ARCHAEOLOGICAL AND PALEOECOLOGICAL INVESTIGATIONS AT THE RICHARD BEENE SITE, SOUTH-CENTRAL TEXAS

edited by
Alston V. Thoms and Rolfe D. Mandel

Volume I: Paleoecological Studies, Cultural Contexts, and Excavation Strategies

with contributions by

Barry W. Baker
David O. Brown
Vaughn M. Bryant Jr.
Patricia A. Clabaugh
J. Philip Dering
John E. Dockall
John Fagan
Glen G. Fredlund
Wulf Gosa
John S. Jacob
Eileen Johnson
Masahiro Kamiya
Rolfe D. Mandel
J. Bryan Mason
Raymond W. Neck
Margaret Newman
Lee C. Nordt
Charlotte D. Pevny
Jesus Reyes, Jr.
D. Gentry Steele
Sunshine Thomas
Alston V. Thoms
Lori Wright

Reports of Investigations 8
Center for Ecological Archaeology
Texas A&M University

2007

ARCHAEOLOGICAL AND PALEOECOLOGICAL INVESTIGATIONS AT THE RICHARD BEENE SITE SOUTH-CENTRAL TEXAS

Volume I: Paleoecological Studies, Cultural Contexts, and Excavation Strategies

Editors

Alston V. Thoms, Principal Investigator

and

Rolfe D. Mandel

Technical Editor
Patricia A. Clabaugh

with contributions by

Barry W. Baker
David O. Brown
Vaughn M. Bryant, Jr.
Patricia A. Clabaugh
J. Philip Dering
John E. Dockall
John Fagan
Glen G. Fredlund
Wulf Gose
John S. Jacob
Eileen Johnson
Masahiro Kamiya
Rolfe D. Mandel
J. Bryan Mason
Raymond W. Neck
Margaret Newman
Lee C. Nordt
Charlotte D. Pevny
Jesus Reyes, Jr.
D. Gentry Steele
Sunshine Thomas
Alston V. Thoms
Lori Wright

TEXAS ANTIQUITIES PERMIT NO. 1589

Reports of Investigations 8
Center for Ecological Archaeology
Texas A&M University

2007

Cover photo: View of the south wall of the spillway trench at the Richard Beene site (41BX831); excavation underway at the early Early Archaic components ca. 10 m below surface.

ABSTRACT

The Richard Beene archaeological site is located about 25 km south of San Antonio on the edge of the first terrace above the Medina River. The site's most salient ecological characteristics are its riverine setting and ecotonal location near the Tamaulipan, Balconian, and Texan biotic provinces, just inside the southwest corner of the continent's eastern woodlands. It is one of some 90 sites discovered and test excavated between 1981 and 1990 as part of cultural resources investigations undertaken for the proposed construction of Applewhite Reservoir by the San Antonio Water System. Officially designated as 41BX831, the Richard Beene site was among 15 sites determined eligible for inclusion on the National Register of Historic Places and for official designation as a State Archeological Landmark. Due to its location within the dam's footpath, full-scale excavation began at Richard Beene site in 1990. When spillway-trench construction was underway in early 1991, however, a public referendum halted construction work along with archeological fieldwork; a second referendum in 1994 resulted in cancellation of the overall project. Analyses, limited field work, professional and public presentations, and report preparations continued until 2007, as various organizations and agencies worked to preserve the site as a center piece for the proposed Land Heritage Institute of the Americas, a 1200 acre, educational, research, and recreational facility.

Excavations totaling 730 m^2 sampled 20 stratigraphically distinct archaeological deposits and yielded more than 80,000 artifacts–flakes, tools, bones, mussel shells, and fire-cracked rocks—buried in 14 m of fine-grained, over-bank alluvium comprising the Applewhite terrace fill. These well stratified and variously preserved archaeological surfaces and zones represented Early (ca. 8800–8600, 8100–7600, and 6900 B.P.), Middle (ca. 4500 and 4100 B.P.) and Late (ca. 3500–2800 B.P.) Archaic occupations along with Late Pre-Columbian (ca. 1200–400 B.P.) occupations. Forty-four radiocarbon ages were obtained from soil bulk-carbon and wood charcoal in archaeological features, isolated charcoal fragments, and tree-burns in artifact bearing sediments. The Richard Beene site virtually stands alone in Texas as a well-dated, deeply buried, well-stratified locality with numerous discrete and substantial artifact and feature assemblages that span the Holocene and a multitude of others that await discovery and study. Moreover, it is one of only a handful of excavated sites along North America's entire Gulf Coastal Plain and the greater Southeast to yield fairly complete archaeological records of the last 10,000 years.

Throughout its 10,000-year history of intermittent habitation, the Richard Beene site was occupied by hunter-gatherer families who encamped along the river, hunted deer, rabbits, and other game in wooded areas, gathered wild roots, arguably from nearby root grounds, and fished and collected river mussels to supplement their diet. Local river gravels provided almost all the raw material for stone tools and chipped-stone technology changed little during the site's millennia-long history. Nearby sandstone outcrops provided cook-stone raw material for use as heating elements in earth ovens and open-air hearths. What fluctuated through time was probably the number of families encamped at a given place and the degree to which game-animal or plant-food procurement dominated their subsistence pursuits. Considerable inter-component variation in densities of chipped stone artifacts, fire-cracked rock, and mussel shells suggests differences in intensity, and perhaps the nature, of occupations. Early, Early Archaic components yielded the highest density and diversity of tool types suggestive of various residential activities, including woodworking, but those components also yielded the largest artifact samples. Assemblages representative of younger components are less diverse and may indicate a narrower range of activities or perhaps shorter-term occupations. Climatic conditions fluctuated through time as well, but usually did not vary far from modern conditions. The site's archaeological record provides a uniquely long-term perspective on regional paleoecology and riverine usage in an ecotonal setting between the North America's western grasslands and eastern woodlands.

ACKNOWLEDGMENTS

The Medina River (aka Applewhite Reservoir) archaeological project spanned more than two decades, from 1981 through 2007, and it now is represented by three monographs submitted to the Texas Historical Commission (THC) and the San Antonio Water System (SAWS) and published in the Center for Ecological Archaeology's Reports of Investigation series. The Center for Ecological Archaeology (CEA) at Texas A&M University (TAMU) began its three-part role in 1989. Historic-sites investigations were undertaken primarily through the Archaeological Research Program at Southern Methodist University and the results are published as *Historic Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas* (2003), edited by J. M. Adovasio and Melissa M. Green. Survey and test-excavations at Pre-Columbian sites were carried out by CEA personnel and reported in *Prehistoric Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas* (2007), edited by David L. Carlson. The present report is the third monograph and these acknowledgments are intended to recognize agencies and individuals who contributed to its completion.

Archaeological and related paleoecological studies were funded by SAWS in conjunction with the proposed construction of the Applewhite Reservoir. SAWS also furnished backhoes and hydraulic lifts, along with operators Cecile Reveile and Jim Hays, for our use in excavations and stratigraphic interpretations. We are especially grateful as well for assistance provided by many SAWS employees, especially Mike Mecke, Chris Powers, Ernie Scholls, Rebecca Cedillo, Bill Allanach, and Tom Pardue. Representatives of Freese and Nichols, Inc., the environmental and engineering firm that SAWS contracted with to oversee the construction project and related assessment and mitigation work, also assisted us throughout the project. Among those who were especially helpful was Barbara Nickerson, Manager of Environmental Services, and Richard Beene, the engineering inspector for whom the site is named.

Skipper Scott, archaeological representative for the Fort Worth District Corps of Engineers (CoE), oversaw our fieldwork and assisted in developing excavation plans in response to a multitude of unanticipated archeological discoveries in dam's spillway trench. THC representatives also assisted us throughout the course of the project and served as technical reviewers of the final reports. Review comments by William Martin and Deborah Beene were especially helpful and led to improvements in the monograph, as did comments from an anonymous reviewer who focused on geoarchaeological issues. Nancy Kenmotsu, then with THC, along with William Martin, and Jim Bruseth offered guidance for addressing unanticipated discoveries in fashions compatible with the project's Programmatic Agreement among the Advisory Council on Historic Preservation, CoE, and SAWS. Dan Potter and Mike Davis, also THC personnel in 1995, provided several days of total-station operation and served as crew chiefs during the Southern Texas Archaeological Association's field school.

Many of our archaeological colleagues visited the site and/or discussed it with us through the years. Among those whose comments were especially helpful are Britt Bousman, Chris Caran, Mike Collins, Tom Hester, and Steve Black. During excavation work and many times thereafter representatives of two San Antonio based Native American groups—Tap Pilam-Coahuiltecan Nations and American Indians in Texas at Spanish Colonial Missions—visited the site. Thorough the years these organizations have endeavored to preserve the Richard Beene site for posterity. Especially persistent in their support were two of the organizations' leaders, Raymond Hernandez and Ramon Vasquez. We are also indebted to the Land Heritage Institute Foundation for its efforts to protect the site, working in partnership with these two Native American groups and many environmentally oriented San Antonio organizations. Especially active in that endeavor were Allison Elder, and Mark Oppelt.

Several members of the Southern Texas Archaeological Association (STAA), including Nancy Beaman, Raymond Smith, and Jim Warren, volunteered for fieldwork in the spring of 1991. In 1995, STAA held its annual field school at the Richard Beene site and we benefited from their substantial labor input. Field school chairman Mike Fulghum, along with the following members played especially important roles: Richard Kinz, Marie Livesay, Lenora Metting, Karen Fulghum, Wilson McKinney, Sandra Billingsly, Norman Flaigg, Tom Miller, Duke Smith, Donald Turner, Smitty Schmiedlin, Lynn Highley, and Curtis Harrell. Graduate and undergraduate students also volunteered their time in the field and lab at that time. TAMU students not otherwise listed below included Brandy Gibson, Amy Holmes, and Jennifer Voncannon. John Arnn, University of Texas at San Antonio, and Richard Stark, University of Texas at Austin, also volunteered in the field for several days.

Special thanks to the TAMU Texas Transportation Institute Research Services staff for coordinating this publication. This project would not have been possible without CEA's entire Medina River field, laboratory, and research team from 1990 to 2007. We wish to especially acknowledge the following individuals:

Steve W. Ahr	Crew Chief
Dawn Alexander	Field Technician
Barry W. Baker	Zooarchaeologist, Field Technician, Author
Edward Baker	Field Technician
Melloy-Ann Baker	Laboratory Assistant
Laura Bergstressor	Graphics Assistant
Arilina G. Bravo	Student worker
Rhonda Brinkmann	Technical Editor (TTI)
David O. Brown	Mollusca Isotope Specialist, Author
Rachel Bruning	Graphics Assistant
Vaughn M. Bryant Jr.	Palynologist, Author
David L. Carlson	Computer/Data-Analysis Guru
Patricia A. Clabaugh	Laboratory Director, Collections/Data Manager, Technical Editor, Author
Wayne Chesser	Field Technician
Michael Crow	Field Technician, Graphics Specialist
Nancy DeBono	Technical Editor
J. Philip Dering	Archaeobotanical Specialist, Author
John E. Dockall	Lithic Specialist, Illustrator, Author
Tom Dureka	Crew Chief
John Fagan	Organic Residue Specialist, Author
David Foxe	Graphics Assistant
Glen G. Fredlund	Molluscan Isotope Specialist, Author
Carl Freuden	Field Technician
Hans Freuden	Field Technician
Jui Gadade	Graphics Specialist
Wulf Gose	Paleomagnetism Specialist, Author
Beverly Guster	Office Manager
Lynne Highly	Laboratory Technician
Rhonda Holley	Laboratory Assistant, Copy Editor
Carrie Jackson	Laboratory Supervisor
Michael Jackson	Field Technician
John S. Jacob	Soil Specialist, Author
Eileen Johnson	Mammoth Specialist, Author
Jeffrey Johnson	Field Technician
Philip R. Johnson	Graphics Specialist
Roger Johnson	Field Technician
John Jones	Palynologist
Mashiro Kamiya	Field Technician, Graphics Specialist
Matt Kautzman	Assistant Crew Chief
Randy Korgal	Crew Chief
David Kuehn	Project Archaeologist
Jeff Leach	Crew Chief
Sergio Ledzema	Graphics Assistant
Don Lloyd	Field Technician
Rolfe D. Mandel	Project Geomorphologist, Report Co-Editor, Author
J. Bryan Mason	Field Technician, Spatial Analysis Specialist, Author
Anita McCulloch	Field Laboratory Supervisor
Sam McCulloch	Project Manager
Ronald Mendoza	Student worker
Robert Merrill	Project Stratigrapher
Francis Meskel	Laboratory Technician
Ann Mesrobian	Crew Chief
Raymond W. Neck	Mollusca Specialist, Author
Margaret Newman	Organic Residue Specialist, Author
Lee C. Nordt	Geomorphologist, Author
Ben W. Olive	Project Archaeologist, Data Manager
Robyn Pearson	Editorial Assistant
Charlotte D. Pevny	Lithics Specialist, Author
Daniel Potter	Project Stratigrapher
Kimberly Rector	Field Technician
Sylvia Renya	Assistant Crew Chief
Jesus Reyes, Jr.	Field Technician
Paula Robertson	Laboratory Technician
Steve Samuels	Computer Mapping Consultant
Linda Solis	Laboratory Technician
Christopher Sparks	Illustrator
Andrea Stahman	Field Technician
D. Gentry Steele	Zooarchaeologist, Author
Richard Stocker	Field Photographer, Field Technician
Susanne Thaler	Field Technician
Sunshine Thomas	Field Technician
Alston V. Thoms	Principal Investigator, Senior Report Editor, Author
An Tran	Student Worker
Patti Wood	Laboratory Assistant
Lori Wright	Biological Anthropologist, Author
Steven Zuckero	Student Worker

Although we—report editors, contributors, and technical editors—wish to acknowledge contributions made by the people and agencies mentioned above, as well as others who inadvertently remain unnamed, we accept the responsibility for our own contributions, including any errors in fact or oversights the report may contain.

TABLE OF CONTENTS

*Appendixes can be found in Volume II.

LIST OF FIGURES

LIST OF TABLES

1

ARCHAEOLOGICAL STUDIES AT THE RICHARD BEENE SITE

Alston V. Thoms

The Richard Beene site (41BX831), an officially designated State Archeological Landmark (SAL), is located 25 km south of San Antonio in south-central Bexar County, Texas, along the right bank of the Medina River (Figures 1.1, 1.2, and 1.3). This report describes and analyzes the site's Native American artifacts and features that were buried as much as 12 m below surface. These cultural deposits are the remains of dozens of encampments representative of archaeological cultures spanning the last 10,000 years of the Holocene epoch. The report also provides environmental and cultural background information that facilitates interpretation of the archaeological remains and the hunter–gatherer lifeways they represent. Discovery of this important, well-stratified and well-dated site in 1989, its subsequent assessment (1990), and partial mitigation (1990–1991, 1995) was undertaken in anticipation of the construction of the Applewhite Dam and Reservoir by the San Antonio Water System (SAWS), a public utility agency within San Antonio's city government.

Six months after dam-construction work began, a public referendum on May 4, 1991 resulted in a vote to abandon the reservoir project as a municipal water supply facility. A second referendum held on August 13, 1994, to determine whether to restart the project as an industrial-water supply, led to a decision to abandon the reservoir project altogether.

Cancellation of the reservoir construction project in 1994 included suspension of fieldwork at the Richard Beene site and other identified SAL sites within the project area. As such, realizing all the goals specified in the archaeological project's overall research design (Carlson 2008; Carlson et al. 1990) was not possible. To do so would have required a more thorough assessment of several sites and mitigation-level excavation of at least a dozen other sites. Nonetheless, researchers addressed many of the research questions and considerable new information and useful data about past lifeways in the lower Medina River valley of south-central Texas were gleaned from the fieldwork and related analyses. Moreover, planning is well along its way to preserve the Richard Beene site permanently, along with several other nearby SAL sites, within a proposed 1,200–acre Land Heritage Institute (LHI) that would function as a land-based educational, research, heritage-tourism, and recreational facility (Texas A&M University 2000).

The Richard Beene site's geographic and geomorphic setting is ideal for the preservation of archaeological sites. It lies a few kilometers below the Balcones Escarpment where the Medina River is deeply entrenched and the valley floor widens just beyond a bedrock-controlled constriction. For more than 20,000 years, the site area has been subjected to floods as the river regularly overflowed its banks and deposited layer upon layer of fine-grained, silty alluvium (Figure 1.4). As presently known, the site consists of at least 20 discrete archaeological components—occupation surfaces and zones—buried in 12 m of alluvium. Well-stratified sediments, between 12 m and 16 m below surface and dated from 11,000 and 14,000 radiocarbon years before present (B.P.), lacked definite cultural remains, but yielded an abundance of Late Pleistocene

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 1–14. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

Figure 1.1. Map of North America showing the Richard Beene site and physiographic and vegetation areas noted in the text.

mammalian, reptilian, avian, fish, and molluscan remains. Importantly, the site's well-preserved paleosols, archaeological components, and paleontological deposits are dated by 44 radiocarbon ages in correct stratigraphic order.

Federal Requirements, State Antiquities Permit, and Collections Curation

Because the proposed reservoir was a federally permitted construction project, federal law, notably Section 106 of the National Historic Preservation Act (1966, as amended), mandated archaeological investigations at 41BX831. Section 106 instructs federal agencies to consider the effects of their projects on historic properties (i.e., those eligible for inclusion on the National Register of Historic Places) prior to implementing the project or issuing a permit for a project. In this case the project re-

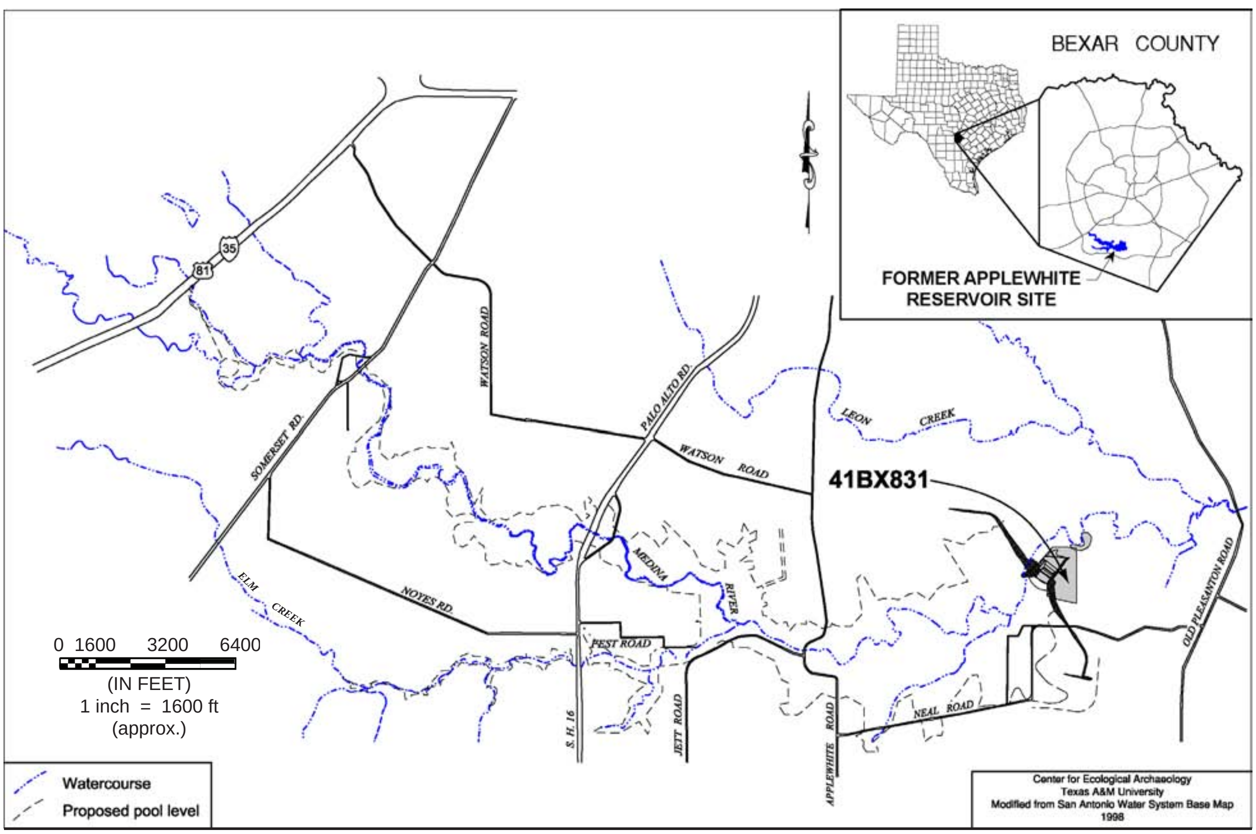


Figure 1.2. Map showing the location of the Richard Beene site in relation to the Medina River and the abandoned Applewhite Reservoir area.

Figure 1.3. The Richard Beene site area (left center) and the Medina River valley (foreground) in relation to downtown San Antonio and the Tower of the Americas (background).

quired a 404 Permit from the U.S. Army Corps of Engineers (CE), the lead federal agency charged with regulating the nation's navigable streams and their tributaries. Archaeological investigations to mitigate adverse effects to significant sites from reservoir construction were also mandated by provisions in the Antiquities Code of Texas (1969, as amended; Title 9, Chapter 191 of the Texas Natural Resources Code), given that the property was owned or designated for purchase by SAWS. The Applewhite Reservoir archaeological project was funded by SAWS pursuant to a Programmatic Agreement among the Fort Worth District Corps of Engineers, the Advisory Council on Historic Preservation, the Texas State Historic Preservation Officer, and SAWS (Advisory Council on Historic Preservation 1990).

Archaeological investigations at the Richard Beene site were conducted according to terms specified under Texas Antiquities Permit No. 1589 issued by the Texas Historical Commission (THC) to SAWS, the project owner and sponsor, and the project's principal investigators on behalf of Texas A&M University (TAMU). Fieldwork (1989–1995) and analytical studies (1989–2007) were carried out by archeologists with the Center for Ecological Archaeology (CEA) (formally the Archeological Research Laboratory [ARL]) at Texas A&M University in College Station, Texas. David L. Carlson served as principal investigator for all studies conducted prior to November 1990. After that, he served as co-principal investigator with Alston V. Thoms, whose principal investigator role focused on the Richard Beene site.

Figure 1.4. Photograph of spillway trench wall at the Richard Beene site, with archaeologists excavating an early, Early Archaic component dated to ca. 8700 B.P.

All artifacts, related samples, and supporting documentation acquired under Antiquities Permit No. 1589 by TAMU (prehistoric sites studies) and Southern Methodist University (SMU) (historic sites studies) during the Applewhite Reservoir Archaeological Project (1989–2007) are permanently housed in the repository at the Department of Anthropology, TAMU, in College Station, which is also the designated final curation facility.

Two isolated human molars, recovered from the site's 6,900–year–old, late, Early Archaic deposits, are among the items curated at the Department of Anthropology. These teeth are described in Appendix E. They were included on the official inventory of human remains and associated funerary objects held by CEA that was prepared in compliance with the Native American Graves Protection and Repatriation Act (NAGPRA) and submitted to the Department of Interior, National Park Service in 1995. No other NAGPRA–related items were recovered from the Richard Beene site.

Project History

Archaeological investigations carried out for the proposed reservoir spanned more than two decades and involved three universities and numerous consultants. The reservoir was designed in the early 1980s by Freese and Nichols, Inc., an engineering and environmental services firm based in Fort Worth, Texas. As planned, it would have impounded approximately 2,500 acres (ca. 1,000 ha) of valley bottomland along a 7–mile (ca. 11 km) stretch of the Medina River and Elm Creek, a major tributary stream (Figure 1.2). The reservoir was to have been owned and managed by SAWS as a water supply facility for the city of San Antonio and surrounding communities (Freese and Nichols, Inc. 1988).

Fieldwork began in 1981 with a pedestrian survey of about half the project area conducted by archaeologists with the Center for Archaeological Research (CAR) at the University of Texas at San Antonio (UTSA). Most of the remaining reservoir tracts were surveyed in 1984 by UTSA archaeologists. In all, the UTSA team recorded 78 sites with prehistoric (Native American) and/or historic (non–Indian) components and test-excavated 12 sites. UTSA also made recommendations for additional testing of several dozen sites, mitigation-level data recovery of a few sites judged to be significant, and a small amount of survey work in previously unsurveyed areas. Results of UTSA's investigations were published in 1987 in a report entitled *Chipped Stone and Adobe: A Cultural Resources Assessment of the Proposed Applewhite Reservoir, Bexar County, Texas* (McGraw and Hindes 1987).

In 1989, Freese and Nichols, Inc., the primary contractor for SAWS's overall reservoir project, contracted with CEA at TAMU to complete the cultural resources studies (Freese and Nichols, Inc. 1988). The scope of work and archaeological research design followed recommendations from THC and CAR–UTSA (Carlson et al. 1990). TAMU subcontracted with the Archaeological Research Program at SMU to carry out recommended investigations at historic-period sites, many of which also contained prehistoric components. CEA was responsible for carrying out recommended investigations at prehistoric sites, including the prehistoric components of historic/prehistoric sites. Besides a detailed testing program at a few sites, pedestrian surveys and resurveys were undertaken in several areas. These included places where archaeological sites were expected to be found, based on terrain and careful examination of 1938 aerial photographs, but had not been discovered during previous surveys.

Results of field investigations and related analytical studies by SMU archaeologists are presented in a report entitled *Historic Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas* (Adovasio and Green 2003). Results of survey work and testing at newly discovered prehistoric sites, along with the work carried out at prehistoric sites and components tested prior to the cancellation of the reservoir construction project, are presented in a second report entitled *Prehistoric Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas* (Carlson 2008). The present report on the Richard Beene site is the third and final monograph in the series that documents the overall results of archaeological and historical investigations carried out in this area by TAMU and SMU.

In early 1990, the Richard Beene site was discovered and recorded by TAMU archaeologists as 41BX831. They subsequently test-excavated the site and determined that it contained several buried components, two of which appeared likely to yield the kinds of artifacts and features that would be useful in addressing the project's research questions concerning relationships between changes in climatic conditions and hunter–gatherer land-use practices (Carlson et al. 1990). Accordingly, the site was judged to be potentially significant and recommended as eligible for official listing as an SAL site and for inclusion on the National Register of Historic Places. Its potential significance was attributed to the presence of stratified, well-preserved remains of Native American encampments buried approximately 1.3 m and 3.0 m below surface and radiocarbon dated to 3090 B.P and 4570 B.P., respectively (Carlson 2008).

THC concurred with recommendations that the site was significant according to SAL and National Register criteria. Accordingly, plans were made for mitigation-level excavation pursuant to the Programmatic Agreement (Advisory Council on Historic Preservation 1990) and TAMU's research design (Carlson et al. 1990). Given that the site was located in the footprint of the dam, where construction was scheduled to begin, it was also the first one to be excavated. Mitigation-level excavations began in November 1990 with a field crew of 4 to 6 individuals, and in December 1990, expanded to a crew of 10 to 12 excavators by (Figure 1.5). Excavation of the site was to be completed in a way that would allow spillway and dam construction to continue without interruption. Dam site construction work began December 1990 with vegetation clearing and initial excavation of a massive spillway trench, eventually reaching about 100 m x 300 m x 15 m in size.

By mid-February 1991, excavation of the 4,500–year–old component was nearing completion and start-up work was beginning at other SALs located near the dam site. It was then that archaeologists made an unanticipated discovery at 41BX831:

Figure 1.5. Site 41BX831 in the early stages of excavation during the fall of 1990; cleaning Block D and exposing the target zone.

a well-preserved hearth-like feature with a surrounding artifact scatter buried 6 m below surface, which was 3 m beneath the previously identified 4,500–year–old component. As plans were being developed to excavate this newly discovered component, another discovery was made at the bottom of the nearby spillway trench, which was then excavated to a depth of about 6.5 m below surface. The new discovery was the remains of an extensive and well-preserved campsite represented by discrete concentrations of river mussel shells and chipped stone debitage, as well as numerous hearth-like features. Radiocarbon ages obtained from soil humates encompassing the archaeological deposits in the original site area and the component in the spillway trench indicated that both occupations were essentially the same age, about 6,900 radiocarbon years old. Insofar as the 6 m deep overburden of alluvium had been removed by heavy machinery in the spillway trench, such that the encampment remains were essentially in a ready–to–excavate state, the focus of excavation work shifted from the original site area to the spillway trench. Within a few weeks, it became evident that several other components were buried as much as 12 m below surface in the spillway trench.

With the discovery of deeply buried archaeological deposits in the spillway trench, site boundaries originally defined for 41BX831 were expanded to encompass the spillway trench and adjacent areas. At that time, the site was formally named the Richard Beene site in recognition of Mr. Richard

Beene, chief field inspector for Freese and Nichols, Inc. It was Mr. Beene who first recognized the remains of the extensive 6,900–year–old encampment exposed by heavy machinery in the spillway trench (Figure 1.6). Had he waited an hour or so to make his report to the archaeological team, the huge pan-scrapers would have obliterated the entire component. Comparatively little would have been learned about that time period, and other discoveries that followed—components dated to 7,600, 8,000, and 8,800 radiocarbon years ago—might not have been made at all. Nor is it likely that the late Pleistocene faunal remains would have been discovered in the spillway trench more than 15 m below surface.

As it turned out, most of the mitigation-level excavation at the Richard Beene site was conducted under "discovery" conditions in the midst of ongoing construction at the dam site (Figures 1.6 and 1.7). With each discovery of a new, ever-deeper, and potentially significant component within the spillway trench, salvage plans were developed by TAMU archaeologists, reviewed and revised as needed, and approved by THC archaeologists. This approach was required by the project's Programmatic Agreement, which specified the following:

> "if previously unidentified properties are identified during construction, the SACWB [San Antonio City Water Board, which became SAWS] shall notify its archeological contractor [TAMU], stop all construction in the vicinity of the resource, and contact the CE within 24 hours of the discovery. The U. S. Army Corps of Engineers shall immediately notify the SHPO [State Historic Preservation Officer]. Field assessment of the site will take place within 48 hours by the CE and the SHPO. Assessment of the site under 36CFR60 will be within 5 days (or less) of discovery, and will include consultation with the SHPO and the SACWB. Treatment of the site will be specified by the CE after assessment and consultation. The CE will provide the Council with a report on work undertaken under this stipulation" (Advisory Council on Historic Preservation 1990:5–6).

Figure 1.6. The spillway trench excavation underway by pan-scrapers in February, 1991 when Mr. Richard Beene (center, wearing hard hat) discovered the remains of an extensive, 6,900-year-old camp site exposed in the bottom of the trench approximately 6.5 m below surface.

Archaeological fieldwork was closed down in an orderly fashion following the first referendum in 1991. A final round of mitigation-level excavation work was carried out at two of the site's components in September and October 1995 where additional work was needed to obtain adequate samples from exposed components. Analytical work continued intermittently through 2003, but was reduced in intensity and eventually postponed during much of the inter-referenda period (December 1991–September 1995). Analytical work was again curtailed substantially in the late 1990s when TAMU archeologists and other specialists worked, at SAWS's request, to assess the potential of the SAWS-owned, abandoned-reservoir property as a proposed educational, research, and recreational facility known as LHI (Texas A&M University 2000). Completion of the final report was further delayed in 2001 when TAMU closed CEA, which had been an active research and student-training center since the 1970s, and transferred project completion responsibility to the Department of Anthropology. A final round of field work—survey and monitoring—was carried out in 2005 in conjunction with landscape stabilization at the site (Appendix J)

Figure 1.7. Typical work days at the Richard Beene site in the midst of ongoing construction of the dam spillway trench in 1991, as excavated from 6 to 12 m below surface and the remains of numerous encampments exposed: (a) pan-scrapers working in the general vicinity of excavations on the 6,900-year-old (i.e., B.P.) surface (Block G); (b) pan-scrapers working in the immediate vicinity of excavations of an 8,000 year old fire-cracked rock feature (Block K); (c) excavations and water screening in full swing at the 6,900 year-old surface (Block G); (d) close-up of shove-skimming and troweling the 6,900 year old surface (Block G); (e) backhoe removing overburden above an 8,800-year-old archaeological deposit (Block T); and (f) field laboratory, located ca. 5 miles from the site.

Project Research Design and Questions

As originally developed, the research design for the overall Applewhite Reservoir archaeological project focused on relating changes in site structure and mobility strategies over time to environmental changes (Carlson et al. 1990; Carlson 2008). Within a few weeks after mitigation-level work began at the Richard Beene site, it was clear that site-preservation conditions were indeed amenable to documenting site structure—i.e., nature/distribution of artifacts and features—in several Holocene components. Preliminary analyses of food remains and raw material types indicated that the well-stratified archaeological assemblages attested almost exclusively to exploitation of environs near the site. Carlson et al. (1990) identified the following research topics and questions that could potentially be addressed with information gleaned from excavation and analysis of the deeply stratified Richard Beene site.

Environment

- What was the nature of the environment (climate, flora, fauna, etc.)?

- Was the climate stable or changing and, if changing, does it represent a sufficiently major change that could have affected prehistoric adaptation patterns?

- Do the changes in environment appear to correlate with suggested changes in subsistence and settlement patterns derived from the archaeological record that have been assigned to various cultural periods (such as phases)?

- What local environmental conditions (meso-environments and micro-environments) were available for human exploitation?

Biotic Resources

- Were bison or pronghorn available (from the adjacent uplands)?

- Were pecans available in the drainage?

- To what extent were deer utilized as compared to other food sources?

- Were mussels and snails used as a food source?

Lithic Resources

- Were the raw materials used in the manufacture of tools and other objects local in origin, or were they imported?

- Was a particular type of lithic raw material utilized in manufacturing projectile points and other tools more than any other type, and was this due to greater availability of a material type or because of inherent characteristics?

Settlement Patterns

- When prehistoric inhabitants left the project area, where did they go and why was this particular seasonal round selected?

- Within the time span of the stage or period, were there times when the project area was not inhabited?

- Are there undisturbed deposits dating to this stage or period within the project area, and if so where are they?

- What season or seasons of the year were the project area sites used by prehistoric peoples, and what was the estimated population at each site?

- Within each stage or period, are settlement patterns and associated technology sufficiently distinctive and different throughout the stage or period to support the concept of phases?

Technology

- What is the composition of the tool kit representing this stage or period?

- What tools are diagnostic of the period?

- What may be said about how tools diagnostic of the period were used?

- How does the technology of stone tool manufacture for this stage or period compare to the other stages or periods?

- Can territorial extent be demonstrated on the basis of diagnostic artifacts, artifact assemblages, or manufacturing methods?

- Do the tool assemblages from sites in the project area provide support for the idea of phases as a useful chronological concept in this region?

Paleoindian Subsistence and Settlement Patterns

- Were the landforms inhabited and utilized by Paleoindian peoples similar to those of the later periods (e.g., bluff lines and terraces)?

- Did the transition from Paleoindian lifeways to those of the Archaic in south-central Texas represent a significant shift in the types of resources that were utilized (e.g., from large to small game animals or from rock shelters to open campsites)?

- When did a broadly based hunting and gathering adaptation begin?

Paleoindian Technology

- Do the later Paleoindian diagnostics (e.g., Angostura) co-occur in good context with Early Archaic diagnostics in sites within the project area, and does this seem to reflect a transition in lifestyles between two cultural stages?

- Does the change in projectile point manufacturing techniques from Paleoindian times to the Early Archaic period represent a major shift in technology or only minor stylistic changes?

Early Archaic Subsistence and Settlement Patterns

- Was the species *Bison bison* present in the region?

- What accounts for the density of Early Archaic sites, which is perceived to be greater in the project area than in the adjacent regions?

Middle Archaic Subsistence and Settlement Patterns

- Do the suggested changes in settlement pattern correlate with the postulated end of the long drought around 4000 B.P.?

- Was there a substantial increase in population densities as has been proposed?

- Is the formation of smaller territories indicated?

- Was there an increase in the interaction sphere of south–central Texas groups?

Late Archaic Subsistence and Settlement Patterns

- Are there specialized hearth facilities that suggest greater reliance on foods requiring roasting or baking?

- How does the population density indicated by sites in south-central Texas compare with the postulated increases in population in Central Texas to the north, and low population densities in the western Gulf Coastal Plain to the east and south?

- How were potential food resources distributed across the region?

Late Pre–Columbian Subsistence and Settlement Patterns

- Are the Austin and Toyah phases distinguishable in the project area, and if so are there differences in subsistence and settlement patterns?

- Were there major changes in subsistence orientation from the Late Archaic to the Late Prehistoric?

- Does the Toyah phase represent an influx of new people following bison herds down from the north, and if so what was the impact on populations living in the project area (absorption, displacement, annihilation)?

- Is the exploitation of bison evident in Toyah phase sites/components in the project area?

Land-Use Intensification as a Research Framework

From a research perspective, the site's archaeological record is especially useful in addressing issues about long-term changes in riverine components of land-use systems. In turn, changes identified in the nature of the site's archaeological assemblages, along with inferred paleoenvironmental conditions, are especially useful in assessing elements of testable models about the nature of long-term land-use change. The land-use model for the project area—the lower Medina River valley and surrounding environs—is a *working model* developed in part from the project's original research design (Carlson et al. 1990) but with an added "intensification" component (Thoms 1989). It draws from regional archaeological records summarized in Chapter 9, as well as from global patterns of long-term land-use intensification.

As used herein, "land use" refers to patterned exploitation of resources by human groups, the manner in which they used places on the landscape, the technologies they employed in the process, and the effect of that exploitation on the ecosystem (cf. Kirch 1982). Land-use "intensification" is a general (i.e., nomothetic) trend through the millennia toward the expenditure of more energy per unit area to recover more food from the same landscape to feed more people (cf. Cohen 1977; Johnson and Earle 1987). As modeled, an imbalance (typically too many people for the available, commonly used food resources) places stress on an existing land-use system and, thus, forces intensification. The working model specifies general temporal trends that are detectable in the local and regional archeological records, but not necessarily at one site or in a single environmental setting. Expected trends are as follows:

- *Late Pleistocene*. Pre-Clovis through Paleoindian (prior to ca. 10,000 B.P.); low population densities without appreciable population circumscription; high group mobility and short-term occupation of sites by family groups; people move to the food resources (i.e., "forager-like") (Binford 1980); reliance on big game to the extent it is present (megafauna, or largest-bodied ungulates), supplemented by a variety of smaller animals, fish, shellfish, and plants. Expectations of the archaeological record: comparatively few sites with comparatively low artifact densities and high diversity in tool types, especially camp maintenance tools; small, minimal investment features, no evidence of the bulk processing of foods other than big game (i.e., deer sized and larger).

- *Early, Early, Holocene*. Early Archaic (ca. 10,000–8300 B.P.); increasing population densities and initial population circumscription; somewhat reduced group mobility but continued forager-like strategies; primary reliance on the largest-bodied available ungulates (probably deer in riverine settings and, at least periodically, bison in adjacent uplands); increasing use of smaller animals, fish, shellfish, and plants, as the availability of larger game animals decreases relative to human population. Expectations of the archaeological record: comparatively more sites, most of which should have low artifact densities and high diversity in tool types, especially camp maintenance tools; small, minimal investment features, no evidence of the bulk processing of foods other than big game, including deer.

- *Middle, Early Holocene through late, Early Holocene*. Early Archaic (ca. 8300–6000 B.P.); increasing population densities, with population circumscription well established; reduced group mobility; a notable reduction in the use of short-term occupation of sites by family groups and the movement of people to the food resources, coupled with an increase in logistically oriented, "collector-like" strategies (Binford 1980); in the absence of bison, reliance on deer in all settings, and increasingly on smaller animals, fish, shellfish, and especially plant foods (roots, prickly pear, pecans, mesquite, and acorns), focusing on the more abundant species with the best cost:benefit ratios. Expectations of the archaeological record: notable increase in site types, including sites with high artifact densities and diversities (i.e., base camps) that can be distinguished from sites with low or high artifact densities and low artifact diversities (i.e., task-specific, logistical sites); overall increase in the diversity and frequency of tool and feature types; initial evidence of increased procurement and bulk processing foods other than big game, including small game, fish, and plant foods.

- *Middle Holocene*. Middle Archaic (ca. 6000–3000 B.P.); continued increases in population densities and population circumscription; increase in collector-like strategies; continued reliance on deer but with an increasing focus on riparian zones and increasing use of smaller animals, fish, shellfish, and especially plant foods; species with cost:benefit ratios lower than those species that were intensively used in preceding time periods will be used more regularly. Expectations of the archaeological record: notable increase in site types, including sites with high artifact densities and diversities (i.e., base camps) that can be distinguished readily from sites with high artifact densities and low artifact diversities (i.e., intensively used task-specific sites); initial appearance of sites with more permanent residential structures and evidence of trade, as well as cemeteries; overall increase in the diversity and frequency of tool and feature types; more evidence of increased procurement and bulk processing resources other than big game, especially plant foods.

- *Early, Late Holocene*. Late and Terminal Archaic (ca. 3000–1200 B.P.); continued increases in population densities and population circumscription; increasing collector-like strategies; reliance on deer in all settings, but with an even greater focus on riverine environments and an ever–increasing reliance on smaller animals and plant foods with lower cost:benefit ratios than those used intensively during preceding periods. Expectations of the archaeological record: village or quasi–village sites (i.e., longer-term occupations with more substantial residential structures, middens, and cemeteries) become more common, as do task-specific sites; the pattern of an increase in the diversity and frequency of tool and feature types should continue; bulk processing features (e.g., large earth ovens and burned rock middens) should become more common, as should evidence of the use of fish and shellfish; evidence of trade should become more abundant.

- *Late, Late Holocene*. Late Prehistoric (ca. 1200–400 B.P.); this essentially represents the pre-protohistoric land use pattern; it is the period when land use was at its maximum intensity, semi-sedentism was at a maximum level, and native populations were at their highest level prior to the population apocalypse brought about by the "discovery" of the New World by Europeans and the introduction of Old World diseases. Expectations of the archaeological record: the equivalent of the Austin focus or some other limited or non-bison hunting phase of the well-known Late Prehistoric periods; tool and feature assemblages, including storage facilities, should be more complex than in earlier periods; midden deposits at base camp/village sites and special purpose sites should be at their densest; cemeteries should be more common than during any other period; evidence of violent deaths should be at an all-time high, as should evidence of trade.

Previous Publications

Although final analytical work and publication of the final report on the Richard Beene site were delayed more than 10 years after major fieldwork ended, numerous articles were published, and Master of Arts theses were written about the site during this interim. Information presented in these articles and theses forms a basis for much of the present report. They include the following:

- Applewhite Reservoir: Mitigation Phase Excavations at 41BX831, the Richard Beene Site. *APR News and Views* 3(2):4. Department of Archaeological Planning & Review, Texas Historical Commission, Austin (Thoms 1991a)

- The Richard Beene Site: A Deeply Stratified Paleoindian to Late Prehistoric Occupation in South–Central Texas. *Current Research in the Pleistocene* 9:42–44 (Thoms and Mandel 1992)

- Knocking Sense from Old Rocks: Typologies and the Narrow Perspective of the Angostura Point Type. *Lithic Technology* 18:16–27 (Thoms 1993a)

- Late Pleistocene and Early Holocene Land Use: A Preliminary Perspective from the Richard Beene Site, 41BX831, Lower Medina River, South Texas (Thoms 1992a) In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene*, edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Pedostratigraphy: Richard Beene Site (41BX831) (Mandel and Jacob 1992), In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene*, edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Plant Remains from the Richard Beene Site (41BX831): Implications for Holocene Climatic Change in South–Central Texas (Dering and Bryant 1992), In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene*, edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Late Pleistocene through Late Holocene Faunal Assemblage from the Richard Beene Site (41BX831), Bexar County, South–Central Texas: Preliminary Results (Baker and Steele 1992), In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene*, edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Late Pleistocene and Early Holocene Environments in the Medina Valley of Texas as Revealed by Nonmarine Molluscs (Neck 1992), In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene*, edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Stable Isotope Analysis of Land Snail Shell Carbonate, the Richard Beene Site (41BX831), Texas (Fredlund and Neck 1992), In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South–Central, Texas: Guidebook to the 10th Annual Meeting of the South–Central Friends of the Pleistocene,* edited by Rolfe D. Mandel and S. Christopher Caran, manuscript on file at Kansas Geological Survey, University of Kansas, Lawrence

- Early and Middle Holocene Occupations at the Richard Beene Site: The 1995 Southern Texas Archaeological Association Field School Project. *La Tierra* 23(4): 8–36 (Thoms et al. 1996)

- A Late Pleistocene Record of the Ringtail from South–Central Texas. *Current Research in the Pleistocene* 10:94–96 (Baker 1993)

- *Preserving the Feature Record: A Systematic Analysis of Cooking and Heating Features from the Richard Beene Site (41BX831), Texas.* Unpublished M.A. thesis. Department of Anthropology, Texas A&M University, College Station (Clabaugh 2002)

- C_4 Plant Productivity and Climate—CO_2 Variations in South–Central Texas during the Late Quaternary. *Quaternary Research* 58:182–188 (Nordt et al. 2002)

- *Analysis of Site Structure and Post-Depositional Disturbance at Two Early Holocene Components, Richard Beene Site (41BX831), Bexar County, Texas.* Unpublished M.A. thesis. Department of Anthropology, Texas A&M University, College Station (Mason 2003)

- *Archaeological Survey and Monitoring in 2005 at the Richard Beene Site, South-Central Texas*. Technical Report No. 7, Center for Ecological Archaeology (Thoms et al. 2005)

Information presented in several written papers given at professional meetings at the national, regional, and local levels also provided a basis for the present report, including:

- "Excavations at the Richard Beene Archaeological Site (41BX831), Lower Medina River Valley, South Texas." 62nd Annual Meeting, Texas Archeological Society, Austin (Thoms 1991b)

- "Floodplain Environments and Archaeological Assemblages in the Lower Medina River Valley, South Texas." 49th Annual Plains Conference, Lawrence, Kansas (Thoms 1991c)

- "Geoarchaeology of a Deeply-Stratified Paleoindian through Late Prehistoric Site (41BX831) in the Lower Medina River Valley, South Texas." 49th Plains Anthropological Conference, Lawrence, Kansas (Mandel 1991)

- "Land Use Diversity on a Subtropical Landscape: Terminal Pleistocene and Early Holocene Archaeology, Lower Medina River Valley, South Texas." 57th Annual Meeting, Society for American Archaeology, Pittsburgh, Pennsylvania (Thoms 1992b)

- "Late Paleoindian Phantoms and Early Archaic Land–Use Strategies: A Savannah Perspective from the Southeastern Periphery of the Southern Plains." 60th Annual Meeting, Society for American Archaeology, Minneapolis, Minnesota (Thoms 1995)

- "Late Pleistocene and Holocene Paleoecology and Archaeology at the Richard Beene Site, Coastal Plain, South-Central North America." 72nd Annual Meeting, Society for American Archaeology, Austin Texas (Thoms and Mandel–Co-Chairs)

Organization of Report

Results of paleoecological and archaeological investigations at the Richard Beene site are presented in two volumes: (1) chapters 1-9 covering project background, paleoecological studies, cultural background, and excavation strategies; and (2) chapters 10-15 covering archaeological studies and a synthesis of overall results, as well as appendices.

The present chapter introduces the Richard Beene site; provides an overview of its discovery, excavation, and relationship to the Applewhite Reservoir project history; discusses the research framework for the overall archaeological project; and acknowledges previous publications and presentations that form the basis of much of this report. Chapter 2 describes and discusses the site's present-day ecological setting and environmental conditions during the Spanish-Colonial era when Native Americans occupied the region. Chapter 3 provides detailed information on geomorphic settings, paleosols, depositional environments, and paleoenvironmental implications. Chapter 4 places the site's excavation areas (i.e., archeological components) within pedostratigraphic and site-formation contexts. Subsequent chapter's present paleoenvironmental data derived from mollusc distributions (Chapter 5), stable-isotope studies of river mussel shells (Chapter 6), and stable-isotope studies of snail shells (Chapter 7).

Chapter 8 provides ethnohistorical and archaeological background information. Excavation strategies and the general nature of archaeological deposits are discussed in Chapter 9. Next are descriptions and discussions about lithic assemblages (Chapter 10), vertebrate-fauna remains (Chapter 11), and plant remains (Chapter 12). Chapter 13 focuses on archaeological features and Chapter 14 examines aspects of site structure derived from artifact density and cluster-analysis data. Chapter 15 synthesizes and compares assemblage data from the site's major components. Appendices are as follows: (A) description of mammoth/mastodon bone; (B) provenience tables for recovered artifacts; (C) artifact-analysis tables; (D) faunal-analysis tables; (E) description of human teeth; (F) feature-analysis tables; (G) paleomagnetism analysis; (H and I) immunological analysis of residue on stone tools and fire-cracked rocks; and (J) Survey/Monitoring work in 2005.

2

ECOLOGICAL SETTING: THE LOWER MEDINA RIVER VALLEY AND SURROUNDING INNER GULF COASTAL PLAIN

Alston V. Thoms and Rolfe D. Mandel

This chapter establishes an ecological context for the ensuing descriptions and discussions of geomorphological, paleoecological, and archaeological records pertaining to the Richard Beene site. The site lies along the right bank of the Medina River and extends more than 100 m to the south, which in terms of the Applewhite Reservoir project, places it directly in the footprint of the proposed dam site (Figures 1.1 and 2.1). In a regional perspective, the site's setting, and its surrounding environs for more than 150 km, are one of a modified humid subtropical climate and savannah vegetation. Within this expansive landscape, however, there is considerable variation in physiographic regions, soil zones, and biotic provinces. Significantly, several regions, provinces, and zones converge within a few kilometers of the Richard Beene site, such that an especially salient ecological characteristic is the site's ecotonal setting—on/near an ecological boundary—wherein species diversity is usually greater compared to interior portions of biotic zones (cf. Butzer 1982; Odum 1971). Carlson (2008) provides detailed descriptions of the modern environment, including geology, soils, climate, flora, and fauna of the site area and vicinity.

Regional Physiography and Climate

The Richard Beene site is located in the lower Medina River valley in south-central Texas. It lies in the westernmost portion of the inner Gulf Coastal Plain of North America's Coastal Plain physiographic province (Figure 2.2), with the Balcones Escarpment and the Edwards Plateau division of the Great Plains province only 25 km to the northwest (Fenneman 1938). The Medina River begins in the Edwards Plateau region of the southern Plains and flows southeast before crossing the Balcones Escarpment and descending onto the Inner Gulf Coastal Plain. Within the Edwards Plateau, it is an incised bedrock stream with high gradient and moderate sinuosity. To the southeast of the Balcones Escarpment, it abruptly changes to a meandering alluvial channel with low gradient, high sinuosity, and a substantial floodplain (Figure 2.3). The Medina River joins the San Antonio River about 20 km east of the site.

The climate of south-central Texas is humid subtropical (Thornthwaite 1948). Mean annual precipitation at San Antonio for the period 1961–1990 is 78.7 cm (30.9 inches) (World Weather Information Service 2006), but there is considerable annual variation in rainfall (National Oceanic and Atmospheric Administration 2006). Monthly averages range from just over 2 inches in March to almost 4 inches in May, with a second peak of about 3.5 inches in September (Carr 1967:4, 8). Snowfall occurs once every few years, usually in January, but freezing temperatures are common and occasionally drop to single digits. Average annual temperature in this part of Texas is about 70 degrees, with the coldest month being January (ca. 54 degrees) and the warmest being July and August (ca. 85 degrees) (Carr 1967).

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 15-26. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

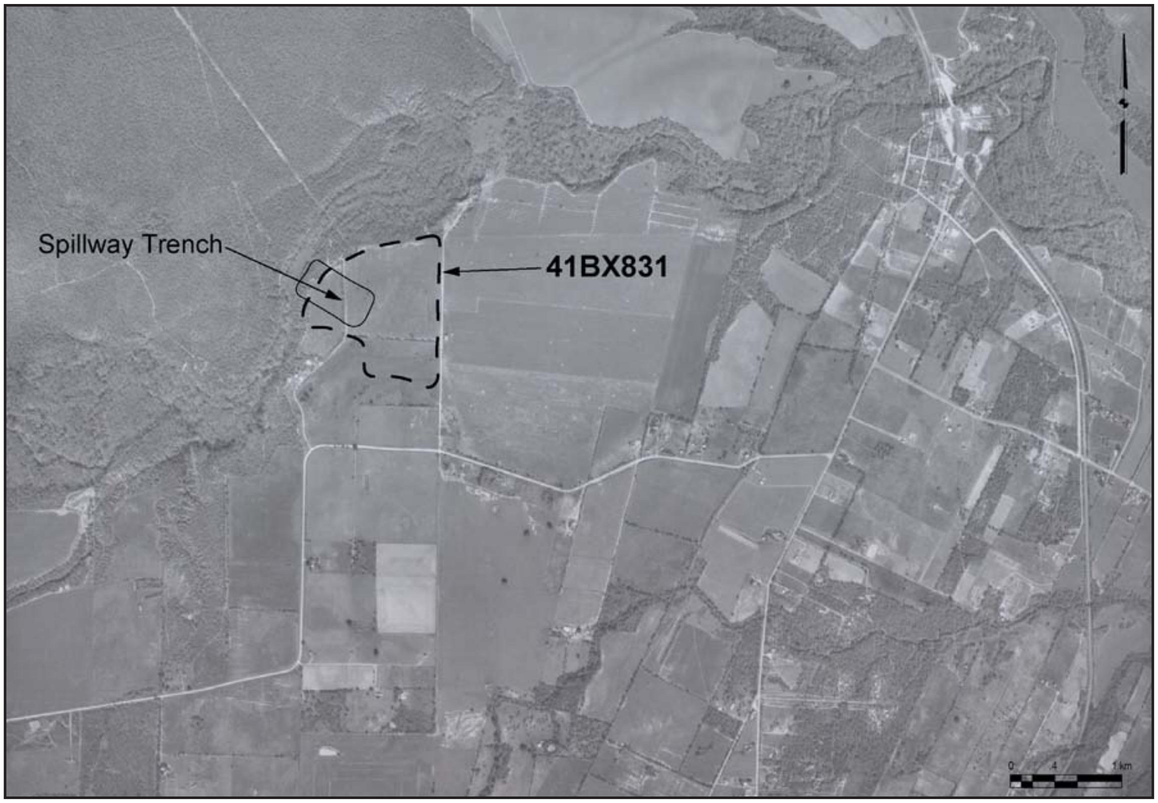


Figure 2.1. The Richard Beene site (41BX831) in relation to spillway trench for the dam at the proposed Applewhite Reservoir.

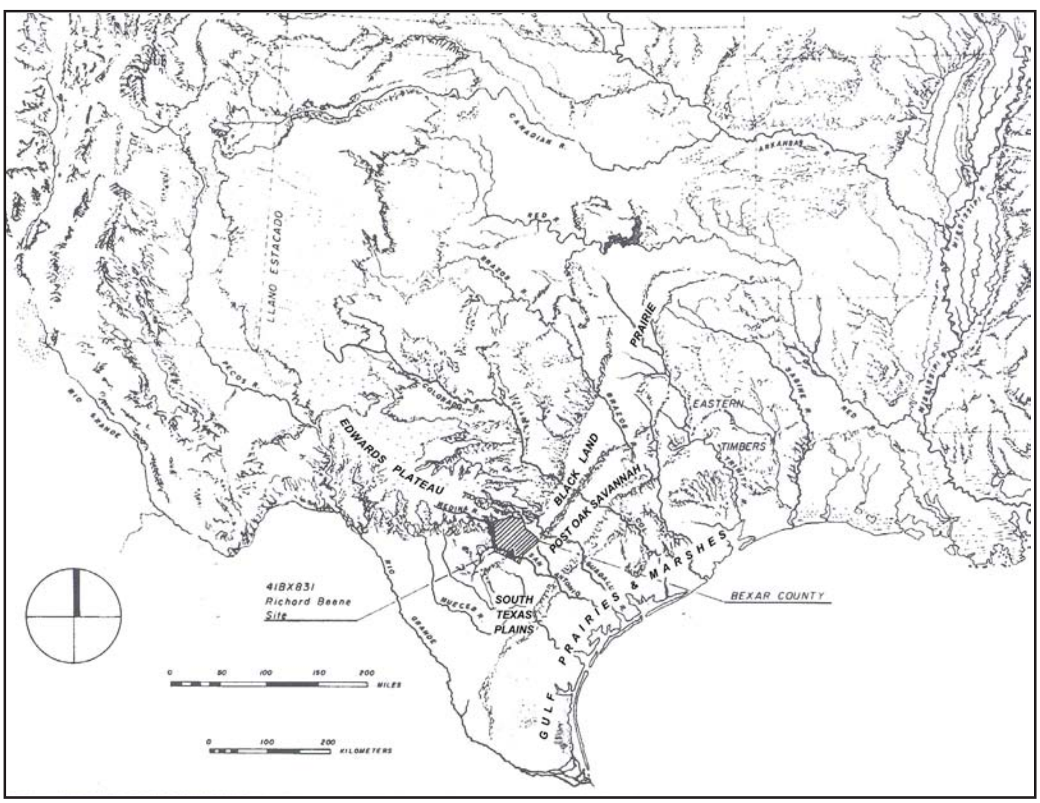


Figure 2.2. Physiographic map, showing the location of the project area in relation to surrounding provinces.

Figure 2.3. The Medina River valley: (a) view to the south, across the Medina River valley some 3 km upstream from the Richard Beene site; and (b) view to north, across the wide floodplain immediately downstream of the site.

This region is prone to intensive rainfall and concomitant severe flooding because of a variety of factors, most notably its proximity to the Gulf of Mexico moisture source, and the effects of tropical storms and easterly waves. Another important element is the orographic uplift of moist gulf air masses along the Balcones Escarpment (Carr 1967). Incursion of polar air masses into central Texas also contributes to torrential rains, especially when these systems converge with tropical storms or easterly waves in the vicinity of the Balcones Escarpment (Holliday et al. 2001). This rare combination of events has produced some of the highest rainfall intensities in the world (Baker 1980; Caran and Baker 1986; Patton and Baker 1977). For example, in 1921 a total of 92.45 cm (36.4 inches) fell in 18 hours at Thrall, Texas (ca. 159 km north of the site), holding, at that time, the world's record for this duration (Bomar 1983, 1992). Thrall, like the Richard Beene site, is situated at the boundary between the Inner Gulf Coastal Plain and Edwards Plateau. The occurrence of extremely heavy rains and associated flooding in the Medina River watershed is an important factor when site formation processes are considered at the Richard Beene site.

Ecoregions and Ecological Zones

From a continental perspective, the Richard Beene site is located near a boundary between two of North America's major ecoregions that comprise the wet eastern forests and dry central plains. An ecoregion is a continuous geographical area characterized by distinctive flora, fauna, climate, landform, and soil, wherein ecological relationships among these variables are essentially similar (Bailey 1978). The entire Medina and San Antonio River basins, and most of the eastern United States, fall within the "humid temperature" ecoregion domain (Bailey 1978). This ecoregion extends some 240 km (150 mi.) west of the Richard Beene site where it borders the "dry" ecoregion domain, which encompasses the Pecos River basin and extends north to Canada. As mapped by the U.S. Department of Agriculture, the Richard Beene site area lies just inside a southwest projection of the Prairie Parkland Province (of the Humid Temperate Domain). This ecological province extends north and east to Lake Michigan and is bordered on the east by the Southeastern Mixed Forest Province and, north thereof, by the Eastern Deciduous Forest Province. Immediately to the south and east of the site is the Prairie Brushland Province, also of the Humid Temperate Domain (Figure 2.4) (Bailey 1978).

Four major ecological zones converge within a few kilometers of the Richard Beene site: (1) the Edwards Plateau (and Balcones Escarpment) to the west; (2) the Blackland Prairie to the north; (3) the Post Oak Savannah to the northeast and east; and (4) the South Texas Plain to the south (Figure 2.5) (Frye et al. 1984). Modern vegetation regimes in these zones are as follows: (1) juniper-oak-mesquite savannah on the Edwards Plateau; (2) bunch

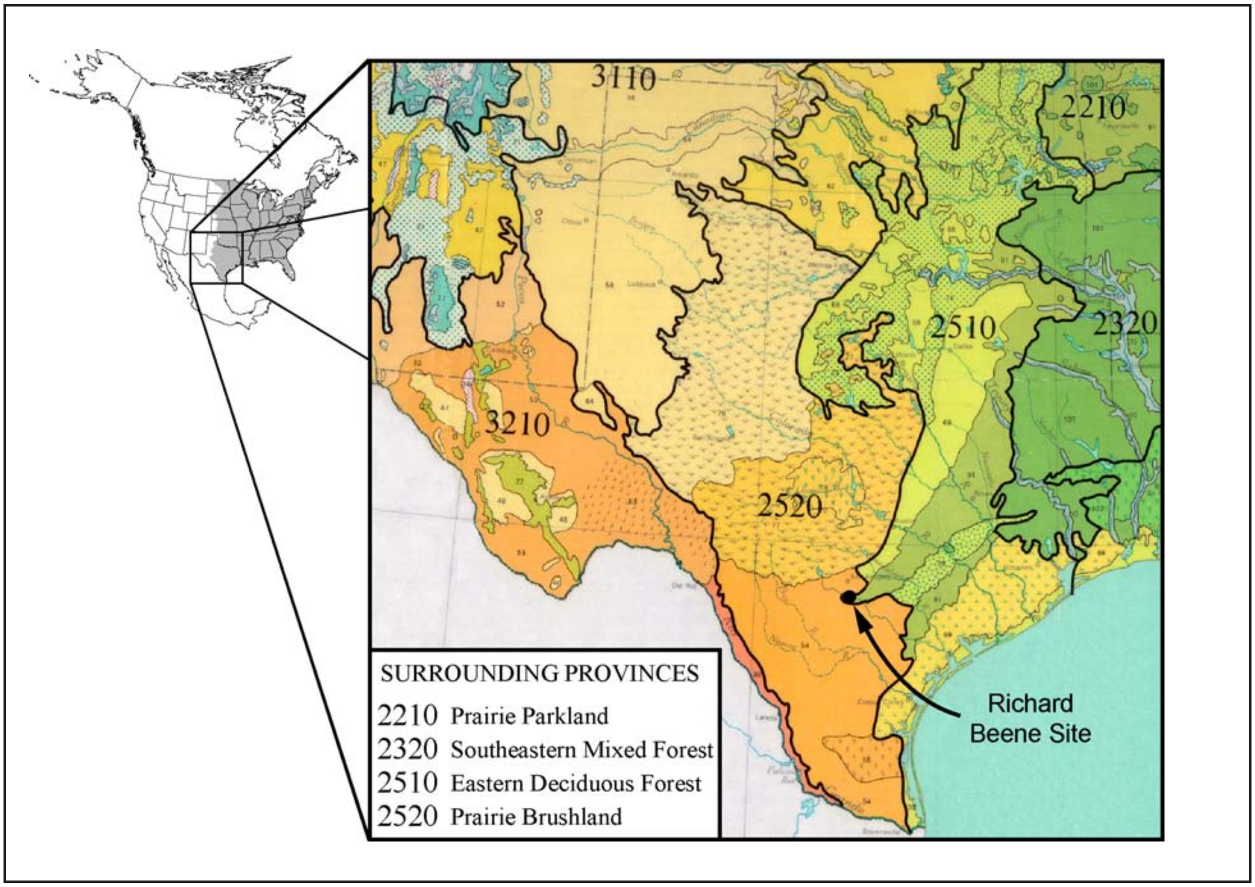


Figure 2.4. The Richard Beene site in relation to potential natural vegetation in south-central North America (modified from Kuchler 1985).

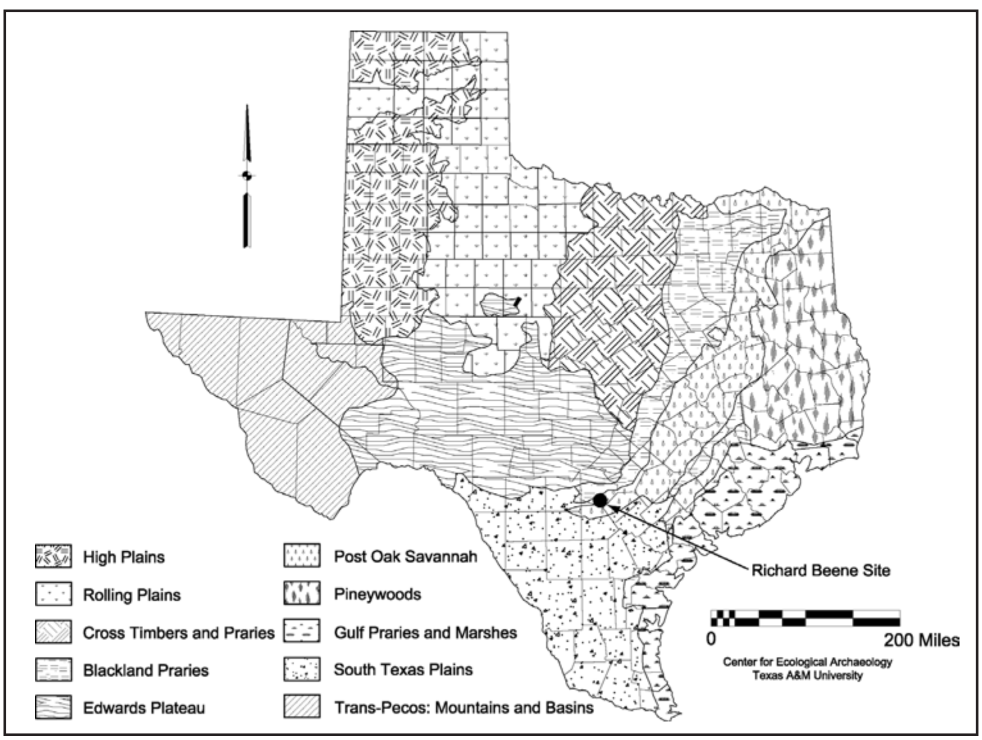


Figure 2.5. The Richard Beene site in relation to Texas' ecological zones (modified from Fry et al. 1984).

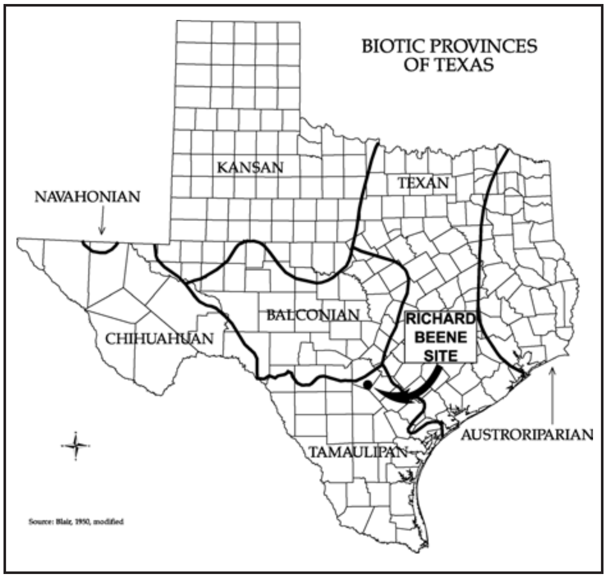


Figure 2.6. The Richard Beene site in relation to Texas' biotic province (redrawn from Blair 1950).

and short grass on the Blackland Prairie; (3) oak-hickory forests, and bunch and short grass in the Post Oak Savannah; and (4) mesquite-chaparral, and bunch and short grass on the South Texas Plain (Arbingast et al. 1976; McMahan et al. 1984).

The distribution of biotic provinces in the site's mesoenvironmental zone, an area within 30 km or so of the site that could be exploited regularly by the site's inhabitants, also exemplifies the ecotonal setting. The boundaries of three biotic provinces intersect in or very near Bexar County (Figure 2.6) (Blair 1950). The Richard Beene site lies at or near the northernmost limits of the Tamaulipan Biotic Province, a region that extends far to the south and coincides roughly with Texas' Rio Grande Plain soil zone (Arbingast et al. 1976:12). This province has a semiarid, megathermal climate that enables plant growth throughout the year and supports a wide range of vertebrate fauna including Neotropical, grassland, and basin desert species (Blair 1950:103).

The Balconian Biotic Province, to the west and northwest of the site, falls largely within the Edwards Plateau physiographic region (Blair 1950:112-114). It has a dry, subhumid, mesothermal climate that supports savannah vegetation. A variety of animals characteristic of desert basin habitats, as well as hardwood and pine forests, occupy this province, as do some grassland and Neotropical species. To the northeast of the site is the Texan Biotic Province that encompasses the Blackland Prairie physiographic region and others to the east. The moist subhumid climate supports both grasslands and hardwood forests, and occasional stands of pines that in turn support a variety of vertebrate grassland and forest species (Blair 1950: 100-101).

Medina River Valley and Vicinity during the Spanish Colonial Era

The earliest accounts of the environment in the immediate vicinity of the Richard Beene site comes from the 1691–1692 Spanish *entrada* led by then Governor Domingo de Teran de los Rios. The expedition, which set out in search of survivors of the ill-fated French settlement at Matagorda Bay as well as places to establish Catholic missions in east Texas, traveled from near Monclova in northeast Mexico, across the Rio Grande near Guerrero, Nuevo Leon, to the vicinity of San Antonio, and on to Caddo country in east Texas (Foster 1995:51-75). On June 12, 1691, the expedition approached the Medina River from the west and crossed it about 15 km upstream from the Richard Beene site near the town of Macdona. Governor Teran described the area, including the Medina and San Antonio river valleys as follows:

> On the 12th, continuing our march toward the east, we discovered a new road [an Indian trail] and traveled over a level region like that along the Rio de la Plata with its herds, until our royal standard halted on the banks of another *arroyo*, which, at various points, on previous trips [de Leon's expeditions, 1689–1690] had been called the Medina. There were a great number of buffaloes here. . . .
>
> On the 13th. Our royal standard and camp moved in the aforesaid easterly direction. We marched five leagues [13 mi.] over a fine coun-

> try with broad plains—the most beautiful in New Spain. We camped on the banks of an *arroyo*, adorned by a great number of trees, cedars, willows, cypresses, osiers, oaks, and many other kinds. I called it San Antonio de Padua [San Antonio River], because we had reached it on his day. Here we found certain *rancherias* in which the Peyeye [Payaya] nation lives. We observed their actions, and I discovered they were docile and affectionate, were naturally friendly, and were decidedly agreeable toward us. I saw the possibility of using them to form *reducciones*—the first one on the Rio Grande, at the presidio, and another at this point. Different nations in between could be thereby influenced. We did not travel on the 14th because it was Corpus Christi day.
>
> On the 15th, we marched towards the east five leagues [13 mi.], across a country much like the preceding, with buffaloes and a great many oak trees. It is suited for all kinds of agriculture. We set up our camp that night upon the banks of a certain *arroyo* [Salado Creek], where there is a considerable quantity of water. This I named the San Ignacio de Loyola. This night we had a terrible storm [Hatcher 1932:14; information in brackets by present author based on Foster 1995].

The expedition's religious leader, Father Damian Mansanet (also Massanett), also kept a daily journal and he made the following observations about the environmental setting in the vicinity of the Richard Beene site:

> Tuesday, 12 [June]. We left Arroyo de San Bernabe and proceeded northeast through a mesquite and oak woods. A distance of about a quarter of a league we emerged from the woods at the foot of a high hill. We immediately entered a level region without trees, the whole forming a beautiful prairie, where there were great numbers of buffaloes and deer. From this prairie could be seen a tall round hill in a northeasterly direction. We turned east and in line with the said hill we could see another one farther to the east. We passed this which is covered with tall mesquite woods. Half a league [1.3 mi.] beyond this is the *arroyo* [Medina River]. It is crossed just below its junction with a dry one. We went this day five leagues [13 mi.] and camped on the far side. We [i.e., the missionaries, as opposed to the governor] gave it the name of San Basilio. In the Indian language it is called Panapay.
>
> Wednesday, 13 [June]. We left San Basilio [Medina River] after having said mass. We continued northeast, a quarter east, until we passed through some low hills covered with oaks and mesquite. The country is very beautiful. We entered a stretch which was easy for travel and advanced on our easterly course. Before reaching the river there are other small hills with oaks. The River is bordered with many trees, cottonwoods, oaks, cedars, mulberries, and many vines. There are a great many fish and upon the highlands a great number of wild chickens [prairie chickens].
>
> On this day, there were so many buffaloes that the horses stampeded and forty head ran away. These were collected with the rest of the horses by hard work on the part of the soldiers. We found at this place the *rancheria* of the Indians of the Payaya nation. This is a very large

> nation and the country where they live is very fine. I called this place San Antonio de Padu [San Antonio River valley near downtown San Antonio], because it was his day. In the language of the Indians it is called Yanaguana . . . [Hatcher 1932:54-55; information in brackets by present author based on Foster 1995].

Members of later Spanish expeditions that passed near the Richard Beene site also recorded their observations about the area's terrain, flora, fauna, and weather conditions, as well as about the native people who lived there (see Chapter 4). Fray Isidro de Espinosa, an ecclesiastical member of a small reconnaissance expedition in April 1709 from the lower Rio Grande to the Colorado River, noted that the Medina River, probably within a couple of miles of the Richard Beene site (Foster 1995: 197, Map 10), was bordered by pecan trees, which he called walnuts, and noted that they were "the daily food of the nations who live along the banks" (Tous 1930a:4). On the return trip he crossed the Medina at or near the same place and noted that several Sijame Indians near Leon Creek were burning the grassland as they traveled toward the Medina River (Tous 1930a:13).

Fray Espinosa also accompanied an expedition in 1716 headed by Captain Don Domingo Ramón from northeast Mexico to the east Texas missions. He described the landscape between the Medina River and Leon Creek and along the San Antonio River, as he contemplated establishing missions:

> [May 13, 1716] . . . we set out through a forest of oaks and scattered mesquite to find the Medina River, going a league north-northeast. Then over rough ground with many groves of holm-oaks, gray oaks, and walnut trees. . . . Having crossed some level ground and groves of box-trees, we went right through a very spacious forest in the direction of east-northeast. Then making some deviations to the northeast we reached the Medina River . . . . By the banks of this river were many poplar trees, blackberry bushes and grapevines on which we saw some green grapes.
>
> [May 14, 1716] We set out from the aforesaid river in the direction of east-northeast through hills and dales all covered with very green gramagrass. Some flint stones were found all along the way to the Arroyo de Leon, which is three leagues [7.8 mi.] distant from the river. In this stream there are pools of water. From thence by northeast we entered the plain at the San Antonio River. At the end of the plain is a small forest of sparse mesquite, and some oaks. To it suceeds the water of the San Pedro; sufficient for a mission. Along the banks of the latter, which has a thicket of all kinds of wood, and by an open path we arrived at the River San Antonio. This river is very desirable (for settlement) and favorable for its pleasantness, location, abundance of water, and multitude of fish. It is surrounded by very tall nopals [prickly-pear cactus], poplars, elms, grapevines, black mulberry trees, laurels, strawberry vines, and genuine fan-palms. There is a great deal of flax and wild hemp, and abundance of maiden-hair fern and many medicinal herbs [Tous 1930b:8-11].

Additional information about the ecological setting in the early eighteenth century comes from Padre Juan Antonio de la Peña, a member of the ecclesiastical delegation with the 1721–1722 expedition under the command of Governor (of Nuevas Filipinas [Tejas] y Coahuila) Marques de San Miguel de Aguayo. The expedition, on its way from Guerrero on the Rio Grande to northeast Louisiana, approached the Medina River very near the Richard Beene site on April 3, 1721, after getting a late start due to a thunderstorm that scattered the horse herd.

Among Padre de la Peña's comments are the following:

> During the remainder of the day we passed through flat country and found a great many deer. We saw around us, almost at the same time, as many as three or four hundred of these animals, and the mounted soldiers that covered the line of march, riding at full speed, captured two by driving them toward the droves of horses. They could have caught several more had they not been afraid of throwing into disorder the line of march. Here also we found a great number of turkeys and quail.
>
> [April 4, 1721] We set out . . . and entered the province of the Texas Indians, or Nuevas Filipinas, which is separated from the Province of Coahuila, Nueva Estremadura, by the Medina River. We traveled east-northeast about three leagues [7.8 mi.] until we came to Leon Creek, in which water can be found the greater part of the year, and in several *esteros* all year round. From here we advanced northeast along a beautiful plain until we came to San Antonio. Most of the route from the Medina River to Leon Creek we crossed low hills and fertile valleys and found a great quantity of flint stone. This kind of stone can be found at several places between the Rio Grande and San Antonio [Forrestal 1935:14-15; information in brackets by present author based on Foster 1995].

Still more information about flora, fauna, and weather conditions along the San Antonio River downstream from the Richard Beene site comes from the journal of Fray Graspar Jose de Solis. He led an inspection tour of Zacatecan missions, including those in San Antonio, from February through August 1768 (Foster 1995:197-214):

> [March 20, 1768] The banks of the river [San Antonio River near Mission San Jose] are shady and pleasant and are covered with a great number of trees of various kinds: sabines, poplars, walnuts, etc. Along the road to the *persidio* [San Antonio] there are a great many mesquites, *huisaches* and oaks. The river is well supplied with eels, *barges, pullones, piltontes, mojarras,* sardines, other fishes. In the woods between La Bahia [along the San Antonio River near present-day Goliad, Texas] and San Antonio there are a few lions and a great number of cattle, horses, deer, wolves, coyotes, rabbits, wildcats, and boars. Along the river I found herons, ducks, geese, turkeys, quail, partridges, sparrow-hawks, eagles, owls, and other birds with which I am not familiar [Forrestal 1931:18; information in brackets by present author based on Foster 1995].
>
> [April 7, 1768] I left the San Joseph [Jose] mission. A strong, cold wind was blowing from the north, and it was raining, snowing and freezing. I passed the San Juan Capistrano mission and crossed the Salado, a river which, though not very deep, has very beautiful banks, covered with large, shady trees [Forrestal 1931:21-22; information in brackets by present author based on Foster 1995].

These and other historical accounts attest to the savannah and grassland mosaic in the uplands surrounding the Richard Beene site, and to well-forested riparian zone along the Medina River. They also attest to a seemingly abundant supply of game animals, fur-bearers, fowl, fish, nut and fruit trees, and prickly-pear cactus, as well as tool-stone raw material, water, and fuel (Foster 1995; Neck 1991; Robbins 1991a, 1991b).

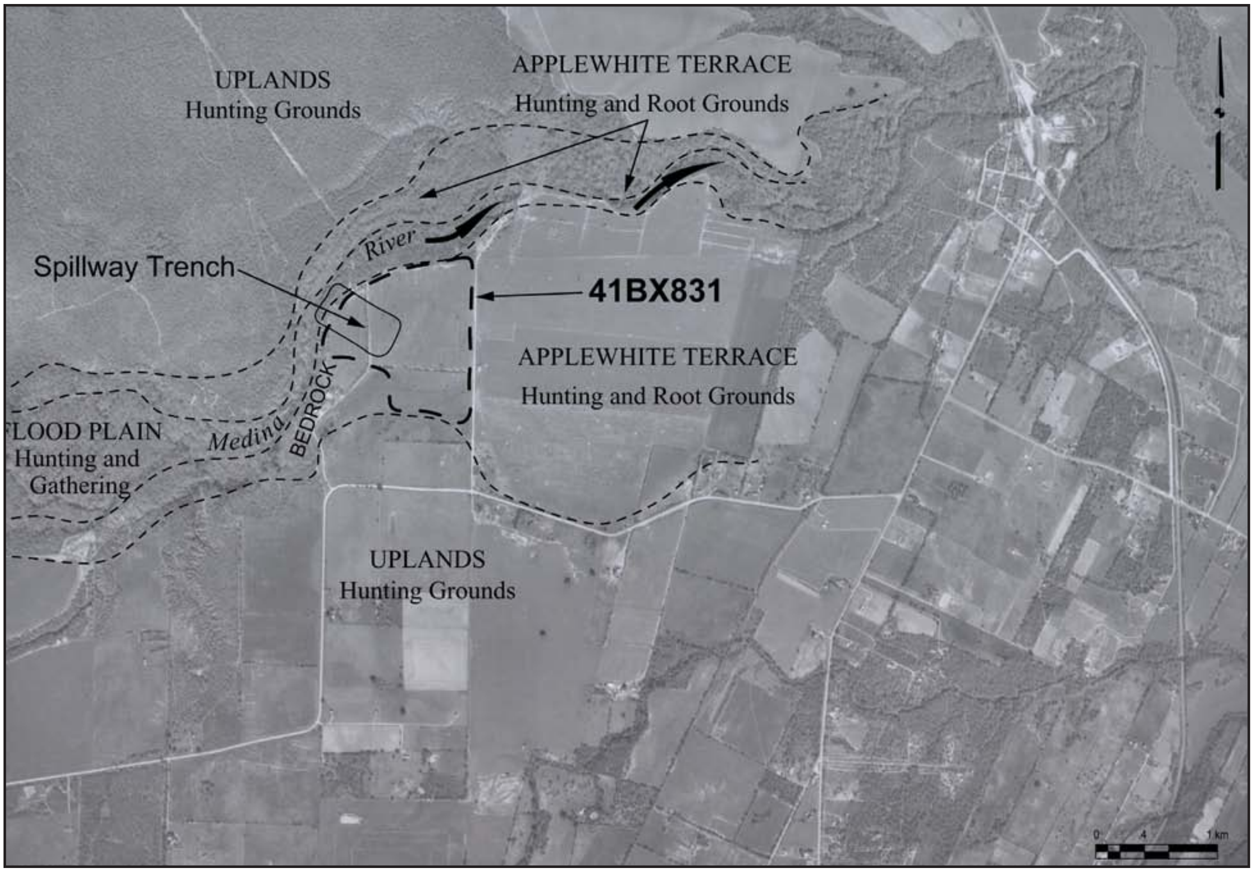


Figure 2.7. Aerial photograph (1985) showing the location of the Richard Beene site in relation to source areas for the subsistence-related archaeological remains.

Natural Resource Potential in the Site Area

The site's setting is decidedly riverine, with bald-knee cypress, sycamore, pecan, and cottonwood growing along the river and on the adjacent floodplain, which lies 10–15 m below the terrace surface and the site's uppermost archaeological deposits. Gravel bars along the river contain an abundance of chert cobbles that undoubtedly provided raw material—tool stone—for the manufacture of chipped-stone tools, in addition to the upland sources noted by Spanish explorers.

Immediately upstream from the site, the modern floodplain is narrow and bounded by outcrops of Wilcox-formation sandstone (Chapter 3), some of which extend upward from the river's edge 15 m to the terrace surface (Figure 2.7). These and other nearby outcrops probably served as source-areas for sandstone used by the site's inhabitants for heating elements—cook stone—in earth ovens, hearths, and perhaps for stone-boiling. Just downstream from the site, the modern floodplain widens, as does the major terrace above it (Figure 2.7). The terrace fill contains the site's archaeological remains and is comprised of fine-grained, over-bank flood deposits that formed the floodplain when the site was occupied. This expansive floodplain would have been rich in a wide variety of wild root foods (i.e., geophytes). Within 2 km to the south, Post Oak Savannah vegetation and sandy soils dominate the upland landscape. Across the river and within 2 km distance is the Blackland Prairie where bison grazed from time to time and a variety of plant foods were available. In short, the people who occupied the Richard Beene site had ready access to a wide variety of resources.

Spanish explorers and travelers of the late seventeenth and eighteenth centuries pointed, in particular, to an abundance of big game animals—bison, deer, and pronghorn—in the site area. Cabeza de Vaca, one of four men who survived a shipwreck and journey on foot across south Texas and northern Mexico in the early sixteenth century, paints a rather different picture (Covey 1993; Favata and Fernandez 1993; Krieger 2002). Some of his observations about subsistence patterns in south-central Texas are directly applicable to the Richard Beene site area. Alex Krieger (2002:41), who studied the survivor's route in unusual detail, places one of the important prickly-pear cactus (i.e., *tuna*) grounds they visited on several occasions a scant 20–40 km south of the Richard Beene site, just over the low divide that separated the Medina and Nueces River basins. Writing of this general area as well as areas nearer the coast, Cabeza de Vaca noted that deer were present, although not especially numerous, and he seldom encountered bison at all. In marked contrast, bison were very abundant from the late 1600s through the late 1700s (Thoms 2004a). What he emphasized about native subsistence practices was the importance of wild plant foods, notably prickly-pear leaves and *tuna* and various kinds of roots (Krieger 2002:182-218).

Such different observations may well be explained by the fact that human populations were probably quite high when Cabeza de Vaca traversed coastal and south Texas. The regions carrying capacity may have been reached insofar as plant foods provided much of the diet and game animals provided a lower percentage of caloric intake. Thereafter, with massive depopulation from Old World diseases (e.g., small pox, measles, and influenza) introduced by the Spanish, the game animal populations would have been effectively higher relative to human populations. In this scenario, the likely result would have been a marked increase in meat consumption and a corresponding decrease in plant food consumption.

At the Richard Beene site, there is considerable indirect evidence for the extensive use of plant foods, primarily an abundance of fire-cracked sandstone that functioned as cooking stones in earth ovens (Chapter 13–15). Cook stones, in general, were widely, perhaps primarily, used to bake root foods in earth ovens throughout east- and south-central Texas (Thoms 1994a,1994b, 2003, 2004b). As discussed in Chapter 8, young prickly-pear leaves as well as prickly-pear *tunas* were cooked in earth ovens and are especially common in the site area.

There are numerous wild root foods that occur in abundance in the fine-grained, floodplain, and terrace soils in the immediate vicinity of the site today and probably in the distant past as well (Table 2.1). Among those are onions (*Allium*, spp.) and false-garlic (*Nothoscordum bivalve)*, both of which Thoms observed growing in widespread patches in densities of more than 100 plants per square meter near the Richard Beene site. Other lily family plants with potentially edible bulbs that grow in the area today and may well have been utilized include: rain lilies (*Cooperia drummondii*), spider lilies (*Hymenocallis liriosme*), and copper lilies (*Habranthus texanus*), and possibly eastern camas (*Camassia scilloides*). Other root-food plants common to the area are ground nut (*Apios americana)*, globeberry (*Ibervillea*, spp.), wild potatoes (*Ipomoea pandurata*), bull nettle (*Cnidoscolus stimulosus*), and buffalo gourd (*Cucurbita foetidissima*). There are also various hydrophytes—plants with underwater roots—in the site area known to have been used by native peoples. These include American lotus (*Nelumbo lutea*), arrowhead (*Sagittaria latifolia* and *S. graminea)* water plantain (*Alisma plantago-aquatica*), and perhaps cane plants, including *Arundinaria gigantica* and *Phragmites*, spp.

To conclude, it seems clear that through the millennia, the inhabitants of the Richard Beene site would have had ready access to ethnographically important food resources, including white-tailed deer, pronghorn, bison, bear, turkey, fish, shellfish, nuts, berries, prickly pear, mesquite beans, and wild root foods (Campbell 1975). Hester (1989a:123) recognized the relatively high productivity potential of similar riverine settings when he referred to riparian forests in the northern part of south Texas as "high density resource zones."

Table 2.1. Ethnographically documented plant foods available in the Post Oak Savannah and adjacent ecological areas (modified from Thoms 1994b:21–22, Table 4 and Thoms and Mason 2001:12, Table 2).

ROOT FOODS	
Arrow-root (*Sagittaria* spp.)	Roots eaten raw, boiled, or baked (in earth oven)
Blazing star (*Liatris* spp.)	Bulbs used for food[3] [probably baked]
Bracken fern (*Pteridium aquilinum* var.)	Roots baked
Cattail (*Typha latifolia* L.)	Roots dried, ground into flour; eaten raw, baked
False garlic, crow poison (*Nothoscordum bivalve*)	Bulbs eaten raw (this is one of the only references to this plant as edible); [probably boiled or baked as are most lily bulbs[2]]
Greenbriar, cat-briar (*Smilax* spp.)	Roots boiled
Ground nut, American potato bean (*Apios americana*)	Tubers eaten raw or boiled: dried and stored for winter use
Jerusalem artichoke (*Helianthus tuberosus*)	Tubers are edible[5,9] [probably baked]
Milkweed, various (*Asclepias* spp.)	Tubers boiled and eaten
Prairie turnip, scurvy pea (*Psoralea* spp.) [5]	Tubers roasted and eaten[6,7] [unclear if local species, *P. linearifolium* and *P. tenuiflorum*, are edible: *P. tenuiflorum* reported toxic to horses, cattle; most information on edible *P. esculenta*]
Spring beauty (*Claytonia virginica*)	Bulbs boiled or baked
Water-chinquapin (*Nelumbo lutea*)	Tubers eaten fresh/dried; seeds eaten raw/baked
Eastern camas (*Camassia scilloides*)	Bulbs eaten, baked in earth oven[2,9]
Wild onion (*Allium* spp.)	Bulbs eaten raw or boiled [also baked[1,2,4]]
Wild potato (*Ipomoea pandurata*)	Tubers dried and ground into flour
Wine-cup (*Callirhoe digitata*)	Roots eaten[8] [probably baked]
SEEDS	
Amberique bean (*Strophostyles helvola*)	Seeds eaten raw or boiled
Partridge pea (*Cassia fasciculata*)	Seeds boiled and eaten
Sunflower, common (*Helianthus annuus*)	Seeds eaten after boiling or roasting[4]
Yucca, beargrass (*Yucca louisianensis*)	Seed pods eaten, boiled or roasted [Mahler (1998) notes genus but not species]; stalks peeled and eaten [stalks of some yucca species are roasted[9]]
NUTS AND FRUITS	
American hop-hornbeam (*Ostrya virginiana*)	Nuts eaten raw or baked
Black hickory (*Carya texana*)	Nuts from this and other hickories eaten raw, boiled or leached; made into meal for eating
Black walnut (*Juglans nigra*)	Nuts eaten raw; boiled for oil
Elm, various (*Ulmus* spp.)	Inner bark made into cakes and eaten [this implies pulverizing and cooking]
Mesquite (*Prosopis glandulosa*)	Seed pods eaten fresh or boiled
Oaks, various red and white (*Quercus* spp.)	Acorns varyingly eaten raw, boiled, leached; processed into meal
Pecan (*Carya illinoinensis*)	Nuts eaten raw; mashed/dried, made into porridge[4]
Prickly pear (*Opuntia* spp.)	Tunas eaten raw or boiled; pads [nopalito] baked
White ash (*Fraxinus americana*)	Cambium [inner bark] cooked and eaten

[1] Driver and Massey (1957)
[2] Thoms (1989)
[3] Wyckoff (1984:12)
[4] McCormick et al. (1975:10-20)
[5] Mahler (1988)
[6] Reid (1977)
[7] Prikryl (1990:13)
[8] Havard (1895:111)
[9] Elias and Dykeman (1990)

3

GEOMORPHIC INVESTIGATIONS

Rolfe D. Mandel, John S. Jacob, and Lee C. Nordt

This chapter presents the results of geoarchaeological investigations at the Richard Beene site. These investigations focus on stratigraphy, geochronology, depositional environments, pedology, and paleo-environments. Pedological aspects of this study are especially important because the sequence of buried soils provides a basis for understanding cycles of alluviation and landscape stability at the site. Establishment of a geochronological record is also a crucial component of the study. Intensive radiocarbon dating at the site not only forms the basis for the cultural chronology, but leads to development of a precise alluvial chronology for the lower Medina River. Comparison of this chronology with other well-dated alluvial records may be used to infer intrinsic and extrinsic controls on fluvial systems in the region. Hence, the ramifications of this study go far beyond the boundaries of the Richard Beene site.

Bedrock Geology and Geomorphic Setting

Bedrock at the Richard Beene site consists of Eocene sedimentary rocks dominated by sandstone of the Wilcox Group (Barnes 1983; Sellards et al. 1967). These rocks have been weathered and eroded into tablelands and gently rolling hills. Extensive outcrops of sandstone are source areas for dunes and eolian sand sheets on the uplands immediately south of the Richard Beene site.

Cultural deposits at the Richard Beene site are associated with the Applewhite terrace, which is the second terrace (T-2) above the modern floodplain of the Medina River (Mandel et al. 2005) (Figures 3.1 and 3.2). The surface of the Applewhite terrace is 12 m above the lowest surface of the modern floodplain. The Applewhite terrace dominates the valley floor and can be traced for considerable distances along the Medina River. It is a paired terrace with a broad, flat tread and few meander scars. A steep scarp separates the Applewhite terrace from the lowest terrace (Miller terrace) (Figure 3.1). A natural levee at the top of the scarp has a gently sloping surface that gradually merges with the tread of the Applewhite terrace. Landowners reported that floodwaters have nearly overtopped the Applewhite terrace. There is no record, however, of flooding on this terrace during the Historic period.

Methods

Most of the geoarchaeological investigation at the Richard Beene site was conducted during the summer and fall of 1991 while archaeological excavations were underway. Profile "windows" in the spillway trench were cleaned with hand shovels and a backhoe was used to expose profiles below the floor of the spillway trench (Figure 3.2). A detailed description of the overall profile (Table 3.1) was prepared in the field using standard procedures and terminology outlined by Soil Survey Staff (1984) and Birkeland (1999). Each soil horizon was described in terms of its texture, Munsell matrix color and mottling, structure, consistency, and boundaries.

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

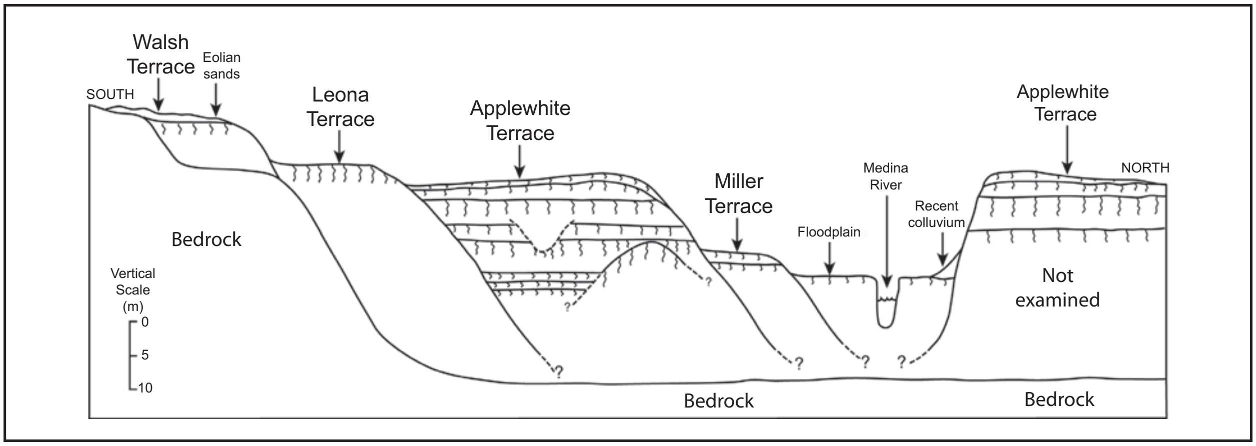


Figure 3.1. Schematic cross-section of the Medina River valley showing the terraces, underlying deposits, and soils.

When present, root channels, clay films, secondary carbonate forms, and ferromanganese concretions were described. Reaction of soils to 10 percent hydrochloric acid was noted, and stages of carbonate morphology were defined according to the classification scheme of Birkeland (1999:Table A-4). In addition, sedimentary features preserved in C horizons of some soils were described to help reconstruct depositional environments.

Soil and sediment samples were collected from the profiles for laboratory analyses. Soils were sampled by horizon using standard U.S. Department of Agriculture procedures (Soil Survey Staff 1984), and unweathered portions of alluvial units (C horizons) were systematically sampled at intervals that were dependent on their thickness (after Krumbein and Graybill 1965). The samples were dried at 40°C in a forced-draft oven and ground to pass through a 2 mm sieve. They were analyzed for particle-size distribution by the pipette method (Kilmer and Alexander 1949) and dry-sieving of sand. The Chittick gasometric method (Dreimanis 1962) was used to determine calcium carbonate equivalent ($CaCO_3$). Total carbon was determined by dry combustion (Nelson and Sommers 1982), and organic carbon was computed as the difference between inorganic C ($CaCO_3$) and total C. For isotopic analysis, C from $CaCO_3$ was collected as CO_2 by dissolving the carbonates in 100 percent H_3PO_3. Soil organic matter was converted to CO_2 by dry combustion with CuO in evacuated sealed quartz tubes, posterior to removal of carbonates in 1N HCL. The CO_2 was purified as per Boutton (1991a). Isotopic composition was determined on a UG-903 (UG Isogas, Middlewich, UK) dual inlet, triple isotope ratio spectrometer.

The micromorphology of soils was assessed by thin-section analysis. Thin sections of undisturbed soil were made from epoxy-resin–impregnated blocks and viewed with a petrographic microscope. Micromorphological terminology follows that of Bullock et al. (1985) and Courty et al. (1989).

Stratigraphic Nomenclature

A bipartite stratigraphic nomenclature was used in this study. Stratigraphic designations are informal and include stratigraphic units and soils. The upper boundary of a stratigraphic unit may be a buried soil that is traceable throughout the project area or a surface soil. Arabic numerals designate the stratigraphic units, beginning with 1, the lowest and oldest unit in the stratigraphic sequence. Prefixes assigned to the units indicate the landform sediment assemblage. For example, with Unit A1, it is the lowest unit in the stratigraphic sequence beneath the Applewhite terrace (“A” = Applewhite).

Soils were included in the stratigraphic framework of every section that was described in the project area. Soils are important to the subdivision of Quaternary sediments, whether the soils are at the present land surface or buried (Birkeland 1999).

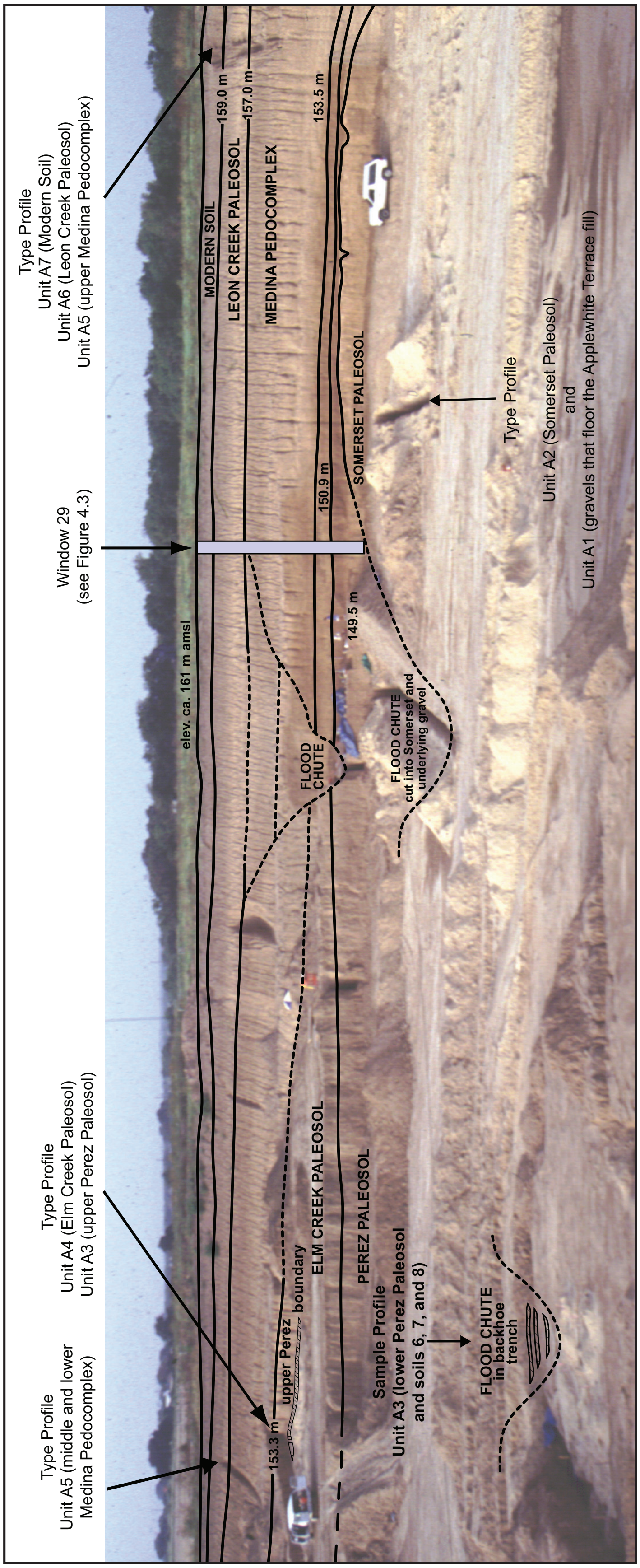


Figure 3.2. Wide-angle photograph of the central section of the south wall of the spillway trench showing the approximate boundaries of paleosols and the locations of type profiles for stratigraphic units.

Table 3.1. Description of the profile exposed in the spillway trench.

Horizon	Depth (cm)	Color		Structure	Texture	Consistence	Boundary	Special Features
		Moist	Dry					
Modern surface soil/Unit A7								
Ap	0-14	10YR3/2	10YR3/3	Compacted	CL	--	c,s	Drastically disturbed by heavy earth-moving equipment.
Bk1	14-37	10YR4/3	10YR5/3	Compacted	CL	--	g,s	Common pedotubules with very dark grayish brown (10YR3/2) fillings; fine fluffy calcium carbonate filaments cover 1-5% of each ped surface.
Bk2	37-51	10YR4/3	10YR5/3	1mP~2f+m sbk	CL	h,fr	g,s	Many worm casts; few land snails; fine somewhat coalesced fluffy calcium carbonate filaments cover 10-20% of each ped surface.
Modern surface soil welded to Leon Creek Paleosol/Unit A6								
Bk3(Ab1)	51-87	10YR4/3	10YR4/3	1mP~2f+m sbk	SiCL	h,fr	g,s	Carbonate morphology similar to overlying horizon but more coalesced fluffy threads.
Bk4	87-154	10YR4/4	10YR5/4	1mP~2f+m sbk	SiCL	h,fr	c,s	Carbonate morphology similar to overlying horizon but some encrusted and stained carbonates.
BCk	154-206	10YR5/4	10YR6/4	1 m sbk	L	h,fr	g,s	Common worm casts; few (1-2%) calcium carbonate filaments.
CB	206-239	10YR6/4	10YR6/3	1c+ m sbk	L	h,fr	c,s	Few pedotubules; very few (<1%) filaments of calcium carbonate.
Medina Pedocomplex/Unit A5								
Akb2	239-289	10YR5/4	10YR5/4	1cP~2m sbk	CL	h,fr	g,s	Lighter sandier zone (10YR 6/4, dry) from 259-264 cm; calcium carbonate filaments cover 5% of each ped surface; very few fluffy carbonates (all coalesced).
ABkb2	289-317	10YR5/4	10YR5/4	1mP~2m sbk	SiC	h,fr	g,s	Calcium carbonate filaments cover 2-10% of each ped surface; no fluffy carbonates; few clay flows in pores.
Bk1b2	317-404	10YR4/4	10YR5/4	2mP~2f+m sbk	SiCL	h,fr	g,s	Calcium carbonate filaments cover 5-10% of each ped surface; very few fluffy carbonates; shiny pressure faces on some peds.
Bk2b2	404-560	10YR5/4	10YR6/4	1mP~2m sbk	SiCL	h,fr	c,s	Calcium carbonate filaments cover 5-10% of each ped surface; very few fluffy carbonates.
Bk3b2	560-597	10YR5/4	10YR5/4	1mP~2m sbk	SiCL	h,fr	c,s	Calcium carbonate filaments cover 5-10% of each ped surface; very few fluffy carbonates; cultural material in upper 5 cm of the horizon.
Bk4b2	597-693	10YR5/4	10YR5/4	1mP~2m sbk	SiCL	h,fr	c,s	Common tubular carbonate forms that are about 2 cm in diameter, and common carbonate plugs that are 5 mm in diameter; many tubules filled with shell fragments, charcoal, and brown (10YR 5/3, dry) sediment.

continued

Horizon	Depth (cm)	Color Moist	Color Dry	Structure	Texture	Consistence	Boundary	Special Features
Medina Pedocomplex/Unit A5								
C2	693-720	10YR6/4	10YR6/4	M	SiCL	h,fr	a,w	Distinct fine (1-2 mm thick) horizontal bedding; common 10YR 5/4 and 10YR 4/4 worm casts.
Elm Creek Paleosol/Unit A4								
Bk1b3	720-768	10YR5/6	10YR5/6	1f+mP~1m+c abk	SiCL	h,fr	g,s	Few (2%) hard calcium carbonate filaments 1 mm thick; few land snail shells.
Bk2b3	768-820	10YR5/6	10YR5/6	1mP~1m+c abk	SiCL	h,fr	g,s	Few (0-1%) hard calcium carbonate filaments 1 mm thick; a bed of 7.5YR 5/6 silty clay loam with common (20%) carbonate lithoclasts at a depth of 815-819 cm.
CBb3	820-980	10YR5/6	10YR7/4	1m abk	CL	h,fr	g,s	Faint fine (1-2 mm thick) horizontal bedding; common 10YR 5/4 worm casts.
Cb3	980-1,020	10YR6/4	10YR7/4	M	SiCL	h,fr	a,w	Faint horizontal bedding; common distinct strong brown (7.5YR 5/8) rhyzomottles; few (2-3%) light gray (10YR7/2) reduction zones around pores; few (1%) carbonate-lined tubules that are 5-8 mm wide and 10-20 cm long.
Perez Paleosol/Unit A3								
Bkb4	1,020-1,068	7.5YR4/4	7.5YR6/4	1cP~2m+c abk	SiCL	vh,fi	g,s	Few round siliceous pebbles; few fine and medium pores; Common medium distinct 7.5YR 6/4 mottles; 2-5% fine (1-2 mm) calcium carbonate filaments concentrated on ped faces; 5% coarse carbonate-lined pedotubules that are 5-8 mm wide and 10-20 cm long; thin faint aureole of oxidized iron around the edges of pedotubules, but interiors of pedotubules are light gray (10YR 7/2) iron depletion zones.
Bkssb4	1,068-1,136	7.5YR5/4	7.5YR6/4	2m+f abk	SiCL	vh,fi	g,s	Few round siliceous pebbles; few fine and medium pores; few (3%) brown (7.5YR 4/3) mottles; 2-5% fine (1-2 mm) calcium carbonate filaments concentrated on ped faces; 5% coarse carbonate-lined pedotubules that are 5-8 mm wide and 10-20 cm long; thin faint aureole of oxidized iron around the edges of pedotubules, but interiors of pedotubules are light gray (10YR 7/2) iron depletion zones; most faces are bounded by distinct slickensides that are inclined 20-30 degrees from the horizontal; moderate medium wedge-shaped aggregates part to angular blocky structure; some coarse and medium prismatic structure.

continued

Table 3.1. Continued.

Horizon	Depth (cm)	Color		Structure	Texture	Consistence	Boundary	Special Features
		Moist	Dry					
Perez Paleosol/Unit A3								
B'k b4	1,136-1,169	7.5YR5/4	7.5YR6/4	2c abk	SiCL	vh,fi	g,s	Few round siliceous pebbles; common pores; few fine faint yellowish brown (7.5YR 5/6) mottles; 5% fine (1-2 mm) calcium carbonate filaments concentrated on ped faces; 5% coarse carbonate-lined pedotubules that are 5-8 mm wide and 10-20 cm long; thin faint aureole of oxidized iron around the edges of pedotubules, but interiors of pedotubules are light gray (10YR 7/2) iron depletion zones.
BCkb4	1,169-1,227	7.5YR5/4	7.5YR6/4	1m+c abk	CL	vh,fi	g,s	Common round siliceous pebbles and few rounded carbonate lithoclasts; common fine and medium pores; few fine faint yellowish brown (7.5YR 5/6) mottles; 5-10% fine (1-2 mm) calcium carbonate filaments concentrated on ped faces; 5-10% coarse carbonate-lined pedotubules that are 5-8 mm wide and 10-20 cm long; thin faint aureole of oxidized iron around the edges of pedotubules, but interiors of pedotubules are light gray (10YR 7/2) iron depletion zones.
CBkb4	1,227-1,257	7.5YR5/4	7.5YR5/4	1f+m abk	CL	vh,fi	g,s	Few round siliceous pebbles; common fine and medium pores; few fine faint yellowish brown (7.5YR 5/6) mottles; 1% coarse carbonate-lined pedotubules that are 5-8 mm wide and 10-20 cm long; thin faint aureole of oxidized iron around the edges of pedotubules, but interiors of pedotubules are light gray (10YR 7/2) iron depletion zones.
Ckb4	1,257-1,357	10YR6/6 (50%)	10YR7/4 (50%)	M	FSL	h,fr	a,s	Few tubular depletion zones as above; 1% fine and very fine calcium carbonate filaments; 2 cm thick lens of fine gravel 63 cm below top of horizon.
Soil 6/Unit A3								
Bk1b5	1,357-1,375	10YR5/6	10YR6/6	1m abk	SiCL	h,fr	g,s	Few tubular depletion zones as above; 1% fine calcium carbonate filaments; few fine faint yellowish brown (10YR 5/8) mottles; many fine and medium pores.
Bk2b5	1,357-1,459	10YR5/6	10YR5/6	1m sbk	SiCL	h,fr	a,s	Few tubular depletion zones as above; 1-2% fine calcium carbonate filaments; few fine faint yellowish brown (10YR 5/8) mottles; common fine and medium pores.
Soil 7/Unit A3								
Bkb6	1,459-1,505	10YR5/6		1m sbk	SiCL	h,fi	a,s	Few distinct strong brown (7.5YR 4/6) mottles; common pale brown (10YR 6/3) and brown (10YR 5/3) pedotubules;

continued

Table 3.1. Continued.

Horizon	Depth (cm)	Color		Structure	Texture	Consist-ence	Boundary	Special Features
		Moist	Dry					
Soil 8/Unit A3								
A1b7	1,505-1,540	10YR44		1f sbk	SiC	h,fi	g,s	Few fine faint yellowish brown (10YR 5/8) mottles; 1-2% depletion pedotubules as above; <1% calcium carbonate filaments; few brown (10YR 5/3) clay balls.
A2b7	1,540-1,575	10YR5/6		1f sbk	SiC	h,fi	g,s	Few fine faint yellowish brown (10YR 5/8) mottles; 1-2% depletion pedotubules as above; <1% calcium carbonate filaments; few pink (7.5YR 7/4) sand bodies; few brown (10YR 5/3) clay balls.
C7	1,575-1,600	10YR7/4 (75%)	10YR 5/8 (25%)	M	SiCL	h,fi	a,i	Few fine depletion pedotubules as above; few carbonates in pedotubules.
Somerset Paleosol/Unit A2								
Bkmb8	1,600-1,638	10YR8/2		Laminar	L	vh	c,s	Eroded petrocalcic; dissolution cavities filled with dark sediment from above.

Abbreviations: Structure 1=weak, 2=moderate, 3=strong, f=fine, m=medium, c=coarse, P=prismatic, sbk=subangular blocky, abk=angular blocky, GR=granular, M=massive; Texture: S=sand, Si=silt, C=clay, L=Loam, V=very, F=fine, Co=coarse, G=gravelly; Consistence: fi=firm, fr=friable, h=hard, so=soft, v=very, sl=slightly; Boundaries: c=clear, g=gradual, a=abrupt, s=smooth, w=wavy, I=irregular

Symbols: (+) and: (~) parting to

Buried soils are numbered consecutively from the top of a section downward, with the number following the b (for example, Bkb1). In addition to being numbered, five buried soils that have a consistent stratigraphic position, and are laterally traceable in the field, were assigned names.

Identification of Buried Soils

Identification of buried soils (paleosols) in late-Quaternary valley fill was essential for identifying intervals of floodplain stability at the Richard Beene site. However, recognition of buried paleosols was complicated by: (1) truncation by erosion prior to burial; (2) diagenesis of horizons after burial; and (3) deposition of organic- and/or clay-rich alluvium that was not subsequently modified by soil genesis. Therefore, several criteria were used in combination to differentiate buried soils from alluvium that has not been modified by pedogenesis. These criteria are as follows:

Structure. Aggregation of individual soil particles produces structure. Individual aggregates, or peds, are classified into several types on the basis of shape, i.e., granular, blocky, columnar, and prismatic. However, the structure criterion cannot be used alone to differentiate buried soils from depositional units. Flood drapes are often composed of high proportions of clay that are rich in 2:1-layer silicate minerals. The shrinking and swelling of these clays give the alluvial deposits an angular blocky structure, but internally these aggregates are massive and dense. Also, clay-rich flood drapes often display conchoidal angular fracturing.

Micromorphological Features. Surface soils display certain micromorphological features that are not present in pedogenically unmodified sediment. Buried paleosols must also display some of these features. Evidence of soil development includes the presence of soil plasma, soil skeletal grains, voids, and other pedological features, such as cutans and pedotubules. Detection of these features requires the use of a hand lens and/or thin sections and a petrographic microscope.

Evidence of Bioturbation. Modern soils generally have evidence of bioturbation. This evidence may consist of krotovinas, worm casts, or root channels. Hence, buried paleosols should show some evidence of bioturbation.

Lateral Extent. Soils are laterally extensive and are not restricted to particular landforms. They can cross lithological discontinuities and, in valleys, can be traced from abandoned channels to natural levees, and from terraces up onto valley side-slopes. Thus, a buried paleosol can be mapped in three dimensions over varying topography, whereas a depositional unit will be restricted to a particular landform.

The terms "soil" and "deposit" should not be confused (Mandel and Bettis 2001). The term "soil" is often used by engineers to represent any deposit of unconsolidated rock material (regolith). Archaeologists also commonly use this term when referring to the medium from which artifacts are recovered. In this study, "deposit" refers to a package of sediment, and "soil" refers to the zones within a deposit that have been altered by pedogenic processes.

Radiocarbon Assays

Standard radiocarbon assays were conducted by Beta Analytic, Inc., the University of Texas at Austin, and Southern Methodist University. Small charcoal samples were submitted to Beta Analytic, Inc., for radiocarbon dating analyses using the accelerator mass spectrometry (AMS) technique. The AMS measurements were made in triplicate at the ETH University in Zurich, Switzerland, and at the University of Arizona. Samples were pretreated by the radiocarbon laboratories for removal of roots and $CaCO_3$, and all but nine ages were d^{13}C corrected. More than 40 radiocarbon ages were determined on materials from the Richard Beene site. These materials were either charcoal or total decalcified soil carbon. Radiocarbon ages are reported as uncalibrated years before present (B.P.).

Radiocarbon ages determined on soils are mean residence times for all decalcified organic carbon in the soil samples (Campbell et al. 1967). Although mean residence time does not provide the absolute numerical age of a buried soil, it does give a minimum age for the period of soil development, and it provides a limiting age on the overlying material (Geyh et al. 1975; Scharpenseel 1975; Birkeland 1999:150; Haas et al. 1986).

Results of Investigations: Soils, Stratigraphy, and Geochronology

Unit A1

Unit A1 is at the base of the valley fill beneath the Applewhite terrace. This unit consists of stratified, coarse-grained channel deposits composed largely of siliceous sand and carbonate gravel. Boring logs indicate that Unit A1 extends across the valley floor and is 3–5 m thick (McClelland Engineers, Inc. 1985). The time at which this unit began to aggrade is unknown. However, based on a radiocarbon age determined on charcoal from the overlying unit (Unit A2), aggradation of Unit A1 ceased sometime before ca. 33,000 B.P.

Unit A2

Unit A2 rests conformably on Unit A1 and consists of very fine sand grading upward to silty clay loam (Table 3.2). Unit A2 is 3–4 m thick and has been greatly modified by soil development. The Somerset paleosol, formed at the top of Unit A2 (Figure 3.2), has a strongly expressed Bkm-Bk profile (Table 3.1, Figures 3.3 and 3.4). Calcium carbonate content in the Somerset paleosol ranges from 55.3 to 69.3 percent (Table 3.3). The petrocalcic (Bkm) horizon is 35–45 cm thick and has stage V carbonate morphology (Figure 3.5). In some places, the petrocalcic horizon was partially or completely stripped off by erosion before the Somerset paleosol was buried (Figure 3.6). Large fragments of the petrocalcic horizon that probably represent rip-up clasts were recorded in several of the fire-cracked rock features associated with the Perez paleosol.

Charcoal from a natural burn zone in stratified loamy fine sand at the bottom of Unit A2 yielded a ^{14}C age (AMS) of 32,850±530 B.P. (Table 3.4), and decalcified organic carbon from the lower 10 cm of the Somerset paleosol was dated at 20,080±560 B.P. (Table 3.5). Hence there was a transition from lateral accretion (represented by Unit A1) to vertical accretion (represented by Unit A2) at ca. 32,000 B.P. Overbank deposition slowed and soil development was underway on the late-Wisconsin floodplain by ca. 20,000 B.P., if not sooner.

Unit A3

Unit A3 consists of fine-grained overbank deposits that fill a paleochannel and, in most areas, overlap Unit A2. The texture of these overbank deposits ranges from fine sandy loam to silty clay (Table 3.2). Unit A3 is typically 5–6 m thick and completely fills the paleochannel that truncates Unit A2 (Figure 3.2). At the Richard Beene site, three weakly expressed soils (Soils 6, 7, and 8) are developed in fine-grained alluvium composing the lower half of Unit A3 (Figures 3.2, 3.3, and 3.7). These three soils have not been documented elsewhere in the project area, and it is likely that they are limited to the channel fill at the Richard Beene site. Soil 8 consists of an over-thickened A horizon above a C horizon (Table 3.1). Soils 6 and 7 are truncated Bk horizons with weak stage I carbonate morphology; the A horizons were stripped off by erosion before the soils were buried (Table 3.1). Soil 6 is formed in a deposit that slightly coarsens upward (Table 3.2). Soils 7 and 8, however, are developed at the top of upward-fining sequences (Table 3.2).

Several small pieces of wood charcoal from a dark, amorphous, organic- and bone-rich zone in the upper 10 cm of Soil 7 yielded a ^{14}C age (AMS) of 12,745±190 B.P. (Table 3.4). Radiocarbon ages of 13,640±210 and 13,480±360 B.P. were determined on soil carbon from the upper 10 cm of Soils 7 and 6, respectively (Table 3.5). In addition, soil carbon from the upper and lower 10 cm of the A horizon of Soil 8 yielded ^{14}C ages of 13,960±150 and 15,270±170 B.P., respectively (Table 3.5). Although the ages determined on soil carbon are in correct stratigraphic order, there is a ca. 1,000-year discrepancy between the ages determined on charcoal and soil carbon from the same zone in Soil 7. Also, carbon from Soil 6 yielded an age that is ca.

Table 3.2. Particle size distributions in soil horizons exposed in the spillway trench.

Horizon	Depth (cm)	Sand*(% wt)						Silt (% wt)			Clay (% wt)	Texture	V.F. Sand/ Fine Sand (% wt)	Clay free Sand/Silt (% wt)
		VC	C	M	F	VF	Total	C	F	Total				
Modern surface soil/Unit A7														
Ap	00-14	0.1	0.2	1.5	14.5	15.2	30.7	13.3	27.5	40.8	28.5	CL	1.0	0.8
Bk1	14-37	0.0	0.2	1.4	13.8	13.4	28.4	11.5	31.9	43.4	28.2	CL	1.0	0.7
Bk2	37-44	0.1	0.1	1.0	11.7	10.6	23.1	11.0	34.1	45.1	31.8	CL	0.9	0.5
Bk2	44-51	0.0	0.1	1.1	9.4	9.7	19.9	9.8	36.4	46.1	34.0	CL	1.0	0.4
Modern surface soil welded onto the Leon Creek Paleosol/Unit A6														
Ab1(Bk)	51-69	0.1	0.2	0.9	8.5	8.6	17.9	9.8	36.6	46.4	35.7	SiCL	1.0	0.4
Ab1(Bk)	69-87	0.1	0.2	1.0	8.7	7.6	17.2	7.9	37.9	45.8	37.0	SiCL	0.9	0.4
Bkb1	87-120	0.0	0.1	1.2	9.5	7.2	17.6	7.3	38.5	45.8	36.6	SiCL	0.8	0.4
Bkb1	120-154	0.0	0.1	1.7	15.3	7.9	24.5	6.4	35.2	41.6	33.9	CL	0.5	0.6
BCkb1	154-206	0.0	0.1	3.9	3.2	13.5	48.6	7.7	20.2	27.9	23.5	L	0.4	1.7
CBb1	206-223	0.1	0.1	1.1	19.7	18.3	38.7	12.3	24.7	37.0	24.3	L	0.9	1.0
Medina Pedocomplex/Unit A5														
Akb2	223-264	0.1	0.1	2.1	11.8	10.1	23.8	10.1	35.4	45.4	30.8	CL	0.9	0.5
Akb2	264-289	0.1	0.1	0.9	6.7	8.1	15.7	9.6	39.6	49.2	35.1	SiCL	1.2	0.3
ABkb2	289-317	0.0	0.1	0.4	3.3	4.5	8.1	9.9	41.1	51.1	40.8	SiC	1.4	0.2
Bk1b2	317-360	0.0	0.1	0.1	1.0	2.4	3.6	9.5	44.8	54.3	42.1	SiC	2.4	0.1
Bk1b2	360-404	0.1	0.0	0.1	0.8	3.2	4.1	14.2	42.0	56.2	39.7	SiCL	3.9	0.1
Bk2b2	404-456	0.0	0.0	0.1	0.6	3.2	3.8	10.2	47.5	57.7	38.5	SiCL	5.2	0.1
Bk2b2	456-508	0.1	0.1	0.3	1.9	5.1	7.4	13.9	43.1	57.0	35.6	SiCL	2.6	0.1
Bl2b2	508-560	0.1	0.1	0.1	0.7	3.8	4.5	9.9	46.1	56.0	39.5	SiCL	5.3	0.1
Bk3b2	560-597	0.0	0.1	0.1	2.6	4.9	7.5	10.2	43.1	53.3	39.2	SiCL	1.9	0.1
Bk4b2	597-693	0.1	0.3	0.7	4.8	6.8	12.4	8.7	41.2	49.9	37.7	SiCL	1.4	0.2
Cb2	693-706	0.0	0.1	0.1	1.6	7.5	9.1	14.5	41.1	55.6	35.3	SiCL	4.6	0.2
Cb2	706-720	0.1	0.0	0.0	3.0	9.7	12.5	13.6	39.6	53.2	34.3	SiCL	3.3	0.2
Elm Creek Paleosol/Unit A4														
Bk1b3	720-744	0.0	0.0	0.0	0.8	4.7	5.4	16.0	38.8	54.8	39.8	SiCL	5.7	0.1
Bk1b3	744-768	0.1	0.1	0.1	0.1	4.4	4.7	10.8	43.9	54.7	40.6	SiC	43.0	0.1
Bk2b3	768-794	0.1	0.0	0.1	1.1	6.0	7.1	12.6	40.6	53.1	39.8	SiCL	5.3	0.1
Bk2b3	794-820	0.0	0.1	0.2	1.3	4.9	6.4	10.8	43.4	54.2	39.4	SiCL	3.7	0.1
CBb3	820-980	0.1	0.0	0.1	5.8	20.3	25.5	13.1	30.0	43.1	31.4	CL	3.5	0.6
Cb3	980-1,000	0.0	0.1	0.2	2.8	13.3	15.9	16.7	35.0	51.8	32.3	SiCL	4.8	0.3
Cb3	1,000-1,020	0.0	0.0	0.1	3.1	12.3	15.0	15.8	34.0	49.8	35.2	SiCL	4.0	0.3
Perez Paleosol/Unit A3														
Bkb4	1,020-1,044	0.2	0.3	0.7	4.7	7.2	12.8	13.7	34.5	48.3	38.9	SiCL	1.5	0.3

continued

Table 3.2. Continued.

Horizon	Depth (cm)	Sand*(% wt)						Silt (% wt)			Clay (% wt)	Texture	V.F. Sand/ Fine Sand (% wt)	Clay free Sand/Silt (% wt)
		VC	C	M	F	VF	Total	C	F	Total				
Perez Paleosol/Unit A3														
Bkb4	1,044-1,068	0.2	0.5	1.1	6.0	7.0	14.4	11.2	38.5	49.7	35.9	SiCL	1.2	0.3
Bkssb4	1,068-1,102	0.2	0.4	0.9	7.0	7.0	15.1	13.0	32.6	45.6	39.3	SiCL	1.0	0.3
Bkssb4	1,102-1,136	0.3	0.6	1.3	7.6	7.5	16.9	12.8	30.4	43.2	39.9	SiCL	1.0	0.4
B'kb4	1,136-1,169	0.3	0.6	1.6	9.6	7.8	19.5	10.2	31.4	41.6	38.9	SiCL	0.8	0.5
BCkb4	1,169-1,198	0.2	0.8	2.1	12.2	9.7	24.4	12.9	26.9	39.8	35.8	CL	0.8	0.6
BCkb4	1,198-1,227	0.6	0.8	3.5	17.0	13.1	34.2	10.5	24.5	35.0	30.8	CL	0.8	1.0
CBkb4	1,227-1,257	0.7	0.9	2.8	17.9	12.6	34.0	9.0	24.8	33.8	32.2	CL	0.7	1.0
Cb4	1,257-1,307	0.0	0.1	5.7	46.5	15.3	65.9	3.8	11.5	15.3	18.8	FSL	0.3	4.3
Cb4	1,307-1,357	0.2	0.7	9.5	49.5	12.0	70.1	4.5	10.2	14.6	15.3	FSL	0.2	4.8
Soil 6/Unit A3														
Bk1b5	1,357-1,375	0.0	0.2	1.8	33.8	16.5	51.7	5.3	17.6	23.0	25.3	SCL	0.5	2.3
Bk2b5	1,375-1,425	0.0	0.1	1.4	32.6	20.9	54.3	3.0	19.9	22.8	22.9	SCL	0.6	2.4
Bk2b5	1,425-1,459	0.0	0.0	0.4	14.5	16.7	31.2	11.3	27.9	39.1	29.7	CL	1.2	0.8
Soil 7/Unit A3														
Bkb6	1,459-1,485	0.0	0.2	0.3	1.7	4.4	6.4	8.7	44.6	53.3	40.3	SiC	2.5	0.1
Bkb6	1,485-1,505	0.1	0.1	0.2	0.9	4.8	6.0	14.0	45.3	59.3	34.7	SiCL	5.2	0.1
Soil 8/Unit A3														
A1b7	1,505-1,540	0.0	0.1	0.3	1.3	2.9	4.5	16.1	35.5	51.6	43.9	SiC	2.2	0.1
A2b7	1,540-1,575	0.0	0.1	5.5	1.2	2.8	9.4	5.6	45.2	50.8	39.8	SiCL	2.3	0.2
Cb7	1,575-1,600	0.1	0.0	1.2	2.1	3.6	6.6	10.8	49.1	59.9	33.5	SCL	1.7	0.1
Somerset Paleosol/Unit A2														
Bkmb8	1,600-1,638	1.0	2.5	4.9	18.6	14.3	40.4	8.9	25.5	34.4	25.2	L	0.8	1.2
Bk1	1,638-1,676	0.2	1.1	3.2	21.7	16.0	41.4	8.7	27.3	35.9	22.7	L	0.7	1.2
Bk2	1,676-1,698	0.1	0.4	2.0	20.0	13.9	36.0	9.4	27.2	36.6	27.4	L	0.7	1.0
Bk2	1,698-1,720	0.0	0.2	1.2	14.4	13.8	29.2	15.7	25.7	41.5	29.3	CL	1.0	0.7
Bk3	1,720-1,745	0.0	0.1	0.1	1.0	2.4	3.6	9.5	44.8	54.3	42.1	SiC	2.4	0.1

*Particle-size limits (mm): Sand: VC = 2.0-1.0, C = 1.0-0.5, M = 0.5-0.25, F = 0.25-0.10, VF = 0.10-0.05
Silt: Total = 0.05-0.002, Fine = 0.02-0.002
Clay: Total = < 0.002, Fine = <0.0002

Texture classes: S = sand, Si = silt, C = clay, L = loam, V = very, F = fine, Co = coarse, G = gravelly, ex = extremely, v = very

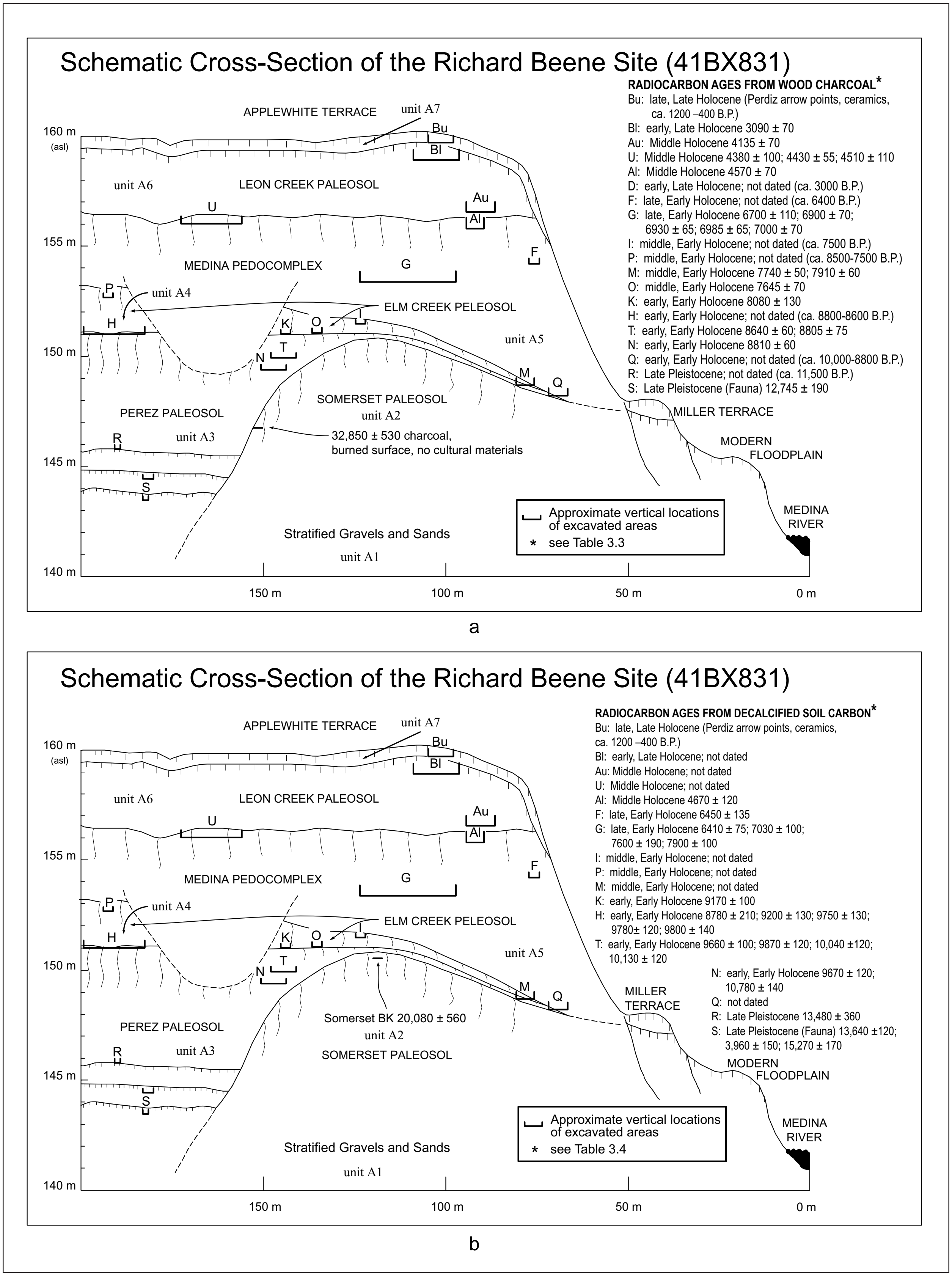


Figure 3.3. Schematic cross-section showing stratigraphic units, soils, and radiocarbon ages from: (a) wood charcoal; and (b) total decalcified soil carbon.

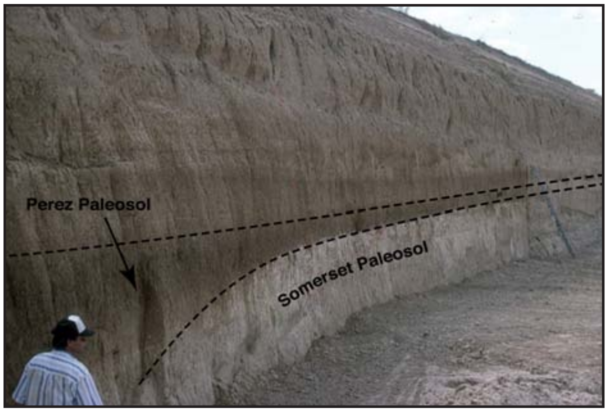


Figure 3.4. Photograph showing the Somerset and Perez paleosols; note how the parent material (Unit A3) of the Perez paleosol is draped over the Somerset paleosol and thins to the north (right).

750 years older than the age of the charcoal in Soil 7. Given the problems associated with ^{14}C ages determined on soil carbon, the ^{14}C age determined on the charcoal should be considered a more reliable indicator of the age of the deposit that is the parent material for Soil 7.

Soil 6 is capped by fine sandy loam grading upward to silty clay loam that composes the upper 1.5 m of Unit A3 (Table 3.2). Many stream-worn carbonate nodules and a few siliceous pebbles are scattered through Unit A3. It is likely that most of the carbonate nodules were derived from the eroded, carbonate-rich Somerset paleosol developed in Unit A2.

A thick, strongly expressed soil (Perez paleosol) is developed at the top of Unit A3 (Figures 3.2, 3.3, and 3.8). The Perez paleosol has a Bk-Bkss-B'k-BCk-CBk profile (Table 3.1); the A horizon was stripped off by erosion before the soil was buried. The total thickness of the paleo-solum is about 2 m. Several features of the Perez paleosol distinguish it from the other buried soils in the Applewhite terrace fill. First, there are distinct carbonate-lined pedotubules with light-gray (10YR 7/2) interiors throughout its solum. The pedotubules are 10–20 cm long and 5–8 mm in diameter. Most of these features are spiral-shaped root casts that have been enriched with secondary calcium carbonate (rhyzoliths), and their light-gray interiors represent iron depletion zones. Second, wedge-shaped aggregates within the Bkssb4 horizon are bounded by distinct slickensides that are inclined 20–30 degrees from the horizontal. These features are products of shrinking and swelling of the soil because of the high clay content (>35 %) and abundance of 2:1 expanding clay minerals. Third, the Perez paleosol is "draped" over the eroded surface of the Somerset paleosol in a manner similar to an alluvial deposit (Figures 3.2–3.4). This is a sedimentological feature ascribed to deposition of "soil sediment" on the paleo-landscape. Finally, many well-rounded pea-sized pebbles are scattered throughout the fine-grained matrix of the Perez paleosol. Although some of these pebbles are siliceous, most are carbonate lithoclasts. The carbonate lithoclasts are approximately the same size and all are well rounded. Also, micro-morphological analyses revealed that their surfaces are very smooth. Hence, these carbonate forms were transported by water and deposited with the fine-grained alluvium; they are not in situ carbonate nodules or concretions. There are two primary sources of the lithoclasts: (1) the Somerset paleosols; and (2) the surface soil developed in valley fill beneath the Leona terrace. As the Medina River dissected the Somerset paleosol and cut laterally into the Leona terrace, many carbonate nodules were incorporated into the alluvium. During high-magnitude floods, it is likely that these nodules (now lithoclasts) were suspended in viscous fine-grained hypersediment flows that spread out across the broad early Holocene floodplain. As flow velocities decreased during the waning stages of floods, the lithoclasts and clay-rich sediment settled out of suspension together.

The Perez paleosol received influxes of alluvium while pedogenesis was occurring; hence soil formation and deposition occurred simultaneously. In such cumulic soils, the A horizon builds up with the accumulating parent material, and the material in the former A horizon can eventually become the B horizon (Birkeland 1999:184; Nikiforoff 1949; Mandel and Bettis 2001). Soil data indicative of soil upbuilding are supported by the archaeological evidence from the Perez soil at the Richard Beene site (Chapters 4 and 9).

Rhythmic flood deposition and repeated human occupancy resulted in a complex of stratified, vertically stacked, and individually sealed early Holocene cultural horizons within the Perez paleosol.

Table 3.3. Calcium carbonate ($CaCO_3$) and organic carbon content of soil samples.

Horizon	Depth (cm)	$CaCO_3$ Equiv. (% wt)	Organic Carbon (%wt)
AP	00-14	49.6	1.26
Bk1	14-37	52.5	1.07
Bk2	37-44	52.8	0.90
Bk2	44-51	53.2	0.79
Leon Creek Paleosol			
Ab1 (Bk)	51-69	52.6	0.84
Ab1 (Bk)	69-87	53.7	0.60
Bkb1	87-120	51.7	0.52
Bkb1	120-154	55.5	0.12
BCb1	154-206	60.4	0.29
CBb1	206-223	55.3	0.06
Medina Pedocomplex			
Akb2	223-264	52.4	0.33
Akb2	264-289	50.8	0.27
ABkb2	289-317	48.9	0.24
Bk1b2	317-360	46.7	0.29
Bk1b2	360-404	48.7	0.20
Bk2b2	404-456	48.6	0.23
Bk2b2	456-508	48.0	0.17
Bk2b2	508-560	49.2	0.15
Bk3b2	560-597	45.2	0.45
Bk4b2	597-693	47.2	0.46
Cb2	693-706	47.9	0.31
Cb2	706-720	47.8	0.44
Elm Creek Paleosol			
Bk1b3	720-744	41.0	0.54
Bk1b3	744-768	43.5	0.46
Bk2b3	768-794	43.3	0.24
Bk2b3	794-820	45.7	0.23
CBb3	820-980	47.6	0.53
Cb3	980-1,000	48.5	0.06
Cb3	1,000-1,020	47.4	0.11
Perez Paleosol			
Bkb4	1,020-1,044	42.9	0.29
Bkb4	1,044-1,068	40.6	0.27
Bkssb4	1,068-1,102	38.2	0.29
Bkssb4	1,102-1,136	37.9	0.16
B'kb4	1,136-1,169	38.0	0.12
BCkb4	1,169-1,198	41.1	0.27
BCkb4	1,198-1,227	42.1	0.13
CBkb4	1,227-1,257	44.9	0.13
Cb4	1,257-1,307	20.9	0.14
Cb4	1,307-1,357	21.8	0.05
Soil 6			
Bk1b5	1,357-1,375	22.3	0.73
Bk2b5	1,375-1,425	38.3	0.11
Bk2b5	1,425-1,459	40.5	0.23

continued

Table 3.3. Continued

Horizon	Depth (cm)	$CaCO_3$ Equiv. (% wt)	Organic Carbon (%wt)
		Soil 7	
Bkb6	1,459-1,485	44.0	0.59
Bkb6	1,485-1,505	53.6	0.50
		Soil 8	
A1b7	1,505-1,540	40.7	0.93
A1b7	1,540-1,575	45.8	0.46
Cb7	1,575-1,600	65.3	0.10
		Somerset Paleosol	
Bkmb8	1,600-1,638	69.3	0.02
Bk1b8	1,638-1,676	61.8	0.33
Bk2b8	1,676-1,698	55.9	0.34
Bk2b8	1,698-1,720	55.6	0.30
Bk3b8	1,720-1,745	55.3	0.34

These horizons contained chipped stone debitage, cores and core fragments, stone tools, fire-cracked rock (FCR), mussel shells, and bones and bone fragments, mostly from rabbit- and deer-sized animals. Diagnostic artifacts included Angostura projectile points, fragments of lanceolate projectile points, and

Figure 3.5. Photograph of the petrocalcic (Bkm) horizon developed in the upper 35-45 cm of the Somerset paleosol; photo-scale has 10 cm increments.

Figure 3.6. Photograph illustrating erosion of the petrocalcic horizon of the Somerset paleosol.

Table 3.4. Radiocarbon ages derived from charcoal in archaeological deposits and features.

Lab Assay No. (CEA ^{14}C Record No.)	Calibrated Results (2 sigma, 95% probability)	Conventional (^{13}C Adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Block/BHT Provenience	Depth, m amsl (m below surf.)	Pedostratigraphic context	Material and Association	Cultural Component and Period
BETA 36702 (41BX831-F1)	3080-3470	3090±70	NA	-	ca. 158.65 m (1.3-4 m bs)	Upper Leon Creek	Charcoal, Feature 1	Upper Leon Creek; late, Late Archaic
BETA 43330 (41BX831-1)	4450-4830	4135±70	-24.50	Upper Block A	ca. 157.5 m (2.5 m bs)	Lower Leon Creek, C horizon.	Charcoal, tree burn	Lower Leon Creek; Middle Archaic
BETA 38700 (41BX831-F1)	4980-5470	4570±70	-26.30	Lower Block A	ca. 157.4 m (2.6 m bs)	Upper Medina	Charcoal, tree burn	Lower Leon Creek; Middle Archaic
AA 20401 (41BX831-47)	4660-5310	4380±100 (AMS)	NA	Block U	156.71-.61 m (ca 3.43 m bs)	Upper Medina	Charcoal, isolated fragments	Upper Medina; Middle Archaic
GX 21746 (41BX831-48)	4870-5290	4430±55 (AMS)	NA	Block U	156.71-.61 m (ca 3.43 m bs)	Upper Medina	Charcoal, diffuse porous	Upper Medina; Middle Archaic
AA 20402 (41BX831-49)	4860-5470	4510±110 (AMS)	NA	Block U	156.41 m (3.59 m bs)	Upper Medina	Charcoal, isolated fragments	Upper Medina; Middle Archaic
AA 20400 (41BX831-46)	7340-7790	6700±110 (AMS)	NA	Block G	153.63 m (6.37 m bs)	Lower Medina	Charcoal	Lower Medina; late, Early Archaic
BETA 47523 ETH 8536 (41BX831-30)	7590-7920	6985±65 (AMS)	NA	Block G	153.58 m (6.42 m bs)	Lower Medina	Charcoal, Tree Burn	Lower Medina; late, Early Archaic
BETA 47524 ETH 8538 (41BX831-31)	7590-7920	6900±70 (AMS)	NA	Block G	153.63-53 m (ca.6.42 m bs)	Lower Medina	Charcoal, Feature 30	Lower Medina; late, Early Archaic
BETA 47530 ETH 8543 (41BX831-37)	7680-7940	7000±70 (AMS)	NA	Block G	153.48 -42 m (ca 6.45 mbs)	Lower Medina	Charcoal, Feature 43	Lower Medina; late, Early Archaic

continued

Table 3.4. Continued

Lab Assay No. (CEA ^{14}C Record No.)	Calibrated Results (2 sigma, 95% probability)	Conventional (^{13}C Adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Block/BHT Provenience	Depth, m amsl (m below surf.)	Pedostratigraphic context	Material and Association	Cultural Component and Period
BETA 47525 ETH 8538 (41BX831-32)	7620-7930	6930±65 (AMS)	NA	Block G	153.44 -30 m (ca.6.64 m bs)	Lower Medina	Charcoal, Feature 44	Lower Medina; late, Early Archaic
BETA 47529 ETH 8542 (41BX831-36)	8220-8590	7645±70 (AMS)	NA	Block O	150.92 m (9.08 m bs)	Elm Creek, upper portion	Charcoal, Feature 108	Elm Creek; middle, Early Archaic
BETA 44386 (41BX831-9)	8600-9400	8080±130	-26.00	Block K	150.35 m (10.65 m bs)	Elm Creek	Charcoal	Elm Creek; middle, Early Archaic
BETA 78656 CAMS 17625 (41BX831-38)	8590-8890	7910±60 (AMS)	-25.50	Block M	148.33-.20 m (ca11.68mbs)	Elm Creek	Charcoal, Feature 80	Elm Creek; middle, Early Archaic
BETA 78657 CAMS 17626 (41BX831-39)	8410-8590	7740±50 (AMS)	-25.40	Block M	148.33-.20 m (ca11.68mbs)	Elm Creek	Charcoal, Feature 80	Elm Creek; middle, Early Archaic
BETA 80687 CAMS 18801 (41BX831-40)	9500-9890	8640±60	-26.00	Block T	149.50-.40 m (ca 10.55 mbs)	Upper Perez, Bk horizon	Charcoal, Feature 106	Upper Perez; early, Early Archaic
BETA 47527 ETH 8540 (41BX831-34)	9560-10,150	8805±75 (AMS)	-25.00	Block T	149.45-.28 m (ca 10.64mbs)	Upper Perez, Bk horizon	Charcoal, isolated frag	Upper Perez; early, Early Archaic
BETA 80974 CAMS 19197 (41BX831-43; (^{14}C- 44)	7990 (7920) 7670 BC	8810±60	-24.00	Block N BHT 44	149.40 m (10.6 m bs)	Upper Perez, Bk horizon	Charcoal, hull (pecan or hickory)	Upper Perez; early, Early Archaic
BETA 47526 ETH 8539 (41BX831-33)	14,270-15,900	12,745±190 (AMS)	NA	Block S BHT 39	144.26 m (15.74 m bs)	Upper Soil 7	Charcoal, Feature (natural pit w/ bone) 95	To date, non-cultural Late Pleistocene fauna
BETA 47528 ETH 8541 (41BX831-35)	N/A	32,850±530 (AMS)	NA	BHT 54	147.00 m (13.0 m bs)	Somerset, C horizon, stratified	Charcoal, burned surface	To date, non-cultural Late Pleistocene floral

Table 3.5. Radiocarbon ages determined on decalcified organic carbon from paleosols and archaeological features.

Lab Assay No. (CEA ^{14}C Record No.)	Calibrated Results (2 sigma, 95% probability)	Conventional (^{13}C Adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Block/BHT Provenience	Depth, m amsl (m below surf.)	Pedostratigraphic context	Material and Association	Cultural Component and Period
BETA 43332 (41BX831-3)	4980-5640	4670±120	-24.00	South wall of the spillway trench	-	Upper Medina	Soil bulk carbon, burn surface	Upper Medina; Middle Archaic
BETA 43333 (41BX831-4)	7020-7600	6450±135	-24.20	Block F	ca. 154.0 m (6.0 m bs)	Middle Medina	Soil bulk carbon, FCR Feature	Middle Medina; late, Early Archaic
BETA 44547 (41BX831-17)	8460-9010	7900±100	-22.60	Block G	153.55 m (6.45 m bs)	Lower Medina	Soil bulk carbon, Feature 30	Lower Medina; late, Early Archaic
BETA 43334 (41BX831-5)	7980-8980	7600±190	-22.90	Block G	ca. 153.5 m (6.5 m bs)	Lower Medina	Soil bulk carbon, mussel shell	Lower Medina; late, Early Archaic
BETA 43335 (41BX831-6)	7100-7460	6410±75	-23.70	Block G	ca. 153.5 m (6.5 m bs)	Lower Medina	Soil bulk carbon, FCR feature	Lower Medina; late, Early Archaic
BETA 44548 (41BX831-18)	7670-8100	7030±100	-23.50	Block G	153.45 m (6.55 m bs)	Lower Medina	Soil bulk carbon, Feature 43	Lower Medina; late, Early Archaic
BETA 44544 (41BX831-14)	9330-10,400	8780±210	-23.00	Block H BHT 1 (S wall)	152.92 m (7.08 m bs)	Near bottom of Elm Creek (graded silts)	Soil bulk carbon	Elm Creek;early, Early Archaic
BETA 44545 (41BX831-15)	9920-10,740	9200±130	-22.40	Block H BHT 1 (S wall)	152.52m (7.48 m bs)	Eroded top of Elm Creek	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 44541 (41BX831-11)	9920-10,670	9170±110	-20.20	Block H, BHT 35 (S wall)	150.33 m (9.67 m bs)	Top of Elm Creek	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 44387 (41BX831-10)	8610-9080	8010±70	-25.30	Block K	150.35 m (9.65 m bs)	Elm Creek (?)	Soil bulk carbon, Feature 64	Elm Creek; middle, Early Archaic
BETA 43877 (41BX831-7)	10,700-11,630	9780±120	-21.00	Block H, BHT 1	151.15 m (8.85 m bs)	Elm Creek, C horizon (redepo-sited Perez Bk)	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 43878 (41BX831-8)	10,640-11,550	9750±130	-21.00	Block H, BHT 1	151.35 m (8.65 m bs)	Elm Creek, C horizon (redepo-sited Perez Bk)	Soil bulk carbon	Upper Perez; early, Early Archaic

continued

Table 3.5. Continued

Lab Assay No. (CEA ^{14}C Record No.)	Calibrated Results (2 sigma, 95% probability)	Conventional (^{13}C Adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Block/BHT Provenience	Depth, m amsl (m below surf.)	Pedostratigraphic context	Material and Association	Cultural Component and Period
BETA 44546 (41BX831-16)	10,690-11,900	9800±140	-20.10	Block H BHT 36 (E wall)	150.89 m (9.11 m bs)	Top of Perez	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 44542 (41BX831-12)	10,600-11,260	9670±120	-20.30	Block N, BHT 35 (S wall)	149.10m (10.9 m bs)	Top of Perez	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 44543 (41BX831-13)	12,340-13,150	10,780±140	-20.80	Block N, BHT 35 (S wall)	148.76 m (11.24 m bs)	Lower Perez	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 47564 (41BX831-26)	10,700-11,220	9660±100	-21.00	Block T Trench 48	149.67m (10.33 m bs)	Perez Bk horizon	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 47565 (41BX831-27)	10,790-11,940	9870±120	-20.60	Block T Trench 48	149.39 m (10.61 m bs)	Perez Bk horizon	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 47566 (41BX831-28)	11,200-12,270	10,040±120	-20.50	Block T Trench 48	149.18 m (10.82 m bs)	Perez Bk, horizon	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 47567 (41BX831-29)	11,260-12,320	10,130±120	-20.70	Block T Trench 48	148.85 m (11.15 m bs)	Perez Bk, horizon	Soil bulk carbon	Upper Perez; early, Early Archaic
BETA 47558 (41BX831-20)	14,760-17,210	13,480±360	-24.30	Block R BHT 39	145.34m (14.66 m bs)	Upper Soil 6	Soil bulk carbon	To date, non-Cultural Late Pleistocene fauna
BETA 47559 (41BX831-21)	15,640-17,140	13,640±210	-26.60	Block S BHT 39	144.44m (15.56 m bs)	Upper Soil 7	Soil bulk carbon	To date, non-Cultural Late Pleistocene fauna
BETA 47560 (41BX831-22)	16,180-17,340	13,960±150	-19.70	Block S BHT 39	143.94 m (16.06 m bs)	Soil 8	Soil bulk carbon	To date, non-Cultural Late Pleistocene fauna
BETA 47561 (41BX831-23)	17,610-18,950	15,270±170	-20.90	Block S BHT 39	143.54 m (16.46 m bs)	Soil 8	Soil bulk carbon	To date, non-Cultural Late Pleistocene fauna
BETA 47563 (41BX831-25)	22,390-[24,000]	20,080±560	-22.60	BHT 57 (E wall)	146.68 m (13.32 m bs)	Somerset, C horizon, stratified	Soil bulk carbon	To date, non-Cultural Late Pleistocene floral

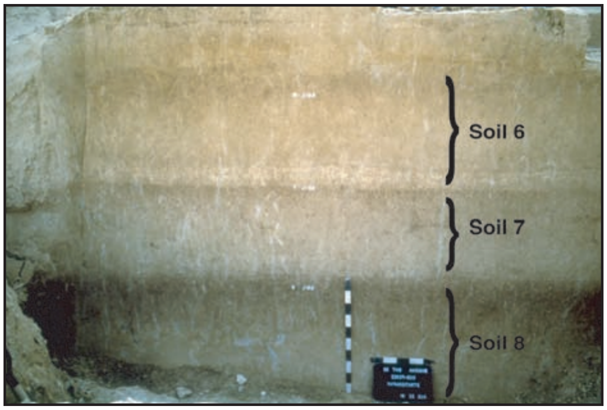


Figure 3.7. Photograph showing buried Soils 6, 7, and 8 in the lower half of Unit A3; photo-scale is 1 m long.

Clear Fork adzes. There were also many scrapers, gravers, drills, and edge modified flakes.

The integrity of the archaeological record varies with depth below the surface of the Perez paleosol. For example, many of the artifacts near the bottom of the soil were in horizontal angles of repose, whereas those near the top were often tilted or turned on their edges. Also, all of the intact fire-cracked rock features in the Perez paleosol were in the lower half of this soil. Greater soil mixing, and hence greater disturbance of artifacts and features, should be expected in the upper part of the soil because of the mass-wasting movements of expandable clays (argillipedoturbation in the Bkss horizon) and redistribution of material by tree throws (floral pedoturbation) and burrowing animals (faunal pedoturbation) that likely occurred when the Perez paleosol was a surface soil.

Although pedoturbation probably caused some movement of artifacts, other lines of evidence suggest that floods had a greater effect on cultural horizons near the top of the Perez paleosol. Specifically, faunal remains were less numerous and more stream-worn in the upper half of the soil compared to those in the lower half. Also, the upward increase in artifact disturbance within the Perez paleosol is accompanied by an increase in the size and frequency of stream-worn pebbles. This sedimentological evidence suggests that flood magnitudes increased during the final stages of soil upbuilding. Turbulent, high-magnitude floods entrain more and larger pebbles compared to low-magnitude and less tur-

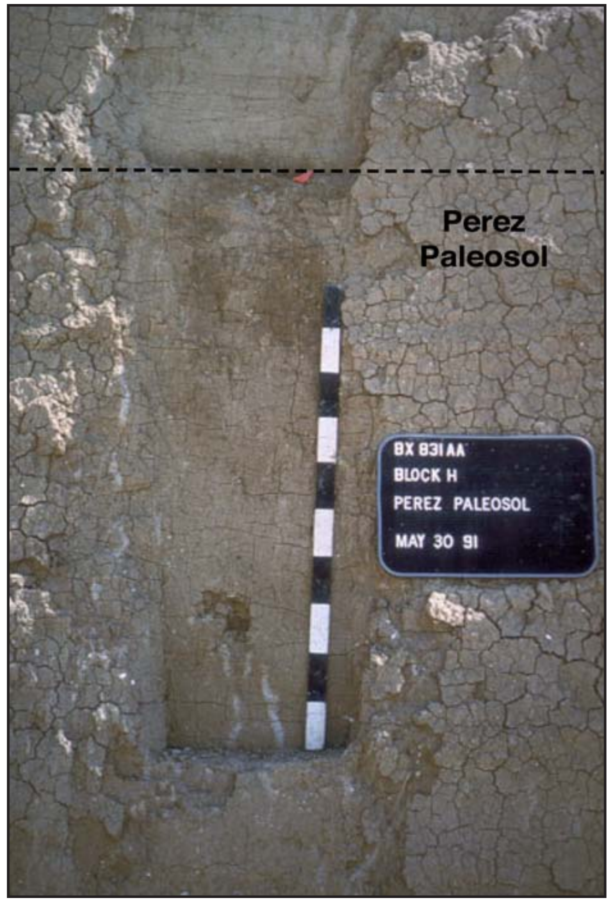


Figure 3.8. Photograph of the Perez paleosol in Block H; photo-scale is 1 m long.

bulent floods. It is also important to note that high-magnitude floods are usually erosive; hence they can move artifacts and disturb or destroy cultural features on a floodplain. Deep flood scours are common at the top of the Perez paleosol (Figure 3.9), and the presence of laminated, sandy sediment in the scours (Figures 3.10 and 3.11) indicates that they are products of high flood-flow velocities.

The most disturbed cultural component, with the exception of Block T (see Chapter 4), rests on the eroded surface of the Perez paleosol (Figure 3.12). This cultural zone is poorly preserved and contains no *in situ* archaeological features (Chapter 9). Instead, there were random concentrations of chipped stone artifacts, FCR, and mussel shells. There were also many stream-worn pebbles 2–4 cm in diameter. Many of the artifacts rested on their edges at near vertical angles of repose, and some were imbricated. These artifacts were concentrated

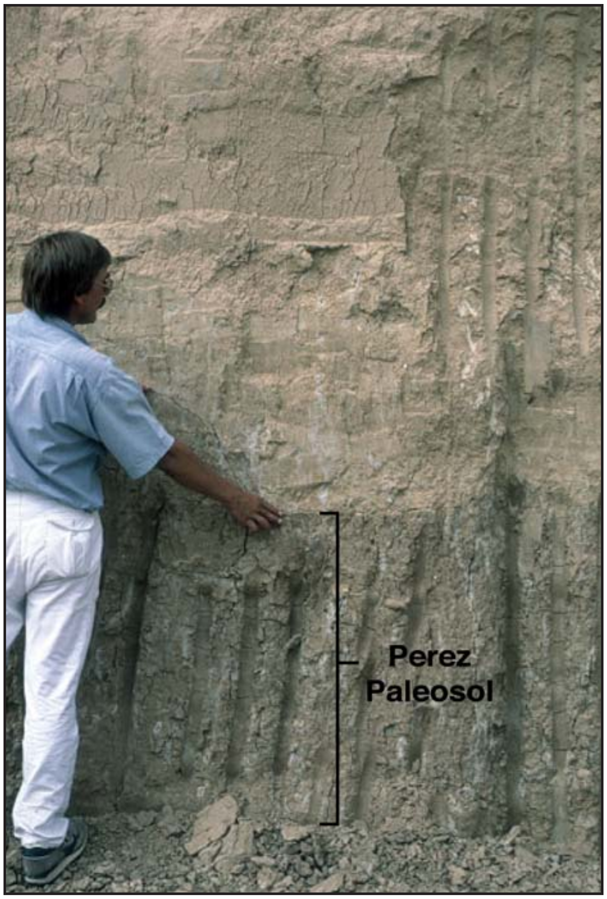


Figure 3.9. Photograph showing a flood scour at the top of the Perez paleosol.

in flood scours eroded into the top of the Perez paleosol, and some artifacts were scattered in laminated sandy and loamy flood deposits immediately above the soil. The obvious implication is that the artifacts and stream-worn pebbles form a lag deposit that resulted from a high-energy flood that stripped the top of the Perez paleosol. The artifacts and coarser sediment immediately above the Perez paleosol were probably deposited immediately after the erosion event, possibly by the same flood that formed the scours. However, the edges of most of the FCR did not seem significantly rounded, and even small chert flakes were razor sharp. This suggests that the cultural material was not transported very far by flood waters.

Ten radiocarbon ages provide a numerical chronology for the Perez paleosol (Tables 3.4 and 3.5). Seven of these ages were determined on total decalcified soil carbon, and three ages were determined on charcoal. The ages on soil carbon range from ca. 10,800 B.P. for the lower 10 cm of the paleosol (Bkb4 horizon) to ca. 9600 B.P. for the upper 10 cm

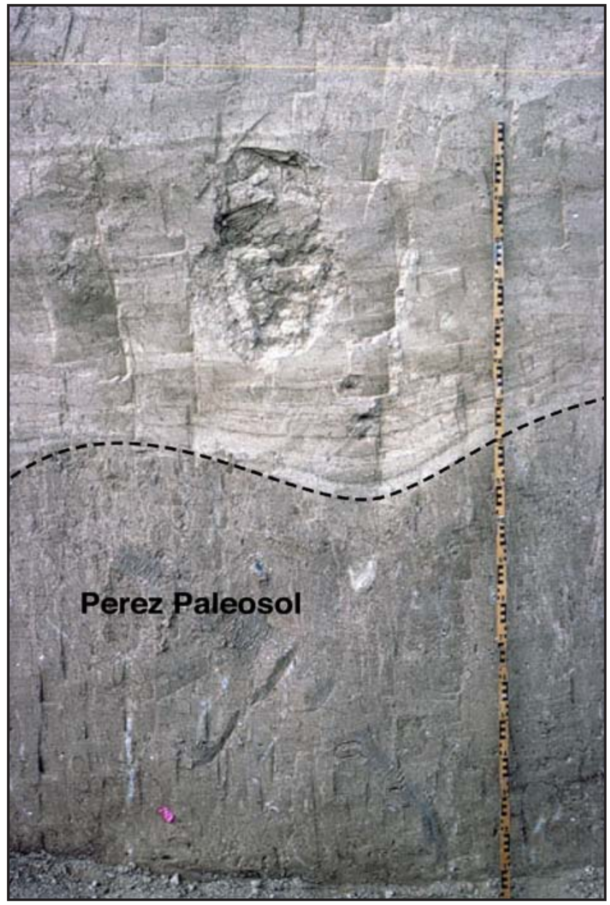


Figure 3.10. Photograph showing laminated loamy and sandy alluvium (lower Unit A4) above the flood-scoured surface of the Perez paleosol.

Figure 3.11. Close-up photograph of the laminated alluvium above the flood-scoured surface of the Perez paleosol.

Figure 3.12. Photograph of disturbed cultural materials resting on the flood-scoured surface of the Perez paleosol.

of the paleosol (Table 3.5). Based on these ages, cumulic soil development spanned approximately 1,200 years and the Perez paleosol was buried soon after ca. 9600 B.P. However, a charcoal sample from the upper 10 cm of the Perez paleosol yielded an AMS radiocarbon age of 8640±60 B.P. (Beta-80687/CAMS-18801), and charcoal samples from the lower 30 cm of the Bkb4 horizon of the Perez paleosol yielded AMS radiocarbon ages of 8805±75 B.P. (Beta-4752) and 8810±60 B.P. (Beta-80974/CAMS-19197) (Table 3.4). Hence, despite the fact that the radiocarbon ages determined on soil carbon from the Perez paleosol are in correct stratigraphic order, there is a ca. 1,000-year discrepancy between the ages determined on charcoal and soil carbon from the upper 30 cm of the paleosol. This discrepancy between charcoal and soil-carbon ages is remarkably similar to the one detected in soils 6 and 7 in Unit A3 (see previous discussion). Given that all the soils in Unit A3 have cumulative properties, this discrepancy is not surprising, as explained below.

In alluvial settings, cumulative soils often have organic-rich sediment continuously added to their surfaces (Birkeland 1999:166). Consequently, there are two inherited sources of older organic carbon. The first inherited source is from the erosion and redeposition of organic-rich upland topsoil containing carbon complexed with clays. Organic carbon from the eroded A horizon of an upland soil includes a mixture of organic matter, which varies from that fraction being added daily to that synthesized and resynthesized over several hundreds or thousands of years (Birkeland 1999:137). Accordingly, there is a certain amount of mean residence time associated with soil sediment deposited on a floodplain. Mean residence times for upland soils range from about 200 to 2,000 years, with 1,000 years being the average (Paul 1969). Hence, some of the soil sediment that formed the Perez paleosol may have been 1,000 years old when it was deposited. This alone may account for the 1,000-year discrepancy between the ages determined on charcoal and soil carbon.

The second source of inherited organic carbon is derived from older alluvium in the river valley. The parent material of the Perez paleosol was derived from many different sources, including older valley fill beneath the Applewhite and Leona terraces. Although "fresh" organic carbon derived from vegetation at the time of cumulic soil formation is superimposed on, and mixed with, inherited, more oxidized (and therefore less significant) sources of organic carbon, the inherited older carbon can bias a radiocarbon age determined on total organic carbon from the cumulic soil. Whether this bias can be as great as 1,000 years is unknown, but it may be at least a partial source of the discrepancy between the ages determined on charcoal and soil carbon.

Radiocarbon ages determined on charcoal from the top of the Perez paleosol and lower part of the overlying Elm Creek paleosol indicate that the Perez paleosol was buried after ca. 8600 but before ca.

7750 B.P. Unit A4 mantles the Perez paleosol and is described below.

Unit A4

Unit A4 is typically 3 m thick and consists mostly of calcareous fine-grained overbank deposits. Soil development has modified the upper 2.6 m of this unit. However, sedimentary features in the form of thin, horizontal beds of silt loam, loam, fine sandy loam, and very fine sand are well preserved in the lower 2 m of Unit A4. At the Richard Beene site, a few lithic artifacts and bones and several isolated fire-cracked rock features, were recovered from Unit A4.

The Elm Creek paleosol at the top of A4 (Figures 3.2, 3.3, 3.13, and 3.14) is the least-developed soil in the Holocene alluvium beneath the Applewhite terrace. It has a thin, weakly expressed Bk-CB-C profile (Table 3.1); the A horizon was stripped off by fluvial erosion before burial. The Bkb3 horizon (Bk1b3 + Bk2b3) is 1 m thick and is a yellowish brown (10YR 5/6, dry) silty clay loam. Structural development is weak, and carbonate morphology does not exceed stage I in the paleo-solum (Table 3.1). Encrusted calcium carbonate filaments about 1 mm thick compose 2 percent or less of the soil matrix in the Bkb3 horizons, and secondary carbonates line the interiors of pedotubules in the Cb3 horizon. A 4-cm-thick bed of silty clay loam with common granule-size carbonate lithoclasts was observed near the bottom of the Bk2b3 horizon, and faint horizontal bedding was detected throughout the CBb3 and Cb3 horizons. Bedding in the Cb3 horizon becomes more distinct towards the scarp that separates the Applewhite terrace from the Miller terrace.

The organic C content has a normal depth trend in most of the Elm Creek paleosol; it decreases from 0.54 percent in the upper 24 cm of Bk1b3 horizon to 0.23 percent in the lower 26 cm of the Bk2b3 horizon (Table 3.3). However, organic C abruptly increases to 0.53 percent in the CBb3 horizon before dropping off to 0.06 percent in the underlying Cb3 horizon. The relatively high concentration of organic C in the CBb3 horizon is probably due to deposition of sediment rich in organic matter; hence it is a sedimentological feature and is not related to pedogenesis.

Calcium carbonate content is high throughout Unit A4, ranging from 41 percent in the upper 24 cm of the Bk1b3 horizon to 48.5 percent in the Cb3 horizon. These values indicate that there has been only slight leaching of primary calcium carbonate in the upper part of the Elm Creek paleosol.

Particle size distribution in Unit A4 is characterized by a general upward fining of the alluvium (Table 3.2). On a clay-free basis the proportion of fine silt increases upward from 76.9 to 91.0 percent. This increase in fine silt is matched by a 14 percent decrease in the proportion of sand. Although the general trend is one of upward fining, there are distinct irregularities in particle-size distribution within Unit A4. For example, on a clay-free basis the proportion of sand increases from 23.5 percent in the Cb3 horizon to 37.2 percent in the CBb3 horizon, but abruptly drops off to 10.6 percent in the Bk2b3 horizon. Also, the ratio of very fine sand to fine sand (clay-free) dramatically increases from 5.6 in the upper 26 cm of the Bk2b3 horizon to 37.0 in the lower 24 cm of the Bk1b3 horizon, but drops off to 6.0 in the upper 24 cm of the Bk1b3 horizon. These patterns indicate that primary bedding in Unit A4 has not been completely destroyed by soil development, even within the upper part of the truncated Bk1b3 horizon.

In the section near the western end of the spillway trench, the Elm Creek paleosol is welded into two buried soils: (1) the Middle Elm Creek paleosol; and (2) the lower Elm Creek paleosol (see Figure 4.3 in Chapter 4, this volume). The upper, middle, and lower Elm Creek paleosols converge to the south, forming a single paleosol.

Altogether the soil evidence and archaeological findings suggest that the Elm Creek paleosol represents a relatively short period of floodplain stability. However, radiocarbon dating of this pedocomplex proved problematic. Five radiocarbon ages ranging from ca. 9170–9780 B.P. were determined on total decalcified soil carbon from different depths of the Elm Creek paleosol (Table 3.5). Although these ages are in correct stratigraphic order, small

Figure 3.13. Photograph of the Elm Creek paleosol developed in Unit A4.

pieces of wood charcoal recovered from fire-cracked rock features in the Elm Creek paleosol yielded AMS radiocarbon ages of 8080±140, 7910±60, 7740±60, and 7645±70 B.P. (Table 3.4). Hence, as is the case with Unit A3, there is a discrepancy between radiocarbon ages determined on charcoal and soil carbon. Specifically, where soil and charcoal samples were collected from the same horizon, the soil-carbon age was 1,000–1,500 years older than the ages of the charcoal samples. Therefore, the soil-carbon ages should be adjusted by ca. 1,000 years.

Considering only radiocarbon ages determined on charcoal, aggradation of Unit A4 began sometime between 8640±60 B.P. (age determined on charcoal from a feature in the Perez paleosol) and 8080±130 B.P. (age determined on charcoal from a feature in the Elm Creek paleosol). Cumulic soil development continued until as late as 7645±70 B.P., and the Elm Creek paleosol was buried by ca. 7000 B.P.

Unit A5

Unit A5 is 4.8 m thick and consists of calcareous fine-grained overbank deposits. It is the most thoroughly studied stratigraphic unit at the site and contains Middle and Early Archaic components (Chapter 9). Cutbanks and deep gullies also provided opportunities to examine the full thickness of Unit A5 at several other localities in the project area.

The clay-free particle size distribution indicates that there are three fining-upward sequences in the

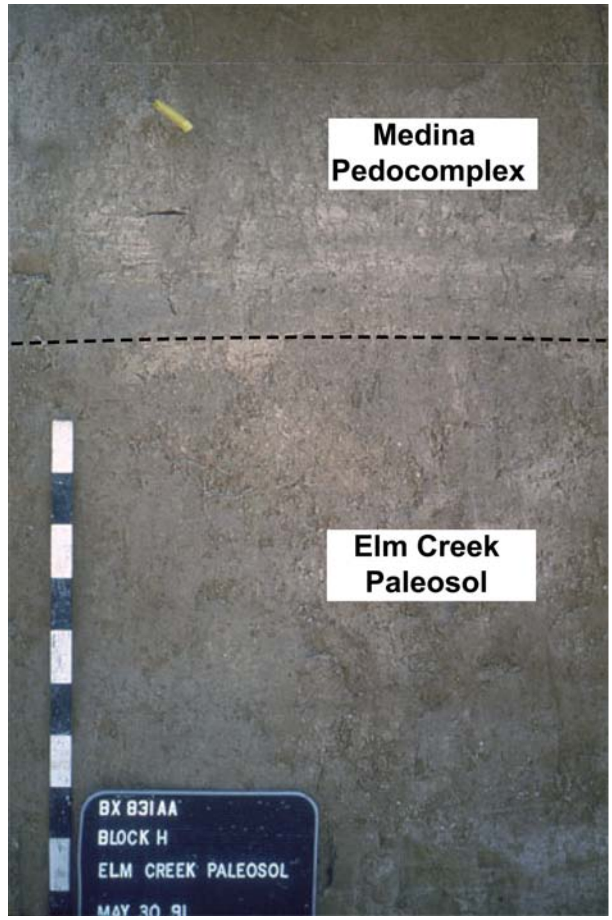


Figure 3.14. Photograph of the Elm Creek paleosol and lower 60 cm of the Medina pedocomplex; photoscale is 1 m long.

lower 3.86 m of Unit A5 (Table 3.2). However, the cycle is reversed in the upper 94 cm of the unit, with the proportion of sand increasing to the top of Unit A5 and continuing to increase into the lower 40 cm of Unit A6. This increase in the sand content may be attributed to a change in the depositional environment. Specifically, if the Medina River moved closer to the study site during the final stage of Unit A5 aggradation and continued to shift southward during the early stage of Unit A6 aggradation, the clay-rich alluvium characteristic of a distal floodplain setting would be mantled by sandier levee deposits associated with a near-channel floodplain setting. Another explanation is that there was an increase in the energy of floods during these stages of deposition. An increase in energy would have been accompanied by an increase in the amount of sand transported and deposited by floodwaters.

The Medina pedocomplex, consisting of at least two buried soils welded together, is developed at the top of Unit A5 and is the thickest soil in the valley fill beneath the Applewhite terrace (Figures 3.2, 3.3, 3.14, and 3.15). This pedocomplex has a very distinct profile that stands out in cutbank exposures and gully walls throughout the project area. Hence it became an important stratigraphic marker during the course of the archeological and geomorphological investigations.

The Medina pedocomplex is over 4.5 m thick and is characterized by an Ak-ABk-Bk profile (Table 3.1). The Akb2 horizon is 50 cm thick and is a yellowish brown (10YR 5/4, dry) clay loam (Table 3.1). Filaments of $CaCO_3$ cover 5 percent of each ped surface in this horizon, and there are few fluffy carbonate masses (stage I+). A 28-cm-thick transitional zone (ABkb2 horizon) consisting of yellowish brown (10YR 5/4, dry) silty clay separates the Akb2 horizon from the Bkb2 horizon. The Bkb2 horizon is 3.76 m thick and is a yellowish brown (10YR 5/4 to 6/4, dry) silty clay loam. The clay maximum (42.1%) is in the upper 43 cm of the Bk1b2 horizon (Table 3.2). The Bkb2 horizon exhibits moderate development in terms of structure and secondary carbonate forms. Weak prismatic structure parts to moderate, medium subangular-blocky structure throughout most of the Bkb2 horizon, and filaments of $CaCO_3$ cover 5–10 percent of each ped surface. Also, tubular carbonate forms that are about 2 cm in diameter are common in the lower 96 cm of the Bkb2 horizon. The C2 horizon consists of laminated yellowish brown (10YR 6/4, dry) silty clay loam.

There is no evidence of strong weathering in the Medina pedocomplex. Calcium carbonate content is high (52.4–45.2%) throughout the paleosol despite weak carbonate morphology (Table 3.3). Also, there is an irregular depth trend of $CaCO_3$ (Table 3.3).

The organic C content of the Medina pedo-complex does not steadily decrease with depth (Table 3.3). Instead, it is very irregular, especially in the lower part of the Bkb2 horizon. This depth trend is typical of a pedocomplex that forms as cumulization produces an over-thickened soil profile. Increases in organic C mark the positions of former A horizons that were buried and subsequently transformed into Bk horizons. The archaeological evidence supports the soils data. For example, in situ features and artifacts in the Bk4b2 indicate that this horizon was once a living surface, i.e., an A horizon. After being buried through cumulization, it was subjected to pedogenic processes that converted it to a Bk horizon. However, soil-forming processes did not obliterate all evidence of alluviation. Because cumulative soils on valley floors typically have organic-rich alluvium continuously added to their surfaces, their properties, including organic C content, are partly sedimentological and partly pedological.

Figure 3.15. Photograph of the upper ca. 1.5 m of the Medina pedocomplex; note the dark zone (former A horizon) in the lower 40 cm of the pedocomplex.

A suite of 15 ^{14}C ages provides a numerical chronology for the development of the Medina pedocomplex (Tables 3.4 and 3.5). Five separate charcoal samples from the lower half of the Medina pedocomplex yielded AMS ^{14}C ages of 7000±70 B.P. (Beta-47530; Feature 43), 6985±65 B.P. (Beta-47523; Feature 76, tree burn), 6930±65 B.P. (Beta-47525; Feature 44), 6900±70 B.P. (Beta-47524; Feature 30), and 6700±110 B.P. (AA-20400; Block G). Four separate charcoal samples from the top of the Medina pedocomplex yielded ^{14}C ages of 4570±70 B.P. (Beta-38700; Feature 2 burned tree), 4510±110 B.P. (AA-20402; Block U), 4430±55 B.P. (GX-21746; Block U), and 4380±100 B.P. (AA-20401; Block U).

Three ^{14}C ages determined on total decalcified soil carbon were very similar to the ages determined on charcoal collected from the same portion of the Medina pedocomplex. These ages were 7030±100 B.P. (Beta-44548; lower Medina pedocomplex), 6450±135 B.P. (Beta-43333; middle Medina pedocomplex), and 4670±120 (Beta-43332; upper Medina pedocomplex). Other ^{14}C ages determined on soil carbon were 500–1000 years too old. In sum, cumulic soil development was underway in Unit A5 by ca. 7000 B.P. and continued to ca. 4400 B.P., thereby producing the Medina pedocomplex. The Medina pedocomplex was buried soon after ca. 4400 B.P.

Unit A6

Unit A6 is 3–4 m thick and consists of levee and distal floodplain deposits. Most of this unit is fine textured, containing silty clays and clay loams, but it becomes coarser (loam) near its base. Although modern and prehistoric soil development has greatly modified the upper part of Unit A6, it has not obliterated primary bedding in the lower 50–60 cm of the unit. The bedding is characterized by laminae that are 1–5 mm thick and many are rich in fine and very fine sand.

The Leon Creek paleosol is developed at the top of Unit A6 (Figures 3.2, 3.3, 3.14, and 3.16). This paleosol was observed at many localities throughout the project area. The Bk horizon of the modern surface soil is welded to the Leon Creek paleosol. Hence the paleosol is a composite soil with properties ascribed to two sets of pedogenic processes: (1) the first set operated when the top of Unit A6 was a stable surface; and (2) the second set has been operating since sediment composing Unit A7 was deposited on top of the Leon Creek paleosol. The portion of the soil profile that represents welding of the modern soil to the A horizon of the Leon Creek paleosol is designated as the Ab1 (Bk) horizon (Table 3.1). This horizon is 36 cm thick at 41BX831 and is a dark brown (10YR 4/3, dry) silty clay loam. It was impossible to determine the depth of welding below the Ab1 (Bk) horizon. However, variations in clay content with depth suggest that the Bk horizon of the modern surface soil is welded through the entire solum of the Leon Creek paleosol (Table 3.2). Specifically, the proportion of clay steadily increases from the upper 37 cm of the surface soil down into the Ab1 (Bk) horizon, and then it gradually decreases to the bottom of Unit A6.

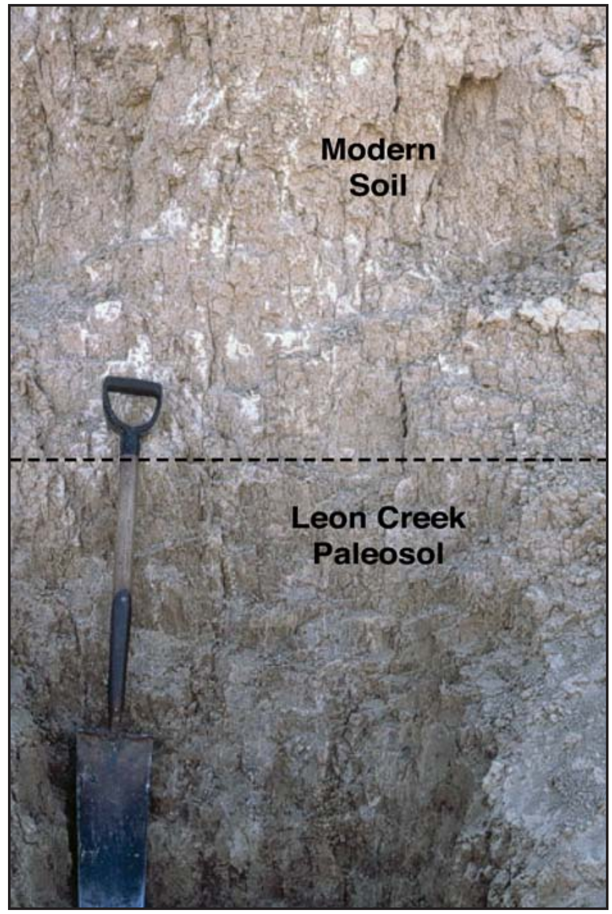


Figure 3.16. Photograph of the Leon Creek paleosol developed in Unit A6 and the modern surface soil developed in Unit A7; welding of the surface soil onto the Leon Creek paleosol has created a gradual boundary between the two soils.

Radiocarbon assays indicate that most of the sediment composing Unit A6 accumulated between ca. 4100 and 3200 B.P. Wood charcoal from a tree burn on or near a Middle Archaic occupation surface at the bottom of Unit A6 yielded a ^{14}C age of 4135±70 B.P. (Beta-43330). Rapid overbank deposition after ca. 4100 B.P. sealed the Middle Archaic component in and below laminated alluvium that composes the lower 70 cm of Unit A6. Aggradation of Unit A6 ceased about 900 years later based on a ^{14}C age of 3210±90 B.P. (Tx-6470 and Tx-6471) determined on soil carbon from the lower 20 cm of the Bkb1 horizon at separate localities in the Applewhite project area (Mandel et al. 2008). Charcoal from an oven-like feature in the upper 25 cm of the Leon Creek paleosol at Richard Beene yielded a ^{14}C age of 3090±70 B.P. (Beta-36702). Radiocarbon ages determined on soil carbon from the upper 20 cm of this paleosol at three separate localities in the Applewhite project area are as follows: 3050±70 (Tx-6466), 2810±80 (Tx-6567), and 2740±80 B.P. (Tx-6569) (Mandel et al. 2008). Hence the Leon Creek paleosol represents about 500 years of soil development.

Unit A7

Unit A7 is the uppermost stratigraphic unit beneath the Applewhite terrace. It consists of levee deposits that become thinner and finer grained from the scarp to the tread of the terrace. Although Unit A7 is only 51 cm thick in the profile at the Richard Beene site, it is as much as 1.5 m thick at several other localities that were studied in the Applewhite project area (Mandel et al. 2008). This unit includes all sediment between the present terrace surface and the first buried soil (Leon Creek paleosol).

As noted earlier, the modern surface soil is developed through Unit A7 and the upper part of Unit A6 (Figure 3.16). This soil is a well-drained mollisol with a weakly expressed A-Bk profile (Table 3.1). Most of the A horizon was stripped off by heavy equipment during the construction of the trench at 41BX831. However, at undisturbed localities the A horizon typically is 25 cm thick and is a dark grayish brown (10YR 4/2, dry) to dark brown (10YR 3/3, dry) clay loam (Table 3.1). The Bk horizon is a brown (10YR 4/3, dry) clay loam with weak, medium prismatic structure that parts to moderate, fine and medium subangular blocky structure.

Complex soil development characterizes the lower part of the Bk horizon. Based on physical and chemical data (Tables 3.1 and 3.2), the Bk horizon is welded to the A horizon of the Leon Creek paleosol. This accounts for the prismatic structure in the Akb1 (Bk) horizon. Also, the grain-size data reveal a distinct clay peak in the lower 18 cm of the A horizon of the Leon Creek paleosol (Table 3.2).

Carbonate morphology is weak (stage I) throughout the Bk horizon of the modern soil, including the portion that is welded to the Leon Creek paleosol. Fine fluffy filaments of calcium carbonate cover 1–5 percent of each ped surface in the Bk1 horizon. These filaments become coalesced and cover more surface area of each ped (10–20%) in the Bk2 horizon and upper 103 cm of the Leon Creek paleosol.

The upper 51 cm of the modern soil has a well-defined depth trend of organic C; it steadily decreases from 1.26 percent in the Ap horizon to 0.79 percent in the lower 7 cm of the Bk2 horizon (Table 3.3). However, as noted earlier, organic C increases in the upper 18 cm of the horizon due to welding of the modern soil to the A horizon of the Leon Creek paleosol. Organic C drops off again below the Akb1 horizon and steadily decreases to a low of 0.06 percent in the CBb1 horizon.

The calcium carbonate content is high throughout the surface soil, ranging from 49.6 percent in the Ap horizon to 53.2 percent in the CB horizon (Table 3.3). Hence primary calcium carbonate has not been leached from the solum.

Based on radiocarbon ages determined on charcoal from the top of the Leon Creek paleosol, the alluvium comprising Unit A7 accumulated after ca. 3000 years B.P. The presence of Late Prehistoric cultural materials in the upper 40 cm of Unit A7 indicates that the rate of sedimentation dramatically decreased on the Applewhite terrace between 1200 and 400 years B.P. Thoms (Chapter 4) suggests that the apparent absence of Late Prehistoric features in Unit A7 is due to slow rates of deposition and to signifi cant bioturbation in the upper part of this unit during the past millennium.

Summary of the Soil Stratigraphy in the Richard Beene Section

In a gross sense, all of the soils in the Richard Beene section are monotonously similar. The section consists mainly of clay loams and silty clay loams, punctuated occasionally by loam or fine sandy loam C horizons. The entire section is calcareous, but some differences were noted in distribution of secondary calcium carbonate forms. The dominant secondary carbonate forms are coalesced carbonate filaments, and occasionally "fluffy," non-coalesced carbonate filaments were observed. The Somerset paleosol is capped by a thin, laminar petrocalcic horizon. Secondary carbonates also line many depletion tubules throughout the section, representing zones of iron loss along old root channels apparently caused by seasonal reduction.

Soil Morphology

Excluding the petrocalcic horizon of the Somerset paleosol, none of the soils evinced particularly advanced stages of soil development. There were no zones where carbonates had been leached, for example, and carbonate morphology varied only slightly in degree, hardly at all in kind. Even below the thin petrocalcic cap, carbonate and general soil morphology is similar to the soils above. The Perez paleosol was slightly reddened with respect to the other units (7.5YR versus 10YR), but this color difference is not pronounced.

Calcium Carbonate Equivalent

Most of the samples averaged about 50 percent $CaCO_3$, with an anomalous low value (20%) in the lower part of the Perez paleosol and upper part of Soil 6. There is no evidence of leaching or major redistribution of $CaCO_3$ in the Richard Beene section (Figure 3.17).

Organic Carbon

None of the samples had particularly high concentrations of organic C. Because these samples had relatively high $CaCO_3$ values and low organic C values, there is an inherent analytical error given the precision of the respective laboratory procedures. Acceptable error limits of the Chittick procedure for $CaCO_3$, as run in the Texas A&M University Soil Characterization Laboratory, range to 3 percent of replicate samples. A 3 percent relative error or variance at 50 percent $CaCO_3$ translates to a possible 0.18 percent organic C error, a significant figure when dealing with the low values found in this section. Hence, depth trends may not be as transparent as they would with greater precision. The upper part of each paleosol shows an increase in organic C with respect to the overlying materials (with the exception of the Somerset laminar cap), but depth trends are not always consistent (Figure 3.18). The lack of depth trend, of course, may also be due to the uneven character of soil development expected under cumulic processes and weak development.

Only the modern surface soil and Leon Creek paleosol show a well-defined depth trend of organic C with depth (Figure 3.17). A cumulic soil, by definition, has an irregular depth trend in organic C (fluventic subgroups) (Soil Survey Staff 1992). The irregular trend of organic C with depth throughout most of the Richard Beene section thus underscores the cumulic nature of the soils. Except for the Somerset paleosol, the uppermost part of each buried soil has a higher concentration of organic C with respect to underlying and overlying sediments. The Elm Creek paleosol, the least developed of the Holocene soils, has the most irregular organic C distribution. Soils 6, 7, and 8, also considered to be weakly developed, show somewhat consistent internal depth trends of decreasing organic C with depth, except for the base of Soil 6. The very low value in the Somerset paleosol corresponds to the laminar cap or petrocalcic horizon.

Particle-Size Distribution

Most of the sediments in the Richard Beene section are silty clay loams, silt clays, and clay loams. Mean

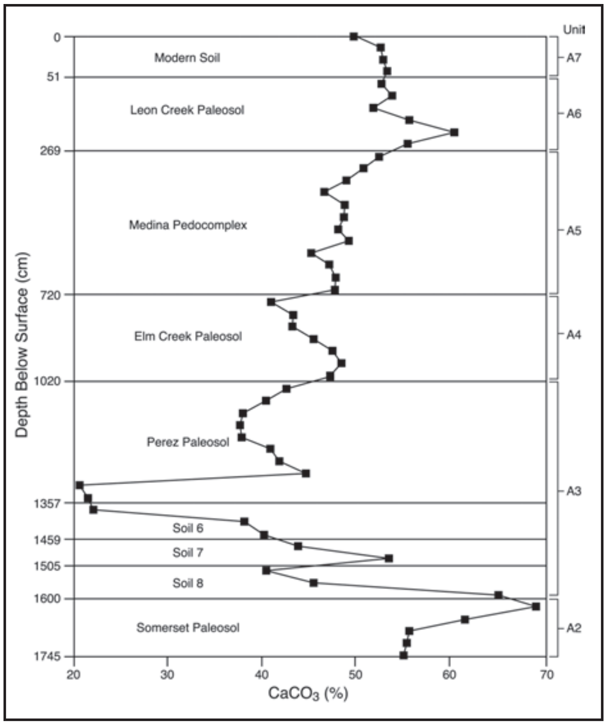


Figure 3.17. Diagram showing the depth trend of calcium carbonate ($CaCO_3$).

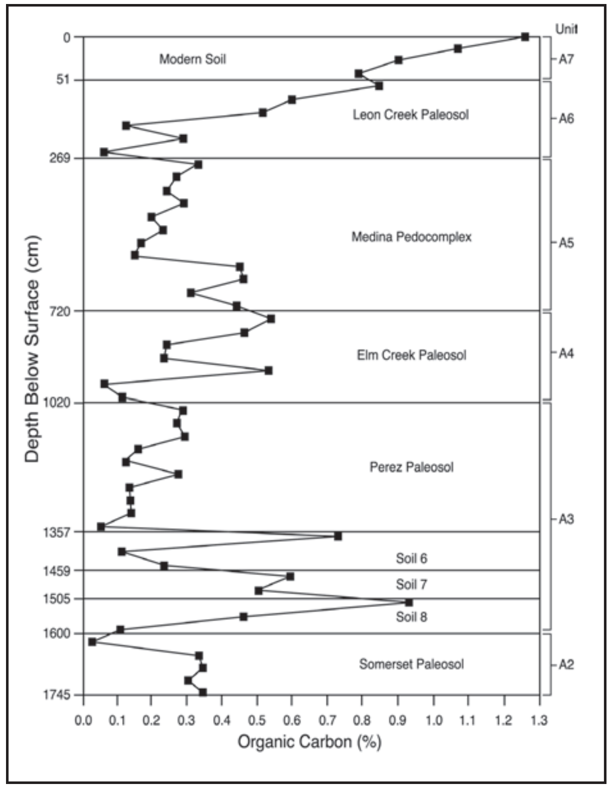


Figure 3.18. Diagram showing the depth trend of organic carbon.

particle diameter was graphed to analyze relative changes with depth (Figure 3.19) and serves as a summary variable for the somewhat complex particle-size data. The mean diameter graph shows a relatively homogeneous distribution with depth except for three prominent divergences: order of magnitude increases at the bottom of the Leon Creek paleosol, the bottom of the Perez paleosol, and the top of Soil 6. There is a less-pronounced peak at the top of the Somerset paleosol. The Leon and Perez peaks correspond to relatively well-defined sandy C and CB horizons, while the peak in the Somerset paleosol is less well defined texturally.

Micromorphology

The primary objective of the micromorphic analysis was to examine differences in pedogenesis, particularly differences in carbonate morphology. All of the thin sections examined are dominated by a "crystallic" fabric, the result of an abundance of finely disseminated particles of $CaCO_3$. Secondary carbonate forms observed included acicular, or needle-shaped, $CaCO_3$ crystals in voids, "pseudosparitic" crystals along void walls, and fabric reorganization along voids. Pseudosparitic coats consisted of 5–15 μm crystals along void walls (the usual definition of sparite is crystals greater than 15 μm). These coats may correspond to encrusted carbonate filaments in the macromorphic descriptions. Sand and silt-sized fragments of $CaCO_3$ have obvious fossils, suggesting a clastic origin. In general, it was not possible to quantify differences in secondary carbonates. The C and CB horizons generally have fewer developed secondary carbonates than the Bk horizons, although these are not pronounced differences. The Leon Creek and Somerset paleosols probably have the most distinct secondary carbonates. Nests of acicular carbonate crystals are common in both of these soils.

Analysis of Stable Carbon Isotopes: Theory

Analysis of stable carbon isotopes in soils has been successfully used in many paleoenvironmental studies (e.g., Ambrose and Sikes 1991; Fredlund and Tieszen 1996; Guillet et al. 1988; Kelly et al. 1991, 1993; Krishnamurthy et al. 1982; Nordt 1993, 2001;

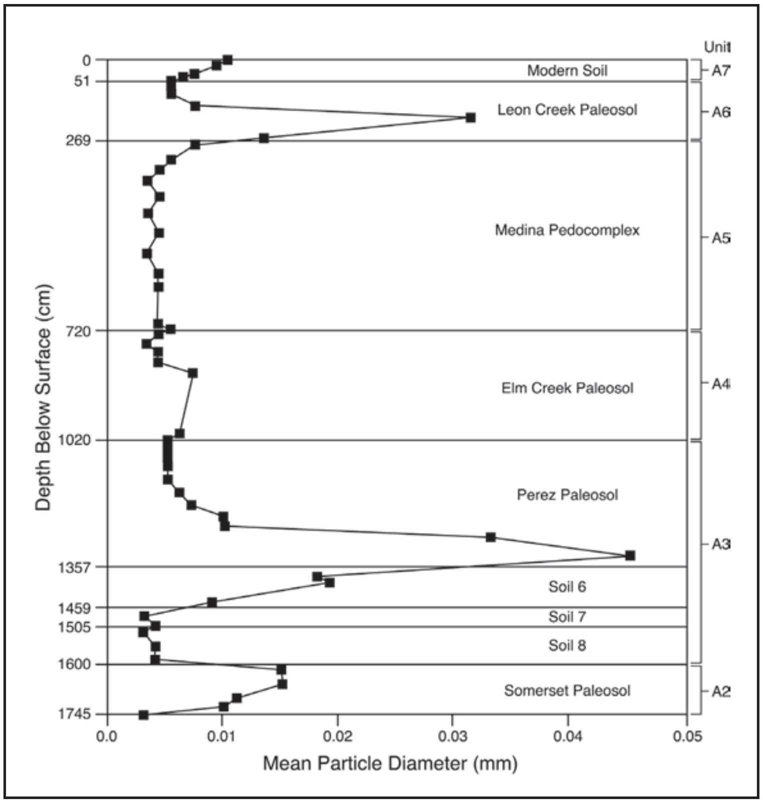


Figure 3.19. Diagram showing the depth trend of mean particle diameter.

Nordt et al. 1994; Schwartz et al. 1986; Schwartz 1988). To understand the theory behind this analytical technique, the ecology of C_3 and C_4 plants must be considered. During photosynthesis, C_4 plants discriminate less against $^{13}CO_2$ than C_3 plants (O'Leary 1981; Vogel 1980). This difference in carbon isotope fractionation results in a char-acteristic carbon isotope ratio in plant tissue that serves as an indicator for the occurrence of C_3 and C_4 photosynthesis (Nordt 1992:52, 2001:421–423). Boutton (1991a) reported that $\delta^{13}C$ values of C_3 plant species have a mean of 27 percent, whereas the $\delta^{13}C$ values of C_4 plant species have a mean of 13 percent. Thus, C_3 and C_4 plant species have distinct, nonoverlapping $\delta^{13}C$ values and differ from each other by approximately 14 percent (Boutton 1991b).

Nearly all trees, shrubs, forbs, and cool season grasses are C_3 species. Hence forests and most other temperate plant communities are dominated by C_3 species. Plants with the C_4 photosynthetic pathway are common in warm, subtropical environments with high light intensity, such as grasslands, savannahs, deserts, and salt marshes. Studies have shown that both the proportion of C_4 species and the proportion of C_4 biomass in a given plant community are strongly related to environmental temperature (Boutton et al. 1981; Teeri and Stowe 1976; Tieszen et al. 1979). These relationships are invaluable in paleoecological studies when the relative proportions of C_3 versus C_4 species can be reconstructed (Nordt et al. 1994, 1995, 2002).

There is little change in the carbon isotopic composition of plant litter as it decomposes and is incorporated into the soil organic matter (Melillo et al. 1989; Nadelhoffer and Fry 1988). Consequently, the isotopic composition of soil organic matter reflects the dominant species (C_3 versus C_4) in the plant community that contributed the organic matter (Dzurec et al. 1985; Nadelhoffer and Fry 1988; Stout and Rafter 1978). The stable carbon isotopic composition of soil organic matter in surface soils and buried paleosols may, therefore, be used to infer vegetation change (Hendy et al. 1972; Krishnamurthy et al. 1982; Nordt et al. 1994). Going one step further, the stable carbon isotopic values may be used to reconstruct climates.

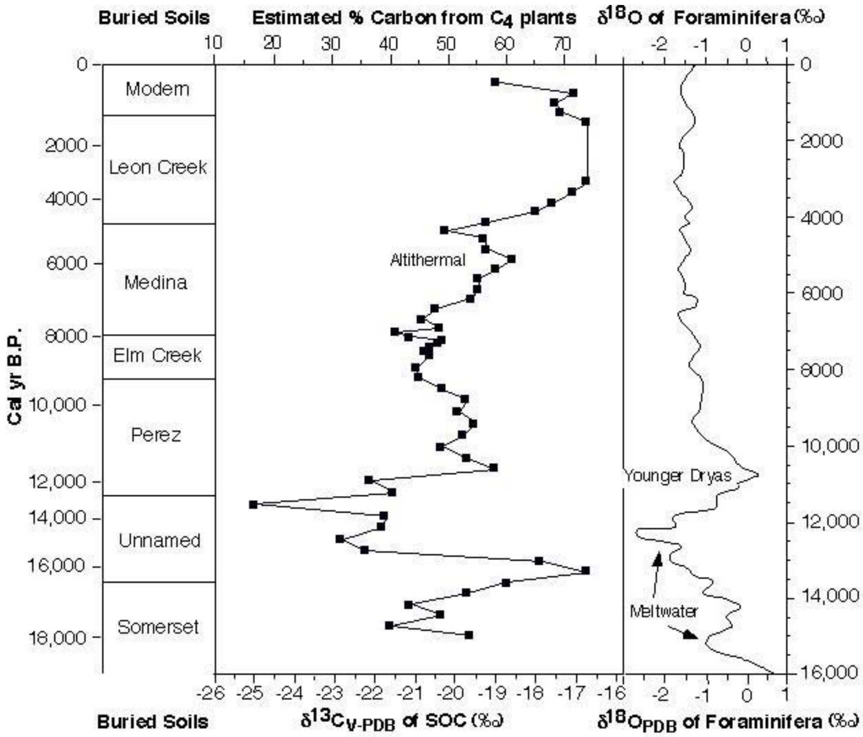


Figure 3.20. $\delta^{13}C_{V}$-^{pdb} values of soil organic carbon (SOC) in the sequence of buried soils; values are shown with respect to buried soil, calendar years (left axis), radiocarbon years (right axis), and $\delta^{18}O_{PDB}$ values of foraminifera in the Gulf of Mexico (values from Leventer et al. 1982, for core EN32-PC6, with chronology modified by Flower and Kennett 1990); the proportion of organic carbon derived from C_4 plant production (top axis) was estimated by mass balance calculations (from Nordt et al. 2002).

The stable carbon isotopes from soils at the Richard Beene site are presented in Nordt et al. (2002). These results are summarized in the following discussion and are compared to other paleoenvironmental data for the site and region.

Before presenting the results of the isotope analysis, it is important to consider some of the characteristics of the paleosols at the Richard Beene site. As already noted, there is a sequence of buried soils beneath the Applewhite terrace. These soils formed in sediments deposited in a slowly aggrading flood basin setting. With the exception of the Somerset paleosol, there are no erosional unconformities. All the buried soils formed from carbonate-rich alluvium with textures consisting mainly of silty clay loam, loam, clay loam, and sandy clay loam. The calcium carbonate content of detrital alluvium, derived from surrounding Cretaceous bedrock, ranged from approximately 20 to 55 percent, with minor redistribution into secondary carbonate forms. The buried soils have weakly expressed A-Bw or A-Bk horizonation and formed during a few hundred years of pedogenesis prior to burial. The exception is the Leon Creek paleosol that formed during 1,000–1,500 years of quasi landscape stability. The absence of redoximorphic features indicative of frequent saturation in the buried soils reduces the possibility that riparian vegetation was a major factor during landscape evolution at the Richard Beene site.

Organic carbon concentrations range from 1.2 percent to 0.1 percent throughout the buried soil sequence and decrease with depth in each soil (Table 3.3; Figure 3.18). Although some of the organic carbon in the soils is detrital, this is not problematic for interpreting the $\delta^{13}C$ values. The Medina River drainage basin encompasses a relatively uniform ecosystem such that any detrital organic carbon transported into the alluvium is largely derived from eroded upland soils that formed in equilibrium with the same climate as the Medina River alluvial soils. Thus, the pedogenic and detrital organic components should provide a similar record of the paleovegetation. $\delta^{13}C$ values of organic carbon from soils at the Richard Beene site ranged from -16.7 to -25.1 percent during the last ca. 15,000 years (Figure 3.20). These data indicate that plant communities at the site varied from strongly C_3 dominated to strongly C_4 dominated. It is likely that these changes in vegetation were in response to regional climatic change.

From ca. 15,000 to 10,000 B.P., $\delta^{13}C$ values of soil organic carbon show large and rapid fluctuations as summer solar insolation began to increase following the last glacial maximum (COHMAP 1988) (Figure 3.20). At the Richard Beene site, this period was characterized by floodplain sedimentation (lower Unit A3) punctuated by soil development (Soils 6, 7, and 8). Distinct periods of low relative C_4 productivity occurred between ca. 15,500 and 14,000 B.P. and between ca. 13,000 and 11,000 B.P., which correlates with two well-documented episodes of glacial meltwater flux from the Laurentide ice sheet into the Gulf of Mexico via the Mississippi River. These meltwater spikes were recorded as negative $\delta^{18}O$ anomalies (Figure 3.20) in foraminifera from Gulf sediments (Kennett et al. 1985; Leventer et al. 1982; Spero and Williams 1990). It appears that cold water inputs into the Gulf of Mexico resulted in cooler climatic conditions at least as far inland as the Richard Beene site, thereby reducing the relative productivity of C_4 grasses during the two meltwater episodes.

There is a distinct period of high relative C_4 productivity between ca. 11,000 and 10,500 B.P. (Figure 3.20). It is likely that accumulation of sediment composing the C horizon of the Perez paleosol was underway at this time. The increase in C_4 productivity, implying warmer temperatures, corresponds precisely with significant reduction in cold meltwater flow into the Gulf of Mexico (Broecker et al. 1989; Spero and Williams 1990; Teller 1990) and perhaps to greater summer monsoonal precipitation and temperatures (COHMAP 1988). In north-central Texas, $\delta^{18}O$ and $\delta^{13}C$ values of pedogenic $CaCO_3$ indicate higher temperatures and high relative C_4 productivity, respectively (Humphrey and Ferring 1994). In central Texas, fossil vertebrates (Toomey et al. 1993) and fossil pollen (Bryant and Holloway 1985) indicate higher mean annual precipitation. However, Holliday (2000) documents high C_4 plant production and temperatures between 11,000 and 10,000 B.P. on the Southern Great Plains that correlates with episodic drought as indicated by the emergence of upland eolian deposits. Regardless of moisture availability, all evidence points to increasing temperatures in most of Texas between 11,000 and 10,500 B.P.

Between 10,500 and 9000 B.P., when aggradation of Unit A3 was slowing down, relative C_4 productivity initially decreased, then increased slightly (Figure 3.20). However, between 9000 and 8600 B.P., which includes the period when the Perez paleosol developed (ca. 8800–8600 B.P.), $\delta^{13}C$ values of soil carbon decrease, suggesting an increase in relative C_3 productivity and, therefore, cooler temperatures.

There are no dramatic shifts in $\delta^{13}C$ values of soil organic carbon between 8600 and 7000 B.P. (Figure 3.20); a mixed C_3/C_4 plant community was in place. Unit A4 aggraded and the Elm Creek paleosol formed during this period. However, $\delta^{13}C$ values of soil organic carbon decreased appreciably at ca. 7000 B.P., evidence of a cooling trend. The interval from 8000–7000 B.P. has recently been recognized as the most prominent and globally widespread cold period in the past 10,000 years (Barber et al. 1999; Hu et al. 1999).

Between 7000 and 5000 B.P. $\delta^{13}C$ values of soil organic matter steadily increase (Figure 3.20), indicating more relative C_4 productivity compared to the early Holocene. This warm interval correlates with the well-known warm, dry Altithermal of the North American Great Plains. At the Richard Beene site, it is marked by aggradation of the thickest package of fine-grained alluvium (Unit A5/Medina pedocomplex) in the stratigraphic sequence. Hence, increased aridity, punctuated by infrequent but intense rainfalls characteristic of the region (Chapter 2), generated high sediment yields in the Medina River basin.

For a brief period after ca. 5000 B.P., $\delta^{13}C$ values sharply decreased (Figure 3.20), indicating reduced relative C_4 productivity and temperatures compared to the Altithermal. The latter stage of pedogenesis in the Medina pedocomplex at the top of Unit A5, the aggradational phase of Unit A6, and the development of the Leon Creek paleosol span this period. Dramatic cooling after 5000 B.P. is also indicated by the $\delta^{13}O$ values of carbonate from mussel shells in the Leon Creek paleosol, with the most extreme values, and therefore the lowest mean annual temperatures, dated to ca. 4100 B.P. (Chapter 6). Also, $\delta^{13}C$ values of snail shell carbonate suggest cooling and/or more mesic conditions from ca. 4500 to 4000 B.P. (upper Medina pedocomplex and lower Leon Creek paleosol) (Chapter 7). The occurrence of a cool interval in the study area immediately following the Altithermal is supported by fossil pollen data showing an increase in tree cover beginning at ca. 5000 B.P. and continuing to at least 3000 B.P. (Bousman 1998a).

At Richard Beene, $\delta^{13}C$ values of soil organic carbon increased dramatically between 4000 and 1500 B.P. (Figure 3.20), pointing to another period of high relative C_4 productivity and temperature. The final stage of pedogenesis in the Leon Creek paleosol at the top of Unit A6, and the aggradation phase of Unit A7, span this period. The isotopic signals from snail shell carbonates suggest that, for the Holocene record, the warmest and/or driest conditions were reached between 4000 and 3000 B.P. (Chapter 7). Isotopic data for mussel shells also indicate a warming trend after ca. 4000 B.P. (Chapter 6).

A general trend toward lower $\delta^{13}C$ values after ca. 1500 B.P. (Figure 3.20) suggests that the climate was becoming slightly cooler, although conditions were still relatively warm. During this period, the modern surface soil formed in Unit A7. The isotopic signals from snail shell and mussel shell carbonates also suggest slight cooling during the past 1,500 years (Chapters 6 and 7).

The stable carbon isotope values from Richard Beene demonstrate the potential for this technique to provide detailed information on the paleoenvironment of the site and the region. Several issues important to interpretation of these data can be addressed with further stable carbon isotope analyses. To accurately interpret the isotopic values in terms of standing vegetation and thereby climate change, it is important to understand the nature of local variability of isotopic composition of the soil organic carbon. Vegetation varies across landscapes, and we must therefore have a better understanding of how this variation translates into variations in buried soil organic carbon. The Richard Beene site provides a unique natural experiment for this study because there are microtopographic variations among the different buried soils. Therefore, various paleotopographic positions on past landscapes can be sampled and analyzed to see how local topographic (edaphic) conditions influence carbon isotopic composition. This analysis could also be extended to other localities to further study local variations. Once local variation/variability is better understood, stable carbon isotope profiles could be used as a correlation aid for linking localities together and for evaluating the relative time span represented by stratigraphic sections.

4

EXCAVATION AREAS AND SITE-FORMATION CONTEXTS

Alston V. Thoms

This chapter places the various excavation areas or blocks within the site's pedostratigraphic context as defined and discussed in Chapter 3. It also characterizes preservation conditions and discusses site formation processes, thereby setting the stage for subsequent chapters that discuss the site's paleoecological indicators and archaeological assemblages. Excavation blocks at the Richard Beene site were designated alphabetically according to the sequence in which they were first identified, beginning with Block A, composed of two middle Holocene occupation "surfaces," and ending with Block U, a middle Holocene occupation "zone." Other blocks, from B through T, sampled late and early Holocene as well late Pleistocene deposits. Figure 4.1 illustrates the location of the excavated blocks in plan view. Table 4.1 summarizes pedostratigraphic, chronological, and related site preservation data for each block.

As used herein, occupation "surface" refers to a discrete lens of cultural material, less than 30 cm thick, that contained well-preserved features and artifact concentrations. Based on our field examinations and subsequent analytical work, artifacts from the best preserved "surfaces" (e.g., Block G) were distributed through as much as 30 cm of the profile and may represent a single occupation or, more likely, several occupations spanning several decades at most. This magnitude of vertical distribution of artifacts, which represents an arguably discrete occupation(s), is quite common and results primarily from bioturbation (Johnson 2002), as well as argilliturbation (Wood and Johnson 1978). The term occupation "zone" is used to designate lenses of cultural material more than 30 cm thick that exhibit a continuous vertical distribution of artifacts and features (e.g., Block B), which appear to represent several occupations probably spanning several centuries. In other cases, "zones" represent eroded surfaces and "lag concentrations" of artifacts originally deposited over several decades or perhaps centuries (e.g., Block H).

At the Richard Beene site, nine substantial block excavation areas range in size from about 15 m^2 to just over 230 m^2. These included, from youngest to oldest, upper and lower B, upper and lower A, G, I, H, N, and T (Figure 4.1). Block B is subdivided into upper and lower portions, with the upper portion (late, late Holocene, ca. 1200–400 B.P.) embedded in the modern soil (stratigraphic Unit A7, see Chapter 3) and the lower portion in the Leon Creek paleosol, which dates two millennia earlier (Unit A6). Block A, middle Holocene in age, is also subdivided based on encompassing paleosols but, in this case, the lower portion—within the B horizon of the Medina pedocomplex (Unit A5)—is only a few centuries older than the upper portion, which is encased in the B/C horizon of the overlying Leon Creek paleosol (Unit A6) that dates to about 4100 B.P. Cultural materials in each of the other excavation blocks are readily assignable to a single paleosol. In Block H, early, early Holocene in age (ca. 8800–8600 B.P.), the relationship between age of archaeological deposits and their position within a paleosol is complex. Much of the material was recovered from the C horizon of the Elm Creek

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 61-86. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

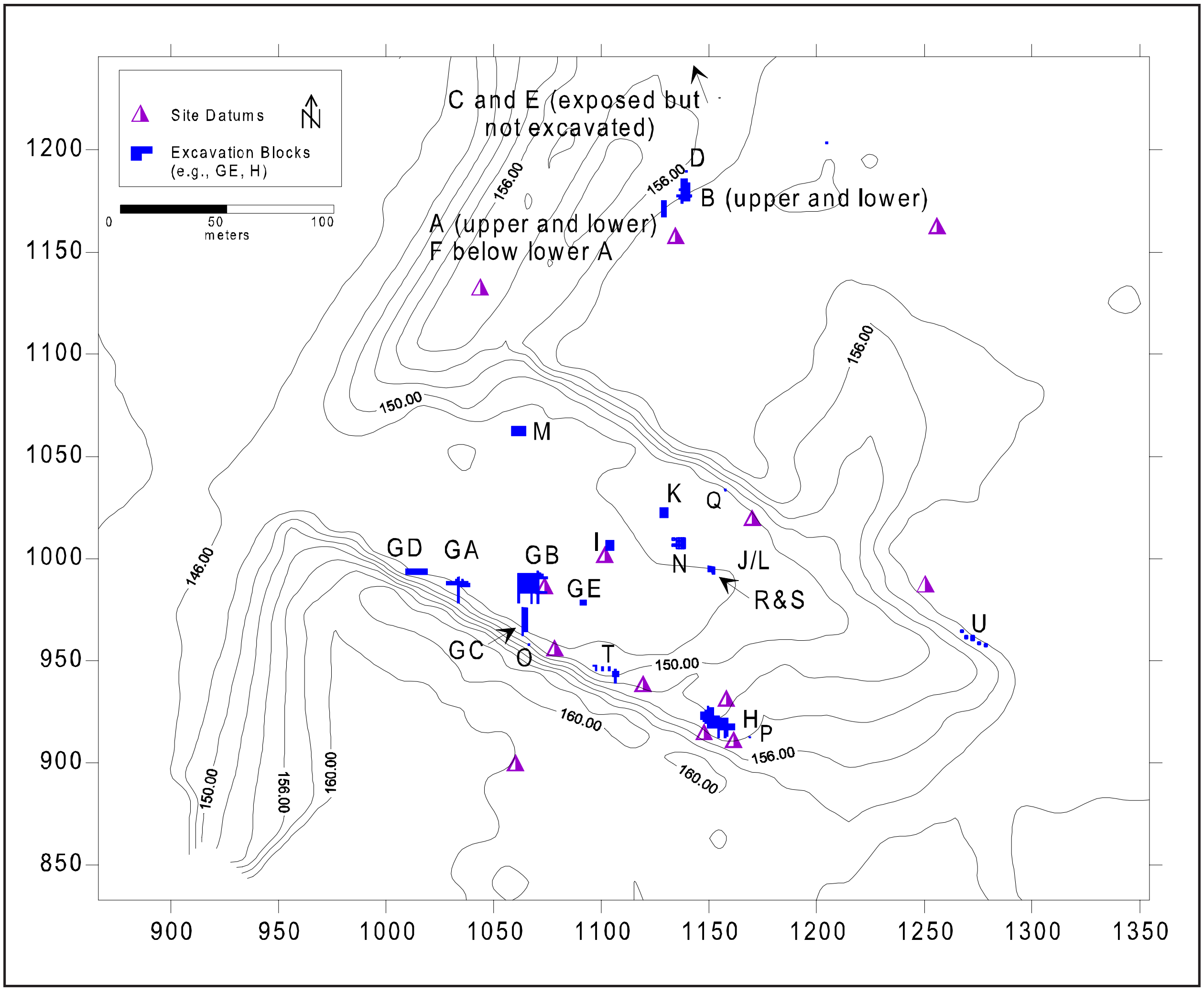


Figure 4.1. Planview topographic map showing locations of excavation blocks and mapping surfaces (J/L).

paleosol (Unit A4), which included redeposited sediments and artifacts from the upper part of the Perez paleosol (upper Unit A3).

Scattered artifacts and isolated features were also recovered in eight smaller blocks, ranging in size from 1 to 6 m^2—U, D, F, P, O, K, M, and Q—and distributed throughout the Medina pedocomplex and the Elm Creek and Perez paleosols (Figure 4.1). Block D, located in the upper Leon Creek paleosol northeast of Block B, was opened and partially shovel-skimmed, which resulted in the recovery of a few flakes and pieces of fire-cracked rocks (FCR) and mussel shell. Block F, located 1.5 m below lower Block A in the middle portion of the Medina paleosol, was identified in profile, and a small unit was opened over a possible hearth feature (oxidized sediment and FCR). Further excavations in Blocks D and F were not undertaken due to time constraints that developed after discovery of extensive cultural deposits in Block G.

Two other small areas—Blocks R and S—were excavated in late Pleistocene deposits that yielded an abundance of paleontological remains but lacked definite cultural remains (Figure 4.1). Blocks R and S were the deepest excavations at the site (14.5–15.0 m below surface). They sampled paleosols 6, 7, and 8 in the lower portion of stratigraphic Unit A3. Blocks E, a livestock bone bed in the modern soil, and C, a scatter of mussel shells and FCR in the upper part of the Leon Creek paleosol, were opened at the downstream end of the site but not excavated due to time constraints. “Blocks” J and L

Table 4.1. Summary of pedostratigraphic, chronological, and related site-preservation data for block-excavation areas.

Block (avg. elev. m asl)	Temporal designation (^{14}C age)	Paleosol, horizon (strat. unit)	Feature preservation condition	Artifacts in vert. repose	Stream-worn pebbles	Snail concen-trations	Root casts and krotovina	Tree-burn charcoal	Burned sediments	Overall assess. block preservation
E, gully (159–153m)	modern gully fill; late 19th–early 20th century	Gully fill, A and A/B (Unit A7)	good; bone bed recent	unknown	unknown	unknown	unknown	unknown	unknown	good; observed livestock bone
upper B (160.5 m)	late, late Holocene; 1200–400 B.P. (est.)	Modern soil, (aka Payaya) Ap–Bk1 (Unit A7)	poor to moderate	few	few	scattered only	common	common	few	poor to moderate
lower B (159.0 m)	early, late Holoc.; 3200–2800 B.P.	Leon Creek, Bk3(Ab1) (Unit A6)	moderate	common	few	few to common	common to abundant	common	few to common	moderate
C (159.0 m)	early, late Holoc.; 2500 B.P. (est.)	Leon Creek, Bk3(Ab1) (Unit A6)	moderate	unknown	unknown	unknown	unknown	unknown	unknown	undetermined; observed mussel shell/FCR fea.
D (154.5 m)	early, early Holoc.; 2800 B.P. (est.)	Leon Creek, Bk3(Ab1) (Unit A7)	none observed	few	few	scattered only	few	absent	absent	undetermined
upper A (157.0 m)	middle Holocene; 4135 B.P.	Leon Creek, CB (Unit A6)	good	few	few	scattered only	common	common	few to common	good
lower A (156.5 m)	middle Holocene; 4570 B.P.	Medina, ABkb2 (Unit A5)	good	few	few	few	common to abundant	common	few	good
U (156.7 m)	middle Holocene; 4510 B. P.	Medina, ABkb2 (Unit A5)	poor	common	few	scattered and in rills	few	few	few	poor to moderate
F (155.0 m)	late, early Holoc.; 5400- 6400 B.P (est.)	Medina, Bk2b2 (?) (Unit A5)	good	unknown	unknown	unknown	unknown	unknown	unknown; common in feature	good; observed FCR feature
G (153.5 m)	late, early Holoc.; ca. 6900 B.P.	Medina, Bk3b2 (Unit A4)	good	few	few	common to abundant	few	common	common	good

continued

Table 4.1. Continued.

Block (avg. elev. m asl)	Temporal designation (^{14}C age)	Paleosol, horizon (strat. unit)	Feature preservation condition	Artifacts in vert. repose	Stream-worn pebbles	Snail concen-trations	Root casts and krotovina	Tree-burn charcoal	Burned sediments	Overall assess. block preservation
P (153.29–151.2 m)	middle, early Holoc.; 8500-7500 B.P. (est.)	Elm Creek all horizons (Unit A4)	none observed	few	few	scattered only	few	absent	few	poor
O 150.9 m	mid., early Holoc.; 7645 B.P.	Elm Creek, Bk1–2b3 (Unit A4)	good	unknown	unknown	unknown	unknown	unknown	unknown; common in feature	good; observed FCR feature
I 150.45 m	mid., early Holoc.; 7800 B.P. (est.)	Elm Creek, Bk1–2b3 (Unit A4)	none observed	rare	few	scattered only	absent	rare	absent	moderate; very low artifact density
K 150.35 m	mid., early Holoc.; 8080 B.P.	Elm Creek, Bk1–2b3 (Unit A4)	good	few	few	scattered only	rare	absent	unknown; common in feature	good; FCR feature only
M 148.25 m	mid., early Holoc.; 7740 & 7645 B.P.	Elm Creek, Bk1–2b3 (Unit A4)	good	few	few	scattered only	rare	absent	unknown; common in feature	good; FCR feature only
H 151.0 m	early, early Holoc.; 8600–8800 B.P. (est.)	Elm Creek, Cb3 (Unit A4); Perez Bkb4 (upper Unit A3)	poor	common to abund.	abundant	scattered only	absent in Elm Cr.; abundant in Perez	absent	rare	poor
T 149.5 m	Early, early Holoc.; 8640 & 8805 B.P.	Perez, Bkssb4 (upper Unit A3)	moderate	common	common to abund.	few	common	absent	rare to common	moderate
N 149.0 m	early, early Holoc.; 8810 yr B.P.	Perez, Bkssb4 (upper Unit A3)	none observed	few to common	common	few to common	common	absent	absent	poor to moderate

continued

Table 4.1. Continued.

Block (avg. elev. m asl)	Temporal designation (^{14}C age)	Paleosol, horizon (strat. unit)	Feature preservation condition	Artifacts in vert. repose	Stream-worn pebbles	Snail concen-trations	Root casts and krotovina	Tree-burn charcoal	Burned sediments	Overall assess. block preservation
J (area) 151-148 m	mid., early Holoc; 7200–8500 B.P. (est.)	Perez, all horizons (upper Unit A3)	variable	not recorded	not recorded	not recorded	not recorded	not recorded	not recorded	good to poor, depending on surface/zone
L (area) 151.0–148	early, early Holoc.; 8600–9000 B.P. (est.)	Perez, all horizons (upper Unit A3)	variable	not recorded	not recorded	not recorded	not recorded	not recorded	not recorded	good to poor, depending on surface/zone
Q 147.7 m	early, early Holoc.; 8600–10,000 B.P.	Perez horizon ? (upper Unit A3)	none observed	few	common	scattered only	absent	absent	absent	Moderate
R 145.35 m	late Pleistocene (faunal remains) 12,500 B.P. (est.)	Soil 6, Bk1b5 (lower Unit A3)	good (non-cultural)	absent	few	absent	common	few	common	good
S 145.26 m	late Pleistocene (faunal remains) 12,745 B.P.	Soil 7, Bkb6 (lower Unit A3)	good (non-cultural	absent	few	absent	common	few	common	good

Table 4.2. Radiocarbon ages—conventional, calibrated, and calendar—derived from charcoal in archaeological deposits and features.

Lab Assay No.	Cultural Period	Conventional (^{13}C adjusted) ^{14}C Age B.P.	$^{13}C/^{12}C$ Ratio	Calibrated (1 sigma 68% prob.)	Calendric Age B.P.	Calendric Age B.C.	Block/ BHT	Depth m amsl (m below surf.)	Pedostratigraphic context	Sample Association
BETA 36702	late, Late Archaic	3090±70	n/a	3215–3376	3296±80	1346±80	–	ca. 158.65 m (ca. 1.3–4 m bs)	Upper Leon Creek	Feature 1
BETA 43330	Middle Archaic	4135±70	-24.50	4563–4786	4675±111	2725±111	Upper Block A	ca. 157.5 m (2.5 m bs)	Lower Leon Creek C horizon	tree burn
BETA 38700	Middle Archaic	4570±70	-26.30	5095–5399	5247±152	3297±152	Lower Block A	ca. 157.4 m (2.6 m bs)	Upper Medina	tree burn
AA 20401	Middle Archaic	4380±100 (AMS)	n/a	4884–5208	5046±162	3096±162	Block U	156.71–.61 m (ca. 3.43 m bs)	Upper Medina	isolated frags
GX 21746	Middle Archaic	4430±55 (AMS)	n/a	4937–5222	5080±142	3130±142	Block U	156.71–.61 m (ca. 3.43 m bs)	Upper Medina	diffuse porous
AA 20402	Middle Archaic	4510±110 (AMS)	n/a	4993–5310	5152±158	3202±158	Block U	156.41 m (ca. 3.59 m bs)	Upper Medina	isolated frags
AA 20400	late, Early Archaic	6700±110 (AMS)	n/a	7487–7659	7573±86	5623±86	Block G	153.63 m (ca. 6.37 m bs)	Lower Medina	isolated frags
BETA 47523 ETH 8536	late, Early Archaic	6985±65 (AMS)	n/a	7745–7905	7825±80	5875±80	Block G	153.58 m (ca. 6.42 m bs)	Lower Medina	tree burn
BETA 47524 ETH 8538	late, Early Archaic	6900±70 (AMS)	n/a	7681–7820	7751±69	5801±69	Block Ga	153.63–53 m (ca. 6.42 m bs)	Lower Medina	Feature 30
BETA 47530 ETH 8543	late, Early Archaic	7000±70 (AMS)	n/a	7754–7915	7835±80	5885±80	Block Ge	153.48 –42 m (ca. 6.45 m bs)	Lower Medina	Feature 43
BETA 47525 ETH 8538	late, Early Archaic	6930±65 (AMS)	n/a	7705–7841	7773±68	5823±68	Block Ge	153.44 –30 m (ca. 6.64 m bs)	Lower Medina	Feature 44

continued

Table 4.2. Continued.

Lab Assay No.	Cultural Period	Conventional (^{13}C adjusted) ^{14}C Age B.P.	$^{13}C/^{12}C$ Ratio	Calibrated (1 sigma 68% prob.)	Calendric Age B.P.	Calendric Age B.C.	Block/ BHT	Depth m amsl (m below surf.)	Pedostratigraphic context	Sample Association
BETA 47529 ETH 8542	middle, Early Archaic	7645±70 (AMS)	n/a	8402–8524	8463±61	6513±61	Block O	150.92 m (ca. 9.08 m bs)	Upper Elm Creek	Feature 109
BETA 44386	middle, Early Archaic	8080±130	-26.00	8770–9199	8985±214	7035±214	Block K	150.35 m (ca. 10.65 m bs)	Elm Creek (?)	Feature 64
BETA 78656 CAMS 17625	middle, Early Archaic	7910±60 (AMS)	-25.50	8656–8919	8788±131	6838±131	Block M	148.33–.20 m (ca. 11.68 m bs)	Elm Creek (?)	Feature 80
BETA 78657 CAMS 17626	middle, Early Archaic	7740±50 (AMS)	-25.40	8463–8572	8518±54	6568±54	Block M	148.33–.20 m (ca. 11.68 m bs)	Elm Creek (?)	Feature 80
BETA 80687 CAMS 18801	early, Early Archaic	8640±60	-26.00	9559–9682	9621±61	7671±61	Block T	149.50–.40 m (ca. 10.55 m bs)	Upper Perez Bk horizon	Feature 106
BETA 47527 ETH 8540	early, Early Archaic	8805±75 (AMS)	-25.00	9717–10,071	9894±177	7944±177	Block T	149.45–.28 m (ca. 10.64 m bs)	Upper Perez Bk horizon	isolated frags
BETA 80974 CAMS 19197	early, Early Archaic	8810±60	-24.00	9741–10,069	9905±164	7955±164	Block N BHT 44	149.40 m (ca. 10.6 m bs)	Upper Perez Bk horizon	hull (pecan or hickory)
BETA 47526 ETH 8539	Non-cultural Late Pleistocene fauna	12,745±190 (AMS)	n/a	14,797–16,107	15452±655	13502±65 5	Block S BHT 39	144.26 m (ca. 15.74 m bs)	Upper Soil 7	Feature 95 (natural pit w/ bone)
BETA 47528 ETH 8541	Non-cultural Late Pleistocene floral	32,850±530 (AMS)	n/a	37,316–38,878	38097±781	36147±78 1	BHT 54	147.00 m (ca. 13.0 m bs)	Somerset C horizon, stratified	burned surface

Table 4.3. Radiocarbon ages—conventional, calibrated, and calendar—derived from decalcified bulk soil carbon in paleosols and archaeological features.

Lab Assay No.	Cultural Period	Conventional (^{13}C adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Calibrated (2 sigma, 95% prob.)	Block/ BHT	Depth m amsl (m below surf.)	Pedostratigraphic context	Sample Association
BETA 43332	Middle Archaic	4670±120	-24.00	4980-5640	S. wall of spillway trench	–	Upper Medina	burned surface
BETA 43333	late, Early Archaic	6450±135	-24.20	7020-7600	Block F	ca. 154.0 m (6.0 m bs)	Middle Medina	FCR Feature
BETA 44547	late, Early Archaic	7900±100	-22.60	8460-9010	Block G	153.55 m (6.45 m bs)	Lower Medina	Feature 30
BETA 43334	late, Early Archaic	7600±190	-22.90	7980-8980	Block G	ca. 153.5 m (6.5 m bs)	Lower Medina	mussel shells
BETA 43335	late, Early Archaic	6410±75	-23.70	7100-7460	Block G	ca. 153.5 m (6.5 m bs)	Lower Medina	FCR feature
BETA 44548	late, Early Archaic	7030±100	-23.50	7670-8100	Block G	153.45 m (6.55 m bs)	Lower Medina	Feature 43
BETA 44544	early, Early Archaic	8780±210	-23.00	9330-10,400	Block H BHT 1 (SW wall)	152.92 m (7.08 m bs)	Near bottom of Elm Creek (graded silts)	–
BETA 44545	early, Early Archaic	9200±130	-22.40	9920-10,740	Block H BHT 1 (SW wall)	152.52m (7.48 m bs)	Eroded top of Elm Creek	–
BETA 44541	early, Early Archaic	9170±110	-20.20	9920-10,670	Block N BHT 35 (S wall)	150.33 m (9.67 m bs)	Top of Elm Creek	–
BETA 44387	middle, Early Archaic	8010±70	-25.30	8610-9080	Block K	150.35 m (9.65 m bs)	Elm Creek (?)	Feature 64
BETA 43877	early, Early Archaic	9780±120	-21.00	10,700-11,630	Block H BHT 1	151.15 m (8.85 m bs)	Elm Creek, C horizon (redeposited Perez Bk)	
BETA 43878	early, Early Archaic	9750±130	-21.00	10,640-11,550	Block H BHT 1	151.35 m (8.65 m bs)	Elm Creek, C horizon (redeposited Perez Bk)	

continued

Table 4.3. Continued.

Lab Assay No.	Cultural Period	Conventional (^{13}C adjusted) ^{14}C B.P. Age	$^{13}C/^{12}C$ Ratio	Calibrated (2 sigma, 95% prob.)	Block/ BHT	Depth m amsl (m below surf.)	Pedostratigraphic context	Sample Association
BETA 44546	early, Early Archaic	9800±140	-20.10	10,690-11,900	Block H BHT 36 (E wall)	150.89 m (9.11 m bs)	Top of Perez	
BETA 44542	early, Early Archaic	9670±120	-20.30	10,600-11,260	Block N BHT 35 (S wall)	149.10m (10.9 m bs)	Top of Perez	–
BETA 44543	early, Early Archaic	10,780±140	-20.80	12,340-13,150	Block N BHT 35 (S wall)	148.76 m (11.24 m bs)	Lower Perez	–
BETA 47564	early, Early Archaic	9660±100	-21.00	10,700-11,220	Block T BHT 48	149.67m (10.33 m bs)	Perez Bk horizon	–
BETA 47565	early, Early Archaic	9870±120	-20.60	10,790-11,940	Block T BHT 48	149.39 m (10.61 m bs)	Perez Bk horizon	–
BETA 47566	early, Early Archaic	10,040±120	-20.50	11,200-12,270	Block T BHT 48	149.18 m (10.82 m bs)	Perez Bk, horizon	–
BETA 47567	early, Early Archaic	10,130±120	-20.70	11,260-12,320	Block T BHT 48	148.85 m (11.15 m bs)	Perez Bk, horizon	–
BETA 47558	Non-cultural; Late Pleistocene fauna	13,480±360	-24.30	14,760-17,210	Block R BHT 39	145.34m (14.66 m bs)	Upper Soil 6	–
BETA 47559	Non-cultural; Late Pleistocene fauna	13,640±210	-26.60	15,640-17,140	Block S BHT 39	144.44m (15.56 m bs)	Upper Soil 7	–
BETA 47560	Non-cultural; Late Pleistocene fauna	13,960±150	-19.70	16,180-17,340	Block S BHT 39	143.94 m (16.06 m bs)	Soil 8	–
BETA 47561	Non-cultural; Late Pleistocene fauna	15,270±170	-20.90	17,610-18,950	Block S BHT 39	143.54 m (16.46 m bs)	Soil 8	–
BETA 47563	Non-cultural; Late Pleistocene floral	20,080±560	-22.60	22,390-24,000	BHT 57 (E wall)	146.68 m (13.32 m bs)	Somerset, C horizon, stratified	–

refer to areas within the spillway trench where artifacts and features, exposed in the Perez paleosol during construction, were mapped and collected.

Radiocarbon Ages for Paleosols, Block Excavation Areas, and Archaeological Features

The site's archaeological and paleontological remains, as well as its paleosols, are well dated by 44 radiocarbon ages, 24 of which are derived from total decalcified soil carbon. Soil-carbon (i.e., decalcified organic carbon) ^{14}C ages are all in correct chronological order (Chapter 3), as are the 20 ages from wood charcoal, including 12 obtained by the AMS technique. Table 4.2 lists the site's ^{14}C ages derived from wood charcoal, their vertical and horizontal proveniences, and their pedostratigraphic and cultural contexts. Table 4.3 provides similar information for ^{14}C ages derived from soil carbon.

In general, ^{14}C ages derived from soil carbon in sediments encasing cultural material are about 1,000 years older than ages derived from wood charcoal associated with archaeological features and tree burns therein (Chapter 3). In two cases (Feature 64, Block K and Feature 43, Block G; see Tables 4.3), however, a ^{14}C age on wood charcoal overlapped with ages on soil carbon from the same feature. In these cases, it is likely that the soil-carbon sample contained enough silt- and clay-sized particles of wood charcoal to render the resulting age essentially the same as the AMS age on wood charcoal from the feature. In short, ^{14}C ages derived from wood charcoal provide reliable estimates of the age of a particular occupation zone or surface, while the ^{14}C ages derived from soil carbon provide mean-residence time for the paleosols. As such, wood charcoal ages, when available, are used to date cultural materials in a given block. When only soil-carbon ages are available for a particular excavation block, we subtracted 1000 years from those dates and used the resulting figure as an estimate of the age of associated archaeological materials.

Block Excavation Areas in Pedostratigraphic Context

An important goal of our field-mapping effort was to gather and compile sufficient data to generate maps showing the horizontal distribution of the uppermost boundary or surface of each major paleosol. These maps are useful in illustrating spatial relationships among paleosols, block excavation areas, and isolated artifacts and features observed or recovered during and after spillway-construction work. When used in conjunction with a surface topography map illustrating the configuration of the spillway trench at the time of abandonment, these maps also reveal where paleosols and artifact-bearing deposits are likely to be preserved in place and thereby available for future excavation (see Appendix J; Figure 23). As noted, plans are presently underway for the Richard Beene site and surrounding acreage to be developed as the Land Heritage Institute (LHI), a 1200 acre facility dedicated to heritage- and eco-tourism, education, and field research purposes. As planned, archaeological and paleoecological studies will be undertaken regularly (Texas A&M University 2000).

We used a total station transit to conduct the following tasks: (1) map the post-construction landscape, including the spillway trench, sediment pond, levee, drainage ditch, and mechanically excavated ground surface adjacent to the trench; and (2) map stratigraphic sequences along the spillway trench's vertical walls and in backhoe trenches dug on the gentle slopes and floor of the spillway trench. The Elm Creek and Perez paleosols, exposed in backhoe trenches and along the lower spillway trench walls, were mapped in 30 backhoe-cut windows (Figure 4.2), and a hand-cut "window" (No. 29) along the south wall exposed the entire section (Figure 4.3). Figure 4.4 illustrates the mapped configuration of the surfaces of the Elm Creek and Perez paleosols. Figure 4.5 provides a three-dimensional perspective of the spillway trench at the time construction work ceased and shows the location of the main block excavation units on that surface.

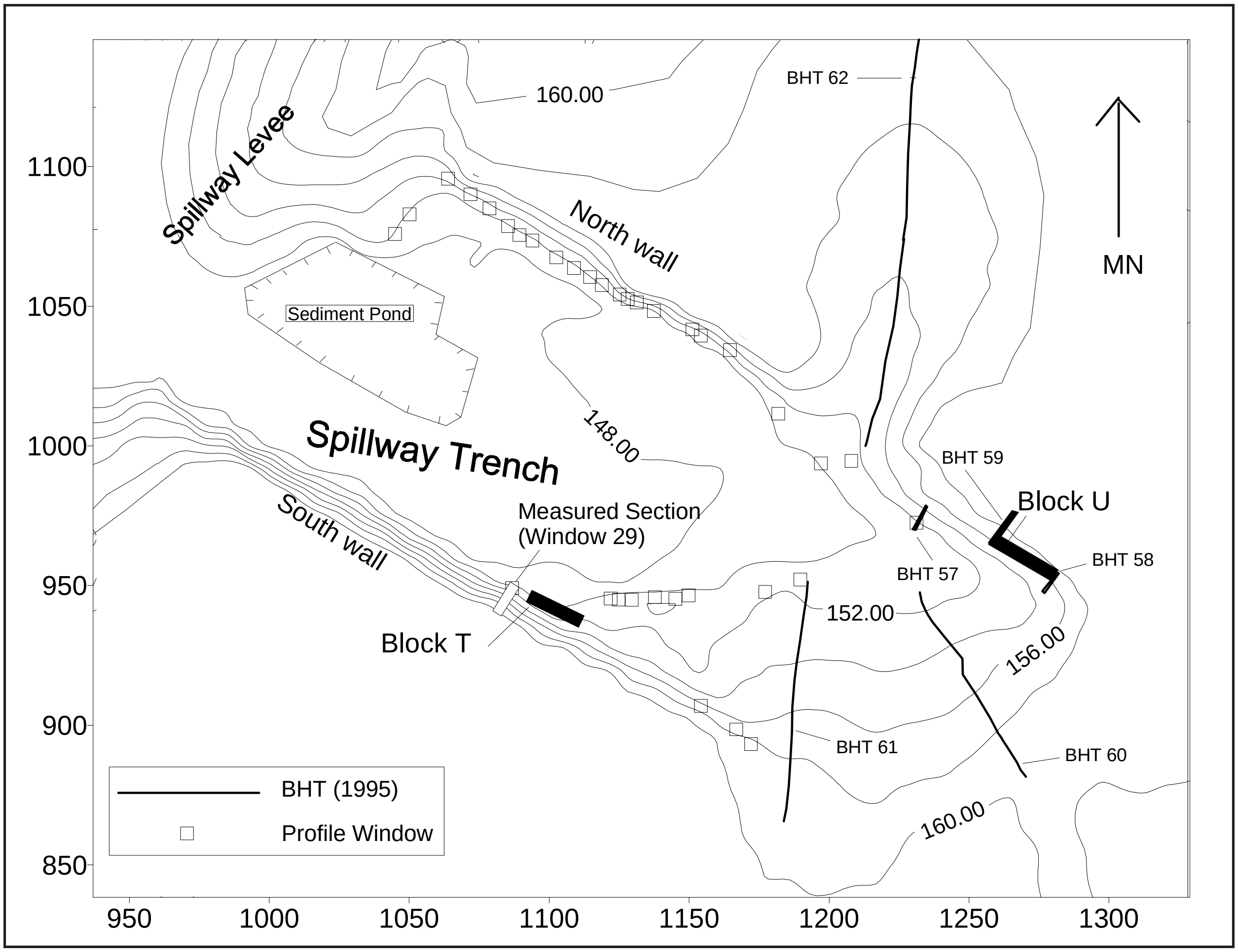


Figure 4.2. Topographic map of the spillway trench area showing the locations of selected mapping windows and backhoe trenches used to generate paleosol surface maps shown in Figure 4.4.

In cross section, the upper boundaries of the middle Holocene pedocomplex (Medina) and early, late Holocene paleosol (Leon Creek) are relatively flat except for a slight dip toward the river channel (Figures 4.6 and 4.7). In contrast, the upper boundaries of the underlying early Holocene soils (Elm Creek and Perez paleosols) dip appreciably toward the river, and their thicknesses decrease dramatically, almost to the point of merging (Figures 4.6 and 4.7). In part, the slope results from the floodplain being traversed by a flood-chute/tributary channel. In profile, this channel appears as a cut-and-fill, with well-stratified, fine-grained sediments. The paleochannel's bank nearest the valley wall tends to be at least a meter higher than the bank on the river side of the channel, which creates bench-like surfaces along both sides of the flood chute, with the lower bench sloping toward the river (Figures 4.6 and 4.7).

In some parts of the site, the Elm Creek and Perez paleosols are 2–4 m thick, but they are comparatively thin (<1 m) where they overlie a bench-like remnant of the Somerset paleosol, which is well over 20,000 years old (Figure 4.6). Judging from radiocarbon ages (ca. 7820 B.P.) obtained from charcoal in an FCR feature (No. 80, Block M), it seems likely that the Perez paleosol may have "pinched out" in the area of the feature, such that the Elm Creek paleosol directly overlays the Somerset paleosol. In any case, the surface of the Elm Creek paleosol, before its burial by rapidly deposited alluvium, probably exhibited at least 5 m of relief. Its elevation near Block P, some 400 m from today's

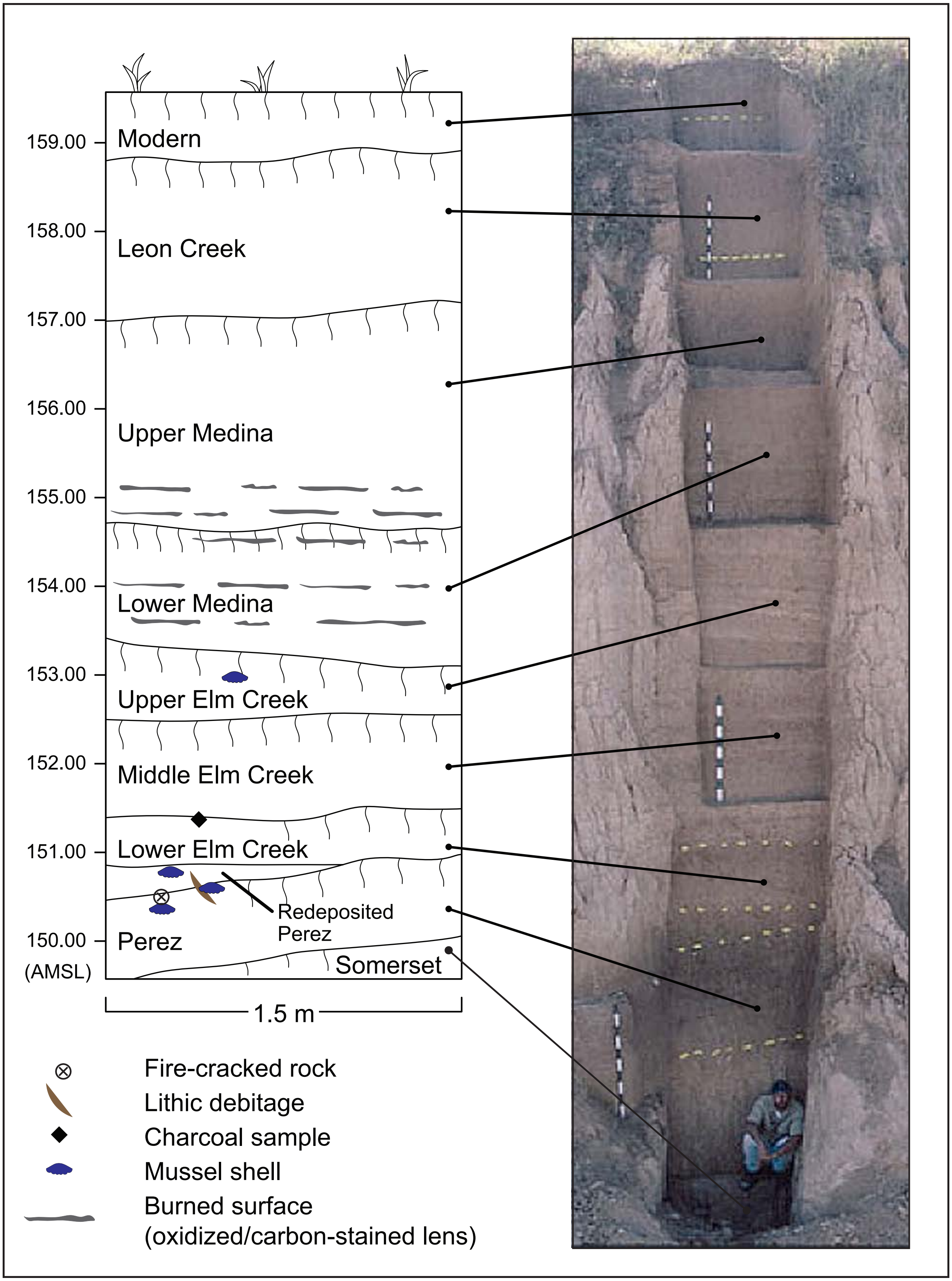


Figure 4.3. Pedostratigraphic sequence as shown in Window 29 on the south wall of the spillway trench (see location in Figure 4.6).

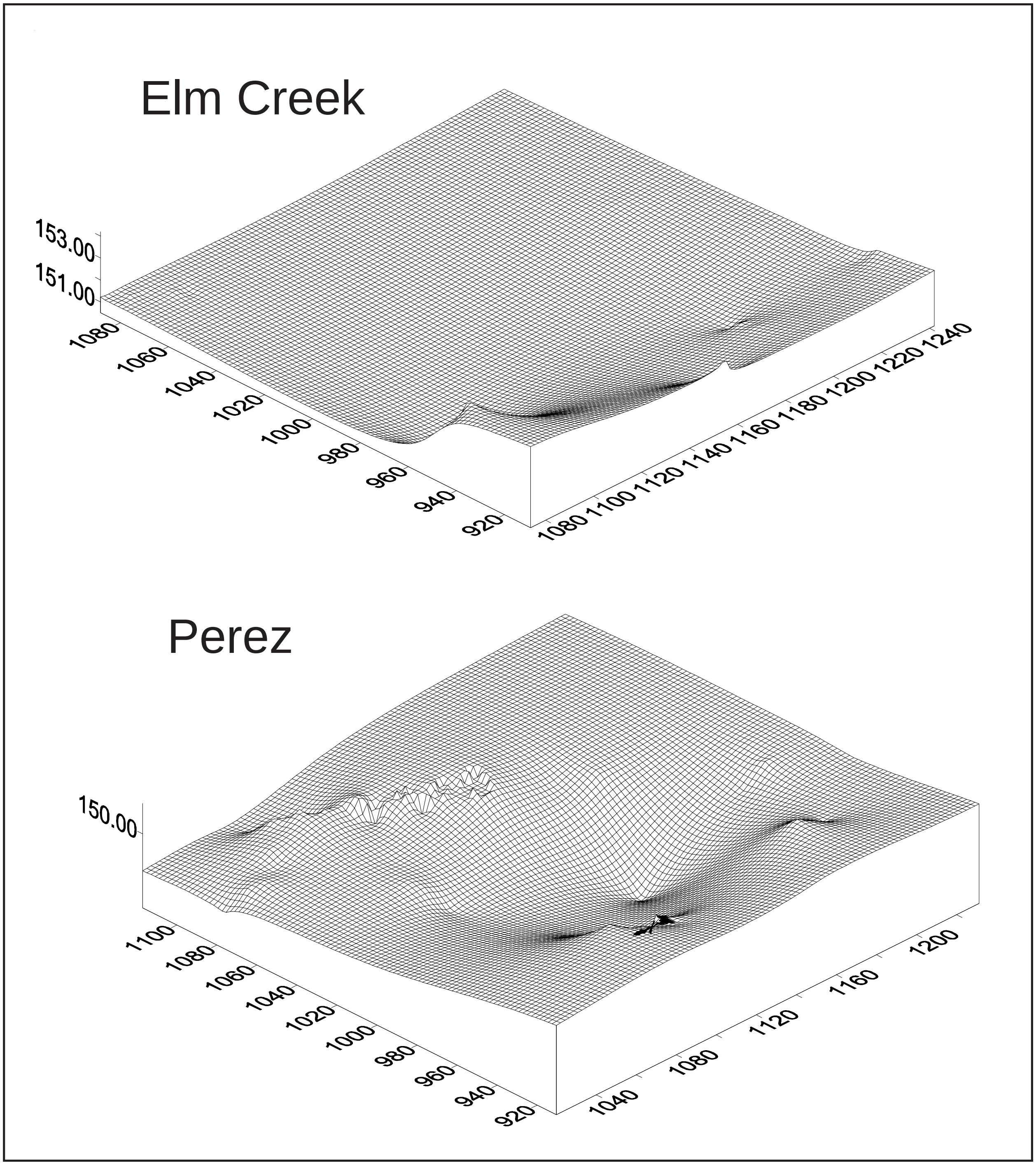


Figure 4.4. Paleotopographic maps of the surfaces of the Elm Creek and Perez paleosols as derived from elevations obtained in profile windows and backhoe trenches shown in Figure 4.2.

river channel, is about 153 m above sea level (asl), and at Feature 80 (Block M), some 225 m from the modern channel, the upper boundary elevation was probably about 148.5 m asl (Figures 4.1, 4.6, and 4.7).

Differences in the elevation of archaeological deposits of similar age in the Bk horizon of the Perez paleosol illustrate that 8800 radiocarbon years ago the floodplain also sloped significantly toward the river. This is illustrated by the horizontal and vertical distribution of well-dated sediments and wood charcoal from Blocks H, T, and N, as shown in Figure 4.8. In this case, the truncated surface of the Perez paleosol on the valley-wall side of the flood-chute/tributary channel where Block H is located is about 151 m asl, about a meter higher than the river-side area where Block T is located. Moreover, the surface of the Perez paleosol in Block N, also on the river-side of the flood chute and closer to the river, lies at about 149 m asl. As shown in Figure 4.7, soil-carbon ages derived from the upper Bk horizon of the Perez paleosol range from ca. 9800–9600 B.P., whereas, wood charcoal from this horizon yielded ^{14}C ages ranging from ca. 8800–8600 B.P.

Block Excavation Areas in Depositional Context

For most of the last 15,000 years, the lower Medina River has been a low-gradient, flood-prone system, with floodplain alluvium consisting mainly of silty clay and silty clay loam. As discussed in Chapter 3,

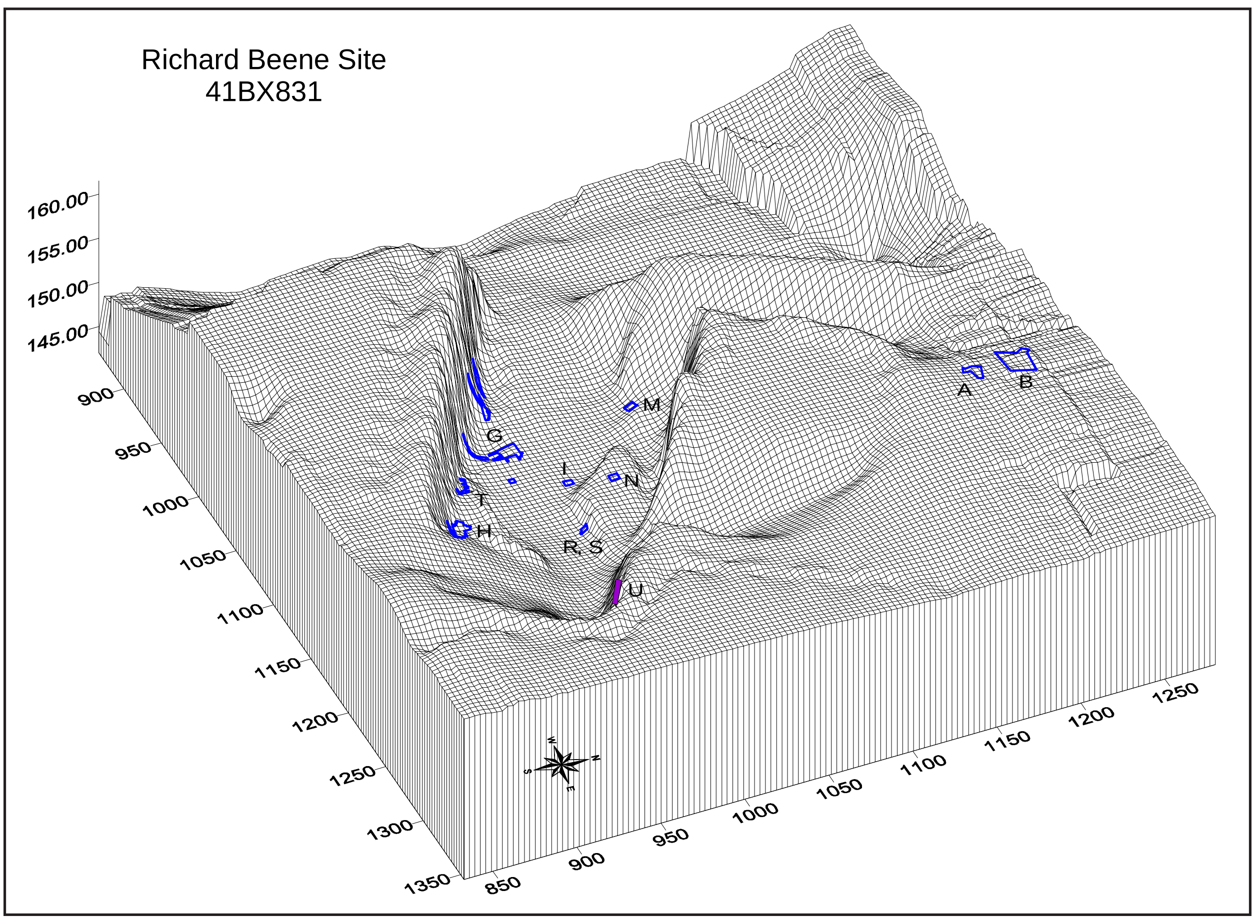


Figure 4.5. Three-dimensional computer graphic showing the layout of the spillway trench at the time the construction project was abandoned and the locations of block excavation areas on the floor and along the walls of the dam spillway trench.

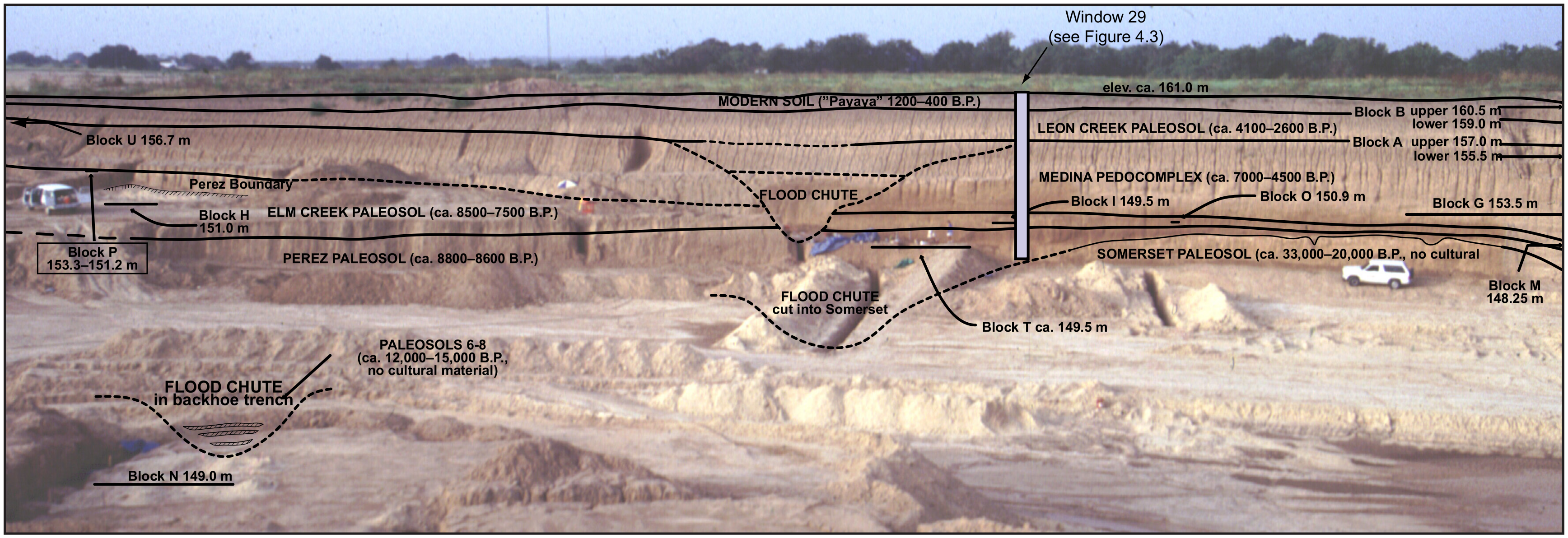


Figure 4.6. Wide-angle photograph of the central section of the south wall of the spillway trench showing the approximate boundaries of paleosols, ages of assemblages therein, and locations of block excavation areas.

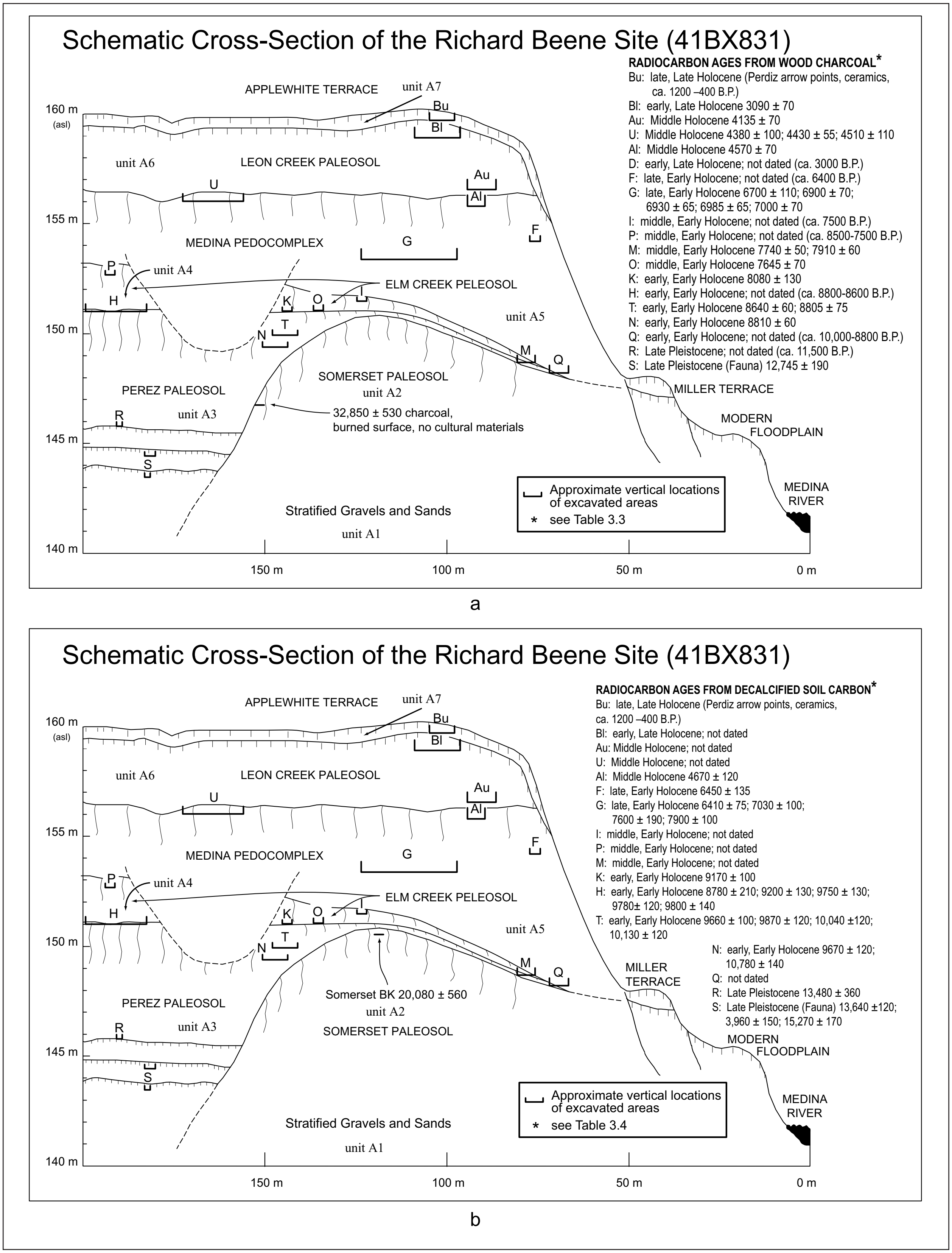


Figure 4.7. Schematic cross section showing paleosols, block excavation areas, and related ^{14}C ages derived from: (a) wood charcoal; and (b) decalcified bulk soil carbon.

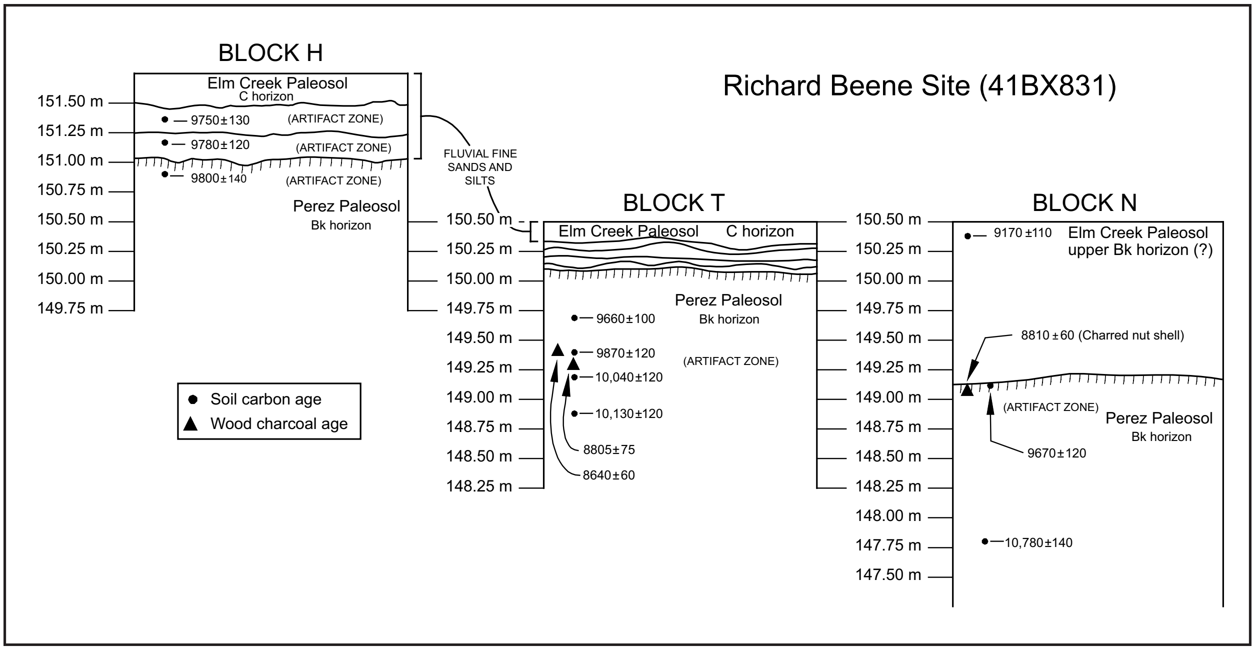


Figure 4.8. Correlation of stratigraphic profiles, elevations, and radiocarbon ages from the upper portion of the Bk horizon of the Perez paleosol in Blocks H, T, and N (see Figures 4.1 and 4.6 for block locations).

radiocarbon ages and geomorphic studies attest to rapid deposition of preconditioned (i.e., allochthonous) sediments, with intermittent periods of relative stability that resulted in the formation of well-developed soils, several of which were subsequently truncated by fluvial erosion. In general, rapid deposition tends to enhance site preservation. Nonetheless, the site's archaeological deposits are differentially preserved because of varying degrees of pedoturbation, as well as fluvial energy levels that resulted in alluvial deposition and erosion.

While the alluvial sediments at the Richard Beene site are composed mainly of silt and clay, there is significant variation in the quantity of stream-worn gravels in the various stratigraphic units, paleosols, and parts thereof. It can be assumed that the amount of gravel (pebbles up to ca. 4 cm in diameter) in the deposits affords a relative measure of fluvial-energy levels. The most probable source of stream-worn gravels during the late Pleistocene and early, early Holocene would have been local exposures of the gravel-rich Unit A2 and the caliche-capped Somerset paleosol. It is also possible that the valley wall, which in the site area is represented by scarps along the Leona and Walsh terraces (Chapter 3), was a source area for stream-worn gravel. It is not likely that the flood chute that traversed the site prior to the late Holocene served as a conduit for gravel insofar as its fine-grained channel fill lacked gravel altogether.

Our studies indicate the presence of two decidedly different depositional environments. The first is best represented by comparatively high-energy and gravel-rich environments, including: (1) the late Pleistocene, as exhibited in Blocks R and S; (2) the early, early Holocene, as exhibited by poorly preserved archaeological deposits in Block H; and (3) the beginning of the middle, early Holocene, as exhibited by the low-density archeological deposits in Block I.

Early, early Holocene deposits sampled in Block H best exemplify the high-energy environment. Block H is composed of the truncated Bk horizon of the Perez paleosol along with the immediately overlying artifact- and gravel-bearing sediments of the Elm Creek paleosol's C horizon. These overlying sediments are composed of lenses of sandy silt and redeposited silty clay and clay loam from the underlying Perez paleosol. Elsewhere, however, early, early Holocene deposits, including those sampled in Blocks N and T, are better preserved, in

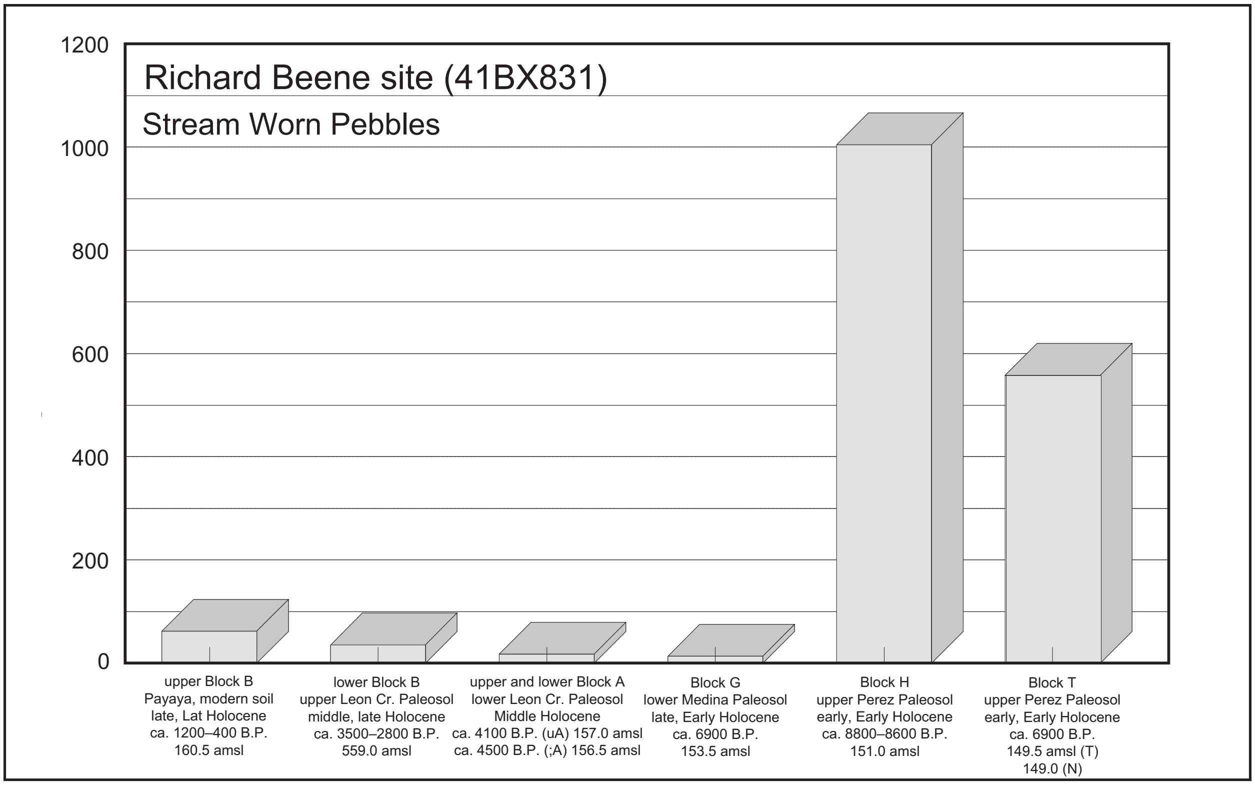


Figure 4.9. Bar graph of weight/density of stream worn pebbles in archaeologically screened sediments from major block excavations in the various paleosols.

that they contain much less gravel and/or in situ features (Figure 4.9). Linear arrangements of fire-cracked rocks and mussel shells in Block U indicate that some parts of the uppermost Medina paleosol were truncated by comparatively high-energy fluvial processes that disarticulated FCR features. It is also possible that the linear arrangements resulted from artifacts falling into large cracks that characterize the regions clayey soils during droughts.

The second type of depositional environment is characterized by a lower-energy and gravel-poor system characteristic of some of the middle, early Holocene and most of the period of record thereafter (Figure 4.9). This setting is exemplified by the comparatively well-preserved archaeological deposits in Block G that sampled the silty-clay-loam Bk3b2 horizon of the Medina pedocomplex. Low-energy depositional environments are also represented in blocks excavated in the Elm Creek, upper Medina, and Leon Creek paleosols as well as the modern soil.

The fine-grained sediments comprising the Applewhite terrace fill are derive from soils developed from limestone on the Edwards Plateau (Chapter 3). Field observations suggest that these "soil sediments" are especially prone to forming high-viscosity flows. These high-viscosity flows tend to result in rapid rates of deposition, and they probably entrap and transport gravel, as well as similar-sized artifacts. If velocity was sufficiently high, such flows (i.e., flood scouring; see Chapter 3) over remains of an encampment might completely remove the lighter fraction of cultural clasts, such as bones, charcoal, and smaller flakes. The heaviest fraction, including larger FCR and pieces of chipped stone, might be transported for very short distances. Low-viscosity flood water, given sufficient velocity, would also remove the lighter fraction of cultural debris, but it might not be as effective a medium for transporting steam-worn gravel to the encampment site.

In any case, a high-viscosity or a high-velocity scenario (i.e., flood scouring) likely accounts for

Figure 4.10. A lag-concentration, fire-cracked feature (No. 99) in Block H (early, early Holocene; Cb3 horizon of Elm Creek paleosol) that contains an abundance of gravel, along with nearly imbricated mussel shells, flakes, and small, tabular pieces of fire-cracked rocks (sandstone).

Figure 4.11. A natural micro-pothole around a stream-worn cobble that was created and partially filled with small pebbles during a Medina River flood in 1991.

the lag-like character of the upper early, early Holocene archaeological zone in Block H (Chapters 9 and 14). Features in this block consist mainly of concentrations of large pieces of FCR with smaller or lighter items, including flakes, mussel shells, and especially gravel embedded around the FCR. Moreover, many flakes and pieces of mussel shell, along with tabular pieces of FCR occurred in near vertical angles of repose, often in imbricated groupings (Figure 4.10). As is discussed in Chapter 13, one or more flood-scouring events probably removed the sediment matrix from these FCR features, such that the large clasts remained essentially in place horizontally but were displaced vertically and served as "traps" for smaller clasts being transported laterally via fluvial processes. As noted, these features appear to have been encased in the upper part of the Perez paleosol, but after the flood(s) they became embedded in what would become the C horizon of the Elm Creek paleosol.

Field observations of over-bank floodwater flowing over gravel-rich sediments revealed that micro-potholes form around larger clasts and partially fill with much smaller clasts, producing a configuration of diverse-sized clasts that closely resemble the "lagged" features in Block H (Figure 4.11). A somewhat lower velocity of a high-viscosity flow, or simply a lower-velocity flood, might remove many of the lighter clasts and leave the heavier clasts in place. This kind of scenario could well account for the better preserved features in Block T (Figure 4.12).

The volume of gravel recovered from the well-preserved archaeological deposits in Block G, which date to the late, early Holocene (ca. 6900 B.P.), is very low in comparison to Block H. The relative paucity of gravel in Block G is consistent with a scenario that lower-velocity, high-viscosity flows covered the occupation surface without significantly affecting the archaeological deposits. In this case, it is suggested that sediment deposited by a high-viscosity, low-velocity flood would simply blanket artifacts and features, and subsequent floods could well bury the site beyond the reach of intensive bioturbation. This kind of scenario could account for the well-preserved character of the archaeological deposit in Block G. Most of the artifacts were in horizontal angles of repose, pit feature boundaries were abrupt, and FCR features were almost pristine (Figure 4.13).

It should also be noted, however, that the most likely source of gravel in the upper Perez paleosol would have been nearby exposures of the Somerset paleosol. As noted, the Somerset paleosol was buried a meter or more when the Medina parent material (Block G) began to accumulate.

In short, the paucity of gravel in Block G could be accounted for by the lack of a source area although the well-preserved character of Block G features attests to a low energy depositional environment.

Figure 4.12. A comparatively intact fire-cracked feature (No. 107) in Block T (early, early Holocene; Bk horizon of Perez paleosol), that yielded less gravel than Block H and had notably fewer flakes, mussel shell, and tabular pieces of fire-cracked rocks in vertical angles of repose.

Figure 4.13. A well-preserved fire-cracked rock feature (No. 68 [originally No. 45]) in Block G (late, early Holocene; Bk3b2 horizon of Medina paleosol), that contained far less gravel than Blocks H and T.

Block Excavation Areas in Bioturbation and Argilliturbation Contexts

The site's archaeological deposits, even under the best of open-site preservation conditions, are continuously and systematically disturbed by soil-formation processes, notably floral- and faunal-turbation, and by argilliturbation that involves shirking, swelling, and cracking of clay-rich deposits (cf. Wood and Johnson 1978). An important result of these natural soil-formation processes is that, provided sufficient time, cultural debris deposited on a given surface may be buried beneath a biomantle (Johnson 2002). Biomantle formation is of course time dependent, such that the longer cultural debris lies on or near the surface, the more it is to be affected by pedoturbation in general.

During fieldwork, we categorized each block excavation or portion thereof, according to whether it was well preserved and thereby representative of an occupation surface, or moderately to poorly preserved and thereby designated as a zone. The best-preserved occupation "surface," Block G, probably represents several occupations over a period of a few decades. However, the vertical distribution of mussel shells, originally deposited as surface concentrations ranges from 10 to 25 cm below that surface. A similar pattern occurs with flake concentrations. As noted, this magnitude of vertical distribution of artifacts is quite common and arguably results primarily from bioturbation and argilliturbation.

Argilliturbation results in the downward displacement of artifacts, as they fall into cracks that extend to the surface. In that process, artifacts that first came to rest in horizontal angles of repose can be redeposited in vertical angles of repose. Fluvial transport of artifacts can also result in vertical angles of artifact repose, as was noted for the imbricated artifacts in Block H. Part of our excavation protocol was to document, on level-form drawings, the presence and distribution of artifacts encountered in vertical or near-vertical angles of repose. These data remain to be quantified, but the information recorded on level forms is sufficient to estimate the relative occurrence of such artifacts (Table 4.1). This estimate serves as another measure of the relative intactness of the site's archaeological deposits.

In general, artifacts in vertical angles of repose were very abundant only in Block H, an early, early Holocene deposit. They were common in most blocks excavated in the uppermost Bk horizon of a given paleosol, including upper Block B (modern soil), lower Bock B (upper Leon Creek paleosol, early, late Holocene), and Block U (upper Medina pedocomplex, middle Holocene), and Block T (upper Perez paleosol, early, early Holocene). Relatively few artifacts occurred in vertical angles in upper Block A (CB horizon of Leon Creek paleosol, middle Holocene), lower Block A (ABkb2 of

Medina pedocomplex, middle Holocene), and G (Bk3b2 of Medina pedocomplex; late, early Holocene).

Other measures of bioturbation recorded on level forms included the nature, distribution, and relative abundance of: (1) snail-shells, especially discrete concentrations characteristic of natural accumulations on the surface at the base of woody plants; (2) root casts and krotovina or rodent burrow casts; (3) tree burns; and (4) concentrations of carbon-stained and oxidized sediments, which may suggest either tree burns or cultural features.

In general, a widespread occurrence of well-preserved snail-shell concentrations and scatters, primarily *Rabdotus* spp., should be indicative of a well-preserved surface. On the other hand, a paucity of shells could indicate disturbance, especially flood-scouring, or perhaps rapid deposition, such that snails would not have ample time to accumulate. An abundance of root casts and krotovina would suggest substantial bioturbation whereas, other things being equal, the near absence of these manifestations would be consistent with flood-scouring and rapid re-deposition. Of course, a paucity of root casts and krotovina should also characterize rapid deposition sufficient to bury an occupation surface beyond the reach of roots and rodents. As a measure of bioturbation, charcoal, as well as carbon-stained and oxidized matrix indicative of burned stumps and root, should be consistent with patterns expected for root casts and krotovina.

Digitized plan-view maps showing the distribution of these bioturbation indicators in major block excavation areas clearly illustrate differences in preservation conditions. Block H (early, early Holocene), which is substantially disturbed by flood scouring, has the lowest density of snail-shell concentrations, tree burns, root casts, and krotovina (Figure 4.14). Blocks T and N, which were not subject to the same kind of high-energy scouring, contain more snails, root casts, and krotovina, but tree-burns and burned sediment are rare to absent. Block G (late, early Holocene), the best-preserved surface in terms of feature preservation, shows the highest density of snail-shell concentrations. Tree burns/burned matrix are also common. Moreover, there are relatively few root casts and krotovina, which is consistent with rapid, low-energy deposition subsequent to the occupations (Figure 4.15). Upper and lower Block A (middle Holocene) are also well preserved, but they have far fewer snail shells and substantially more root casts, krotovina, and evidence for tree burns. Lower Block B (early, late Holocene), which contains several discrete FCR features, is exemplary of moderately preserved occupation zones wherein snail shells are scattered but rarely concentrated, and root casts, krotovina, and tree burns are common, especially near the terrace scarp (Figure 4.16). Upper Block B (late, late Holocene) exhibits similar characteristics, but while FCR was abundant, intact features were not encountered, presumably because they were disarticulated by various pedoturbation processes.

Summary

Preservation conditions at the Richard Beene site vary substantially from block to block, but overall, the occupation surfaces and zones are well stratified. Alluvial deposition tended to be rapid, with almost 15 m of fine-grained sediments accumulating within the last 12,000 radiocarbon years, at an overall average rate of about 12.5 cm per century. However, the long-term trend of rapid deposition was punctuated by periods of stability, spanning centuries and marked by well-developed Bk horizons with archaeological deposits dated to about 1200–400, 3500–2800, 4600–4100, 8500–7500, and 8800–8600 B.P. Preservation conditions of the various occupation surfaces and zones vary considerably, with those in the uppermost part of Bk horizons usually not as well preserved as those in the lower part of Bk horizons and B/C horizons in general. Figures 4.1, 4.6, and 4.7 illustrate the locations and pedostratigraphic settings for major excavation blocks, as well as several smaller ones. Table 4.1 characterizes each block according to its relative state of preservation as assessed by the abundance of stream-worn pebbles and various indicators of argilliturbation and bioturbation.

Excavated deposits (upper Block B) dated to the late, late Holocene (ca. 1200–400 B.P.) are com-

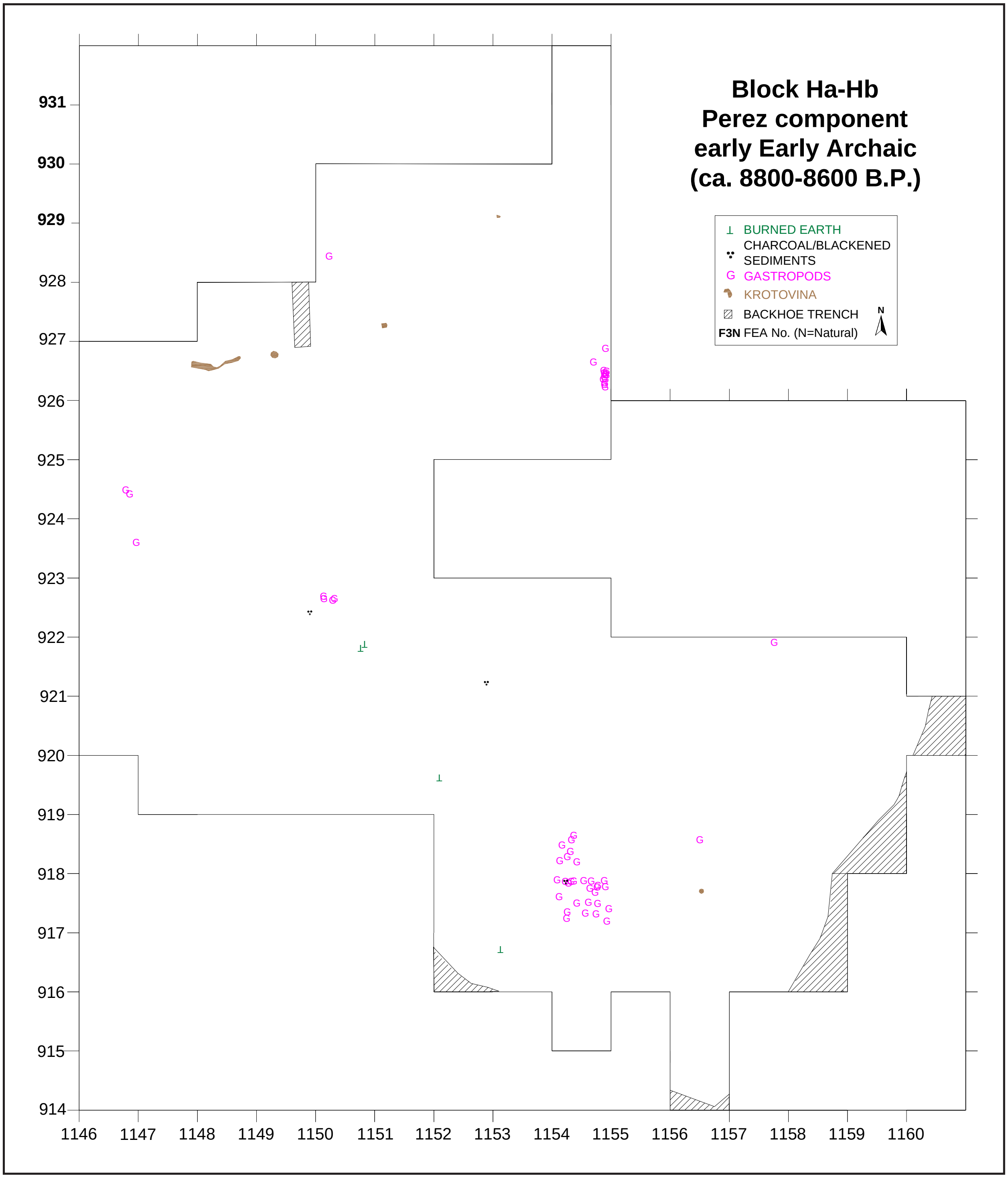


Figure 4.14. Plan view map of Block H (early, early Holocene) showing the sparse distribution of snail shells, root casts and krotovina, tree-burn charcoal, and burned sediments, which suggests the block is poorly preserved in comparison to most other excavation blocks.

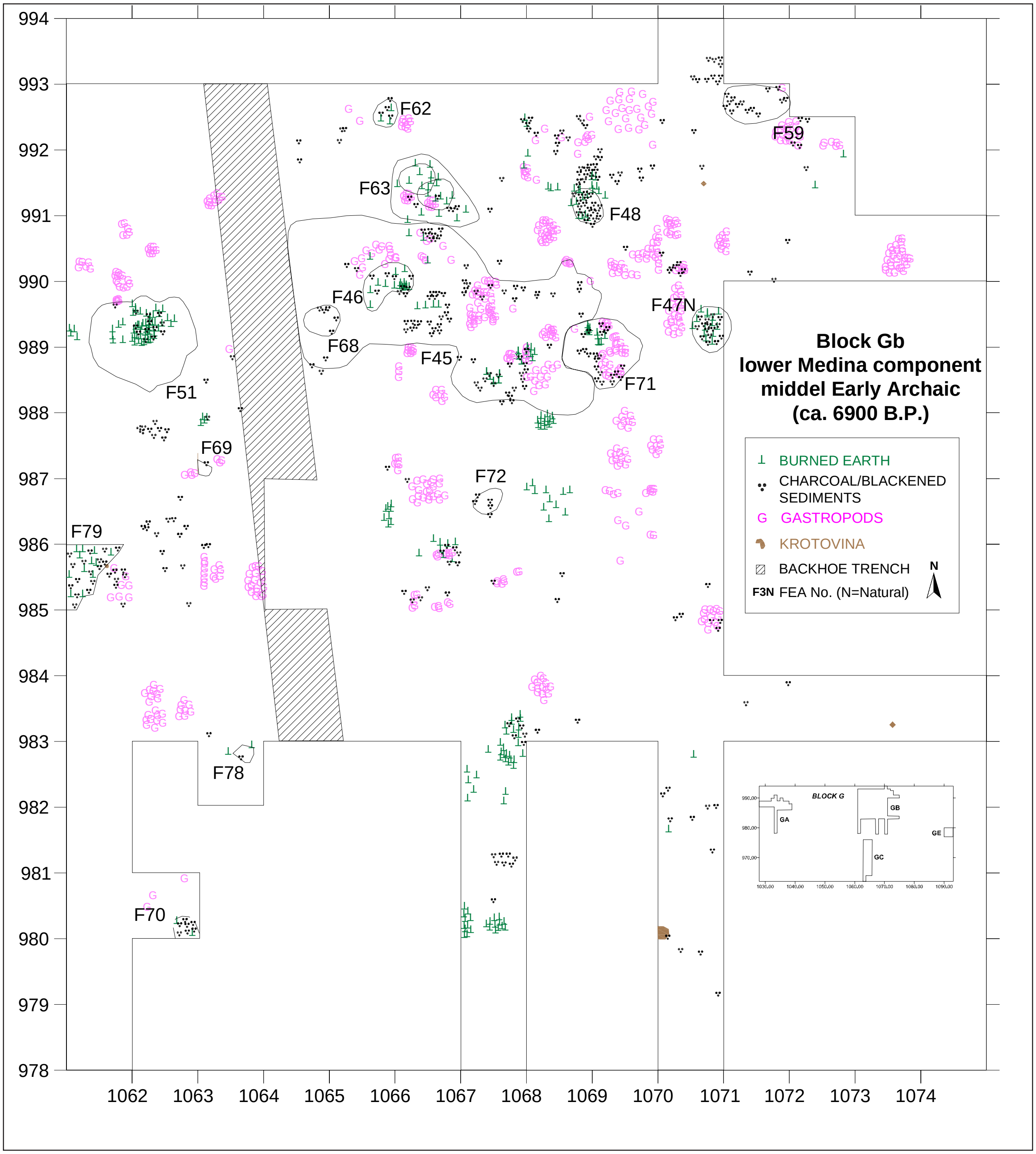


Figure 4.15. Plan view map of Block Gb (late, early Holocene) showing the widespread distribution and relative abundance of snail-shell concentrations, tree-burn charcoal, and burned sediments, which suggests the block is minimally pedoturbated, little impacted by floodwater, and well preserved in comparison to most other excavation blocks.

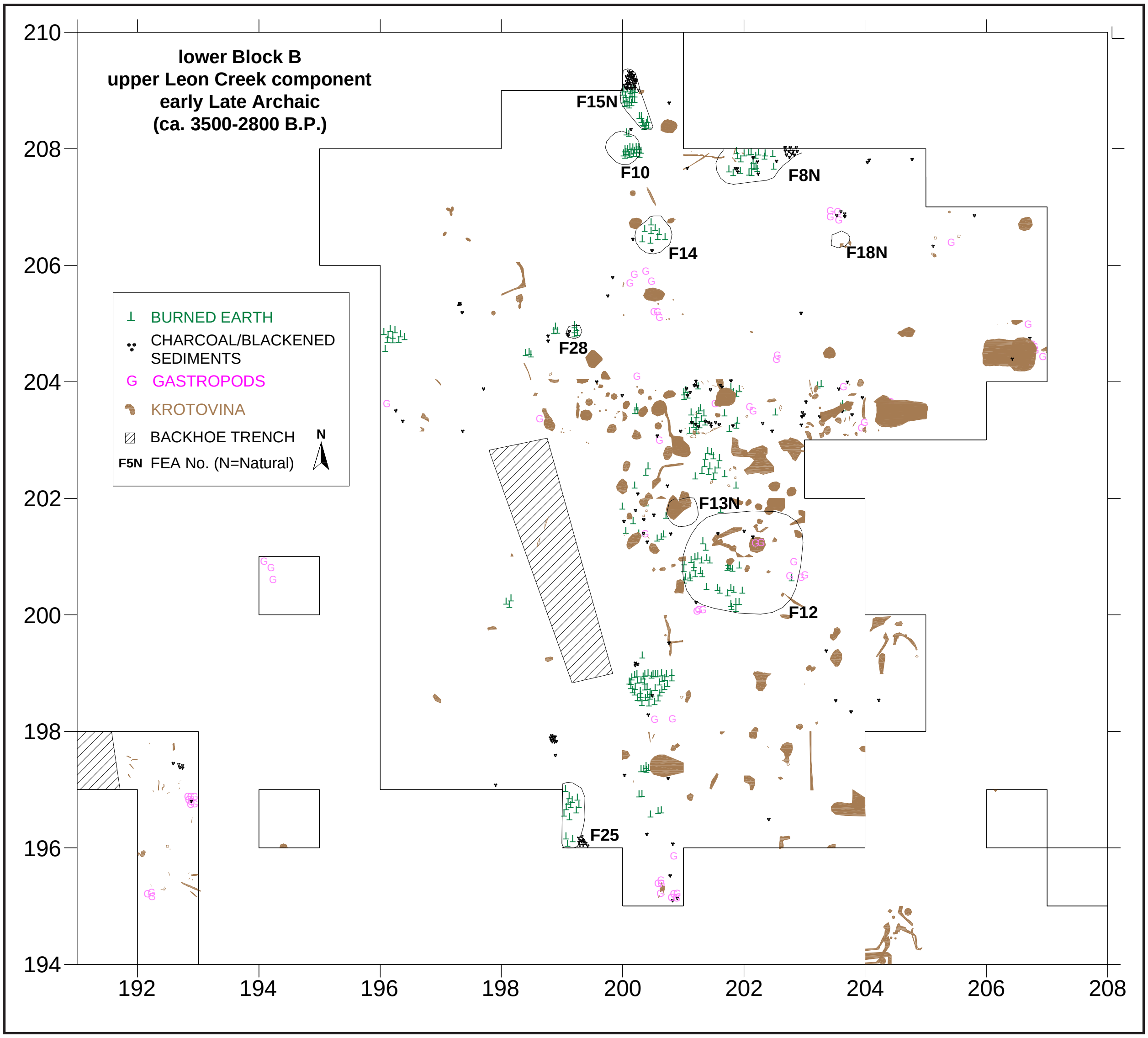


Figure 4.16. Plan view map of lower Block B (early, late Holocene) showing the widespread distribution and relative abundance of tree-burn charcoal, root casts, and krotovina, which suggests the block is substantially bioturbated but nonetheless moderately well-preserved in comparison to most other excavation blocks.

paratively poorly preserved, due largely to slower overall rates of deposition and significant bioturbation during the last millennium or so. Discrete features were common, and in some cases stratified, in the early, late Holocene deposits (lower Block B, ca. 3500–2800 B.P.), suggesting that deposition was comparatively rapid, but not so rapid as to prevent soil development and significant bioturbation that masked occupation surfaces. The middle Holocene deposits (ca. 4600 and 4100 B.P.) in upper and lower Block A were comparatively well preserved and consisted of at least two occupation surfaces. Almost all of the artifacts were in horizontal angles of repose, although bioturbation was readily apparent, especially near the terrace scarp. Block U, also middle Holocene in age, was impacted by fluvial erosion and considerable argilliturbation, although one poorly preserved FCR feature was identified.

In Block G, which is well dated and where the most extensive excavations occurred, almost all of the mussel shells, FCR, and chipped stone artifacts were found in horizontal angles of repose. In short, late, early Holocene occupation surfaces (ca. 6900 B.P.) were not adversely impacted by high-energy floods or subjected to significant bioturbation. Moreover, rodent burrows, root casts, and other forms of bioturbation were limited. Block H's early, early Holocene (ca. 8800–8600 B.P.) deposits stand in marked contrast. Fire-cracked rock features, while present, are lag concentrations that also include chipped stone artifacts, mussel shells, and a high density of stream-worn pebbles up to about 4 cm in diameter. Many artifacts rested on their edges (i.e., vertical angles of repose), sometimes imbricated, in small erosional gullies or rills. Blocks N and T, also early, early Holocene in age, are somewhat better preserved, although features are rare and artifact densities are much lower.

Our limited excavation of late Pleistocene deposits (Blocks R and S, ca. 15,000–12,750 B.P.) did not yield definitive cultural material. Because the reservoir construction project was terminated unexpectedly, we were only able to examine a few tens of meters of backhoe trench profiles carefully and to excavate a few cubic meters within the 5 m of alluvium between the early Holocene cultural deposits in the upper portion of the Perez paleosol and the fauna-rich late Pleistocene sediments that extended to at least 15 m below surface.

Elsewhere in the spillway trench area, however, well preserved fragments of isolated bison and mammoth bones, and large mussel shells were found in late Pleistocene deposits and in gravel beds that formed following major floods in the mid 1990s (Chapter 11 and Appendix A). Considering that Plainview, Folsom, and Clovis materials have been excavated from sites within a few tens of kilometers of this part of the lower Medina River valley (Chapter 8), it seems likely that the Richard Beene site will eventually yield cultural remains representative of the Paleoindian period, perhaps including pre-Clovis times.

5

LATE PLEISTOCENE AND HOLOCENE ENVIRONMENTS IN THE MEDINA VALLEY OF TEXAS AS REVEALED BY NONMARINE MOLLUSKS

Raymond W. Neck

The existence of deep, stratified alluvial sediments in the Medina Valley of southern Bexar County, Texas presents an opportunity to investigate the environmental history of this region from the late Pleistocene through the Holocene, and up to the present. This opportunity is significant for two reasons. First, the late Pleistocene and Holocene sediments can be assessed for changes in the microhabitats available to nonmarine mollusks. Second, the results of any analysis of paleoassemblages from this area are likely to be significant for several avenues of research: late Quaternary history of the transition zone between the uplifted limestone of central Texas and the Coastal Plain; environmental change in a geographical locality that is far removed from any glacial front of the Pleistocene; and taphonomic factors that affect the relationship between the paleofauna and the paleoassemblage that is extracted from the sediments.

The lower Medina Valley is located in the transition zone between the Balconian and Tamaulipan biotic provinces as delineated by Blair (1950). Although all such boundary lines are conceptual models, the delineation between these two biotic provinces is rather sharp. However, there are noted edaphic islands or lineal dispersal routes that can be observed from modern dispersal patterns or inferred from relictual populations. Investigations that analyze the prehistory of this area have the opportunity to reveal variations in geographical ranges of various species that are classified as either Balconian or Tamaulipan in zoogeographic affinity. Sufficient variation from the modern distributional patterns may also indicate the need to postulate temporal shifts in the boundary zone between these two biotas. Very little discussion on the history of the boundaries between biotic provinces in central Texas has been published, although Durden (1974) discussed the history of the biotic provinces of North and Central America over time periods much longer than the Pleistocene. Gehlbach (1991) published his thoughts concerning the environmental barriers on the eastern margin of the Balconian Biotic province and the alleged early Holocene origin of this boundary.

The paleoenvironmental history of the South Texas Plains, a term that applies to most of the Tamaulipan Biotic province in southern Texas, is largely unknown. However, a few molluscan paleoassemblages from southern Texas have been reported with variable attempts at analysis. Hubricht (1962) reported seven species of terrestrial gastropods from “loess, near San Antonio River, 5 mi. south of San Antonio.” Five of the species reported in this paleoassemblage are moderate- to large-shelled species that occur in this region today. However, two small-shelled species present in the assemblage are not found living in the area today. Hubricht (1962) provided only limited comments on the paleoenvironmental significance of this “loess” sample, except to note that the occurrence of one of the extralimital species indicated the climate was colder and wetter when these deposits were laid down than it is today.” No estimate of age,

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site in South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 87–100. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas

other than Pleistocene, was given for this assemblage.

Other paleoassemblages from southern Texas have been reported. Hubricht (1962) also reported the occurrence of a very species-diverse assemblage in "loess" near Palo Blanco Creek west of Falfurrias. This assemblage contained a number of aquatic gastropods that are characteristic of modern boreal and austral faunas. The terrestrial gastropod species recorded from this assemblage include only species that can be found in central and southern Texas today, although not necessarily in the immediate vicinity of his collection locality. Neck (1987) reported a stratified paleoassemblage in alluvium of the Nueces River near Uvalde, Texas, just south of the Balcones escarpment. These sequential assemblages indicate different vegetational and edaphic environments that are best interpreted as a series of natural successional stages and do not require any change in macroclimate. All species present in the various layers in this site are living in the immediate area of the site today.

Other analyses of nonmarine molluscan paleoassemblages from southern Texas have involved sites that were closer to the coast. Neck (1983) reported on a low-diversity assemblage extracted from late Pleistocene sediments associated with a tributary of Los Olmos Creek in Kleberg County. The recovered assemblage indicated slightly greater effective moisture but no major changes in molluscan microhabitats. Another paleoassemblage from the extreme southern part of Texas in Cameron County included a mixed brackish and freshwater species assemblage that has more relevance to postulated Holocene sea-level changes (Neck 1985) than to inland nonmarine environmental changes.

Methods

A series of 3-liter sediment samples was removed from 32 proveniences at 41BX831. These samples ranged from the modern soil surface to deep stratigraphic units identified as Late Wisconsinan. The modern soil is designated as Venus clay loam by the U.S. Soil Conservation Service (Taylor et al. 1966); other stratigraphic names are from Mandel et al., as presented in Chapter 3. A stratigraphic summary of these samples is presented in Table 5.1.

Samples were wet-screened through nested soil sieves (#4, #8, #16, and #30). Retained shell material was hand-picked from the resultant residue. Shells were identified to species and classified as adult or immature. In the case of one species, *Rabdotus mooreanus,* four size classifications were identified: adult, adolescent, juvenile, and hatchling.

A series of freshwater mussels extracted from cultural contexts were provided to the author from previously screened material. Identifications of the shell remains were made from familiarity with the species of the area and comparison to material in a reference collection belonging to this author.

Results

A total of 20 species was identified from the shell material extracted from the 32 sediment samples and from cultural context samples (Tables 5.2, 5.3, and 5.4). This molluscan assemblage consists of one pea clam, two freshwater mussels, one freshwater operculate gastropod, three freshwater pulmonate gastropods, one operculate terrestrial gastropod, and 11 terrestrial pulmonate gastropods. Ten species of freshwater mussels were recovered from cultural contexts (including seven species not found in the sediment samples).

Paleoenvironmental Reconstruction

The molluscan shell remains extracted from the sediments of 41BX831, as documented in Tables 5.3 and 5.4, demonstrate an overall homogeneity that belies the environmental information that can be inferred from the distribution of the species present. Below is a first attempt to reconstruct the paleoenvironment of 41BX831 as demonstrated in the molluscan remains present in these sediments. The reconstruction is described in terms of the vegetational community types and structure in temporal sequence

Table 5.1. Stratigraphic positions of soil and sediment samples analyzed for mollusks.

Sample No.	Depth Below Surface (cm)	Stratigraphic Unit	Soil	Soil Horizon
1m*	0-25	A7	Modern	A and Bk1
1f†	0-25	A7	Modern	A and Bk1
2	37-51	A7	Modern	Bk2
3	51-87	A6	Leon Cr. Paleosol	Ab1(Bk)
4	87-154	A6	Leon Cr. Paleosol	Bkb1
5	154-206	A6	Leon Cr. Paleosol	BCkb1
6	206-223	A6	Leon Cr. Paleosol	CBb1
7	223-289	A5	Medina Pedocomplex	Akb2
8	289-317	A5	Medina Pedocomplex	ABkb2
9	317-404	A5	Medina Pedocomplex	Bk1b2
10	404-508	A5	Medina Pedocomplex	Bk2b2
11	508-560	A5	Medina Pedocomplex	Bk2b2
12	560-597	A5	Medina Pedocomplex	Bk3b2
13	597-693	A5	Medina Pedocomplex	Bk4b2
14	693-720	A5	Medina Pedocomplex	Cb2
15	720-768	A4	Elm Cr. Paleosol	Bk1b3
16	768-820	A4	Elm Cr. Paleosol	Bk2b3
17	820-980	A4	Elm Cr. Paleosol	CBkb3
18	980-1,020	A4	Elm Cr. Paleosol	Cb3
19	1,020-1,068	A3	Perez Paleosol	Bkb4
20	1,068-1,136	A3	Perez Paleosol	Bkssb4
21	1,136-1,169	A3	Perez Paleosol	Bk'b4
22	1,169-1,227	A3	Perez Paleosol	BCkb4
23	1,227-1,257	A3	Perez Paleosol	CBkb4
24	1,257-1,357	A3	Perez Paleosol	Cb4
25	1,357-1,375	A3	Soil 6	Bk1b5
26	1,375-1,459	A3	Soil 6	Bk2b5
27	1,459-1,485	A3	Soil 7	Bkb6
28	1,485-1,505	A3	Soil 7	Bkb6
29	1,505-1,540	A3	Soil 8	A1b7
30	1,540-1,575	A3	Soil 8	A2b7
31	1,575-1,600	A3	Soil 8	Cb7

*Sample 1m was collected in a mesquite-covered area at 41BX831.
†Sample 1f was collected in a plowed field at 41BX831.

from the oldest available time period to the present. The breaks between vegetational types are somewhat arbitrary since any temporal variation in the environment will be gradual. Some of the inferred temporal boundaries are likely the result of the temporal distance between samples. Also, keep in mind that these reconstructions and the chosen boundaries are based solely on the molluscan remains. Although it is likely that molluscan shell remains can provide very powerful information on the paleoenvironment of this region, these remains are—in the end result—only valid from the ecological perspective of the constituent molluscan species.

Zone 1—Marsh or Wet Grassland/Meadow—Samples 31–25 (ca. 15,300–12,500 B.P.)

This zone includes samples recovered from Soils 6, 7, and 8, and spans the period ca. 15,300–12,500 B.P. These lower levels are most remarkable in the limited number of species represented. Indeed, except for a few, scattered fragments of snail shell

Table 5.2. Molluscan species recovered from 41BX831.

Species (listed alphabetically)	Species Codes	Description
Amblema plicata	Ap	A medium-sized to large freshwater mussel that is found in moderate-sized streams with flowing water and a firm substrate of either sand or gravel.
Cincinnatia cincinnatiensis	Cc	A small freshwater operculate gastropod that is found in shallow spring-fed streams with a firm substrate and slow current. Present in Texas during the Pleistocene, *C. cincinnatiensis* has since been extirpated from Texas.
Cyrtonaias tampicoensis	Ct	Restricted to the southern and central portions of Texas and the northeastern portion of Mexico where it occurs in generally slow to ponded waters over a sand mud substrate.
Deroceras cf. aenigma	Da	The designation given here to a series of slightly thickened, multi-layered slug plates that were recovered from the lower portion of the sediment column at 41BX831. *D. aenigma* is a species known only from fossil slug plates that are preserved in Late Pleistocene and Early Holocene sediments, mostly in the southern Great Plains. Although nothing can be known directly about the preferred habitat of this species, its occurrence in the fossil record has generally been as part of a paleoassemblage that accumulated under cooler and/or more moist conditions than are present today.
Deroceras leave	Dl	A small gray to brownish slug that is found in protected habitats underneath rocks or downed wood, under which it may burrow to deeper soil layers with sufficient moisture. This species may also be found around the margins of wetlands—marshes, ponds, or small streams—where it may actually enter the aquatic habitat to forage and absorb water. This slug contains a small internal plate of calcium carbonate that is often preserved in sediments, allowing identification of the species.
Euconulus fulvus	Ef	A terrestrial gastropod that is common in many of the Late Pleistocene and Early Holocene molluscan paleoassemblages in the central portion of the United States. Living populations of this species are restricted to the northeastern United States as far south as the Applachian Mountains with disjunct populations present in montane habitats of the Trans-Pecos Texas.
Gastrocopta pellucida	Gpe	Found under cover objects in many types of habitats, generally rather open habitats with limited woody plant cover.

continued

Table 5.2. Continued.

Species (listed alphabetically)	Species Codes	Description
Gastrocopta procera	Gpr	A small terrestrial gastropod that is often found in association with *Gastrocopta pellucida*, although *G. procera* requires more moisture than *G. pellucida*.
Gyraulus parvus	Gp	A small aquatic snail that is found in small spring pools and on aquatic vegetation in slow-moving water.
Helicodiscus singleyanus	Hs	A small disc-shaped gastropod that is often found in the same microhabitats as the species of *Gastrocopta* listed above.
Helisoma anceps	Ha	A medium-sized aquatic snail that is found in spring-run streams over limestone gravel and cobble in the Texas Hill Country.
Lampsilis bracteata	Lb	Restricted to the Texas Hill Country and the immediate downstream areas of streams that drain this area. Typical habitat is flowing water over small gravel substrate.
Lampsilis hydiana	Lh	A freshwater mussel that is usually found in slow-moving water over sand or firm clay substrate.
Lampsilis teres	Lt	A freshwater mussel that is usually found in flowing water over sand or firm clay substrate.
Megalonaias nervosa	Mn	A medium-sized to very large freshwater mussel that is found in moderate to large streams. Although this species is very typical of lotic habitats, particularly gravel riffles, it has successfully adapted to large reservoirs in northern Texas.
Oligyra orbiculata	Oo	The only terrestrial operculate that occurs in the central Texas area. This species is found in a wide variety of habitats that have a certain amount of cover material in the form of wood or rock. Substrate is usually calcareous in nature.
Physella vigata	Pv	A freshwater gastropod that is found in ponds and streams with slow-moving water.
Pisidium casertanum	Pc	Probably the most widely distributed freshwater bivalve in the world. This species is found in a great variety of freshwater habitats.
Polygyra texasiana	Pt	A medium-sized terrestrial gastropod that is found under rocks and downed wood in open woodlands, savannahs, and prairies.

continued

Table 5.2. Continued.

Species (listed alphabetically)	Species Codes	Description
Pupoides albilabris	Pa	A small terrestrial gastropod that is found in a variety of habitats with cover in the form of wood, rocks, or deep leaf litter.
Quadrula apiculata	Qap	Occurs in various types of water, but it is most often found in slow-moving to ponded water.
Quadrula aurea	Qau	Restricted to the Texas Hill Country and downstream portions of the rivers that drain this area. Preferred habitat appears to be flowing water over small gravel or sand.
Rabdotus mooreanus	Rm	A large terrestrial gastropod that is found in open woodlands, savannahs, and prairies. This species is often found up on vegetation during the hot periods of the year.
Strobilops texasiana	St	Another small terrestrial gastropod that is found in mesic microhabitats, often in subhumid habitats. This species is usually found under downed wood, usually associated with woody vegetation.
Succinea cf. solastra	Ss	An amber snail that is found in usually xeric microhabitats where the soil is periodically saturated with water. Habitat types include open woodland or brushlands and brushy savannahs. This species is known only from southern Texas, but undoubtedly occurs in northeastern Mexico. It is apparently closely related to *Succinea luteola*, which is more widespread and usually more abundant. Some workers would probably synonymize *S. solastra* under *S. luteola*.
Toxoplasma texasensis	Tt	A small freshwater mussel that is typically found in slow-moving or ponded water over a sand or mud substrate.
Tritogonia verrucosa	Tv	Typically found in flowing water in a gravel or coarse sand substrate.

(some of which can be identified), the only molluscan remains present in these samples are slug plates of at least one, and likely two, species of gray slugs. The near absence of non-slug remains may be partially taphonomic as discussed in the next section of this chapter, but the analysis will be made assuming that the dominant molluscan life during the time period represented in these sediments was one or two species of slugs. Living populations of *Deroceras laeve* in this area are found concentrated under cover material in seasonally moist micro-habitats. This species may enter the margins of aquatic habitats. *Deroceras aenigma* is assumed to have lived in cooler and wetter climates than those now present in the region, but the details of the habitat have not been and probably cannot be described for an extinct species. The restriction of *D. aenigma* to the lower portions of this section may be an indication of cooler and moister microhabitats than those available during deposition of alluvium composing

Table 5.3. Distribution of freshwater mollusks recovered from column at 41BX831

Sample No.	Unit No.	Species Codes						
		Pc	Ap	Lt	Cc	Pv	Gp	Ha
				Zone 5 4000 B.P. - Present				
1m[*]	A7	-	-	-	-	-	1+0	-
1f[†]	A7	-	-	-	-	-	-	-
2	A7	-	-	-	1+0	-	1+0	-
3	A6	-	-	-	1+0	-	2+0	-
4	A6	-	-	-	2+0	-	3+5	-
				Zone 4 4500 - 4000 B.P.				
5	A6	1+0	-	-	5+0	-	4+6	-
6	A6	-	-	-	2+6	-	4+11	-
7	A5	-	-	-	1+0	-	3+1	-
				Zone 3 8000 - 5000 B.P.				
8	A5	1+0	-	-	3+0	-	5+1	-
9	A5	-	-	-	1+0	-	-	-
10	A5	-	-	-	-	-	-	-
11	A5	-	-	-	-	-	-	-
12	A5	-	-	-	-	-	-	-
13[~]	A5	-	-	-	-	-	-	-
14	A5	-	-	-	-	0+1	1+0	-
15	A4	-	-	-	-	-	-	-
16	A4	-	-	-	-	-	-	-
17	A4	-	-	-	-	-	-	-
18	A4	-	-	-	-	-	2+0	1+0
				Zone 2 12,500 - 8000 B.P.				
19	A3	-	2+0	-	-	-	2+0	-
20	A3	-	-	-	-	-	-	-
21	A3	-	-	0+1	-	-	-	-
22	A3	-	-	-	-	-	-	-
23	A3	-	-	-	1+0	-	-	-
24	A3	-	-	-	-	-	-	-
				Zone 1 15,300 – 12,500 B.P.				
25	A3	-	-	-	-	-	-	-
26	A3	-	-	-	-	-	-	-
27	A3	-	-	-	-	-	-	-
28	A3	-	-	-	-	-	-	-
29	A3	-	-	-	-	-	-	-
30	A3	-	-	-	-	-	-	-
31	A3	-	-	-	-	-	-	-

[~]Unidentifiable unionid fragments were found in this sample.
[*]Sample 1m was collected in a mesquite-covered area at 41BX831.
[†]Sample 1f was collected in a plowed field at 41BX831.
Note: Species codes in this table are defined in Table 5.2. Two numbers are shown for each species recovered from a particular sample (for example, 2+6). The first number represents adults and the second number represents immature specimens.

Table 5.4. Distribution of terrestrial gastropods recovered from the column at 41BX831.

Sample	Unit	Species Codes										
No.	No.	Oo	Pa	Gpe	Gpr	St	Ss	Hs	Dl	Da	Rm	Pt
Zone 5 4000-Present												
1m[*]	A7	-	12+8	2+0	25+2	-	0+10	9+3	-	-	1f+3+4+0	2+0
1f[†]	A7	1+0	5+8	-	-	1+0	2+17	8+0	-	-	1+0+2+14	0+2
2	A7	-	9+5	-	-	-	3+31	24+7	-	-	4+7+18+6	8+2
3	A6	5+0	2+1	-	-	-	2+8	4+1	-	-	1+5+12+8	5+1
4[~]	A6	3+0	1+0	-	1+0	-	1+16	2+4	-	-	12+7+21+6	-
Zone 4 4500-4000												
5	A6	-	1+2	-	-	-	1+7	13+0	-	-	3+5+4+12	4+15
6	A6	1+0	2+1	1+0	1+0	-	2+12	12+19	-	-	2+1+4+1	1+0
7	A5	-	1+3	-	2+0	-	1+3	7+12	-	-	f+1+4+0	0+1
Zone 3 8000-5000 B.P.												
8	A5	f^	-	-	-	-	2+11	3+0	-	-	1+3+1+1	2+3
9	A5	-	1+0	-	-	-	0+5	1+0	-	-	2+3+1+0	2+1
10	A5	-	1+0	-	-	-	0+1	2+0	-	-	2+3+1+0	1+0
11	A5	-	1+0	-	-	-	1+0	-	-	-	3+1+0+0	1+0
12	A5	-	-	-	-	-	1+6	1+0	-	-	6+5+3+5	1+0
13	A5	-	-	-	-	-	1+0	-	-	-	3+7+3+1	0+1
14	A5	-	2+1	-	-	-	0+1	5+2	-	-	1+2+5+3	0+1
15	A4	-	-	-	-	-	-	-	-	-	1+4+3+0	5+2
16	A4	-	-	-	-	-	-	-	-	-	f	-
17	A4	1+0	-	-	-	-	1+1	-	-	-	2+4+2+0	-
18	A4	-	-	-	-	-	0+1	-	-	-	-	0+1
Zone 2 12,500-8000 B.P.												
19	A3	1+0	-	-	-	-	0+2	-	-	-	4+3+0+0	-
20	A3	3+0	-	-	-	-	-	-	-	-	f+4+5+22	1+4
21	A3	5+0	-	-	-	-	-	-	-	-	5+5+8+23	-
22	A3	4+0	-	-	-	-	-	-	-	-	4+2+8+19	2+5
23	A3	5+0	-	-	-	-	0+3	-	-	-	2+4+6+19	2+3
24	A3	1+0	-	-	-	-	-	-	-	-	f	1+0
Zone 1 15,300-12,500 B.P.												
25	A3	-	-	-	-	-	-	-	4+0	-	f?	-
26	A3	-	-	-	-	-	-	-	-	-	f?	-
27	A3	f	-	-	-	-	-	-	-	-	f	-
28	A3	f	-	-	-	-	-	-	2+0	-	-	f
29	A3	f	-	-	-	-	-	-	-	-	f	f
30	A3	f	-	-	-	-	-	-	7+0	6+0	f	-
31	A3	-	-	-	-	-	-	-	-	-	f	-

[~]One secondarily deposited shell of Euconulus fulvus (Ef) was recovered from this sample.
^f=fragment.
[*]Sample 1m was collected in a mesquite-covered area at 41BX831.
[†]Sample 1f was collected in a plowed field at 41BX831.
Note: Species codes used in this table are defined in Table 5.2. Where two numbers are shown for each species recovered from a particular sample (for example, 12+8), the first number represents adults and the second number represents juveniles. Where four numbers are shown for *Rabdotus mooreanus*, the first, second, third, and fourth number represents adults, adolescents, juveniles, and hatchlings, respectively.

the upper portion of this section. The dominance of the assemblage by slugs indicates that a wet prairie or meadow could have been the likely vegetational community type. The absence of aquatic forms suggests that this community was a "terrestrial" marsh, i.e., dominated by wetland grasses and sedges rather than a deeper wetland with emergent and submergent aquatic vegetation. However, if we assume that substantial amounts of terrestrial gastropod shell was dissolved, the same fate could have been met by freshwater gastropod and bivalve shells; any record of these aquatic habitats would have been lost. Seasonal loss of surface water is possible, even likely, but the substrate did not desiccate to the extent that is observed in temporary ponds of today.

Zone 2—Savannah with Flooding Interludes—Samples 24–19 (ca. 12,500–8000 B.P.)

This zone includes all of Unit A3 above Soil 6 and spans the period ca. 12,500–8000 B.P. Several environmental conditions are indicated by the species present in these sediments. Significant beyond the mere presence of these species is also the size-class structure of some of the species. The abundance of *Oligyra orbiculata* indicates the presence of substantial amounts of woody vegetation, but the occurrence of *Rabdotus mooreanus* indicates the presence of open space between these woody plants. Most of the specimens of *R. mooreanus* are hatchlings, indicating that the oviposition and hatching niche of this species was well represented, but that the area must have periodically become desiccated as indicated by the abundance of dead hatchlings and relative paucity of the more mature size classes. The presence of freshwater mussel shells and gastropod shells that appear to be flood debris indicates the occurrence of surface water at the site or a substantial alluvial input. The most likely vegetational community and general environment that meets these restrictions is an open savannah with scattered woody vegetation and substantial grass cover. The periodic moist conditions, often followed by rapid desiccation, would seem to indicate the occurrence of periodic alluvial input with flood debris. Local precipitation would seem to be low to moderate and, possibly, seasonal in occurrence.

Zone 3—Mid-grass Prairie (?)—Samples 18–8 (ca. 8000–5000 B.P.)

This zone includes the Elm Creek paleosol and all but the upper 30 cm of the Medina pedocomplex, and spans the period 8000–5000 B.P. Several gastropod species or groups of species indicate the occurrence of an open habitat that had no great amount of woody vegetation. Most of this section indicates conditions that were conducive to survival and reproduction of *Rabdotus mooreanus*. Levels without substantial *R. mooreanus* are those layers with aquatic snails, indicating alluvial input of flood debris, or the occurrence of many small-shelled species, indicating the occurrence of more continually moist soil conditions. The absence of *Oligyra orbiculata* from most of these levels indicates the rarity of woody plants. This zone seems to indicate the occurrence of low but dependable amounts of moisture. The plant community most likely to fit this description is a mid-grass prairie. However, the ability to reconstruct a paleoenvironmental prairie setting will be discussed in the following section of this chapter.

Zone 4—Mid-grass Prairie with Surface Water—Samples 7–5 (ca. 4500–4000 B.P.)

This zone includes the upper 30 cm of the Medina pedocomplex and the lower 30 cm of the Leon Creek paleosol, and it spans the period 4,500–4,000 B.P. The presence of *Rabdotus mooreanus* and *Helicodiscus singleyanus* indicates the continued existence of an open vegetational community. The presence of *Pupoides albilabris* and the near absence of *Oligyra orbiculata* indicate the occurrence of some cover material, probably wood, on the soil surface but the local absence of substantial amounts of woody plants. The occurrence of both fresh shells of *Gyraulus parvus* and *Cincinnatia cincinnatiensis* indicates the input of alluvium with flood-debris shells or the likely local occurrence of surface water. The peak of flood-debris shell input appears to be in level 6. The nature of this surface water is unclear and may have included small streams or ponds, possibly floodplain pools. The limited amount of burned shell fragments recovered during this study peaks and is almost restricted to this zone, indicating the likelihood of periodic fires that aid in maintenance of a mid-grass prairie.

Zone 5—Short- to Mid-grass Savannah to Prairie — Samples 4–1 (ca. 4000 B.P.–Present)

This zone includes the middle and upper portions of the Leon Creek Paleosol and the modern surface soil, Venus clay loam. The patterns of occurrence of most of the snail species present indicate the continued dominance of open grassland habitats. The presence of *Oligyra orbiculata* represents the return of woody vegetation to the site as an obvious, but possibly minor, portion of the plant community. Eroded and fresh shells of *Gyraulus parvus* and *Cincinnatia cincinnatiensis* indicate the input of flood-debris shells and the reduction of local surface water. *Pupoides albilabris* indicates the occurrence of downed wood in an area that is generally dry, although the possible occurrence of periodically saturated soil conditions is not eliminated.

Discussion

Molluscan paleoassemblages recovered from the various zones of 41BX831 present an overall indication of relative homogeneity on the species level. Although there is enough variation in relative amounts of species to reconstruct different plant communities, the paleoassemblage in total contains relatively few species with very little representation of extralimital species. This species homogeneity is probably due to the lack of major changes in the physiognomy of the site through the Late Wisconsinan and Holocene. Postulated plant communities—be they marsh, meadow, grassland, or savannah—are all dominated by graminoid species with minimal to only moderate occurrence of woody species. This relative stability throughout a period, with presumed significant variations in the ambient climate, is a result of the relative importance of edaphic factors in relation to climatic factors in determining the basic structure of the plant community at this site with fine-grained, tightly packed soil.

Some variation in effective moisture that can be related to climate is indicated by the occurrence of two extralimital species. The aquatic gastropod, *Cincinnatia cincinnatiensis*, was widespread during the Quaternary in Texas, although most localities are located to the north or east of Central Texas (Fullington 1978). The slug, *Deroceras aenigma*, is presumably an extinct species that lived in habitats similar to those of the modern *Deroceras laeve*, but habitat details are unavailable. Some native slug populations in the montane areas of western Texas have been assigned to this species in field and museum notes, but this specific designation has never been applied to any living population in a published report to date.

No shells of the terrestrial gastropod species that are present in the upper reaches of the Medina River and that are characteristic of the modern Balconian biotic province were recovered from these sediments. Not only were these species not living at this site during the Late Wisconsinan and Holocene, but shells of these species were not a recognizable component of the flood debris that was transported by high waters during this time period. The lack of shift of the boundary of the Balconian terrestrial gastropods may not be typical of all faunal groups, however. Comprehensive investigations of several of the dominant faunal groups would be required to produce a definitive study of the spatial dynamics of this boundary through the late Quaternary.

A significant proportion of the shells recovered from the section are not autochthonous to this site. Many of these shells were deposited as flood debris by ebbing flood waters. Most if not all of the *Cincinnatia cincinnatiensis* probably lived in a smaller spring-run stream upstream from this site. The single shell of *Euconulus fulvus* is an adult shell that was secondarily deposited at this site. The biological origin of this shell was undoubtedly a protected woodland in a canyon in the upper reaches of the Medina River in the Texas hill country. This species has since been extirpated from central Texas.

Charred shell remains were rare in the samples from 41BX831. All charred remains were very fragmentary gastropod shells. Samples 2 and 19 contained charred fragments of *Rabdotus mooreanus*. Charred fragments of *Polygyra texasiana* and *Oligyra orbiculata* were recovered from samples 6 and 8, respectively. An unidentifiable fragment was recovered from sample 7. These few fragments may indicate the relative rarity of ground fires in this area, possibly due to lack of sufficient fuel load to carry a significant fire that would leave evidence in the form of charred shell.

The near lack of non-slug remains in the lowermost levels, combined with the fragmentary, etched condition of the few gastropod shell remains in these levels, raises the possibility of the occurrence of significant taphonomic changes of the original paleoassemblages, which themselves were merely a sample of the original paleofauna of this area. Molluscan shells are largely crystalline calcium carbonate with variable amounts of organic compounds present in the various layers. The most common crystalline form of calcium carbonate in terrestrial gastropods is aragonite, but the calcium carbonate in the slug plates is calcite (Evans 1972:23). As calcite is more stable than aragonite (Chave et al. 1962), in certain chemical environments, shells—even slug plates—that are composed of calcite could be expected to be differentially preserved, especially in older sediments wherein there would have been sufficient time for calcite dissolution.

The reconstruction of prairie habitats as discussed above is somewhat problematic. It is doubtful that one can accurately postulate the occurrence of a prairie environment from terrestrial gastropods alone. In essence, the presumed existence of prairies during Late Wisconsinan and essentially all of the Holocene at 41BX831 is based on the absence of gastropods indicating the presence of woody plants. This "negative postulation" may not be inaccurate in its conclusions but is not as sure or "clean" as a "positive postulation" based on the presence of indicator taxa. A survey of living gastropods of several prairie remnants in Texas has revealed the occurrence of a very low species-diversity fauna, which is characteristic of prairie sites elsewhere, as well (Neck n.d.). However, all of these species can be found in savannahs and open woodlands. Some species may also be found in the more exposed or well-drained portions of closed woodlands. The lack of terrestrial gastropod species that are endemic to prairie habitats is paralleled by most plant groups, including grasses, and many faunal groups, including vertebrates, and may reflect the relatively recent occurrence of broad expanses of prairie habitat.

The freshwater mussel remains extracted from various cultural contexts of 41BX831 form a remarkably near-complete sample of the fauna present in this river (Table 5.5). Of the 12 species of freshwater mussels known from the San Antonio River system (Neck 1989; Strecker 1931), 10 were identified in the shell assemblages recovered from this site. The two species not found in this site (*Anodonta grandis* and *Anodonta imbecillis*) are species with very thin, friable shells and less soft-tissue biomass per individual than the other species. These two species are less common in archeological remains than their modern occurrence and abundance would indicate (Murray 1981). Of the 10 species identified from this site, all but one has been recorded from the Medina River system. This single new species for the Medina River is *Megalonaias nervosa*, which was not known to Strecker (1931) from within the San Antonio River system. He did note, however, that its occurrence in this river system was "possible," a designation apparently given because *M. nervosa* was known from all other river systems in Texas. Moreover, Neck (1989) reported *M. nervosa* from the San Antonio River from museum collections at Texas Christian University and Trinity University.

The mussel assemblage from this site reveals both environmental and cultural results that can be analyzed. The aquatic habitats indicated by the constituent species include a moderately large stream with riffles and an occasional slow-water pool. The occurrence of small shells of *Toxolasma texasensis* may indicate the sampling of a small tributary stream. A number of the shells are rather small in size and may indicate resource depletion, preference for a chowder-type food as a supplement (dessert?), or collection activities by opportunistic children. On the other hand, the existence of rather large shells of several species in samples 17 to 20 indicates the occurrence of a large stream with moderately rapidly flowing water.

The pattern of mussel distribution does not correlate with shell size, which presumably is a function of the quality of the riverine aquatic system.

Maximum utilization of freshwater mussels in this portion of the Medina River valley as food items by humans occurred during the Middle and Late Archaic. Reasons for increased reliance on, or at least utilization of, freshwater mussels during this time period probably involve cultural bias of changes in the non-riverine environment of this area. Maximum size of mussel shells, and the meat in easily collectable units, was greatest during the early, Early Archaic, although moderately large *Amblema plicata* persisted into the Middle Archaic. In general, shell sizes of the freshwater mussel species utilized as food items during the time of peak utilization tend to be smaller than the average observed in both living and early Holocene samples from the Medina River valley.

Summary

The molluscan paleoassemblage extracted from the sediments at 41BX831 suggests that over the past 15,000 years there have been relatively minor vegetational differences from those conditions that are observed today. Specifically, the available evidence indicates that woody plants have been occasional to rare in percentage composition from at least the Late Wisconsinan throughout the Holocene to the present. Late Wisconsinan vegetation habitats are best classed as meadows or wet prairies with very limited presence of woody plants. The Late Wisconsinan–early Holocene transitional period appears to have been a time of increased moisture stress for terrestrial species although the large size of shells of some of the aquatic species indicates excellent aquatic habitat conditions. Woody vegetation became more abundant, but the area was likely a savannah that experienced periodic droughts.

The early Holocene environment was likely a savannah that provided moderately harsh conditions for the grass-associated *Rabdotus mooreanus* but was favorable to the woody plant-associated *Oligyra orbiculata*. The abundance of hatchling and adult *R. mooreanus* is an indication that moisture may have been very seasonal in distribution. In the early Holocene and initial portions of the middle Holocene, ca. 9000–5000 B.P., the molluscan remains indicate a decrease in available water and increase in thermal (evaporative) stress. Moisture stress experienced by terrestrial gastropods may have been less seasonal during this time period with fewer very wet seasons but also fewer very dry periods. The resultant plant community appears to have been a mid- to short-grass community with a return of woody vegetation, but woody plants still remained a minor portion of the landscape. Subsequently, moisture levels increased in the middle Holocene with more indications of surface water and soil water after 4500 B.P., but woody plants appear to have been very rare during this time period. This increase in surface water may be partially the result of an indicated increase in flood debris input of shells of aquatic species.

After about 4000 B.P., the indicated environment is not different, at present levels of resolution, from the modern environment. The relationship of this mid-Holocene dry period to the much-discussed Altithermal of higher latitudes is unknown at this time. The degree of the increase in drought conditions appears to be less severe, but its occurrence in an approximately contemporaneous period is very intriguing indeed.

It is important to note that the molluscan species recovered from an undated locality in alluvium of the San Antonio River near the current study site indicate some major changes in the general environment at some point upstream from this other locality. Seven species of terrestrial gastropods have been reported from San Antonio River alluvium, two of which do not live in this region today. Whereas *Gastrocopta armifera* is found in protected areas of north-central and Panhandle Texas (Fullington, personal communication, 1992; Neck 1990), *Discus cronkhitei* is not found living in eastern North America south of a line drawn from Kentucky to South Dakota (Hubricht 1985:107). However, western montane populations of *D. cronkhitei* are known as far south as the Guadalupe Mountains of Texas (Fullington 1979).

The difference in the apparent environmental conditions as demonstrated in these two paleoassemblages illustrates the complexity of analysis of the environmental changes in the past. Molluscan

Table 5.5. Distribution of freshwater mussels from cultural samples at 41BX831.

Cultural	Species Codes										
Level	Ap	Mn	Qap	Qau	Tv	Ct	Lb	Lh	Lt	Tt	?*
Late Prehistoric											
1	5+3	-	-	-	-	-	-	-	-	-	-
2	1+1	-	-	-	-	0+1	-	-	-	-	-
Upper Late Archaic											
3	3+7	-	-	-	1+2	-	-	-	1+0	-	-
4	1+1	-	-	-	-	-	-	0+2	-	-	-
5	18+8	1+0	2+0	3+3	2+2	2+4	-	0+1	3+4	3+1	0+1
Middle Late Archaic											
6	2+3	-	-	-	0+2	-	-	-	0+4	-	-
7	3+2	-	-	0+1	-	1+1	-	-	-	-	-
8	1+1	-	0+1	0+1	-	1+1	-	0+1	2+2	-	-
Lower Late Archaic											
9	7+7	-	-	2+4	-	0+1	-	-	3+3	8+1	15+0
Upper Middle Archaic											
10	23+21	5+3	2+0	-	-	2+2	0+4	3+1	-	-	-
Lower Middle Archaic											
11	5+7	-	4+2	1+4	-	-	-	-	4+2	-	4+0
12	1+0	-	-	-	-	0+1	-	-	0+1	0+1	-
Early Archaic											
13	4+8	-	-	-	-	-	-	0+1	3+3	-	-
14	3+3	-	-	-	-	-	-	-	-	14+12	-
15	5+3	-	-	0+2	-	1+0	-	-	1+0	-	-
16	21+18	-	-	-	1+0	1+0	-	1+2	-	-	-
Upper Late Paleoindian											
17	4+5	-	-	-	-	-	-	-	0+1	-	-
18	5+3	-	1+0	-	-	0+1	-	-	0+1	-	-
Lower Late Paleoindian											
19	1+1	-	-	-	-	-	-	-	0+1	-	-
20	1+2	-	-	-	-	-	-	-	-	-	-

*Unidentifiable remains, usually an individual pseudocardinal tooth.

Note: Species codes used in this table are defined in Table 5.2. Two numbers are shown for each species recovered from a particular cultural level (for example, 5+3). The first number represents adults and the second number represents immature specimens.

shells, indeed any biotic remains in sediments, are habitat proxies, not climate proxies. Certainly, climate is a major factor in the environment of any particular species, but many other factors impinge upon and limit the direct effect of the ambient climate on the occurrence and abundance of any particular species. To properly interpret the significance of the biotic remains in any site, one must understand the environmental limitations of each species and be able to recreate, mentally, the habitat and microenvironment in which the constituent species of the paleoassemblage live. Reconstruction involves vegetational community structure, soil texture and drainage, amount and nature of soil cover, and any other salient environmental factors that affect the dispersal and survival of any particular species in the paleoassemblage.

6

FRESHWATER SHELL ISOTOPE STUDIES

David O. Brown

This study examines patterns of stable isotopes of oxygen and carbon measured in mussel shells from excavated contexts at the Richard Beene site as proxy indicators of past environments. Understanding past cultural dynamics requires consideration of the environmental setting and potential changes to that setting. Although freshwater shell isotope studies have some limitations for precise paleoenvironmental reconstruction, they nonetheless provide an independent source of data for the interpretation of past climates and environments that can be used to refine and/or validate data from other sources.

It has long been recognized that the differential distribution of the isotopes of oxygen and carbon can be linked to environmental parameters. Extrapolation of the modern distribution of oxygen isotopes has been directly related to temperature and precipitation regimes. This relationship has been used to infer past global and regional climates. Measurements of oxygen isotopes from ice cores, in conjunction with other data, have aided in the development of a detailed global climatic model extending back into the late Pleistocene. Since Urey (1947) first suggested a relationship between the ratio of $^{18}O/^{16}O$ trapped in marine carbonate fossils and the paleotemperature of ancient oceans, researchers have attempted to extend the description of ancient climates millions of years into the past and to develop detailed regional models of past climates. Similarly, the differential distribution of carbon isotopes has been linked to carbon-processing pathways inherent in broad classes of plants. In recent decades, both oxygen and carbon isotopes have been used as important proxy indicators of paleoenvironments and resulting data have proven useful in archaeological studies.

Stable Isotope Studies

Stable isotopes, some 300 of which occur naturally in more than 60 chemical elements, are defined by the number of neutrons within the atomic nucleus which in turn affect the atomic weight of the element. Typically, one isotopic variant is dominant while the others are found in small percentages relative to the primary form. Unlike radiogenic isotopes, which change their form and atomic weight through time, the total reservoir of stable isotopes remains relatively unchanged. Differences in the behavior of the isotopes of a particular element can often be attributed to slight differences in their atomic weight. These behavioral differences can lead to small variations in stable isotope percentages that have been linked to environmental conditions. Stable isotope studies, particularly those focusing on environmental questions, have generally keyed on low-atomic-weight elements from hydrogen to sulfur. In part, this is because these low-atomic-weight elements are among the most common found in nature, but also because the addition or subtraction of neutrons from the nucleus of lighter elements results in a greater proportional weight change and a greater tendency to behavioral differences.

Following early marine shell isotope studies directed primarily toward tracking ocean paleotemperatures, researchers turned their attention to fresh-

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 101-112. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

water shell studies and the reconstruction of continental climates. Clayton and Degens (1959) used oxygen isotope fractionation as a means of distinguishing marine versus freshwater depositional environments. Keith et al. (1964) looked at the variation among freshwater molluscan species, sampling shell from lakes and rivers from Saskatchewan to Missouri, examining several hundred isotope fractionation readings from 64 different marine and freshwater sites. In an attempt to test the validity of freshwater shell from different environments in environmental reconstruction, they sampled multiple shells of the same species from the same sample site. They ran multiple samples from different points on single shells of several different species and they conducted comparative analyses between shell and soft parts of molluscs. Their analyses included a number of freshwater molluscan genera that are typically found in the vicinity of the Richard Beene site such as *Lampsilis*, *Quadrula*, and *Amblema*.

Keith and his colleagues (1964:1772) found that shell carbonates clearly reflected the latitude effect in oxygen isotope fractionation caused by a progressive depletion of the heavier ^{18}O as one moves northward. They also noted that while there are slight differences between different species in the same environment, the differences between lacustrine and riverine examples of the same species are much greater than the interspecific differences. Ultimately, isotopic fractionation is a result of environmental differences rather than vital effects or specific differences in fractionation (Keith et al. 1964:1774).

Many of the early stable isotope studies of freshwater molluscs used samples from lacustrine environments. Stuiver (1968, 1970) studied lake marls and molluscan shells in cores from Pretty Lake in Indiana, Queechy Lake and Henderson Pond in New York, and Pickerel Lake in South Dakota. He noted a distinct postglacial warming beginning between 9,000 and 10,000 years ago, a cooling trend between 5,000 and 2,500 years ago, and a slight warming trend over the last 1,500 years (Stuiver 1970:5254). These findings correlated with pollen cores from Pickerel and Pretty Lakes. Stuiver (1970:5256) concluded that freshwater shells grow in isotopic equilibrium with their environment and that interspecific variation was small, less than 0.7‰ in the seven species he sampled from Lake Huron. While his findings did not allow the precise calculation of paleotemperatures, he suggested that they were closely correlated with the isotopic values.

Fritz and Poplawski (1974) examined oxygen and carbon isotope fractionation in gastropods and pelecypods collected from lakes in southern Ontario as well as specimens grown under laboratory conditions. They found seasonal variation in oxygen isotope fractionation from several lakes, with annual per mil change as high as 6‰. Their results indicated that the $\delta^{18}O$ isotopic fractionation was climatically controlled, related to both temperature and evaporation, but also associated with flushing and lake inflow/outflow. Among the first researchers to include carbon in a shell isotope study, they suggested that $\delta^{13}C$ was primarily controlled by dissolved inorganic carbon in the water source rather than vital effects or food sources.

In a subsequent study of ostracods and molluscs in a core from Lake Erie with sediments dating to 15,000 B.P., Fritz and his colleagues were able to correlate some of the earliest isotopic changes with documented changes in the pollen records and paleovegetation of the lake area, while some of the more recent changes were attributed to shifts in lake hydrology (Fritz et al. 1975). Combining $\delta^{18}O$ and $\delta^{13}C$ in a single plot showed strong clustering of the values from different time periods, separating the clusters better than oxygen alone. This covariance between $\delta^{18}O$ and $\delta^{13}C$ in carbonates has been clearly demonstrated in closed basin lakes, whereas open basin systems and rivers tend toward weaker covariance and a more limited range of $\delta^{18}O$ values (Talbot 1990:276).

Dettman and Lohman (1993) compared $\delta^{18}O$ and $\delta^{13}C$ in mussels from the modern Huron River in Michigan to Paleogene unionids from fluvial and lacustrine contexts in the Powder River Basin in Montana and Wyoming, using high-resolution microsampling. They found well-preserved seasonal variation in $\delta^{18}O$ and $\delta^{13}C$ from both modern and fossil specimens, and noted a strong correlation between the modern specimens and measurements of $\delta^{18}O$ and $\delta^{13}C$ in the Huron River. In a later paper, Dettman et al. (1999) measured $\delta^{18}O$ and $\delta^{13}C$ in molluscs from the Huron River, confirming that seasonality is well preserved and suggesting that bulk shell $\delta^{18}O$ values should closely approximate the average parameters of past environments. But while strong seasonality was present in the $\delta^{13}C$ measurements, they concluded that the variation was not a simple function of dissolved inorganic carbon in the stream. They suggested that an indeterminate amount of more negative carbon from organic carbon was in the stream (Dettman et al. 1999:1055). This mixing of inorganic carbon and metabolic carbon has also been noted in more recent studies of molluscs by McConnaughey et al. (1997) and Ricken et al. (2001).

The reconstruction of past climates from isotopic composition is a complex process with many complicating factors (e.g., Faure 1986:442–446; Hoefs 1987). In the case of $\delta^{18}O$, the entrapment of the lighter $\delta^{16}O$ in glaciers may alter the composition of the oceans, ultimately changing the character of meteoric water and complicating the interpretation of climatic effects during periods of intense glaciation and deglaciation (Hoefs 1987:142). Unfortunately, the magnitude of this effect, which may complicate the interpretation of late Pleistocene climates, is only poorly understood.

Even greater potential problems arise from variations in meteoric water, evaporated from the oceans and almost always much lighter than the source water. While the nature of the process is reasonably well understood, actual precipitation varies widely in isotopic composition. The isotopic composition of meteoric water is influenced by latitude, altitude, annual rainfall, rainfall seasonality, and temperature (Dansgaard 1964). Although global estimates have been constructed for precipitation values (Yurtsever 1975), there are many local factors which affect isotopic content. The result is only rarely a linear relationship and, while some studies have suggested temperature, precipitation, rainfall amount, or latitude as the single most important factor, the relationship is generally considered a multivariate one with critical factors changing through time and place. In general, tropical and lower latitude maritime isotopic composition is influenced by rainfall amount and seasonality, while in higher latitudes, temperature is a more important criterion (Rozanski et al. 1993:8–11). Continentality is also a critical variable as interior continental precipitation tends to be more deficient in the heavier ^{18}O than continental margins (Rozanski et al. 1993:5–8).

The interpretation of the ^{18}O of freshwater lakes and rivers is further complicated by the conflation of processes. Closed-basin lakes may be dominated by evaporation, which leads to relative enrichment of the heavier ^{18}O, while open-basin lakes are more temperature dominated and responsive to meteoric isotopic composition. Rivers and creeks may be almost totally dependent on meteoric isotopic composition, or their isotopic signature may be largely determined by the composition of aquifer water, which introduces a lag factor and perhaps mixing of recharge waters in the equation.

Other problems with studies of oxygen isotopes in biogenic carbonates are more directly related to the organisms themselves and their manipulation of carbonates. First of all, while certain organisms appear to maintain a near-perfect isotopic equilibrium between ambient water and secreted carbonates, others perform a biological fractionation during shell secretion (Anderson and Arthur 1983:65–75). This effect has been studied in laboratory conditions, and while the general conditions and species for which it occurs are known, it is still not completely documented. Apparent differences in isotopic fractionation also depend upon shell mineralogy. The two primary carbonate shell crystalline forms, calcite and aragonite, as well as biogenic silica, are found to have different $\delta^{18}O$ values (Horibe and Oba 1972). Unfortunately, though many freshwater species are primarily aragonite, many also have calcite and even vaterite deposits within the shells, complicating the analysis of $\delta^{18}O$ values. Worse still is the tendency of aragonite to be replaced by calcite through time, in a process which may alter values of $\delta^{18}O$.

Finally, there is a potential problem with postmortem alteration of shell isotope composition. While this has been studied somewhat for marine animals, there are few data available for potential postdepositional alteration of freshwater shell in active pedogenic environments. At the Aubrey site in the upper Trinity basin in north-central Texas, Humphrey and Ferring (1994) discussed the pedogenic alteration of soil carbonates in relation to the isotopic composition of soil carbonates. Their conclusion, based upon the literature, was that the effect was minimal, that is, insufficient to alter the original $\delta^{18}O$ of the meteoric waters. While this probably holds true for shell carbonates as well, there has been little study of in situ isotopic exchange and the conditions or environments which may enhance or hinder it.

Analytical Method

A total of 34 samples of mussel shell was submitted to Coastal Science Laboratories, Inc., in Austin, Texas, for analysis of the stable isotopic ratios for both ^{18}O and ^{13}C. Samples were selected from shell concentrations and cultural features from well-dated strata at the Richard Beene site. The stratigraphic units and cultural components as well as the blocks, units, and features cited here are discussed Chapters 3, 4, and 9.

In addition to the archaeological samples from the Richard Beene site, two modern samples from the Medina River were included to provide a baseline for the analysis. These two specimens were collected by Joe Bergmann of Boerne from the Medina River at the FM 1604 bridge near McDonna in October 1972 and September 1973. According to Mr. Bergmann, the specimens were both dead less than a week when collected.

In an attempt to control for the effects of potential interspecific differential fractionation, all samples were extracted from adult *Amblema plicata* specimens. The three-ridge mussel, as it is known, is characterized by three pronounced ridges on the shell exterior and is easily identifiable even from fragmentary specimens. In addition to being the dominant bivalve species at the site (Chapter 5), these large, thick-walled specimens offered a larger potential sample size with perhaps less potential surface exchange area than thinner-walled species. In addition to their size and thick, solid shells, which made them attractive to the historic shell button industry, they are found in a wide range of aquatic environments in streams, rivers, lakes, and sloughs (Howells et al. 1996:33–35). They live at water depths from 2.5 cm to 1.5 m (and perhaps much greater), inhabit a range of substrates, and tolerate low water conditions and droughts. The three-ridge mussel is found throughout much of Texas east of the Pecos River and is common in archaeological deposits.

Insofar as was possible, the shell samples from any given unit-level or feature were limited to either right or left valves to rule out bias inherent in including two valves from the same individual. Samples for analysis were taken by crushing approximately half of a single valve from anterior to posterior margin. This bulk sampling technique roughly approximates the method used by Keith et al. (1964) and other researchers who have used sections across the dorsal surface of the shell. Using the entire half valve maximizes the influence of later years in the clam's life, represented by the outermost layers of the shell, and thus helps to minimize extreme short-term variation in climatic patterns that may be inherent in short-lived molluscs such as terrestrial gastropods, which typically have life spans ranging from a few months to three or four years (Heller 1990:286–288). In contrast, large mussels may live up to 50 years (Heller 1990:293; Raymond Neck, personal communication, 1993). *A. plicata* is listed by Heller (1990) as having a life span of 16 years.

Most of the specimens selected for the study may be 5 to 10 years old, although there was a great deal of variation in individual clam sizes. Mean and maximum shell sizes were quite different between strata, suggesting the possibility of climatic limits on growth or predation pressures. In the selected sample, the individuals from the upper Perez paleosol were by far the largest (and were in relatively better state of preservation than clams from some younger strata). The largest individual specimen sampled in the study, weighing 38 g, was from this layer. In contrast, most of the Middle and Late Archaic individuals were smaller; shells from the upper Leon Creek paleosol were the smallest and most fragmentary. Neck (Chapter 5) noted this trend, suggesting collection of the smaller shells may indicate predation, although he notes that it could as easily represent a preference for chowder or children collecting shells.

Bulk sampling as utilized here obviously does not provide the same degree of precision that microsampling of shell sections can. Microsampling along the length of the shell has been used in recent years to reconstruct not only climatic seasonality, but variability on a monthly or weekly basis (Reische 1998; Schoene and Flessa 2002). While such sampling could ultimately revolutionize the field of paleoclimatic research, it is costly, time consuming, and requires some assumptions regarding growth of the shell. Additionally, it is all but impossible to precisely date such fine chronologies in fossil shells.

Kenneth Winters (personal communication, 2003) of Coastal Science Laboratories provided the following description of the method:

> Shell samples were broken and ground with a glass mortar and pestle. Pieces of each large sample were selected for grinding, which approximated the composition of the whole shell. The remaining pieces were saved for other studies. Sample material which passed a 140 mesh sieve was used for analysis. Samples were acidified with 100 % phosphoric acid at 30º ± 1 in a water bath (McCrea 1950). Appropriate laboratory working standards and NIST standards were acidified and analyzed along with each batch of samples analyzed. Stable isotope values of samples and standards were determined by analysis in a VG Micromass Series II Model 10 triple collector mass spectrometer. Data from each batch of samples were calculated by comparison with data obtained from standards analyzed with each batch.

As a check on the results of the analysis, 6 of the 34 samples were run twice for both δ^{18}O and δ^{13}C. Three of the δ^{13}C and two of the δ^{18}O sample values were identical, while three of the δ^{13}C and four of the δ^{18}O values varied by 0.1‰. Coastal Science Laboratories suggests that the results are accurate to within 0.2‰.

Analytical Results

Table 6.1 shows the δ^{18}O and δ^{13}C values for each sample with the elevation and the estimated age of each sample group. The dates from this sequence are from charcoal samples from cultural features (Chapter 4). Sample values for δ^{18}O range from -1.2 to -3.9‰, a total range of 2.7‰. Standard deviation is 0.8‰. Values for ^{13}C range from -5.0 to -8.9‰, a range of 3.9‰. The standard deviation for ^{13}C is 0.8‰. Unlike the results from closed-basin freshwater lacustrine samples, there is very little correlation between the ^{18}O and ^{13}C values, with an r value of -0.12 for all individual samples. Excluding the modern sample, which has the most extreme δ^{13}C values, the correlation is only slightly stronger at r = -0.19. The grouped samples show a slightly different pattern. The r value for the average values of the grouped samples is -0.06. Removing the modern group yields a correlation of r = -0.18, nearly identical to the result for the individual samples with the modern ones removed. Excluding both the modern group and the group from the lower Leon Creek component, which has an extreme δ^{18}O value, yields a positive correlation coefficient of r = 0.29. Excluding only the mean of the lower Leon Creek group (i.e., including the modern group), the r value shows a notable negative correlation at -0.57. Figure 6.1, which plots grouped values of δ^{18}O and δ^{13}C plotted against mean sample elevation, suggests that in spite of the wide range of correlation coefficients, the two isotope data sets approximate a mirror image of each other.

The spread of coefficients suggests that the δ^{18}O and δ^{13}C values are independent variables that are not directly interrelated to one another and perhaps reflect different aspects of shell construction. Although both isotopic values represent aspects of the environment within which the molluscs secreted their shells, they may measure different components of the ecosystem, or at least sample them at different levels. Nonetheless, the apparent visual correlation between the two data sets does indicate that the values are related at some level.

Figure 6.2 shows the mean, minimum, and maximum ranges of grouped $\delta^{18}O$ values plotted against the sample elevation (with radiocarbon ages shown on the chart). The mean of grouped $\delta^{18}O$ samples is -3.0‰, (0.2‰ less than the mean of all individual samples) with a standard deviation of 0.7‰. The total range of $\delta^{18}O$ values for all samples extends from -1.2 to -3.9‰, while the range of means for sample periods is -1.4 to -3.5‰. Excluding the extreme sample for the lower Leon Creek sample, the range is only -2.9 to 3.5‰. Note that the least variation within a grouped sample occurs in the lower Leon Creek group (standard deviation = 0.17‰) at 4135 B.P. while the greatest variation is found in the two samples of the upper Medina group (standard deviation = 0.49‰) dated to approximately 4570 B.P.

Amongst the larger groups of samples (i.e., upper Leon Creek, lower Leon Creek, lower Medina, and upper Perez), there is considerable individual variability in the $\delta^{18}O$ values. The tightest cluster is found among the extreme values of the lower Leon Creek component samples. These eight samples yield a standard deviation of 0.17‰. The lower Medina with a 0.29‰ standard deviation among six samples shows a somewhat greater spread of values. The upper Perez with a standard deviation of 0.33‰ among six samples is very close to the lower Medina in dispersion of values, while the upper Leon Creek, with a 0.45‰ standard deviation and eight samples is the worst of the larger samples. Standard deviation is essentially meaningless for the three groups of two samples from the modern era, from the upper Medina and from the Elm Creek, but the Elm Creek samples have identical $\delta^{18}O$ values, while the upper Medina samples are separated by 0.70‰, essentially the same range as the six lower Medina samples at 0.66‰. The modern samples, collected a year apart, show a variability of 0.2‰, essentially the same as the level of analytical error indicated by Coastal Laboratories.

Various studies, including Keith et al. (1964), Stuiver (1970), and LéColle (1985) have noted that within samples from the same area, the ^{18}O values for carbonate, expressed relative to the PDB standard (based on stable isotope values of Cretaceous belemnites from the Peedee Formation of South Carolina), are generally close to the ^{18}O values for ambient water relative to standard mean ocean water (SMOW) (as originally defined by Craig 1961). Several relevant ambient water values have been collected from the central and south Texas area. One such value is the weighted mean of -3.8‰ SMOW for three years' rainfall between 1962–1965 and 1973–1975 for Waco, the nearest International Atomic Energy Agency (IAEA) gauging station (1969, 1970, 1979, and 1983). Annual values ranged from a high of -2.8‰ in 1974 to a low of -4.7‰ in 1964, while individual monthly samples ranged from -9.9 up to 2.7‰, with a standard deviation of 2.7‰. Although the Richard Beene site is 290 km southwest of Waco, the 30.99-inch annual average precipitation at San Antonio is not radically different than the 33.79-inch average at Waco. The next nearest IAEA isotope gauging station, at Chihuahua, Mexico, located in a substantially more arid environment and subject to a more continental climate, features a significantly lower annual rainfall total of 14.12 inches and an average $\delta^{18}O$ weighted mean of -6.2‰ (IAEA data).

The U.S. Geological Survey (USGS) has published $\delta^{18}O$ values for water samples collected from the Nueces River near Three Rivers, approximately 100 km south of the Richard Beene site (Coplen and Kendall 2000). A total of 15 samples was collected between October 1984 and August 1987. The mean of these values, which were collected from various months of the year, is -2.8‰ SMOW, with a standard deviation of 0.9‰ and a range from -0.3 to -3.9‰ SMOW. Note that the SMOW mean of this value is equivalent to the -2.8‰ PDB mean of all $\delta^{18}O$ samples from the Richard Beene site. Coplen and Kendall's (2000) study included a number of other sample sites in Texas that provide an excellent comparative database, and generally validate the association between the isotopic values of streams and meteoric water.

One additional $\delta^{18}O$ data set is available for the Edwards Aquifer wells and springs. While isotope data are not available for all sites in all years, a number of samples were run between 1988 and 1990

Table 6.1. Oxygen and carbon isotope results by stratigraphic unit.

Sample	Weight (g)	Stratigraphic Unit	Period	^{14}C Age (yr. B.P.)	Elev. (m amsl)	$\delta^{18}O$	$\delta^{13}C$
38	-	Streambed	Modern	(1972)	160	-3.02	-8.16
39	-	Streambed	Modern	(1972)	160	-2.82	-8.90
1	7.4	upper Leon Creek	early, Late Archaic	3090	159	-3.71	-7.05
2	12.6	upper Leon Creek	early, Late Archaic	3090	159	-3.03	-7.43
3	4.7	upper Leon Creek	early, Late Archaic	3090	159	-2.77	-5.73
4	9.1	upper Leon Creek	early, Late Archaic	3090	159	-2.58	-6.43
5	8.3	upper Leon Creek	early, Late Archaic	3090	159	-3.60	-5.02
6	8	upper Leon Creek	early, Late Archaic	3090	159	-3.23	-5.25
13	9.6	upper Leon Creek	early, Late Archaic	3090	159	-3.28	-6.56
15	7.8	upper Leon Creek	early, Late Archaic	3090	159	-3.74	-5.95
7	13.5	lower Leon Creek	Middle Archaic	4135	157	-1.35	-6.78
8	14.2	lower Leon Creek	Middle Archaic	4135	157	-1.37	-5.66
9	10.4	lower Leon Creek	Middle Archaic	4135	157	-1.59	-6.82
10	8.9	lower Leon Creek	Middle Archaic	4135	157	-1.64	-6.40
11	11.1	lower Leon Creek	Middle Archaic	4135	157	-1.62	-7.34
12	12.8	lower Leon Creek	Middle Archaic	4135	157	-1.32	-7.08
36	9.9	lower Leon Creek	Middle Archaic	4135	157	-1.35	-5.73
37	10.2	lower Leon Creek	Middle Archaic	4135	157	-1.18	-7.17
41	-	upper Medina	Middle Archaic	4570	156.5	-3.60	-6.00
44	-	upper Medina	Middle Archaic	4570	156.5	-2.90	-6.30
19	9.3	lower Medina	late, Early Archaic	6930	153.5	-3.06	-6.57
20	7.7	lower Medina	late, Early Archaic	6930	153.5	-3.31	-6.06
21	5.2	lower Medina	late, Early Archaic	6930	153.5	-2.67	-6.43
22	8.9	lower Medina	late, Early Archaic	6930	153.5	-3.26	-6.45
23	6.6	lower Medina	late, Early Archaic	6930	153.5	-2.65	-6.96
24	18.3	lower Medina	late, Early Archaic	6930	153.5	-2.87	-6.43
42	-	Elm Creek	middle, Early Archaic	8080	150.5	-3.40	-7.80
43	-	Elm Creek	middle, Early Archaic	8080	150.5	-3.40	-6.30
25	12.1	upper Perez	early, Early Archaic	8805	149.5	-3.03	-6.79
26	9	upper Perez	early, Early Archaic	8805	149.5	-3.55	-6.26
27	8.2	upper Perez	early, Early Archaic	8805	149.5	-3.93	-6.74
28	20.1	upper Perez	early, Early Archaic	8805	149.5	-3.67	-6.07
29	38	upper Perez	early, Early Archaic	8805	149.5	-3.30	-6.02
30	17.8	upper Perez	early, Early Archaic	8805	149.5	-3.20	-6.88

(Brown et al. 1991; Nalley 1989; Nalley and Thomas 1990). Values are available for 70 sample points in five counties. Most are well samples that range in depth from 115 to 3194 ft. Only one location in Comal County near New Braunfels and another in Hays County near San Marcos are surface spring sites. These two springs have mean $\delta^{18}O$ values of -4.2‰ (three samples) and -4.1‰ (two samples), respectively (the standard is not given but is presumably SMOW). The overall mean of all sample sites for the three-year period (only a few sites were sampled twice during the period—most are unique samples) is -4.4‰. The overall county totals range from -4.1‰ in Medina County to -4.4‰ in Bexar and Uvalde County. There is not a great deal of variation in the total sample; the overall range is from -3.4 to -5.2‰, a total range of 1.8‰, with a standard deviation of 0.3‰. Only 7 of 13 sites sampled in subsequent years yielded a different result; the remaining 6 samples were unchanged. Those that did

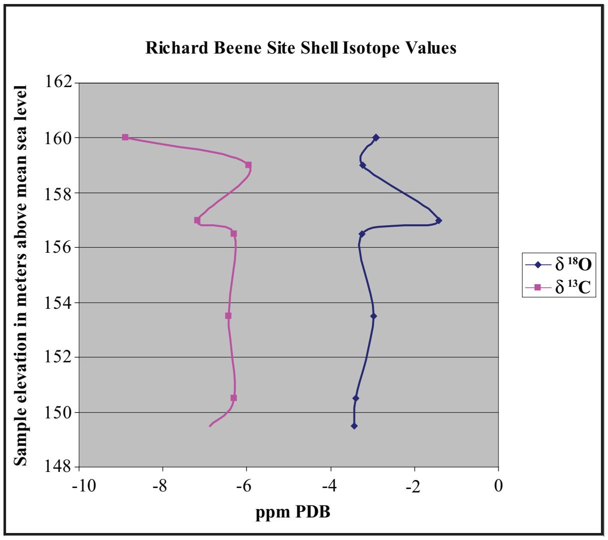


Figure 6.1. Plot of $\delta^{18}O$ and $\delta^{13}C$ results for grouped samples.

increase showed a slight tendency to increase very slightly from 1988 to 1989.

The average change for all 13 sites sampled in both years was 0.01‰; the greatest change by any one site was -0.15‰. Note that these values are slightly more negative than those of either the Waco or the Three Rivers sites, and also more negative than the corresponding shell values. Also, the total range of values and the standard deviation of the aquifer values are considerably smaller than the prehistoric shell sample in spite of the large number of aquifer values sampled. The low variability in the aquifer samples probably reflects mixing of waters from different seasons and different years within the various water-bearing strata.

Ultimately, the paucity of spring sites, the great depth of most of the wells, and the lack of any time depth for the sample makes it difficult to relate this to the archaeological sample. Of course, the Medina River originates well above the Edwards Aquifer recharge zone, largely from springs in the Glen Rose formation (Holt 1956), and the $\delta^{18}O$ values of these springs are unknown although the Medina River contributes to Edwards Aquifer recharge in the Medina Lake area. The Medina River is also fed by springs east of Medina Lake that are apparently not linked to Edwards Aquifer water (Holt 1956).

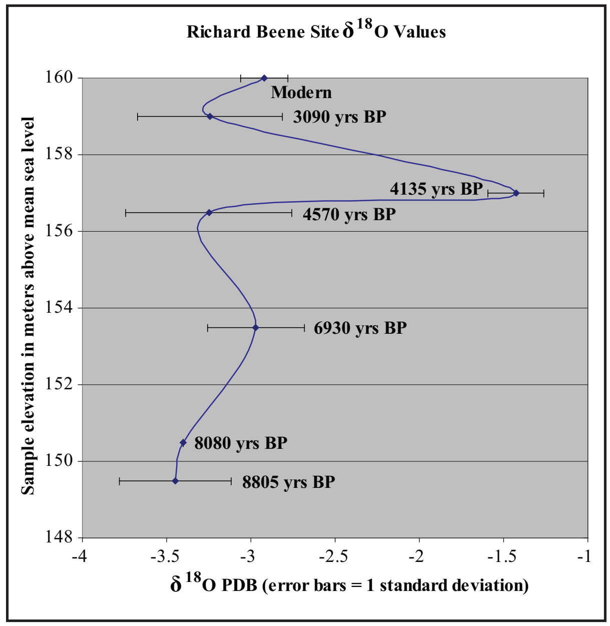


Figure 6.2. Plot of $\delta^{18}O$ results for grouped samples.

Using the SMOW-PDB relationship as a general guide, it would appear that the archaeological samples tend to be more positive than the aquifer samples. And while the data are far too sketchy to be certain, it is likely that local effects like water temperature, humidity, evaporation, and shell fractionation significantly alter the original spring-derived $\delta^{18}O$ values of the stream. In effect, the stream water is thought to quickly equilibrate with its downstream environment. Kendall and Coplen (2001) have suggested this, noting that local variables seemed to have a greater influence on the isotopic composition of river water than groundwater.

Figure 6.3 shows the mean and ranges for $\delta^{13}C$ plotted against the estimated ages. The overall mean for $\delta^{13}C$ is -6.57‰, and the standard deviation is 0.78‰. The mean of the prehistoric samples is -6.45‰ with a standard deviation of 0.62‰. Although linking the variation in $\delta^{18}O$ values to parameters in the Richard Beene site and Medina River paleoenvironments is complicated, the processes by which the isotopic forms of oxygen equilibrate under varying conditions of water temperature, air temperature, humidity, rainfall, and evaporation can be linked to past environmental conditions with some degree of caution. On the other hand, while carbon reflects the broad environment, the variable nature of $\delta^{13}C$ "equilibration" in stream waters within a carbonate-rich environment cannot be so easily modeled or interpreted.

While early researchers (Fritz and Poplawski 1974; Fritz et al. 1975) were optimistic about the use of $\delta^{13}C$ values from freshwater shell to model past environments, more recent studies have noted the compounding of inorganic and metabolic carbon (Dettman et al. 1999; Ricken et al. 2001). Numerous studies have shown that $\delta^{13}C$ does present a strong seasonal signal, but it is much less predictable than $\delta^{18}O$. As illustrated in Figure 6.1, there is an obvious relationship between $\delta^{18}O$ and $\delta^{13}C$, although the actual negative correlation is not strong. It is difficult if not impossible to directly interpret parameters of the past environment from the $\delta^{13}C$ values, but it is worth noting the trends shown in Figure 6.3.

The most obvious aspect of the chart is the dramatic difference reflected by the modern shell sample mean $\delta^{13}C$ value of -8.53‰. This value is within the -2.9 to -10.8‰ range of a series of $\delta^{13}C$ analyses carried out on Edwards Aquifer waters in the San Antonio area, though well above the -6.57‰ overall mean for that study, which was conducted in 1970 and 1972 (Maclay et al. 1980). Of course the modern mean is identical to the overall mean of the current investigation, although the modern range, based on 27 spot samples drawn largely from Bexar County, is understandably wider than the 34 shell samples, each of which averages 5 to 10 years of $\delta^{13}C$ values, suggesting that this low carbon range would have incorporated a long period of values well above the modern and prehistoric averages. While many modern changes may have contributed to this difference, changing agricultural practices and dumping waste into rivers are probably among the most significant contributors to this extreme value.

In contrast the two most extreme values from the prehistoric samples are the upper Leon Creek sample, which shows the most positive $\delta^{13}C$ values of any sample, and the Elm Creek sample, which has the lowest mean. Note that both of these have relatively high sample variability. The remaining sample groups all cluster around -6.5‰ $\delta^{13}C$. Note also that the lower Medina and upper Perez groups, both close to this global mean, have much tighter clustering than any of the other samples. What these differences mean cannot be interpreted at this time.

Paleoclimatic Implications

The earliest studies of $\delta^{18}O$ variability demonstrated a direct relationship between marine shell isotopic fractionation and water temperature. Since Urey's (1947) original paleotemperature equations, numerous studies have tried to reconstruct past climatic parameters. The most precise attempts have developed the relationship between shell carbonate $\delta^{18}O$, water $\delta^{18}O$, and water temperature. In this case, the shell carbonate values are known, while both past temperature and past water $\delta^{18}O$ are unknowns. For reconstructions of ocean paleotemperatures from marine shell carbonates, it has always been possible to make certain assumptions about the isotopic composition of past oceans. Such assumptions are rarely possible given the widely fluctuating $\delta^{18}O$ of continental waters where there are wide ranges in individual storm events, short-term, seasonal, and annual variation in the isotopic values of $\delta^{18}O$, given changes in the amount of precipitation, temperature, and local conditions of evaporation.

Dettman and Lohman (1993:157–160) identified three primary types of paleotemperature regimes in their attempt to reconstruct Paleogene climates: temperature-dominated environments with constant $\delta^{18}O$ water, temperature-dominated environments with variable $\delta^{18}O$ water, and environments dominated by seasonally variable $\delta^{18}O$ water. While these models neatly describe the primary processes in isotopic fractionation, they may not be mutually exclusive, or so clearly separable in all cases. And unfortunately, shifting global climatic patterns could easily alter the basic pattern of any region, making the precise reconstruction of paleotemperatures impossible.

The modern Texas data suggest a temperature-dominated environment with variable $\delta^{18}O$ of water. Past studies indicate that $\delta^{18}O_{shell}$ values vary inversely with $\delta^{18}O_{water}$ around a mean temperature estimated by Grossman and Ku (1986) at around

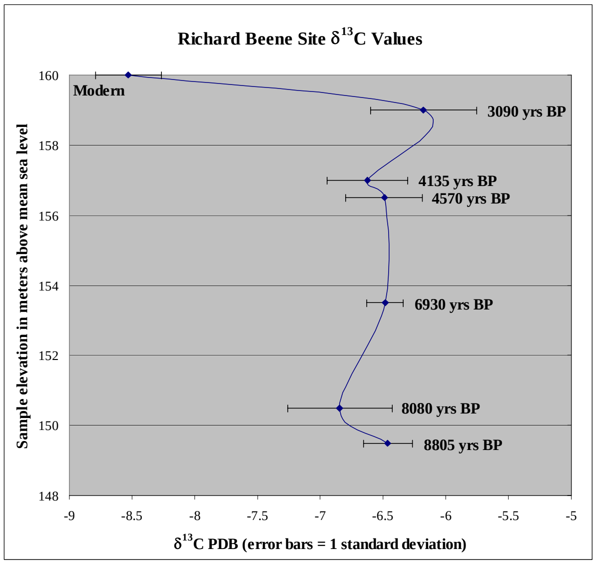


Figure 6.3. Plot of δ^{13}C results for grouped samples.

20.6ºC. At that temperature $\delta^{18}O_{shell}$ equals $\delta^{18}O_{water}$ with a small remainder (about 0.2–0.3‰) that accounts for the fractionation between water and aragonite (the primary carbonate structure of many unionids). For higher temperatures, $\delta^{18}O_{shell}$ values decrease and vice versa with lower temperatures. When $\delta^{18}O_{water}$ increases during the summer as it does in most of Texas, the corresponding summer growth of mussels should reflect lower $\delta^{18}O_{shell}$ values, dampening the seasonal variation in $\delta^{18}O_{shell}$ values. Nonetheless, the mean annual $\delta^{18}O_{shell}$ value should still remain close to the annual mean of δ^{18}O water. If one were to project a similar isotopic regime into the past, and assume that variation in $^{18}O_{shell}$ values were due to greater variation in temperature rather than variation in isotopic composition, it might be possible to construct a crude temperature reconstruction from the available data.

Such a reconstruction is fraught with difficulties, however, not the least of which is that modern δ^{18}O water values are not available for the Medina River in the Richard Beene site area and values that are available are from spot samples in the Nueces River 100 km to the south. These Nueces River samples, collected by Coplen and Kendall (2000), comprise an incomplete segment of the total record although they do cover a period of several years. In that study, the USGS recorded δ^{18}O values for 15 single samples of water from the Nueces River near Three Rivers, taken on different days at different times of the year between 1983 and 1987 (Coplen and Kendall 2000). In a follow-up paper, Kendall and Coplen (2001:1376–1378) examined the relationships between δ^{18}O in stream water and environmental variables across the United States, finding high correlations between δ^{18}O and temperature (r = 0.85) and between δ^{18}O and latitude (r = 0.78) for study sites east of the 97th parallel. Somewhat lesser correlations were found between δ^{18}O and potential evapotranspiration (r = 0.61) and between δ^{18}O and precipitation (r = 0.46) in the same area. Correlations between δ^{18}O and these environmental parameters west of the 97th parallel were significantly less, with temperature the highest at r = 0.44. They nonetheless do conclude that the isotopic composition of river water is an excellent proxy for the reconstruction of the composition of average rain and groundwater recharge.

In addition, the degree to which the modern δ^{18}O value can be used as a baseline for the relationship between past δ^{18}O values and the corresponding climate is an open question, given extensive modification of the drainage basin and lowering of aquifer levels through extensive pumping. Construction of Medina Lake and the Diversion Dam Lake above Castroville and the irrigation water removed at that point have unquestionably altered the original composition of the water. Lakes, with their greater surface area, tend to foster evaporation and should yield slightly heavier water (i.e., more positive δ^{18}O values) in outflow than inflow. The Richard Beene site is about 50 km southeast of Medina Lake and perhaps twice as far in river miles, and the overall effects of evaporation within the lake are probably minimized as outflow δ^{18}O equilibrates with the downstream environment. Nonetheless, it is not impossible that there is still some residual effect on the δ^{18}O values.

Pumping from wells in the Edwards, the Glen Rose, and smaller localized aquifers has almost certainly reduced spring flow along the river. Reducing aquifer input should make streamflow values more subject to precipitation and ambient water conditions, decreasing the stabilizing effect of the δ^{18}O mixing within the water-bearing strata and increasing δ^{18}O variability due to the greater dependence on highly variable seasonal rainfall. In addition to increased variability, the presumably lowered contributions of the aquifer water may also have a tendency to elevate the $\delta^{18}O$ values slightly. The overall effect of both of these modern changes could complicate the estimation of paleotemperatures. If the direction of effect postulated above is correct, then the modern $\delta^{18}O$ values may be heavier than past $\delta^{18}O$ values for similar climate trends, and thus the estimates of past temperatures seem slightly cooler than they are. The magnitude of this effect cannot be determined, nor is it clear whether it could affect paleotemperature estimates.

While it would be meaningless at this point to try to reconstruct precise paleotemperatures for the Richard Beene site area, it may be possible to look at the projected direction and magnitude of possible past changes using the aragonite equation derived by Grossman and Ku (1986), given as:

$$T^{o}C = 20.6 - 4.34(^{18}O_{aragonite} - \delta^{18}O_{water})$$

and the Nueces River $\delta^{18}O$ data. Using these values and estimates of regional air temperatures from the U.S. Weather Service and Medina River water temperatures near La Coste in the years 1996–1998 (Ging and Otero 2003), and making some assumptions about the similarities in past processes, it is possible to create a scenario in which the paleotemperature variation, with the exception of the extreme lower Leon Creek samples, is about 2.3°C, or 4.1ºF.

Taking the modern San Antonio mean annual temperature (about 20.6°C) as the baseline, most of the estimated temperatures are about 1–2°C warmer than the present temperature. The warmest, at 2.3°C higher than the modern mean, is the upper Perez group of samples, with the slightly younger Elm Creek not far behind at 2.1°C warmer. Given the extremes reported by other researchers for this period, these values may underestimate the difference, but more critical to this estimate is the difficulty in estimating the range of regional isotope values in post-Pleistocene south-central Texas. This calculation could well underestimate the actual value of the change. Using this generalized reconstruction scenario, the upper Leon Creek and upper Medina groups are both about 1.4°C warmer than today, a value that is probably not significantly different than the modern climate given the errors in the estimation process. It is worth noting, however, that the lower Medina samples are essentially identical to the modern sample at only 0.2ºC warmer.

The most complex and questionable reconstruction, the lower Leon Creek group, also reflects the strongest deviation from the modern values and from the mean of all samples. Using the Grossman and Ku equation and the rough estimates of other system parameters from modern south Texas, the temperature of this period would have been 6.5ºC cooler than today, a rather extreme estimate that places the annual mean of the Richard Beene site close to the modern mean for Amarillo (13.8ºC, or 59.6ºF). While such an extreme may have been possible, it seems a rather large deviation for a mid-Holocene trend. Importantly however, Nordt et al. (2002) report an apparent cold spike during roughly the same period (Chapter 3). When one considers that the mussels reflect only the average climate of a decade or so, this suggested cold period is not completely impossible. On the other hand, such extreme values also point to potential major shifts in the North American isotopic regime. In any case, whether or not it is possible to estimate a precise value for this period, it is evident that the lower Leon Creek shell data represent a dramatic extreme deviation from the rest of the data, and are an indication that climates were not the same 4100 years ago as they are today.

Conclusions

In this chapter, $\delta^{18}O$ and $\delta^{13}C$ values have been examined in shell carbonate derived from samples collected from known stratigraphic units at the Richard Beene site. As suggested by many other researchers, the $\delta^{13}C$ values are very difficult to interpret, with the modern sample radically different than the prehistoric examples. For reasons that cannot be clearly parsed out of the complex series of potential influences, the $\delta^{13}C$ values from the upper Leon Creek and the Elm Creek show greater deviation from the overall mean of the prehistoric samples. In the latter case, the more negative values of $\delta^{13}C$

could indicate a more pronounced input of regional vegetation over dissolved inorganic carbon in the stream. It is difficult, however, to clearly identify whether this would favor C^3 or C^4 processes since both are more negative than the inorganic supply. The former case might suggest a lesser input of such organic carbon into the system, but even if this were the case, it is difficult to associate this with a particular climatic regime.

Overall, the $\delta^{18}O$ values of shell carbonate derived from the prehistoric samples at the Richard Beene site show a general trend of slight predicted variation around the modern San Antonio mean temperatures, with the most extreme values found in the lower Leon Creek stratigraphic unit, dated to about 4135 B.P. If the regional isotopic regime remained stable throughout the Holocene (which it probably did not), the values for this period would suggest a climate significantly cooler than today, at least for a period of a decade or two. Most of the remainder of the values is very close to the modern mean temperature, with the early Elm Creek and upper Perez only a few degrees warmer.

While it has been possible to derive only very gross estimates of past climates in the Richard Beene site area in this chapter, the potential for such reconstruction is not exhausted. Notwithstanding the problems of reconstructing a system where two variables (original $\delta^{18}O$ of water and temperature) are unknown, there are potential data sets which could contribute greatly to the strength of this reconstruction. One would be a long-term series of isotopic measurements of water (and water temperature) in the Medina River near the Richard Beene site. This would take out much of the uncertainty of using values from distant proxy locations. Increasing the sample of periods could also be very helpful in trying to build a joint model of past processes with other proxy indicators from the site. Adding Late Prehistoric values as well as samples that might cover the long gaps between the upper and lower Medina and between the lower Medina and the Elm Creek would be particularly useful. Along these same lines, adding samples from contexts prior to the upper Perez sample would help to anchor the sequence in known climatic shifts from the late Pleistocene into the early Holocene. Finally, microsampling of a series of specimens from selected layers could identify patterns of seasonal variation in isotopic fractionation through time. Analysis of such variation could provide a wealth of information on past climate dynamics.

7

STABLE ISOTOPE ANALYSIS OF LAND-SNAIL SHELL CARBONATE

Glen G. Fredlund and Raymond W. Neck

This chapter presents results of isotopic analysis of land-snail shells from the Richard Beene site (41BX831). Although isotopic analysis of land snails is not a new approach, the present study, originally conducted in 1992, represents its first application in Texas. Other studies have followed (e.g., Goodfriend and Ellis 2000, 2002). The method has been used to infer late Quaternary climate and vegetation change in a number of geographical and geological contexts (e.g., Abell 1985; Goodfriend and Magaritz 1987; LéColle 1985; Yapp 1979) and has proved especially sensitive in arid and semi-arid climates (e.g., Goodfriend 1990, 1991, 1992). Carbon and oxygen stable isotopic measurements provide important clues to local and regional shifts in vegetation and climate. Although the general utility of the approach is well established, the method remains both underdeveloped and under applied worldwide (Goodfriend 1992). The primary objective of the present study is to assess the potential of the method in south-central Texas.

The Richard Beene site presents an ideal situation for application of the method. The stratigraphic sequence of alluvial deposits and paleosols at this site is well described and dated (Chapter 3). Although snails are absent from the lower portions of the section, the snail record does span almost the entire Holocene. Interpretations of the snail assemblages per se are discussed in Chapter 5. This chapter presents the analyses of oxygen and carbon isotope data from land-snail shell carbonate and its interpretation.

Interpretation of Snail Isotopic Signals

Isotopic Fractionation

The interpretation of stable isotope data is predicated on an understanding of the processes that lead to differential fractionation of stable isotope members, in this case $^{16}O/^{18}O$ and $^{12}C/^{13}C$. The processes of fractionation are not chemical but physical mass effects (Hoefs 1987). For example, a water molecule which includes heavy oxygen (^{18}O) is physically heavier, and therefore more difficult to evaporate, and yet more readily condensed than is a normal molecule of water. When evaporation occurs, water molecules with heavier oxygen tend to be left behind while lighter water is removed. When condensation occurs, heavier water molecules tend to be removed from the atmosphere through "rain out," while lighter water remains in the vapor state. Change in the isotopic composition of meteoric (atmospheric) water is modeled using this Rayleigh condensation concept (Rozanski et al. 1993). These, and similar mass effects, lead to differentiation or fractionation of stable isotopes of oxygen and carbon discussed in this paper.

Although the processes that underlie the fractionation of stable isotopes are conceptually simple, interpretation of stable isotopic data is often obtuse. This complexity results from the multiplicity of fractionation processes that may affect any single isotopic signal. While multiple fractionation

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site in South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 113-122. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

processes may reinforce one another, as often as not they act independently and may even negate effects of preceding fractionation processes. The key to interpreting stable isotope data in this complex, sometimes contradictory, environment is empirical evidence gathered from controlled modern and experimental situations. This chapter presents some basic data on modern isotope variability but falls far short of what will ultimately be needed to confidently interpret the snail isotope record of south-central Texas.

Oxygen Isotopic Composition of Snail Shell Carbonate

On a regional scale, the oxygen isotope composition of land-snail shell carbonate typically reflects the $^{18}O/^{16}O$ composition of precipitation (Abell 1985; Goodfriend 1991, 1992; LéColle 1985; Yapp 1979). This meteoric signal is often obscured by a number of secondary processes that lead to further isotopic fractionation (Goodfriend 1992; Goodfriend and Magaritz; Goodfriend et al. 1989; Magaritz et al. 1981). The relationship between the isotope composition of precipitation and shell carbonate is determined by two sets of processes: (1) environmental factors governing the isotope composition of the snail body water, and (2) isotope fractionation between snail body water and shell carbonate. Studies in the eastern Mediterranean indicate that the isotopic composition of snail body water is principally governed by the composition of atmospheric water vapor, rather than precipitation directly (Goodfriend et al. 1989; Magaritz and Heller 1983). Composition of water vapor can deviate from precipitation values in regions adjacent to large water bodies or at a finer scale, within the microhabitats occupied by snails. However, in typical situations, isotope composition of precipitation and water vapor are closely correlated. Snail body water is typically ^{18}O enriched relative to precipitation. Although this enrichment is not fully understood, the fractionation is hypothesized to occur during snail respiration (Goodfriend et al. 1989).

Shell carbonate is precipitated from dissolved bicarbonate in the body fluids of the snail (Goodfriend 1992; Goodfriend et al. 1989). The oxygen isotope composition of the carbonate generally conforms to the model of equilibrium isotopic fractionation for water-bicarbonate-biogenic carbonate systems (Fritz and Poplawski 1974). There is some evidence that nonequilibrium fractionation may occur, resulting in slight enrichment of the shell carbonate (Goodfriend 1989). The equilibrium model is temperature dependent: ^{18}O enrichment increases as temperature decreases (Epstein et al. 1953). This trend with temperature may act to negate some of the meteoric signal resulting primarily from “rain out” depletion of ^{18}O as air masses move inland from marine sources. Interpretations are further complicated by both seasonal changes in precipitation and the seasonal activity (and dormancy) of differing snail species. Because of seasonality factors, the isotope composition of the shell carbonate does not correlate with annual averages, but with the composition of the precipitation during the season of snail activity and growth. Though the effects of these external (environmental) and internal (metabolic) fractionation processes may often be difficult to disentangle, the strongest signal is typically the meteoric signal.

Goodfriend and Ellis (2002) tested this model by analyzing modern *Rabdotus* shells along an east-west transect across Texas. Although this transect spanned a strong climatic gradient they were unable to find a coherent pattern in the oxygen isotopes from shell carbonate. They hypothesized that isotopic variability related to the complexity and variability of the vegetation structure along the transect may have obscured the hypothesized environmental signal. Balakrishnan et al. (2005b) set up a similar experiment along an east-west transect stretching from eastern Oklahoma to the foothills of the Rocky Mountains. Although this transect spans a similar precipitation gradient to that used by Goodfriend and Ellis (2002), the vegetation structure, dominated by grasslands, was generally less complex and variable than that in Texas. Balakrishnan et al. (2005b) were able to identify a statistically significant environmental gradient. However, the oxygen isotope ratio gradient for the entire transect was less that 2‰ while within-site variability was typically greater than 3‰. The potential for applications of this model to fossil records (e.g. Balakrishnan et al. 2005a) is encouraging, but limited by the relatively high levels of non-meteoric variability in the system.

Any long-term variability in ^{18}O composition of snail shells from the Richard Beene site is hypothesized to come from the meteoric signal. The isotopic composition of precipitation for this near-coastal area of Texas should be controlled by two processes: (1) evaporation from the Gulf of Mexico; and (2) air mass modification as moisture-laden air moves inland. The first mechanism is controlled by temperature and humidity during evaporation from the Gulf. It may also be affected by the isotopic change resulting from glacial melt-water dilution during the late Pleistocene and early Holocene (Nordt et al. 2002). Variability associated with evaporation of Gulf waters is probably less than that associated with air mass modification as the water vapor moves inland (Grootes 1993). The "rain out" effect is not necessarily linearly related to distance inland but affected by all mechanisms that trigger condensation including orographic (topographic) lifting and frontal (air mass collision) lifting (Abell 1985; Goodfriend 1991; LéColle 1985). Long-term shifts in air mass collision zones (cf. Bryson et al, 1970) could possibly cause changes during the Holocene in south-central Texas. Air-mass composition may also be modified by the addition of water vapor from the terrestrial surface (Grootes 1993).

Water vapor from other air masses (i.e., Pacific air masses) may also contribute to long-term variability in the meteoric signal of central Texas. Long-term changes in the seasonality of precipitation may also affect isotope composition of shell carbonate. It is difficult, if not impossible, to prioritize these potential sources of variability without additional empirical evidence from modern snail assemblages. The working hypothesis for the Richard Beene record is that shifts in oxygen isotope composition are primarily meteoric in origin and controlled by temperature through one or more of the processes listed above. This results in an isotopically lighter signal correlated with cooler and/or wetter conditions, and relatively heavier oxygen composition correlated with warmer and/or dryer climate.

Interpretation of Stable Carbon Isotopes

As with oxygen, the interpretation of stable carbon isotope data derived from snail shells is not straightforward. Carbonate composition is affected by: (1) organic (plant) carbon in the snail diet subsequently released as respiratory CO_2; (2) modification of metabolic isotope composition by pedogenic and lithologic carbonates; and (3) atmospheric CO_2 incorporated though isotopic exchange as the shell carbonate is formed (Goodfriend 1992). The potential variability of shell carbonate composition is affected by both moisture and temperature. Typically, increased ingestion of organic carbon from plants will yield shell carbonate depleted in ^{13}C (Goodfriend and Magaritz 1987). Slower rates of feeding will yield shell carbonate closer to atmospheric equilibrium. This typically translates into isotopically lighter carbonate produced during mesic climatic episodes and isotopically heavier carbonate associated with dry climates.

The metabolic rate effect is reinforced by the isotopic variability associated with alternative photosynthetic pathways (C_3, C_4, and Crassulacean Acid Metabolism or CAM). Plants using the more common C_3 photosynthetic pathway yield isotopically lighter organic carbon and therefore isotopically lighter shell carbonate (Goodfriend and Magaritz 1987). Plants using either the C_4 or CAM systems yield ^{13}C-enriched organic carbon, and therefore isotopically heavier shell carbonate.

Using their east-west Texas transect of modern snail assemblages Goodfriend and Ellis (2002) tested this assumed relationship. They demonstrated a significant relationship between the climate-vegetation context and land snail shell carbonate and organic matter. Although the relationship was demonstrable they again cautioned the potential effects of local vegetation on the isotopic composition of the snail shells. They found that, while general climate controlled vegetation characteristics such as percent C_4 biomass had some effect, the micro-habitat and diet of the snails had the strongest effect. More recently Balakrishnan et al. (2005b) used isotopic values derived from the composite samples representing many individual snails demonstrating stronger correlations among snail shell isotopes (carbonate) and vegetation composition. The relative strength of their results is likely the result of better controlling for vegetation complexity than the Goodfriend and Ellis (2002) study. Their results demonstrate that snail shell carbonates can be expected to range from -10‰ for C_3 dominated vegetation to -3‰ for C_4 grasslands. Applications of this approach to fossil records (Balakrishnan et al. 2005a; Goodfriend and Ellis 2002) have already made positive and consistent contributions to our understanding of regional environmental history.

The balance among C_3, C_4, and CAM plants may also indirectly affect snail shell carbonate composition through the pedogenic carbonate system. The isotopic balance in pedogenic carbonate is itself controlled by numerous factors including lithologic (or parent material) composition, vegetation composition (C_3/C_4), and temperature (Cerling 1984; Cerling et al. 1989, 1991; Quade et al. 1989). Since the fossil shell assemblages analyzed in this study are from a single site, it is relatively safe to assume that the lithologic or parent source material for carbonates is a constant. The net effect of the other variables is somewhat ambiguous. The pedogenic carbonate variable generally acts to reinforce, rather than negate, the other environmental signals potentially imparted to snail shell carbonate. Overall, environmental variables affecting shell carbonate composition appear to act to reinforce one another. Isotopically lighter carbon signals should correlate with cooler and/or wetter climates, and isotopically heavier signals should correspond to warmer and/or drier climates.

Methods

Sample and Species Selection

Shell samples analyzed include representative shells for modern and fossil assemblages. The modern sample includes 15 individual molluscs from modern surface samples. The fossil analysis includes 42 individuals taken from 11 stratigraphic samples. Sample numbers correspond with the volumetric samples taken for snail-assemblage analysis (Chapter 5). Stratigraphic zones discussed conform to the chronostratigraphy as defined in Chapter 3. Stratigraphic analysis of snails includes three terrestrial species: *Rabdotus moreanus*, *Polygyra texasiana*, and *Oligyra orbiculata*. Of these, *Rabdotus* and *Polygyra* occupy more xeric micro-habitats, while *Oligyra* is more typically a woodland taxon. In addition, several shells of *Biomphalaria havenesis*, an aquatic species not present in the fossil record, were analyzed from the modern assemblage. A single fossil of *Amblema plicata*, a fresh water mussel, was also analyzed. We analyzed multiple shells for each stratigraphic sample wherever possible.

Laboratory Analysis and Reporting of Stable Isotopic Ratios

Pretreatment of shell samples includes ultrasonic washing to remove sediment and a weak acid rinse to obtain clean snail shell carbonate (aragonite). Determination of the stable isotopic ratios ($^{13}C/^{12}C$ and $^{18}O/^{16}O$) was performed by Krueger Enterprises, Inc., using standard mass spectrometry. The data are reported in ‰ (per mil) notation calculated by:

$$\delta \mathbf{R}\_\text{sample ‰}=[\ \mathbf{R}\_\text{sample}/\mathbf{R}\ \text{standard})\ \text{“}\ 1]\times 1000$$

Where:

$^{13}C/^{12}C$ standard is Pee-Dee Beliminite (PDB)
$^{18}O/^{16}O$ standard is standard mean oceanic water (SMOW)

$$\delta^{18}O_{(SMOW)} = (1.03037 \times \delta^{18}O_{(PDB)}) + 30.37$$

Isotopic ratios are reported in per mil deviations from the isotopic standards where lower (more negative) values are relatively lighter in isotopic composition (Table 7.1). Note that the $\delta^{18}O_{(SMOW)}$ values reported here are roughly +30‰ greater than the $\delta^{18}O_{(PDB)}$ values.

Results

Isotopic Composition of Modern Shells

Analysis of modern snails provides a basis for evaluating the fossil signal (Figure 7.1). The average modern $\delta^{18}O_{(PDB)}$ of water vapor and precipitation within the study area should range from -3.0‰ to -4.0‰ (Yurtsever 1975). Given the typical +5‰ enrichment by land-snail shells, and the correction for differences in reporting standard, the $\delta^{18}O$ of mod-

Table 7.1. Results of isotope analysis of mollusk shells.

Number	Sample	Genus	Species	$\delta^{13}C$	$\delta^{16}O$
1	1	*Rabdotus*	*mooreanus*	-12.1	28.9
2	1	"	"	-8.9	29.3
3	1	"	"	-7.9	28.7
4	1	"	"	-6.6	28.7
5	2	"	"	-8.9	28.2
6	2	"	"	-7.6	28.9
7	2	"	"	-8.1	29.0
8	3	"	"	-6.1	28.2
9	3	"	"	-8.0	30.4
10	3	"	"	-8.2	27.9
11	4	"	"	-8.2	28.8
12	4	"	"	-9.5	28.9
13	4	"	"	-6.8	27.8
14	5	"	"	-9.2	29.1
15	5	"	"	-10.0	29.3
16	9	"	"	-8.6	29.6
17	9	"	"	-7.5	29.6
18	9	"	"	-8.3	27.3
19	9	"	"	-9.6	29.2
20	11	"	"	-8.5	27.2
21	12	"	"	-7.6	28.7
22	12	"	"	-7.5	28.7
23	12	"	"	-10.7	29.7
24	12	"	"	-6.4	31.0
25	13	"	"	-9.1	29.0
26	13	"	"	-7.4	29.3
27	13	"	"	-8.4	28.5
28	15	"	"	-8.2	29.5
29	15	"	"	-10.0	27.0
30	15	"	"	-8.6	27.9
31	15	"	"	-9.1	29.3
32	19	"	"	-11.0	28.4
33	19	"	"	-8.6	29.1
34	19	“	“	-11.9	29.8
35	19	"	"	no	data
36	19	"	"	-8.5	29.7
37	21	"	"	-9.7	29.3
38	21	"	"	-9.2	30.0
39	1	*Polygyra*	*texasiana*	-8.9	29.0
40	1	"	"	-8.6	29.5
41	1	"	"	-6.4	28.4
42	2	"	"	-6.4	30.2
43	2	"	"	-6.9	30.5
44	2	"	"	-6.9	28.5
45	3	"	"	-0.9	28.2
46	3	"	"	-5.2	28.1
46	5	"	"	-4.7	28.0
47	5	"	"	-6.5	28.3
48	1	*Oligyra*	*orbiculata*	-9.6	27.5
49	1	"	"	-7.8	29.0
50	1	"	"	-9.5	27.8
51	3	"	"	-3.2	28.8
52	3	"	"	-7.0	28.7
53	3	"	"	-5.9	27.4
54	4	"	"	-7.2	27.7
55	4	"	"	-4.3	27.6
56	9	"	"	-6.7	27.6
57	1	*Biomphalaria*	*havanensis*	-9.8	27.2
58	1	"	"	-7.2	27.7
59	1	"	"	-10.9	24.0
60	1	"	"	-10.9	26.9
61	1	"	"	-8.8	27.4
62	19	*Amblema*	*plicata*	-6.5	27.3

ern snails should range around +32.0‰ or +31.0‰. Except for a single outlier of +24.0‰, the $\delta^{18}O$ values for modern snails are close to the expected, with values ranging from +27.2‰ to +29.5‰, and an average of +28.3‰ (Tables 7.2 and 7.3). The outlier sample is omitted from further analysis. Differences among the species are also consistent with the habitats and microhabitats of the snails. The aquatic species, *Biomphalar havenesis*, yielded $\delta^{18}O$ values which are isotopically lighter, while the open-vegetation adapted terrestrial species *Rabdotus moreanus* and *Polygyra texasiana* are isotopically heavier. Except for the omitted sample, the within-species variability is relatively lower for terrestrial taxa than it is for the aquatic *Biomphalar* species. These data suggest that a weak environmental signal exists within the modern samples.

The $\delta^{13}C$ values for the modern snails also fall within the range reported by previously published studies. The $\delta^{13}C$ values range from -10.9‰ to -6.4‰, with an average for all species of -8.8‰. This value falls midway between values for very mesic and very xeric snail localities. On average, *Biomphalaria havanensis,* the aquatic species, yielded slightly lighter isotopic composition (-9.2‰) than did the terrestrial species (ca. -8.9‰). This inter-species differentiation also suggests a coherent environmental signal. However, the high within-species standard deviations (0.8 to 2.0‰) swamps any minor differences among modern species analyzed. Variability within the surface sample is greater than that documented in the fossil record. The source of this high modern variability is not known (Table 7.3).

The Fossil Data Scatter

The fossil data scatter even more strongly suggests consistent and coherent differences among species (Figure 7.2). Isotopic differences among species show up most clearly in the $\delta^{13}C$ record where *Rabdotus* values are on average -2.6‰ lighter than the average for *Polygyra* and about -2.0‰ lighter than the average for *Oligyra*. The oxygen isotopic differences, although less pronounced, are consistent with that observed in the modern data set. The $\delta^{18}O$ values of *Rabdotus* are isotopically lighter than either *Polygyra* or *Oligyra* (ca. -2.0‰ to -2.5‰ re-

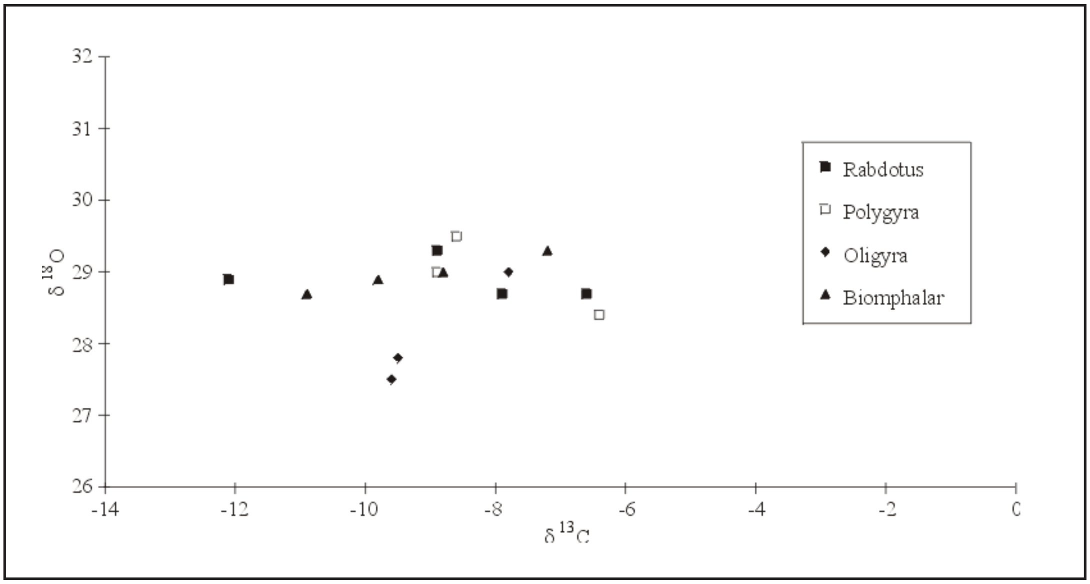


Figure 7.1. Distribution and relationship between δ^{13}C and δ^{18}O for modern snail shell carbonate.

spectively). The single fossil mussel specimen (*Amblema plicata*) yielded isotopic values just outside the average values of the terrestrial snail taxa. The *Amblema* sample is isotopically lighter than the average δ^{18}O value and slightly heavier than the average δ^{13}C value. This pattern is consistent with hypothesized environmental controls on stable carbon isotopic composition of snail carbonate.

Given the hypothesized environmental controls on the oxygen and carbon isotopic signals of shell carbonate, the data scatter should exhibit a general negative correlation. Weak negative correlation between the two isotopic signatures has been documented elsewhere (e.g., Goodfriend and Magaritz 1987; Yapp 1979). Although these data do suggest weak negative correlation at least for *Rabdotus mooreanus* and *Polygyra texasiana*, the relationships are too weak to be of statistical significance. This lack of statistical correlation suggests that the signals are either responding to different environmental signals or that no strong environmental signal is preserved by one or both of the isotopic pairs.

Stratigraphic Interpretation of the Oxygen Isotopic Record

There are no clear patterns in the stratigraphic plots of the δ^{18}O data (Figure 7.3). The most convincing portion of this oxygen isotope stratigraphy is the shift toward lower (lighter) values from modern to Leon Creek samples. This shift is most substantial for Leon Creek *Polygyra,* which show about -1.5‰ decline from modern levels. A -0.5‰ drop in the Leon Creek *Oligyra* and *Rabdotus* values occurs slightly lower in the section. The *Rabdotus* record, which extends back into the early Holocene Perez paleosol, shows some continued irregularity. A single sample from the middle of the Medina pedocomplex was significantly out of line with the average

Table 7.2. Summary of modern isotope data.

Snail Species:	# of Shells	δ^{13}C		δ^{16}O	
		Avg.	STD	Avg.	STD
Biomphalaria havanensis	4	-9.2	1.6	27.3	0.3
Oligyra orbiculata	3	-9.0	0.8	28.1	0.6
Polygyra texasiana	3	-8.0	1.1	29.0	0.4
Rabdotus mooreanus	4	-8.9	2.0	28.9	0.2
All Species	14	-8.8	1.3	28.0	0.4

Table 7.3 Average of δ values for each species for each stratigraphic sample. Horizontal lines mark the boundaries between stratigraphic zones: Modern, Leon Creek, Medina, Elm Creek, and Perez.

Sample	Paleosol	*Rabdotus*	*Polygyra*	*Oligyra*	*Amblema*	*Biompha.*	Count
1	Modern Soil Surface	28.9	29.0	28.1	-	26.6	15
2	Modern Soil B Horizon	28.7	29.7	-	-	-	6
3	Upper Leon Cr.	28.8	28.1	28.3	-	-	8
4	Middle Leon Cr.	28.5	-	27.6	-	-	5
5	Lower Leon Cr.	29.2	28.1	-	-	-	4
9	Medina, Bk	28.9	-	27.6	-	-	5
11	Medina, Bk	27.2	-	-	-	-	1
12	Medina, Lower Bk	29.5	-	-	-	-	4
13	Medina, Bk	28.9	-	-	-	-	3
15	Elm Cr., Bk	28.4	-	-	-	-	4
19	Perez, Bk	29.3	-	-	27.3	-	5
21	Perez, Bk	29.6	-	-	-	-	2
Avg.	-	28.9	28.9	28.0	27.3	26.6	62
STD	-	0.8	0.9	0.6	0.0	1.3	N/A
Count	-	37	10	9	1	5	62

values from this stratum. Disregarding this sample, there is an overall weak shift in the $\delta^{18}O$ (‰) *Rabdotus* values toward heavier than modern values in the Medina pedocomplex. The average isotopic values from the upper Elm Creek paleosol are relatively lighter than the average modern values. In the early Holocene Perez paleosol the trend is again toward heavier isotopic values. Given the overall scatter of $\delta^{18}O$ (‰) *Rabdotus* values, and the poor correspondence among species, paleoenvironmental interpretation of this isotopic record lacks persuasion.

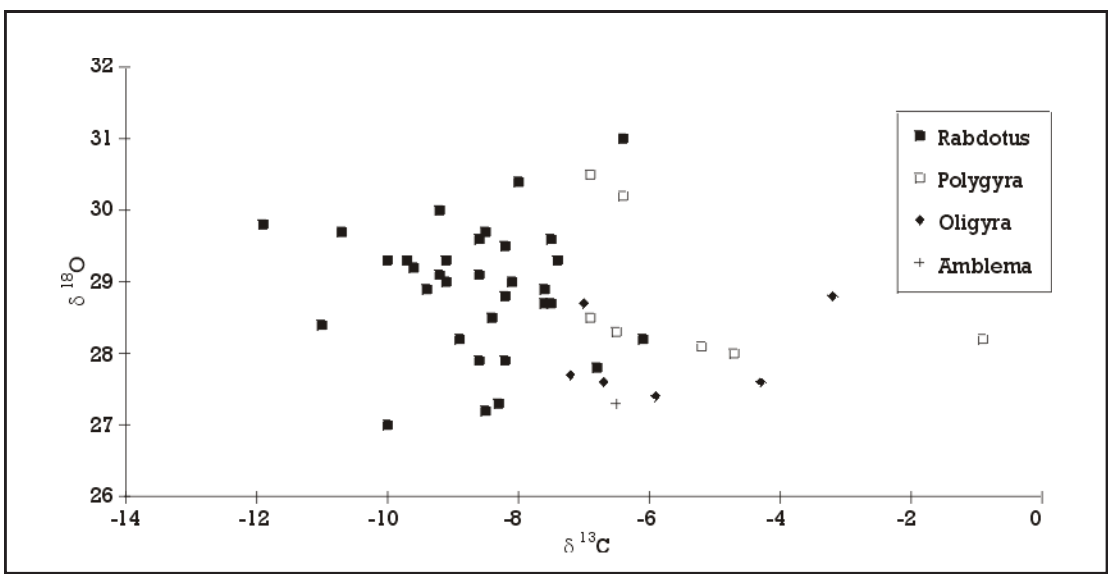


Figure 7.2. Distribution and relationship between $\delta^{13}C$ and $\delta^{18}O$ for fossil snail shell carbonate.

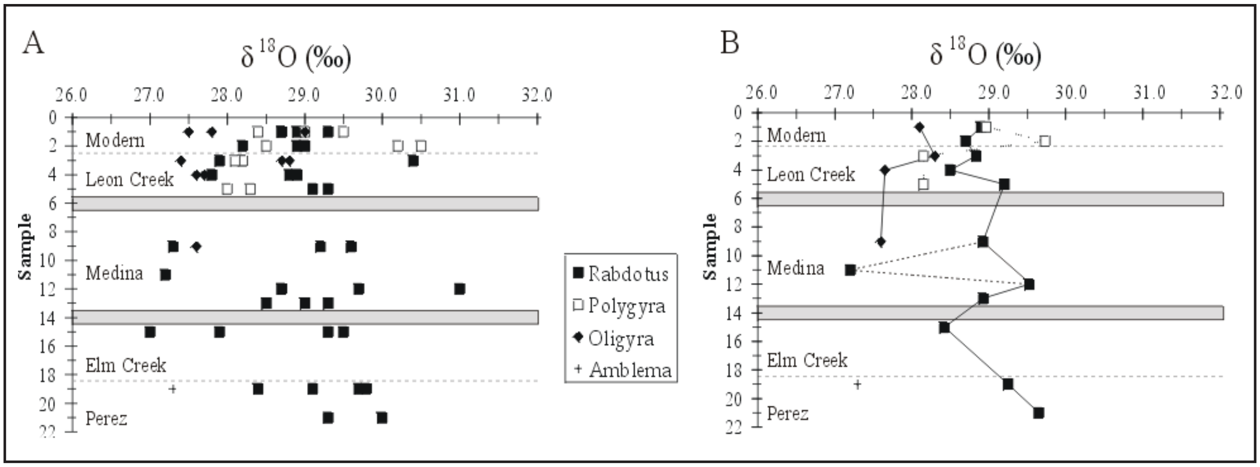


Figure 7.3. The δ18O data by stratigraphic sample: (a) scatter of values for each sample; (b) average δ18O values for each species for each stratigraphic sample; biomphalar values from modern stratigraphic sample (Sample 1) not shown.

Stratigraphic Interpretation of the Carbon Isotopic Record

There are better indications that the $\delta^{13}C$ stratigraphic record presents a coherent long-term environmental signal (Table 7.4). The consistent, parallel shift among the three independent species centered on the upper levels of the Leon Creek is striking. This shift toward larger (less negative) values is strongest for *Polygyra,* which shows a +5‰ enrichment in ^{13}C. The enrichment for *Oligyra* is about +3.5‰, while the shift in *Rabdotus* is about +2‰. The reduction of values in the lower Leon Creek, although not as strong for *Polygyra*, is about equal to that measured for *Rabdotus*. This spike in carbon isotope values suggests warmer and/or drier than modern conditions during the deposition of the upper Leon Creek sediments.

The coherence in the $\delta^{13}C$ values in the upper portion of the Richard Beene record lends more confidence to environmental interpretation of the lower portion of the record where only *Rabdotus* values are available. The higher average $\delta^{13}C$ values in the lower levels of the Medina pedocomplex suggest a return to warmer and/or drier than modern conditions. The data scatter from the Elm Creek and Perez paleosols suggest a general decline in $\delta^{13}C$ values (Figure 7.4). The lower (more negative) values from the Perez paleosol, averaging from -10.0‰ to -9.5‰, indicates somewhat cooler and/or wetter than modern conditions. This carbon isotopic variability further reinforces that derived from soil organic carbon from the site (Nordt et al. 2002).

Conclusions

Initial analysis of isotopic signals from snail shell carbonate from the Richard Benne site is encouraging. Although the oxygen signal is not interpretable at this time, the consistency and coherence in the carbon isotopic record seems to be a valid paleoenvironmental signal. Zonation within the carbon data indicates cooler and wetter conditions early in the Holocene (Perez and Elm Creek paleosols) with gradual warming from 10,000–7000 B.P. Warmer and/or more xeric conditions are documented for the mid-Holocene (Medina pedocomplex), 7000–4500 B.P. Cooler and/or more mesic conditions occurred from 4500 to 4000 B.P. (upper Medina and lower Leon Creek paleosols). Conditions reached their warmest and/or driest between 4000 and 3000 B.P. (upper Leon Creek paleosol). The shift toward current conditions appears to have happened rapidly, with the fastest change centering around 2000 B.P.

This snail carbonate record is supported by the stable carbon isotope record from organic carbon (Nordt et al. 2002). Their interpretation of Holocene

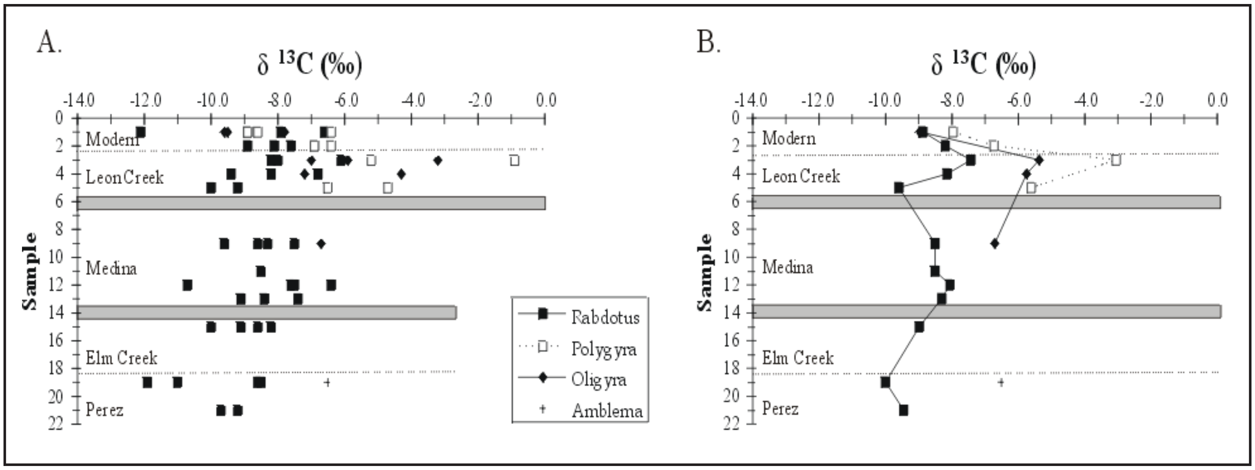


Figure 7.4. The $\delta^{13}C$ by stratigraphic sample: (a) scatter of values for each sample: (b) average $\delta^{13}C$ values for each species for each stratigraphic sample; biomphalar values from modern stratigraphic sample (Sample 1) not shown.

environmental change at Richard Beene generally matches that from the shell carbonate. The two records match both in their general chronological trends and signal amplitude throughout most of the section. In both records the Leon Creek paleosol appears as the warmest and/or driest climatic episode. The two records do diverge somewhat during the mid-Holocene (Medina pedocomplex), but this may be due to the lack of data currently available for snails. This corroboration lends general confidence to the snail record.

Although the snail isotope record, and the related organic carbon record, is intriguing, the environmental significance of the signal remains problematic. Most important is the ambiguity between moisture and temperature aspects of the signal. The spatial scale of the isotopic record also remains

Table 7.4. Average of $\delta^{13}C$ values for each species for each stratigraphic sample; horizontal lines mark the boundaries between stratigraphic zones: Modern, Leon Creek, Medina, Elm Creek, and Perez.

Sample	*Paleosol*	*Rabdotus*	*Polygyra*	*Oligyra*	*Amblema*	*Biompha*	Count
1	Modern Soil Surface	-8.9	-8.0	-9.0	-	-9.5	15
2	Modern Soil B Horizon	-8.2	-6.7	-	-	-	6
3	upper Leon Cr.	-7.4	-3.1	-5.4	-	-	8
4	middle Leon Cr.	-8.1	-	-5.8	-	-	5
5	lower Leon Cr.	-9.6	-5.6	-	-	-	4
9	Medina, Bk	-8.5	-	-6.7	-	-	5
11	Medina, Bk	-8.5	-	-	-	-	1
12	Medina, Lower Bk	-8.0	-	-	-	-	4
13	Medina, Bk	-8.3	-	-	-	-	3
15	Elm Cr., Bk	-9.0	-	-	-	-	4
19	Perez, Bk	-10.0	-	-	-6.5	-	5
21	Perez, Bk	-9.4	-	-	-	-	2
Avg.	-	-8.7	-6.1	-6.8	-6.5	-9.5	62
STD	-	1.3	2.1	2.0	0.0	1.4	N/A
Count	-	37	10	9	1	5	62

ambiguous. Unless alluvial transport of snail assemblages is more important than local deposition of snail assemblages, the spatial scale of the record, like that for snail habitats, may be extremely localized. Changes in snail shell isotopes, therefore, may represent local vegetation shifts rather than climatically determined regional changes. Despite these caveats, this initial isotopic analysis of shell carbonate at the Richard Beene site is extremely encouraging and indicates that further investments in this approach are warranted.

8

CULTURAL CONTEXTS: ETHNOHISTORIC AND ARCHAEOLOGICAL RECORDS

Alston V. Thoms

Ethnohistoric accounts attest to the presence of hunter-gatherer groups with high residential mobility throughout south-central Texas from the sixteenth through the eighteenth century. These linguistically diverse groups are commonly known under the geographic rubric of Coahuiltecans or Coahuiltecos. Their homelands encompassed what is today south-central Texas and northeast Mexico (Campbell and Campbell 1981; Foster 1995, 1998; Hester 1999; Krieger 2002; Thoms 2001). For a detailed discussion of settlement and subsistence patterns reported for groups living in the Richard Beene site area and vicinity, the reader is referred to Hindes and McCullough's (2008) overview in a companion volume to the present report entitled *Prehistoric Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar County, Texas* (Carlson 2008). The present chapter focuses on regional and local archaeological records, but it begins with an overview of what Álvar Núñez Cabeza de Vaca wrote in the early sixteenth century about living and working with Indian people in what is today coastal and south Texas (Figure 8.1).

Cabeza de Vaca and his three non-Indian traveling companions survived shipwrecks and sickness to spend part of the mid-1530s with Karankawan and other Coahuiltecan bands along the Texas coast and adjacent inland regions. They met still other Indian groups on their way west to find Spanish settlements on the Pacific coast of northwest Mexico and described aspects of their settlement and subsistence patterns. Cabeza de Vaca's narrative, originally entitled *Relacion de los Naufragios* (*Account of the Disasters*) and first published in 1555, was probably written between 1537 and 1541 (Krieger 2002). Also of interest is Alex Krieger's translation of the well known sixteenth-century historian Gonzalo Fernando de Oviedo y Valdez's book entitled *Historia General y Natural de las Indias* (*General and Natural History of the Indies*), which included seven chapters that summarized the survivors' accounts and presented new information based on the historian's interviews with Cabeza de Vaca in Spain (Krieger 2002:5, 243–301)

Prior to beginning their monumental journey across south-central North America, the shipwreck survivors gathered a great deal of information about native lifeways in interior regions, including descriptions of villages and house types, as well as food-procurement and cooking practices. On their way across the continent, the Old World interlopers may have visited prickly-pear (i.e., *tuna*) grounds only 20–40 km south of the Richard Beene site (Krieger 2002:41). Insofar as Cabeza de Vaca's observations about land-use patterns in south-central Texas and northeast Mexico predate the apocalyptic population crashes from Old Word diseases, they provide unique snapshots of early sixteenth-century life-

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 123-138. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

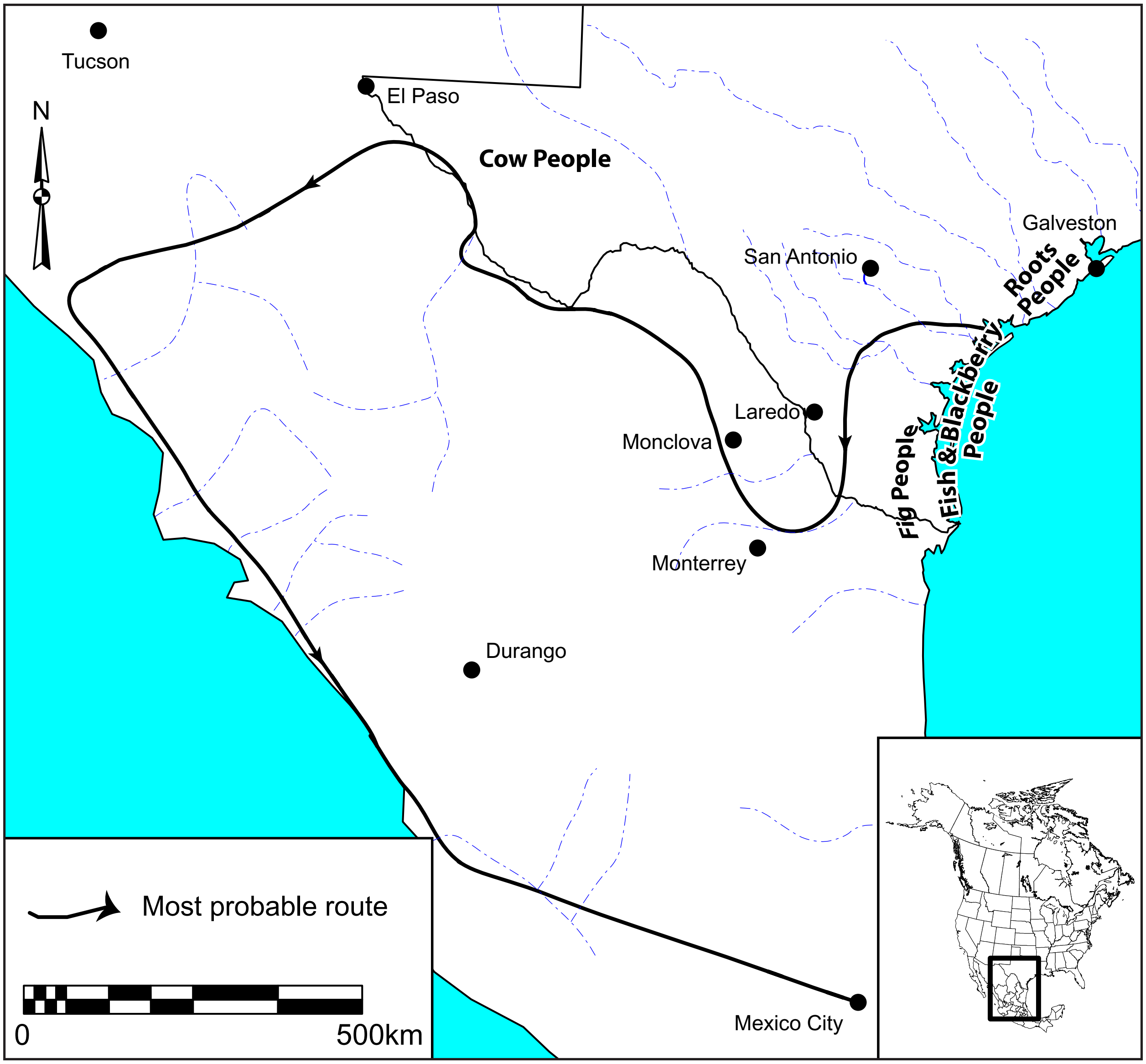


Figure 8.1. Map showing Cabeza de Vaca's proposed route across coastal and south Texas and the general location of the food-named groups he encountered (adapted from Krieger 2002:145 Map 4).

ways. These glimpses are arguably applicable to the middle Medina Valley during the late Pre-Columbian era and probably earlier periods as well.

Cabeza de Vaca's Accounts of Villages and House Types

In writing about the Yguazes, an inland group, Cabeza de Vaca noted "their dwellings are of mats placed on four arches; they carry them on their backs and move every two or three days to look for food" (Krieger 2002:1954). Similar wickiup-like structures were described for coastal groups. Substantially larger residential structures were constructed as well, including a "hut" built on Galveston Island especially for numerous shipwreck survivors that contained "many fires in it" (Krieger 2002:181).

Winter tended to be a season of limited mobility when the Indians "closed up their huts [*chozas*] and settlements [*ranchos*] and were unable to withstand or protect themselves" (Krieger 2002:188; brackets added by Krieger). This statement is translated differently and more to the point at hand in

Covey's version of Cabeza de Vaca's narrative: "the natives retire inside their huts in a kind of stupor, incapable of exertion (Covey 1993:67). When the Indians were in a "region where their enemies can attack them they set their huts at the edge of the wildest and thickest brush" and cut a narrow trail to the center of the thicket where they make a place for their wives and children to sleep. "When night comes they light fires in their huts so that if there are any spies around they [the spies] may think that they are inside them. And before dawn they light the same fires again…" (Krieger 2002:208).

Cabeza de Vaca's accounts and information provided by other Europeans who traversed the region in the late 1600s and early 1700s consistently attest to temporary villages composed of wickiup-like structures of various sizes (Krieger 2002; Foster 1998). Village sizes on the Gulf Coastal Plain, as reported by Cabeza de Vaca, ranged from a few huts to those with 50 or 100 dwellings (Krieger 2002:206, 213). Village sizes reported by Henri Joutel, who traversed the Post Oak Savannah east and northeast of the Richard Beene site in the late 1680s, ranged from three huts and 15 people, to 25 huts with several families each, to 40 huts, to as large as 200–300 huts with 1000–1200 inhabitants (Foster 1998:160, 167, 177, 186).

In short, single- and multi-family residential structures with interior fires for cooking and warmth were commonplace in south-central Texas and surrounding regions when Europeans first arrived. It seems reasonable to conclude, as have archaeologists working in similar settings in the American Southeast (Chapter 13), that villages composed of wickiups were also occupied during the preceding millennia, although they may not have been as numerous or populous as they were during early post-contact times.

Cabeza De Vaca's Accounts of Food-Procurement and Cooking Facilities

Cabeza de Vaca's account attests to regional patterns in the nature of available food resources and it provides a basis for relating changes in cook-stone technology to land-use intensification. Cook stones, as used here, are hot rocks used as heating elements in earth ovens, grills, and hearths, as well as those used for stone boiling. "Cook-stone technology" is used herein in a fashion similar to tool-stone or chipped-stone technology and specifically in reference to processes employed in the procurement, utilization, and discard of rocks that served as heating elements for cooking food (Thoms 2003).

The years between 1528 and 1535, when Cabeza de Vaca lived in Texas, revealed to him that the native people there were well adapted to their environment and, accordingly, he adopted their lifeways. His narrative attests to the difficulty of learning how to hunt, fish, dig roots, and collect other plant foods, as well as how to prepare foods, tan hides, and, ultimately, to make his living as a trader and healer. Cabeza de Vaca and his Old World companions relied mainly on roots, cactus, deer, and rabbits during their trek across south-central North America, as did most of the Indian people they encountered along the way. Fish and shellfish were important food resources along the coast. Pecans were a staple for as much as two months a year in some parts of the Gulf Coastal Plain. Bison were important in some areas far to the west with extensive prairies and in the grasslands (Krieger 2002). Much of what Cabeza de Vaca wrote about was bison, however, hunting was learned indirectly through Indians who interacted regularly with bison-hunting groups living west and north of his route across the continent.

Cabeza de Vaca occasionally referred to groups he encountered in a given area by a "food name" that called attention to the primary food resource(s) in that particular ecological area. Drawing from his comments, much of south-central Texas can be modeled in terms of its productivity potentials for deer, fish, roots, and prickly-pear cactus: (1) the *Fish and Blackberry People* lived in the Gulf Prairies and Marshes area, including the barrier islands, which is modeled as rich in fish and roots and moderate in deer and cactus; (2) the "Roots People" (e.g., *Yguazes)* lived inland and probably exploited the outer edge of the Post Oak Savannah area, which is modeled as being root rich, deer moderate, and fish and cactus poor; and (3) the *Fig People*, who relied

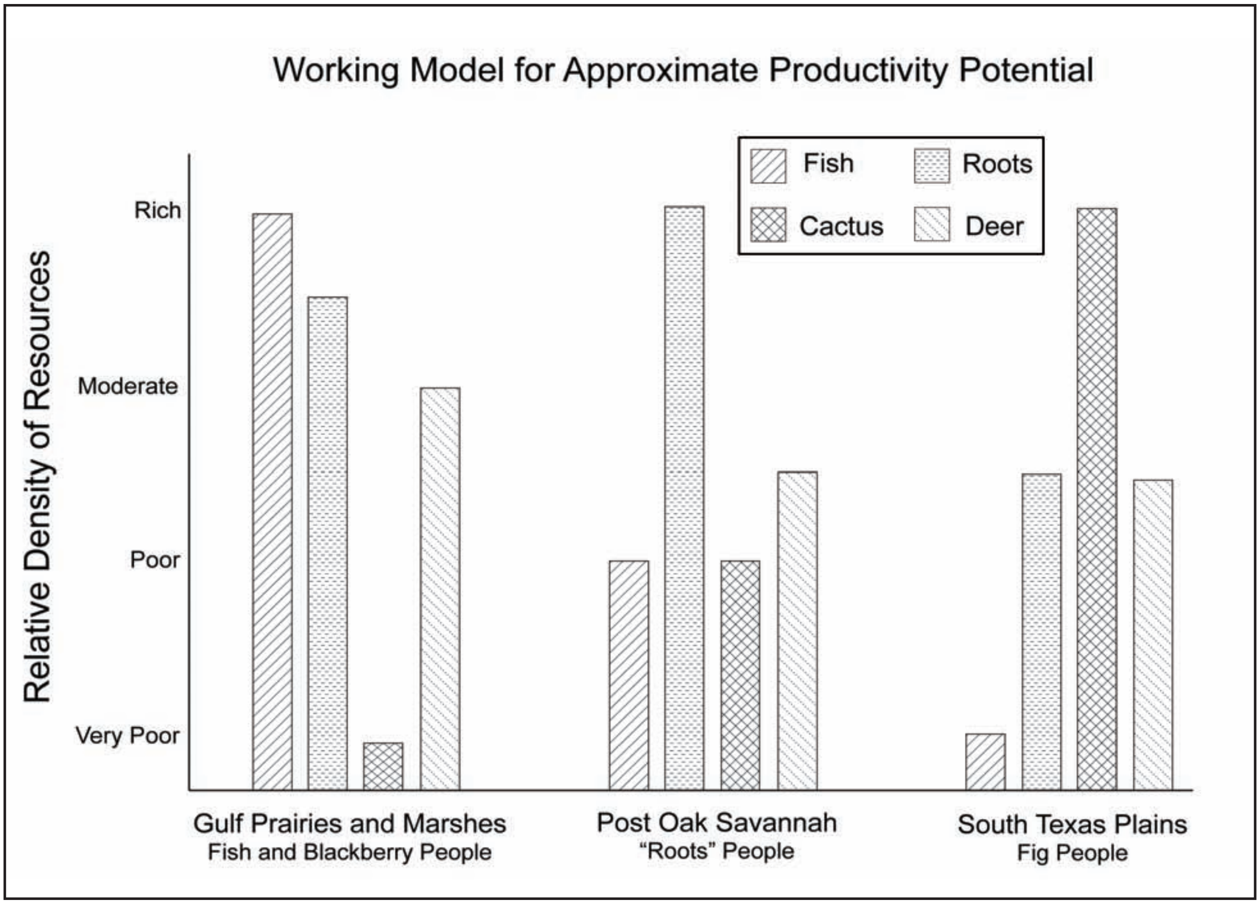


Figure 8.2. Graph showing the relative importance of food resources in ecological areas occupied by food-named groups of the Gulf Coastal Plain, as modeled, based on Cabeza de Vaca's account.

heavily on *tunas,* are representative of groups that lived primarily in the South Texas Plains, an area modeled here as cactus rich, root moderate, deer poor, and very moderate in fish resources (Figure 8.2).

The *Fish and Blackberry People* of the Gulf coast area spent much of the year on the islands, but they also spent time on the adjacent mainland. Staple foods during the winter months were fish (for two months) and roots (for five months), including those dug from beneath standing water and from canebreaks. Oysters and blackberries were staples during spring months. Prickly-pear *tuna* was a late-summer staple and pecans were a staple for two months in the fall. Deer were important, but they seem often to have been in short supply. The only cooking container mentioned is an earthen pot that was taken by one of the Spaniards from a village on Galveston Island. Except for ceramic vessels that were presumably used in cooking, there are no descriptions of cooking techniques.

Inland groups included the *Yguazes* whose "food supply is principally roots of two or three kinds and they look for them through all the country" (Krieger 2002:194). Cabeza de Vaca did not apply a food name to any of the groups inhabiting this region, but for ease of comparison, interior groups are referred to herein as the "Roots People." Oviedo y Valdez summarized the importance of root foods as follows: "These Indians eat roots, which they take out from under the ground [during] the greater part of the winter. And [there] are very few [roots] and [these] are taked out with much labor, and the greater part of the year they suffer very great hunger. All the days of their life they must work at it [digging roots] from morning to night" (Krieger 2002:271; brackets added by Krieger).

The unnamed roots they exploited were widespread on the landscape and bitter tasting even when cooked for two days in earth ovens (Krieger 2002:194). Cooking in an earth oven for two days implies the use of stone heating elements to maintain high temperatures for prolonged periods, presumably to render these as-yet-unidentified roots digestible (Thoms 1989, 1998, 2003; Wandsnider 1997). While we do not know which roots were used in the various ecological areas of the Gulf Coastal Plains, it is unlikely that they were any of the well-known agave or agave-like food plants because these plants do not grow well in the coastal plains. They are, however, prolific in areas to the west, such as the Edwards Plateau and Trans-Pecos regions (Dering 1999). Prickly pear, on the other hand, grows well in the coastal plains and hill country. Deer were the primary game animal in most interior regions, but bison were hunted in the adjacent prairie regions, presumably the Blackland Prairie or perhaps the northernmost South Texas Plains (Krieger 2002).

Groups who lived in the South Texas Plains included those referred to by Cabeza de Vaca as the *Fig People*, in reference to their reliance on prickly-pear *tunas* (Krieger 2002:197–202, 204). Unnamed roots were also important. Deer seemingly provided the bulk of the meat diet. They were sometimes hunted using drive techniques. Of the importance of deer, Oviedo y Valdez noted that south Texas Indians "kill some deer sometimes, and it even happens that a few people kill two or three hundred deer. This nobleman Andres Dorantes (present author's note: one of de Vaca's companions) says that in eight days he saw that sixty Indians killed as many [deer] as the number he has said, and that it also happens [that they] kill five hundred. Many other times, or most [times], they do not kill any" (Krieger 2002:272).

The *Fig People* cooked prickly-pear pads and green fruits overnight in a "hot oven." In general, ethnographic accounts suggest that it is primarily when earth ovens cook for more than 24–36 hours that they contain stone heating elements (Smith 2000; Thoms 1989, 2003; Wandsnider 1997). It seems likely that overnight cooking could be accomplished with coals alone and would not necessarily require a stone heating element. In one account, Cabeza de Vaca noted that in exchange for tanning hides he and his colleagues sometimes received a piece of deer meat and that they ate it raw. "If we had put it to roast, the Indian that came up would take it and eat it" (Krieger 2002:205–206). That kind of roasting was probably done over an open-air fire; if the meat had been cooked in an earth oven, it could not be snatched away so easily. In any case, there are many ethnographic accounts, from elsewhere in western North America, of cooking on and in the coals, without any rocks, as well as cooking on open air hearths with stone heating elements while using other rocks to prop up skewered meat (e.g., Smith 2000).

Cabeza de Vaca wrote that he, as well as the Indians, collected juice from prickly-pear *tuna* in a "trench that we made in the earth" and that they did this "for lack of other vessels" (Krieger 2002:198). However, later in the narrative, but well before he described bison-hunting and farming groups far to the west, Cabeza de Vaca presented ample evidence for the use of pottery in south-central Texas. In writing about a "drink" made from leaves of a holly-like or live-oak-like shrub, he reported that "they roast it [leaves] in some vessels" and then they "fill the vessel with water and thus keep it over the fire and when it has boiled twice they pour it into a dish [*vasija*] and cool it with half a gourd" (Krieger 2002:211). This suggests that pottery vessels were in regular use at residential encampments but were not necessarily taken on logistical forays.

As the Old World interlopers traveled west, beyond the homelands of the *Fig People* and through "broken" country in northeast Mexico, "overgrown" with brush, they encountered Indian people who relied heavily on rabbits and hunted deer in the nearby mountains. Rabbit and deer meat was cooked in earth ovens, and it can be inferred from Cabeza de Vaca's comments that cooking time was no more than 10 hours (Krieger 2002:212–215). Such short-term ovens may not have used rock heating elements, as there are ample ethnographic accounts of cooking meats, as well as roots, beans, and corn for "a couple" to "several" hours and as much as "all day" or "all night" in rockless earth ovens (Thoms 1998; Wandsnider 1997). Some of the groups who lived west of the *Fig People* used bottle gourds "that floated to them on the river." It was in these regions, presumably along the Rio Grande or one of its southern tributaries, that for the first time since leaving the southeastern forests the travelers encountered farming peoples who lived in permanent houses and ate beans and melons (Krieger 2002:216–219).

On their way to the west coast, the Old Worlders passed along the southernmost bison ranges, presumably somewhere southeast of El Paso. Some of the people there lived in permanent houses, relied on corn, beans, and squash, and undoubtedly used pottery, but seasonally they left their villages to hunt bison. Other groups were apparently mobile hunters and gatherers. Among them were the people Cabeza de Vaca referred to as "those of the cows" (or *Cow People* [Covey 1993:115117]) because they killed so many bison, as did the people who lived 50 leagues up river (Krieger 2002:223). It was there that the Old Worlders observed for the first time what to them was an exotic cooking technique:

> Their method of cooking is so new that being such I want to set it down here, so it may be seen and known how diverse and strange are the inventions and industries [*ingenious y industrias*] of human beings. They do not have *ollas* [pottery vessels] to cook what they want to eat [so] they half fill a large gourd with water and into the fire they toss many stones of the kind that will more easily burn. And when they see that the stones are burning they take them up with wooden tongs and put them into that water which is in the gourd until they make it boil with the fire [heat] that the stones carry. And when they see that water boils they put in it what they want to cook. And during all this time they do not do anything else but take out some stones and toss in others so that the water may [keep] boiling and cook what they want, and thus they cook [Krieger 2002:223–224; brackets added by Krieger].

When Cabeza de Vaca and those accompanying him continued on their way across north-central Mexico, they encountered many farming communities, and on one occasion they were given "a great amount" of corn products, squash, beans, and cotton blankets (Krieger 2002:224–225). In this same region, there was also an abundance of deer, and deer hides were important as trade items. When they neared the Pacific coast, Cabeza de Vaca reported that native agricultural practices had been curtailed severely insofar as the Indians had deserted villages that had been burned by the Spanish. The local people, as well as Cabeza de Vaca and those traveling with him, were quite hungry and found themselves subsisting on the "bark of trees and [on] roots" (Krieger 2002:228). It is noteworthy that roots seem to have been a common element in the diets of most groups from the Gulf of Mexico to the Pacific ocean.

Regional Archaeological Records

Archaeology in the eastern section of the Edwards Plateau, the southern part of the Blackland Prairie, and the adjacent areas of the Gulf Coastal Plains is now fairly well known. The existing data base comes mainly from federally mandated cultural resources studies conducted during the last 20–25 years. Results of these and earlier studies demonstrate that hunter-gatherers continuously occupied the regions surrounding the Richard Beene site throughout the last 11,500 years, and there is some evidence for pre-Clovis-period utilization of the landscape (Black 1989a, 1989b; Hester 1989).

This section of the chapter was prepared in the mid-1990s. For more recent overviews of regional archaeological records, the reader is referred to *The Prehistory of Texas* (Perttula 2004). In addition, Mason (2003) compared the Early Archaic components at the Richard Beene site to several recently excavated Early Archaic sites in the region (Figure 8.3), including Wilson-Leonard (Bousman 1998b; Collins 1998), Armstrong (Schroeder and Oksanen 2002), Woodrow Heard (Decker et al. 2000), Num-

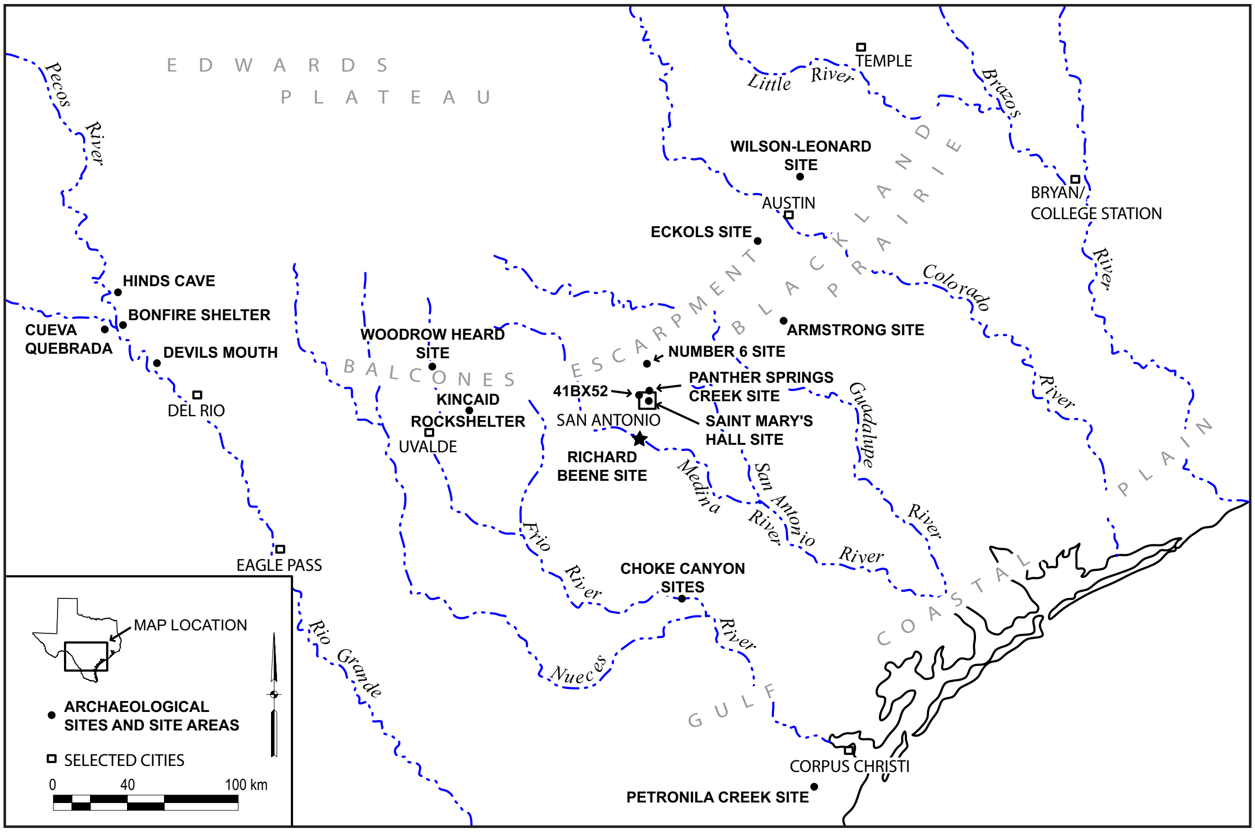


Figure 8.3. Map showing the locations of selected archaeological sites and project areas in the inner Gulf Coastal Plain.

ber 6 (Potter 1995), and the Eckols sites (Karbula 2000).

Survey and excavation work carried out in the lower Nueces River valley in conjunction with the construction of Choke Canyon Reservoir (ca. 85 km south-southeast of 41BX831, on the Frio River Figure 8.3) revealed a long history of hunter-gatherer land use on the South Texas Plain (Hall et al. 1986:394–406). A variety of late Paleoindian projectile point types, including Plainview, Golondrina, Angostura, and Scottsbluff, were surface-collected from sites located on high-terrace remnants, and local residents reported finding Folsom and Clovis points on similar landforms. Buried Early and Middle Archaic components were identified at two sites (41LK31/32 and 41LK51) where charcoal from fire-cracked rock (FCR) features yielded radiocarbon ages ranging from 6360±90 B.P. to 4690±80 B.P. A Bandy point, considered to be representative of the Early Archaic period, was recovered from 41LK51 (Hall et al.1986:96, 397, 585). A few other sites yielded Early Archaic projectile points, but in general, the Middle and Late Archaic periods and the Late Prehistoric period were better represented than the earlier periods (Hall et al. 1986).

Archaeological investigations in the upper Salado Creek basin of northern Bexar County (ca. 35 km north of the Richard Beene site) also reveal a long history of hunter-gatherer land use. Radiocarbon ages from the Panther Springs Creek site (41BX228), located along the boundary between the Edwards Plateau and the Blackland Prairie, indicate that especially intensive occupation occurred between 5500 and 1000 B.P.; some of the projectile-point types are suggestive of occupation several thousand years earlier as well (Black and McGraw 1985). Other excavated sites in the upper Salado Creek basin yielded Clovis, Folsom, and Plainview points indicating occupation during the early Paleoindian period (ca. 11,200–10,000 B.P.), as well as

Golondrina and Angostura points characteristic of the late Paleoindian period (ca. 10,000–8000 B.P.). Projectile points representative of the Archaic (ca. 8000–1200 B.P.) and late Pre-Columbian periods are also found at many of the sites in the Salado Creek basin (Hester 1977a; McGraw 1985a:303–326).

In addition to projectile points, other diagnostic Clovis materials including cores, blades, core tablets, and tools made on blades were excavated at 41BX52, an upper Salado Creek basin site that also produced Folsom artifacts. The Paleoindian material was embedded in a gravel-rich stratum separated from overlying cultural deposits by a sterile depositional unit (Frison et al. 1991). St. Mary's Hall (41BX229), another site in the Salado Creek basin, yielded Plainview points, cores, a chopper, large bifacial preforms in various stages of reduction, a bifacial Clear Fork tool, a large uniface, and several edge-modified tools (Hester 1991a; Hester and Knepper 1991).

The comparatively deeply buried, multicomponent Wilson-Leonard site (41WM235), located in the prairie zone some 180 km northeast of the Richard Beene site, added to a growing body of evidence attesting to extensive use of the regional landscape prior to 8000 B.P. (Bousman 1998b; Collins 1998; Weir 1985). Kincaid Rockshelter in the western part of south Texas (ca. 150 km west of 41BX831) also yielded Paleoindian and Early Archaic artifacts, including several varieties of Angostura points (Collins et al. 1988). Collectively, the widespread occurrence of fluted and lanceolate projectile points in Bexar County and surrounding regions provides ample evidence for substantial human occupation of the region during the late Pleistocene and early Holocene (Hester 1977b; Largent et al. 1991; Meltzer 1986).

There is some evidence, albeit equivocal, for pre-Clovis occupation in south Texas, as is the case for other parts of the Americas (Fagan 1992:240–244; Hester 1989). Two stratigraphic zones with cultural materials at Cueva Quebrada, located along the lower Rio Grande, produced radiocarbon ages ranging from about 14,300 to 12,300 B.P.; both zones yielded chipped stone artifacts, and the lower one contained remains of extinct fauna (Collins 1976). Hester (1989:121) included two loci on the Gulf Coastal Plains as potential pre-Clovis sites: (1) Berger Bluff (41GD30), located about 150 km southeast of the Richard Beene site, yielded chipped stone artifacts associated with an "unprepared, fired surface," termed a "small hearth," and an adjacent deposit of "microfauna"; radiocarbon ages from charcoal in these deposits ranged from ca. 11,550 to 7700 B.P. (Brown 1987); and (2) a fossil locality on Petronila Creek near the mouth of the Nueces River, some 150 km south-southeast of the Richard Beene site, yielded mammoth bones, some of which appeared to have been modified by humans (Hester 1989).

Another possible pre-Clovis site (41BX1239) was discovered along the San Antonio River about 25 km downstream from the Richard Beene site. Remains of at least one mammoth, including tusks, a mandible, and teeth and long-bone fragments, were found in well-stratified palustrine sediments at the base of a Perez-like paleosol (ca. 8600–10,000+ B.P.) in a chute or channel incised in a Somerset-like paleosol (ca. >20,000 B.P.) (Caran 2001; Thoms et al. 2001). Two of the long-bone fragments exhibited linear marks interpreted as possible cut and saw marks "probably made by lithic tools," as well as helical fracture surfaces characteristic of human-caused fractures (Johnson 2001:35–41). The presence of these sites highlights the potential for pre-Clovis people in the lower Medina River valley.

Archaeological Records in the Applewhite Reservoir Area

Archaeological survey and testing work conducted in 1981 and 1984 for the proposed Applewhite Reservoir identified dozens of prehistoric sites, most of which were assigned to the Early, Middle, or Late Archaic periods (McGraw and Hindes 1987). Late Pre-Columbian (i.e., Late Prehistoric) sites were recorded as well, but their frequency was comparatively low. Early Archaic features and tools were unusually common and included large FCR features, Guadalupe tools, and Martindale points. Several lancoelate projectile points reminiscent of Paleoindian types were surface-collected, but it was postulated that "the diverse riparian resource zones within the drainage basin areas may have been less significant than the broad savannah adjacent to or south of the study area, which contained the forage necessary for large groups of herd animals" (McGraw and Hindes 1987:364). It was also recognized that sites dating to this period may have been eroded by scouring or buried deeply in terrace fill.

Subsequent archaeological and paleoenvironmental investigations in 1989 and 1990 demonstrated that, indeed, sites and paleosols were buried deeply in the Medina River valley (Mandel et al. 2008). Five paleosols were identified in the upper 15 m of terrace alluvium and in alluvial fan deposits. Charcoal and bulk sediment samples yielded radiocarbon ages for the paleosols ranging from about 11,200 to 1600 B.P. and demonstrated a potential for buried Paleoindian sites in the reservoir area. Additional survey work resulted in the discovery of several new sites. More than 20 sites were test-excavated and yielded cultural materials representative of the late Paleoindian and all subsequent culture periods. Radiocarbon assays on charcoal and soil carbon from these sites yielded ages from about 8400 to 800 B.P. (McCulloch et al. 2008).

Site 41BX831—subsequently named the Richard Beene site—was one of those discovered during the new survey work. Backhoe and test-pit excavations led to the identification of three components at the site. The Middle Archaic component, 2.6 m below surface in the upper Medina pedo-complex, yielded a radiocarbon age of 4570±70 B.P. An oven-like feature in the Late Archaic component, 1.25 m below surface in the upper Leon Creek paleosol, yielded an age of 3090±70 B.P. Based on the presence of arrow points and bone-tempered pottery, the upper 30 cm of the site's deposits were assigned to the late Pre-Columbian period (McCulloch et al. 2008).

Survey and testing work in 1997 along State Highway 16 was undertaken in conjunction with construction of a new waterline by the San Antonio Water System. Several sites were investigated, including 41BX859, located about 3 km upstream from the Richard Beene site (Thoms and Olive 1997). Exploratory backhoe trenches (BHT) revealed fine-grained alluvium typical of the Applewhite terrace fill with stratified archaeological deposits encased in two paleosols.

The upper paleosol extended from 0.7 m below the modern surface to at least 1.9 m below surface, the maximum depth of the BHTs at the site. It was interpreted as equivalent to the Leon Creek paleosol, which is dated from about 2800–4200 B.P. at the Richard Beene site and elsewhere in the Applewhite Reservoir project area (Mandel et al. 2008). Charred remains of a burned tree root that appeared to have originated in the upper Leon Creek paleosol (2A/Bk horizon), which also contained the best-preserved archaeological component, yielded an age of 3360±80 B.P. (Thoms et al. 2008). As such, this component is approximately the same age as the upper Leon Creek component at the Richard Beene site, which yielded an age of ca. 3090 B.P.

The lower paleosol, ca. 3.5 and 6.0 m below the terrace surface, was exposed in BHTs dug along the terrace scarp. It was interpreted as equivalent to the Medina pedocomplex at the Richard Beene site, which extends from about 3 to 6.5 m below surface, and is dated ca. 4300–7000 B.P. (Chapters 3 and 4). Cultural material observed in the Medina pedocomplex in BHT profiles were limited to a few pieces of FCR and a single flake (Thoms et al. 2008).

Judging from the amount and type of artifacts recovered, the well-preserved upper Leon Creek component at 41BX859 represents a short-term occupation by a small group engaging primarily in hunting-related activities. While cultural materials were scattered over a large area, the highest concentration was within a few meters of the terrace scarp, in a setting that overlooked the Medina River and its small floodplain. Only a few tools were recovered, including a reworked Clear Fork tool, possibly used as a hide scraper, and two thin biface fragments that probably represent broken or unfinished projectile points. Chipped stone debitage was scattered in low densities throughout the excavated area, and one discrete chipping station was identified. As a whole, the chipped-stone assemblage was indicative of final-stage biface manufacturing and reconditioning (Thoms et al. 2008).

Compared to similarly aged sites elsewhere in the Applewhite project area, the upper Leon Creek component at 41BX859 yielded much less FCR, suggesting that hot-rock cooking was not a major activity. The chipped-stone debitage assemblage at the site also differed from other sites in the reservoir area, including the Richard Beene site, insofar as large-sized and corticated flakes indicative of early-stage manufacturing were poorly represented. While the Late Archaic components at the Richard Beene site yielded more bone fragments than did site 41BX859, deer-sized bones are most common at both sites. Mussel shells also occur at both sites, but in much lower densities at 41BX859 (Thoms et al. 2008).

Patterns in the Interregional Archaeological Records

In reviewing the prehistory of the South Texas Plains, Black (1989b:61) recognized that the portion of the south Texas Gulf Coastal Plain north and east of the Frio River seems "to be more closely linked to central Texas than we previously realized." Hester (1989:121) also recognized broad similarities in the archaeological records for south and central Texas, as well as for the adjacent parts of the lower Pecos River canyonlands. Table 8.1 summarizes information compiled by Black (1989a, 1989b) for the major prehistoric cultural periods in south and central Texas.

In his synthesis of south and central Texas, and the adjacent lower Pecos River canyonlands, Hester (1989:121) identified several "adaptation types as abstractions designed to suggest broad cultural-ecological patterns." Four types potentially pertain to the archaeology of the Richard Beene site and surrounding environs: (1) Pleistocene foragers and hunters; (2) specialized hunters; (3) Holocene foragers and hunters; and (4) specialized plant collectors.

Hester's (1989) "Pleistocene foragers and hunters" adaptation type, which dates prior to 11,200 B.P., is a hypothetical pre-Clovis construct wherein generalized hunting and gathering activities predominate and specialized big-game hunting is of lesser importance. As noted earlier in this discussion, two south Texas sites, Berger Bluff (Brown 1987) and Cueva Quebrada (Collins 1976), as well as the Petronila Creek fossil locality, are "potential candidates" for this adaptation type. Site 41BX1239 is also a potential pre-Clovis candidate (Thoms et al., 2001).

"Specialized hunters" of big game animals, including mammoth and modern bison, operated in the northern part of the South Texas Plains and adjacent regions at various times in the past. This pattern was especially evident when bison densities were comparatively high during parts of the late Holocene period (Hester 1989). Groups representative of this adaptation type are believed to have relied heavily on broad spectrum hunting and gathering, while taking advantage of increased numbers of big game. This type of adaptation is represented by several archaeological cultures: (1) Early Paleoindian period, 11,200–10,00 B.P.; (2) part of the Late Archaic period, ca. 2800 B.P.; and (3) during the last part of the Late Prehistoric period, 600–400 B.P.

In the northern part of the South Texas Plains, the "Holocene foragers and hunters" adaptation type occurred during the Late Paleoindian period, during most of the Early, Middle, and Late Archaic periods, and for all but 200 years of the Late Prehistoric period. Hester argues that the modern environment developed during the middle and late Holocene, and it was then that "high-density resource zones" such as riparian forests began to play important roles in regional land use systems. Holocene foragers and hunters utilized "practically all available plant and animal species," including deer, snakes, other reptiles, rabbits, other small game, fish, river mussels, berries, prickly-pear, and roots (Hester 1989:122–123).

Hester (1989:123–124) applied the "specialized plant collector" adaptation type only to central Texas. It began as early as 5000 B.P. and is represented mainly by burned-rock middens. He argues that the consensus opinion is that these features represent

Table 8.1. Selected Characteristics of Archaeological Cultures in southern Central and northern South Texas; Data Summarized from Black's (1989a, 1989b) Review of the Central Texas Plateau Prairie and the South Texas Plains.

TIME PERIODS	CENTRAL TEXAS	SOUTH TEXAS
LATE PREHISTORIC Cen. TX: 1200-400 B.P. Sou. TX: 1200-400 B.P.	**Diagnostics:** Austin: Scallorn arrow points and other expanding stem forms; Toyah: Perdiz arrow points and pottery, also beveled knives and small end scrapers **Population/Site Density:** population decline during Austin, possibly major population movements **Site Locations:** increased use of rockshelters **Subsistence:** deer most important throughout, but bison too during Toyah and perhaps limited agriculture **Other:** interaction with Caddo populations to north and east; intergroup conflict during Austin phase; reintroduction of blade technology during Toyah interval	**Diagnostics:** Austin: Scallorn, Edwards, Fresno, Padre points; Toyah: Perdiz, beveled knives, small end scrapers; pottery throughout **Population/Site Density:** fairly high populations, sites very common **Site Locations:** primarily confined to water-proximate locations, upland sites less common **Subsistence:** (best preservation) emphasis on faunal exploitation, deer most common, bison, & pronghorn, along with an extraordinarily wide range of species **Other:** rapid culture change, widespread (interregional, Central and South Texas, and beyond) similarities, influences from southern plains
LATE/TERMINAL ARCHAIC Cen. TX: 3000-1200 B.P. **LATE ARCHAIC** Sou. TX: 2400-1200 B.P.	**Diagnostics:** Late: Montell, Castroville, Marcos (broad triangular blades); Terminal: Ensor, Frio, Darl, Fairland (small expanding stems) **Population/Site Density:** population density high (some argue highest of all in Terminal Archaic), more sites in Terminal Archaic than earlier **Site Locations:** more sites in riverine settings (?) **Subsistence:** less specialized; bison and deer hunting & more plant resources, fewer burned rock middens **Other:** trading evident, more cemeteries	**Diagnostics:** Ensor, Frio, Marcos, Fairland, Ellis, small distally beveled tools, Nueces scrapers, corner-tang knives **Population/Site Density:** population higher than before, sites very common **Site Locations:** virtually all topographic settings **Subsistence:** focused on plants and small animals (rodents and rabbits), [presumably deer too?] **Other:** roasting features more common and more carefully constructed, trade evident, possibly territorially focused cemeteries
MIDDLE ARCHAIC Cen. TX: 5000-3000 B.P. Sou. TX: 4500-2400 B.P.	**Diagnostics:** Early: Nolan and Travis; Late: Pedernales, Langtry, and Marshall, Bulverde throughout **Population/Site Density:** populations higher (some argue highest of all), many more sites than earlier **Site Locations:** very widespread, especially burned rock midden sites **Subsistence:** deer most important, but nuts (acorns) very important, also yucca and river mussels **Other:** appearance of burned rock middens; "primary forest efficiency"	**Diagnostics:** Pedernales, Langtry, Kinney, Bulverde, Lange, Morhiss, Tortugas, medium to small distally beveled tools **Population/Site Density:** population growth, sites more common **Site Locations:** upland, alluvial, and tributary settings **Subsistence**: reliance on plants (acorns and mesquite beans), deer, snails, river mussels, other animals **Other:** roasting hearths, more restricted territories, cemeteries

continued

Table 8.1. Continued

TIME PERIODS	CENTRAL TEXAS	SOUTH TEXAS
EARLY ARCHAIC Cen. TX: 8000-5000 B.P. (**"Transitional Period": 9000-7000 B.P.**) Sou. TX: 8000-4500 B.P.	**Diagnostics:** Martindale, Uvalde, Gower, Bell, Nolan, Bulverde points, Guadalupe and unifacial Clear Fork tools **Population/Site Density:** low, more sites than during previous period **Site Locations:** concentration along Balcones Escarpment **Subsistence:** large technological inventory of unspecialized tools suggests a wide range of resources **Other:** small, highly mobile bands	**Diagnostics:** Andice, Bell, Bandy, Martindale, Uvalde (early expanding stems), Early Triangular, Guadalupe and unifacial Clear Fork tools **Population/Site Density:** low, sites are generally uncommon **Site Locations:** high terraces, upland locations, buried in valley alluvium **Subsistence:** river mussels, snails, turtle, fish [presumably deer too?] **Other:** small bands, extremely large territories
PALEOINDIAN Cen. TX: 11,200-8000 B.P. (**"Transitional Period": 9000-7000 B.P.**) Sou. TX: 11,200-8000 B.P.	**Diagnostics:** Early (pre-10,000 B.P.): Clovis, Folsom, Plainview; Late: Golondrina, Angostura, Scottsbluff, Meserve, also some forms of stemmed and barbed points **Population/Site Density:** very low, few are intact (e.g.,Wilson-Leonard) **Site Locations:** too few sites to detect patterns **Subsistence:** Early: now-extinct big game (e.g., mammoth and bison); Late: fully Archaic lifeway (i.e., deer, small game, river mussels) **Other:** small bands, nomadic hunters	**Diagnostics:** Early: Clovis, Folsom, Plainview; Late: Golondrina, Angostura; finely flaked end scrapers on blades, bifacial Clear Fork tools **Population/Site Density:** low, sites uncommon, except on Nueces-Guadalupe Plain **Site Locations:** high terrace, uplands, buried in valley alluvium **Subsistence:** Early: big game; Late: generalized **Other:** small bands, with extremely large territories

the remains of repeatedly used earth ovens, and that the burned rock and ashy soil is related to leaching tannic acids from acorns or perhaps other nut foods. Deer and river mussels also were important food resources to specialized plant collectors, but "specialized nut harvesting and processing was the main character of this adaptation type" (Hester 1989:124). Subsequently, Black and Creel (1997) argued convincingly that central Texas' burned-rock middens and the earth ovens embedded in them were used primarily to bake agave and sotol. Large earth ovens and other FCR features along the eastern margin of the Edwards Plateau, however, were also used to cook camas and other lily bulbs (Collins 1998; Dering 2003; Schroeder and Oksanen 2002).

Features resembling the central Texas burned-rock middens have been reported from sites in the Choke Canyon Reservoir area as well. There too, the consensus opinion, albeit "stretching the inference very thin," was that the features may have been related to processing acorns (Hall et al. 1986:401). An alternative speculation was that the large "heat-fracture sandstone hearth features" at one of the sites (41MC209) may have been used to process other plant foods, perhaps mesquite beans, prickly pears, or yucca (Thoms et al. 1981:187–196). In any case, there continues to be considerable discussion on the function of burned-rock middens (Black and Creel 1997).

Burned-rock features, including circular concentrations up to 5 m in diameter and linear clusters more than 2 m in length, were the most common feature type observed during the initial survey and testing work for Applewhite Reservoir (McGraw and Hindes 1987). Based on their spatial association with temporally diagnostic artifacts, some of these features were considered to be Early Archaic in age. Although these features were not considered to be morphologically similar to central Texas burned-rock middens, McGraw and Hindes (1987:365–364) recommended comparing them to similar features within and adjacent to the Balcones Escarpment. A large FCR feature was excavated (1.25 m below surface) at one of the sites (41BX793) recorded and tested during subsequent investigations. It covered at least 4 m^2, and charcoal associated with it yielded a radiocarbon age of 3880±50 B.P. (McCulloch et al. 2008).

Fire-Cracked Rock Features and Their Functions

The most ubiquitous evidence for pre-Columbian cooking in south-central Texas and adjacent parts of the Post Oak Savannah is the presence of FCR features at many, if not most, sites. One of the largest earth ovens was found at the Wilson-Leonard site; the heating element consisted of a thick lens of FCR more than 2 m in diameter that contained charred camas bulbs dated to ca. 8200 B.P. (Collins 1998). Smaller earth ovens, with lenses less than a meter in diameter, are widely distributed in the central and southern portion of the Post Oak Savannah (Fields 1995). Many of these features are in shallow basins dug into sandy sediments (Clabaugh and Judjahn 2004; Thoms 2004b).

Earth ovens are perhaps the best studied of hot-rock cooking facilities (Black and Creel 1997; Ellis 1997; Thoms 1989, 1998; Wandsnider 1997). There are, however, numerous other ethnographically documented cooking facilities that include cook stones, most of which were probably used throughout North America at one time or another (Thoms 2003). These include the following generic types: (1) earth ovens, sometimes called dry ovens, with a rock heating element heated in situ; (2) steaming pits, sometimes called wet ovens, with rocks heated outside the pit; (3) open-air hearths with a cook-stone griddle; and (3) stone boiling in a pit with rocks heated nearby (Figure 8.4).

Fields (1995), Quigg et al. (2000), Rogers (1997), and Rogers and Kotter (1995) are among those who have interpreted various FCR features and scatters as evidence for the importance of stone boiling in the Post Oak Savannah and surrounding regions. Quigg et al. (2001) reported that stone-boiling rocks from south Texas sites have yielded both animal and plant residues. In the Great Plains, stone-boiling is often associated with making pemmican and represented by dense, extensive scatters of FCR and fragments of bison bone broken up in prepara-

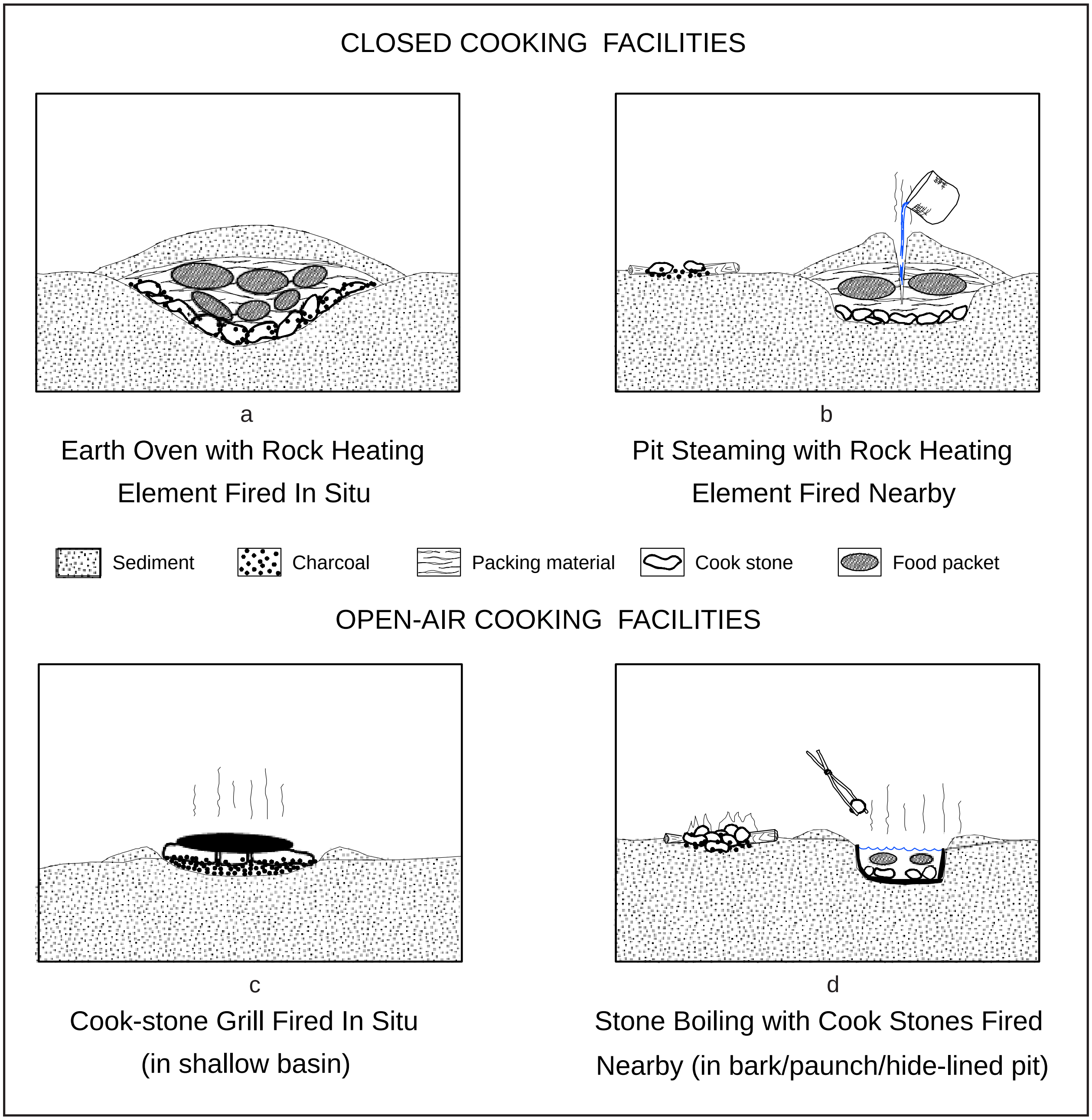


Figure 8.4. Examples of generic cook-stone features typical of those used in western North America: (a) closed oven with a fired-in-situ heating element; (b) closed steaming pit with cook stones heated outside the pit; (c) open-air, hot-rock griddle; and (d) stone boiling in a pit with cook stones heated on a nearby surface fire.

tion of marrow extraction and rendering bone grease (Reeves 1990).

A wide variety of foods, including large and small game, fish and shellfish, and many different plants, is also baked in earth ovens (Ellis 1997). It is becoming increasingly clear, however, that across North America earth ovens with rock heating elements tend to be indicative of baking root foods, especially those that require prolonged cooking to render them readily digestible (Thoms 1989, 2003; Wandsnider 1997). As noted in Chapter 2, there are numerous edible plants in the vicinity of the Richard Beene site, and many of them are known to have been prepared by baking in earth ovens, typically with rock heating elements (Table 2.1). Moreover, Cabeza de Vaca's narrative attests to the importance of oven-cooked root foods everywhere on the Gulf Coastal Plain (Krieger 2002). Only a few of the excavated earth ovens in and around the Post Oak Savannah have yielded definite plant food remains, and among those are charred bulbs from onions (*Allium* spp.), eastern camas (*Camassia scilloidies*), false garlic (*Nothoscordum bivalue*), and as yet unidentified species (Black and Creel 1997; Collins 1998; Dering 2003; Schroeder and Oksanen 2002).

Among the plant foods observed to grow in considerable abundance in the lower Medina Valley are wild onions and false garlic, both of which have been found in earth ovens with rock heating elements (Dering 2003). These particular geophytes appear to be among the plants likely to sustain long-term, systematic exploitation: (1) they grow abundantly in the bottomland that comprises the modern floodplain and Applewhite terrace; (2) they are easily dug from moist silty soils; and (3) root grounds are in close proximity to the raw materials necessary to prepare foods cooked in earth ovens with rock heating elements, namely cook-stone raw material, fuel, green-plant packing material, and water (cf. Thoms 1989:380–382, 456–459; Thoms 2004b).

Concluding Comments

Ethnohistoric and archaeological records attesting to Native American land-use practices in the middle Medina Valley indicate that, in general, the kinds of settlement and subsistence patterns reported by Cabeza de Vaca extended into the distant past. For the last 10,000 years or so, the region's inhabitants appear to have been mobile hunters and gatherers who inhabited many of the same places on the landscape, arguably lived in wickiup structures that left little in the way of archaeological remains, and relied heavily on deer, rabbits, prickly-pear, and root foods. These staples were undoubtedly supplemented by many other foods, including pecans, river mussels, fish, and a wide variety of other animals.

It remains to be determined just what foods were cooked in FCR features known to be present throughout the Applewhite Reservoir area. The degree to which stone-boiling was practiced needs to be addressed systematically. In any case, intensive procurement and processing of root foods has been incorporated into the present project's working model for land-use systems. If the large FCR features found at several Early and Middle Archaic sites in the area (McGraw and Hindes 1987; McCulloch et al. 2008) are indicative of plant-food processing, some form of "specialized" plant collecting may have been well underway by 4000–5000 B.P. in the middle Medina Valley. Recent discoveries of earth ovens and charred camas bulbs more than 8000 years old (Collins 1998; Dering 2003; Schroeder and Oksanen 2002) suggest that the onset of hot-rock cookery and baking lily bulbs in Texas extends back to the early Holocene, as is the case in other parts of North America.

9

EXCAVATION STRATEGIES AND THE GENERAL NATURE OF ARCHAEOLOGICAL DEPOSITS

Alston V. Thoms

This chapter describes excavation strategies, presents an overview of the site's archaeological assemblages, and provides a chronological context for each excavation area. It sets an archaeological stage for subsequent chapters (10–13) that describe and analyze the site's lithic artifacts and cultural features, as well as its floral and faunal remains. In turn, those chapters set the stage for spatial analyzes of artifact and feature distributions (Chapter 14).

As used herein, cultural time periods from the early, Early Archaic through the Late Pre-Columbian are represented by "components" (i.e., temporally discrete archaeological deposits) that are designated by the paleosol, or portion thereof, in which a given deposit is buried. Block designations (A–U) and subdivisions thereof (upper and lower) refer to specific excavation areas within the site, such that each block or subdivision is representative of one component of a given archaeological period. Excavation blocks were designated as they were laid out, such that their alphabetical order is unrelated to their stratigraphic positions or depths below surface.

Excavation goals for archaeological deposits at the Richard Beene site were established primarily under discovery conditions during ongoing construction of the spillway trench (Chapter 1). Accordingly, we endeavored to: (1) identify and isolate intact features and well-preserved *occupation surfaces* represented by thin lenses (ca. 10–20 cm) of primarily in situ artifacts and features; (2) in the absence of such surfaces, identify and isolate *occupation zones* represented by thick (i.e., 30–40 cm) vertically isolated lenses of artifacts, some in situ, others displaced; (3) excavate horizontally extensive areas to recover spatially and numerically large samples of tools and features; and (4) insofar as possible, sample each stratigraphically distinctive archaeological deposit exposed by heavy machinery during dam construction.

Following the discovery of extensive remains of campsites buried more than 6 m below surface in the spillway trench (Chapter 1), a backhoe trenching was used to locate and isolate buried features, occupation surfaces, and artifact zones in the spillway trench before they were unceremoniously exhumed by heavy machinery (Figure 9.1). Once archaeological deposits beneath the spillway trench floor were selected for excavation, overlying sediments were mechanically removed to within about 40 cm of the target surface or zone. Next, we hand-dug meter-wide and meter-deep cross trenches across the selected areas in arbitrary 10 cm levels, unless natural stratigraphy was evident. If the latter were the case, identifiable strata were subdivided into levels of 10 cm or less.

Cross trenches facilitated identification of cultural deposits as either well-preserved occupation surfaces or comparatively disturbed artifact zones likely to represent several surfaces that became mixed as a result of pedoturbation or flood scouring. These exploratory trenches, along with 1 x 1 m excavation units in the quadrants delimited by the cross trenches, served as starting points for excavation of a given occupation surface or zone. They

In: *Archaeological and Paleoecological Investigations at the Richard Beene Site, South-Central Texas*, 2007, edited by A. V. Thoms and R. D. Mandel, pp. 139–176. Reports of Investigations No. 8. Center for Ecological Archaeology, Texas A&M University, College Station, Texas.

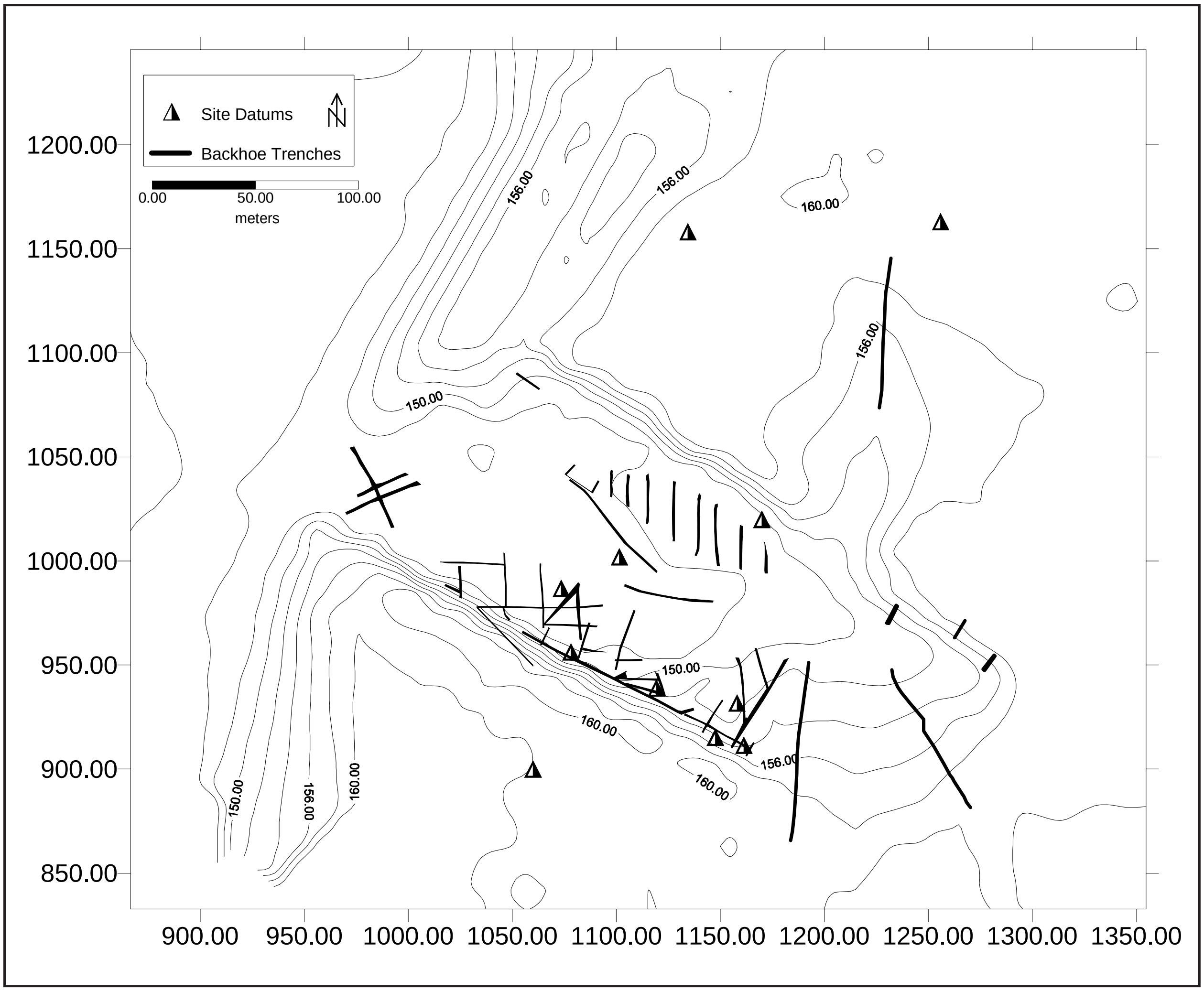


Figure 9.1. Planview showing the location of backhoe trenches excavated in the spillway trench area during the course of the project.

also yielded samples of artifacts and features from the deposits above and below the selected surface or zone in each block area.

All block areas were hand-excavated using shovel-skimming and troweling techniques. Sediments from cross trenches and exploratory 1 x 1 m units were water-screened through ¼-inch hardware cloth. Constant volume samples (10 x 10 x 10 cm) for fine screening (water-screening through 1 mm mesh) were taken from each level of each 1 x 1 m unit in the cross trenches. In the horizontally excavated areas, non-feature sediments were water-screened through ¼-inch hardware cloth and constant volume samples were taken from each 1 x 1 m unit. Features were cross-sectioned to obtain a profile. Feature fill was water-screened through 1/8-inch hardware cloth and constant volume and bulk samples were taken from the fill.

In 1990 and 1991, we spent ten months in the field with a crew ranging in size from about 10 to 40 individuals, including lab personnel and volunteers from the Southern Texas Archaeological Association (STAA). Additional excavation work was undertaken in 1995 by TAMU–CEA personnel and STAA field school participants (Thoms et al. 1996). These excavations focused on archaeological deposits in the upper Perez paleosol (ca. 8800 B.P., 9 m below surface) and upper Medina pedocomplex (ca. 4500 B.P., 3 m below surface).

In all, approximately 730 m^2 (168 m^3) of artifact- and bone-bearing sediments were excavated in discrete occupation zones and surfaces. This included: (1) 22 m^2 in upper Block B, dated to the Late Pre-Columbian (i.e., Late Prehistoric) period; (2) 120 m^2 in lower Block B, dated to the Late Archaic period; (3) 61 m^2 in upper and lower Block A and Block U, dated to the Middle Archaic period; (4) 233 m^2 in Block G, dated to the late, Early Archaic period; (5) 241 m^2 in Blocks H, N, and T, dated to the early, Early Archaic period. Smaller areas were excavated in 10 other places, including the work done in deposits dated to the middle, Early Archaic and in the late Pleistocene sediments (Blocks R and S) that yielded the paleontological remains (Figures 9.2 and 9.3; Table 9.1).

Artifacts recovered from excavation blocks and "surface collection" on mechanically exposed areas on the spillway trench floor and walls, include: 31,231 pieces of chipped-stone debitage, 153 cores, 505 chipped-stone tools, 8,650 mussel-shell umbos (i.e., hinges), 11,529 bone fragments, and 28,166 pieces of fire-cracked rock (FCR), mostly sandstone from local bedrock outcrops (Table 9.1).

Late Pre-Columbian Period, Payaya Component (ca. 1200–400 B.P.), Upper Block B

Excavations in upper Block B confirmed the presence of Late Pre-Columbian occupations in the uppermost 20–30 cm of the site (Figure 9.4). These occupations are herein termed the Payaya component, a name derived from a Coahuiltecan band encountered nearby in 1691 by then Governor Domingo de Teran de los Rios (Hatcher 1932). Artifacts were exposed on the surface and buried in the modern soil's A and upper B horizons (Figure 9.5). The area excavated totaled 22 m^2 (4.6 m^3). Although this block yielded a considerable quantity of cultural

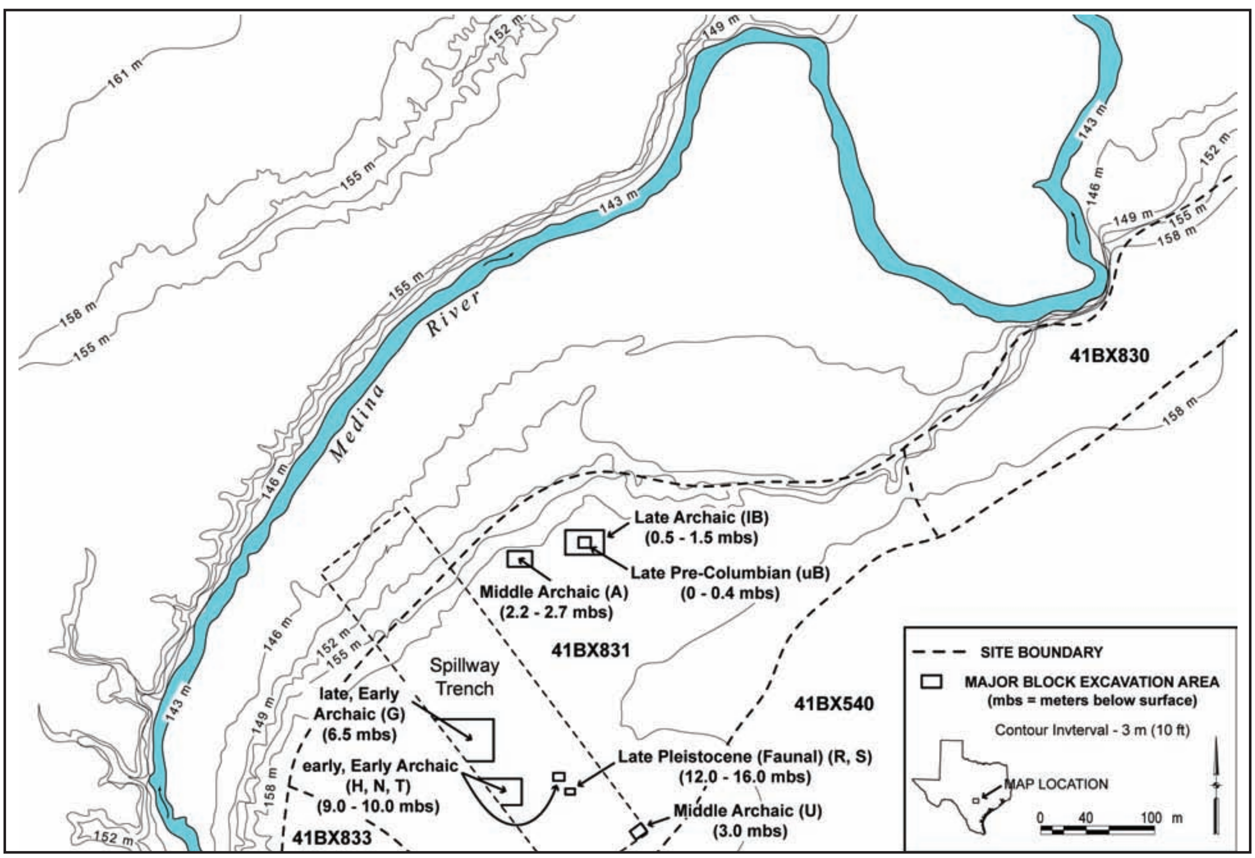


Figure 9.2. Map of the spillway trench and vicinity showing the approximate location of excavation blocks.

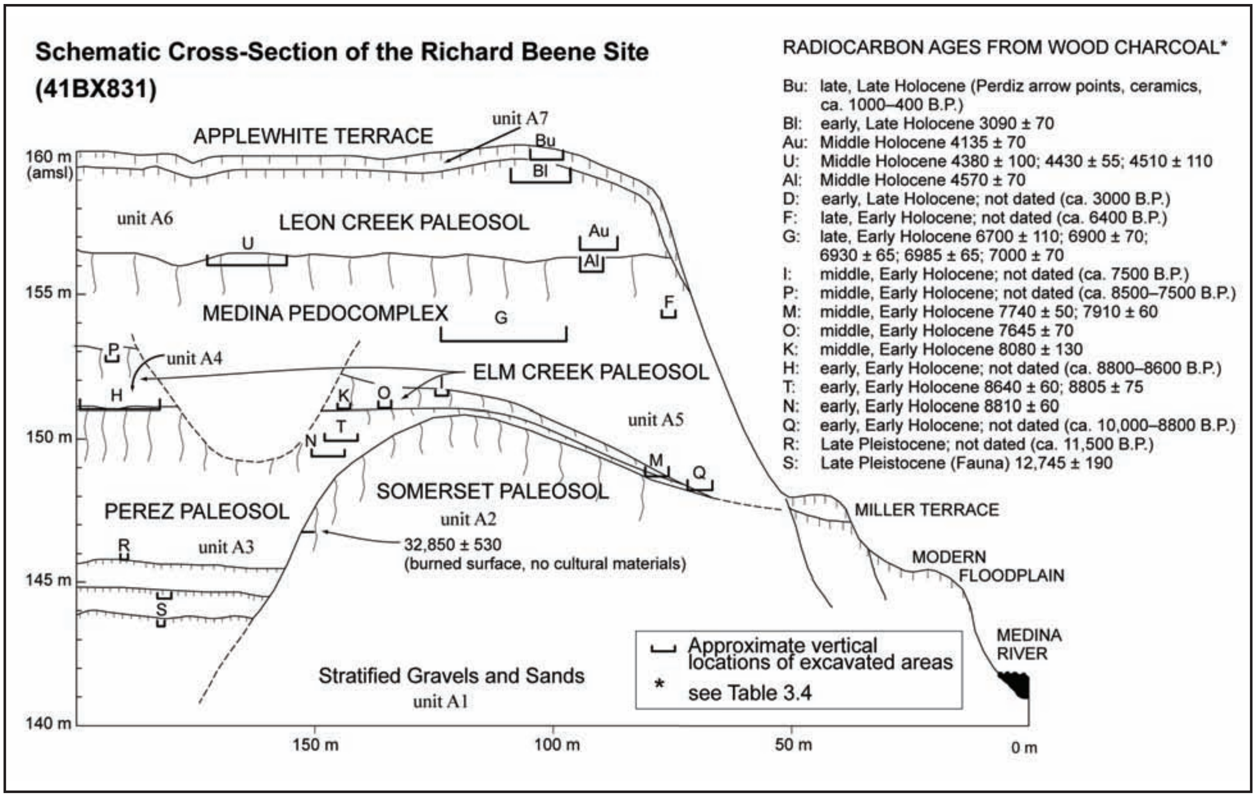


Figure 9.3. Schematic profile, showing paleosol stratigraphic units (Chapter 3), approximate statigraphic positions and radiocarbon ages of block excavation areas and cultural-period designations.

Figure 9.4. Upper Block B excavation area that yielded cultural materials–arrow points and bone-tempered pottery and a sheet midden deposit–from modern soil and represented the late site's Payaya component of the Late Pre-Columbian period (ca. 1200–400 B.P.).

material, discrete features were not recognized during field work. Chipped stone, FCR, and mussel shell occurred in sufficient densities and were sufficiently intermixed to be considered a sheet-midden deposit. It is possible, however, that some of the denser FCR concentrations, and perhaps some of the oxidized areas not readily interpreted as tree-root burns, could be the remains of once-discrete features (Figure 9.6). The ostensible absence of well-preserved features, however, is likely a result of slow rates of deposition along with significant bioturbation and argilliturbation during the last millennium or so (Chapter 4).

Temporally diagnostic artifacts include Perdiz and Scallorn arrow points (Figure 9.7z, aa) and several bone-tempered, plainware sherds (Leon Plain). Other materials included 626 pieces of chipped-stone debitage, 1 hammerstone, 2 cores, 1 heavy-duty tool (i.e., thick edge-modified flake), 128 mussel-shell umbos, 43 bone fragments, and 570 pieces of FCR. The only identified faunal remains from the Late Pre-Columbian component were frog and

Table 9.1. Summary of excavation areas, cultural components, and artifacts recovered.

Block* (avg. elev. m above sea level)	Temporal Designation (age of surface/zone)	Cultural Period and Component Designations	Excavat. area, m^2(vol.m^3)	Vert. Distr. Artifacts	Fea Cond. Count[1] (density[2])	Debitage Count[1] (density[2])	FCR Count[1] (density[2])	Umbo Count[1] (density[2])	Bone Count[1] (density[2])	Tool/Core Count[1] (density[2])
E, gully (159–153 m)	modern gully fill; late 19th – early 20th cen. livestock bone	Historic period; non-Indian component	exposed only (ca. 9 m^2)	20 cm	good, but bone bed is recent	none recovered	none recovered	none recovered	none recovered	none recovered
upper B (160.5 m)	late, late Holocene; 1200–400 B.P. (est.)	Late Pre-Columbian period; Payaya component	22 m^2 (4.6 m^3)	20-30 cm	poor 2 (0.4/m^3)	626 (136.1/m^3)	570 (123.9/m^3)	128 (27.8/m^3)	43 (9.4/m^3)	5 (1.1/m^3)
lower B (159.0 m)	early, late Holocene; 3500–2800 B.P. (est.)	Late Archaic period; upper Leon Creek components	120 m^2 (36.1 m^3)	100 cm	moderate 9 (0.3/m^3)	7583 (210.1/m^3)	13,014 (360.5/m^3)	2463 (68.2/m^3)	1765 (48.9/m^3)	130 (3.6/m^3)
D (159.0 m)	early, late Holocene; mussel shell / FCR; 3800–2800 B.P. (est.)	Late Archaic period; upper Leon Creek component	ca. 16 m^2 (1.4 m^3)	10 cm	none observed	47 (33.5/m^3)	98 (72.0/m^3)	205 (150.6/m^3)	21 (15.4/m^3)	not recovered
upper A (157.0 m)	mid Holocene; 4,135 B.P.	Middle Archaic period; lower Leon Creek component	37 m^2 (8.6 m^3) ?	20 cm	good 4 (0.5/m^3)	69 (8.0 m^3)	194 (22.6 m^3)	240 (27.9 m^3)	92 (10.7 m^3)	1 (0.1 m^3)
lower A (156.5 m)	mid Holocene; 4570 B.P.	Middle Archaic period; upper Medina components	18 m^2 (4.1 m^3) ?	20 cm	good 6 (1.5/m^3)	1315 (320./m^3)	104 (25.4/m^3)	47 (11.5/m^3)	144 (35.1/m^3)	1 (0.2 m^3)
U (156.7 m)	mid Holocene; 4510 B.P.	Middle Archaic period; upper Medina component	6 m^2 (1.8 m^3)	20-30 cm	poor 1 (0.6/m^3)	192 (106.7/m^3)	377 (209.44/m^3)	10 (5.6/m^3)	33 (18.3/m^3)	3 (1.7/m^3)
F (155.0 m)	late, early Holoc.; FCR feature; 6400–5400 B.P. (est.)	late, Early Archaic period; middle Medina component	2 m^2 fea. (0.6 m^3)	few	good 1 (den. n/a)	10 (17.7/m^3)	21 (37.17/m^3)	4 (7.08/m^3)	5 (8.85/m^3)	not recovered

continued

Table 9.1. Continued.

Block* (avg. elev. m above sea level)	Temporal Designation (age of surface/zone)	Cultural Period and Component Designations	Excavation area, m^2 (vol.m^3)	Vert. Distr. Artifacts	Fea Cond. Count[1] (density[2])	Debitage Count[1] (density[2])	FCR Count[1] (density[2])	Umbo Count[1] (density[2])	Bone Count[1] (density[2])	Tool/Core Count[1] (density[2])
G (153.5 m)	late, early Holocene; ca. 6900 B.P.	late, Early Archaic period; lower Medina component	233 m^2 (37.2 m^3)	10–25 cm	good 34 (0.9/m^3)	10,612 (285.3/m^3)	915 (24.6/m^3)	2055 (55.2/m^3)	5174 (13.9/m^3)	105 (2.8/m^3)
P (153.29–151.2 m)	middle, early Holocene; 8500–7500 B.P. (est.)	middle, Early Archaic period; Elm Creek components	4 m^2 (3.1 m^3)	100 cm; v. low density	none observed	73 (23.5/m^3)	100 (32.8/m^3)	19 (6.2/m^3)	17 (5.6/m^3)	2 (0.7/m^3)
O (150.9 m)	middle, early Holocene; FCR feature only; 7645 B.P.	middle, Early Archaic period; Elm Creek component	feature in profile; not excavated	few	good 1 (den., n/a)	not collected	not collected	not collected	not collected	2 from in/adjacent to feature
I (150.45 m)	middle, early Holocene.; 7800 B.P. (est.)	middle, Early Archaic period; Elm Creek component	15 m^2 (1.1 m^3)	ca. 10–20 cm	none observed	61 (55.5/m^3)	93 (86.9/m^3)	11 (10.3/m^3)	23 (21.5/m^3)	not recovered
K (150.35 m)	middle, early Holocene.; FCR feature only; 8080 B.P.	middle, Early Archaic period; Elm Creek component	6 m^2 (1.0 m^3)	15 cm	good 1 (den., n/a)	253 (253.0/m^3)	298 (298.0/ m^3)	83 (83.0/ m^3)	53 (53.0/m^3)	6 (6.0/m^3)
M (148.25 m)	middle, early Holocene; FCR feature only; 7740 & 7910 B.P.	middle, Early Archaic period; Elm Creek component	3 m^2 (0.2 m^3, exposed/sampled)	15 cm	good 1 (den., n/a)	3 (17.53 m^3)	63 (315.0/m^3)	1 (5.9/m^3)	10 (58.8/m^3)	not recovered
H (151.0 m)	early, early Holocene; 8800–8600 B.P. (est.)	early, Early Archaic period; upper Perez component	170 m^2 (42.2 m^3)	50 cm	poor 19 (0.5/m^3)	6850 (162.3/m^3)	9381 (222.3/m^3)	2736 (64.8/m^3)	728 (17.3/m^3)	396 (9.4/m^3)
T (149.5 m)	early, early Holocene; 8805 & 8640 B.P.	early, Early Archaic period; upper Perez component	52 m^2 (12.0 $m^{3)}$	20–30 cm	moderate 3 (0.3/m^3)	2199 (183.3/m^3)	1292 (107.7/m^3)	308 (25.7/m^3)	543 (45.3/m^3)	184 (15.3/m^3)

continued

Table 9.1. Continued.

Block* (avg. elev. m above sea level)	Temporal Designation (age of surface/zone)	Cultural Period and Component Designations	Excavation area, m^2 ($vol. m^3$)	Vert. Distr. Artifacts	Fea Cond. Count[1] (density[2])	Debitage Count[1] (density[2])	FCR Count[1] (density[2])	Umbo Count[1] (density[2])	Bone Count[1] (density[2])	Tool/Core Count[1] (density[2])
N (149.0 m)	early, early Holocene; 8810 B.P.	early, Early Archaic period; upper Perez component	19 m^2 (8.0 m^3)	20–30 cm.	none observed	211 (26.4/m^3)	230 (28.8/m^3)	61 (7.6/m^3)	156 (19.5/m^3)	9 (1.1/m^3)
J (exposed surfaces) (151–148 m)	middle, early Holocene; 8500–7200 B.P. (est.)	middle, Early Archaic period; primarily Elm Creek components	Exposed surfaces; map and collection	115 cm	variable	20 (n/a)	not collected	not collected	not collected	7 (n/a)
L (exposed surfaces) (148.6–148.3 m)	early, early Holocene; 9000–8600 B.P. (est.)	early, Early Archaic period; primarily upper Perez components	Exposed surfaces; map only	30 cm	variable	80 (prob. chipping station; (n/a)	1 (n/a)	not collected	not collected	39 (n/a)
Q (147.7 m)	early, early Holocene; 10,000–8,600 B.P. (est.)	early, Early Holocene probable upper Perez component	3 m^2 (0.6 m^3)	10 cm	poor	18 (30.0/ m^3)	21 (35.0/m^3)	9 (15.0/m^3)	1 (1.7/m^3)	not recovered
R (145.35 m)	late Pleistocene (faunal remains) 12,500 B.P. (est.)	Ostensibly non-cultural deposits dating to early Paleoindian period; Soil 6	4 m^2 (1.7 m^3)	30 cm	good, no cultural features	not recovered	not recovered	not recovered	477 (280.6/m^3)	not recovered
S (145.26 m)	late Pleistocene (faunal remains) 14,000–12,745 B.P.	Ostensibly non-cultural deposits dating to early Paleoindian period; Soils 7 and 8	4 m^2 (4.0 m^3)	100 cm	good; no cultural features	not recovered	not recovered	not recovered	2457 (617.57m^3)	not recovered
TOTALS	–	–	730m^2 (168 m^3)	–	–	31,231	28,166	8,650	11,529	658

[1]Item counts include cultural material from all excavation units, such that items collected from surface exposures of the respective pedostratigraphic unit are excluded

[2]Density figures are per cubic meter (1.0 m^3)

*Block was planned for in the upper Leon Creek but was not excavated

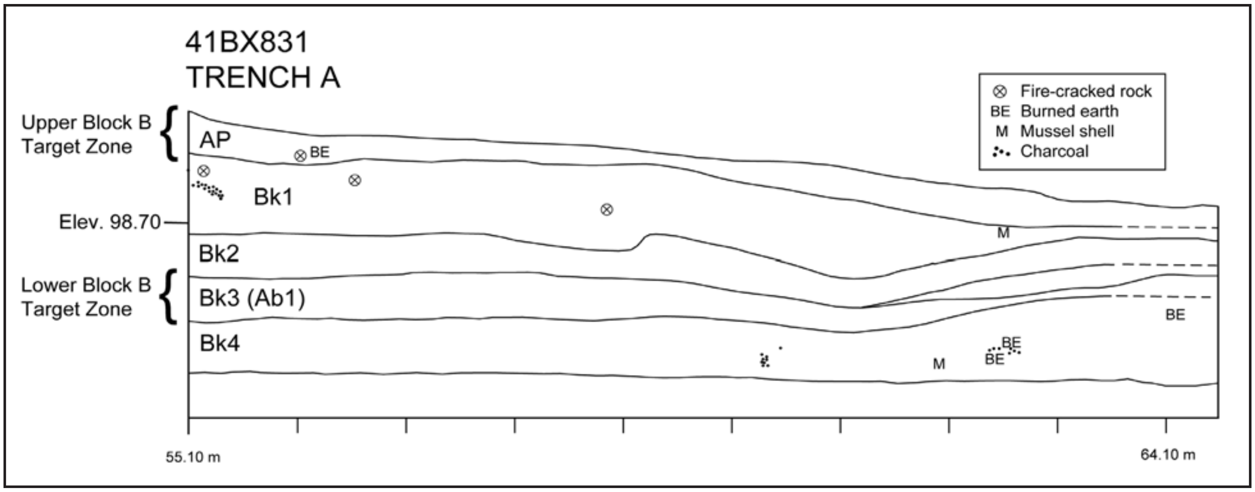


Figure 9.5. Profile of the modern soil and its artifact-bearing strata in upper Block B, which contained the Late Pre-Columbian period Payaya component.

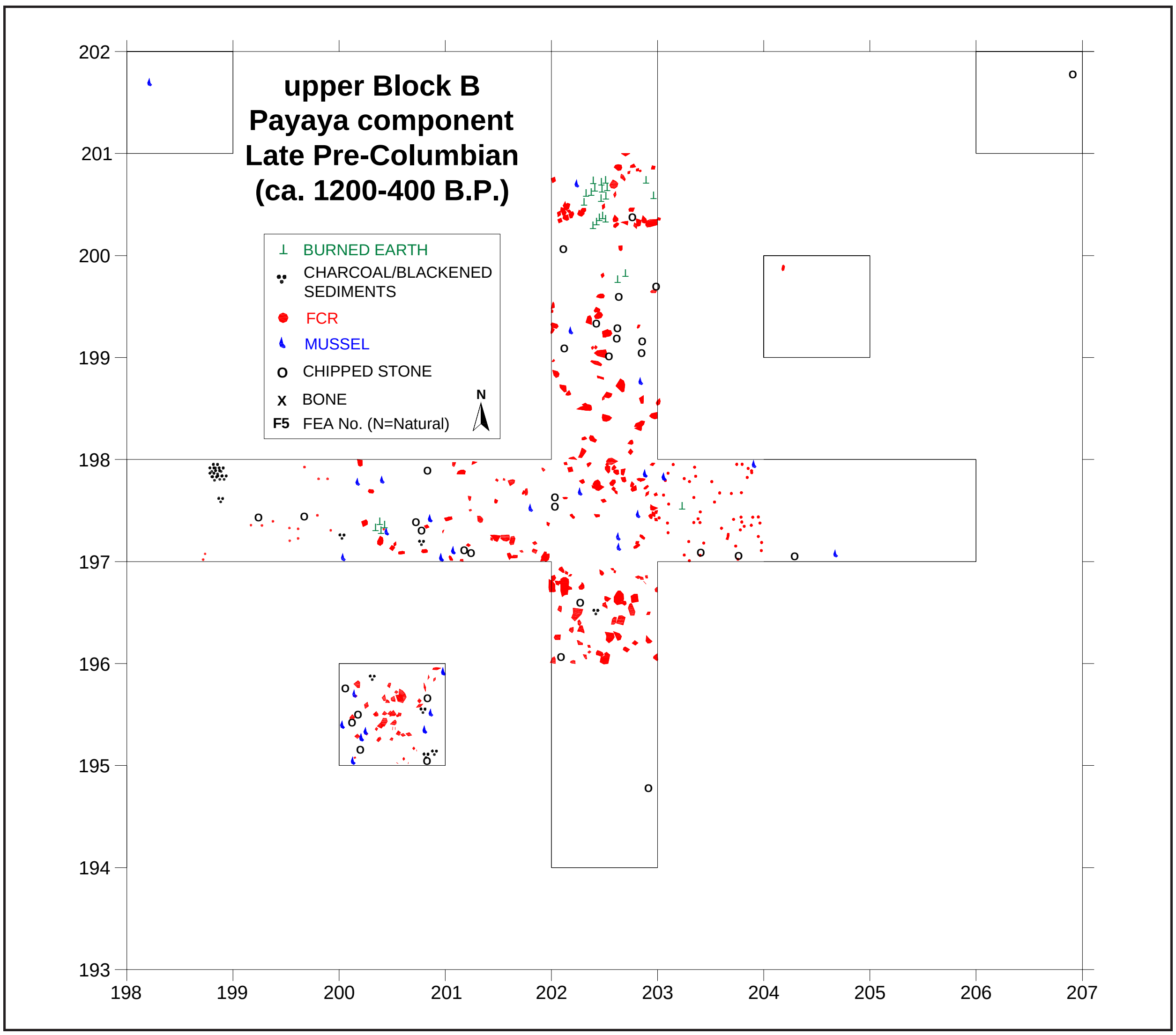


Figure 9.6. Planview map showing the distribution of mapped cultural materials and natural features in the Payaya component (upper Block B; Late Pre-Columbian period, ca. 1200–400 B.P.).

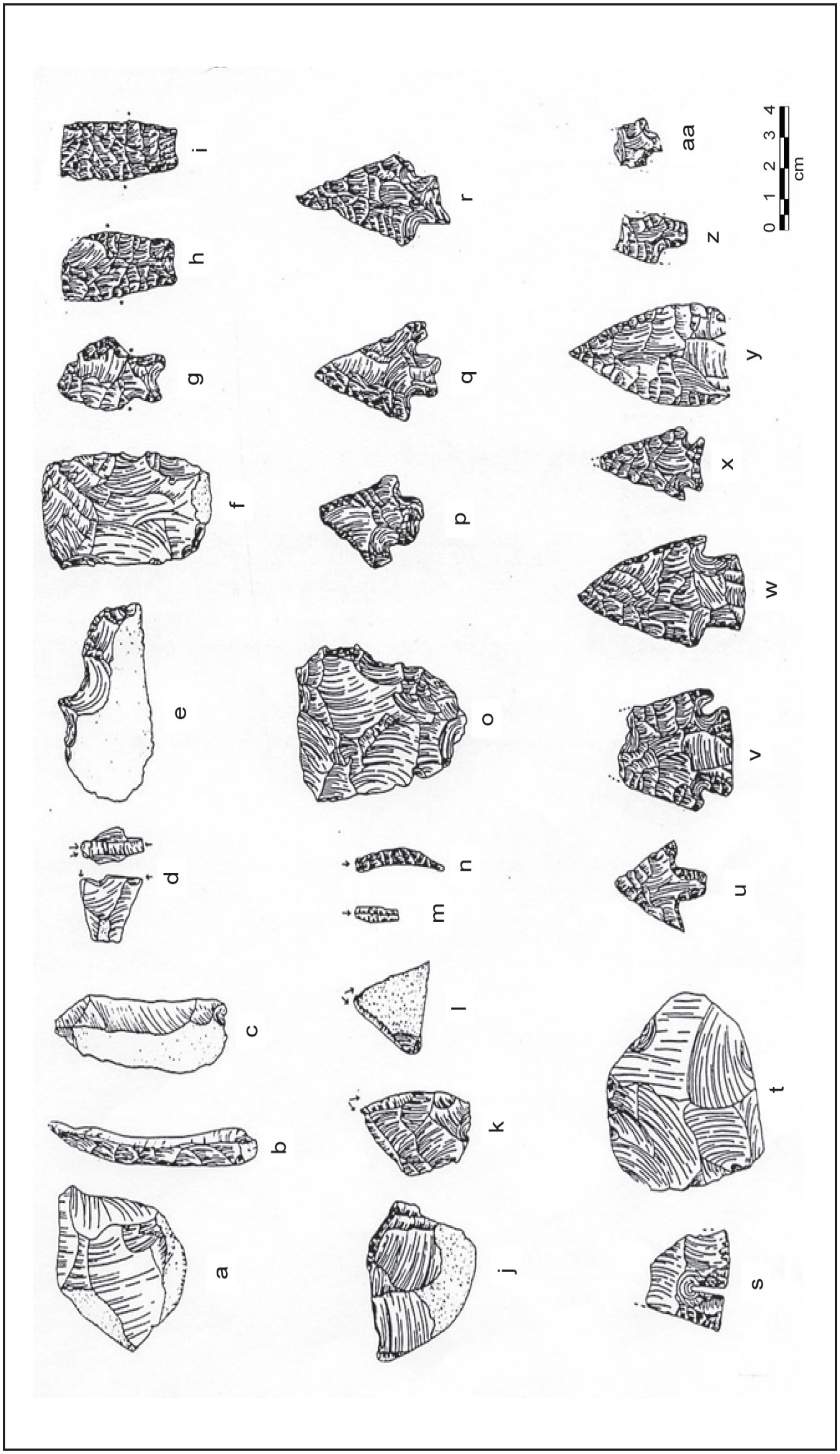


Figure 9.7. Selected artifacts: (a–i) early, Early Archaic period (upper Perez component, Block H, ca. 8700 B.P.); (j–r) late, Early Archaic period (lower Medina component, Block G, ca. 6900 B.P.); (s) Middle Archaic dart point from the upper Medina component (ca. 4500 B.P.); (t–y), Late Archaic period (lower Block B, upper Leon Creek component, ca. 3500–2800 B.P.); and (z–aa) Late Pre-Columbian period (upper Payaya component, ca. 1200–400 B.P.).

large mammal (deer-size) bones. The kinds of artifacts recovered from the Payaya component represent tool manufacturing and refurbishing, hunting, shellfish procurement, and considerable hot rock cookery. Overall, however, occupation intensity was comparatively moderate, as measured by artifact densities (Table 9.1).

Late Archaic Period, Upper Leon Creek Components (ca. 3500–2800 B.P.), Lower Block B and Block D

We mechanically removed the upper 50 cm of sediments in lower Block B where we planned to excavate the Late Archaic component identified during the testing phase. Hand-dug cross-trenches, test pits, and backhoe trench profiles led to the identification of three occupation zones, all of which had FCR features, shallow basin-shaped pits, and mussel-shell concentrations. In all, we hand-excavated a total of 120 m^2 (36.1 m^3) in the upper Leon Creek paleosol (Bk3[Ab1]), that encased these zones (Figure 9.8).

Occupation zones appeared in profile as higher-density artifact lenses within a continuous vertical and horizontal distribution of cultural material (Figure 9.9). Vertical separation of lenses and features suggests that deposition was fairly rapid during the late Holocene, but not so rapid as to prevent

Figure 9.8 Excavations underway in lower Block B, which yielded cultural materials–numerous dart points, other stone tools and features–representative of the Late Archaic period (ca. 3500–2800 B.P.), one of the site's upper Leon Creek components.

soil development and significant bioturbation and argilliturbation that masked occupation "surfaces".

We excavated about 65 m^2 in the upper zone (Figure 9.10. 9.11)) that yielded mainly small, expanding stem Ensor points (Figure 9.7 x). Excavations focused (120 m^2) on the middle or "target" zone, which had the highest density of FCR and most of the large, broad blade dart points, including Marcos and Lange types (Figure 9.7 v, w). This zone also encompassed the previously identified pit feature (No. 12) dated to 3090 ± 70 B.P. Further excavation of this rodent-impacted feature showed it to

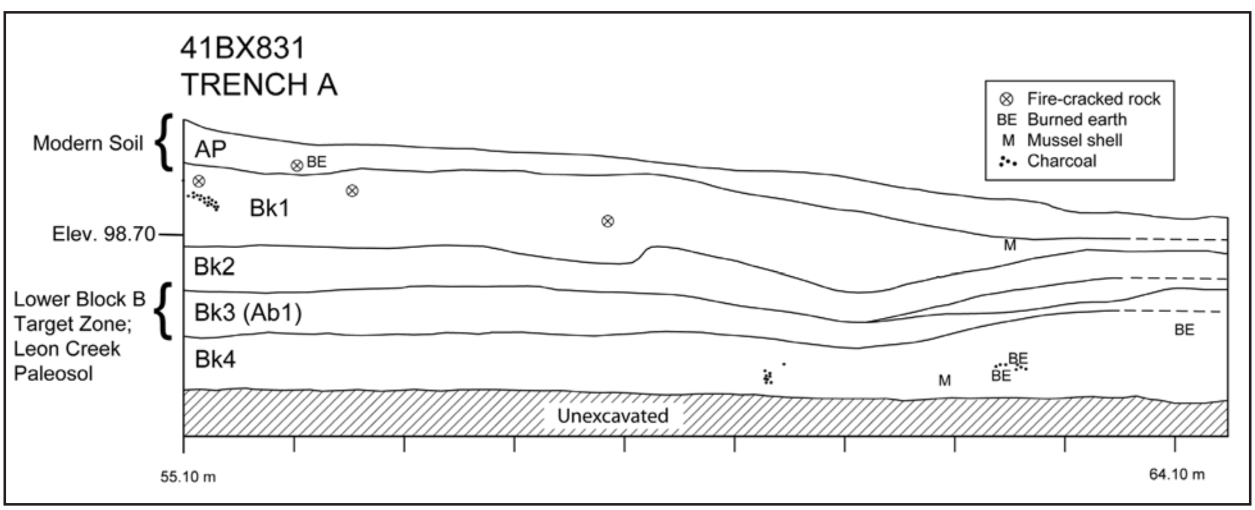


Figure 9.9 Profile of Leon Creek paleosol and its artifact-bearing strata in lower Block B, which encompassed the Late Archaic upper Leon Creek components.

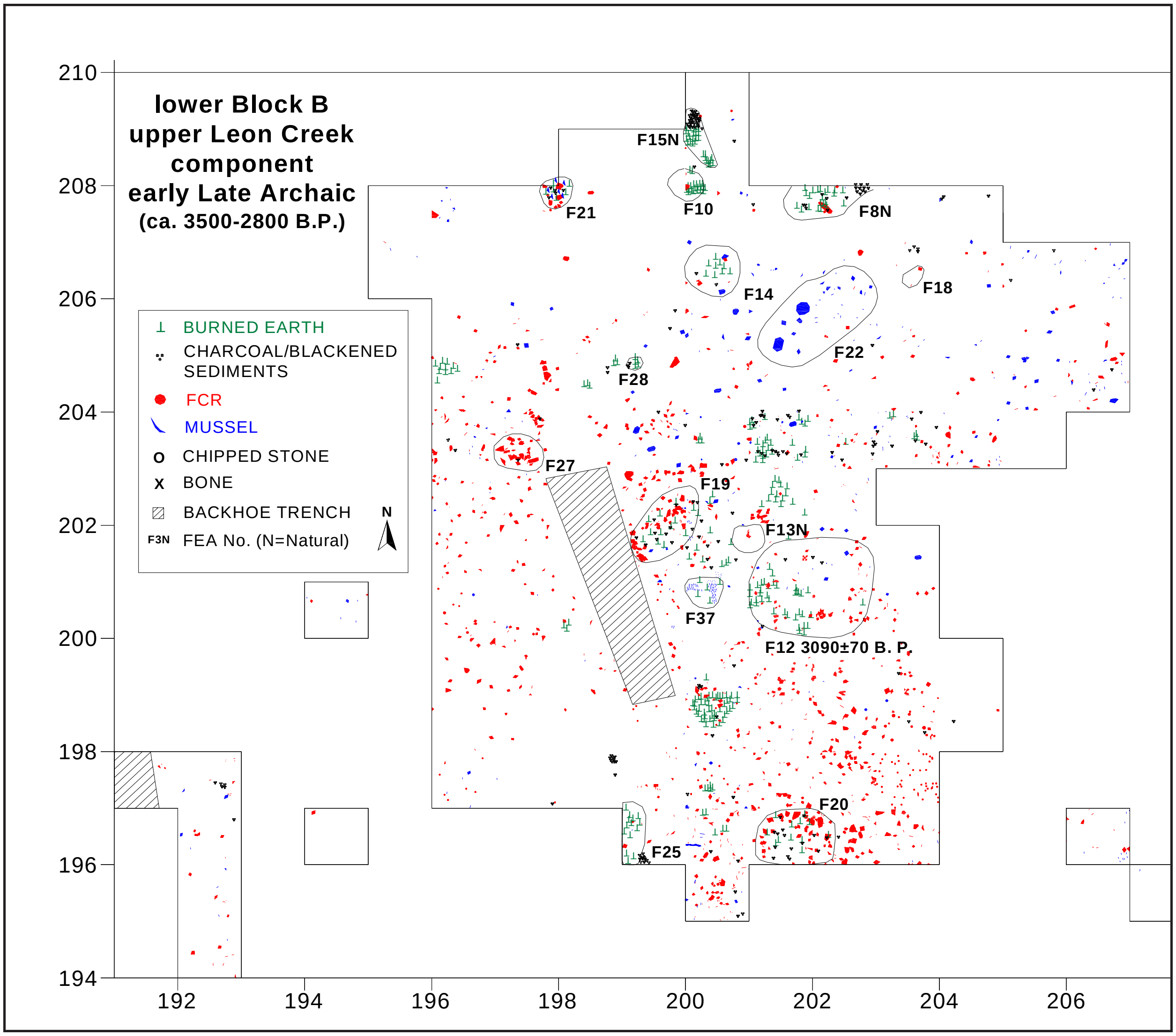


Figure 9.10. Planview showing the distribution of FCR and mussel shells and features in the upper Leon Creek component's (lower Block B, Late Archaic period, ca. 3500–2800 B.P.).

be basin-shaped, about 2.0 m in diameter, and 25 cm deep. Its base was oxidized and further delineated by a thin scatter of FCR. Given its structure, and considering the paucity of chipped-stone artifacts and faunal remains in and around the feature, it may represent a large earth oven used to cook plant foods.

Only about 20 m^2 were excavated in the lower part of the Late Archaic deposit; all of the units were dug in the cross trench. The only diagnostic artifact was a Langtry-like point (Figure 9.7 u) and it was recovered from the deepest part of the cross trench (ca. 1.75 m bs). The corner-notched and stemmed dart points from the Late Archaic components are consistent with the ^{14}C age on the oven-like feature and with other dates from the Leon Creek paleosol ranging from 3500 to 2800 B.P. (Mandel et al. 2008; McCulloch et al. 2008). Occupation intensity for the upper Leon Creek components was quite high, as measured by FCR and mussel-shell umbo densities. These densities are among the highest from the site. This component also yielded a comparatively high density of lithic debitage (Table 9.1).

Artifacts recovered from this block include 8,571 pieces of chipped-stone debitage, 4 hammerstones, 23 cores (e.g., Figure 9.7 t), 23 heavy-duty tools (i.e., thick edge-modified flakes and cobble tools), 24 light-duty tools (i.e., less than 1 cm thick,

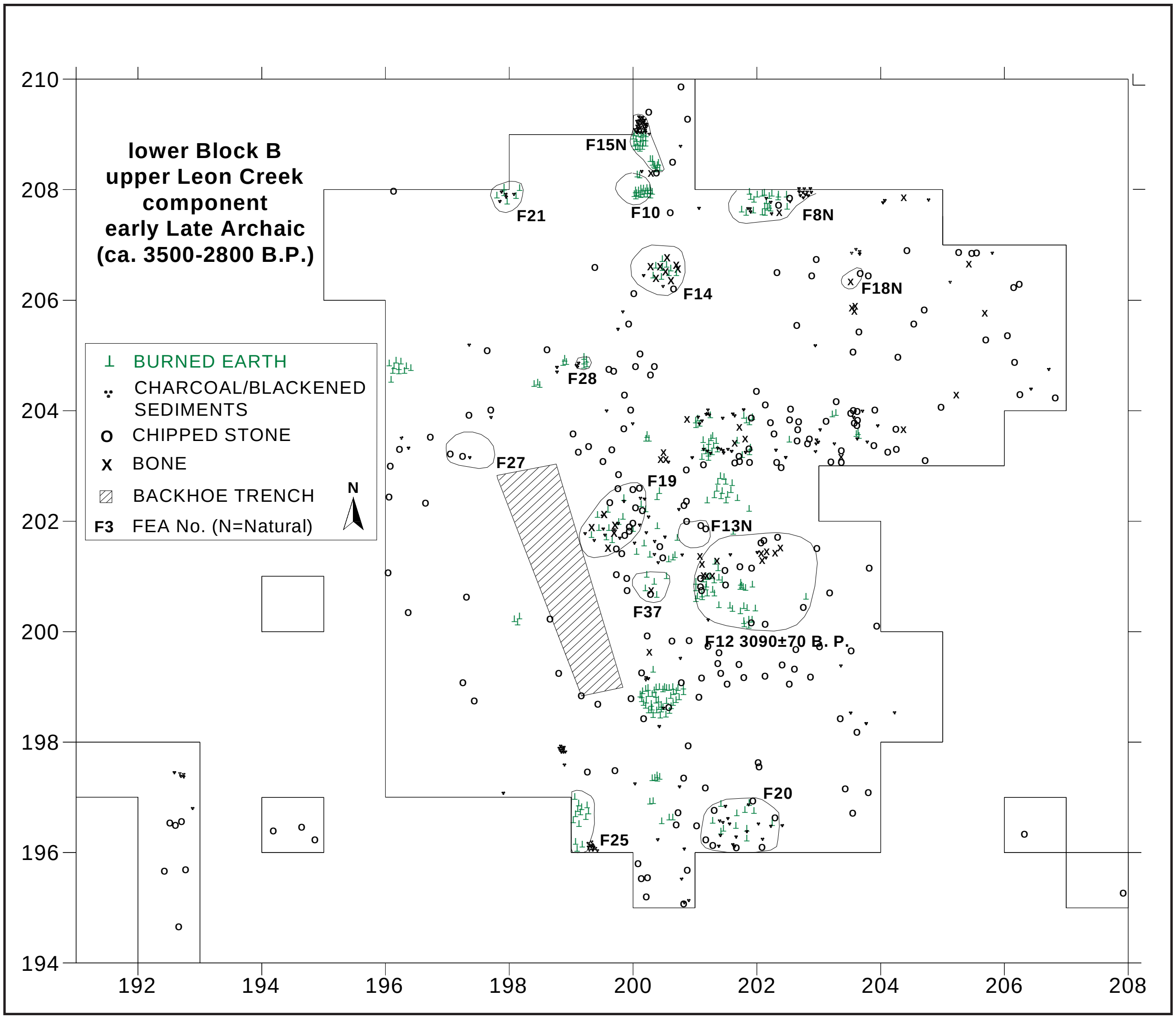


Figure 9.11. Planview showing the distribution of chipped stone and bone and features in the upper Leon Creek components (lower Block B, Late Archaic period, ca. 3500–2800 B.P.).

i.e., thin edge-modified flakes), 7 thick bifaces (more than 1 cm thick), 33 thin bifaces (1 cm or less thick), 10 projectile points, 3 nonflaked (i.e., ground, pecked, or incised) tools, 2,685 mussel shell umbos, 1,416 bone fragments, and 13,396 pieces of FCR. Preservation of recovered bone was comparatively good. Deer, beaver, canid, rabbit, several kinds of small rodents, frog, turtle, and snake remains were identified in the various occupation zones (Chapter 11).

Block D, located about 40 m east of Block B (Figure 4.1), was opened (16 m^2) to expose a lens of mussel shells and other artifacts discovered in the upper Leon Creek paleosol. Excavation units were laid out and shovel-skimmed down to the target zone. Exposed artifacts were collected, but the block was abandoned when Early Archaic deposits were found in the spillway trench (i.e., Block G) and excavations thereafter focused on that part of the site (Blocks H–U). Artifacts recovered from Block D included 47 pieces of chipped-stone debitage, 98 pieces of FCR, 205 mussel-shell umbos and 21 bone fragments. Neither tools nor cores were found during the minimal excavations (Table 9.1).

Middle Archaic Period, Lower Leon Creek and Upper Medina Components (ca. 4600–4100 B.P.), Upper and Lower Blocks A and U

We used a backhoe to remove about 2 m of alluvium overlying Middle Archaic deposits (Block A) along the terrace edge that had been identified during the testing phase (McCulloch et al. 2008). In the process, we discovered an archaeological deposit (upper Block A) about 40 cm above the previously identified artifact lens (lower Block A, Figure 9.12).

The upper deposit was a discrete occupation surface marked by a 3–m–diameter, thin lens of mussel shells (Feature 3) in sandy silt deposits that formed the CB horizon of the Leon Creek paleosol (Figure 9.13). Most of the shells were in horizontal angles of repose, indicating that the feature was well preserved. This component also had several well-preserved, basin-shaped, rockless hearths (e.g. Feature 9) about 40 cm in diameter and 15 cm deep (Figure 9.14). Wood charcoal from a tree-burn (Feature 74) that appeared to originate on/near the occupation surface yielded a ^{14}C age of 4135 ± 70 B.P. Upper Block A (37 m^2) produced 69 pieces of chipped-stone debitage, 1 projectile point fragment, 240 mussel-shell umbos, 92 bone fragments, and 194 pieces of FCR.

Figure 9.12. Upper Block A excavation area, yielded cultural materials–a few stone tools and features–representative of one of the site's lower Leon Creek components of the Middle Archaic period (ca. 4100 B.P.).

Lower Block A, about 2.6 m below surface and 0.5 m below upper Block A, is encased in the uppermost Medina pedocomplex (Figure 9.15). Wood charcoal from a tree-burn that appeared to originate on/near the occupation surface yielded a ^{14}C age of 4570 ± 70 B.P. A dense scatter of lithic debris, with most of the flakes in horizontal angles of repose,

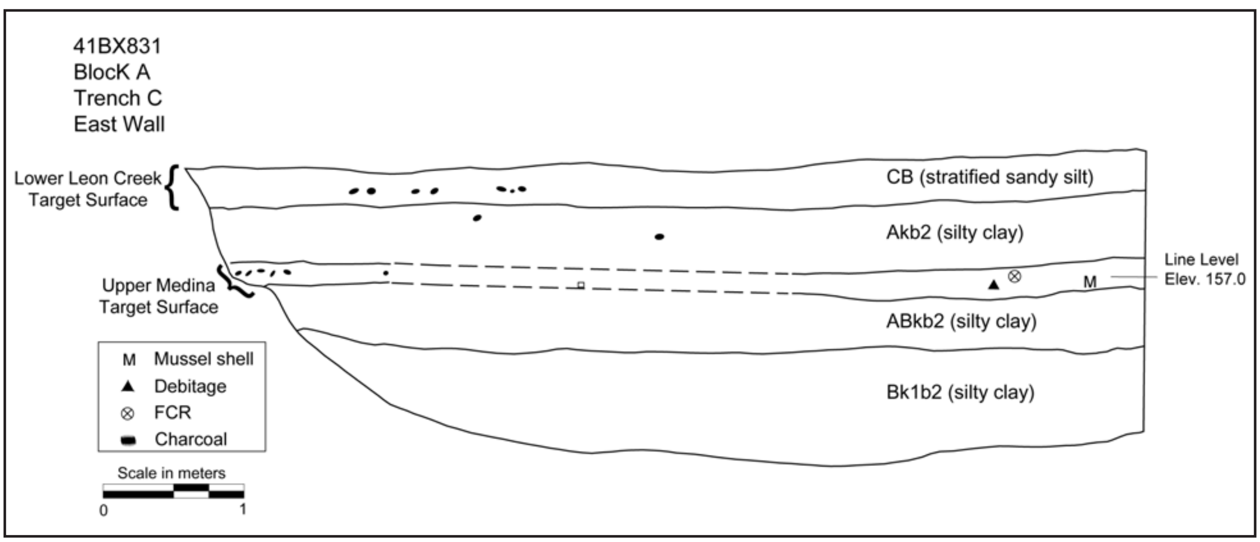


Figure 9.13. Profile of backhoe trench excavated through two Middle Archaic components exposed in Block A: (1) the lower Leon Creek paleosol and its artifact-bearing stratum (2BCb) in upper Block A; and (2) the upper Medina pedocomplex and its artifact-bearing (3BK1b) stratum in lower Block B.

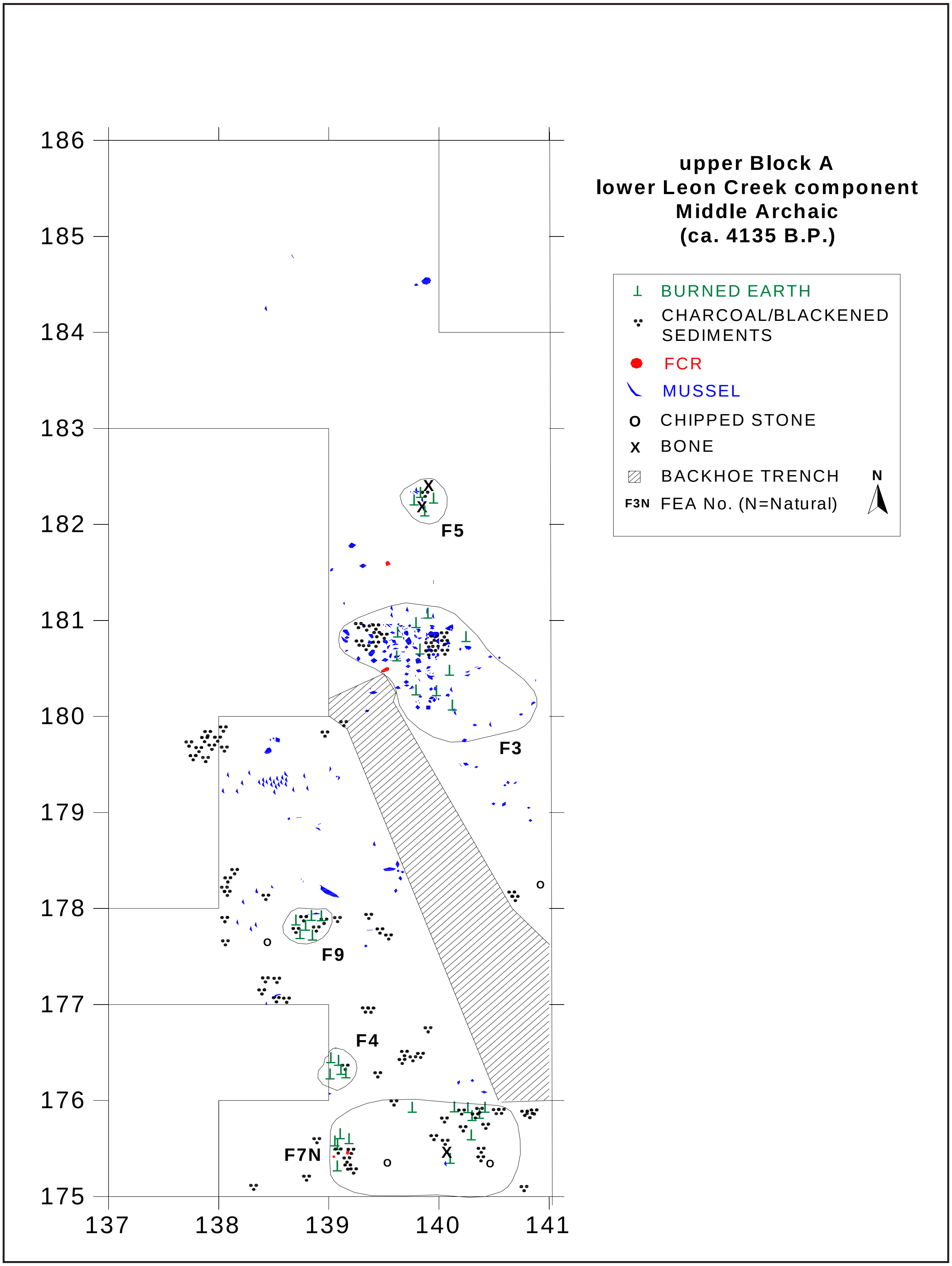


Figure 9.14. Planview showing the distribution of cultural materials and features in upper Block A, lower Leon Creek component (Middle Archaic period, ca. 4100 B.P.).

Figure 9.15. Lower Block A excavation area, yielded cultural materials–a few stone tools and features–representative of one of the site's upper Medina components of the Middle Archaic period (ca. 4600 B.P.).

and small, basin-shaped, rockless and rock-filled features demarcated this well-preserved surface (Figure 9.16). Lower Block A (18 m^2) produced 1315 pieces of chipped-stone debitage, 1 thin biface, 47 mussel-shell umbos, 144 bone fragments, and 104 pieces of FCR.

Most of the faunal remains from upper and lower Block A were from deer and rabbit-sized animals. A probable dart point barb, possibly from a Bell/Andice-like point, was the only chronologically diagnostic artifact recovered from lower Block A. We also collected fragments of two deeply corner-notched, Bell/Andice-like points (Figure 9.7 s) from exposures of the upper Medina pedocomplex near Block U, located about 100 m to the south–southeast of Block A (Figure 9.2).

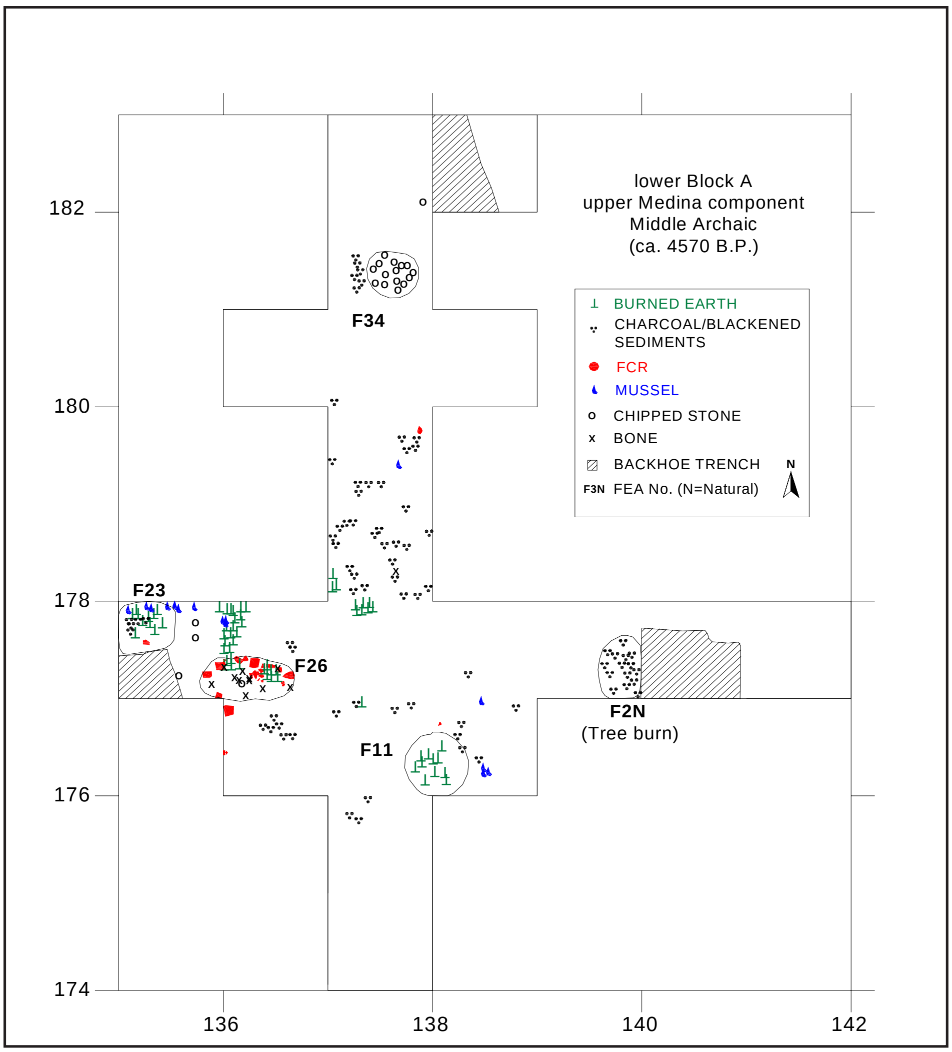


Figure 9.16. Planview showing the distribution of cultural materials and features in lower Block A, an upper Medina component (Middle Archaic period, ca. 4600 B.P.).

Block U (6 m^2) produced 249 pieces of chipped-stone debitage, 10 mussel-shell umbos, 33 bone fragments, and 302 pieces of FCR, as well as a Desmuke point and two Bell/Andice-like stems (Figures 9.17 and 9.18). A Uvalde point and a Travis-like specimen were also recovered from near-by exposures of the upper Medina pedocomplex, in the same vicinity as the aforementioned Bell/Andice points.

The Uvalde point, usually considered to be an Early Archaic form, differs markedly from other Middle Archaic chipped-stone artifacts in that it exhibits a distinctive weathering-related patina that likely developed from prolonged exposure to sunlight. Insofar as none of the other Middle Archaic tools had a similar patina, it is possible that this arguably Early Archaic point was collected and brought to the site by one of its Middle Archaic occupants. Of course, it is also possible that the Uvalde point was "mechanically" redeposited during excavation of the spillway trench.

Figure 9.17. Excavations by members of the Southern Texas Archaeological Association in Block U, yielded cultural materials—a few tools and a comparatively high density of fire-cracked rocks—representative of one of the site's upper Medina components of the Middle Archaic period (ca. 4500 B.P.).

In general, the site's Middle Archaic components appear to represent short term occupations. With the exception of chipped-stone debitage in lower Block A and FCR in Block U, artifact densities were comparatively low (Table 9.1). Features were few in number and spatially separated.

Late, Early Archaic Period, Lower Medina Components (ca. 6900–6400 B.P.), Blocks F and G

After completing Block A excavations, we dug a backhoe trench through the block's floor to search for older archaeological deposits. This trench exposed a hearth-like feature with FCR (No. 24, ca. 5 m below surface) in the 3Bk2b horizon of the Medina pedocomplex. Total decalcified carbon (i.e., soil carbon) from in the feature's fill yielded a ^{14}C age of 6450 ± 135 B.P. (Figure 9.19). The feature, along with a small area around it, designated Block F, yielded 10 pieces of chipped-stone debitage, 21 pieces of FCR, four mussel-shell umbos, and 5 small bone fragments (Table 9.1). To the extent that ages derived from soil carbon in the site's paleosols tend to be about 1000 years older than wood-charcoal ages, Feature 24 may date to as late as 5500 B.P. Insofar as two other carbon-stained cooking features at the site yielded overlapping ages from wood charcoal and soil carbon, however, it is quite possible the feature indeed dates to about 6450 B.P.

As we excavated the small area in Block F, we contemplated the looming monumental task of removing more than 5 m of overburden to expose a large area around what we believed to be the site's oldest and deepest component. It was then that Richard Beene, the site's namesake, reported his discovery of an extensive Early Archaic component buried 6.5 m below the surface and exposed on what at that time was the floor of the spillway trench. We abandoned plans to expand Block F and quickly geared up for large-scale excavations—Block G—

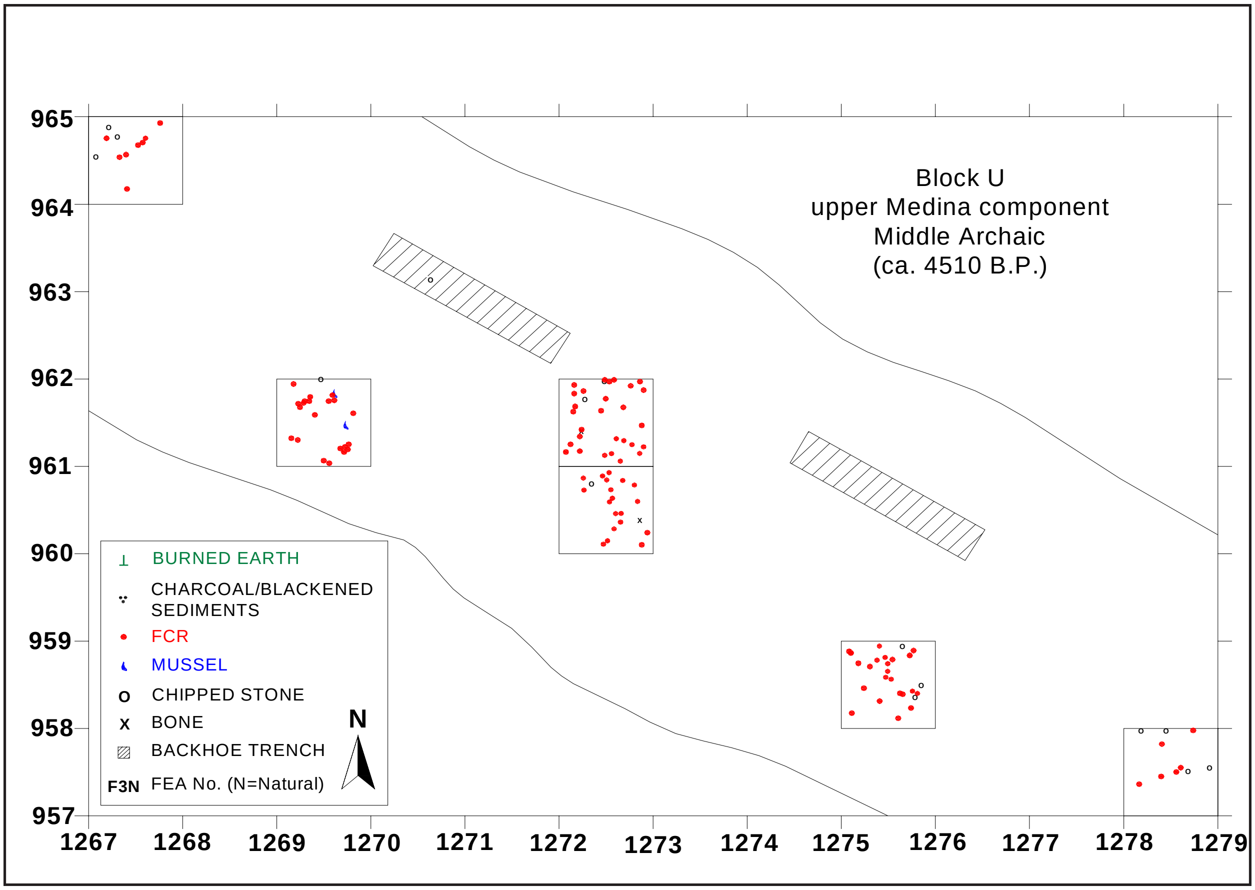


Figure 9.18. Planview showing the distribution of cultural materials in Block U, an upper Medina component (Middle Archaic period, ca. 4500 B.P.).

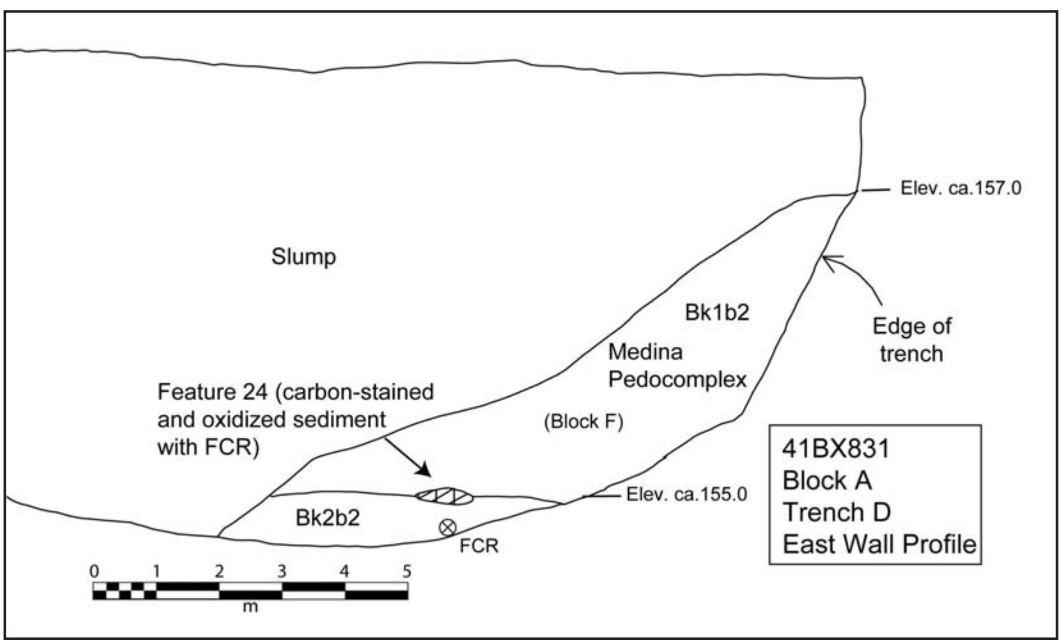


Figure 9.19. Profile of backhoe trench in Block A showing Feature 24 and Block F in the middle portion of the Medina pedocomplex.

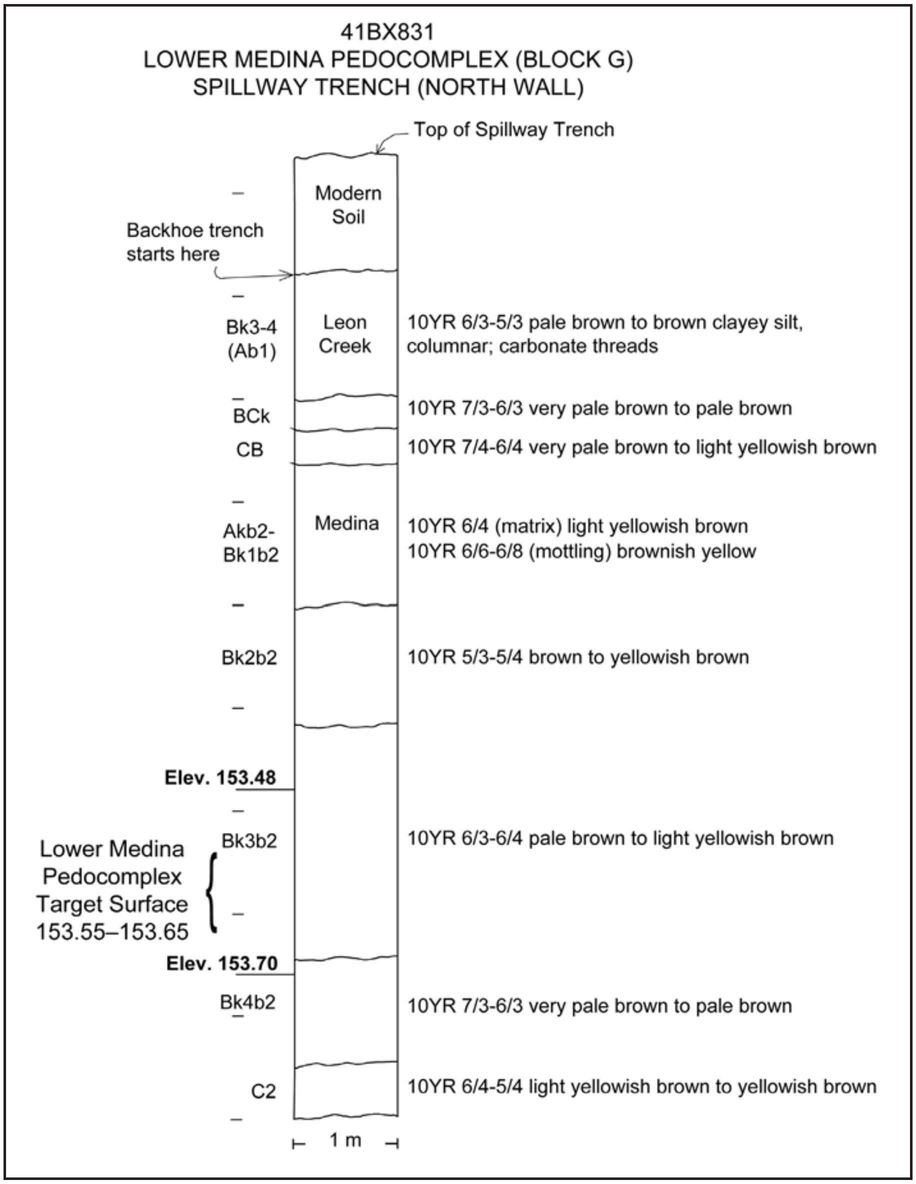
in the footprint of the dam (Figure 9.2). The water-screening system was upgraded, the crew size tripled, and some 230 m^2 of unusually well-preserved living surfaces in three quasi-contiguous subblocks were excavated in silty clay loam near the base of the Medina pedocomplex (Figure 9.20).

As we geared up for work, we submitted soil carbon samples for rapid turnaround ^{14}C assays from four carbon-stained FCR features exposed in the Block G area. Age estimates received a week later ranged from ca. 7900 to 6400 B.P. and averaged 7200 B.P. (Table 4.3). Subsequently, we submitted four wood charcoal samples from three cooking-pit features and a tree-burn for AMS dating. Elevations of these three features and the tree-burn varied only by about 30 cm over an area 100 x 100 m in size. Radiocarbon age estimates were as follows: (1) Feature No. 76 (tree-burn), 6985 ± 65 B.P.; (2) Feature No. 30, 6900 ± 70 B.P.; (3) Feature No. 44, 6930 ± 65 B.P.; and (4) Feature No. 43, 7000 ± 70 B.P. The "pooled average" is 6954 ± 34 B.P. (Figure 9.3; Table 4.2).

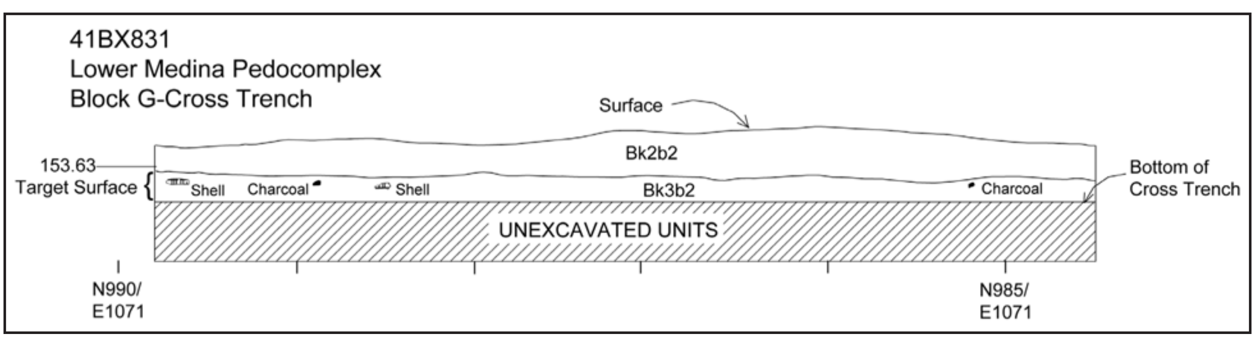
Almost all the mussel shells, lithic tools, and other artifacts in Block G were found in horizontal angles of repose, indicating the component had not been adversely impacted by high-energy floods or subjected to significant pedoturbation. Moreover, rodent burrows, root casts, and other forms of bioturbation were limited (Chapter 4). Most of the cultural material appeared to be within the depositional unit that composed the Bk3b2 horizon of the Medina pedocomplex (Figure 9.21a–b; Chapter 3). We estimated that as much as 90 percent of the cultural material was confined to a lens no more than 15 cm thick (Figures 9.22–9.25).

The pan scrapers, especially those with teeth, damaged this component to some extent (Chapter 4), but most of the features were in good condition. Two types of small cooking features were especial-

Figure 9.20. Excavations underway in Block G, which yielded cultural materials–numerous dart points, adzes, drills, other stone tools, features–representative of one of the site's lower Medina components of the late, Early Archaic (ca. 6900 B.P.).



a



b

Figure 9.21. Profiles of lower Medina pedocomplex and its artifact-bearing stratum in Block G, which encompassed the lower Medina Creek component of the late, Early Archaic: (a) spillway trench wall adjacent to Block G; and (b) cross-trench through Block Ga.

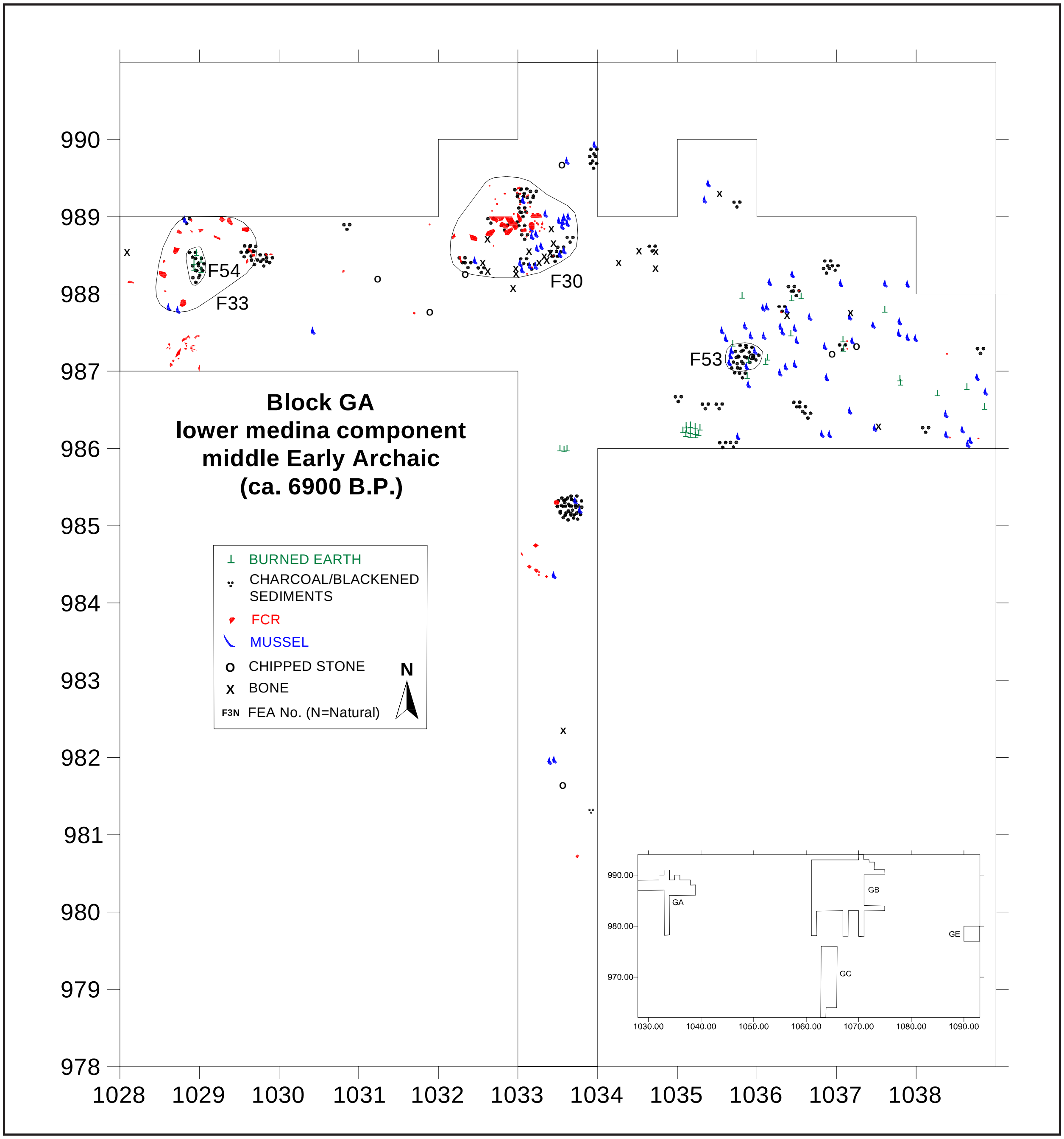


Figure 9.22. Planview of Block Ga showing the distribution of cultural materials and features in the lower Medina component (Block G, late, Early Archaic period, ca. 6900 B.P.).

ly common in this component: (1) those with an FCR lens in shallow (ca. 10–15 cm deep) circular to oval, basin-shaped pits (ca. 40–60 cm) with oxidized bottoms and sides; and (2) those in a rockless, basin-shaped pit of similar size with oxidized bottoms and sides, typically filled with carbon-stained sediments. Other feature types included mussel-shell concentrations up to several meters in diameter, FCR concentrations about 1 m in diameter (probable earth ovens), oxidized areas, and "sheet middens" with bone, mussel shell, chipped-stone debitage and tools, fire-cracked sandstone, and carbon-stained sediments (Chapter 13).

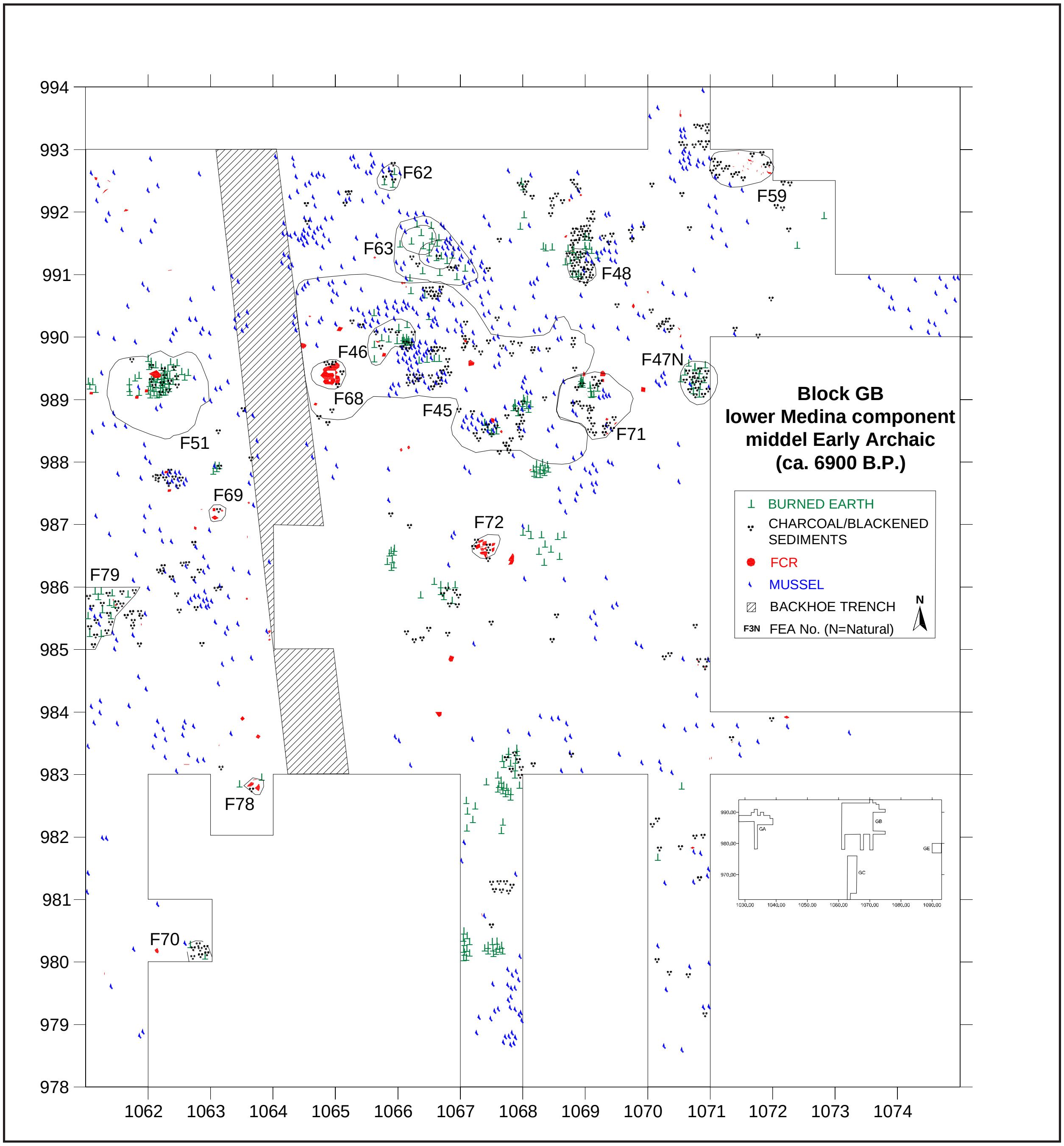


Figure 9.23. Planview of Block Gb showing the distribution of FCR and mussel shells and features in the lower Medina component (Block G, late, Early Archaic period, ca. 6900 B.P.).

Cultural materials recovered from Block G included 10,638 pieces of chipped-stone debitage, 1 hammerstone, 19 cores, 14 heavy-duty tools (i.e., thick edge-modified flakes and cobble tools), 32 light-duty tools (i.e., thin edge-modified flakes), 11 thick bifaces (more than 1 cm thick; Figure 9.7o), 15 thin bifaces (1 cm or less thick), 12 projectile points (Figure 9.7 j), 1 ground-stone tool, 2,038 mussel-shell umbos, 4,850 bone fragments, and only 875 pieces of FCR, most of which was less than 10 cm in size.

Projectile points dominated the formal tool assemblage. With one exception, all the points were

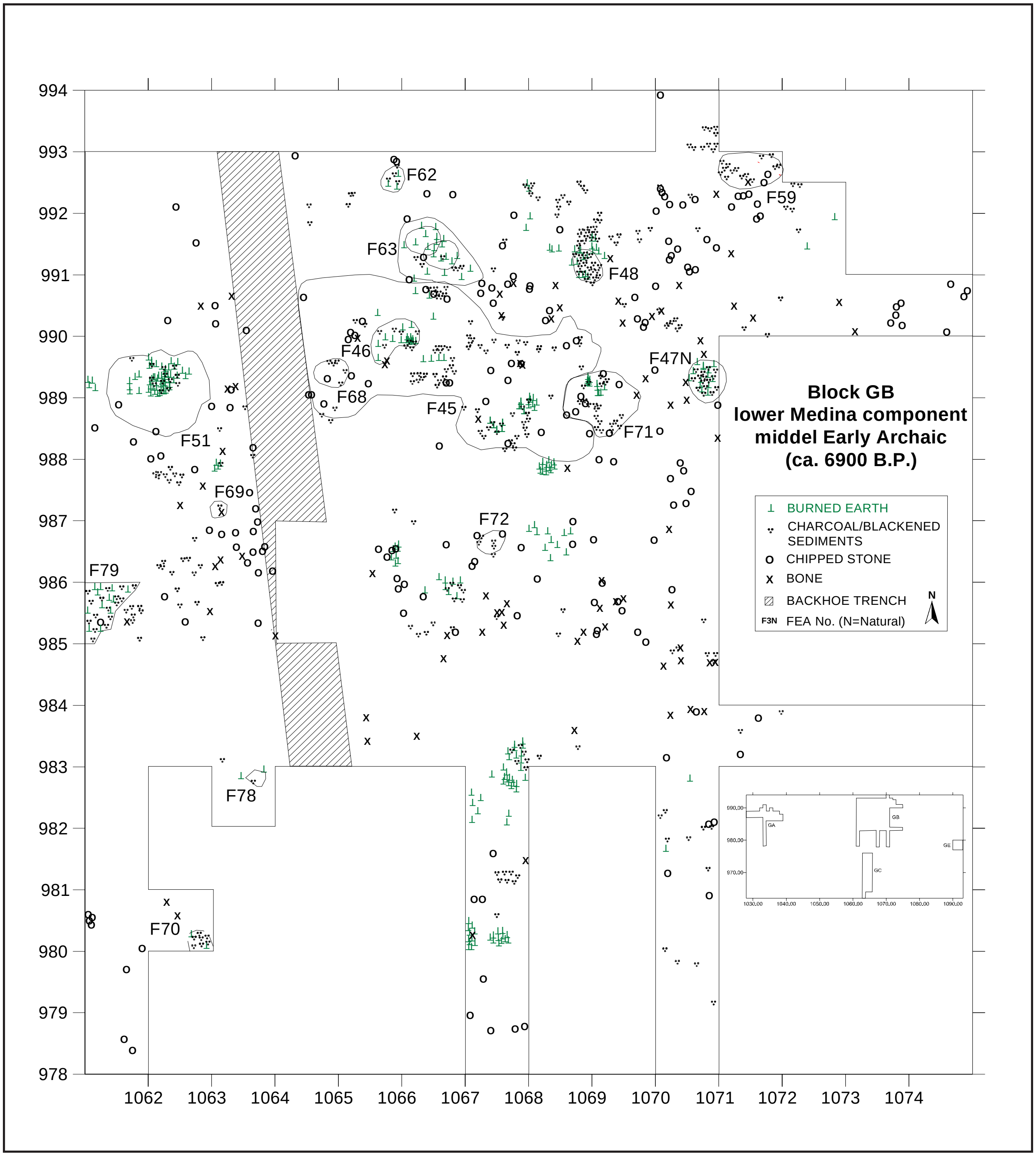


Figure 9.24. Planview of Block Gb showing the distribution of chipped stone and bone and features in the lower Medina component (Block G, late, Early Archaic period, ca. 6900 B.P.).

stemmed/indented-base types, similar to Bandy, Baker, Martindale, and Uvalde (Figure 9.7 p–r). The exception was a lanceolate point morphologically similar to Angostura, but technologically similar to the stemmed/indented base types (Chapter 10). This suggests that the lanceolate-shaped point may be a refurbished stemmed/indented-base form, possibly reworked after a barb or shoulder was broken. Most of the projectile points were fairly complete, but many of them were substantially reworked. Other

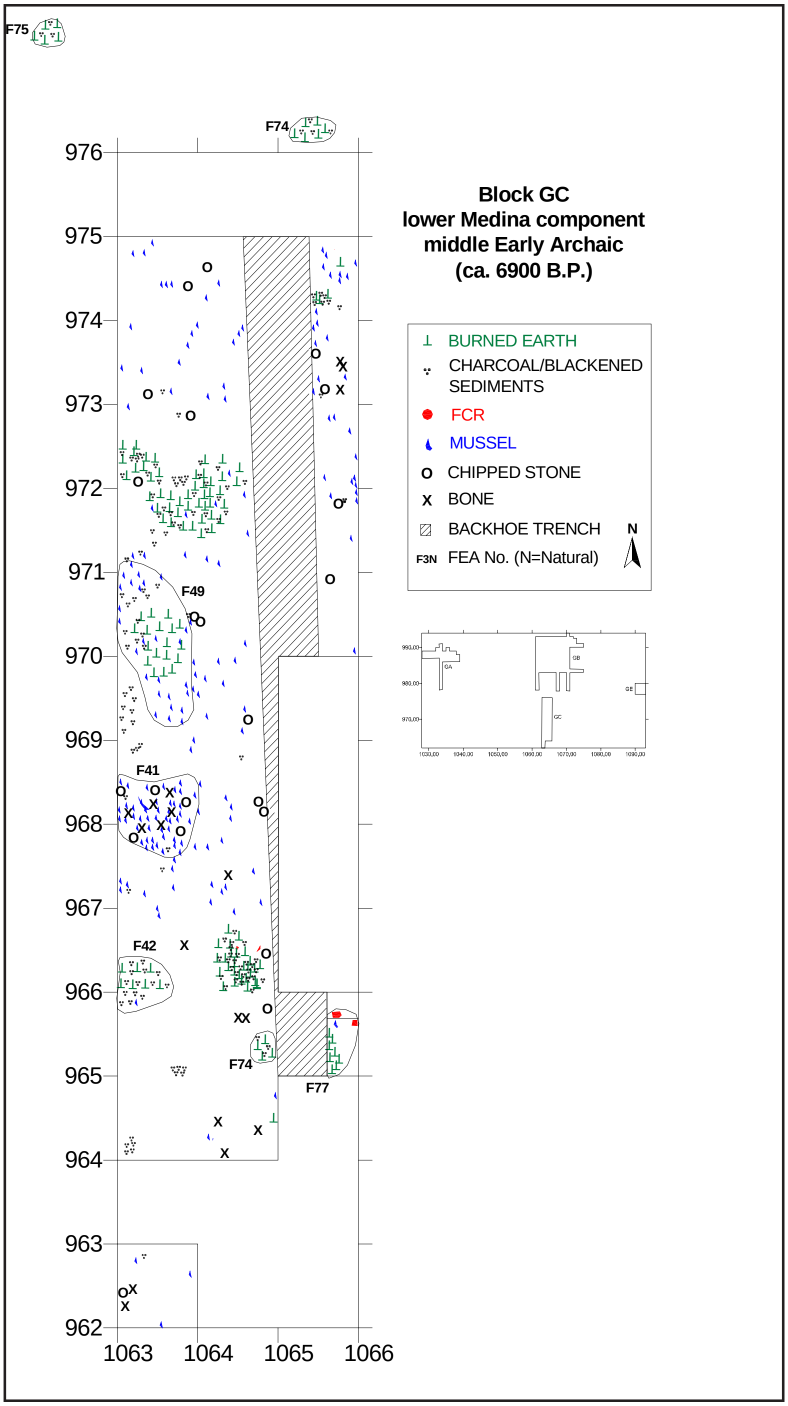


Figure 9.25. Planview of Block Gc showing the distribution of cultural materials and features in the lower Medina component (Block G, late, Early Archaic period, ca. 6900 B.P.).

artifacts included preforms, thin bifaces, a drill fragment, edge-modified flakes, small burin blades, and cores (Figure 9.7 k–n).

Faunal remains were more numerous, varied, and better preserved than in the other components. The recovered skeletal elements included those from deer, pronghorn, canid, porcupine, rabbit/hare, rat, gopher, squirrel, other small rodents, fish, turtles, and snakes. By volume, deer-sized animals dominate the late, Early Archaic faunal assemblage (Chapter 11).

Some of the features overlapped horizontally, and in a few cases "sheet middens" capped small cooking features. This indicates multiple occupations of what was essentially a single surface. Several lines of evidence, however, suggest that this surface may have been exposed for a number of years, perhaps no more than a generation, before it was buried by alluvium: (1) AMS ^{14}C ages on features from across the site are virtually identical; (2) effects of bioturbation are minimal, as evidenced by the presence of so many remarkably well-preserved features and the fact that almost all of the cultural materials are confined to a 15 cm thick lens; and (3) sediments encasing the cultural remains are near the base Medina pedocomplex, where deposition would have been comparatively rapid.

Middle, Early Archaic Period, Elm Creek Components (ca. 8500–7500 B.P.), Blocks O, P, I, K, and M

In marked contrast to the site's other pedostratigraphic units, the Elm Creek paleosol, as exposed in the spillway trench, did not contain sizable areas with moderate to high densities of artifacts interspersed with small cooking features. Pan scrapers exposed seemingly isolated FCR features, most of which were earth ovens about a meter in diameter (Chapter 13), at various places in the spillway trench. A few widely scattered tools, including an adze, a bola-like stone, a thin sandstone grinding slab, and two chipped-stone axes, were recovered from exposures of the Elm Creek paleosol, which varied from 2 m to less than a meter in thickness. The overall nature and distribution of cultural materials indicate that the spillway portion of the site was comparatively underoccupied 8500–7500 years ago. During this long interval, rates of deposition were comparatively rapid, although there were periods of stability of sufficient duration for some soil development (Chapter 3).

Three FCR features exposed in the spillway trench were salvage-excavated (Blocks O, K, and M). In addition, a small "block" (Block P, 4 m^2, 3.1 m^3) was excavated through the Elm Creek paleosol (ca. 1.5 m thick); it yielded a low density of debitage, FCR, mussel shells, and edge-modified flakes (Figure 9.2). A larger block (Block I, 15 m^2), which also had a low artifact density, was opened and partially excavated in the upper part of this pedocomplex (Figure 9.26; Table 9.1). Heavy rainfall and subsequent flooding, along with heavy machinery inadvertently slipping and sliding through the block, resulted in its premature abandonment (Figure 9.27).

Feature 108 (Block O) was exposed in the wall of the spillway trench in a setting where the Elm Creek paleosol was less than a meter thick. The feature, an earth oven, was basin shaped (ca. 0.9 x 0.4 m) and filled with carbon-stained sediment; it contained a few pieces of FCR and mussel shells. The bola-like stone noted above and a core fragment were recovered from the trench wall within a few meters from the feature. Wood charcoal from the feature yielded an AMS ^{14}C age of 7645 ± 70 B.P.

A second earth oven, Feature 64 (Block K), was exposed by pan scrapers and salvaged from what appeared to be the C horizon of the Elm Creek paleosol. Its sandstone heating element (ca. 1 m diameter) was flat bottomed and underlain by carbon-stained sediment, suggesting it was built on the surface or perhaps in a sizable flat-bottomed pit. Surrounding the feature was a scatter of chipped-stone debitage, mussel shell, pieces of FCR, and an adze. Small pieces of wood charcoal from the feature fill yielded a ^{14}C age of 8080 ± 130 B.P.

A third earth-oven feature (No. 80, Block M), similar in structure to Feature 64, yielded ^{14}C ages of 7910 ±60 B.P. and 7740 ± 50 B.P. from small pieces of wood charcoal. It was discovered in the midst of working pan scrapers near the terrace scarp where the combined thickness of the Elm Creek and Perez paleosols was less than a meter. Its precise pedostratigraphic position could not be determined, insofar as it was discovered after the pan scrapers had removed the overlying sediment. The resulting ^{14}C ages, however, indicate that the feature was constructed when the Elm Creek paleosol was developing.

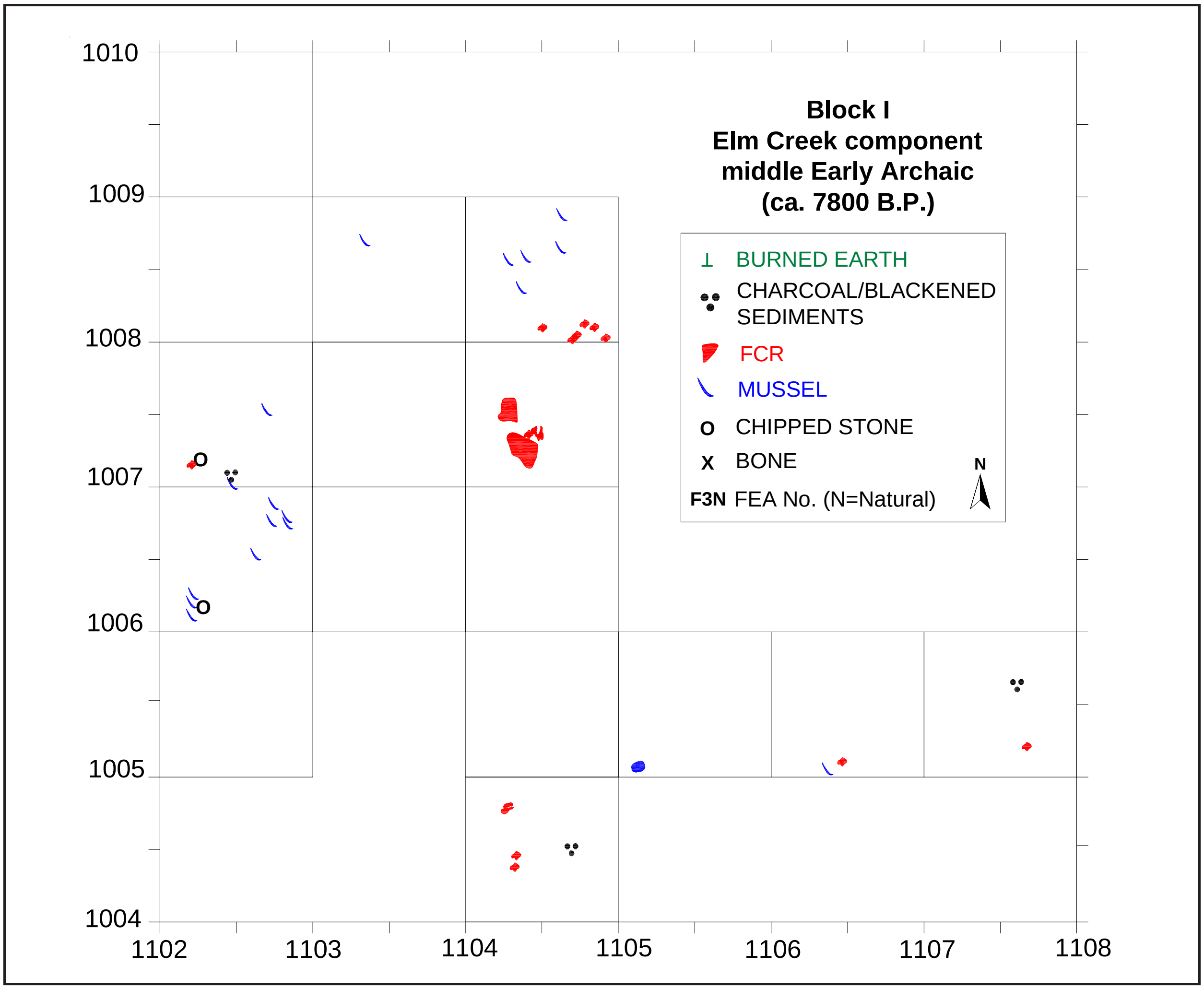


Figure 9.26. Planview of the sparse distribution of mapped artifacts in Block I where a late, Early Archaic component was exposed but only partially excavated.

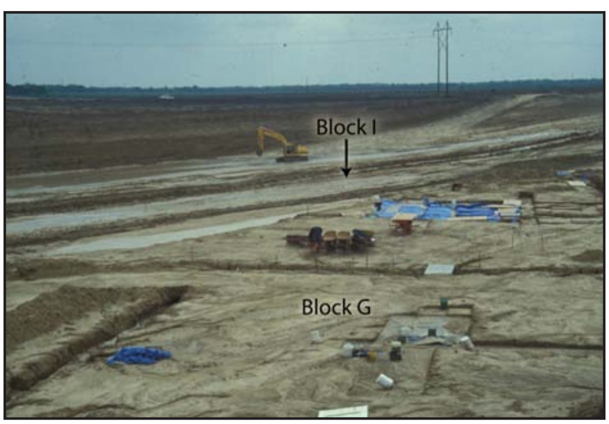


Figure 9.27. The Block I area (Elm Creek component, middle, Early Archaic period, ca. 7800 B.P.) after it was abandoned following heavy rain and flooding.

Early, Early Archaic Period, Upper Perez Components (ca. 8800–8600 B.P.), Blocks H, T, N, and Q

As we completed our excavation of the extensive late, Early Archaic occupation(s), we dug a series of backhoe trenches 2.5 m below Block G to search for older archaeological deposits in advance of the ever-cutting pan scrapers. In the bottom of one of those trenches (ca. 9 m below the modern terrace surface), we found a lens of fire-cracked sandstone, mussel shells, and chipped stone, mixed with small stream-worn pebbles (ca. 0.5–4 cm diameter) in a fine sandy–silt matrix. Overlying sediments were mechanically removed in this part of the site and

Block H was laid out over a high-density area (Figure 9.28). Subsequent trenching and observations of pan-scraper exposures revealed that the artifact-rich zone extended over an area larger than 100 x 100 m.

The upper Perez components of the early, Early Archaic period were not as well preserved as the younger parts of the site (Figure 9.2). This was especially the case in Block H, where all of the FCR features contained a substantial quantity of stream-worn pebbles and the entire area appeared to be flood scoured. Instead of well-preserved features, we found lag concentrations of chipped-stone artifacts, FCR, mussel shells, and stream-worn pebbles up to about 4 cm in diameter that had accumulated around larger pieces of FCR. In some places, artifacts were found "resting" on their edges (vertical angles of repose), often imbricated in rills and potholes eroded into the silty clay sediments. Some concentrations of large FCR, however, appeared to be the remains of rock heating elements in earth ovens a meter or so in diameter (Chapter 13).

In the Block H area, cultural materials were encased in two paleosols: (1) in the well-stratified, lowermost portion of the Cb3 horizon of the Elm Creek paleosol, which included pebble-rich lenses (i.e., stone lines); and (2) in the immediately underlying Bkb4 horizon of the Perez paleosol (Figure 9.29). In two other blocks, T and N (Figure 9.2), cultural materials were confined to the Bkssb4 of the Perez paleosol.

Block Q (3 m^2) was established over an FCR concentration with stream-worn pebbles and a few pieces of lithic debitage (Feature 89) that appeared to be remains of a flood-scoured feature, possibly an earth oven. Feature 89 was exposed by pan scrapers in what appeared to be the C horizon of the Perez paleosol (ca. 14 m below surface, 147.7 m asl). In this area of the site, however, the Perez paleosol was unusually thin (Figure 9.2). Feature 89 is the deepest cultural feature found at the site. While it is possible that it is also the oldest cultural feature excavated at the Richard Beene site, its precise pedostratigraphic position could not be determined because the overlying sediments had been stripped away. Moreover, the presence of stream-worn pebbles within the FCR concentration indicate it was a flood-scoured, "lagged" feature. In any case, this feature may not be as old as its depth suggests, given Feature 80 in Block M, which was at 148.25 m asl, and dated only to ca. 7700 B.P.

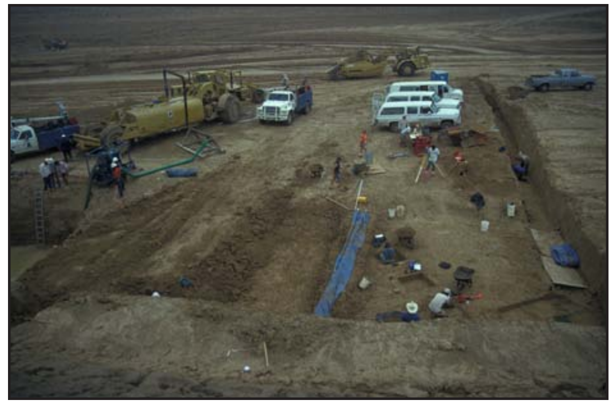


Figure 9.28. Gearing up for excavations in Block H, which yielded cultural materials–stone tools, including projectile points, adzes, a drill, and an abundance of fire-cracked rocks–representative one of the site's upper Perez components of the early, Early Archaic period (ca. 8800–8600 B.P.).

Given an apparent absence of wood charcoal in the initially exposed areas of Block H, sediment samples were submitted for rapid turnaround ^{14}C age determinations on soil-carbon. The results came back within a week (9750 ± 130 B.P., 9780 ± 120 B.P., and 9800 ± 140 B.P.) and indicated that the well-stratified Elm Creek C horizon and the underlying Perez Bk horizon were essentially the same age (Chapter 4). Subsequently, a series of ^{14}C ages obtained from soil-carbon from the upper part of the Perez Bk horizon in Blocks T and N showed that these deposits were roughly the same age as those in Block H. Ages from Block T ranged from 9750 ± 130 B.P. for the truncated Bk horizon of the Perez paleosol, to 10,780 ± 140 B.P. for the lower portion of the Bk horizon, 1.3 m below the truncated surface. Soil-carbon ages from the Perez Bk horizon Block N were 9670 ± 120 B.P. and 10,780 B.P. An age of 9170 ± 130 B.P. was obtained for the overlying Bk horizon of the Elm Creek paleosol in Block N (Chapter 4).

Three radiocarbon ages were also obtained from wood charcoal in the artifact-bearing strata in the Bk horizon of the Perez paleosol. A small sample

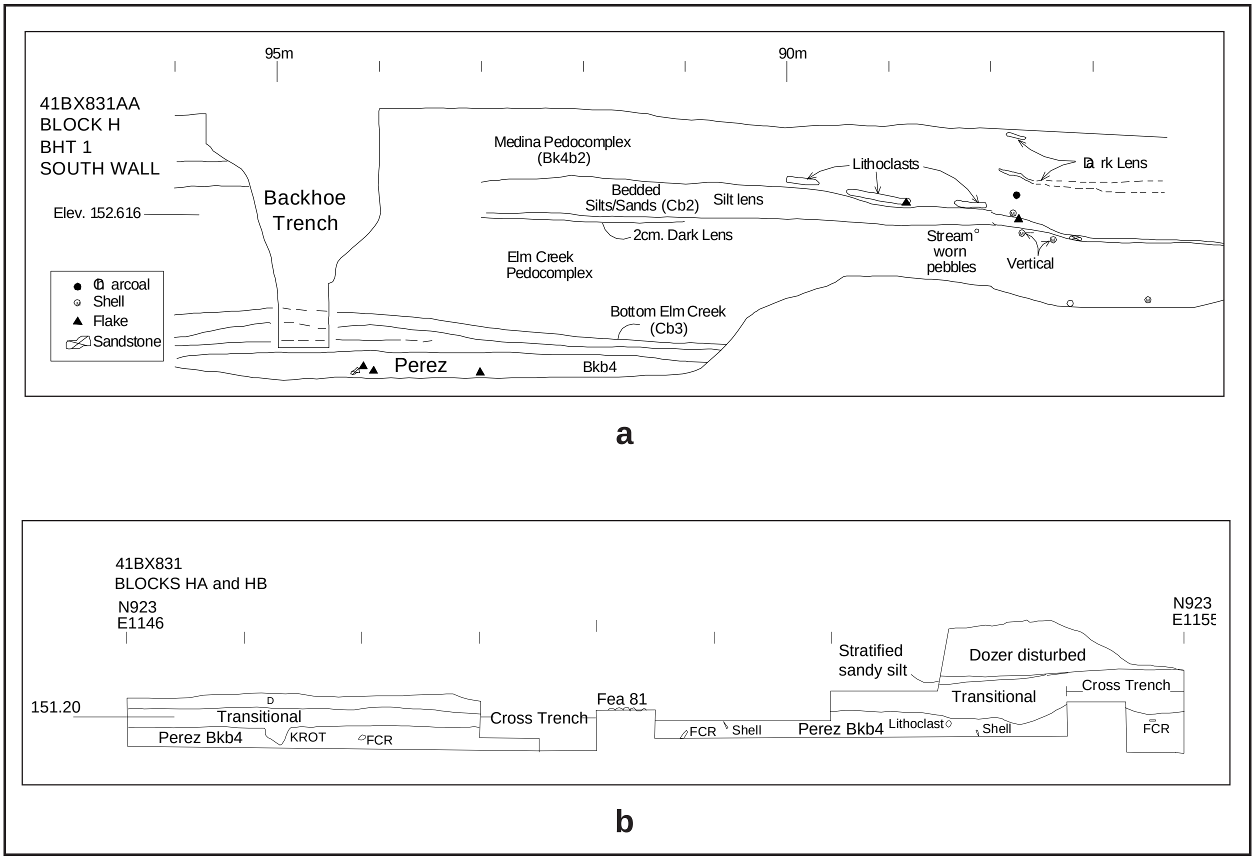


Figure 9.29. Block H profiles showing: (a) artifact-bearing deposits in C horizon of the Elm Creek paleosol and underlying Bk horizon of the Perez paleosol, which encompass an upper Perez component of the early, Early Archaic; and (b) cross-trench through Block H.

recovered in Block T, about 40–50 cm below the truncated Bk horizon, from a sparse, sheet midden deposit (Feature 108) of FCR, mussel shells, chipped stone, bone fragments, and charcoal flecks, yielded an AMS ^{14}C age of 8805 ± 75 B.P. A second small charcoal sample was recovered from an FCR feature (No. 106) in Block T; it yielded an age of 8640 ± 60 B.P. The third sample, a charred nut hull from the Perez Bk horizon in Block N, yield an age estimate of 8810 ± 60. Judging from the relationship between soil–carbon and wood charcoal ages in Blocks T and N, it seems likely that cultural materials from Block H are approximately 8,700 radiocarbon years old as well.

About 170 m^2 were excavated in Block H. Many of the artifacts were distributed through 10 to 30 cm of stratified sandy silt alluvium overlying the truncated Perez paleosol. Some of the items, especially the larger items, may have retained meaningful elements of their original horizontal spatial relationships (Figures 9.30–9.34). In any case, the cultural materials included pieces of FCR up to 15 cm in maximum dimension and thus several times larger than any of the stream-worn pebbles and less likely to have been as horizontally displaced as the pebbles. Moreover, the edges of the FCR were still quite rough and sharp (i.e., not steam-worn) and flakes of chipped stone retained their razor-like edges. This suggests that the cultural material in general was not transported very far as part of the flood's bed load.

Recovered materials from Block H include: 6,858 pieces of chipped-stone debitage, 2 hammerstones, 82 cores (Figure 9.7 t), 111 heavy-duty tools (i.e., thick edge-modified flakes and cobble tools), 114 light-duty tools, 15 thick bifaces, 10 thin bifaces (1 cm or less thick), 12 projectile points, 1 nonflaked (i.e., ground, pecked, or incised) tool, 2,731

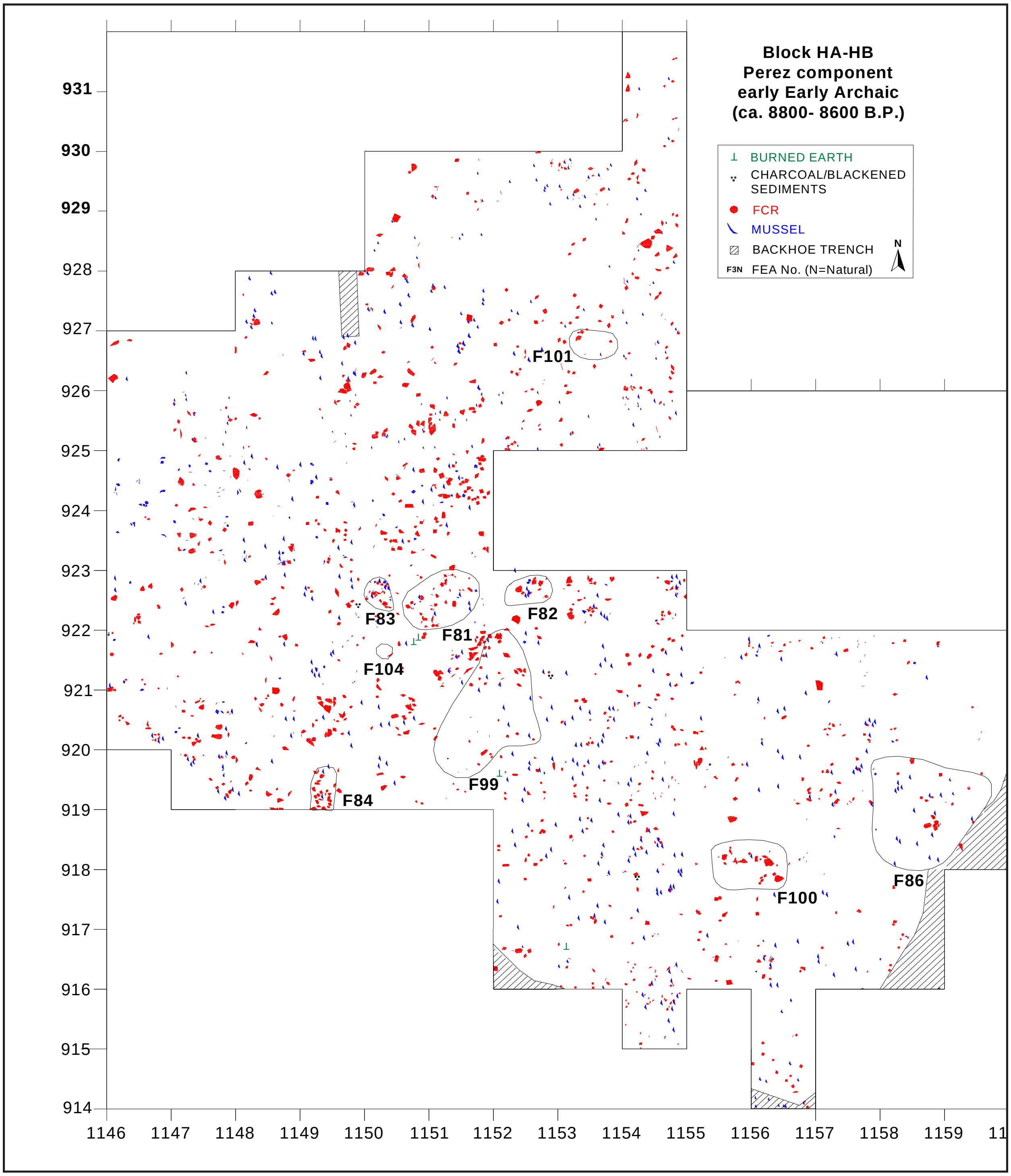


Figure 9.30. Planview of Block Ha/Hb showing the distribution of FCR and mussel shells and cultural features (early, Early Archaic period, ca. 8800–8600 B.P.).

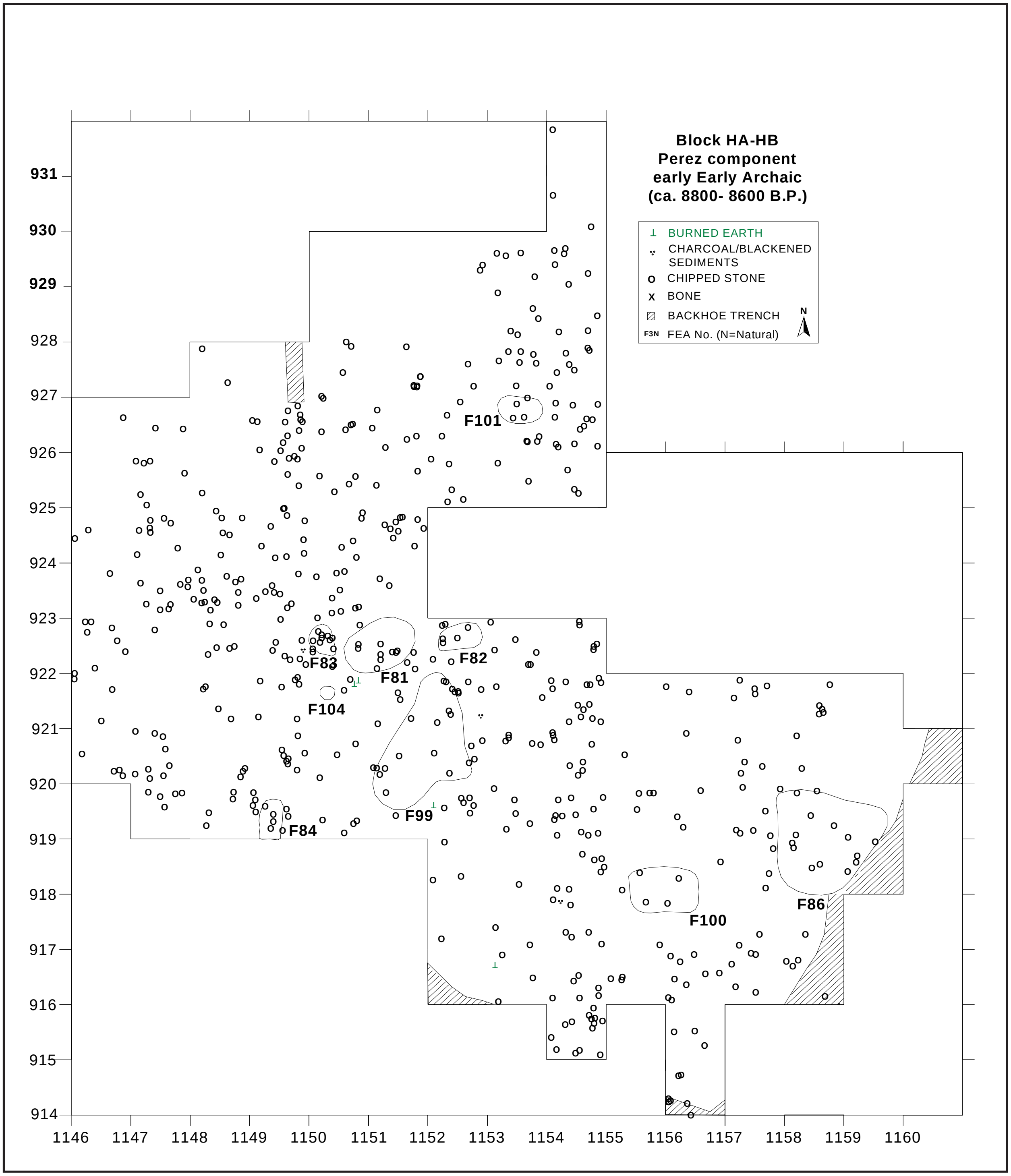


Figure 9.31. Planview of Block Ha/Hb showing the distribution of chipped stone and bone and cultural features (early, Early Archaic period, ca. 8800–8600 B.P.).

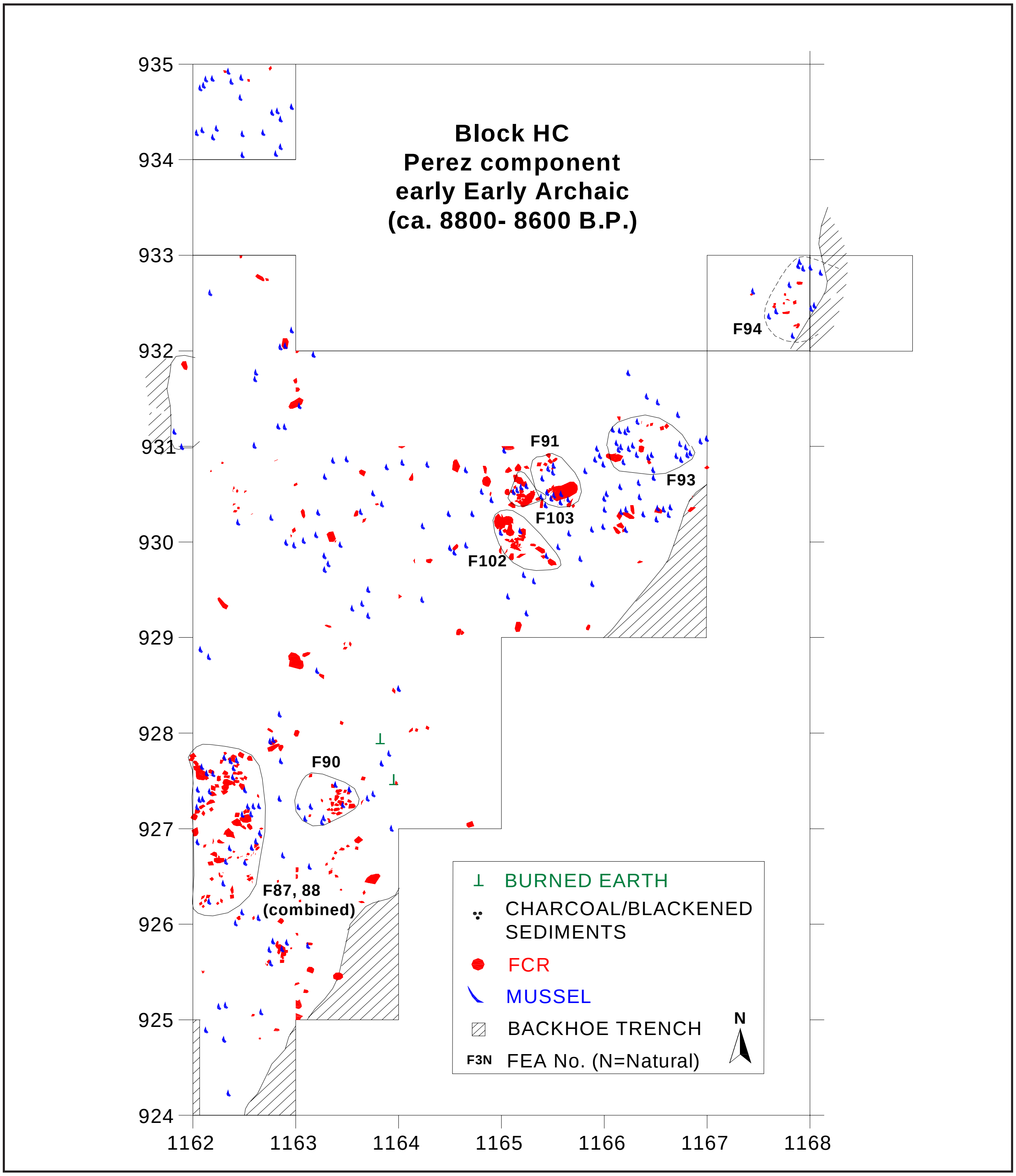


Figure 9.32. Planview of Block Hc showing the distribution of FCR and mussel shells and cultural features (early, Early Archaic period, ca. 8800–8600 B.P.).

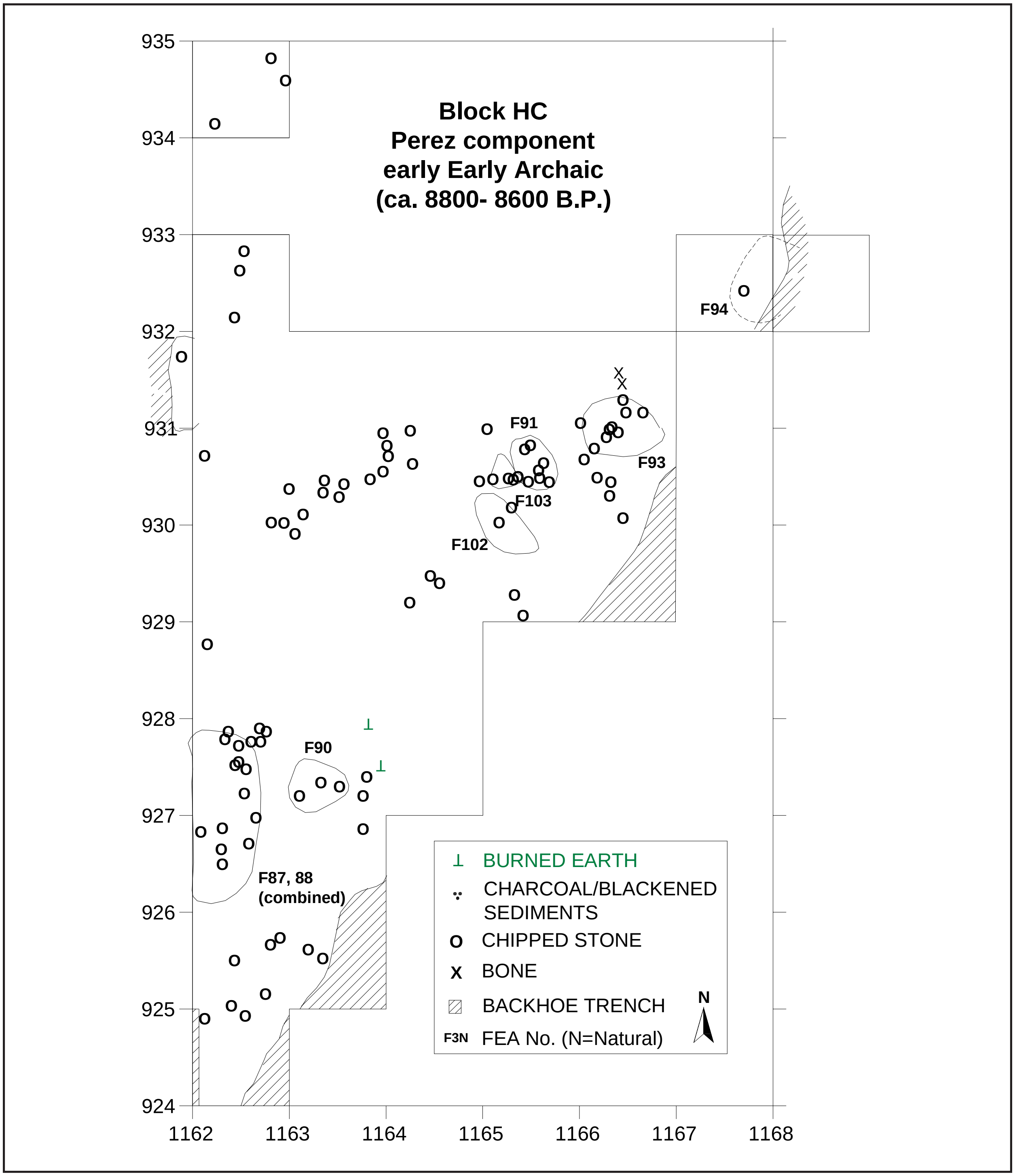


Figure 9.33. Planview of Block Hc showing the distribution of chipped stone and bone and cultural features (early, Early Archaic period, ca. 8800–8600 B.P.).

mussel-shell umbos, 347 bone fragments, and 9,366 pieces of FCR. All but one of the relatively complete projectile points are Angostura types (Figure 9.7 h–i). The aberrant specimen is a stemmed/indented-base point (Figure 9.7 g) morphologically similar to points from the late, Early Archaic component.

Two of the Angostura points were reworked into drills. Adzes–bifacial Clear Fork tools (Figure 9.7 f)–were as common as points, and gravers (Figure 9.7 e) were almost as common. Other artifacts in this diverse assemblage included cobble cores (Figure 9.7 a), blades (Figure 9.7 c), burin spalls (Figure 9.7 b), and burin cores (Figure 9.7 d). Artifact types present in this assemblage, but either absent or virtually absent in the younger assemblages, include large burin spalls and blades; beaked, graver-like tools; and well–made scrapers (Chapter 10). Faunal remains other than mussel shells were scant. The few recovered bone fragments were small and rounded. Here too, deer and rabbit-sized animals were comparatively well represented.

Block T (ca. 52 m^2) sampled a lens of artifacts exposed in the wall of the spillway trench about 0.5–1.0 below the truncated upper boundary of the Perez paleosol (Figures 9.2, 9.34, and 9.35). Compared to Block H, a meter or so higher in elevation, most of the artifacts from Block T were in horizontal angles of repose; stream-worn pebbles were smaller and fewer in number. Moreover, this block produced two FCR features, including a well-preserved ring of FCR, possibly around a shallow basin, as well as a sheet midden composed of FCR, flakes, mussel shell, and bone fragments (Chapter 13) (Figure 9.36). Compared to Block H, faunal remains in Block T, including deer and rabbit-sized mammals, were more numerous, larger in size, and not as well-rounded (Figure 9.37).

Cultural materials from Block T include 1,437 pieces of chipped-stone debitage, 2 hammerstones, 7 cores, 15 heavy-duty tools, 5 light-duty tools, a bifacial Clear Fork tool, a drill made from a reworked Angostura point, 3 other Angostura points and a Plainview-like specimen, 206 mussel-shell umbos, 354 bone fragments, and 3,710 pieces of FCR, including 124 made of caliche. A few pieces

Figure 9.34. Excavations by members of the Southern Texas Archaeological Association underway in Block T, which yielded cultural materials–several stone tools, including projectile points and an abundance of fire-cracked rocks–representative of the early, Early Archaic period (ca. 8800–8600 B.P.) and herein designated as the one of the site's upper Perez components.

of caliche were recovered from Block H as well. The caliche raw material probably came from the Bkm (i.e., petrocalcic) horizon of the Somerset paleosol. The presence of caliche FCR suggests that the Somerset's petrocalcic horizon was exposed somewhere in the immediate vicinity when the site was occupied 8600–8800 years ago. Block T's faunal remains included deer and rabbit-sized mammals, which were more numerous, larger in size, and not as well-rounded, compared with those from Blocks H and N (Chapter 11).

Discovery of the Plainview-like point base hinted that portions of Block T might contain a pre–Angostura component. However, the Block T assemblage compared well to Block H, in that it too contained Angostura points, including one made into a drill, a bifacial Clear Fork tool, and burin spalls. And, as noted, artifact-bearing sediments in Blocks H and T yielded overlapping ^{14}C ages. Insofar as Block T has better preservation of faunal remains and intact features, it may not have been as subjected to the kind of flood scouring that occurred when the Perez paleosol was truncated.

Block N (ca. 19 m^2), located about 75 m north of H and T, also sampled the upper part of the Perez Bk horizon, but at an elevation of about 149 m asl,

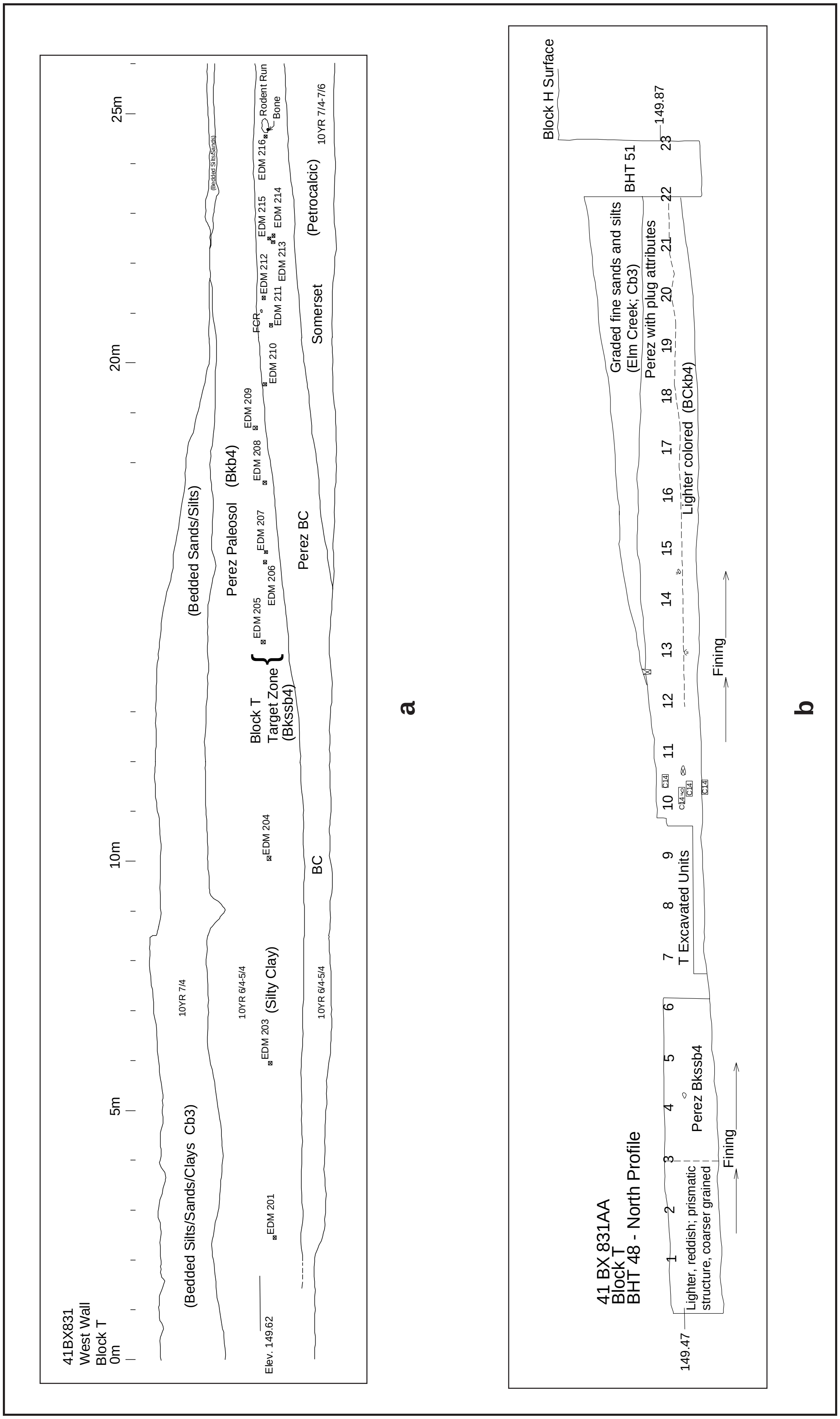


Figure 9.35. Block T profiles showing: (a) artifact-bearing deposits in Bk horizon of the Perez paleosol, which encompass an upper Perez component of the early, Early Archaic; and (b) cross-trench through Block T.

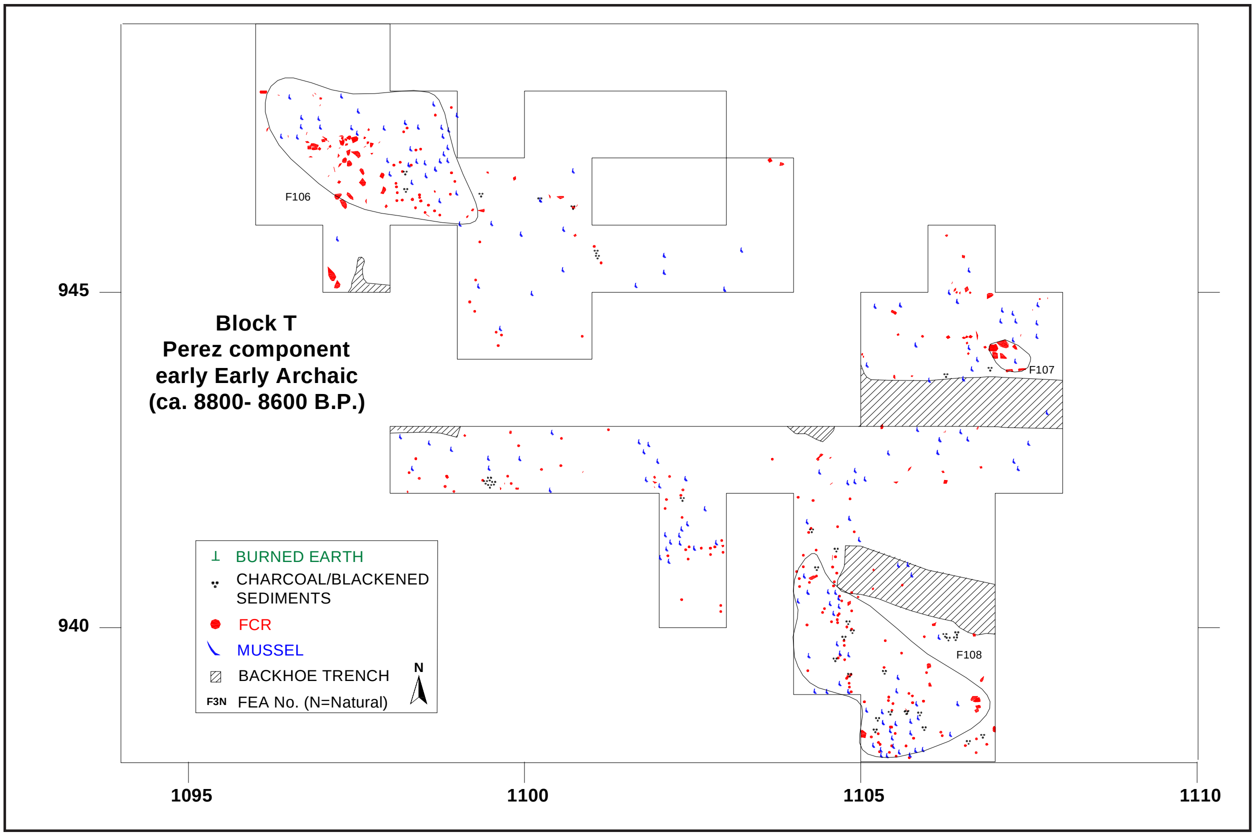


Figure 9.36. Planview showing the distribution of FCR and mussel shells and cultural features in Block T (early, Early Archaic period, ca. 8800–8600 B.P.).

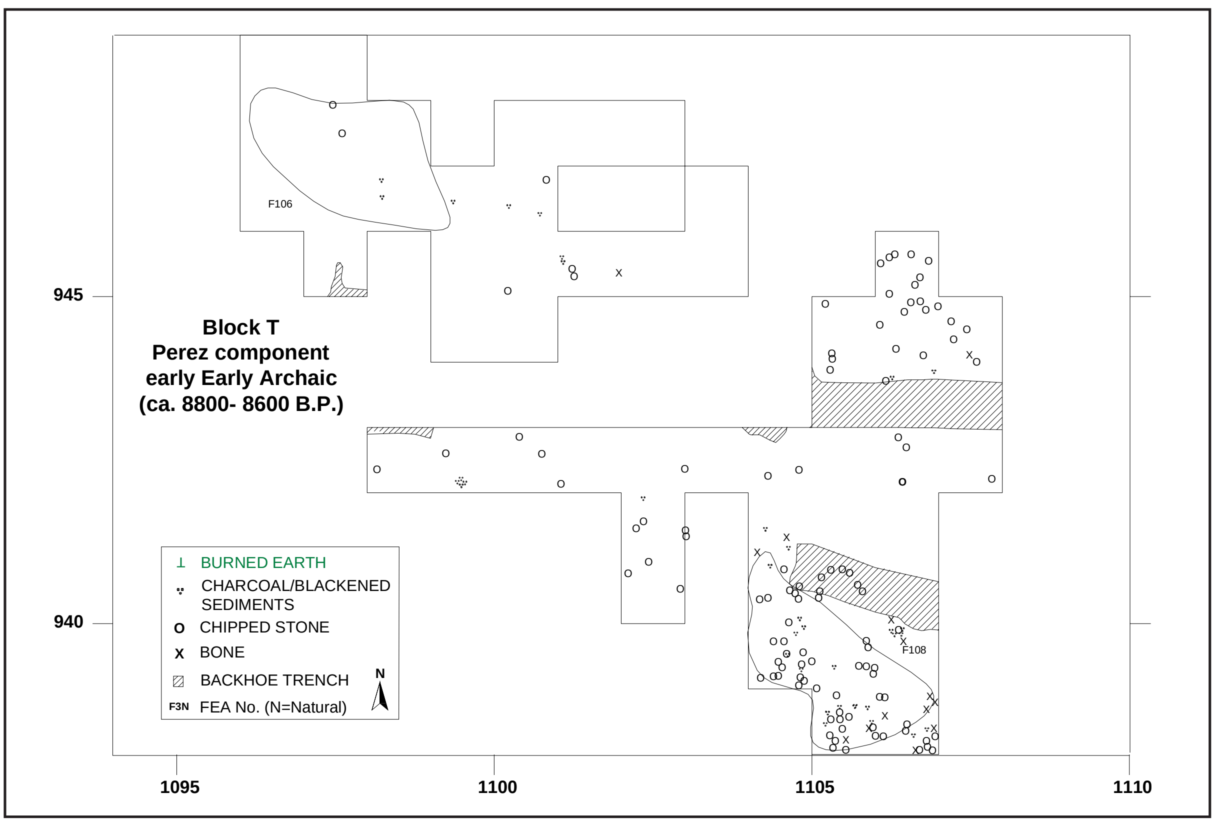


Figure 9.37. Planview showing the distribution of chipped stone, bone, charcoal, and features in Block T (early, Early Archaic period, ca. 8800–8600 B.P.).

compared to 149.5 m at Block T and 151 m asl at Block H (Figures 9.2, 9.38, and 9.39). Compared to Block T, fewer artifacts in Block N were in vertical angles of repose and stream-worn pebbles were smaller and fewer in number. Block N excavations yielded 210 pieces of chipped-stone debitage, several cores and edge-modified flakes, 61 mussel-shell umbos, 177 bone fragments, and 230 pieces of FCR. Mechanical exposures of the upper Perez paleosol in the immediate vicinity of Block N produced Angostura points and a bifacial Clear Fork tool. While Block N was better preserved, per se, it yielded a significantly lower artifact density than did Blocks H and T (Figure 9.40; Table 9.1).

Paleontological Remains and Hints of Paleoindian Components (15,000–12,500B.P.), Blocks R, S, and Surface Find

The deepest excavations at the Richard Beene site—Blocks R and S—were adjacent to what came to be known as the "turtle trench." It was so named because Pleistocene-age turtle remains were exposed in its walls (Chapter 11). This backhoe trench and several others were dug into the floor of the spillway trench to search for the remains of Paleoindian encampments beneath the Perez paleosol. The excavation blocks sampled a series of weakly developed "paleosols" ("Soils" 6, 7, and 8) between 12 and 16 m below the terrace surface (Figures 9.2 and 9.41).

Faunal remains in Soil 6, mostly turtle shell fragments, were embedded in a lens of well sorted sandy sediments sandwiched between two thin gravel lenses (Figure 9.42). Soil 7 yielded burned and unburned bone fragments and a Pleistocene-age marine shell fragment. It is possible, in a speculative sense, that the marine shell was introduced to the site by one of the area's late Pleistocene human inhabitants (Chapter 5). Comparatively few faunal remains were recovered from Soil 8 (Chapter 11). Blocks R and S failed to produce unequivocal cultural material.

In Block S, several small pieces of charcoal from a shallow, amorphous basin (ca. 1 m in width) filled with oxidized, organic- and fauna-rich sediment yielded an AMS radiocarbon age of 12,745 ± 190 B.P. The ^{14}C age determined from soil carbon in the sediments from the same feature was 13,640 ± 210 B.P., again showing the 1,000 year discrepancy between ages derived from wood charcoal and soil carbon in sediments. Other ^{14}C age estimates derived from bulk carbon ranged from ca. 13,500 B.P. for the B horizon of Soil 6 to about 15,300 B.P. for the C horizon of Soil 8.

Due to the unexpected termination of the Applewhite Reservoir construction project, exploration for Paleoindian deposits was limited to a few backhoe trenches and hand excavations in Blocks R and S. Considering that Plainview, Folsom, and Clovis materials have been excavated from elsewhere in the middle Medina River basin (Chapter 8), the Richard Beene site may yet yield remains from the Paleoindian period, including pre-Clovis material.

That potential was partially realized in 2003 in the aftermath of a major flood when a mammoth long bone fragment was recovered by Ramon Vasquez from a newly exposed gravel bar adjacent to the site. Mr. Vasquez is the director of the American Indians in Texas at Spanish Colonial Missions and a member of Tap Pilam–Coahuiltecan Nations, organizations working to preserve the Richard Beene site as part of the proposed Land Heritage Institute of the Americas. As it turns out, the mammoth long bone fragment he found may have been broken/flaked by humans (Appendix A).

Concluding Comments

Fieldwork at the Richard Beene site demonstrated something that archaeologists, geoarchaeologists, and geomorphologists have long maintained valleys that traverse Texas' inner Gulf Coastal Plain, from the Sabine River to the Rio Grande, contain deeply buried archaeological, paleontological, and paleoenvironmental records of late Pleistocene and Holocene times. It is worth repeating that the archaeological record at the Richard Beene site is unusually well-stratified, well-preserved, and well-dated. Moreover, it provides a unique long-term perspec-

Figure 9.38. Block N excavations, which yielded a few stone tools, including an adze, and fire-cracked rocks–representative of one of the site's upper Perez components of the early, Early Archaic period (ca. 8600 B.P.).

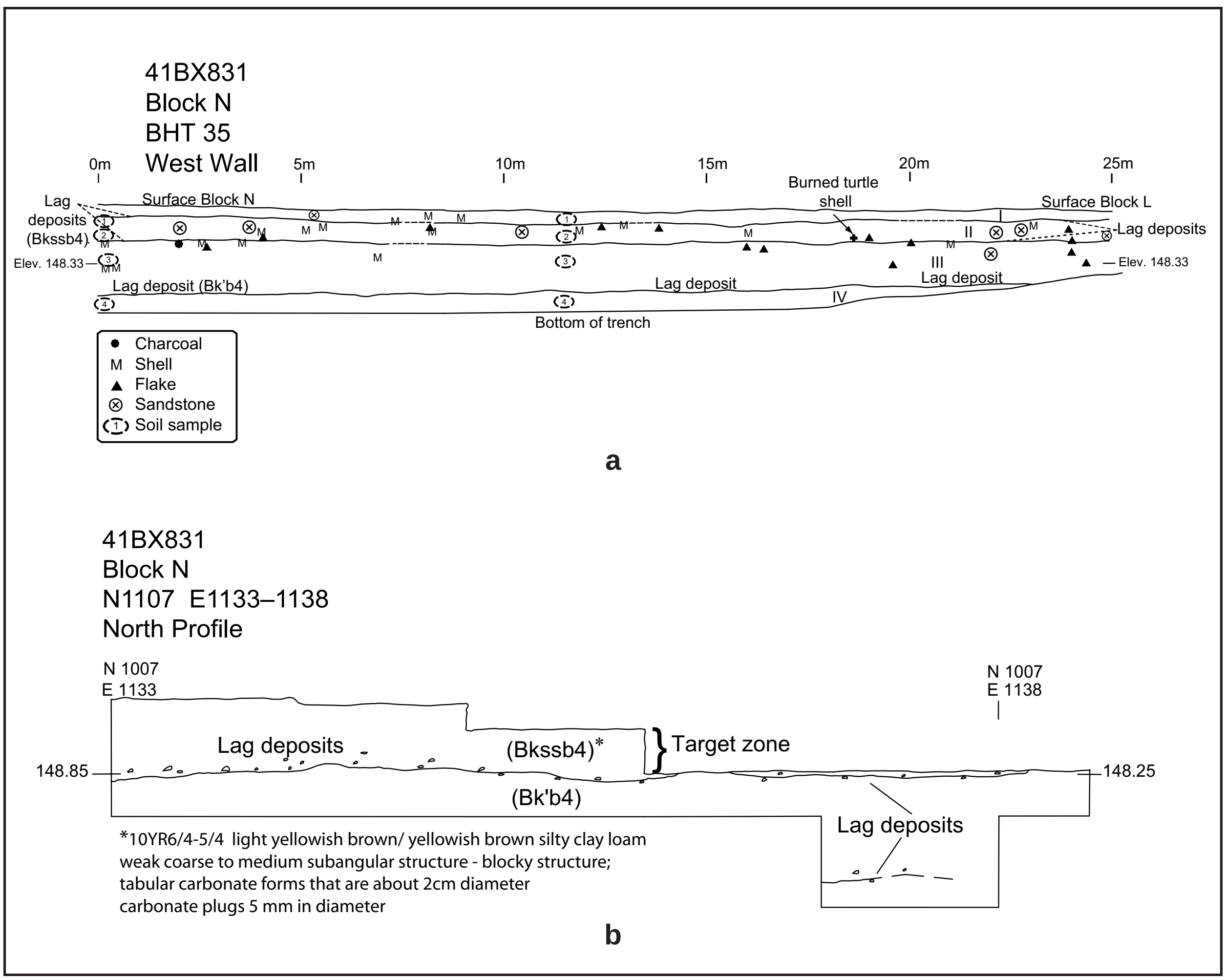


Figure 9.39. Block N profiles showing: (a) artifact-bearing deposits in Bk horizon of the Perez paleosol, which encompass an upper Perez component of the early, Early Archaic; and (b) cross-trench through Block N.

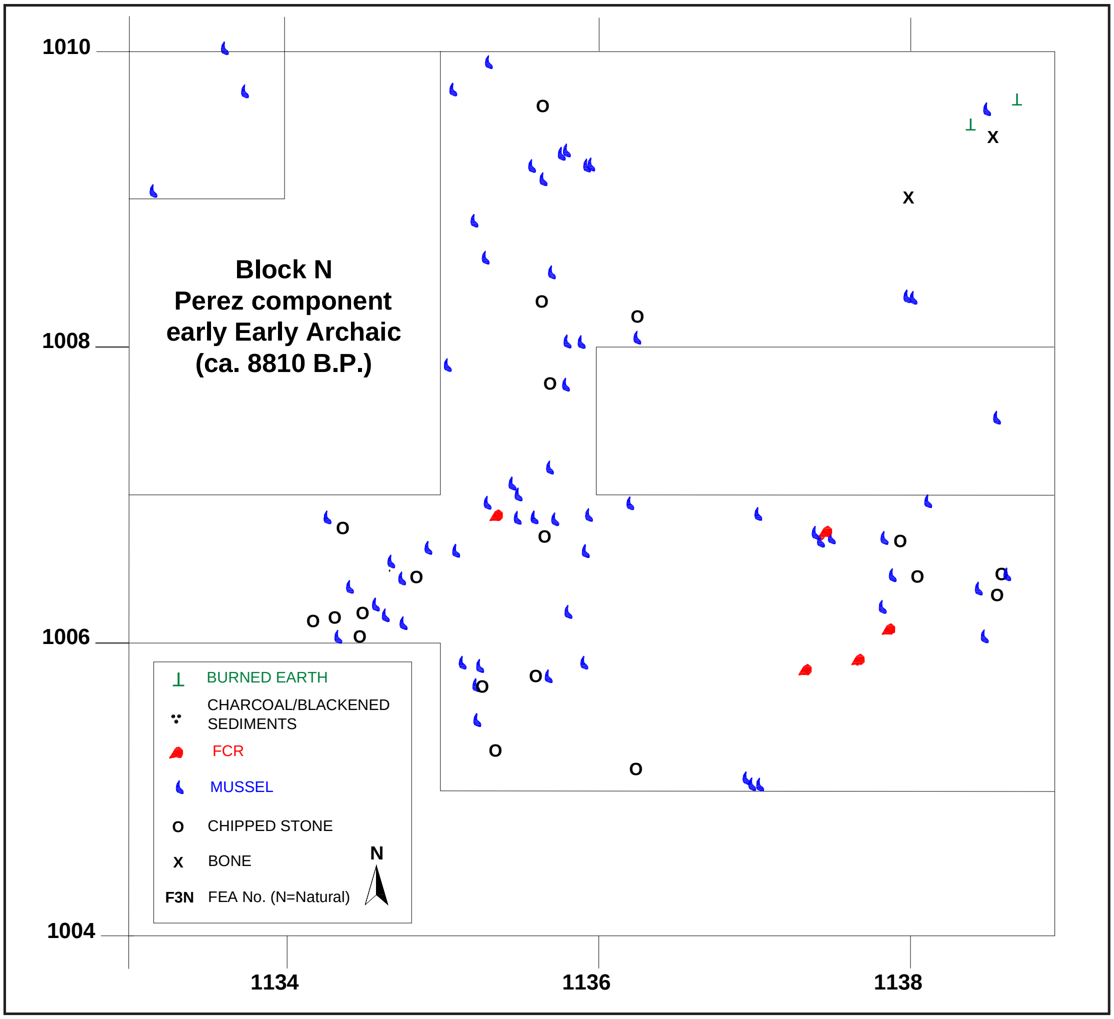


Figure 9.40. Planview showing the distribution of cultural materials in Block N (early, Early Archaic period, ca. 8800–8600 B.P.).

Figure 9.41. Blocks R (upper level) and S (lower level) excavations, which yielded and abundance of late Pleistocene faunal remains, sampled sediments dated ca. 15,000–12,500 B.P.

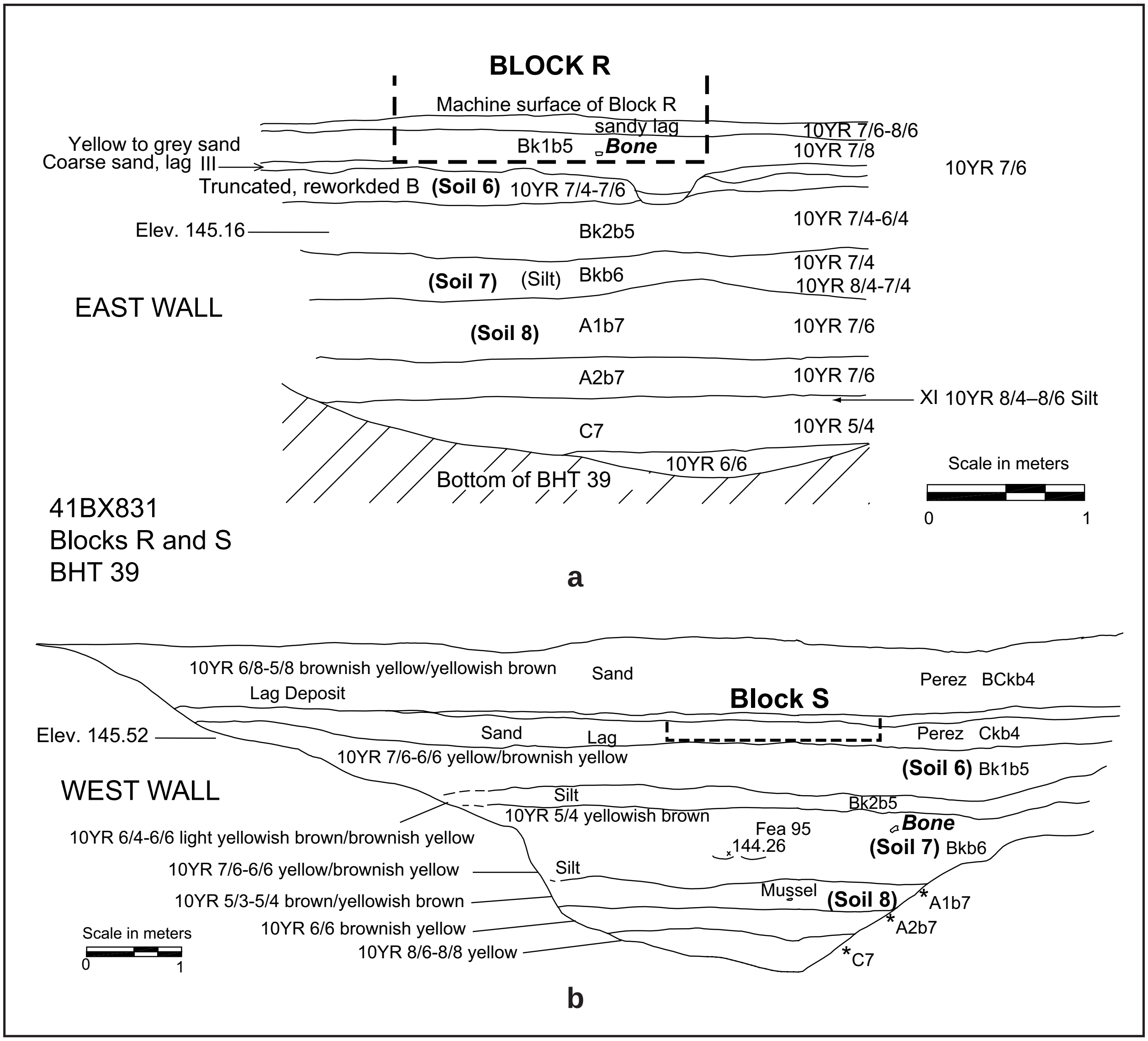


Figure 9.42. Profiles for Blocks R and S, both of which yielded late Pleistocene fauna: (a) fauna-bearing deposits in Soil 6, Block R; and (b) fauna-bearing deposits in soils 7 and 8, Block S.

tive on utilization of a riverine locality. The site serves as a "type record" against which less well-preserved or less complete archaeological records can be compared. Its well-defined components offer an opportunity to fine-tune some of our ideas about projectile points, other temporally diagnostic artifacts, and feature types.

Future archaeological and paleoecological fieldwork at the Richard Beene site, as well new studies using existing data and samples, promise to reveal much more about the dynamics of landscape evolution, site formation processes, and long-term changes in structure of locally available food resources. As the following chapters reveal, the Richard Beene site has already contributed substantially to our knowledge of how Indian people used the local landscape for the past 10,000 years.

REFERENCES CITED*

Abell, P. I.
1985 Oxygen Isotope Ratios in Modern African Gastropod Shells: A Data Base for Paleoclimatology. *Chemical Geology* (Isotope Geoscience Section) 58:83–193.

Advisory Council on Historic Preservation
1990 Programmatic Agreement: Corps of Engineers Permit Program for Applewhite Reservoir Requiring Authorization Under Section 10 of the Rivers and Harbors Act of 1899, and Section 404 of the Clean Water Act, Among the Corps of Engineers, the Advisory Council on Historic Preservation Officer, and the Designated Water Authority. Manuscript on file, Fort Worth Corps of Engineers, Fort Worth, Texas.

Ahler, S. A. and A. A. Swenson
1985 *Test Excavations at Big Hidatsa Village (32ME12), Knife River Indian Villages National Historic Site*. Contributions No. 218. Department of Anthropology, University of North Dakota, Grand Forks. Submitted to the Midwest Archaeological Center, U.S. National Park Service, Lincoln, Nebraska.

Ahr, S. W.
1998 Ramifications of Late Holocene Hide-Processing Geographies along the Lower Medina River, Texas. Unpublished Master's thesis, Department of Anthropology, Texas A&M University, College Station.

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

Anderson, D.G., and J. Schuldenrein (assemblers)
1985 *Prehistoric Human Ecology along the Upper Savannah River: Excavations at the Rucker's Bottom, Abbeville, and Bullard Site Groups*. Russell Papers. Interagency Archeological Services, National Park Service, Atlanta.

Anderson, T. F., and M. A. Arthur
1983 Stable Isotopes of Oxygen and Carbon and their Application to Sedimentologic and Paleoenvironmental Problems. In *Stable Isotopes in Sedimentary Geology*. SEPM Short Course No. 10. Dallas 1983. Michael A. Arthur, Organizer, Thomas F. Anderson, Isaac R. Kaplan, Jan Veizer, and Lynton S. Land, contributors. Tulsa: SEPM.

Arbingast, S. A., L. G. Kennamer, R. H. Ryan, J. R. Buchanan, W. L. Hezlep, L. T. Ellis, T. G. Jordan, C. T. Granger, and C. P. Zlatkovich
1976 *Atlas of Texas.* The University of Texas at Austin, Bureau of Business Research, Austin.

Auffenberg, W.
1969 *The Fossil Snakes of Florida*. Tulane Studies in Zoology, 10:131–216.

Bailey, R. G.
1978 *Ecoregions of the United States* (RARE II, Map B, and accompanying text), prepared by U.S. Department of Agriculture, Forest Service. Geological Survey, Reston, Virginia.

*References are also found in Archaeological and Paleoecological Investigations at the Richard Beene Site –Volume II.

Baker, V. R.
1980 Flood Hazard along the Balcones Escarpment in Central Texas. Alternative Approaches to their Recognition, Mapping, and Management. *Geological Circular* 75–5, Bureau of Economic Geology, The University of Texas, Austin.

Baker, B. W.
1993 A Late Pleistocene Record of Ringtail from South-Central Texas. *Current Research in the Pleistocene* 10:94–96.

Baker, B. W., B. S, Shaffer, K. D. Sobolik, and D. G. Steele
1991 Faunal Analysis. In *Alabonson Road: Early Ceramic Period Adaptations to the Inland Coastal Zone, Harris County, Southeast Texas*, edited by H. Blain Ensor and David L. Carlson, pp. 139–161. Reports of Investigations No. 8. Archaeological Research Laboratory, Texas A&M University, College Station.

Baker, B. W., and D. G. Steele
1992 Late Pleistocene Through Late Holocene Faunal Assemblage from the Richard Beene Site (41BX831), Bexar County, Texas: Preliminary Results. In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran, Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

Balakrishnan, M., C. A. Yapp, D. J. Meltzer, and J. L. Theler
2005a Paleoenvironment of the Folsom Archaeological Site, New Mexico, USA, Approximately 10,500 ^{14}C yr. B.P. as Inferred from the Stable Isotope Composition of Fossil Land Snail Shells. *Quaternary Research* 63:31–44.

Balakrishnan, M., C. A. Yapp, J. L. Theler, B. J. Carter, and D. G. Wyckoff
2005b Environmental Significance of ^{13}C/12C and $^{18}O/^{16}O$ Ratios of Modern Land-Snail Shells from the Southern Great Plains of North America. *Quaternary Research* 63:15–30.

Banks, L. D.
1990 *From Mountain Peaks o Alligator Stomachs: A Review of Lithic Resources in the Trans-Mississippi South, The Southern Plains and Adjacent Southwest*. Memoir Oklahoma Anthropological Society, Oklahoma City.

Barber, D. C., A. Dyke, C. Hillaire-Marcel, A.E. Jennings, J.T. Andrews, M.W. Kerwin, G. Bilodeau, R. Mcneely, J. Southon, M. D. Morehead, and J. M. Gagnon
1999 Forcing of the Cold Event of 8,200 Years Ago by Catastrophic Drainage of Laurentide Lakes. *Nature* 400(6743):344-348.

Barnes. V. E.
1983 Geologic Atlas of Texas, San Antonio Sheet (Revised), 1:250,000 scale. The University of Texas, Bureau of Economic Geology, Austin, Texas.

Beagrie, N., and D. Greenstein
1998 A Strategic Policy Framework for Creating and Preserving Digital Collections. [online]: http://ahds.ac.uk/manage/framework.htm.

Bicchieri, M. G.
1972 *Hunters and Gatherers Today*. Holt, Rhinehart, and Winston, New York.

Binford, L. R.
1977 Forty-Seven Trips: A Case Study in the Character of Archaeological Formation Processes. In *Stone Tools as Cultural Markers*, edited by Richard V. S. Wright, pp. 245–36. Australian Institute of Aboriginal Studies, Canberra.

1978a Dimensional Analysis of Behavior and Site Structure. Learning from an Eskimo Hunting Stand. *American Antiquity* 43:330–361.

1978b *Nunamiut Ethnoarchaeology.* Academic Press, New York.

1979 Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research* 35:255–273.

1980 Willow Smoke and Dog's Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45:4–20.

1983 *In Pursuit of the Past: Decoding the Archaeological Record*. Thames and Hudson, New York.

1987 Researching Ambiguity: Frames of Reference and Site Structure. In *Method and Theory for Activity Area Research: An Ethnoarchaeological Approach*, edited by Susan Kent, pp. 63–106. Columbia University Press, New York.

1989 Isolating the Transition to Cultural Adaptations: An Organizational Approach. In *The Emergence of Modern Humans: Biocultural Adaptations in the Later Pleistocene*, edited by Erik Trinkaus, pp. 18–41. Cambridge University Press, New York.

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

Black, S. L.
1989a Central Texas Plateau Prairie. In *From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas*, edited by Thomas R. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bement, pp. 17–38. Research Series No. 33, Arkansas Archeological Survey.

1989b South Texas Plains. In *From the Gulf to the Rio Grande: Human Adaptation in Central,South, and Lower Pecos Texas*, edited by Thomas R. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland Bement, pp. 39–62. Research Series No. 33, Arkansas Archeological Survey.

1995 Turning up the Heat on the Archeology of Hot-Rock Features. Workshop on Hot Rock Features. Council for Texas Archaeology Meeting Spring 1995. Manuscript on file, Texas Archaeological Research Laboratory, University of Texas, Austin.

Black, S. L. and D. G. Creel
1997 The Central Texas Burned Rock Midden Reconsidered. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas,* edited by Stephen L. Black, Linda W. Ellis, Darrell G. Creel, and Glenn T. Goode, Vol. 1, pp. 269–314. Studies in Archeology 22, Texas Archeological Research Laboratory, The University of Texas, Austin and Archeological Studies Program, Report 2, Texas Department of Transportation, Environmental Affairs Division, Austin.

Black S. L. and L. W. Ellis
1997a Appendix B: Feature Descriptions. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas*. Studies in Archeology Volumes 1 and 2, No. 22. Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program Report No. 2. Texas Department of Transportation, Environmental Affairs Department, Austin.

1997b Critically Recording and Observing Burned Rock Features. In *Hot Rock Cooking on the Greater Edwards Plateau Four Burned Rock Midden Sites in West Central Texas,* by Steve L. Black, Linda W. Ellis, Darrel G. Creel, and Glen T. Goode, pp. 779–783. Studies in Archeology No. 22. Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report No. 2. Texas Department of Transportation, Environmental Affairs Department, Austin.

Black, S. L., L. W. Ellis, D. G. Creel, and G. T. Goode
1997 *Hot Rock Cooking on the Greater Edwards Plateau Four Burned Rock Midden Sites in West Central Texas* vols. 1 and 2. Studies in Archeology No. 22. Texas Archeological Laboratory, The University of Texas at Austin, and Archeological Studies Program, Report No. 2. Texas Department of Transportation, Environmental Affairs Department, Austin.

Black, S. L., K. Jolly, and D. R. Potter
1993 The Higgins Experiment Field Report. Wurzback Project Working Papers. Texas Archaeological Research Laboratory, The University of Texas, Austin.

Black, S. L. and A. J. McGraw
1985 *The Panther Springs Creek Site: Cultural Change and Continuity within the Upper Salado Creek Watershed, South-Central Texas*. Center for Archaeological Research, Archaeological Survey Report No. 100. The University of Texas, San Antonio.

Blair, W. F.
1950 The Biotic Provinces of Texas. *The Texas Journal of Science,* 2(1):93–117.

Blankholm, H. P.
1991 *Intrasite Spatial Analysis in Theory and Practice*. Aarhus University Press, Aarhus, Denmark.

Bomar, G. W.
1983 *Texas Weather*. University of Texas Press, Austin.

1992 The Climate of the Inner Gulf Coastal Plain of the South-Central Texas. In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

Bond, C. L.
1978 *Three Archeological Sites at Hoxie Bridge Williamson County, Texas. Texas*. Anthropology Laboratory Report No. 43. Texas A&M Research Foundation, Texas A&M University, College Station.

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

1998b Late Paleoindian Archaeology. In *Wilson-Leonard, An 11,000 Year Archeological Record of Hunter-Gatherers in Central Texas Vol. 1: Introduction, Background and Syntheses*, edited by Michael B. Collins, pp. 161–210. Report No. 10. Texas Archeological Research Laboratory, The University of Texas, Austin and Texas Department of Transportation, Environmental Affairs Division, Austin.

Bousman C. B, M. B. Collins, P. Goldberg, T. Stafford, J. Guy, B. W. Baker, D. G. Steele, M. Kay, G. Fredlund, J. P. Dering, S. Dial, V. Holliday, D. Wilson, P. Takac, R. Balinsky, M. Masson, and J. F. Powell
2002 The Paleo-Indian Archaic Transition in North America: New Evidence from Texas. *Antiquity* 76:980–990.

Boutton, T. W.
1991a Stable Carbon Isotope Ratios of Natural Materials (I). Sample Preparation and Mass Spectrometric Analysis. In *Carbon Isotope Techniques*, edited by David C. Coleman and Brian Fry, pp. 155–171. Academic Press, New York.

1991b Stable Carbon Isotope Ratios of Natural Materials, II. Atmospheric, Terrestrial, Marine, and Freshwater Environments. In *Carbon Isotope Techniques*, edited by D. C. Coleman and B. Fry, pp. 173–185. Academic Press, New York.

Bower, J.
1986 *In Search of the Past: An Introduction of Archaeology.* The Dorsey Press, Chicago.

Bruier, F. L. and G. B. Thomas (editors)
1986 *Standard Operating Procedures for Field Surveys*. United States Army Fort Hood Archaeological Management Series, Research Report No. 14.

Broecker, W. S., J. P. Kennett, B. P. Flower, J. T. Teller, S. Trumbore, G. Bonani, and W. Wolfli
1989 Routing of Meltwater from the Laurentide Ice Sheet during the Younger Dryas Cold Episode. Nature 341:318–321.

Brown, A. G.
1997 *Alluvial Geoarchaeology: Floodplain Archaeology and Environmental Change.* Cambridge University Press, England.

Brown, D. S., J. R. Gilhousen, and G. M. Nalley
1991 *Compilation of Hydrologic Data for the Edwards Aquifer, San Antonio Area, Texas, 1990, with 1934–1990 Summary*. Bulletin 50. Edwards Aquifer Water District. San Antonio. In cooperation with the USGS.

Brown, K. M.
1987 Early Occupations at Berger Bluff, Goliad County, Texas. *Current Research in the Pleistocene* 4:3–5.

1991 Prehistoric Economics at Baker Cave: A Plan for Research. In *Paper on Lower Pecos Prehistory*, edited by Solveig. A. Turpin, pp.97–140. Studies in Archeology 8. Texas Archeological Research Laboratory, The University of Texas at Austin, Austin.

Bryant, V. M., Jr.
1966 Pollen Analysis: Its Environmental and Cultural Implication in the Amistad Reservoir Area. Unpublished Master's thesis, The University of Texas at Austin.

1969 Late Full-Glacial and Post-Glacial Pollen Analysis of Texas Sediments. Unpublished Ph.D. dissertation, The University of Texas at Austin.

1989 Preservation of Biological Remains from Archaeological Sites. In *Interdisciplinary Workshop on the Physical-Chemical-Biological Processes Affecting Archaeological Sites,* edited by Christopher C. Mathewson, pp. 85–115. U.S. Army Corp of Engineers Waterways Experiment Station, Vicksburg. Mississippi.

Bryant, V. M., Jr., and S. H. Hall
1993 Archaeological Palynology in the United States: A Critique. *American Antiquity*, 58:416–421; 277–286.

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

Bryant, V. M. Jr., and J. G. Jones
1989 Pollen Analysis of Samples Collected from Archaeological Sites along the Route of the All American Pipeline. In *Cultural Resources Report for the All American Pipeline Project,* pp. 316–365. New Mexico State University, Las Cruces.

Bryant, V. M., Jr, and D. L. Larson
1968 Pollen Analysis of the Devil's Mouth Site, Val Verde County, Texas. In *The Devil's Mouth Site: The Third Season*, edited by William M. Sorrow. The University of Texas at Austin, Texas Archaeological Research Laboratory, Papers of the Texas Archaeological Salvage Project 14:57–70.

Bryant, V. M., Jr., and D. H. Riskind

1980 The Paleoenvironmental Record for Northeastern Mexico: A Review of the Pollen Evidence. In *Papers on the Prehistory of Northeastern Mexico and Adjacent Texas,* edited by Jeremiah F. Epstein, Thomas R. Hester, and Carol Grimes. The University of Texas at San Antonio, Center for Archaeological Research, Special Report 9:7–31.

Bryson, R. A., D. A. Baerreis, and W. M. Wendland

1970 The Character of Late-glacial and Post-glacial Climate Changes. In *Pleistocene and Recent Environments of the Central Great Plains,* edited by Wakefield, Dort Jr., and J. Knox Jones, pp. 53–73. The University Press of Kansas, Lawrence, Kansas.

Buckley, V. (compiler)

1990 Burnt Offerings. In *International Contribution to Burnt Mound Archaeology*. Worldwell Ltd., Dublin.

Bullock, P., N. Fredoroff, A. Jongerius, G. Stoops, T. Tursina, and U. Babel

1985 *Handbook for Soil Thin Section Description.* Waine Research Publications, Wolverhampton, UK.

Butzer, K. W.

1982 *Archaeology as Human Ecology: Method and Theory for a Contextual Approach*. Cambridge University Press, Cambridge.

1989 Cultural Ecology. In *Geography in America,* edited by Gary L. Gaile, Cort J. Willmott. Columbus, Ohio, Merrill.

1990 The Indian Legacy in the American Landscape. In *The Making of the American Landscape*, edited by M. P.Conzen, pp. 27–50. Unwin Hyman, Boston.

Cable, J. S.

1996 Haw River Revisited: Implications for Modeling Terminal Late Glacier and Early Holocene Hunter-Gatherer Settlement Systems. In *The Paleoindian and Early Archaic Southeast*, edited by David G. Anderson and Kenneth E. Sassaman, pp. 106–148.

Caldwell, J. R.

1958 *Trend and Tradition in the Prehistory of the Eastern United States*. American Anthropologist Memoir No. 88.

Campbell, C. A., E. A. Paul, D. A. Rennie, and K. J. McCallum

1967 Factors Affecting the Accuracy of the Carbon-dating Method in Soil Humus Studies. *Soil Science* 104:81–85.

Campbell, T. N.

1975 *The Payaya Indians of Southern Texas*. Southern Texas Archaeological Association, Special Publication No. 1., San Antonio.

Campbell, T. N. and T. J. Campbell

1981 *Historic Indian Groups in the Choke Canyon Reservoir and Surrounding Area, Southern Texas*. Choke Canyon Series, Vol. 1, Center for Archaeological Research, The University of Texas at San Antonio.

Caran, S. C.
2001 Field Observations on the Stratigraphic Context of Mammoth Remains at 24BX1239. In *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar* County, edited by Alston V. Thoms, pp. 25–27. Technical Report No. 3, Center for Ecological Archaeology, Texas A&M University, College Station.

Caran, S. C., and V. R. Baker
1986 Flooding along the Balcones Escarpment, Central Texas. In *The Balcones Escarpment,* edited by Patrick L. Abbott and C.M. Woodruff Jr., pp. 1–14. Department of Geological Sciences, San Diego State University, San Diego, California.

Carlson, D. L. (editor)
2008 *Prehistoric Archaeological Investigations in the Applewhite Reservoir Area, Bexar County, Texas*. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Carlson, D. L, J. W. Saunders, G. D. Hall, C. S. Mueller-Wille, B. Ensor, S. McCulloch, R. Korgel, A. McCulloch, R. Moir, D. Journey, and K. Hindes
1990 A Research Design for Archaeological Investigations at Applewhite Reservoir, Bexar County, Texas. Manuscript on file, Department of Anthropology, Texas A&M University, College Station.

Carr, J. T., Jr.
1967 *The Climate and Physiography of Texas*. Report No. 53, Texas Water Development Board, Austin.

Cerling, T. E.
1984 The Stable Isotope Composition of Modern Soil Carbonate and its Relationship to Climate. *Earth and Planetary Science Letters* 71, 229–240.

Cerling, T. E., J. Quade, Y. Wang, and J. R. Bowman
1989 Carbon Isotopes in Soils and Paleosols as Ecology and Paleoecology Indicators. *Nature* 341, 138–139.

Cerling, T. E., D. K. Solomon, J. Quade, and J. R. Bowmann
1991 On the Isotopic Composition of Carbon in Soil Carbon Dioxide. *Geochimica et Cosmochimica Acta* 55, 3403–3405.

Chave, K. E., K. S. Defeyes, P. K. Weyl, R. M. Garrels, and M. E. Thompson
1962 Observations on the Solubility of Skeletal Carbonates in Aqueous Solutions. *Science* Vol. 137(3523):33–34.

Clabaugh, P. A.
1994 The Nature and Distribution of Features at 41MU55. In *The Valley Branch Archaeological Project: Excavations at an Archaic Site (41MU55) in the Cross Timbers Uplands, North-Central Texas,* edited by Alston V. Thoms, pp. 81–110. Reports of Investigations No. 15. Archaeological Research Laboratory, Texas A&M University, College Station.

1996 FCR and Cooking Variability at the Richard Beene Site (41BX831): A Deeply Stratified Site in South-Central Texas. Paper presented at the 67th Annual Texas Archeological Society Meeting, San Antonio.

2002 Preserving the Feature Record: A Systematic Analysis of Cooking and Heating Features from the Richard Beene Site (41BX831), Texas. Unpublished Master's thesis, Department of Anthropology, Texas A&M University, College Station.

Clabaugh, P. A. and S. K. Judjahn
2004 The Nature and Distribution of Fire-Cracked Rock Features. In *Yegua Creek Archaeological Project: Survey Results from Lake Somerville State Parks and Trailway, East-Central Texas*, edited by Alston V. Thoms, pp. 151–167. Reports of Investigations No. 5. Center for Ecological Archaeology, Texas A&M University, College Station.

Clayton, R. N., and E. T. Degens
1959 Use of Carbon Isotope Analyses of Carbonates for Differentiating Fresh-Water and Marine Sediments. *American Association of Petroleum Geologists Bulletin* 43:890.

Cobb, C. R., and P. A. Webb
1994 A Source Area Perspective on Expedient and Formal Core Technologies. *North American Archaeologist* 15(3):197–219.

Cohen, M. N.
1977 *The Food Crisis in Prehistory: Overpopulation and the Origins of Agriculture*. Yale University Press, New Haven.

Collins, M. B.
1976 Terminal Pleistocene Cultural Adaptations in Southern Texas. Paper presented at the 9th International Union of Prehistoric and Protohistoric Sciences, Nice, France.

1979 Excavations at Four Archaic Sites in the Lower Ohio Valley, Jefferson County, Kentucky. *Occasional Papers in Anthropology* 1. Department of Anthropology, University of Kentucky, Lexington.

1998 The Place of Wilson-Leonard in Southern Plains Prehistory. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas*, vol. 1, assembled and edited by Michael B. Collins, pp. 277–291. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas, Austin and Archeological Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

2002 The Gault Site, Texas, and Clovis Research. Peopling of the Americas. *Athena Review* 3(2).

Collins, M. B., B. Ellis, and C. Dodt-Ellis
1990 *Excavations at the Camp Pearl Wheat Site (41KR243): An Early Archaic Campsite on Town Creek Kerr County, Texas*. Studies in Archeology No. 6. Texas Archaeological Research Laboratory, The University of Texas at Austin.

Collins, M. B., G. L. Evans, and T. N. Campbell
1988 Paleoindian Components at Kincaid Rockshelter, Uvalde County, Texas. Paper presented at the 59th meeting of the Texas Archeological Society, Houston, Texas.

Collins, M. B., J. Guy, and S. W. Dial
1998 The Archaic Period, 8800–1300 B.P. In *Wilson-Leonard: An 11,000-year Record of Hunter-Gatherers in Central Texas*, edited by .Michael B. Collins, pp. 211–270. Studies in Archaeology Vol. IV, No. 31. Texas Archaeological Research Laboratory, The University of Texas, Austin; and Archeology Studies Program Report, No. 10. Texas Department of Transportation, Environmental Affairs Division, Austin.

Collins, M. B. (editor)
1998 *Wilson-Leonard: An 11,000year Record of Hunter-Gatherers in Central Texas*. Studies in Archaeology Vol. IV, No. 31. Texas Archaeological Research Laboratory, The University of Texas, Austin; and Archeology Studies Program Report, No. 10. Texas Department of Transportation, Environmental Affairs Division, Austin.

Condron, F., J. Richards, D. Robinson and A. Wise
1999 Strategies for Digital Data: Findings and Recommendations from Digital Data in Archaeology. Data Service Department of Archaeology, University of York. [online] http://ads.ahds.ac.uk/project/strategies/10.html

Coplen, T. B., and C. Kendall
2000 Stable Isotope and Oxygen Isotope Ratios for Selected Sites of the U.S. Geological Survey's NASQAN and Benchmark Surface-Water Networks. U.S. Geological Survey Open-File Report 00–160. Reston, VA.

Courty, M. A., P. Goldberg, and R. I. Macphail
1989 *Soil Micromorphology and Archaeology*. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge, UK.

Covey, C. (translator and annotator)
1993 *Cabeza de Vaca's Adventures in the Unknown Interior of America*. Reprinted form 1963 edition by University of New Mexico Press, Albuquerque.

Craig, H.
1961 Standards for Reporting Concentrations of Deuterium and Oxygen-18 in Natural Waters. *Science* 133:1833–1834.

Dalquest, W. W., E. Roth, and F. Judd
1969 The Mammal Fauna of Schulze Cave, Edwards County, Texas. *Bulletin of the Florida State Museum*, 13(4):205–276.

Daniel, Jr., I. R.
1996 Raw Material Availability and Early Archaic Settlement in the Southeast. In *The Paleoindian and Early Archaic Southeast*, edited by David.G. Anderson and Kenneth E. Sassaman, pp. 84–91. The University of Alabama Press, Tuscaloosa.

Dansgaard, W.
1964 Stable Isotopes in Precipitations. *Tellus* 16:436–467.

Davis, W. B.
1974 *The Mammals of Texas*. Bulletin No. 41. Texas Parks and Wildlife Department, Austin.

Dansgaard, W.
1964 Stable Isotopes in Precipitations. *Tellus* 16:436–467.

Davis, W. B.
1974 *The Mammals of Texas*. Bulletin No. 41. Texas Parks and Wildlife Department, Austin.

Decker, S., S. L. Black, and T. Gustavson
2000 *The Woodrow Heard Site, 41UV88: A Holocene Terrace Site in the Western Balcones Canyonlands of Southwestern Texas*. Report No. 14. Texas Archaeological Research Laboratory, The University of Texas at Austin: Texas Department of Transportation, Environmental Affairs Division, Austin.

Dering, J. P.
1977 Plant Macrofossil Study: A Progress Report. In *Archaeological and Botanical Studies at Hinds Cave, Val Verde County Texas*, edited by Harry J. Shafer and Vaughn M. Bryant, Jr, Special Series 1:84–102. Texas A&M University, Anthropology Research Laboratory, College Station.

1979 Pollen and Plant Macrofossil Vegetation Record Recovered from Hinds Cave, Val Verde County, Texas. Unpublished Master's thesis, Texas A&M University, College Station.

1999 Earth-oven Plant Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity* 64(4):659–674.

2003 Botanical Perspectives on Land Use in the Cross Timbers and Prairies: Plant Remains from Burned Rock Middens in Brown County, Texas. In *Archaeological Testing to Determine the National Register Eligibility Status of 18 Prehistoric Sites on Camp Bowie, Brown County, Texas*, edited by Raymond P. Mauldin, David L. Nickels, and Cory J. Broehm, pp. 58–78. Center for Archaeological Research, Archaeological Survey Report, No. 334, The University of Texas at San Antonio.

Dering, J. P., and V. Bryant
1992 Plant Remains From the Richard Beene Site (41BX831): Implications for Holocene Climatic Change in South-Central Texas. In *Late Cenozoic Alluvia Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

Dettman, D. L., and K. C. Lohman
1993 Seasonal Change in Paleogene Surface Water $\delta^{18}O$: Fresh-Water Bivalves of Western North America. In *Climate Change in Continental Isotope Records* edited by Peter K. Swart, Kyger C. Lohmann, Judith A. McKenzie, and Samuel M. Savin, pp. 153–163. Geophysical Monograph 78, American Geophysical Union, Washington, DC.

Dettman, D. L., A. K. Reische, and K. C. Lohman
1999 Controls on the Stable Isotope Composition of Seasonal Growth Bands in Aragonite Fresh-water Bivalves (Unionidae). *Geochimica et Cosmochimica Acta* 63(7/8):1049–1057.

Dockall, J. E. and C. D. Pevny

2008 Lithic Technology and Technological Organization: Results of Lithic Analysis. In *Prehistoric Archaeological Investigations in the Applewhite Reservoir Area, Bexar County, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Dreimanis, A.

1962 Quantitative Gasometric Determination of Calcite and Dolomite by Using the Chittick Apparatus. *Journal of Sedimentary Petrology* 32:520–529.

Driver, H. E., and W. C. Massey

1957 *Comparative Studies of North American Indians*. Transactions of the American Philosophical Society, New Series, 47:2, American Philosophical Society, Philadelphia.

Duaine, C. L.

1971 *Caverns of Oblivion.* Packrat Press, Manchaca, Texas.

Durden, C. J.

1974 Biomerization: An Ecologic Theory of Provincial Differentiation. In *Paleogeographic Provinces and Provinciality*, edited by Charles A. Ross, pp. 18–53. Society of Economic Paleontologists & Mineralogists Special Publication 21.

Elias, T. S. and P. A. Dykeman

1990 *Edible Wild Plants: A North American Field Guide*. Sterling Publishing Co., Inc., New York.

Ellis, L. W.

1997 Hot Rock Technology. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas*, edited by Stephen L. Black, Linda W. Ellis, Darrell G. Creel, and Glenn T. Goode, pp. 43–81. Studies in Archeology 22, Texas Archeological Research Laboratory, The University of Texas, Austin and Archeological Studies Program, Report 2, Texas Department of Transportation, Environmental Affairs Division, Austin.

Epstein, J. F.

1969 The San Isidro Site: An Early Man Campsite in Nuevo Leon, Mexico. Anthropology Series No. 7. Department of Anthropology, University of Texas, Austin.

Epstein, S., R. Buchsbaum, H. A. Lowenstam, and H. C. Urey

1953 Revised Carbonate-water Temperature Scale. *Geological Society of America Bulletin* 62, 417–426.

Ernst, C. H. and R. W. Barbour.

1972 *Turtles of the United States*. University Press of Kentucky, Lexington.

Evans, J. G.

1972 *Land Snails in Archaeology*. Seminar Press, London.

Fagan, B. M.

1992 *People of the Earth: An Introduction to World Prehistory*, Seventh edition. Harper-Collins Publishers, New York.

Faure, G.
1986 *Principles of Isotope Geology*. John Wiley and Sons, New York.

Favata, M. A. and J. B. Fernández (translators and editors)
1993 *The Account: Alvar Nunez Cabeza de Vaca's Relacion*. Arte Publico Press, Houston, Texas.

Fenneman, N. M.
1938 *Physiography of Eastern United States*. McGraw-Hill Book Company, Inc., New York.

Fields, R. C.
1995 The Archeology of the Post Oak Savannah of East Central Texas. *Bulletin of the Texas Archeological Society* 66:301–330.

Flower, B. P. and J. P. Kennett
1990 The Younger Dryas Cool Episode in the Gulf of Mexico. *Paleoceonography* 5:949–961.

Forrestal, P. P.
1931 The Solis Diary of 1767. *Preliminary Studies of the Texas Catholic Historical Society* 1(6):3–31.

1935 Pena's Diary of the Aguayo Expedition. *Preliminary Studies of the Texas Catholic Historical Society* 2(7):2–68.

Foster, W. C. (editor)
1998 *The La Salle Expedition to Texas: The Journal of Henri Joutel, 1684–1687*. Translated by J. S. Warren. Texas State Historical Association, Austin.

Foster, W. C.
1995 *Spanish Expeditions into Texas: 1689–1768*. The University of Texas Press, Austin.

Fredlund G. C. and R. W. Neck
1992 Stable Isotope Analysis of Land Snail Carbonate, the Richard Beene Site (41BX831), Texas. In *Late Cenozoic Alluvia Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

Freese and Nichols, Inc.
1988 Request for Proposals, Archaeological and Historical Resources, Applewhite Water Supply Project, Bexar County, Texas. Document on file at the Department of Anthropology, Texas A&M University, College Station.

Frere-Sautot M. C. (editor)
2003 *Le Feu Domestique et ses Structures au Neolithique et aux Ages des Metaux*. Collection Prehistories No. 9, Editions Monique Mergoil, Saint-Apollinaire, France.

Frison, G. C. and B. A. Bradley
1980 *Folsom Tools and Technology at the Hanson Site*. University of New Mexico Press, Albuquerque.

Frison, G., C., J. Henderson, and G. Goode
1991 Clovis Core and Blade Technology From Site 41BX52. Paper presented at the 49th Plains Anthropological Conference, Lawrence, Kansas.

Fritz, P., T. W. Anderson, and C. F. M. Lewis
1975 Late-Quaternary Climatic Trends and History of Lake Erie from Stable Isotope Studies. *Science* 190:267–269.

Fritz, P., and S. Poplawski
1974 ^{18}O and ^{13}C in the shells of freshwater mollusks and their environments. *Earth and Planetary Science Letters* 24:91–98.

Fry R.G., K.L Brown, C. A. McMahan
1984 *The Vegetation Types of Texas* (Map). Bureau of Economic Geology. University of Texas, Austin.

Fullington, R. W.
1978 The Recent and Fossil Freshwater Gastropod Fauna of Texas. Unpublished Ph.D. dissertation, University of North Texas, Denton, Texas.

1979 The Land and Freshwater Mollusca of the Guadalupe National Park, Texas. In *Biological Investigations in the Guadalupe Mountains National Park, Texas*, edited by Hugh H. Genoways and Robert J. Baker, pp. 91–111. National Park Service Proceedings and Transactions Series 4:1–442. Washington, D.C.

Gaertner, L. M.
1992 *Use-Wear Traces on Early Archaic Dalton Adzes from Northeast Arkansas.* Paper presented at the Society for American Annual Meeting, Pittsburgh, Pennsylvania.

Gehlbach, F. R.
1991 The East-West Transition Zone of Terrestrial Vertebrates in Central Texas: A Biogeographical Analysis. *Texas Journal of Science*, 43(4):415–427.

Geyh, M. A., J. H. Benzler, and G. Roeschmann
1975 Problems of dating Pleistocene and Holocene soils by radiometric methods. In *Paleopedology: Origin, Nature, and Dating of Paleosols*, edited by Dan H. Yaalon, pp. 63–75. Israel University Press, Jerusalem.

Ging, P. B., and C. L. Otero
2003 *Comparison of Temperature, Specific Conductance, pH, and Dissolved Oxygen at Selected Basic Fixed Sites in South-Central Texas, 1996–1998*. National Water Quality Assessment Program. USGS Open File Report 03–087, Austin.

Goodfriend, G. A.
1989 Complementary Use of Amino Acid Epimerization and Radiocarbon Analysis for Dating of Mixed Age Fossil Assemblages. *Radiocarbon* 31:1041–1047.

1990 Rainfall in the Negev Desert During the Middle Holocene Based on ^{13}C Of Organic Matter in Land Snail Shells. *Quaternary Research* 34:186–197.

1991 Holocene Trends in 18O in Land Snail Shells from the Negev Desert and their Implications for Changes in Rainfall Source Areas. *Quaternary Research* 35:417–426.

1992 The Use of Landsnail Shells in Paleoenvironmental Reconstruction. *Quaternary Science Reviews* 11:665–685.

Goodfriend, G. A., and G. L. Ellis
2000 Stable Carbon Isotope Record of Middle to Late Holocene Climate Changes from Land Snail Shells at Hinds Cave, Texas. *Quaternary International* 67:47–60.

2002 Stable Carbon and Oxygen Isotopic Variations in Modern Rabdotus Land Shells in the Great Plains, USA, and Their Relation to Environment. *Geochimica et Cosmochimica Acta* 66(11):1987–2002.

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., M. Magaritz, and J. R. Gat
1989 Stable Isotope Composition of Land Snail Body Water and its Relation to Environmental Waters and Shell Carbonate. *Geochimica et Cosmochimica Acta* 53:3215–3221.

Goodyear, A. C, III., J. L. Michie, and T. Charles
1989 The Earliest South Carolinians. In *Studies in South Carolina Archaeology: Essays in Honor of Robert L. Stephenson*, edited by Albert C. Goodyear III and Glen T. Hanson, pp. 19–52. Anthropological Studies 9, Columbia: South Carolina Institute of Archaeology and Anthropology, University of South Carolina.

Gose, W. A.
1995 Archaeomagnetic Analyses of Rocks from Feature 107, 41BX831. Letter report to A.V. Thoms dated April 27, 1995. Copy on file Department of Anthropology, Texas A&M University, College Station.

2000 Paleomagnetic Studies of Burned Rocks. *Journal of Archaeological Science* 27:409–421.

Graham, R. W.
1987 Late Quaternary Mammalian Faunas and Paleoenvironments of the Southwestern Plains of the United States. In *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, edited by Russell W. Graham, Holmes A. Semken, Jr., and Mary Ann Graham, pp. 24–86. Scientific Papers, Vol. 22, Illinois State Museum, Springfield.

Graham, A. and C. Heinsch
1960 Pollen Studies of Some Texas Peat Deposits. *Ecology,* 41:785–790.

Gregg, S. A., K. W. Kintigh, and R. Whallon
1991 Linking Ethnoarchaeological Interpretation and Archaeological Data: The Sensitivity of Spatial Analytical Methods. In *The Interpretation of Archaeological Spatial Patterning*, edited by EllenM. Kroll and T. Douglas Price, pp. 149–196. Plenum Press, New York.

Grootes, P. M.
1993 Interpreting Continental Oxygen Isotope Records. In *Climate Change in Continental Isotopic Records*, edited by Peter K. Swart, Kyger C. Lohmann, Judith A. McKenzie, and Samuel M. Savin, pp. 37–46. American Geophysical Union, Washington, D.C.

Grossman, E. L. and T. Ku
1986 Oxygen and Carbon Isotope Fractionation in Biogenic Aragonite: Temperature Effects. *Chemical Geology*, Isotope Geoscience Section 59:59–74.

Gunn, J., T. R. Hester, R. Jones, R. L. Robinson, and R. A. Mahula
1982 Climate Change in Southern Texas. In *Archaeological Investigations at Choke Canyon Reservoir, South Texas: The Phase I Findings*, edited by Grant D. Hall, Stephan L. Black, and Carol Graves. The University of Texas at San Antonio, Center for Archaeological Research, Choke Canyon Series, 5:578–597.

Haas, H., V. Holliday, and R. Stuckenrath
1986 Dating of Holocene Stratigraphy with Soluble and Insoluble Organic Fractions at the Lubbock Lake Archaeological Site, Texas: An Ideal Case Study. *Radiocarbon* 28:473–485.

Hall, G. D.
2000 Pecan Food Potential in Prehistoric North America. *Economic Botany* 54(1):103–112.

Hall, G. D., T. R. Hester, and S. L. Black
1986 *The Prehistoric Sites at Choke Canyon Reservoir, Southern Texas: Results of Phase II Archaeological Investigations*. Center for Archaeological Research, Choke Canyon Series, Vol. 10. The University of Texas at San Antonio.

Hall, S. A.
1981 Deteriorated Pollen Grains and the Interpretation of Quaternary Pollen Diagrams. *Review of Paleobotany and Palynology,* 32:193–206.

Hamilton, D. L.
2001 *Prehistory of the Rustler Hills: Granado Cave*. The University of Texas Press, Austin.

Harper, K. T. and G. M. Alder
1970 The Macroscopic Plant Remains of Hogup Cave, Utah, and their Paleoclimatic Implications. In *Hogup Cave*, edited by Michael A. Adler. University of Utah, Salt Lake City, Anthropological Papers 93:215–240.

Harris, A. H.
1985 *Late Pleistocene Vertebrate Paleoecology of the West*. The University of Texas Press, Austin.

Havard, V.
1895 Food Plants of the American Indians. *Bulletin of the Torrey Botanical Club* 22:98–123.

Hatch, S. L., K. N. Gandhi, and L. E. Brown
1990 *Checklist of the Vascular Plants of Texas.* Texas Agricultural Experiment Station, College Station, Texas.

Hatcher, M. A.
1932 The Expedition of Don Domingo Teran de los Rios into Texas. *Preliminary Studies of the Texas Catholic Historical Society* 2(1):2–67.

Havinga, A. J.
1964 Investigations into the Differential Corrosion Susceptibility of Pollen and Spores. *Pollen et Spores,* 6:621–635.

Hayden, B.
1979 Paleolithic Reflections. Lithic Technology and Ethnographic Excavations among Australian Aborigines. Australian Institute of Aboriginal Studies, Canberra, Australia and Humanities Press, Inc., New Jersey.

Hayden, B., N. Franco, and J. Spafford
1996 Evaluating Lithic Strategies and Design Criteria. In *Stone Tools: Theoretical Insights into Human Prehistory,* edited by George H. Odell, pp. 9–45. Plenum Press, New York.

Heller, J.
1990 Longevity in Molluscs. *Malacologia* 31(2):259–295.

Hellier, J. R., D. G. Steele, and C. A. Hunter
1995 Analysis of Vertebrate Faunal Remains. In *Archaeological Investigations at the Loma Sandia Site (41LK28): A Prehistoric Cemetery and Campsite in Live Oak County, Texas,* edited by Anna J. Taylor and Cheryl L. Highley, pp. 801–828. Studies in Archaeology 20. Texas Archeological Research Laboratory, University of Texas, Austin.

Hester, T. R.
1989 Historic Native American Populations. In *From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas*, edited by Thomas R. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bement, pp. 115–128. Arkansas Archeological Survey Research Series No. 33.

1977a *Archaeological Research at the Hinojosa Site (41JW8), Jim Wells County, Southern Texas*. Center for Archaeological Research, The University of Texas at San Antonio, Archaeological Survey Report 42.

1977b The Current Status of Paleoindian Studies in Southern Texas and Northeastern Mexico. In *Paleoindian Lifeways,* edited by Eileen Johnson, pp. 169–186. The Museum Journal, XVII, West Texas Museum Association, Texas Tech University, Lubbock.

1989 An Archeological Synthesis. In *From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas,* edited by Thomas R. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bement, pp. 115–128. Arkansas Archeological Survey Research Series No. 33.

Hester, T. R. (editor)
1991a Notes on South Texas Archaeology: 1991–3. Further Notes on the Lithics from the Plainview Occupation at the St. Mary's Hall Site, South Central Texas. *La Tierra* 18(2):1–6.

1991b *The Burned Rock Middens of Texas: An Archeological Symposium*. Texas Archeological Research Laboratory, Studies in Archeology 13, The University of Texas, Austin.

1999 Artifacts, Archaeology, and Cabeza de Vaca in Southern Texas and Northeastern Mexico. *Bulletin of the Texas Archeological Society* 70:17–25.

Hester, T. R., T. C. Hill, Jr., D. Gifford, and S. Holbrook
1975 Archaeological Salvage at Site 41ZV152, Rio Grande Plain of Texas. *The Texas Journal of Science*, 26(1–2):223–228.

Hester, T. R. and D. Knepper
1991 Notes on South Texas Archaeology: 1991–2. The Plainview Points from St. Mary's Hall Site, South Central Texas. *La Tierra* 18(2):1–4.

Hindes, V. K., and S. McCullough
2008 Prehistoric and Protohistoric Background. In *Prehistoric Archaeological Investigations in the Applewhite Reservoir Project Area, Bexar Count, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Hodder, M. A., and I. H. Barfield (editors)
1991 *Burnt Mounds and Hot Stone Technology.* Papers from the Second International Burnt Mound Conference. Sandwell, 12th–14th October 1990. Sandwell Metropolitan Borough Council, Sandwell, West Midlands.

Hoefs, J.
1987 *Stable Isotope Geochemistry.* 3rd ed. Springer-Verlag, Berlin.

Hofman, J. L.
1977 A Technological Analysis of Clear Fork Gouge Production. *Bulletin of the Oklahoma Anthropological Society* 26:105–121.

1978 Gouge Production Strategies: Toward the Study of Archaic Local Groups on the Southern Plains. Wyoming Contributions to Anthropology 1, Spring 1978. University of Wyoming Publications 32(1):154–164. Laramie.

Holloway, R. G.
1981 Preservation and Experimental Diagenesis of the Pollen Exine. Unpublished Ph.D. dissertation, Texas A&M University, College Station.

1986 Macrobotanical Analyses of Charcoal Materials from the Choke Canyon Reservoir Area, Texas. In *The Prehistoric Sites at Choke Canyon Reservoir, Southern Texas: Results of the Phase II Archaeological Investigations* edited by G rant D. Hall, Thomas R. Hester, and S tephen L. Black. The University of Texas at San Antonio, Center for Archaeological Research, Choke Canyon Series 10:437–451.

Holman, J. A.
1979 A Review of North American Tertiary Snakes. *Paleontological Series*, 1(6):200–260. Publications of the Museum, Michigan State University.

1981 A Review of North American Pleistocene Snakes. *Paleontological Series*, 1(7):263–306. Publications of the Museum, Michigan State University.

Holliday, V. T., J. C. Knox, G. L. Running IV, R. D. Mandel, and C. R. Ferring
2001 The Central Lowlands and Great Plains. In *The Physical Geography of North America*, edited by Antony R. Orme, pp. 335–362. Oxford University Press, New York.

Holt, C. L. R., Jr.
1956 *Geology and Ground-Water Resources of Medina County, Texas*. Texas Board of Water Engineers Bulletin 5601. Austin. Prepared in cooperation with the Geological Survey, US Department of the Interior. Second Printing 1976.

Horibe, Y., and T. Oba
1972 Temperature Scales of Aragonite-Water and Calcite-Water Systems. *Fossils* 23/24:69–79.

Howells, R. G., R. W. Neck, and H. D. Murray
1996 *Freshwater Mussels of Texas*. Texas Parks and Wildlife. Inland Fisheries Division. Austin.

Hu, F. S., H. E. Wright, E. Ito, K. Lease
1999 Abrupt Changes in North American Climate during Early Holocene Times. *Nature* 400(6743):437-440

Hubricht, L.
1962 Land Snails from the Pleistocene of Southern Texas. *Sterkiana* 7:1–4.

1985 The Distributions of the Native Land Mollusks of the Eastern United States. *Fieldiana Zoology* (new series) 24:1–191.

Huggett, J.
1985 Expert Systems in Archaeology. In *Current Issues in Archaeological Computing*, edited by Malcolm A. Cooper and Julien D. Richards, pp. 123–142. British Archaeological Reports S271, Oxford.

Hughes, J. T.
1949 Investigations in Western South Dakota and Northwestern Wyoming. *American Antiquity* 4:266–277.

Humphrey, J. D., and C. R. Ferring
1994 Stable Isotopic Evidence for Latest Pleistocene and Holocene Climatic Change in North-Central Texas. *Quaternary Research* 41:200–213.

International Atomic Energy Agency
1969 Environmental Isotope Data No. 1: World Survey of Isotope Concentration in Precipitation (1953–1963). International Atomic Energy Agency Technical Reports Series No. 97. Vienna.

1970 Environmental Isotope Data No. 2: World Survey of Isotope Concentration in Precipitation (1964–1965). International Atomic Energy Agency Technical Reports Series No. 117. Vienna.

1979 Environmental Isotope Data No. 6: World Survey of Isotope Concentration in Precipitation (1972–1975). International Atomic Energy Agency Technical Reports Series No. 192. Vienna.

1983 Environmental Isotope Data No. 7: World Survey of Isotope Concentration in Precipitation (1976–1979). International Atomic Energy Agency Technical Reports Series No. 226. Vienna.

Ingersoll, D. T., J. E. Yellen, and W. Macdonald (editors).
1977 *Experimental Archeology*. Columbia University Press, New York.

Jackson, M. A.
1998 The Nature of Fire-Cracked Rock: New Insights From Ethnoarchaeological and Laboratory Experiments. Unpublished Master's thesis, Department of Anthropology, Texas A&M University.

Johnson, A. W., and T. Earle
1987 *The Evolution of Human Societies: From Group to Agrarian State*. Stanford University Press, Stanford, California.

Johnson, D. L.
2002 Bioturbation, dynamic denudation, and the power of theory. *Geoarchaeology*, 17, 7–40.

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

Johnson, J. K.
1986 Amorphous Core Technologies in the Midsouth. *Midcontinental Journal of Archaeology* 11(2):135–151.

Johnson, L., Jr.
1989 *Great Plains Interlopers in the Eastern Woodlands during Late Paleoindian Times: The Evidence from Oklahoma, Texas, and Areas Close By.* Office of the State Archeologist Report 36, Texas Historical Commission, Austin, Texas.

1991 *Early Archaic Life at the Sleeper Archaeological Site, 41BC65 of the Texas Hill Country, Blanco County, Texas*. Publications in Archaeology, Report No. 39. Texas State Department of Highways and Public Transportation. Austin.

Jones, J. K., Jr., and C. Jones
1992 Revised Checklist of Recent Land Mammals of Texas, with Annotations. *The Texas Journal of Science*, 44(1):53–74.

Karbula, J. W.
2000 Investigations of the Eckols Site (41TV528): A Stratified Prehistoric Terrace Stie on Barton Creek in Travis County, Texas. Unpublished Ph.D. dissertation, Department of Anthropology, The University of Texas, Austin.

Keith, M. L., G. M. Anderson, and R. Eichler
1964 Carbon and Oxygen Isotopic Composition of Mollusk Shells from Marine and Fresh-Water Environments. *Geochímica et Cosmochímica Acta* 28:1757–1786.

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

1989 Morphological Study of the Lerma/Desmuke Problem. Paper presented at the Annual Texas Archeological Society Meeting, Amarillo, Texas

Kendall, C., and T. B. Coplen
2001 Distribution of Oxygen-18 and Deuterium in River Waters Across the United States. *Hydrological Processes* 15(7):1363–1393.

Kent, S.
1984 *Analyzing Activity Areas: An Ethnoarchaeological Study of the Use of Space*. Albuquerque: University of New Mexico Press, pp. 164–226.

Kilmer, V. J., and L. T. Alexander
1949 Methods of Making Mechanical Analyses of Soils. *Soil Science* 68:15–24.

Kimball, L. R.
1981 An Analysis of Residential Camp Site Structure for two Early Archaic Assemblages from Rose Island (40MR44), Tennessee. Unpublished Master's thesis, Department of Anthropology. University of Tennessee, Knoxville.

1993 Rose Island Revisited: The Detection of Early Archaic Site Structure Using Grid-Count Data. *Southeastern Archaeology* 12(2):93–116.

1996 Early Archaic Settlement and Technology: Lessons from Tellico. In *The Paleoindian and Early Archaic Southeast*, edited by David G. Anderson and KennethE. Sassaman, pp. 149–186. The University of Alabama Press, Tuscaloosa.

Kirch, P. V.
1982 The Archaeological Study of Adaptation: Theoretical and Methodological Issues. In *Advances in Archaeological Method and Theory: Selections for Students from Vol.s 1 through 4*, edited by Michael B. Schiffer, pp.101–156. Academic Press, New York.

Kotter, S. M.
1985 *Cherry Tree Shelter: Excavation of a Stratified Late Archaic and Neoarchaic Rockshelter, Travis County, Texas*. Texas Archaeological Survey. Research Report 92. The University of Texas, Austin.

Krieger, A. D. (editor)
2002 *We Came Naked and Barefoot: The Journey of Cabeza de Vaca Across North America*. The University of Texas Press, Austin.

Krumbein, W. C., and F. A. Graybill
1965 *An Introduction to Statistical Models in Geology.* McGraw-Hill, New York.

'Ksan, People of
1980 *Gathering What the Great Nature Provided: Food Traditions of the Gitksan.* University of Washington Press, Seattle.

Kuchler, A. W.
1985 *Potential Natural Vegetation* [map, revised from 1966 edition]. National Atlas of the United States of the America, Department of the Interior, U.S. Geological Survey, Reston Virginia.

Kuhn, S. L.
1990 *Diversity within Uniformity: Tool Manufacture and Use in the "Pontinian" Mousterian of Latium (Italy).* Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

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

Largent, F. B., Jr., M. R. Waters, and D. L. Carlson
1991 The Spatiotemporal Distribution and Characteristics of Folsom Projectile Points in Texas. *Plains Anthropologist*, 36(137):323–341.

Larson, D. A., V. M. Bryant, Jr., and T. S. Patty
1972 Pollen Analysis of a Central Texas Bog. *American Midland Naturalist,* 88:358–367.

Lawrence, B.
1951 Part II. Post-cranial Skeletal Characters of Deer, Pronghorn, and Sheep-Goat with Notes on Bos and Bison. *Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University*, 35(3). Cambridge, Massachusetts.

LéColle, P.
1985 The Oxygen Isotope Composition of Landsnail Shells as a Climatic Indicator: Applications to Hydrogeology and Paleoclimatology. *Chemical Geology (Isotope Geology Section)* 68:157–181.

Lee, R. B.
1969 What Hunters Do for a Living. In *Man the Hunter,* edited by Richard B. Lee and Irven Devore, pp. 30–48. Aldine, Chicago.

Leventer, A., D.F. Williams, and J.P. Kennett
1982 Dynamics of the Laurentide Ice Sheet during the Last Deglaciation: Evidence from the Gulf of Mexico. Earth and Planetary Science Letters 59:11–17.

Lintz, S. C.
1989 Experimental Thermal Discoloration and Heat Conductivity Studies of Caliche from Eastern New Mexico. *Geoarchaeology: An International Journal* 4(4):319–346.

MacDonald, G. F.
1968 Debert: A Paleo-Indian Site in Central Nova Scotia. National Museum of Canada Anthropology Papers 16, Ottawa.

Maclay, R. W., P. L. Rettman, and T. A. Small
1980 *Hydrochemical Data for the Edwards Aquifer in the San Antonio Area, Texas*. Texas Department of Water Resources Publication LP-131. In cooperation with the US Geological Survey and the City Water Board of San Antonio.

Magaritz, M., and J. Heller
1983 Annual Cycle of $^{18}O/^{16}O$ and $^{13}C/^{12}C$ Isotopic Ratios in Landsnail Shells. *Isotopic Geoscience* 1:43–255.

Magaritz, M., J. Heller, and M. Volokita
1981 Land-air Boundary Environment as Recorded by the $^{18}O/^{16}O$ and $^{13}C/^{12}C$ Isotope Ratios in the Shells of Land Snails. *Earth and Planetary Science Letters* 52:101–106.

Mahler, W. F.
1988 *Shinners' Manual of the North Central Texas*. Southern Methodist University Herbarium, Dallas Texas.

Mandel, R. D.
1991 Geoarchaeology of a Deeply-Stratified Paleoindian Through Late Prehistoric Site (41BX831) in the Lower Medina River Valley, South Texas. Paper presented at the 49th Plains Anthropological Conference, Lawrence, Kansas.

Mandel, R. D. and E. A. Bettis III
2001 Use and Analysis of Soils by Archaeologists and Geoscientists: A North American Perspective. In *Earth Science in Archaeology*, edited by Paul Goldberg, Vance T. Holliday, and C. Reid Ferring, pp. 173–204. Kluwer Academic/Plenum, Norwell, Massachusetts.

Mandel, R. D. and J. Jacob
1992 Pedostratigraphy: Richard Beene site (41BX831). In *Late Cenozoic Alluvia Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

Mandel, R.D., L.C. Nordt, and J.S. Jacob
1995 Late Quaternary Landscape Evolution and Paleoenvironments in the Medina River Valley, South-Central Texas. Presented at the Annual Meeting of the Association of American Geographers, Abstracts, p. 193.

Mandel, R. D., J. Saunders, G. Hall, and S. McCulloch
2008 Geomorphological Assessment. In *Prehistoric Sites Investigations in the Applewhite Reservoir Area, Bexar County, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Mason, J. B.
2003 Analysis of Site Structure and Post-Depositional Disturbance at Two Early Holocene Components, Richard Beene Site (41BX831), Bexar County, Texas. Unpublished Master's thesis, Department of Anthropology, Texas A&M University, College Station.

Masson, M. A.
2000 Analysis of Debitage. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas: Vol. III: Artifacts and Special Artifact Studies*, assembled and edited by Michael B. Collins, pp. 683–702. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas, Austin.

McAndrews, J. H., and D. A. Larson
1966 Pollen Analysis of Eagle Cave. In *Preliminary Paleoecology of the Amistad Reservoir Area*, edited by Dee A. Story and Vaughn M. Bryant, Jr., pp. 179–184. Final Report of Research (NSF grant GS-667), The University of Texas at Austin.

McClure, W. L.
1991 Otoliths of Some Texas Fish (Centrarchidae and Sciaenidae). *Texas Archeology* 35(1):14.

McConnaughey, T. A., J. Burdett, J. F. Whelan, and C. K. Paull
1997 Respiration and Photosynthesis: Effects on the Carbon-13 Content of Biological Carbonates. *Geochimica et Cosmochimica Acta* 61:611–622.

McCormick, O. F., III, R. E. Filson, and J. L. Darden
1975 *The Xerox-Lewisville Archaeological Project*. Institute for Environmental Studies, University of North Texas, Denton.

McCrea, J. M.
1950 On the Isotope Chemistry of Carbonates and a Paleotemperature Scale. J*ournal of Chemical Physics* 18:849–857.

McClell and Engineers, Inc.
1985 Geotechnical Investigations, Applewhite Project, San Antonio City Water Board, Vol. II, Spillway and South Embankment: Data. Report on File, Freese and Nichols, Inc., Fort Worth, Texas.

McCulloch, S., J. Saunders, G. Hall, J. Miller, and C. Freuden
2008 Test-Excavated Sites. In *Prehistoric Sites Investigations in the Applewhite Reservoir Area, Bexar County, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

McGraw, A. J.
1985 An Overview of the Prehistoric of the Upper Salado Creek Watershed. In *The Panther Springs Creek Site: Cultural Change and Continuity within the Upper Salado Creek Watershed, South-Central Texas*, edited by Stephen L. Black and A. Joachim McGraw, pp. 303–326. Archaeological Survey Report, No. 100, Center for Archaeological Research, The University of Texas at San Antonio.

McGraw, A. J. and K. Hindes
1987 *Chipped Stone and Adobe: A Cultural Resources Assessment of the Proposed Applewhite Reservoir, Bexar County, Texas*. Center for Archaeological Research, Archaeological Survey Report, No. 163, The University of Texas at San Antonio.

McMahan, C. A., R. G. Frye, and K. L. Brown
1984 The Vegetation Types of Texas: An Illustrated Synopsis to Accompany the Map. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas, 78744

McParland, P.
1977 Experiments in the Firing and Breaking of Rocks. *The Calgary Archaeologist*, 5:1–33.

Melillo, J. M., J. D. Aber, A. E. Linkins, A. Ricca, B. Fry, and K. J. Nadelhoffer
1989 Carbon and Nitrogen Dynamics along the Decay Continuum: Plant Litter to Soil Organic Matter. Plant and Soil 115:189–198.

Meltzer, D. J.
1986 The Clovis Paleoindian Occupation of Texas: Results of the Texas Clovis Fluted Point Survey. *Bulletin of the Texas Archeological Society*, 57:27–68.

Morse, D. F.
1973 Dalton Culture in Northeast Arkansas. *Florida Anthropologist* 26(1):23–38.

Murray, H. D.
1981 Unionids from Indian Sites in McMullen and Live Oak Counties, Texas. *Bulletin of the American Malacological Union* 1981:10–11.

Nadelhoffer, K. F. and B. Fry
1988 Controls on Natural Nitrogen-15 and Carbon-13 Abundances in Forest Soil Organic Matter. Soil Science Society of America Journal 52:1633–1640.

Nalley, G. M.
1989 *Compilation of Hydrologic Data for the Edwards Aquifer, San Antonio Area, Texas, 1988, with 1934–1988 Summary*. Bulletin 48. Edwards Aquifer Water District. San Antonio. In cooperation with the USGS.

Nalley, G. M., and M. W. Thomas
1990 *Compilation of Hydrologic Data for the Edwards Aquifer, San Antonio Area, Texas, 1989, with 1934–1989 Summary*. Bulletin 49. Edwards Aquifer Water District. San Antonio. In cooperation with the USGS.

National Oceanic and Atmospheric Administration
2006 Monthly/Annual/Average Precipitation, San Antonio, Texas (1871–June 2006). National Weather Service Forecast Office, Austin/San Antonio, Texas. http://www.srh.noaa.gov/ewx/html/cli/sat/satmonpcpn.htm

Neck, R. W.
1983 Paleoenvironmental Significance of a Nonmarine Pleistocene Mulluscan Fauna from Southern Texas. *Texas Journal of Science* 35(1):147–154.

1985 Paleoecological Implications of a Holocene Fossil Assemblage, Lower Rio Grande, Cameron County, Texas. *Pearce-Sellards Series (Texas Memorial Museum)* 41:1–20.

1987 Terrestrial Gastropod Succession in a Late Holocene Stream Deposit in South Texas. *Quaternary Research* 24(2):202–209.

1989 Freshwater Bivalves of Medina Lake, Texas: Factors Producing a Low-diversity Fauna. *The Texas Journal of Science* 41(4):319–325.

1990 Ecological Analysis of the Living Molluscs of the Texas Panhandle. *American Malacological Bulletin* 8(1):9–18.

1991 Diary of Jean Louis Berlandier: An Environmental View of South Texas and Adjacent Mexico, 1828–1834. In *A Texas Legacy: The Old San Antonio Road and the Caminos Reales, A Tricentennial History, 1691–1991*, edited by A. Joachim McGraw, John W. Clark, Jr., and Elizabeth A. Robbins, pp. 269–281. Texas State Department of Highways and Public Transportation, Austin, Texas.

1992 Late Pleistocene and Holocene Environments in the Medina Valley of Texas as Revealed by Nonmarine Molluscs. In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas,* edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

n.d. Survey of Living Gastropods in Prairie Remnants in Texas. Ms. in possession of author.

Nelson, D. W., and L. E. Sommers
1980 Total Carbon, Organic Carbon, and Organic Matter. In *Methods of Soil Analysis, Part 2 - Chemical and Microbiological Properties,* 2nd ed., edited by A. L. Page, R. H. Miller, and D. R. Keeney, pp. 539–579. Monograph No. 9, American Society of Agronomy, Madison, Wisconsin.

Nikiforoff, C. C.
1949 Weathering and Soil Evolution. *Soil Science* 67:219–230.

Nordt, L. C.
1993 *Archaeological Geology of the Fort Hood Military Reservation, Fort Hood, Texas*. U.S. Army Fort Hood, Archaeological Resources Management Series, Research Report No. 25.

2001 Stable Carbon and Oxygen Isotopes in Soils: Applications fro Archaeological Research. *Earth Science in Archaeology,* edited by Paul Goldberg, Vance T. Holliday, and C. Reid Ferring, pp. 419–448. Kluwer Academic/Plenum, Norwell, Massachusetts.

2002 C4 Plant Productivity and Climate-CO2 Variations in South-Central Texas during the Late Quaternary. Quaternary Research 58:182–188.

Nordt, L. C., T. W. Boutton, J. S. Jacob, and R. D. Mandel
1994 Late Quaternary Climates of Central Texas Based on the Stable Isotopic Composition of Organic Carbon. Presented at the 52nd Annual Plains Conference, Lubbock, Texas.

1995 $\delta^{13}C$ of Paleosol Organic Carbon Indicates Vegetation and Climate Change during the Last 15,000 years in the Southern Great Plains. Paper presented at the Annual meeting of the Ecological Society of America.

Nordt, L.C., T.W. Boutton, C.T. Hallmark, and M.R. Waters
1993 Late Quaternary Vegetation and Climate Changes in Central Texas Based on the Isotopic Composition of Organic Carbon. *Quaternary Research* 41:109–120.

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

O'Connell, J. F.
1987 Alyawara Site Structure and its Archaeological Implications. *American Antiquity* 52:74 108.

Odum, E. P.
1971 *Fundamentals of Ecology*. W. B. Saunders, Philadelphia.

O'Leary, M. H.
1981 Carbon Isotope Fractionation in Plants. *Phytochemistry* 20:553–567.

Parmalee, P. and W. Kippel
1974 Freshwater mussels as a prehistoric food resource. *American Antiquity* 39:421–434.

Parry, W.J., and R.L. Kelly
1985 Expedient Core Technology and Sedentism. In: *The Organization of Core Technology*, edited by Jay K. Johnson and Carol A. Morrow, pp. 285–304. Westview Press, Boulder.

Patton, P. C., and V. R. Baker
1982 Morphometry and Floods in Small Drainage Basins Subject to Diverse Hydogeomorphic Controls. *Water Resources Research* 15:941–952.

Paul, E. A.
1969 Characterization and Turnover Rate of Soil Humic Constituents. In *Pedology and Quaternary Research,* edited by Stephen Pawluk, pp. 63–76. University of Alberta Printing Department, Edmonton, Alberta.

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

Pierce, C.
1984 Analysis of Cooking Stones from a Late Period Chumash Village. Paper presented at the 49th Annual Meeting of the Society for American Archaeology, Portland, Oregon.

Plog, F., and D. L. Carlson
1989 Computer Applications for the All American Pipeline Project. *Antiquity* 63:256–267.

Potter, D.R.
1995 Past and Present Environments. In *Archeology along the Wurzbach Parkway. Module 1, Introduction, Conceptual Framework, and Contexts of Archaeological Investigations in Bexar County, South-Central Texas*, edited by Daniel R. Potter, Stephen L. Black, and Kevin Jolly, pp.7–18. Texas Archeological Research Laboratory, The University of Texas, Austin.

Prikryl, D. J.
1990 *Lower Elm Fork Prehistory: A Redefinition of Cultural Concepts and Chronologies along the Trinity River, North-Central Texas*. Office of the State Archeologist Report No. 37. Texas Historical Commission, Austin.

Quade, J., T. E. Cerling, and J. R. Bowman
1989 Systematic Variations in Carbon and Oxygen Isotopic Composition of Pedogenic Carbonate along Elevation Transects in the Southern Great Basin, United States. *Geological Society of America Bulletin* 101, 464–475.

Quigg, J. M., C. Lintz, G. Smith, and G. Monks
2000 *Lino Site: A Stratified Late Archaic Campsite in a Terrace of the San Idelfonzo Xewwk Webb County, Southern Texas*. Technical Report No. 23756, TRC Mariah Associates, Inc., Austin and Archeological Studies Program, Report No 20., Texas Department of Transportation, Environmental Affairs Division, Austin.

Quigg, J. M., M. E. Malainey, R. Przybylski, and G. Monks
2001 No Bones about It: Using Lipid Analysis of Burned Rocks and Ground Stone Residues to Examine Late Archaic Substances Practices in South Texas. *Plains Anthropologists* 46(77):283–303.

Reeves, B. O. K.
1990 Communal Bison Hunters of the Northern Plains. In *Hunters of the Recent Past*, edited by Leslie B. Davis and Brian O.K. Reeves, pp. 168–194. Unwin Hyman, London.

Reid, K.
1977 *Psorelea esculenta* as a Prairie Resource: An Ethnographic Appraisal. *Plains Anthropologist* 22(78, part 1):321–327.

Reische, A. K.
1998 Seasonal Variation in 13-C of Dissolved Inorganic Carbon and Aragonitic Shell of Fresh-Water Bivalves (Unionidae) in the Huron River and Fleming Creek, Michigan. Unpublished Master's thesis, Department of Geological Sciences, University of Michigan. Summarized on website at http://www.geo.lsa.umich.edu/~kacey/mill/rec_unio.html

Reily, P., and S. Rahtz
1992 *Archaeology and the Information Age: A Global Perspective*. Routledge, London.

Ricken, W., T. Steuber, H. Freitag, M. Hirschfeld, and B.Niedenzu
2001 Recent and historical discharge of a large European river system - oxygen isotopic composition of river water and skeletal aragonite of Unionidae in the Rhine. *Paleogeography, Paleoclimatology, Paleoecology* 193:73–86.

Ricklis, R. A., and M. B. Collins
1994 *Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas.* Studies in Archeology 1 and 2(19). Texas Archaeological Research Laboratory, The University of Texas, Austin.

Ritchie, W. A.
1957 *Traces of Early Man in the Northeast*. New York State Museum and Science Service Bulletin 367.

Robbins, E. A.
1991a The First Routes into Texas: A Review of Early Diaries. In *A Texas Legacy, The Old San Antonio Road and the Caminos Reales: A Tricentennial History, 1691–1991*, edited by A. Joachim McGraw, John W. Clark, Jr., and Elizabeth A. Robbins, pp. 61–113. Texas State Department of Highways and Public Transportation, Austin.

1991b The Natural Setting Encountered: The Scenic Landscape. In *A Texas Legacy: The Old San Antonio Road and the Caminos Reales, A Tricentennial History, 1691–1991*, edited by A. Joachim McGraw, John W. Clark, Jr., and Elizabeth A. Robbins, pp. 245–268. Texas State Department of Highways and Public Transportation, Austin, Texas.

Robinson, R. L.
1979 Biosilica and Climatic Change at 41GD21 and 41GD21A. In *Archaeological Investigations of Two Prehistoric Sites on the Coleto Creek Drainage, Goliad County, Texas*, edited by Daniel E. Fox. The University of Texas at San Antonio, Center for Archaeological Research, Archaeological Survey Report, 69:126–138.

1982 Biosilica Analysis of Three Prehistoric Archaeological Sites in the Choke Canyon Reservoir, Live Oak County, Texas: Preliminary Summary of Climatic Implications. In *Archaeological Investigations at Choke Canyon Reservoir, South Texas: The Phase I* Findings, edited by Grant D. Hall, Stephen L. Black, and Carol Graves. The University of Texas at San Antonio, Center for Archaeological Research, Choke Canyon Series 5:597–610.

Rogers, R.
1997 *National Register Testing at Site 41LE120, Sandow Mine, Lee County, Texas*. Document No. 970348 (EH&A Job No. 17359), Espey, Huston & Associates, Inc., Austin, Texas.

Rogers, R. and S. Kotter
1995 *Archaeological Investigations at the Chesser Site (41LE59) at the Sandow Lignite Mine, Lee County, Texas*. Espey, Huston & Associates, Inc., Austin, Texas.

Rozanski, K., L. Araguás-Araguás, and R. Gonfiatini
1993 Isotopic Patterns in Modern Global Precipitation. In *Climatic Change in Continental Isotope Records*, edited by Peter K. Swart, Kyger C. Lohmann, Judith A. McKenzie, and Samuel M. Savin, pp. 1–36. Geophysical Monograph 78. American Geophysical Union. Washington, DC.

Sanchez, J. M.
1926 A Trip to Texas in 1828. Translated by C. E. Castaneda. *Southwestern Historical Quarterly* 29(4):269.

Schalk, R. F., and D. Meatte
1988 The Archaeological Features. In *The Archaeology of Chester Morse Lake: The 1986–87 Investigations for the Cedar Falls Improvement Project*, edited by Randall F. Schalk and Richard L. Taylor, pp. 8.1–8.58. Report submitted to the Seattle Water Department. Center for Northwest Anthropology, Washington State University, Seattle Research Unit.

Scharpenseel, H. W.
1975 Radiocarbon Dating of Soils-Problems, Troubles, Hopes. In *Paleopedology: Origin, Nature, and Dating of Paleosols*, edited by Dan H. Yaalon, pp. 77–88. Israel University Press, Jerusalem.

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

Schmidly, D. J.
1983 *Texas Mammals East of the Balcones Fault Zone*. Texas A&M Press, College Station.

Schoene, B. S. and K. W. Flessa
2002 Sclerochronology and High Resolution Ecological Reconstruction in a Bivalve Mollusk. G*eological Society of America Abstracts with Programs* 31(7):A–461. Denver.

Schroeder, E. A. and E. R. Oksanen
2002 *Data Recovery at the Armstrong Site (41CW54) Caldwell County, Texas Vol. I: Background, Methods, and Site Context*. PPA Cultural Resources Report 0284. Paul Price Associates, Inc., Austin, Texas.

Schwartz, D. P.
1988 Space-Time Clustering of Large Earthquakes: A Western U.S. Perspective with Implications for the East. *Seismological Research Letters* 59:318.

Schwartz. D., A. Mariotti, R. Lanfranchi, and B. Guillet
1986 $^{13}C/^{12}C$ Ratios of Soil Organic Matter as Indicators of Vegetation Changes in the Congo. *Geoderma* 39:97–103.

Scott, R. F.
1982 Part I: Prehistoric Investigations. In *Excavations at Sites . 41LK31/32 and 41LK202 in the Choke Canyon Reservoir South Texas*. Choke Canyon Series 8. Center for Archaeological Research, The University of Texas at San Antonio.

Seidel, M. E. and H. M. Smith
1986 Chrysemys, Pseudemys, Trachemys (Testudines: Emydidae): Did Agassiz Have it Right? *Herpetologica*, 42(2):242–248.

1961 Fossil Vertebrates from Longhorn Cavern Burnet County, Texas. *The Texas Journal of Science*, 13(3):290–310.

Sellards, E. H., W. S. Adkins, and F. B. Plummer
1967 The Geology of Texas. Bureau of Economic Geology *Bulletin 3232*. The University of Texas, Austin.

Semken, H. A., Jr.
1961 Fossil Vertebrates from Longhorn Cavern Burnet County, Texas. *The Texas Journal of Science*, 13(3):290–310.

Shafer, H. J.
1975 Clay Figurines from the Lower Pecos Region, Texas. *American Antiquity,* 40(2):148–158.

1986 *Ancient Texans: Rock Art and Lifeways Along the Lower Pecos*. Texas Monthly Press, San Antonio.

Shaffer, B. S.
1991 The Economic Importance of Vertebrate Faunal Remains from the Nan Ruin (LA 15049): A Classic Mimbres Site, Grant County, New Mexico. Unpublished Master's thesis, Texas A&M University, College Station.

Shiner, J. L.
1975 The Clear Fork Gouge Revisited. *Bulletin of the Texas Archeological Society* 46:179–188.

Smith, A. H.
2000 Kalispel Ethnography and Ethnohistory. In *The Calispell Valley Archaeological Project Final Report, Vol. 1, Project Background and Environmental Context*, edited by William Andrefsky, Jr., Greg C. Burtchard, Kira M. Presler, Stephen R. Samuels, Paul H. Sanders, and Alston V. Thoms, pp. 4.10–4.46. Project Report No. 16. Pullman, WA: Center for Northwest Anthropology, Department of Anthropology, Washington State University.

Smith, B. D.
1986 The Archaeology of the Southeastern United States: From Dalton to de Soto, 10,500–500B.P. *Advances in World Archaeology* 5:1–92, edited by Fred Wendorf and Angela E. Close. Academic Press, Inc., Orlando, Florida.

Smith, F. T.
2005 *From Dominance to Disappearance: The Indians of Texas and the Near Southwest, 1786–1859*. University of Nebraska Press, Lincoln.

Sobolik, K. D. and D. G. Steele
nd. A Turtle Atlas to Facilitate Archaeological Identifications. Manuscript on file, Zooarchaeological Research Laboratory, Department of Anthropology, Texas A&M University, College Station.

Soil Survey Staff
1984 Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey. Soil Survey Investigation Report 1, U.S. Department of Agriculture-Soil Conservation Service, Washington, D.C.

1992 *Keys to Soil Taxonomy*. 5th ed. Soil Management Support Services Technical Monograph No. 19, Pocahontas Press, Blacksburg, Virginia.

South, S.
1979 Historic Site Content, Structure, and Function. *American Antiquity* 44:213–237.

Spero, H.J., and D.F. Williams
1990 Evidence for Seasonal Low Salinity Surface Waters in the Gulf of Mexico over the Last 16,000 Years. Paleoceanography 5:963–975.

Strecker, J.
1931 The Distribution of Naiades or Pearly Fresh-Water Mussels of Texas. *Baylor University Museum Bulletin* 2, Waco, Texas.

Steele, D. G.
1986a Analysis of Vertebrate Faunal Remains. In *The Clemente and Herminia Hinojosa Site, 41JW8: A Toyah Horizon Campsite in Southern Texas*, edited by Stephen L. Black, pp. 108–136. Special Report No. 18. Center for Archaeological Research, The University of Texas at San Antonio.

1986b Appendix V. Analysis of Vertebrate Faunal Remains from 41LK201, Live Oak County, Texas. In *Archaeological Investigations at 41LK201, Choke Canyon Reservoir, South Texas*, edited by Cheryl Lynn Highley, pp. 200–249. Choke Canyon Series, Vol. 11. Center for Archaeological Research, The University of Texas at San Antonio.

Steele, D. G. and C. A. Hunter
1986 Appendix III. Analysis of Vertebrate Faunal Remains from 41MC222 and 41MC296, McMullen County, Texas. In *The Prehistoric Sites at Choke Canyon Reservoir, Southern Texas: Results of Phase II Archaeological Investigations*, edited by Grant D. Hall, Thomas R. Hester and Stephen L. Black, pp. 452–502. Choke Canyon Series, Vol. 10. Center for Archaeological Research, The University of Texas at San Antonio.

Stevenson, M.
1991 Beyond the Formation of Hearth-Associated Assemblages. In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll and T. Douglas Price, pp. 269–300. Plenum Press, New York.

Stewart, M. C.
1977 Pits in the Northwest: A Typological Analysis. In *Current Perspectives in Northeastern Archeology Essays in Honor of William Ritchie,* edited by Robert E. Funk and Charles F. Hayes III. Researches and Transactions of the New York State Archeological Association 17:1. New York.

Stout, J. D., and T. A. Rafter
1978 The 13C/12C Isotopic Ratios of Some New Zealand Tussock Grassland Soils. In Stable Isotopes in the Earth Sciences, edited by B. W. Robinson, pp. 75–83. DSIR Bulletin 220. Wellington, New Zealand.

Strecker, J.
1931 The Distribution of Naiades or Pearly Fresh-Water Mussels of Texas. Baylor University Museum Bulletin 2, Waco, Texas.

Stuiver, M.
1968 Oxygen 18 Content of Atmospheric Precipitation During the Last 11,000 Years in the Great Lakes Region. *Science* 162:994–995.

1970 Oxygen and Carbon Isotope Ratios of Fresh-Water Carbonates as Climatic Indicators. *Journal of Geophysical Research* 75(27):5247–525.

Swanton, J. R.
1946 The Indians of the Southeastern United States. Bureau of American Ethnology, Smithsonian Institution, Washington, D.C., *Bulletin*, 137:1–943.

Talbot, M. R.
1990 A Review of Paleohydrological Interpretation of Carbon and Oxygen Ratios in Primary Lacustrine Carbonates. *Chemical Geology (Isotope Geoscience Section)* 80:261–279.

Taylor, F. B., R. B. Hailey, and D. L. Richmond
1966 *Soil Survey of Bexar County, Texas*. United States Agriculture Department, Soil Conservation Service, in cooperation with the Texas Agricultural Experiment Station. U. S. Government Printing Office, Washington D. C.

Teeri, J. A., and L. G. Stowe
1976 Climatic Patterns and Distribution of C4 Grasses in North America. *Oecologia* 23:1–12.

Teller, J.T.
1990 Meltwater and Precipitation Runoff to the North Atlantic, Arctic, and Gulf of Mexico from the Laurentide Ice Sheet and Adjacent Regions during the Younger Dryas. *Paleoceanography* 5:897–905.

Teltser, P. A.
1991 Generalized Core Technology and Tool Use: A Mississippian Example. *Journal of Field Archaeology* 18:363–375.

Texas A&M University
2000 Assessment of Resources Available for Development of a Land Heritage Institute of the America. Unpublished report on file at the San Antonio Water System, San Antonio.

Thomas, D. H.
1991 *Archaeology: Down to Earth*. Harcourt Brace Javanovich College Publishers, Forth Worth, Texas.

Thoms, A. V.
1986 Hot Rocks: The Short-Term Storage of Energy in the Calispell Valley. In *Calispell Valley Archaeological Project Interim Report for 1984 and 1985 Field Seasons,* edited by Alston V. Thoms and Greg C. Burtchard, pp. 447–477. Contributions in Cultural Resource Management No. 10, Center for Northwest Anthropology, Washington State University, Pullman.

1989 The Northern Roots of Hunter-Gatherer Intensification: Camas and the Pacific Northwest. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Pullman.

1991a Applewhite Reservoir: Mitigation Phase Excavations at 41BX831, The Richard Beene Site. *APR News and Views*, 3(2):4. Department of Archeological Planning & Review, Texas Historical Commission, Austin.

1991b *Excavations at the Richard Beene Archaeological Site (41BX831), Lower Medina River Valley, South Texas*; Paper presented at the 62nd Annual Meeting, Texas Archeological Society, Austin.

1991c *Floodplain Environments and Archaeological Assemblages in the Lower Medina River Valley, South Texas;* Paper presented at the 49th Annual Plains Conference, Lawrence, Kansas.

1992a Late Pleistocene and Early Holocene Land Use Patterns: A Perspective from the Preliminary Results of Archaeological Studies at the Richard Beene Site, 41BX831, Lower Medina River, South Texas. In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas*, edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

1992b *Land Use Diversity on a Subtropical Landscape: Terminal Pleistocene and Early Holocene Archaeology, Lower Medina River Valley, South Texas*; Paper presented at the 57th Annual Meeting, Society for American Archaeology, Pittsburgh, Pennsylvania.

1993a Knocking Sense from Old Rocks: Typologies and the Narrow Perspective of the Angostura Point Type. *Lithic Technology* 18:16–27.

1993b The Structure of Natural Resources in the Post Oak Savannah: Regional Productivity Potential. In *The Brazos Slopes Archaeological project: Cultural Resource Assessment for Texas A&M University Animal Science Teaching and Research Complex, Brazos County, Texas,* edited by Alston V. Thoms, pp. 7–20. Reports of Investigations No. 14, Archaeological Research laboratory, Texas A&M University, College Station.

1994a Hunter-Gatherers and Horticulturalists in the Central Cross Timbers: Evidence from the Ethnohistoric and Archaeological Records. In *The Valley Branch Archaeological Project: Excavation at an Archaic Site (41MU55) in the Cross Timbers Uplands, North-Central Texas*, edited by Alston V. Thoms, pp. 25–39. Reports of Investigations No.15, Archaeological Research Laboratory, Texas A&M University, College Station.

1994b The Central Cross Timbers: Resource Productivity Potential from a Hunter-Gatherer Land-Use Perspective. In *The Valley Branch Archaeological Project: Excavations at an Archaic Site (41MU55) in the Cross Timbers Uplands, North-Central Texas*, edited by Alston V. Thoms, pp. 9–24. Reports of Investigations No. 15, Archaeological Research Laboratory, Texas A&M University, College Station.

1994c Proposal for Feature Recovery, Survey, and Site Assessment at Lake Koocanusa and Other Kootenai Forest Lands. On file at the Center for Ecological Archaeology Laboratory. Texas A&M University, College Station.

1995a Late Paleoindian Phantoms and Early Archaic Land-Use Strategies: A Perspective from the Southeastern Periphery of the Southern Plains. 60th Annual Meeting, Society for American Archaeology, Minneapolis, Minnesota.

1995b Sediments and Natural Site Formation Processes at 41WT5. In *The Anson Jones Plantation: Archaeological and Historical Investigations at 41WT5 and 41WT6, Washington County, Texas*, edited by Shawn B. Carlson, pp. 107–132. Reports of Investigations No. 2. Center for Environmental Archaeology, Texas A&M University, College Station.

1996 1995 Investigations at the Richard Beene Site, South-Central Texas. *Cultural Resource Management News & Views* 8(1):10–17.

1996 Cook-Stone Archaeology in Texas: Assessing the Nature of Fire-Cracked Rock Features in South-Central North America. Symposium at the 67th Annual Meeting of the Texas Archeological Society, San Antonio, Texas.

1997 Late Pleistocene and Early Holocene Regional Land Use Patterns: A Perspective from the Preliminary Results of Archaeological Studies at the Richard Beene Site, 41BX831, Lower Medina River, South Texas. In *Late Cenozoic Alluvial Stratigraphy and Prehistory of the Inner Gulf Coastal Plain, South-Central Texas,* edited by Rolfe D. Mandel and S. Christopher Caran. Guidebook: 10th Annual Meeting of the Friends of the Pleistocene. Manuscript on file, Kansas Geological Society, University of Kansas, Lawrence.

1998 Earth Ovens and Plateau Root Foods. In *Archaeology of Prehistoric North America: An Encyclopedia*, Plateau editor, David Pokotylo, pp. 232–235, 664–666. Garland Publishing, Inc., New York.

2001 *Reassessing Cultural Extinction: Change and Survival at Mission San Juan Capistrano, Texas*. Reports of Investigations No. 4, edited by Alston V. Thoms. Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V.

2003 Cook-Stone Technology in North America: Evolutionary Changes in Domestic Fire Structures During the Holocene. In *Le Feu Domestique et ses Structures au Neolithique et aux Ages des Metaux*, edited by Marie-Chantal Frere-Sautot, pp. 87–96. Collection Prehistories No. 9, Editions Monique Mergoil, Saint-Apollinaire, France.

2004a Natural Resource Structure and Land-Use Potential in the Middle Reach of the Yegua Creek Basin. In *Yegua Creek Archaeological Project: Survey Results from Lake Somerville State Parks and Trailway, East-Central Texas*, edited by Alston V. Thoms, pp.9–28. Reports of Investigations No. 5, Center for Ecological Archaeology, Texas A&M University, College Station.

2004b An Assessment of Archaeological Records at Late Somerville State Parks and Trailway: Past Land-Use Patterns and Future Research Directions. In *Yegua Creek Archaeological Project: Survey Results from Lake Somerville State Parks and Trailway, East-Central Texas*, edited by Alston V. Thoms, pp. 169–186. Reports of Investigations No. 5, Center for Ecological Archaeology, Texas A&M University, College Station.

2004c Yegua Creek Archaeological Project: Survey Results from Lake Somerville State Parks and Trailway, East-Central Texas. Reports of Investigations No. 5. Center for Ecological Archaeology, Texas A&M University, College Station.

2007 Cook-Stone Feature Preservation Issues and Site Integrity in Lake Koocanusa and Vicinity. In *Sites and Site Formation Processes in the Tobacco Plains and Vicinity: Archaeological Investigations in the Middle Kootenai River Valley, Northwest Montana*, edited by Alston V. Thoms and Patricia A. Clabaugh, pp 311–336. Reports of Investigations No. 9. Center for Ecological Archaeology, Texas A&M University, College Station.

2007 Ethnographically Documented Land-Use Patterns and Archaeological Expectations. In *Sites and Site Formation Processes in the Tobacco Plains and Vicinity: Archaeological Investigations in the Middle Kootenai River Valley, Northwest Montana*, edited by Alston V. Thoms and Patricia A. Clabaugh, pp. 59–75. Reports of Investigations No. 9, Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V., and S. W. Ahr
1995 The Pampopa-Talon Crossing and Heermann Ranch Sites: Preliminary Results of the 1994 Southern Texas Archaeological Association Field School. *La Tierra* 22(2):34–67.

Thoms, A. V., S. W. Ahr, and P. A. Clabaugh
2008 The Pampopa-Talon Crossings and Heermann Ranch Sites: Preliminary Results of the 1994 Southern Texas Archaeological Society Field School. In *Prehistoric Sites Investigations in the Applewhite Reservoir Area, Bexar County, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Thoms, A. V., S. W. Ahr, D. D. Kuehn, and R. D. Mandel
2001 Archaeological Survey Methods and Results. In *A Cultural Resources Survey of a Proposed Water Pipeline Route in South Bexar* County, edited by Alston V. Thoms, pp. 29–42. Technical Report No. 3, Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V. and P. A. Clabaugh
1994 Residue Analysis as Assessments of Artifact and Feature Function: Analysis of Replicated Specimens and Stone Artifacts from 41MU55. In *The Valley Branch Archaeological Project: Excavation at an Archaic Site (41MU55) in the Cross Timbers Uplands, North-Central Texas*, edited by Alston V. Thoms, pp. 151–166. Reports of Investigations No.15, Archaeological Research Laboratory, Texas A&M University, College Station.

Thoms, A.V., P. A. Clabaugh, S. Thomas, and M. Kamiya
2005 *Archaeological Survey and Monitoring in 2005 at the Richard Beene Site, South-Central Texas.* Technical Report No. 7, Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V., D. K. Kuehn, B. Olive, J. Dockall, P. Clabaugh, and J. Johnson
1996 Early and Middle Holocene Occupations at the Richard Beene Site: The 1995 Southern Texas Archaeological Association Field School Project. *La Tierra* 23 (4):8–36.

Thoms, A. V., and R. D. Mandel
1992 The Richard Beene Site: A Deeply Stratified Paleoindian to Late Prehistoric Occupation in South-Central Texas. *Current Research in the Pleistocene* 9:42–44.

Thoms, A. V., and J. B. Mason
2001 Environmental Setting. In *Prehistoric and Historic Occupation in Central Brazos County: Archaeological Investigations of Two City Parks, Veterans Park and Athletic Complex and Lick Creek Park, College Station, Texas*, edited by J. Phillip Dering and J. Bryan Mason, pp. 5–22. Technical Report No. 4, Center for Ecological Archaeology, Texas A&M University, College Station.

Thoms, A. V., J. L. Montgomery, and A. W. Portnoy
1981 *An Archaeological Survey of a Portion of the Choke Canyon Reservoir Area in McMullen and Live Oak Counties, Texas*. Center for Archaeological Research, Choke Canyon Series: Vol. 3, Center for Archaeological Research, The University of Texas at San Antonio.

Thoms, A. V. and B. W. Olive
1997 A Late Holocene Component from Multi-component Site 41BX859. *News and Views: Cultural Resources Management* (Texas Historical Commission), 9(2):16–19.

Thoms, A. V., B. O. Olive, and P. A. Clabaugh
1994 Disarticulation of the Valley Branch Site: Landscape Evolution and Natural Site Formation Processes. In *The Valley Branch Archaeological Project: Excavation at an Archaic Site (41MU55) in the Cross Timbers Uplands, North-Central Texas*, edited by Alston V. Thoms, pp. 167–185. Reports of Investigations No.15, Archaeological Research Laboratory, Texas A&M University, College Station.

Thoms, A. V., B. O. Olive, D. D. Kuehn, J. Dockall, and P. A. Clabaugh
2008 Investigations at 41BX859: A Stratified Late Holocene Site. In *Prehistoric Sites Investigations in the Applewhite Reservoir Area, Bexar County, Texas*, edited by David L. Carlson. Reports of Investigations No. 7, Center for Ecological Archaeology, Texas A&M University, College Station, in press.

Thornthwaite, C. W
1948 An Approach Toward a rational Classification of Climate. *Geographical Review* 38:55–94.

Tous, G.
1930a The Espinosa-Olivares-Aquirre Expedition of 1709: Espinosa's Diary. Preliminary Studies of the Texas Catholic Historical Society 1(3):2–14.

1930b Ramaón Expedition: Espoinosa's Diary of 1716. *Preliminary Studies of the Texas Catholic Historical Society* 1(4):2–24.

Toweill, D. E.
1976 Movements of Ringtails in Texas' Edwards Plateau Region. Unpublished Master's thesis, Department of Wildlife and Fisheries Sciences, Texas A&M University. College Station.

Trigger, B. C.
1999 *A History of Archaeological Thought*. Cambridge University Press, Cambridge.

Turner, E. S., and T. R. Hester
1999 A Field Guide to Stone Artifacts of Texas Indians. 3rd ed. Gulf Publishing Company, Houston Texas.

Urey, H. C.
1947 The Thermodynamic Properties of Isotopic Substances. *Journal of the Chemical Society of London* 108:562–581.

Vines, R.A.
1960 *Trees, Shrubs, and Woody Vines of the Southwest*. The University of Texas Press, Austin.

Vogel, J. C.
1980 *Fractionation of the Carbon Isotopes during Photosynthesis*. Springer, Berlin.

Wandsnider, L.
1997 The Roasted and the Boiled: Food Composition and Heat Treatment with Special Emphasis on Pit-Hearth Cooking. *Journal of Anthropological Archaeology* 16:1–48.

Ward, J. H., Jr.
1963 Hierarchical Grouping to Optimize an Objective Function. *Journal of the American Statistical Association* 58:234–236.

Waters, M. R.
1992 *Principles of Geoarchaeology: A North American Perspective*. University of Arizona Press, Tucson.

Watts, W. A.
1973 Rates of Change and Stability of Vegetation in the Perspective of Long Periods of Time. In *Quaternary Plant Ecology,* edited by Harry J. B. Birks and Richard G. West, pp. 195–206. Blackwell Scientific Publications, Oxford.

Weaver, W. G. and F. L. Rose
1967 Systematics, Fossil History, and Evolution of the Genus Chrysemys. *Tulane Studies in Zoology*, 14:63–73.

Weir, F. A.
1985 An Early Holocene Burial at the Wilson-Leonard Site in Central Texas. *Mammoth Trumpet*, 2(1):1,3.

Wells, P. V.
1976 Macrofossil Analysis of Wood Rat (*Neotoma*) Middens as a Key to the Quaternary Vegetational History of Arid America. *Journal of Quaternary Research*, 6(2):223–248.

Whallon, R.
1984 Unconstrained Clustering for the Analysis of Spatial Distributions in Archaeology. In *Intrasite Spatial Analysis in Archaeology,* edited by Harold J. Hietala, pp. 242–277. Cambridge University Press, New York.

Willey, G. R. and P. Phillips
1958 M*ethod and Theory in American Archaeology*. The University of Chicago Press, Chicago.

Wissler, C.
1917 *The American Indian: An Introduction t the Anthropology of the New World*. Douglas C. McMurtrie, New York.

1940 *Indians of the United States: Four Centuries of Their History and Culture*. Doubleday & Company, Inc., Garden City, New York.

Wolynec, R. B.
1977 The Systematic Analysis of Features from the Koster Site: A Stratified Archaic Site. Unpublished Ph.D. dissertation, Department of Anthropology, Northwestern University, Evanston, Illinois.

Wood, W. R., and D. L. Johnson
1978 A Survey of Disturbance Processes in Archaeological Site Formation. In *Advances in Archaeological Method and Theory*, edited by Michael B. Shiffer, 1:315–381. New York: Academic Press.

World Weather Information Service
2006 San Antonio, Texas, United States of America. World Meteorological Organization. http://www.worldweather.org/093/c00825.htm

Wyckoff, D. G.
1984 The Cross Timers: An Ecotone in Historical Perspective. In *Contributions to Cross Timbers Prehistory*, edited by Patricia L. Kawecki and Don G. Wyckoff, pp. 1–20. Studies in Oklahoma's Past No. 12, Oklahoma Archaeological Survey, and Cross Timers Heritage Association No. 3, Oklahoma Archaeological Survey, University of Oklahoma, Norman.

Yanovsky, E.
1936 Food Plants of the North American Indians. Washington, D.C., *United States Department of Agriculture Publication*, 237:1–83.

Yapp, C. J.
1979 Oxygen and Carbon Isotope Measurements of Land Snail Shell Carbonate. *Geochimica et Cosmochimica Acta* 43, 629–635.

Yellen, J. E.
1977 *Archaeological Approaches to the Present: Models for Reconstructing the Past.* Academic Press, New York.

Yoakum, J. D.
1978 Pronghorn. In *Big Game of North American: Ecology and Management*, edited by John L. Schmidt and Douglas L. Gilbert, pp. 102–121. Stackpole Books, Harrisburg, Pennsylvania.

Yurtsever, Y.
1975 Worldwide Survey of Stable Isotopes in Precipitation. In *Report Sect. Isotope Hydrol*ogy, IAEA, Vienna.