structure our evaluation of the Burnham finds.

Are These Human Artifacts?

In the 110 years since W.H. Holmes (1893) published "The Natural History of Flaked Stone Implements", archaeologists have learned much about the human decisions and actions involved with knapping stone. Thanks to skilled replicators like D. Crabtree (1966), J.B. Sollberger (1976, 1985), E. Callahan (1979), and B. Patten (1999), the products and by-products of making unifacial and bifacial tools with different methods and techniques are well documented and very recognizable. While modern analogues are not always appropriate for interpreting prehistory, the fracture of brittle, elastic, rigid, isotropic solids like chert and obsidian (Faulkner 1972:6-22) hasn't changed through time. The products and by-products of such fracture share the same attributes whether they were made 100,000, 10,000 or only 10 years ago. On this basis, and remembering that knapping is a sequential reduction process (Bleed 2001; Bradley 1977; Callahan 1979; Holmes 1894; Muto 1971), studies of prehistoric chipped stone assemblages have revealed the structure of diverse, often innovative, prevalent ways that past societies worked particular raw materials into cores for flake and biface tools (Carr 1994; Collins 1999a, 1999b; Hofman 1992; Johnson and Morrow 1987; Wyckoff 1999a). From these and countless other studies of prehistoric stone work-

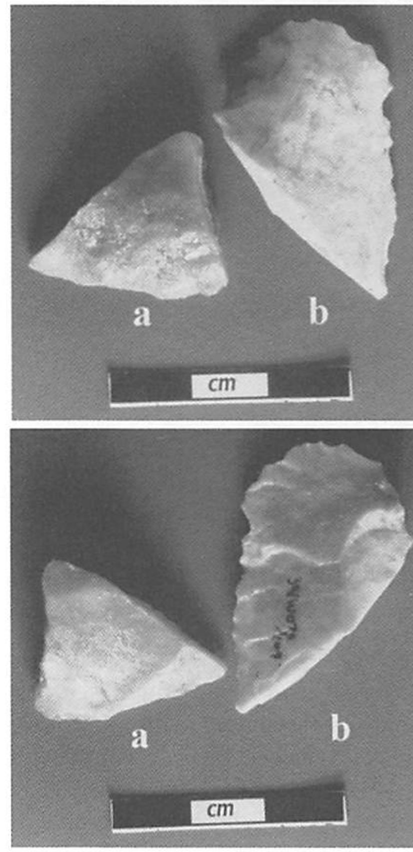


Figure 20.32. The triangular piece out of a biface edge (a) and the decortication flake (b) with the bifacially flaked acute edge (long side) and segment of a unifacially flaked steep edge (short side). Scale is in centimeters.

ing, it is abundantly clear that humans knap stone in rather prescribed (learned), patterned ways. Whether as cobbles, nodules, or angular blocks, the raw material has to be preliminarily shaped in order to produce bifaces or flakes of desired shapes and sizes. Once these preliminarily flaked cores are made, further shaping or thinning occurs, often accompanied by certain kinds of platform or edge preparation. Whatever the preparatory maneuver, it produces distinctive traces on the product and correspondingly distinctive kinds of debris. Likewise, flake scars and the debitage that produced them are created as bifaces or desired flakes are futher shaped and/or thinned into finished tools.

While less numerous as the studies cited above, published literature exists on the natural processes that can flake stone (Barnes 1939; Jones and Campbell 1925; Warren 1905, 1914, 1921). Flakes from natural processes, like gravel being compacted together in a stream deposit, characteristically have:

1. many platforms with right or obtuse angles;
2. rare traces of platform preparation;
3. diffuse bulbs of force;
4. illogical flake removal patterns;
5. striations on flake scars and the ventral faces of flakes;

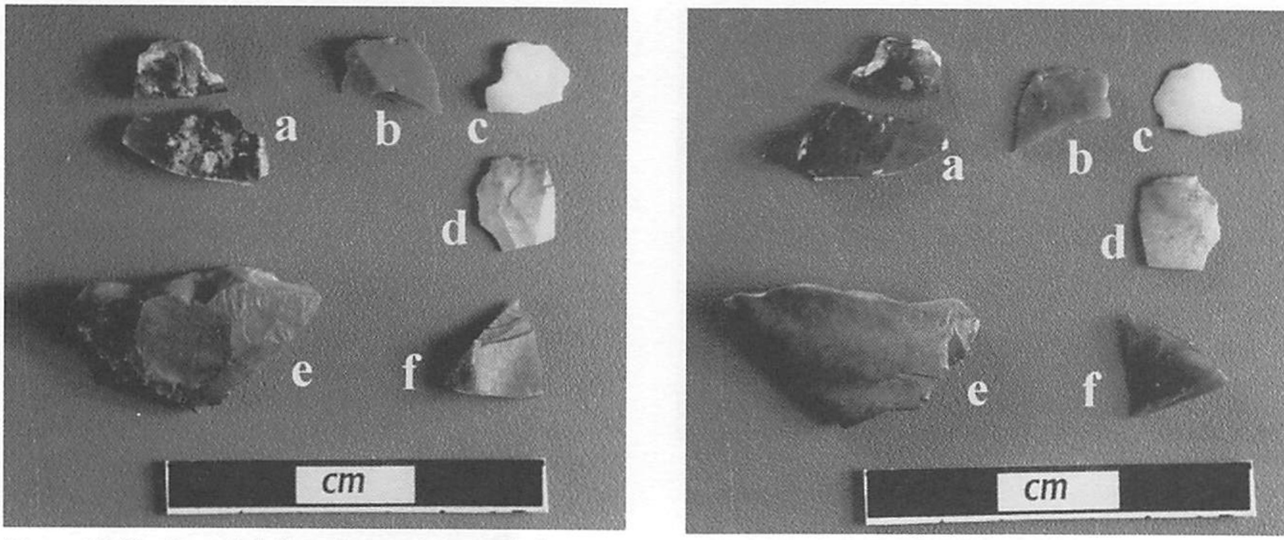


Figure 20.33. Dorsal (left) and ventral (ventral) faces of six selected flakes from the Burnham East Grid excavations: a, Artifact #1/49; b, Artifact #23; c, Artifact #22; d, Artifact #52; e, Artifact #14; and f, Artifact #21, Scale is in centimeter increments. See Tables 17.3, 17.4, and 17.5 for attributes and measurements of the individual items.

6. rare flake scars on their dorsal faces, and
7. many right angle (step or hinge) terminations.

These criteria have been used to discriminate human from natural flaking on ancient chipped stone materials found in England and North America (Barnes 1939; Patterson 1983; Schnurrenberger and Bryan 1985; Simpson et al. 1986).

Kent Buehler (this volume) analyzed all of the siliceous stone objects recovered from the Burnham site. Fifty-five pieces manifest attributes of having been flaked. One is a large, angular flint cobble with two flakes removed from one of its faces (Fig. 20.31). Two specimens resemble broken tools (Fig. 20.32). One of these is a triangular segment out of the edge of what appears to be a flaked biface (Fig. 20.32a) that was broken radially (e.g., Bradley 1982:192-193). The other tool is an elongated primary decortication flake that has bifacial scalar flaking along one acute edge and unifacial, overlapping scalar flaking along the opposite (steeper) edge (Fig. 20.32b). The remaining 52 pieces are small to minute flakes or parts of flakes (Figs. 16.1 to 16.51). Buehler thoroughly documents that many of these flakes display platforms where fracture was initiated (e.g., Fig. 20.33a-d), noticeable to prominent (as opposed to diffuse) bulbs of force (ibid.), and dorsal faces that retain segments of scars from previously removed flakes (Fig. 20.33a-f). Several flakes with platforms have overhanging lips on the ventral faces (Fig. 20.33c-d); these flakes look like those removed when resharpenting a biface. If recovered from any ordinary archaeological site in northwestern Oklahoma, these 55 objects would not look out of place. Buehler (this volume) concludes that they were flaked by humans.

When viewing these flaked objects collectively, it is difficult to disagree with Kent's conclusion. The flakes look like debris from patterned, purposeful tool making and tool resharpening. The elongated section of a decortication flake shows evidence of a worn cutting edge along one side and a scraping edge on the other. Radially broken bifaces are reported for prehistoric sites on the Plains, and tested cobbles are common wherever flint or quartzite occur as residual nodules or redeposited gravel.

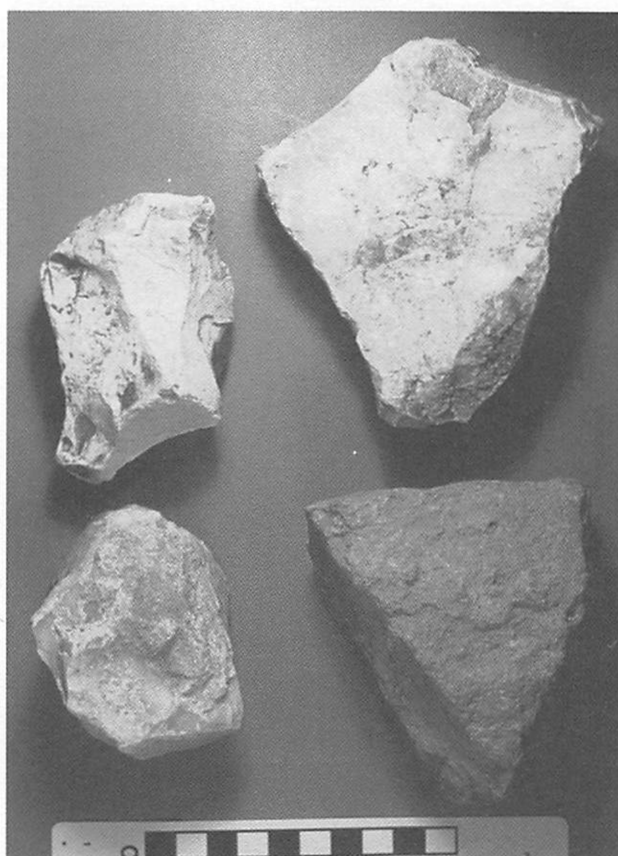


Figure 20.34. Examples of Day Creek chert cobbles collected along West Moccasin Creek. These show some of the variable cortex and shapes of clasts now being transported downstream. Scale is in centimeters.

Lithologically, the cobble, the biface section, and most (29 of 51 total) of the flakes are of Day Creek chert. One flake is of Ogallala quartzite (Fig. 20.33e). Both Day Creek chert and Ogallala quartzite have bedrock occurrences on the ridge north of the Burnham site (Fay 1965). These two raw materials have been knapped by humans living in northwestern Oklahoma at least since early Holocene times (Bailey 2000; Neel and Burnham 1986; Thurmond and Wyckoff 1999).

Because Day Creek chert and Ogallala quartzite are in the modern drainage (West Moccasin Creek), their bedrock exposures also must have been within the mid-Wisconsinan drainage represented by the alluvium-filled channels at the Burnham site. That being the case, why aren't the Burnham chipped stone objects the result of natural flaking as chert and quartzite pieces were entrained as gravel? Day Creek chert clasts collected along West Moccasin Creek show the kinds of cortex and natural edge angles (potential platforms) on this material as it is being moved downstream (Fig. 20.34). The surfaces of Day Creek chert pebbles and cobbles are susceptible to abrasion from water-carried sediment and to patina development in sunlight and air. One flake section (Fig. 17.30) displays noticeable abrasive "frosting" on its faces. The biface edge fragment (Fig. 20.32a) shows abrasion on one face, but the scaler flaking along the worked margin is not abraded. The remainder of the Burnham site's Day Creek specimens have flaked dorsal faces that are not abraded. The combination of dorsal faces showing scars of previous flaking, the lack of waterworn flaked surfaces, and the presence of prepared platforms, including seven retaining remnants of bifacially flaked edges, are attribute combinations that make the Burnham objects resemble human, not naturally, knapped materials.

Years of archaeological research on the Southern Plains have repeatedly demonstrated that prehistoric people carried preferred knappable stone far beyond its bedrock sources (e.g., Hofman 1992; LeVick 1975; Tunnell 1978). For that reason, identifying exotic stone in the Burnham chipped stone materials is another means to supporting the claim they are of human origin.

Two flakes (Fig. 20.33e-f) resemble Edwards chert from central Texas. Figure 20.33f is a match for the "root beer" variety of Edwards chert. Unfortunately, neither of these flakes fluoresces under a ultra-violet (U-V) light like speciments of the the central Texas chert. Despite this lack of confirming evidence, these two flakes don't resemble raw materials common to the Cimarron drainage. The remaining flakes include one of unidentified quartzite while the rest are unidentified cherts (Table 17.11). These specimens are mainly fragments of flakes, and they are too small to fluoresce and be compared with the U-V reactions of known Oklahoma, Kansas, and Texas cherts.

The tool made from an elongated section of a decortication flake (Fig. 20.32b) is believed (Buehler, this volume) to be Alibates agatized dolomite. Well known prehistoric quarries of Alibates material are known along the South Canadian River in the Texas panhandle (Bryan 1950:14-15; Holliday and Welty 1981). While it is tempting to view Alibates as an exotic chert at the Burnham site, in recent years waterworn cobbles of this material have been found in gravel deposits along the Cimarron River in Beaver and Kingfisher counties upstream and downstream from the Burnham locality.

In conclusion, some basis exists for concluding that the Burham chipped stone objects are human artifacts. In particular, flakes with platforms include examples with bifacially

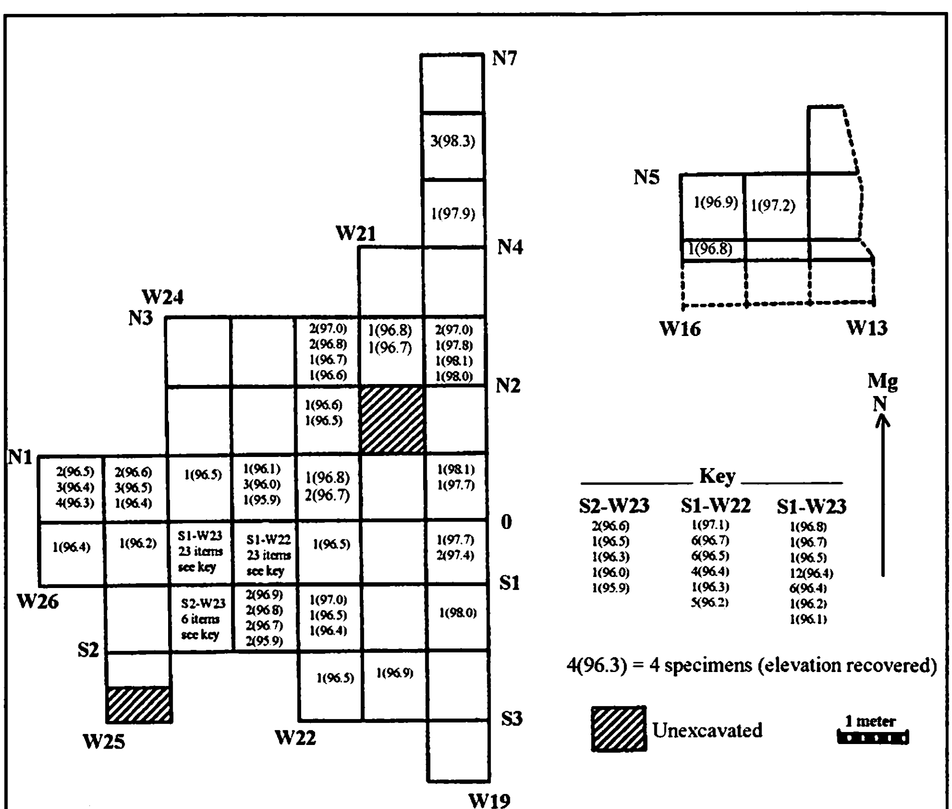


Figure 20.35. Distribution of chert natural clasts found in squares manually dug in the East Exposure of the Burnham site.

flaked platforms. Also, dorsal faces of flakes exhibit remnants of scars of previously removed flakes with orientations congruent with patterned flaking and retouching like that common to human knapping. Two broken objects display patterned flaking consistent with tool making, one being a multi-purpose implement. Finally, a couple of flakes appear to be of chert exotic to the Cimarron River drainage. If so, then people are the most likely means that these materials got to the Burnham site.

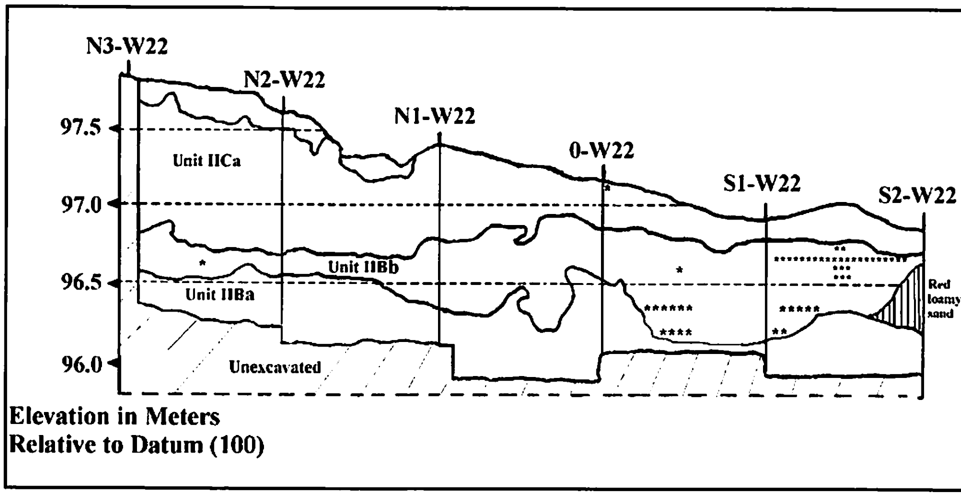
Do the Artifacts Come from an Unmixed or Undisturbed Deposit?

To begin answering this question, another is asked first. Where were the artifacts found? They weren't found everywhere. Profile scrapings and fill from two shallowly dug 1x1 m squares yielded approximately 0.3m³ of fill from the Southwest Exposure. All was waterscreened; no chert objects were recovered. Nearly three cubic meters of gleyed sediment from the Northwest Exposure were dug and waterscreened, and no chert pebbles nor any flakes were found.

All of the natural chert clasts and all of the chert or quartzite pieces that look humanly modified came from the East Exposure. The natural chert clasts manifest a distribution scattered through levels and squares across the East Grid (Fig. 20.35). In contrast, the pieces that look humanly knapped are, with one exception, clustered in sedimentary Unit IIB, the lowest pond deposit. The one exception is a midsection of a flake (Fig. 16.47) that was found in level 97.3 (3.6 to 3.7 m below datum) of East Grid square S1-W20. This square and depth correlate with the lower part of sedimentary Unit IICa (Table 20.1).

Not only are the chipped stone objects overwhelmingly from the lowest pond deposit, they are predominantly from the uppermost part (substratum IIBb; Table 20.1) of that deposit. Only the flaked cobble of Day Creek chert (Fig. 20.31) was found in the reddish brown loam (along the boundary between substrata IIBa and IIBb). In contrast, with the one exception noted above, all of the flakes came from the gleyed sediment of substratum IIBb. These flakes were dispersed through 90 cm of the gleyed IIBb sediment, but 21 flakes

Figure 20.36. Schematic correlation of flake distributions with strata as recorded along N3-W22 to S2-W22 stakes in the East Grid. The flakes (asteriks) are placed in the level from which they were recovered; these are not in situ locations. Note: Three flakes from Unit IIB are not shown because their find spots were higher than Unit IIB occurs in this profile.



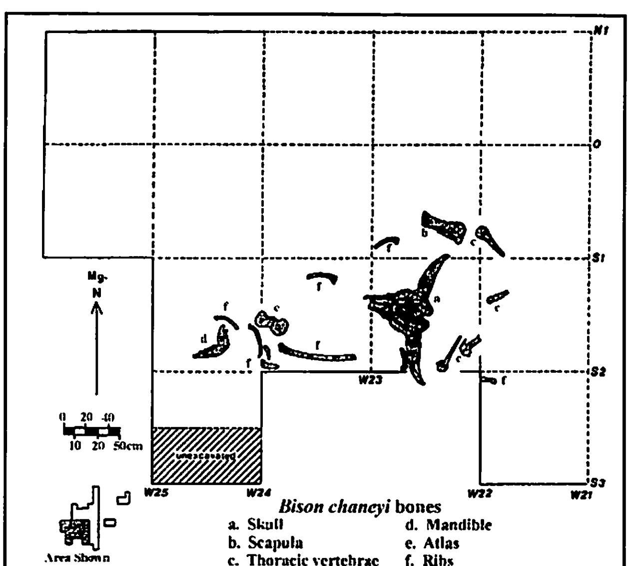


Figure 20.37. Distribution of bison bones in East Grid.

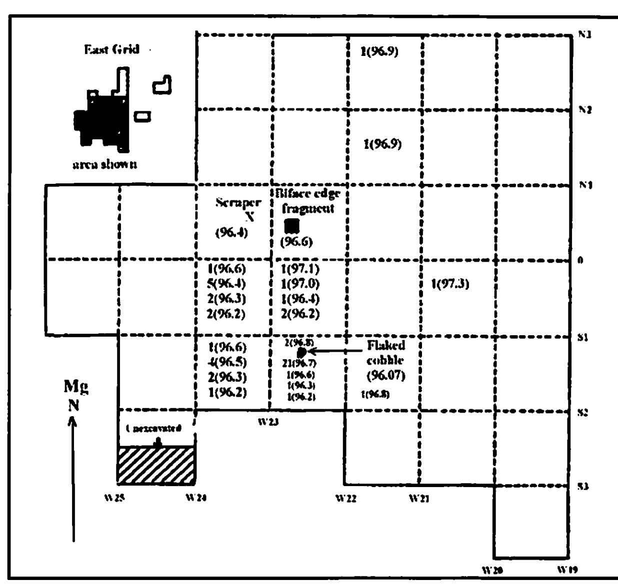


Figure 20.38. Chipped stone distribution in East Grid.

(40% of the 52 flake specimens) were recovered from the sediment lying between elevation 96.8 and 96.7 (Fig. 20.36). Twenty-five flakes (48% of 52 specimens) were scattered at depths below elevation 96.7, whereas only five flakes (9.6% of total) were recovered from gleyed IIBb sediments above elevation 96.7. The upper boundary of substratum IIBb was irregular. It varied from as low as 96.7 (in the North 1 and North 2 rows of squares) to as high as 96.95 (in the 0-W21 and 0-W22 squares). Most of the flakes (36 of 52, 69%) came from the South 2 row of squares where the upper boundary of substratum IIBb was between 96.9 and 96.8. Clearly, then, the influx of flakes occurred near the end of the time that sediment accumulated in the Burnham site's earliest pond setting.

As Figure 20.36 shows, the recovered flakes are restricted in their vertical distribution. Less apparent but also evident in this figure is the fact that the flakes and the other chipped stone objects are horizontally clustered. Buehler (this volume) has already discussed this distribution, and we briefly remark on it here. With few exceptions, the flakes and the other chipped stone artifacts are intermixed or closely adjacent the skull and other bones of the initially exposed *Bison chaneyi* (compare Figs. 20.37 and 20.38). Because the flakes are small, and because several look like biface resharpening flakes, it is tempting to consider them debris from retouching bifaces and unifaces used to dismember this large-horn bison. A thorough microscopic examination of the *Bison chaneyi* skull and other bones from these squares fails to reveal any marks that could be confidently considered the result of butchering.

Having reviewed where the artifacts were found, we return to the original question. Are they in an unmixed or undisturbed deposit? With one exception they were found in the lowest of the stratified pond deposits that were manifest only at the site's East Exposure. Composed of two substrata (Units IIBa and IIBb; Table 20.1), this lowest deposit does display an irregular upper boundary (e.g., Fig. 20.36). Also, the boundary between the two substrata of this lowest deposit is irregular, even to the degree of showing several unusual "flares" (Figs. 2.14, 5.17, 20.36; Plate 3a). These intra-deposit irregularities are interpreted to be the result of biogenic disturbances, most likely four-legged mammals wading in the pond. Although readily visible, these disturbances seem to have had little effect on the distributions of flakes and other chipped stone objects. The flakes, which are small and light in weight, are predominantly in the upper part of the uppermost gleyed sediment (Unit IIBb), whereas the slightly heavier, broken tools come from near this substratum's lower boundary while the heavy flint cobble was resting in the underlying substratum (Unit IIBa). These distributions don't bear witness to extensive mixing or disturbances within the lowest pond deposit. Instead, they look like what one would expect when objects larger and heavier than the sand and silt of Unit IIb settled in this sediment while it was saturated with water, probably even roiled by spring flow.

Only one flake was found outside of sedimentary Unit IIB. A midsection of a chert flake (Fig. 16.47) came from a manually dug level that was at least 30 cm higher than Unit IIB. This flake was in Unit IICa, the second lowest pond deposit. Because no other chipped stone objects were recovered from Unit IIC, the single broken flake must have come from the underlying Unit IIB deposit. The flake was recovered in square S1-W20, which is a full meter east of where flakes were prevalent in Unit IIB (Fig. 20.38). No krotovinas or other visible disturbance were recorded in square S1-W20, but it could have been redeposited there from disturbed Unit IIB deposits nearby. Many crayfish krotovinas extending into Unit IIB are recorded (Fig. 19.7) just northeast of square S1-W20, so perhaps the broken flake was moved upward there and washed into S1-W20.

Crayfish burrows and deformed sediments do attest to disturbed deposits in the East Exposure sequence (Figs. 4.5, 4.8, 19.8, 19.9; Plates 4a, 4b). Crayfish burrows were numerous in the Unit IIB sediments exposed in the 1992 backhoe trench (Figs. 2.32, 2.33), but this is some 13 m northeast of where the artifacts were found. Only one such burrow is recorded for a square where an artifact was recovered. A distal end of a flake (Fig. 16.49) came from square N1-W21, and a long, vertical krotovina was plotted and photographed in the east wall of that square (Figs. 5.19, 19.8). Krotovinas and signs of soft sediment deformation were not observed or recorded for any other squares where artifacts or bison bones were recovered. Consequently, it is very unlikely that the artifacts were introduced into Unit IIB from processes originating above squares S2-W21, S2-W22, S2-W23, S1-W22, S1-W23, 0-W21, and 0-W22 (Fig. 20.38).

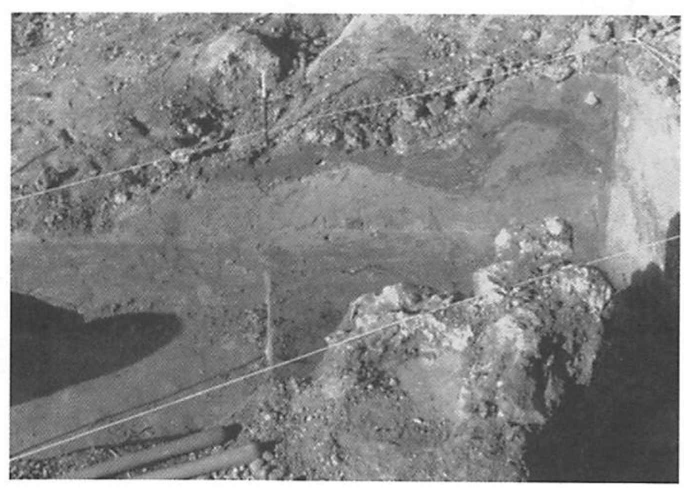


Figure 20.39. Looking north during initial uncovering of the Bison chaneyi *skull in square S2-W22. Indurated carbonate nodules are on top of the skull. Note the shallow disturbances from grading and erosion in the profile beyond the carbonates. Photo taken October 30, 1986, by Don Wyckoff.*

Figure 20.40. Looking east at indurated carbonates along the top of Unit IIB in square N1-W22. Photograph taken September 19, 1988, by Don Wyckoff.

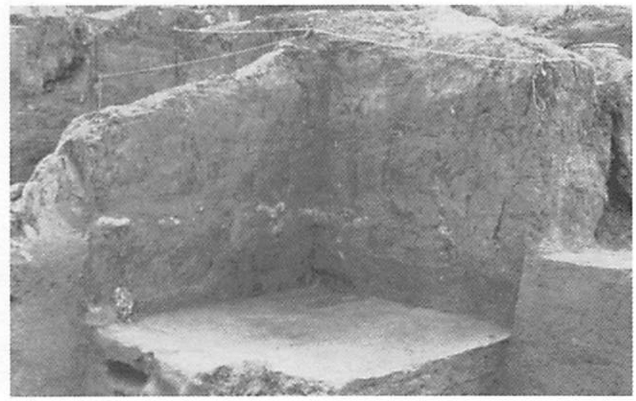


Figure 20.41. Looking northeast at indurated carbonate nodules near upper boundary of Unit IIB in square 0-W21. Photograph taken October 16, 1989, by Don Wyckoff.

It is particularly unlikely that Holocene artifacts could have filtered into Unit IIB sediments in these squares from overlying (and now lost to the dam construction) deposits. An indurated, nearly continuous, layer of calcium carbonate overlay most of these squares (Figs. 20.39, 20.40, 20.41).

In summary, disturbances and mixing are evident in East Exposure deposits at the Burnham site. But in Unit IIB, the lowest in the sequence of pond deposits, the evidence for disturbance and mixing is minimal and is predominantly between the two substrata that comprise this lowest pond deposit, not between it and pond deposits overlying it. The minimal mixing in Unit IIB is demonstrated by the chipped stone artifacts. They are vertically distibuted fairly consistent with their sizes and weights. Larger, heavier objects are lower in the deposit than small, light ones. Elsewhere, krotovinas and sediment deformation were observed, but controlled excavations in or adjacent those places failed to recover any stone objects manifesting flaking.

Despite these findings, the artifact-bearing substrata at the Burnham site are not the original, primary contexts for the recovered chipped stone objects. They are in a secondary context, one to which these chert pieces were moved by spring and/or stream flow. Horizontally, the flaked stone pieces and the natural chert clasts exhibit a notable overlap (Fig. 20.35), one that suggests their distributions were the result of the same processes. That these processes also affected the *Bison chaneyi* bones is most likely. These bones display more diverse orientations and angles than the horse bones uncovered in Unit IICb only a few meters to the east (Todd, this volume). Clearly, the taphonomic histories of these two concentrations of bones are different.

Having worked at and observed the Burnham site for over 15 years, much has been seen and learned about erosion of the loamy fine sand and fine sandy loam soils at this location. When dry, these soils are almost as hard as rock. This character undoubtedly influenced the judgment of soils scientists who, after recently surveying Woods County, told us that the soil at the site was 5 to 7 ft. thick and underlain by Marlow Formation sandstone. Our coring and trenching there demonstrated that soil-forming, unconsolidated sediments are 5 to 7 times that thick. More importantly, however, was seeing the effects of running and standing water on these soils. Today, most rainfall in Woods County falls during violent thunderstorms. The runoff from these storms easily cuts through these fine textured soils and forms narrow, deep rills. These have slightly angular paths downslope. Angular sections along these paths frequently are undercut so that they weaken and 3 to 4 ft. thick blocks of soils slump or twist and topple. Some blocks occasionally dam a rill, but subsequent runoff typically dissolves them while also widening the rills into V-shaped gullies. These and our backhoe and hand-dug trenches would hold water at times. When that happened, the standing water would dissolve the base of the exposure and cause blocks of soil or sediment to slough into the water (Fig. 2.20). This process usually left a near vertical wall that could be similarly eroded when standing water again collected in that gully or trench.

The erosion described above was witnessed at the Burnham site and also at a large pond recently built on West Moccasin Creek about a mile north of the site. The observed processes seem relevant to the taphonomic situations documented for bone beds and sediments at the Burnham site. Located near the east edge of an ancient stream and pool, the *Bison chaneyi* skull and other bones appear as if they had toppled into the water in a sloughing block of shoreline, whereas the horse bones found to the east seem to be the remains of an animal that had died along a later, shallow shoreline. This interpretation implies that the bison bones were originally on the ground above the water. Once in the water, the bison bones seem to have impeded stream flow enough that natural chert pebbles and flaked objects settled into the sediment. Subsequently, these were dispersed slightly by stream flow and especially by animals wading in the water. The generally north to south distributions of the natural clasts and chipped stone objects (Figs. 20.35 and 20.38) suggests that these originated north or northeast of

Table 20.14. Chronological Assessments for Sedimentary Units IIBa and IIBb, East Exposure, Burnham Site.

Subunit Date (years before present)	Sample #	Provenience and material
Unit IIBb		
22,670 ± 330	RA-C0352	Hackberry seed from elevation 96.3 in square S1-W23.
31,150 ± 700	Beta 23045	Unsorted snail shells from elevations 96.5 to 96.3 in square S1-W22.
35,689 ± 710	RA-C0354	Hackberry seed from elevation 96.8 in square N2-W20.
35,890 ± 850	AA-3837	Unsorted snail shells from elevations 96.5 to 96.3 in square S1-W22.
≥ 37,000 ± 4000		Electronic spin resonance result on fossil horse tooth from elevation 96.4 in square S1-W23.
35,000 ± 9000		Electronic spin resonance result on gleyed sediment from elevation 96.4 in square S1-W23.
40,190 ± 870	RA-C0419	Hackberry seed from elevation 96.6 in square S1-W22.
46,200 ± 1600	NZA-2823	Charcoal from elevation 96.72 in square #3 in 1992A backhoe trench.
98,000 ± 4500	SMU-217E1	Uranium series date on molar from *Bison chaneyi* mandible found under bison skull in S2-W22.
10,210 ± 270	NZA-3009	Charcoal plotted at elevation 96.35 in square S1-W22.
Unit IIBa		
26,820 ± 350	AA-3838	Charcoal from elevation 96.26 in square S1-W22.
36,300 ± 1700	NZA-1416	Charcoal from elevation 96.2 in square 0-W25.
37,590 ± 820	RA-C0291	Hackberry seed from elevation 96.1 in square S3-W24.

where they were found. Our 1991 and 1992 excavations were undertaken in those directions to try to find the paleosol, or zone within one, from which these objects eroded.

Are These Contexts Reliably Dated?

The preceding chapter and this one have contained lengthy discussions of the efforts and results at dating the Burnham site. With 3 conventional radiocarbon, 17 accelerator, 1 uranium series, and 2 electronic spin resonance dates, the Burnham site has almost as many chronological results as 20 dated paleontological sites reported from southwestern Kansas to northwestern Texas. Sheer numbers of dates don't necessarily translate into being reliably dated, but they can convey a sense of a site's age.

Thirteen chronological assessments are available for Unit IIB, the lowest pond deposit where the artifacts were found. These dates are listed in Table 20.14. Most attest to an age before the last glacial maximum. One date, however, is much younger, whereas another appears to be far too old. This latter is the uranium series result on one of the *Bison chaneyi* teeth. As noted previously (Wyckoff and Carter, this volume), the analyst who undertook the uranium series dating had problems deriving an accurate assessment, in part due to the very worn, largely dentine character of this tooth. The young date (Sample NZA-3009) is an accelerator assessment on charcoal. This fragment was uncovered at elevation 96.35 in square S1-W22 during the 1988 excavations. Dated at 10,210 + 270 years before present, this sample is not believed relevant to the Unit IIB deposit. Hastily selected because sufficient funds remained for one more date (Wyckoff and Carter 1994:75-76), this sample is now recognized as having come from tan sediment that washed down a rill which had developed on the East Exposure slope between the 1986 and 1988 excavations. The origin of this tan sediment is around elevation 98.0 some four meters northeast of square S1-W22. In 1989, excavations at this higher location yielded charcoal that was dated at 11,580 + 350 years before present (Sample #NZA-1090).

Excluding the two dates discussed above, eleven results assess the age of artifact-bearing substrata IIBa and IIBb (Table 20.14). These results range from 22,600 to 46,200 years ago. Within this span of 24,000 years, seven samples fall between 31,000 and 38,000 years ago. This time frame is believed most relevant for the age of the artifact bearing sediments. The other dates from these substrata are considered as background noise: the older ones being charcoal and hackberry seeds flushed from old soils upslope or upstream, the younger ones being materials that filtered into the gleyed sediments several millennia after they were deposited.

While Unit IIB is dated by reliable methods or techniques, the deposit is not considered precisely dated. Combinations of aquatic and terrestrial gastropods from Unit IIB in the East Exposure were dated at 31,150 + 700 years ago by conventional radiocarbon technique and 35,890 + 850 years ago by tandem mass accelerator (Table 20.14). So, using gastropods from the very same context resulted in a time difference exceeding 4000 years. Because Unit IIB gastropods include the same taxa as those from the Northwest Exposure, and because the elevations of both exposures' lowest gleyed deposits were similar, accelerator dates were obtained on samples of specific aquatic and terrestrial snails from the same context in Northwest Exposure (samples AA-11687 and AA-11688 in Table 20.2). Even these results are 5000 years apart!

Whether by conventional or accelerator technology, radiocarbon dating is not able to precisely assess the mid-Wisconsinan age of the artifact-yielding deposit. The problems lie with the nature of the context and the diverse organic materials available for submittal. The Burnham context is not a discrete human habitation feature, such as a hearth, nor is it a discrete paleosol, such as the nearby Burnham paleosol with charred wood atop it. Instead, the submitted samples (and the artifacts) come from a secondary context, one composed of alluvial and lacustrine sediments. The sand, silt, and clay particles comprising these sediments are derived from diverse soils, sediments, and even bedrock that were upstream from the site. Incorporated in these sediments were bits of plant remains of diverse ages. Some of these organic particles were the charcoal flecks and hackberry seeds submitted for radiocarbon dating. These materials' ages reflect the chronology of the primary context where they were first deposited, not the age of the gleyed sediments at the Burnham site. In contrast, the aquatic gastropods comprise organisms that were living where this sediment accumulated due to water flow. In other words, the stream or pond setting was the primary context for the aquatic gastropods. Thus, the effort was made to date one aquatic and one terrestrial species of snails from this lowest pond deposit, even though these fossils have long-recognized, and still unresolved, problems of carbon adsorption, loss, and diagenesis that affect the results of radiocarbon dating. This effort resulted in a date that generally agreed with a majority of the radiocarbon dates on plant remains. In essence, the dating of diverse materials, some of which ultimately came from diverse sources, did not allow refining the chronology of the artifact-bearing deposit. That it is over 30,000 years old is most likely. That it is around 35,000 years old is most probable.

The Burnham Site: A Lingering Glance and Some Final Thoughts

The simple recovery of a noteworthy bison skull obviously turned into a much larger project (Wyckoff 1999b). Retrieving the skull was easy in 1986, and the associated excavation and waterscreening revealed that vertebrate and invertebrate fossils were present and abundant. These findings supported the conclusion that the Burnham site was a viable location to gather information about late Pleistocene settings, fauna, and environments for northwestern Oklahoma. But it was the discovery of flint flakes among the waterscreened debris from that initial testing that really triggered the following six years of field work. Believing that the Burnham deposits were very old, much older than the usual late Pleistocene North American settings yielding signs of humans, the subsequent field work was undertaken to determine where the apparent artifacts occurred, how they got there, and when that happened. To accomplish these goals the Burnham research was undertaken as an interdisciplinary project, one in which diverse findings would be integrated in order to place them in a geological and environmental context that was well defined in time. The project's colleagues were determined that this was not going to be just another archaeological undertaking with incidental studies of spuriously recovered plant remains, snail shells, animal bones, or the deposits in which they were found.

As the preceding pages attest, the Burnham site yielded diverse evidence and substantial information. More identifiable fossils come from there than are documented for any late Pleistocene paleontological site in the region. Because they come from dated interbedded paleosols and ponded sediments, the site's gastropod assemblage provides unprecedented information on ecological niches and the environment for a little-known late Pleistocene period on the Southern Plains. Through the combination of manually dug metric squares, mechanical coring, and limited trenching with backhoe and bulldozer, the excavations disclosed a complicated record of landscape-forming processes and changes. Again, because of the numerous chronological assessments undertaken, most of the soils and sediments representing these processes and changes are known to have formed mainly between 40,000 and 30,000 years ago.

Long before 40,000 years ago, water draining from the high ridge north of the Burnham site cut a northeast-southwest canyon into the Marlow Formation red sandstone. Only a couple of meters of this canyon's bedrock south wall was exposed in the 1986-1992 excavations, but fine sandy alluvium with gravel stringers were found to depths indicating that this drainage was seven to nine meters below this bedrock wall. Considerable runoff must have occurred to create such a deep cut. This erosion was undoubtedly enhanced by rapid flow off the ridge to the north, because the dolomite-capped ridge would have been closer than it is today. Although never as expansive (with the groundwater collecting ability) as the Southern High Plains, the ridge north of the Burnham site has eroded by the same geological processes, namely spring sapping, sheetflooding, slope wash, and rockfalls (Simpkins and Gustavson 1987). Studies of caprock retreat in the Texas panhandle provided estimates ranging from .038 mile/1000 years to .119 mile/1000 years before the Ogallala aquifer was lowered by historic farming (Gustavson and Simpkins 1989). Caprock retreat for the ridge north of the Burnham site has unquestionably been less (because it lacks such an extensive aquifer), but even if reduced to one-fourth the rate of the Texas panhandle that would put the south escarpment of the Burnham ridge somewhere between 0.5 mile to 1.5 miles farther south 50,000 years ago. This escarpment is now three miles north of the Burnham site.

By 40,000 years ago, the accumulation of fluvial sediments slowed in the bedrock-lined drainage, and this led to the development of the first discernible soil at the Burnham location. Occurring around site elevation 98.0, a thin, clay and carbonate-enriched paleosol occurs north and south of a narrow gully that eventually held periodically ponded water. Several radiocarbon dates from the Burnham paleosol indicate plants were growing on it by 37,000 years ago. Actual plants associated with this paleosol include hackberry, which still grows here today, and pawpaw, a fruit-bearing bushy tree that today grows no closer than 120 miles east of the site. The few identifiable bones found with the paleosol include elements from giant tortoise, gopher tortoise, dire wolf, and eastern wood rat (Table 20.3). A small assemblage of snails recovered from the Burnham paleosol consists of nine taxa (Table 20.3), all of which are land species that still can be found in northwestern Oklahoma. All in all, the plants, mammals, reptiles, and snails associated with the Burnham paleosol bear witness to grasslands and riparian woodlands that existed when winters were warmer and seasonal drought was less than today.

By 36,000 years ago, the Burnham paleosol was being buried by reddish, loamy fine sands rich in calcium carbonate. The prevailing fine texture and the presence of several discontinuous layers of soft to slightly hard carbonate nodules makes these calcic paleosols resemble soils developed in eolian deposits elsewhere on the Southern Plains (Hawley et al. 1976; Holliday 1989, 1990). However, this accumulating soil profile also involved overbank deposition and even slope wash from weathering Marlow Formation sandstone. The several layers of carbonate nodules attest to periodic stability and the genesis of calcic horizons during relatively dry climatic conditions.

Meanwhile, the previously existing gully had become part of a spring-fed drainage in which a pond formed, probably as a result of beaver dams. This marked the beginning of a sequence of five lacustrine settings at the location. From the available evidence, none of these ever exceeded an acre or so in extent. While radiocarbon dates implicate these ponds were present between 36,000 and 11,000 years ago, the four lowest pond deposits (Burnham Units IIB, IIC, IID, and IIE) probably were formed between 36,000 and 22,000 years ago. Notably, no soil horizon or alluvial stratum at the Burnham site convincingly bears witness to the Wisconsinan full glacial period of 21,000 to 14,000 years ago.

Because of abundant fossils, and because artifact-looking chert objects were recovered there, the two lowest pond deposits were the focus of the Burnham field research. Designated at sedimentary units IIB and IIC, these two deposits were confined to discernible channels, consisted predominantly of gleyed fine sediments, and contained countless gastropods and numerous bones. Little difference exists between the mammals, reptiles, fish, and gastropods associated with these two stratified sedimentary units, and they most likely existed for only a few decades apiece sometime between 36,000 and 34,000 years ago. This places them around the middle of the Wisconsinan glacial period.

From the sediments of these two oldest ponds come aquatic gastropods that tell us much about the character of these watery settings. *Valvata tricarinata* occurs in both Unit IIB and Unit IIC. Because of its rather unusual requirement of cold water for reproduction, *Valvata tricarinata* provides evidence that these ponds were deep and fed by springs whose outflowing water was around 57° F. Where these ponds were shallower, several gastropod taxa (Physidae, *Planorbella trivolvis*, and *Gyraulus parvus*) bear witness to warmer water with submerged and emergent vegetation. The diverse aquatic snails, several kinds of aquatic turtles, a few aquatic snakes, and a couple of salamander species implicate that these ponds persisted for several years. Yet the presence of a single hardy sunfish would suggest that the ponds were at the headwaters of this drainage where other fish hadn't migrated. If other predatory fish had been present it seems unlikely that salamanders would have thrived there.

Among the several gastropod taxa from Units IIB and IIC are a few stress tolerant species indicative of a fluctuating shoreline and to marshy areas along that shore. Also representative of such niches are the northern leopard frog, bullfrog, and possibly the southern bog lemming. Brushy to wooded areas around or near these ponds were homes to the eastern box turtle, eastern woodrat, and rabbits. Such areas must also have been habitats frequented by giant tortoise and the Shasta ground sloth. Some terrestrial snail taxa attest to nearby meadows and grasslands. These places undoubtedly were favored by the hispid pocket mouse, least shrew, prairie vole, black-tailed prairie dog, mammoth, camel, small horse, and occasional large-horned bison represented by fossil bones found in Unit IIB and Unit IIC deposits. Except for some species that didn't survive the Pleistocene-Holocene transition between 12,000 and 10,000 years ago, the assemblages of vertebrates and invertebrates recovered from these two lowest pond deposits look strikingly like those found in this region today. Overall, these assemblages support the inference that the climate was warmer during winter months while the growing seasons had slightly more effective moisture than occurs in the region today.

Many readers will be incredulous at the claim that people were present at the Burnham location in mid-Wisconsinan times. Yet there are two parts of chipped stone tools, a large flint cobble showing two flakes removed, and 51 flakes of flint and quartzite. All but one flake came from the lowest sedimentary unit (IIB), and the majority were within five feet of the skull, vertebrae, shoulder blade, and ribs of a large-horned *Bison chaneyi.* This is a poorly known variety of bison but one that was clearly precursor to *Bison antiquus*, the late Wisconsinan form known to have been hunted by Paleoindian people bearing such well known material cultures as Clovis and Folsom on the Southern Plains. Though the Burnham association of artifacts with *Bison chaneyi* is a secondary one, that is, both the bones and the artifacts were redeposited in the earliest pond sediments, it is difficult to see the proximity of bones, flakes, and flaked objects as the result of totally random distribution. Regrettably, the primary context from which these objects originated was not found during extensive geoarchaeological investigations in 1992 (Wyckoff and Carter 1994).

The Burnham site is not the smoking gun needed to resolve current controversies about the presence of pre-Clovis humans in North America, but neither is it the product of archaeology done with smoke and mirrors. At the Burnham site, artifacts were recovered when and where they were not expected. The message received by some of us working on this project is that archaeologists should be involved with investigations of geological and paleontological contexts predating the last glacial maximum. To say this more bluntly, archaeologists should not walk away from deposits that look older than Clovis. For western Oklahoma, numerous gleyed deposits look like ponds and playas where bones of horses, mammoths, and camels accumulated. We intend to continue investigating these locations. By coring it should be possible to trace out the former shores of these settings and hopefully find bone beds. Careful excavation of these will, at the very least, provide taphonomic information about the natural processes that create such contexts, but such work may also reveal more about humans being here a lot longer ago than many people currently believe.

References Cited

Adovasio, J.M. and J. Page. 2002. *The First Americans: In Pursuit of Archaeology's Greatest Mystery*. Random House, New York.

Adovasio, J.M. and D.R. Pedler. 1997. Monte Verde and the Antiquity of Humankind in the Americas. *Antiquity* 71:573-580.

Alsozatai-Petheo, J. 1986. An Alternative Paradigm for the Study of Early Man in the New World. *New Evidence for the Pleistocene Peopling of the Americas*, edited by A. Bryan, pp. 15-23. University of Maine, Center for the Study of Early Man, Orono.

Anderson, D.G. and J.C. Gillam. 2000. Paleoindian Colonization of the Americas: Implications for an Examination of Physiography, Demography, and Artifact Distribution. *American Antiquity* 65(1):43-66.

Bailey, B.B. 2000. *The Geoarchaeology of Day Creek Chert: Lithostratigraphy, Petrology, and the Indigenous Landscape of Northwest Oklahoma and Southwest Kansas*. Ph.D. dissertation, Department of Anthropology, University of Oklahoma. Norman.

Baker, F.C. 1938. New Land and Freshwater Mollusca from the Upper Pliocene of Kansas and New Species of Gyraulus from Early Pleistocene Strata. *Nautilus* 51(4):126-131.

Barnes, A.S. 1939. The Differences between Natural and Human Flaking on Prehistoric Flint Implements. *American Anthropologist* 41:99-112.

Beaudoin, A.B., M. Wright, and B. Ronaghan. 1996. Late Quaternary Landscape History and Archaeology in the 'Ice Free Corridor': Some Recent Results from Alberta. *Quaternary International* 32:113-126.

Birkeland, P.W. 1999. *Soils and Geomorphology*. Oxford University Press, New York.

Bleed, P.J. 2001. Trees or Chains, Links or Branches: Conceptual Alternatives for Consideration of Stone Tool Production and Other Sequential Activities. *Journal of Archaeological Method and Theory* 8(1):101-127.

Bond, G., W. Broecker, S. Johnson, J. MacManus, L. Lebeyrie, J. Andrews, S. Huoan, R. Jantschik, S. Clasen, C. Simet, K. Tedesco, M. Klas, G. Bonani, and S. Ivy. 1992. Evidence for Massive Discharges of Icebergs into the North Atlantic Ocean during the Last Glacial Period. *Nature* 360:245-251.

Bond, G. W. Broecker, S. Johnson, J. MacManus, L. Labeyrie, J. Jouzen, and G. Bonani. Correlations between Climate Records from North Atlantic Sediments and Greenland Ice. *Nature* 365:143-147.

Bonnichsen, R. and K.L. Turnmire. 1991. *Clovis Origins and Adaptations*. Oregon State University, Center for the Study of the First Americans, Peopling of the Americas Publications. Corvallis.

Bonnichsen, R. and K.L. Turnmire. 1999. *Ice Age People of North America, Environments, Origins, and Adaptations*. Oregon State University Press and the Center for the Study of the First Americans, Corvallis.

Bradley, B.A. 1977. *Experimental Lithic Technology, with Special Reference to the Middle Paleolithic*. Ph.D. dissertation, Corpus Christi College, University of Cambridge.

Bradley, B.A. 1982. Chapter Three: Lithic Technology. *The Agate Basin Site, A Record of the Paleoindian Occupation of the Northwestern High Plains*, compiled and edited by G.C. Frison and D.J. Stanford, pp. 181-212. Academic Press, New York.

Broecker, W., G. Bond, M. Klas, E. Clark, and J. MacManus. 1992. Origin of the Northern Atlantic's Heinrich Events. *Climate Dynamics* 6:265-273.

Bryan, A.L. (editor). 1978. *Early Man in America*. University of Alberta, Department of Anthropology, Occasional Papers 1. Edmonton.

Bryan, A.L. (editor). 1986. *New Evidence for the Pleistocene Peopling of the New World.* University of Maine, Center for the Study of Early Man, Orono.

Bryan, K. 1950. *Flint Quarries-The Sources of Tools and, at the Same Time, the Factories of the American Indian.* Papers of the Peabody Museum of American Archaeology and Ethnology 17(3). Harvard University, Cambridge.

Caire, W., J.D. Tyler, B.P. Glass, and M.A. Mares. 1989. *Mammals of Oklahoma.* University of Oklahoma Press, Norman.

Callahan, E. 1979. The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts. *Archaeology of Eastern North America* 7(1):1-180.

Caran, S.C. and R.W. Baumgardner, Jr. 1986. Stop 12A:Quitaque Creek Section. *Geomorphology and Quaternary Stratigraphy of the Rolling Plains, Texas Panhandle*, edited by T.C. Gustavson, pp. 56-57. University of Texas at Austin, Bureau of Economic Geology, Guidebook 22.

Caran, S.C. and R.W. Baumgardner, Jr. 1990. *Quaternary Stratigraphy and Paleoenvironments of the Texas Rolling Plains.* Geological Society of America Bulletin 102:768-785.

Carpenter, C.C. and J.J. Krupa. 1989. *Oklahoma Herpetology, An Annotated Bibliography.* University of Oklahoma Press, Norman.

Carr, P.J. (editor). 1994. *The Organization of American Prehistoric Chipped Stone Technologies.* International

Monographs in Prehistory, Archaeological Series 7. Ann Arbor.

Carter, B.J., P.A. Ward III, and J.T. Shannon. 1990. Soil and Geomorphic Evolution within the Rolling Red Plains Using Pleistocene Volcanic Ash Deposits. *Geomorphology* 3:471-488.

Chapman, M.R. and N.J. Shackleton. 1998. Millenial-scale Fluctuations in North Atlantic Heat Flux during the Last 150,000 Years. *Earth and Planetary Science Letters* 159:57-70.

Chlachula, J. 1996a. Geology and Quaternary Environments of the First Preglacial Paleolithic Site Found in Alberta, Canada. *Quaternary Science Reviews* 15:285-313.

Chlachula, J. 1996b. Some Artifact-Diagnostic Criteria of Quartzite Cobble-Tool Industries from Alberta. *Journal Canadien d'Archeologie* 20:61-74.

Cifelli, R.L., K.S. Smith, and F. von Hofe Grady. 2002. Dire Wolf (*Canis dirus*) in the Pleistocene of Oklahoma. *Oklahoma Geology Notes* 62(3):92-96.

Cohen, M. 1992. Native Plants for Desert Tortoises. *Tortuga Gazette* 28(2):6-7.

Collins, M.B. 1999a. Clovis Blade Technology. University of Texas Press, Austin.

Collins, M.B. 1999b. Clovis and Folsom Lithic Technology on and near the Southern Plains: Similar Ends, Different Means. *Folsom Lithic Technology, Explorations in Structure and Variation*, edited by D.S. Amick, pp. 12-38. International Monographs in Prehistory, Archaeological Series 12. Ann Arbor.

Conant, R. and J.T. Collins. 1998. *A Field Guide to Reptiles and Amphibians, Eastern and Central North America*. Houghton Mifflin Company, Boston.

Cook, H.J. 1927. New Geological and Paleontological Evidence Bearing on the Antiquity of Mankind in America. *Natural History* 27:240-247.

Cook, H.J. 1928. Glacial Age of Man in New Mexico. *Scientific American* 139:38-40.

Cortijo, E. L. Labeyrie, M. Elliot, E. Balbon, and N. Tisnerat. 2000. Rapid Climatic Variability of the North Atlantic Ocean and Global Climate: A Focus of the IMAGES Program. *Quaternary Science Reviews* 19:227-241.

Crabtree, D.E. 1966. A Stoneworker's Approach to Analyzing and Replicating the Lindenmeier Folsom. *Tebiwa* 9)1):3-39.

Crawford, H.S., C.L. Kucera, and J.H. Ehrenreich. 1969. *Ozark Range and Wildlife Plants*. U.S. Department of Agriculture, Forest Service, Agriculture Handbook 356. Washington, D.C.

Cross, F.B. 1967. *Handbook of Fishes of Kansas*. University of Kansas, Museum of Natural History, Miscellaneous Publication 45.

Cross, F.B. 1970. Fishes as Indicators of Pleistocene and Recent Environments in the Central Plains. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Jones, Jr., pp. 241-257. University of Kansas, Department of Geology, Special Publication 3.

Czaplewski, N.J., J.P. Thurmond, and D.G. Wyckoff. 2001. Wild Horse Creek #1: A Late Miocene (Clarendonian-Hemphillian) Vertebrate Fossil Assemblage in Roger Mills County, Oklahoma. *Oklahoma Geology Notes* 61(3):60-67.

Dalquest, W.W. 1957. First Record of Bison alleni from a Late Pleistocene Deposit in Texas. *Texas Journal of Science* 9:346-354.

Dalquest, W.W. 1961. Two Species of Bison Contemporaneous in Early Recent Deposits in Texas. *Southwestern Naturalist* 6(2):73-78.

Dalquest, W.W. 1964. A New Pleistocene Local Fauna from Motley County, Texas. *Kansas Academy of Science, Transactions* 67(3):499-505.

Dalquest, W.W. 1965. New Pleistocene Formation and Local Fauna from Hardeman County, Texas. *Journal of Paleontology* 39:63-79.

Dalquest, W.W. and J.A. Baskin. 1992. Mammals of the Elm Creek Local Fauna, Late Pleistocene of Beaver County, Oklahoma. *American Midland Naturalist* 127:13-20.

Dalquest, W.W. and G.E. Schultz. 1992. *Ice Age Mammals of Northwestern Texas*. Midwestern State University, Wichita Falls.

Dalquest, W.W. and F.B. Stangl, Jr. 1989. Late Pleistocene Mammals from the Northwestern Corner of the Oklahoma Panhandle. *Texas Journal of Science* 41:35-47.

Dalquest, W.W., F.B. Stangl, Jr., and J. Kocurko. 1990. Zoogeographic Implications of Holocene Mammal Remains from Ancient Beaver Ponds in Oklahoma and New Mexico. *Southwestern Naturalist* 35:105-110.

Davis, L.C. 1975. *Late Pleistocene Geology and Paleoecology of the Spring Valley Basin, Meade County, Kansas*. Ph.D. dissertation, University of Iowa, Department of Geology. Iowa City.

Dice, L.R. 1922. Some Factors Affecting the Distribution of the Prairie Vole, Forest Deer Mouse, and Prairie Deer Mouse. Ecology 3:29-47.

Dillehay, T.D. 1989. *Monte Verde: A Late Pleistocene Settlement in Chile: Paleoenvironment and Site Context, Vol. I*. Smithsonian Institution Press, Washington, D.C.

Dillehay, T.D. 1997. *Monte Verde: A Late Pleistocene Settlement in Chile: The Archaeological Context, Vol. II*. Smithsonian Institution Press, Washington, D.C.

Dillehay, T.D. 2000. *The Settlement of the Americas: A New Prehistory*. Basic Books, New York.

Dincauze, D. 1984. An Archaeological Evaluation of the Case for Pre-Clovis Occupations. *Advances in World Archaeology*, Vol. 3, edited by F. Wendorf and A. Close, pp. 275-323. Academic Press, New York.

Dixon, E.J. 1993. *Quest for the Origins of the First Americans*. University of New Mexico Press, Albuquerque.

Drake, R.J. 1975. Fossil Nonmarine Molluscs of the 1961-63 Llano Estacado Paleoecological Study. *Late Pleistocene Environments of the Southern High Plains*, edited by F. Wendorf and J.J. Hester, pp. 201-246. Southern Methodist University, Fort Burgwin Research Center, Publication 9.

Dredge, L.A. and L.H. Thorleifson. 1987. The Middle Wisconsinan History of the Laurentide Ice Sheet. *Geographie Physique et Quaternaire* 41(2):215-235.

Dundas, R.G. 1999. Quaternary Recors of the Dire Wolf, *Canis dirus*, in North and South America. *Boreas* 28:375-385.

Dyke, A.S., J.T. Andrews, P.U. Clark, J.H. England, G.H. Miller, J. Shaw, and J.J. Veillette. 2002. The Laurentide and Innuitian Ice Sheets during the Last Glacial Maximum. *Quaternary Science Reviews* 21(1-3):175-192.

Dyke, A.S. and V.K. Prest. 1987. Late Wisconsinan and Holocene History of the Laurentide Ice Sheet. *Geographie Physique et Quaternaire* 41(2):237-264.

Easton, N.A. 1992. Mal De Mer Above Terra Incognita, or, "What Ails the Coastal Migration Theory?" *Artic Anthropology* 29(2):28-42.

Faulkner, A. 1972. *Mechanical Principles of Flintworking.* Ph.D. dissertation, Department of Anthropology, Washington State University. Pullman.

Fay, R.O. 1959. Pleistocene Course of the South Canadian River in Central Western Oklahoma. *Oklahoma Geology Notes* 19:3-12.

Fay, R.O. 1965. *Geology of Woods County.* Oklahoma Geological Survey, Bulletin 108. Norman.

Fladmark, K.R. 1979. Routes: Alternative Migration Corridors for Early Man in North America. *American Antiquity* 44(1):55-69.

Fowells, H.A. 1965. *Silvics of Forest Trees of the United States.* U.S. Department of Agriculture, Forest Service, Agriculture Handbook 271. Washington, D.C.

Frye, J.C. and A.B. Leonard. 1952. *Pleistocene Geology of Kansas.* University of Kansas, Kansas Geological Survey, Bulletin 99.

Goodfriend, G.A. 1987. Radiocarbon Age Anomalies in Shell Carbonate of Land Snails from Semi-Arid Areas. *Radiocarbon* 29(2):159-167.

Goodfriend, G.A. 1989. Complementary Use of Amino-Acid Epimerization and Radiocarbon Analysis for Dating of Mixed-Aged Fossil Assemblages. *Radiocarbon* 31(3):1041-1047.

Goodfriend, G.A. and M. Magaritz. 1987. Carbon and Oxygen Isotope Composition of Shell Carbonate of Desert Land Snails. *Earth and Planetary Science Letters* 86:377-388.

Goslar, T. and M.F. Pazdur. 1985. Contamination Studies on Mollusk Shell Samples. *Radiocarbon* 27(1):33-42.

Graham, R.W. and E.L. Lundelius, Jr. 1984. Coevolutionary Disequilibrium and Pleistocene Extinctions. *Quaternary Extinctions, A Prehistoric Revolution*, edited by P.S. Martin and R.G. Klein, pp. 223-249. University of Arizona Press, Tucson.

Gray, F. and H.M. Galloway. 1969. *Soils of Oklahoma.* Oklahoma State University, Agricultural Research, Miscellaneous Publication 56. Stillwater.

Gray, F. and M.H. Roozitalab. 1976. *Benchmark and Key Soils of Oklahoma, A Modern Classification System.* Oklahoma State

Grayson, D.K. 1988. Perspectives on the First Americans. *Americans Before Columbus: Ice Age Origins*, edited by R. Carlisle, pp. 107-123. University of Pittsburgh, Department of Anthropology, Ethnology Monographs 12.

Guidon, N. and B. Arnaud. 1991. The Chronology of the New World: Two Faces of One Reality. *World Archaeology* 23(2):167-178.

Gustavson, T.C., R.W. Baumgardner, Jr., S.C. Caran, V.T. Holliday, H.H. Mehnert, J.M. O'Neill, and C.C. Reeves, Jr. 1991. Quaternary Geology of the Southern Great Plains and an Adjacent Segment of the Rolling Plains. *Quaternary Nonglacial Geology, Conterminous United States*, edited by R.B. Morrison, pp. 477-501. Geological Society of America, The Geology of North America, Vol. K-2. Boulder, Colorado.

Gustavson, T.C. and W.W. Simpkins. 1989. *Geomorphic Processes and Rates of Retreat Affecting the Caprock Escarpment, Texas Panhandle.* University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 180.

Hall, E.R. 1955. *Handbook of Mammals of Kansas.* University of Kansas, Museum of Natural History and State Biological Survey, Lawrence, Kansas.

Hawley, J.W., G.O. Bachman, and K. Mauley. 1976. Quaternary Stratigraphy in the Basin and Range and Great Plains Provinces, New Mexico and Western Texas. *Quaternary Stratigraphy of North America*, edited by W.C. Mahaney, pp. 235-274. Douglas, Hutchinson, and Ross, Inc., Stroudsburg, Pennsylvania.

Haynes, C.V. 1969. The Earliest Americans. *Science* 166:709-715.

Heinrich, H. 1988. Origin and Consequences of Cyclic Ice-rafting in the Northeast Atlantic Ocean during the Past 130,000 Years. *Quaternary Research* 29:142-152.

Hibbard, C.W. 1955. *The Jinglebob Interglacial (Sangamon?) Fauna from Kansas and Its Climatic Significance.* University of Michigan, Museum of Paleontology, Contributions 12(10).

Hibbard, C.W. 1960. An Interpretation of Pliocene and Pleistocene Climates in North America. *Annual Report of the Michigan Academy of Science, Arts, and Letters* 62:5-30.

Hibbard, C.W. 1970. Pleistocene Mammalian Local Faunas from the Great Plains and Central Lowland Provinces of the United States. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Jones, Jr., pp. 395-433. University of Kansas, Department of Geology, Special Publication 3.

Hibbard, C.W. and D.W. Taylor. 1960. *Two Late Pleistocene Faunas from Southwestern Kansas.* University of Michigan, Museum of Paleontology, Contributions 16(1).

Hofman, J.L. 1992. Recognition and Interpretation of Folsom Technological Variability on the Southern

Plains. *Ice Age Hunters of the Rockies*, edited by D.S. Stanford and J.S. Day, pp. 193-225. Denver Museum of Natural History and University Press of Colorado, Niwot.

Hofman, J.L. 1993. An Initial Survey of the Folsom Complex in Oklahoma. *Bulletin of the Oklahoma Anthropological Society* 41:71-105.

Holliday, V.T. 1989. The Blackwater Draw Formation (Quaternary): A 1.4-plus MY Record of Eolian Sedimentation and Soil Formation on the Southern High Plains. *Bulletin of the Geological Society of America* 101:1598-1607.

Holliday, V.T. 1990. Soils and Landscape Evolution of Eolian Plains: The Southern High Plains of Texas and New Mexico. *Geomorphology* 3:489-515.

Holliday, V.T. and C.M. Welty. 1981. Lithic Tool Resources of the Eastern Llano Estacado. *Bulletin of the Texas Archeological Society* 52:201-214.

Holmes, W.H. 1894. Natural History of Flaked Stone Implements. *Memoirs of the International Congress of Anthropology, Chicago* 1894:120-139.

Hubricht, L. 1985. *The Distribution of the Native Land Mollusks of the Eastern United States*. Field Museum of Natural History, Fieldiana 24. Chicago.

Jelinek, A.J. 1960. A Late Pleistocene Vertebrate Fauna from Texas. *Journal of Paleontology* 34:933-939.

Johnson, C.S. and D.E. Savage. 1955. A Survey of Various Late Cenozoic Vertebrate Faunas of the Panhandle of Texas, Part I: Introduction, Description of Localities, Preliminary Faunal Lists. *University of California, Publications in Geological Science* 31:27-50.

Johnson, H.L. and C.E. Duchon. 1995. *Atlas of Oklahoma Climate*. University of Oklahoma Press, Norman.

Johnson, J.K. and C.A. Morrow (editors). 1987. *The Organization of Core Technology*. Westview Press, Boulder.

Kasper, S. 1989. *Vertebrates from the Late Pleistocene Carrol Creek Local Fauna, Donley County, Texas*. M.A. thesis, Department of Biology, Midwestern State University, Wichita Falls.

Kasper, S. and D. Parmley. 1990. A Late Pleistocene Herptofauna from the Lower Texas Panhandle. *Texas Journal of Science* 42(3):289-294.

Klots, E.B. 1966. *The New Field Book of Freshwater Life*. G.P. Putnam's Sons, New York.

LeVick, L.E. 1975. A Cache of Preforms from Southwestern Kansas. *Bulletin of the Oklahoma Anthropological Society* 23:177-183.

Leonard, A.B. 1946. Three New Pupillids from the Lower Pleistocene of Central and Southwestern Kansas. *Nautilus* 50:20-24.

Leonard, A.B. 1948. Invertebrates of the Blancan. *Bulletin of the Geological Society of America* 59(6):589-591.

Leonard, A.B. 1959. *Handbook of Gastropods in Kansas*. University of Kansas, Museum of Natural History, Miscellaneous Publication 20. Lawrence.

Lundelius, E.L., Jr. 1967. Late-Pleistocene and Holocene Faunal History of Central Texas. *Pleistocene Extinctions:The Search for a Cause*, edited by P.S. Martin and H.E. Wright, Jr., pp. 287-319. Yale University Press, New Haven.

Lundelius, E.L., Jr. 1972. *Fossil Vertebrates from the Late Pleistocene Ingleside Fauna, San Patricio County, Texas*. University of Texas, Bureau of Economic Geology, Report of Investigations 77:1-74. Austin.

Lynch, T.F. 1990. Glacial-Age Man in South America? A Critical Review. *American Antiquity* 54(1):12-36.

Machette, M.N. 1985. Calcic Soils of the Southwestern United States. *Soils and Quaternary Geology of the Southwestern United States*, edited by D.L. Weide, pp. 1-21. Geological Society of America, Special Paper 203.

Mandryk, C.A.S. 1996. Late Wisconsinan Deglaciation of Alberta: Process and Paleogeography. *Quaternary International* 32:79-86.

Marshall, S.J., T.S. James, and C.K.C. Clarke. 2002. North American Ice Sheet Reconstruction at the Last Glacial Maximum. *Quaternary Science Reviews* 21(1-3):175-192.

Meltzer, D.J. 1983. The Antiquity of Man and the Development of American Archaeology. *Advances in Archaeological Method and Theory* 6:1-51.

Meltzer, D.J. 1989. Why Don't We Know When the First People Came to North America? *American Antiquity* 54(3):471-490.

Meltzer, D.J. 1991. On "Paradigms" and "Paradigm Bias" in Controversites over Human Antiquity in America. *The First Americans: Search and Research*, edited by T.D. Dillehay and D.J. Meltzer, pp. 13-49. CRC Press, Boca Raton.

Meltzer, D.J. 1993. Pleistocene Peopling of the Americas. *Evolutionary Anthropology* 1(5):157-169.

Meltzer, D.J. 1997. Monte Verde and the Pleistocene Peopling of the Americas. *Science* 276:754-755.

Meltzer, D.J., J.M. Adovasio, and T.D. Dillehay. 1994. On a Pleistocene Human Occupation at Pedra Furada, Brazil. *Antiquity* 68:695-714.

Meltzer, D.J., D.K. Grayson, G. Ardila, A.W. Barker, D.F. Dincauze, C.V. Haynes, F. Mena, L. Nunez, and D.J. Stanford. 1997. On the Pleistocene Antiquity of Monte Verde, Southern Chile. *American Antiquity* 62(4):659-663.

Metcalf, A.L. and R.A. Smartt. 1997. Land Snails of New Mexico: A Systematic Review. *Land Snails of New Mexico*, edited by A.L. Metcalf and R.A. Smartt, pp. 1-69. New Mexico Museum of Natural History and Science, Bulletin 10. Albuquerque.

Miller, B.B. 1975. A Sequence of Radiocarbon-Dated Wisconsinan Nonmarine Molluscan Faunas from Southwestern Kansas-Northwestern Oklahoma. University of Michigan, Museum of Paleontology, *Papers in Paleontology* 12:9-18.

Miller, B.B. 1976. The Late Cenozoic Molluscan Succession in the Meade County, Kansas, Area. *Guidebook of* *the 24th Annual Meeting of Midwestern Friends of the Pleistocene*, edited by C.K. Bayne, pp. 73-85. University of Kansas, Kansas Geological Survey, Guidebook Series 1. Lawrence.

Morlan, R. 1988. Pre-Clovis People? Early Discoveries of America. *Americans before Columbus: Ice Age Origins*, edited by R. Carlisle, pp. 31-43. University of Pittsburgh, Department of Anthropology, Ethnology Monographs 12.

Muto, G.R. 1971. A Stage Analysis of the Manufacture of Stone Tools. *Great Basin Anthropological Conference 1970, Selected Papers*, edited by C.M. Aikens, pp. 109-118). University of Oregon Anthropological Papers 1. Eugene.

Muto, G.R. 1976. *The Cascade Technique: An Examination of a Levallois-like Reduction System in Early Snake River Prehistory*. Ph.D. dissertation, Department of Anthropology, Washington State University. Pullman.

Myers, A.J. 1965. Late Wisconsinan Date for the Bar M Local Fauna. *Oklahoma Geology Notes* 25:168-170.

Neel, C. and V. Burnham. 1986. More Early Points from Northwest Oklahoma. *Newsletter of the Oklahoma Anthropological Society* 34(1):9.

Nowak, R.M. 1970. *North American Quaternary* Canis. University of Kansas, Museum of Natural History, Monographs 6. Lawrence.

Patten, B. 1999. *Old Tools-New Eyes, A Primal Primer of Flintknapping*. Stone Dagger Publications, Denver.

Patterson, L.W. 1983. Criteria for Determining the Attributes of Man-Made Lithics. *Journal of Field Archaeology* 10:297-307.

Preston, R.E. 1979. *Late Pleistocene Cold-Blooded Vertebrate Faunas from the Mid-Continental United States*. University of Michigan, Museum of Paleontology, Papers in Paleontology 19.

Rogers, R.A., L.A. Rogers, and L.D. Martin. 1992. How the Door Opened: The Peopling of the New World. *Human Biology* 64(3):281-302.

Smith, G.R. and D.R. Fisher. 1970. Factor Analysis of Distribution Patterns of Kansas Fishes. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Jones, Jr., pp. 259-277. University of Kansas, Department of Geology, Special Publication 3.

Schnurrenberger, D., and A.L. Bryan. 1985. A Contribution to the Study of the Naturefact/Artifact Controversy. *Stone Tool Analysis, Essays in Honor of D.E. Crabtree*, edited by M.G. Plew, J.C. Woods, and M.G. Pavesic, pp. 133-159. University of New Mexico Press, Albuquerque.

Shaak, G.D. and R. Franz. 1978. Faunal Succession and Environments of Deposition of Pleistocene Lake Buffalo, Northwestern Oklahoma. *Oklahoma Geology Notes* 38(5):175-190.

Simpkins, W.W. and T.C. Gustavson. 1987. *Erosion Rates and Processes in Subhumid and Semiarid Climates, Texas Panhandle: Statistical Evaluation of Field Data.* University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 162.

Simpson, R.D., L.W. Patterson, and C.A. Singer. 1986. Lithic Technology of the Calico Mountains Site. *New Evidence for the Pleistocene Peopling of the Americas*, edited by A.L. Bryan, pp. 89-105. University of Maine, Center for the Study of Early Man, Orono.
Smith, G.R. and D.R. Fisher. 1970. Factor Analysis of Distribution Patterns of Kansas Fishes. *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr. and J.K. Jones, Jr., pp. 259-277. University of Kansas, Department of Geology, Special Publication 3.
Sollberger, J.B. 1976. Biface Patterns on Prismatic Flakes. *Bulletin of the Texas Archaeological Society* 47:261-267.

Sollberger, J.B. 1985. A Technique for Folsom Fluting. *Lithic Technology* 14(1):41-50.

Steele, D.G. 1990. Taphonomic Provenience and Mammoth Bone Modification. *Hunters of the Recent Past*, edited by L.B. Davis and B.O.K. Reeves, pp. 87-102. Unwin Hyman, London.

Stephens, J.J. 1960. Stratigraphy and Paleontology of a Late Pleistocene Basin, Harper County, Oklahoma. *Bulletin of the Geological Society of America* 71:1675-1702.

Stettenheim, P. 1957. Bird Fossils from the Late Pleistocene of Kansas. *Wilson Bulletin* 70:197-199.

Taylor, D.W. 1960. *Late Cenozoic Molluscan Faunas from the High Plains*. U.S. Geological Survey, Professional Paper 337. U.S. Government Printing Office, Washington, D.C.

Taylor, D.W. and C.W. Hibbard. 1955. A New Pleistocene Fauna from Harper County, Oklahoma. *Oklahoma Geological Survey*, Circular 37. Norman.

Taylor, R.E., M. Stuiver, and P. J. Reimer. 1996. Development and Extension of the Calibration of the Radiocarbon Time Scale:Archaeological Applications. *Quaternary Science Reviews* 15:655-668.

Theler, J.L., D.G. Wyckoff, and B.J. Carter. 2003. The Southern Plains Gastropod Survey: The Distribution of Land Snail Populations in an American Grassland Environment. *American Malacological Bulletin*, in press.

Thomas, A.E. 2001. *Amphibians of the Eleven Contiguous Western States and Alaska*. Idaho Department of Fish and Game, Boise.

Thurmond, J.P. and D.G. Wyckoff. 1999. The Calf Creek Horizon in Northwestern Oklahoma. *Plains Anthropologist* 44(169):231-250.

Tunnell, C. 1978. *The Gibson Lithic Cache*. Texas Historical Commission, Office of State Archeologist, Report 30. Austin.

Vita-Finzi, C. and N. Roberts. 1984. Selective Leaching of Shells for 14C Dating. *Radiocarbon* 26(1):54-58.

Walden, H.T. 1964. *Familiar Freshwater Fishes of America*. Harper and Row, New York.

Warren, S.H. 1905. On the Origin of Eolithic Flints by

Natural Causes, Especially by the Foundering of Drifts. *Journal of the Royal Anthropological Institute* 35:337-364.

Warren, S.H. 1914. The Experimental Investigation of Flint Fracture and Its Application to the Problem of Human Implements. *Journal of the Royal Anthropological Institute* 44:412-450.

Warren, S.H. 1921. Excavations at the Stone-Age Factory of Graig-Lwyd, Penmaenmawr. *Journal of the Royal Anthropological Institute* 51:165-199.

Waters, M.R. 1985. Early Man in the New World: An Evaluation of the Radiocarbon Dated Pre-Clovis Sites in the Americas. Environments and Extinctions: *Man in Late Glacial North America*, edited by J.I. Mead and D.J. Meltzer, pp. 125-143. University of Maine, Center for the Study of Early Man, Peopling of the Americas Series. Orono.

Wendorf, F. 1961. Invertebrate Collections. *Paleoecology of the Llano Estacado*, assembled by F. Wendorf, pp. 115-114. Fort Burgwin Research Center, Publication 1. Museum of New Mexico Press, Santa Fe.

Wendorf, F. 1966. Early Man in the New World: Problems of Migration. *American Naturalist* 100(912):253-270.

Whitley, D.S. and R.I. Dorn. 1993. New Perspectives on the Clovis vs. Pre-Clovis Controversy. *American Antiquity* 58(4):626-647.

Williams, J.E. 1974. *Atlas of the Woody Plants of Oklahoma*. Oklahoma Biological Survey and R. Bebb Herbarium, University of Oklahoma, Norman.

Wyckoff, D.G. 1999a. Southern Plains Folsom Lithic Technology: A View from the Edge. *Folsom Lithic Technology, Explorations in Structure and Variation*, edited by D.S. Amick, pp. 39-64. International Monographs in Prehistory, Archaeological Series 12. Ann Arbor.

Wyckoff, D.G. 1999b. The Burnham Site and Pleistocene Human Occupations of the Southern Plains of the United States. *Ice Age People of North America*, edited by R. Bonnichsen and K. Turnmire, pp. 340-361. Oregon State University Press, Corvallis.

Wyckoff, D.G. and B.J. Carter. 1994. *Geoarchaeology at the Burnham Site: 1992 Investigations at a "Pre-Clovis Site" in Northwestern Oklahoma*. University of Oklahoma, Oklahoma Archaeological Survey, special publication to fulfill NSF grant DBS-9120314. Norman.

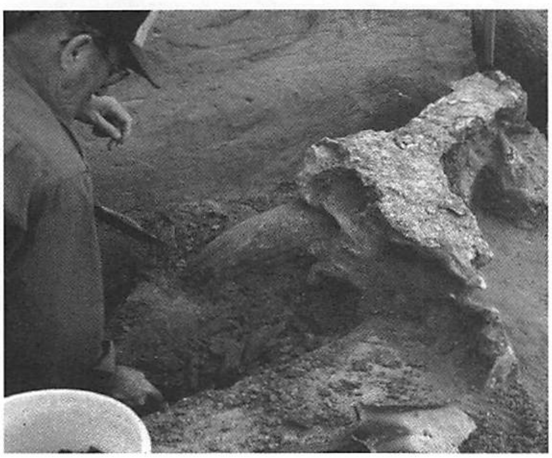
Wyckoff, D.G. and W.W. Dalquest. 1997. From Whence They Came: The Paleontology of Southern Plains Bison. *Plains Anthropologist Memoir* 29:5-32.

Appendix A:
A Chronology of Burnham Site Volunteers and Their Activities

October 1986:
The Initial Testing and Paleontological Salvage Work

Oklahoma Anthropological Society Volunteers
Harold Brown
Scott Francis
Claude Long
Colleagues from the Okalhoma Archeological Survey
Lois Albert
Peggy Flynn Rubenstein
Don Wyckoff

Photos: Right, Peggy starting to uncover the bison skull with Harold Brown and visitor Harold Kamas at waterscreens. Lower left, Claude Long uncovering left horn core of bison. Lower right, Peggy, Scott, and Claude watching as Don prepares to photograph exposed bison skull.



September 1988:
Further Testing

Oklahoma Anthropology Society Volunteers

Ken Bloom
Betty Brown
Harold Brown
Ralph Caffey
Bud Doke
Paul Ferguson
John Flick
Scott Francis
Preston George
Troy Holder
Sherl Holesko
Alvie Laverty
Jimmie Martin
Hazel Matejec
Evalou Milledge
Sue Mitchell

1988 Excavators in East Grid: Preston George (front), Barry Splawn, Sherl Holesko, John Flick, Jimmie Martin, and Don Shockey (back).

September 1988

Oklahoma Anthropological Society Volunteers

Jan Mullins
Terrell Nowka
Harriet Peacher
Mel Phillips
Christina Rich
Lee Romine
Don Shockey
Barry Splawn
Buck Wade
Clarence Westfahl
Lee Woodard

Oklahoma Archeological Survey Colleagues

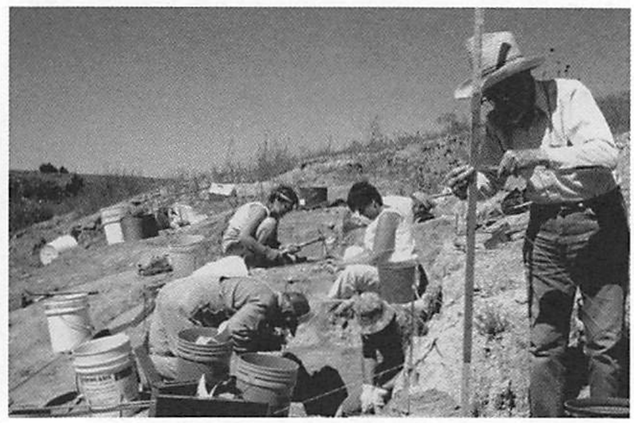
Francie Sisson
Don Wyckoff

Burnham Research Colleagues

Wakefield Dort (University of Kansas)

1988 Excavations: Terrell Nowka and Ken Bloom in East Grid Squares.

Ralph Caffey, Evalou Milledge, and Harold Brown handling the waterscreening chores during the 1988 field work.



Christina Rich, Sheryl Holesko, Terrell Nowka, Don Shockey, John Flick, Barry Splawn, and Preston George in East Grid squares during 1998 excavations.

September and October 1989:
National Geographic Society Sponsored Field Work

Volunteers

Debra Adams
Leland Allebn
Leslie Anderson
Bill Atwood
DeAnna Austin
Paul Benefield
Jack Biggs
Ken Bloonm
Carolyn Boyd
Melissa Bunch
Rena Caffey
Ralph Caffey
Tim Cannon
Michele Chesser
Daryl Coley
Cristie Darr
Austin Dennis
Carol Eames
Roseanne Engel
Paul Ferguson
Shirley Finfrock
John Flick
Scott Francis
Jim George
Preston George
Margaret George
Charlie Gifford
George Hanggi
Nina Hanggi
Hank Hjelm
Irene Johnson
Alvie Laverty
Claude Long
Gene Lounsbury
Ralph McLendon
Don Menzie
Jane Menzie
Bill Menzie

The sign acknowledging sponsorship of the 1989 field work by the National Geographic Society and the Oklahoma Archeological Survey. East exposure visible in background.

Volunteers During the 1989 Excavations

Evalou Milledge
Sue Mitchell
Bobby Nickey
Gant Nickey
Anna Nowicka
Terrell Nowka
Harriet Peacher
Linda Penderson
Barbara Peterson
Charles Rippy
Don Shockey
Barry Splawn
Byron Sudbury
Bob Sweet
Sunni Wager
Richard Williams
Norma Williams
Kim Wiseman
Bill Witchey
Lee Woodard
Ruth Wyckoff

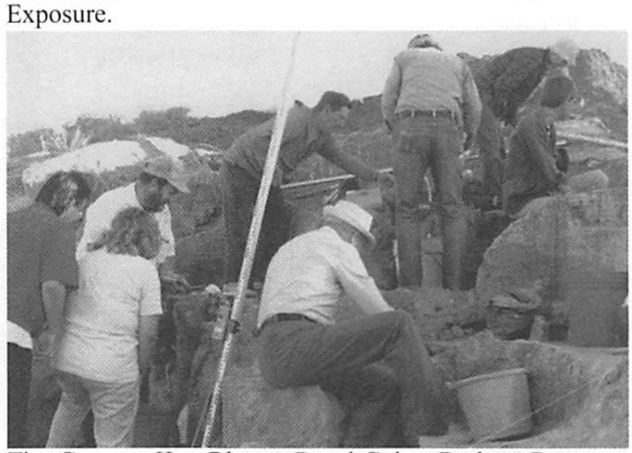
Beginning the manual and backhoe excavations at the East Exposure.

Oklahoma Archeological Survey Colleagues

Lois Albert
Kent Buehler
Bob Brooks
Francie Sisson
Don Wyckoff

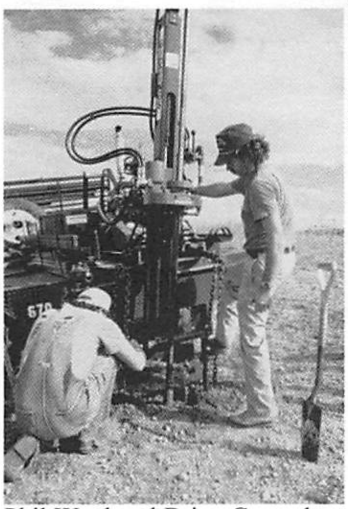
Burham Research Colleagues

Bob Brakenridge
Brian Carter
Wakefield Dort
Larry Martin
Jim Theler
Larry Todd



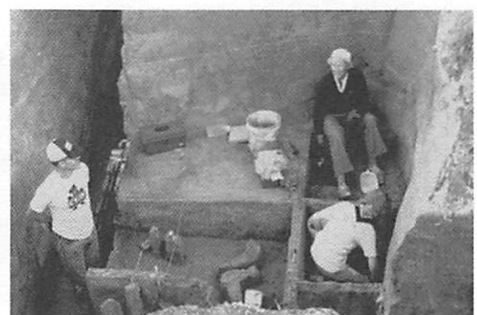
Tim Cannon, Ken Bloom, Daryl Coley, Barbara Peterson, Don Shockey, and Richard Williams working on East Grid squares.

Larry Todd recording bison bones.

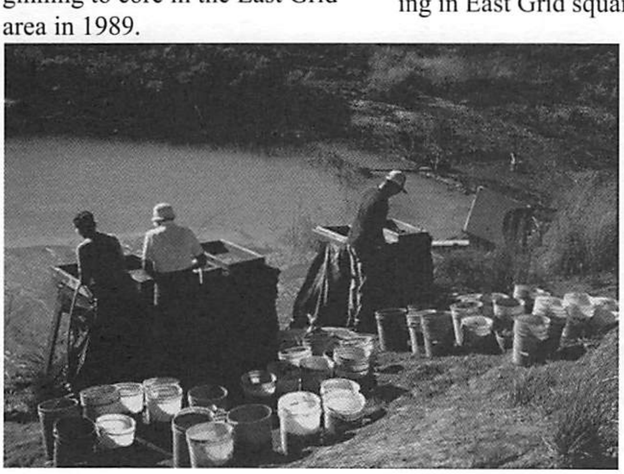


Phil Ward and Brian Carter beginning to core in the East Grid area in 1989.

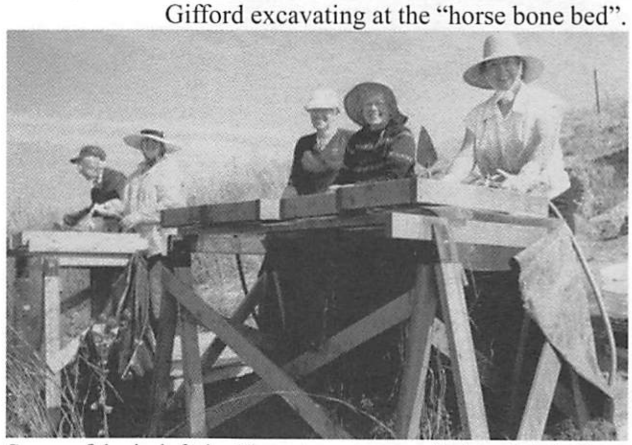
Ralph McLendon and Rene Caffey working in East Grid squares.



Bobby Nickey, Norma Williams, and Charlie Gifford excavating at the "horse bone bed".



The 1989 waterscreens in operation.

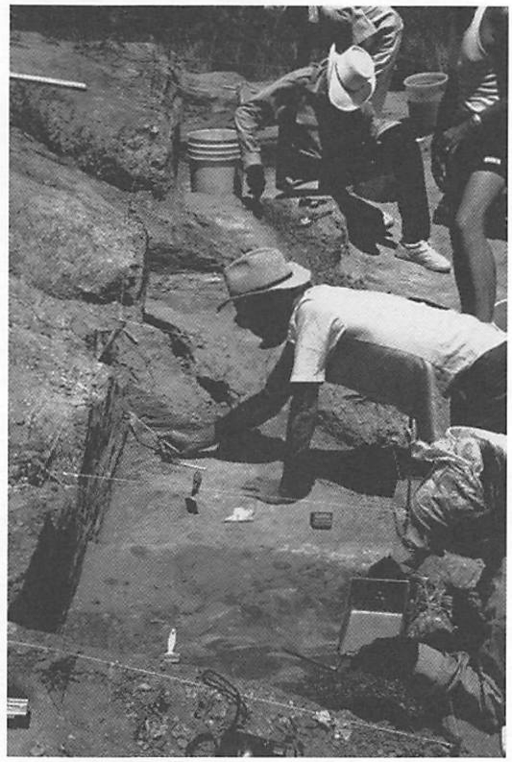


Some of the indefatigable waterscreeners (left to right): Gene Lounsbury, Sunni Wager, Norma Williams, Shirley Finfrock, and Harriet Peacher.

May-June 1991:
Oklahoma Anthropology Society Spring Dig

Oklahoma Anthropological Society Volunteers

Lisa Atkins	Roland Meyer
Robert Bartlett	Dave Morgan
Henry Benedict	Jan Mullins
K. Benedict	Bobby Nickey
Paul Benefield	Gant Nickey
Ken Bloom	Justin Noble
Carolyn Boyd	Terrell Nowka
Paul Boyer	George Odell
Lisa Coffin	Frieda Odell
Scott Coffin	Christian Rich
Tim Cannon	Ken Sherridan
Arletta Cowan	Don Shockey
Marceta Dirickson	Charles Slovacek
Don Dycus	L.M. Sullivan
Paul Ferguson	Mick Sullivan
Preston George	Marta Sullivan
Charlie Gifford	Bob Sweet
George Hanggi	Kevin Tackett
Nina Hanggi	Buck Wade
Sherl Holesko	Lee Woodard
Irene Johnson	
Kristy Johnson	
Pam Leader	
Claude Long	
Ralph McLendon	
Don Menzie	



1991 excavations in the Northwest Exposure. Mick Sullivan, L.M. Sullivan, Christina Rich, and Don Shockey taking out levels from the east side of the exposure.

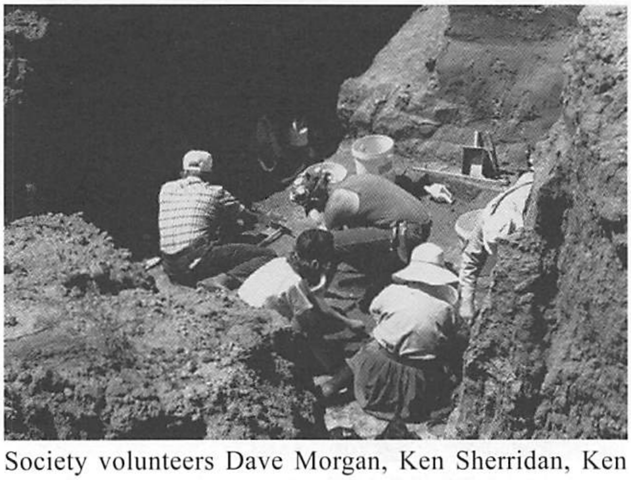
Oklahoma Archeological Survey Colleagues

Lois Albertr	Jack Hofman
Kent Buehler	Don Wyckoff

Burnham Research Colleagues

Brian Carter	Phil Ward
Jim Theler	

All systems go during excavation and waterscreening at the East Exposure.



Society volunteers Dave Morgan, Ken Sherridan, Ken Bloom, Terrell Nowka, and Carolyn Boyd excavating East Grid squares in the Burnham paleosol.

Lee Woodard (center) entertaining Ralph McLendon, Buck Wade, and Tim Cannon at the end of the day.

June 1992:

Geoarchaeological Studies Partially Funded by the National Science Foundation

Volunteers

Leslie Anderson
Ken Bloom
Harold Brown
Ethel Buie
Steve Bull
Shelton Burnham
Betty Cline
Teresa Cobb
Shirley Cobel
Don Davis
Kyle Davis
Shaun Davis
John Flick
Loy Flick
Charlie Gifford
David Harrison
Don Harrison
John Harrison
R. Harrison
Webb Henderson
Johnnie Jacobs
Irene Johnson
Donna Kerr
Kathy Lipps
Bill Lollis
Linda Mager
Sara Manerns
Jay Maulsby
Ralph McLendon
Don Menzie
Jane Menzie
Devonna Minnich
Dave Morgan
Roland Meyer
Bobby Nickey
Barbara Peterson
Don Shockey
Adam Thompson
Bill Thompson
Gary Walz
Michael Walz
Gerald Wells
Ruth Wyckoff

Oklahoma Archeological Survey Colleagues

Kent Buehler
Richard Drass
Don Wyckoff

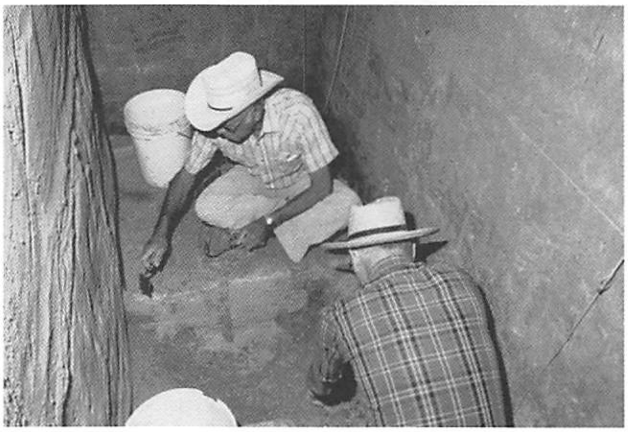
NSF Supported Undergraduates

Jana Cornelius
Michella Miller

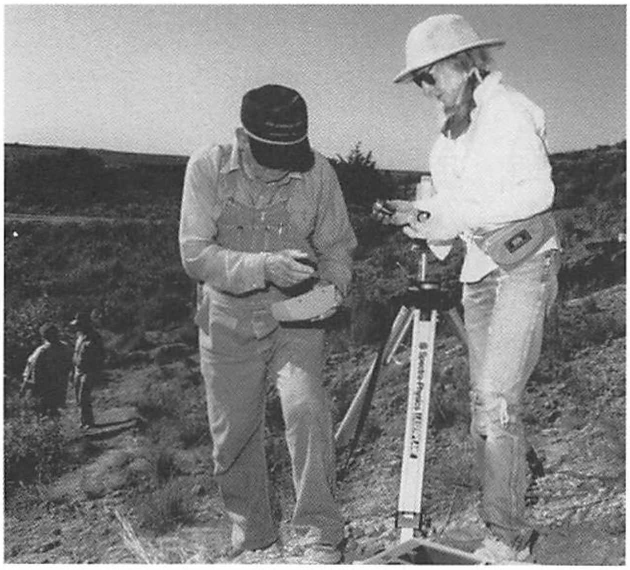
Burnham Site Research Colleagues

Brian Carter
Wakefield Dort
Jim Theler
Phil Ward

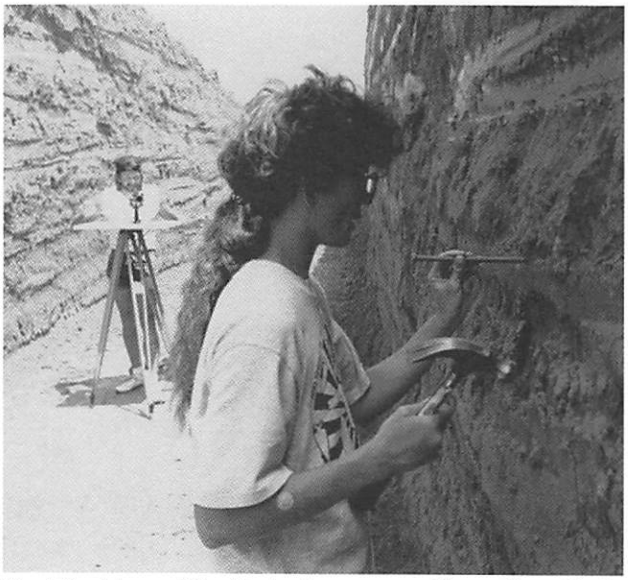
Volunteers working on squares in the Northwest Exposure.



Dave Morgan (facing) and Webb Henderson carefully removing levels from ponded sediment in the gully exposed in the 1992 Backhoe Trench A.



John Flick and Charlie Gifford replacing batteries in the laser beacon.



Kent Buehler and Leslie Anderson recording soil profile in Bulldozer Trench B dug in 1992. Large spikes were used to plot elevations relative to the site's datum.