Index of Texas Archaeology: Open Access Gray Literature from the Lone Star State

Volume 2015 Article 9

2015

Eligibility Assessment of the Slippery Slope Site (41MS69) in TxDOT Right-of-Way in Mason County, Texas

J. Michael Quigg

Paul M. Matchen

Charles D. Frederick
charlesthegeoarchaeologist@gmail.com

Robert A. Ricklis

Recommended Citation

Quigg, J. Michael; Matchen, Paul M.; Frederick, Charles D.; and Ricklis, Robert A. (2015) "Eligibility Assessment of the Slippery Slope Site (41MS69) in TxDOT Right-of-Way in Mason County, Texas," *Index of Texas Archaeology: Open Access Gray Literature from the Lone Star State*: Vol. 2015 , Article 9. https://doi.org/10.21112/ita.2015.1.9
ISSN: 2475-9333
Available at: http://scholarworks.sfasu.edu/ita/vol2015/iss1/9

Eligibility Assessment of the Slippery Slope Site (41MS69) in TxDOT Right-of-Way in Mason County, Texas

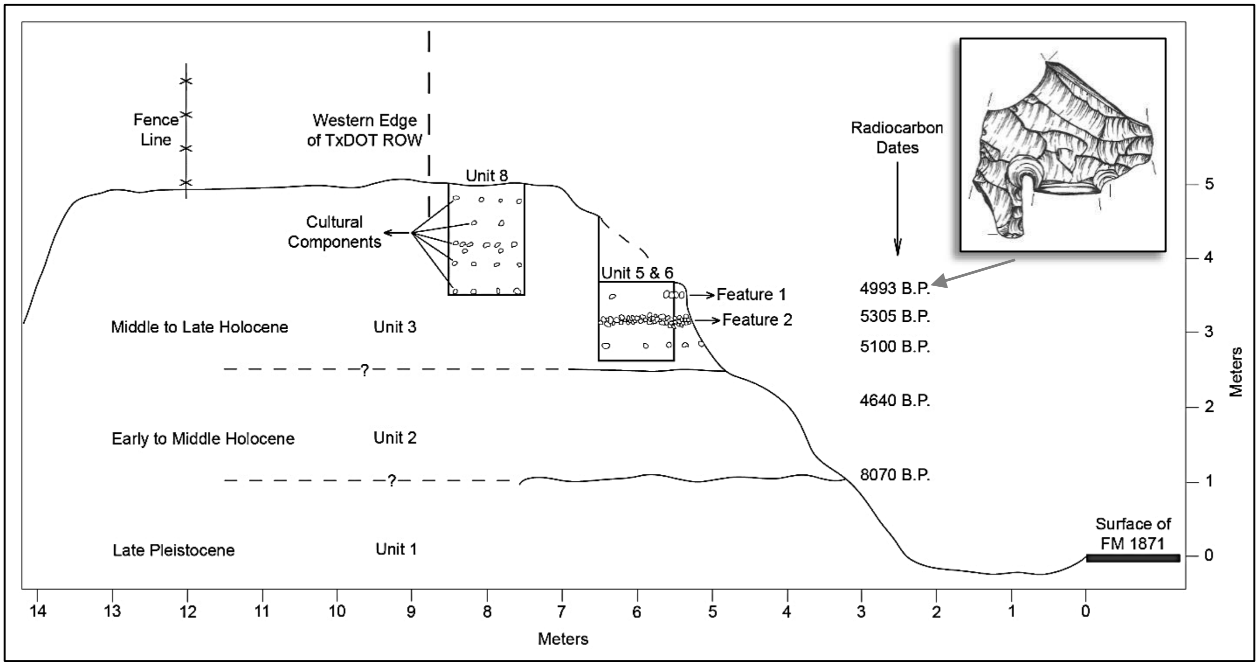
Eligibility Assessment of the Slippery Slope Site (41MS69) in TxDOT Right-of-Way in Mason County, Texas

By:

J. Michael Quigg, Paul M. Matchen, Charles D. Frederick, and Robert A. Ricklis

With contributions by:

Steven Bozarth, Phil Dering, Jeffrey R. Ferguson, Timothy Figol, Michael D. Glascock, Bruce L. Hardy, Mary Malainey, J. Byron Sudbury, and Barbara Winsborough



Prepared for:

Texas Department of Transportation
Environmental Affairs Division
Archeological Studies Program, Report No. 172
Austin, Texas

Prepared by:

TRC Environmental Corporation
TRC Technical Report Nos. 43252 (106895) and 211462
Austin, Texas

Texas Antiquities Committee Permit No. 3447
Principal Investigator J. Michael Quigg

December 2015

Eligibility Assessment of the Slippery Slope Site (41MS69) in TxDOT Right-of-Way in Mason County, Texas

By:

J. Michael Quigg, Paul M. Matchen, Charles D. Frederick, and Robert A. Ricklis

With contributions by:

Steven Bozarth, Phil Dering, Jeffrey R. Ferguson, Timothy Figol, Michael D. Glascock,
Bruce L. Hardy, Mary Malainey, J. Byron Sudbury, and Barbara Winsborough

Prepared for:

Texas Department of Transportation
Environmental Affairs Division
Archeological Studies Program, Report No. 172
118 East Riverside Drive
Austin, Texas 78704

Prepared by:

TRC Environmental Corporation
TRC Technical Report Nos. 43252 (106895) and 211462
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Texas Antiquities Committee Permit No. 3447
J. Michael Quigg, Principal Investigator

TxDOT Scientific Services Contract Nos.
57-3XXSA006, 57- 5XXSA008, 57-7XXSA003, and 57-3XXSA004

December 2015

Printed by:

Document Engine
Round Rock, Texas

December 2015

Jointly published by:

Texas Department of Transportation
Environmental Affairs Division
Archeological Studies Program, Report No. 172
Scott Pletka, Ph.D., Supervisor

and

TRC Environmental Corporation
TRC Technical Report Nos. 43252 (106895) and 211462
Austin, Texas

ISBN # 978-1-935545-39-2

EXECUTIVE SUMMARY

A private landowner reported archeolgical materials were looted along a steep road cut on the southwestern side of Farm to Market (FM) road 1871 along the Llano River south of Mason, Texas (CSJ: 1111-04-002). The landowner was concerned that looting had undermined massive oak trees enough that they might fall directly onto the roadway below. The looting was occurring within Texas Department of Transportation (TxDOT) right-of-way and east of the existing fence line.

In June 2004, archeologists from the Planning, Permitting and Licensing Practice of TRC Environmental Corporation (TRC) Austin office conducted a site specific recording, geoarcheological investigation, and archeological testing for National Register of Historic Places (NRHP) and State Antiquities Landmark (SAL) eligibility assessment at prehistoric site 41MS69, the Slippery Slope site. This cultural resource investigation was conducted for the Environmental Affairs Division of TxDOT through multiple Scientific Services Contracts, Work Authorizations, and Supplemental Work Authorizations over the years and through Texas Antiquities Permit No. 3447, issued by the Texas Historical Commission to Principal Investigator, J. Michael Quigg.

A portion of the Slippery Slope site (41MS69) within the TxDOT right-of-way was exposed along a narrow, north-south area of potential effect (APE) that measured roughly 100 meters (m) long (parallel to the roadway) and sloping nearly 5.5 m tall. This steep road cut had only 2 to 5 m wide treed right-of-way remaining west of the roadway, demarcated by a north-south fence line. However, mid-excavation, the adjacent landowner informed the archeologists most of the flat terrace surface atop the steep road cut was private land. The existing fence line had been moved westward, back from the eroding edge of the steep slope. Consequently, four test units (TUs 1 through 4) were unknowingly excavated on private property, leaving mostly the sloping and eroding deposits within TxDOT right-of-way.

Initially, five narrow, vertical columns/windows hand-cut into and dispersed along the 100 m long exposure revealed three time distinctive alluvial time units. Alluvial Unit 1 was dated greater than 9120 B.P. Alluvial Unit 2 was dated between roughly 5500 and 7990 B.P. Alluvial Unit 3 was dated between roughly 1600 and 5550 B.P. and contained all cultural materials in partially stratified context. Alluvial Unit 3 deposits were no deeper than about 230 centimeters (cm) across the southern half of the exposure. The younger deposits angled upward and pinched out or merged against, and overrode older deposits across the northern half.

Hand-excavation sampled a total of 8.9 m^3, of which 5.8 m^3 were excavated from the top of the road cut down to 150 cm below surface (cmbs). The other 3.1 m^3 were excavated in midslope of the road cut at the southern end, and targeted deeply buried cultural deposits that extended to a depth of 230 cmbs. These investigations documented multiple stratified cultural deposits in the southern end and mostly compressed cultural events in the northern end. The northern half of the APE contained a broad burned rock midden deposit concentrated in the upper 150 cm. This midden appeared to have compressed stratigraphy with minimally the upper 50 cm extensively disturbed, looted and overgrown. Precise age and cultural affiliation of this northern midden was not identified.

Hand-excavations in the southern half of the APE exposure documented minimally 12 vertically distinguishable cultural events. These events included burned rocks and lithic debitage, although they lacked diagnostics or datable materials. Multiple indistinguishable cultural events were also present in the southern end with some affiliated with Marcos, Montell, Pedernales, Bulverde, and Travis points. A partial circular rock filled, rock lined hearth (Feature 1) and a burned rock lens with associated possible cooking basin (Feature 2) were radiocarbon dated to between circa 4700 and 5420 B.P. A broken Andice dart point was discovered at the same depth as Feature 1 and only 90 cm from its edge. Features 1 and 2 and their dates combined with the associated Andice point was the only identifiable component. An ash filled basin (Feature 3) was radiocarbon dated to 3500 B.P. The cultural lenses detected in the southern half were within rapidly accumulated alluvial fines that dated from Middle to Late Archaic periods, ca. 5,400 to 2,000 B.P.

This site recording and eligibility assessment program targeted a very limited portion of the Slippery Slope site (41MS69) within the steeply sloped road cut of the TxDOT right-of-way. TRC archeologists identified complex geoarcheological stratigraphy, documented multiple well-stratified events in limited areas and sampled four cultural features. Burned rock Features 1 and 2 yielded radiocarbon dates and/or diagnostic artifacts consistent with the Bell/Andice/Calf Creek complex, which have rarely been identified and less frequently sampled. Diverse technical analyses directed towards the two Middle Archaic dated features yielded important information concerning the processing and cooking of plant resources not previously identified for this cultural interval. Starch grain analysis on burned rocks selected from both features yielded minimally two types of grasses and unidentified legumes potentially processed and cooked with the rocks. Lack of starch grains in the surrounding sediments indicate starches from feature rocks are of cultural origin.

Lipid residues extracted from Feature 1 and 2 rocks indicate most sampled rocks yielded combinations of plant and animal residues, with the majority dominated by plant residues, and a few dominated by animal residues. Most rocks also contained chemical residues from conifer products. These residues are probably from wood used to heat the rocks, locally juniper or cypress are the best canidates.

High-powered use-wear analysis of selected formal and informal stone tools indicated 71 percent were used in a cutting motion. The other 29 percent exhibit no identifiable use-wear traces. Of the 71 percent with identifiable wear, 50 percent exhibited use-wear consistent with soft materials (e.g., hide), and the other 50 percent exhibited use-wear consistent with hard materials (e.g., wood). Actual microscopic residues of hair, bone collagen, plant tissue, and wood were observed. These results support the occurrence of multiple activities that represents at a minimum working wood and hides around the cooking process.

Neutron activation analysis of Bell/Andice/Calf Creek artifacts and natural Gorman Formation cherts from the immediate area documents a near total reliance on local Edwards and Gorman Formation cherts by occupants of the Bell/Andice interval. Chemically identified Edwards cherts were not chemically similar to the six dominate Fort Hood chert types in Bell County, roughly 150 kilometers to the east. In contrast to what is known from Oklahoma Bell/Andice/Calf Creek artifacts, the local cultural cherts do not appear heat treated to improve knapping qualities.

Results from five flotation samples extracted from feature contexts indicate poor macrobotanical preservation with no charred seeds from Features 1 and 2 and only sparse charcoal. Identified charcoal includes oak and hackberry wood.

Overall pollen, phytolith, starch grain, and diatom preservation was very poor due to the basic pH environment of the cambic Oakalla silty clay loam sediment. Two phytolith samples older than 5500 B.P. yielded no data. Three samples from Features 1 and 2 provided sparse and incomplete phytolith data. Processing phytolith samples also yielded microscopic charcoal, bone flakes, shell, chert debris, marine spicule fragments, and burned hackberry seeds. A cucurbit or wild buffalo gourd phytolith was noted from Feature 1, along with preserved freshwater sponge spicules in Features 1 and 2. Burned Panicoid phytoliths that reflect warm, moist grasses comprised about 30 percent of the Panicoid specimens in Features 1 and 2 along with tree phytoliths. Hot dry climate Chloridoid grass phytoliths dominated the short cell grass phytoliths in Features 1 and 2. The presence and frequency of grass types, combined with the burned hackberry seeds, indicate Features 1 and 2 probably occurred in late summer or fall.

The few diatoms represented indicate water was present in Feature 1, probably from shallow, possibly vegetated, and clear enough to permit light to reach the bottom. The waters contained moderate phosphate and nitrate concentrations, and was potentially seasonal. The extreme diluted nature in samples and reasonably well-preserved diatoms could mean water was used in Feature 1.

The investigated portions of 41MS69 are significant and eligible for listing on the NRHP and as a SAL as recovered data contributed greater insights into the cooking technology and food resources employed during the Bell/Andice/Calf Creek complex, and provide radiocarbon dates for this rare cultural horizon in Texas. TRC's significance testing, however, has removed those deposits considered important. Therefore, no further significant cultural materials in good context remain within the eexisting, steeply sloping TxDOT right-of-way, and no further significant information can be gleaned from additional excavations. Consequently, since no roadway expansion is currently planned for this road cut, TRC recommends no further archeological investigations in the existing TxDOT right-of-way prior to planned cut bank stabilization. The remaining cultural deposits within the APE are not recommended as eligible for listing in the NRHP or designation as a SAL.

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF APPENDICIES

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

During the lengthy analysis and reporting process numerous staff in the Archeological Studies Program of the Environmental Affairs Division of Texas Department of Transportation (TxDOT) aided TRC in completion of this project. In 2004 Dr. Owen Lindauer was the Supervisor of the Archeological Studies Branch and Mr. Jon Budd was the TxDOT district archeologist, both of whom had input into the assessment plan and getting Work Authorization 57-313SA006 in place for the June 2004 fieldwork. Mr. Budd was also instrumental in multiple subsequent Work Authorizations and Supplementals concerning an annotated bibliography, a cultural context study, and preliminary research questions. During the 2004 and 2005 periods Drs. James Abbott and G. Lain Ellis aided in handling radiocarbon samples. Late in 2005 Dr. G. Lain Ellis became Supervisor of the Archeological Studies Branch and directed part of the program for multiple years. Subsequently, Dr. Scott Pletka became Supervisor of the Archeological Studies Program and managed the final Work Authorization 57-306SA004 under General Service Contract No. 57-3XXSA004 that directed the project towards completion of the draft and final technical reports. Dr. Pletka was kind enough to inter the radiocarbon data into the Bayesian model using OxCal, from which he produced the radiocarbon illustration used in Figure 7-34. He also provided comments on the draft final report. Thank you Dr. Pletka for your overall direction in completing this project. Mr. Eric Oksanen, the current TxDOT district archeologist, also provided comments concerning the draft final report which improved the overall quality. Other TxDOT staff that included Al McGraw, James Abbott, Jon Budd, and Scott Pletka participated in various meetings and discussions. Work on this project was stopped in the middle of 2008. Dr. James Abbott, TxDOT geoarcheologist, was instrumental in providing direction to and overseeing the multiple requests for and facilitating the submission of samples for radiocarbon dating provided by TxDOT. Coordination of the original field activities was aided by TxDOT district staff of Mike Walker and Larry Cauanaugh.

The Antiquity Code of Texas permit application was completed by Principal Investigator J. Michael Quigg and submitted to the State, then to the Texas Historical Commission, which approved the proposed field investigations. TRC archeological field staff is thanked for their dedication and strong effort under wet conditions, which made excavation and screening difficult and their ability to navigate the slippery slope without serious incident. The field crew was directed by J. Michael Quigg, Jesse Owens served as Project Archeologist, and senior Crew Chief was Mercedes Cody, with field archeologists Charles Burton and Carl Welch. Mercedes was responsible for prefield activities that included; reading the equipment trailer, hotel and vehicle arrangements, and coordinating with the crew for the field effort. Dr. Charles Frederick served as geoarcheologist and documented five column profiles, completed the detailed sketch map of the APE, and wrote Chapter 5.0. He is thanked for his thoroughness in interpreting the visual stratigraphy without the aid of detailed analysis and for his on-site instruction to the entire crew, which helped immensely.

The 2004 laboratory procedures of washing, sorting, cataloging, and database establishment were conducted by Laboratory Supervisor Mercedes Cody. She was also instrumental in organization and preparation of the initial samples for macrobotanical analysis. Thank you Mercedes for your organization and hard work in handling the many diverse tasks asked of you.

During the background research, TRC staff archeologist Paul M. Matchen conducted 15 readings focused on the theoretical background for the annotated bibliography and subsequent development of specific research questions. He was instrumental in developing the initial three hypotheses/questions for testing and for incorporation into the preliminary research design. Paul also participated in the development and writing of the final research design and the cultural background section concerning the Bell/Andice/Calf Creek complex.

During the readings for the annotated bibliography several researches including Dr. Marjy Duncan, Dr. Richard Drass, and William Neal all in Oklahoma supplied articles and/or reports that contributed to our research. Dr. Alston Thoms from Texas A&M University also supplied TRC with initial draft chapters of the Richard Beene site with pertinent information. Thank you all for your support and helpfulness.

In 2013 and 2014 most laboratory tasks were conducted by Trisha-Ann Gonzales and Shannon Gray, TRC Laboratory Director. Trisha-Ann helped track down and pull samples to send to technical specialist, compiled draft tables of the samples sent to outside laboratories, conducted the necessary sample documentation, crosschecked the database, and prepared samples for shipment. Trisha-Ann also conducted the artifact analysis on the stone tools, and lithic debitage. Trisha-Ann and Shannon proofed and fixed errors in the electronic database, and provided quality assessment and control over the field records and materials during analyses and in preparing the materials for curation. Shannon also completed technical editing tasks of sections and chapters, and helped in many different ways. Thank you Shannon for your management of the database and creation of the many tables, your excellent illustrations, and editing skills. Meghan Bruckse Bury also is thanked for editing skills several chapters and producing the excellent line drawing of the Andice projectile from Feature 1. Ashleigh Knapp formatted and produced the draft and final documents. TRC staff biologist, Barrett Clark is thanked for his identifications of the mussel shell species.

Dr. Charles Frederick of Dublin, Texas conducted the geoarcheological field investigations. His advice and discussions concerning the site stratigraphy with the crew was very useful and informative. He also authored the geoarcheological chapter (5.0) and produced the figures and tables therein. Thank you Charles for another excellent job of interpretation the complex deposits and educating the archeologists.

Dr. Linda Perry, Executive Director of The Foundation for Archaeobotanical Research in Microfossils in Virginia, conducted the initial starch grain assessment on 10 samples and followed that with detailed analysis on another 26 burned rocks and 6 sediment samples for this final technical report. Thank you Linda for your scientific approach to handling the artifacts, your attention to detail in searching for and identifying unusual grains, and continuous communication and interest in working with TRC on diverse artifact classes.

Dr. Phil Dering of Shumla Archeobotanical Services in Comstock, Texas provided identifications of individual charcoal samples and floating the initial bulk sediment samples for features back in 2004. He was also kind enough to continue with charcoal and light fraction analysis in 2013.

Dr. Mary Malainey with the assistance of Timothy Figol in Winnipeg, Manitoba, Canada provided the lipid residue analysis on the initial burned rocks and offered to rerun those initial samples with the newly submitted samples in 20013. Thank you Mary and Tim for continuing to upgrade the technique, and your continued interest and willingness to process the difficult burned rocks.

Dr. Bruce Hardy at Kenyon College in Gambier, Ohio conducted the use-wear and residue analysis on a selected suite of 17 stone tools and wrote the technical report in Appendix G. Thank you Bruce for your keen eye and ability to interpret the complex use-wear.

Dr. Steven Bozarth of the University of Kansas performed the initial presence/absence analyses for pollen and phytoliths on sediment samples for the interim report in 2004. He provided positive recommendations for continued phytolith analysis.

Dr. Byron Sudbury performed the full phytolith analysis on four samples and wrote the methods and results presented in Appendix J. Thank you Byron for your interest in these few samples even though they provide limited chronology through time.

Drs. Michael D. Glascock and Matthew T. Boulanger of the Archaeometry Laboratory at the University of Missouri Research Reactor in Columbia are thanked for they neutron activation analysis on the 60 chert samples from this project. They continue to provide useful comparisons with previous data in the system.

Dr. Barbara Winsborough of Winsborough Consulting in Leander, Texas is thanked for her diatom analysis of ten samples. Thank you Barbara for your willingness to tackle the difficult job of working with the burned rocks and explore new and different avenues of interpretations from this type of sample.

Thank you all for your diverse expertize in helping preserve part of Texas prehistory and contributing to a greater understanding of the past. Any problems in the presentation or errors in content are the responsibility of the project manager.

Mike Quigg
Project Manager

This page intentionally left blank.

1.0 INTRODUCTION

J. Michael Quigg

1.1 INTRODUCTION

This report presents the National Register of Historic Places (NRHP) eligibility assessment of and recommendation for a limited part of prehistoric site 41MS69, the Slippery Slope site, in Mason County, Texas. Fieldwork was conducted by archeologists from the Planning, Permitting and Licensing Practice of TRC Environmental Corporation (TRC) Austin office in June 2004. Work was under contract to the Texas Department of Transportation (TxDOT) through the Environmental (ENV) Affairs Division, Archeological Studies Program under Scientific Services Contract No. 57-3XXSA006, TxDOT issued a Work Authorization (No. 57-312SA006). Investigations were to include site documentation and assessment of a narrow, vertical section of an unrecorded prehistoric site (41MS69) in the existing right-of-way and complete a preliminary assessment report with recommendations (Quigg and Frederick 2005). The investigation was implemented prior to planned bank stabilization along a Farm to Market (FM) road (CSJ: 1111-04-002). Following fieldwork, multiple Work Authorizations were issued under multiple contracts (57-5XXSA008, 57-7XXSA003, and 57-306SA004) with the latest issued in November 2013 to complete a draft and final report and curate the artifacts and documents. TRC fieldwork and all subsequent analysis and reporting were conducted under Texas Antiquities Committee Permit No. 3447 issued to J. Michael Quigg as Principal Investigator.

This project was conducted in accordance with the programmatic agreement between TxDOT and the Texas Historical Commission (THC), and under a Memorandum of Understanding (MOU) between TxDOT and THC. The proposed bank stabilization represents a state sponsored project on public lands with potential to negatively impact cultural resources. Consequently, TxDOT was required to conduct cultural resource investigations to meet its legal responsibilities for identification, evaluation, and treatment of historic properties under state regulations, and the Texas Antiquities Code (Texas Natural Resources Code of 1977 [revised 1987], Title 9 Chapter 191, VACS, Art. 6145-9).

1.2 PROJECT LOCATION

Prehistoric site 41MS69 is mostly buried in alluvial deposits along the right bank (southwestern side) of the Llano River in southern Mason County, about 12 kilometer (km) south of Mason (Figure 1-1). Mason County of west central Texas, located within the Llano Uplift, is a unique mineral section of the more general Edwards Plateau region. Farm to Market road 1871 crosses the Llano River in a general north-south direction and rises upslope from the valley to the uplands in a northerly direction and then turns westward across the uplands. The sloping road section creates a roughly 5.5 meter (m) tall and very steep road cut along the western edge of the roadway (Figure 1-2). The area of potential effect (APE) lies along the western edge of the road and is roughly 100 m long, roughly 2 to 5 m wide, and nearly 5.5 m tall. This steeply sloped APE was bounded by an unnamed creek at the southern end and a contoured and grassed sloped area at the northern end, south of the cattle gate in the existing roadway. Initial road construction removed Holocene and Pleistocene age alluvial deposits, and the existing road is situated where these deposits would have met the modern floodplain of the Llano River. Quantities of cultural material, which include a lengthy burned rock lens below large oak (*Quercus* sp.) trees, are exposed towards the top of this steep rising alluvial deposit.

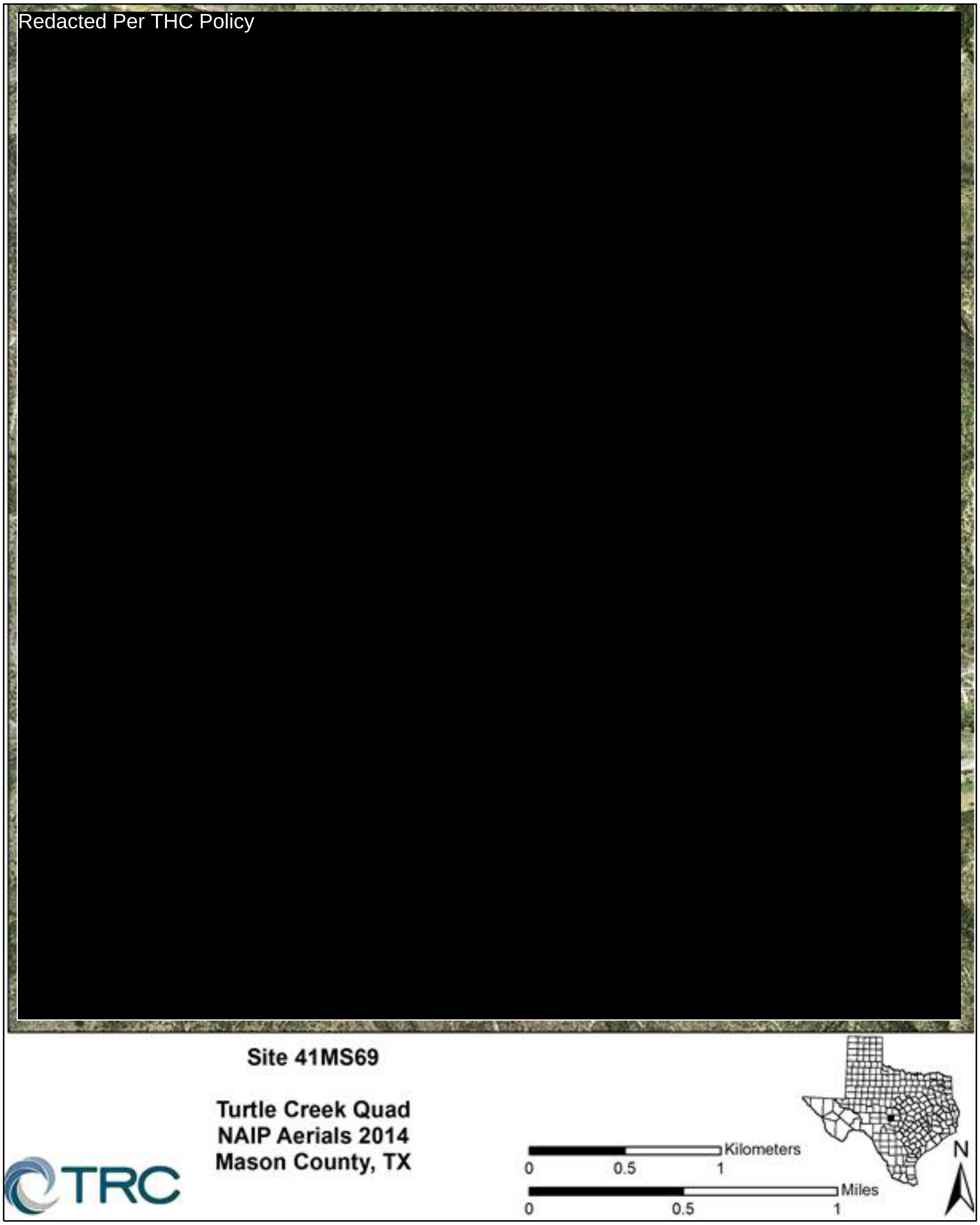


Figure 1-1. **Project location map**.

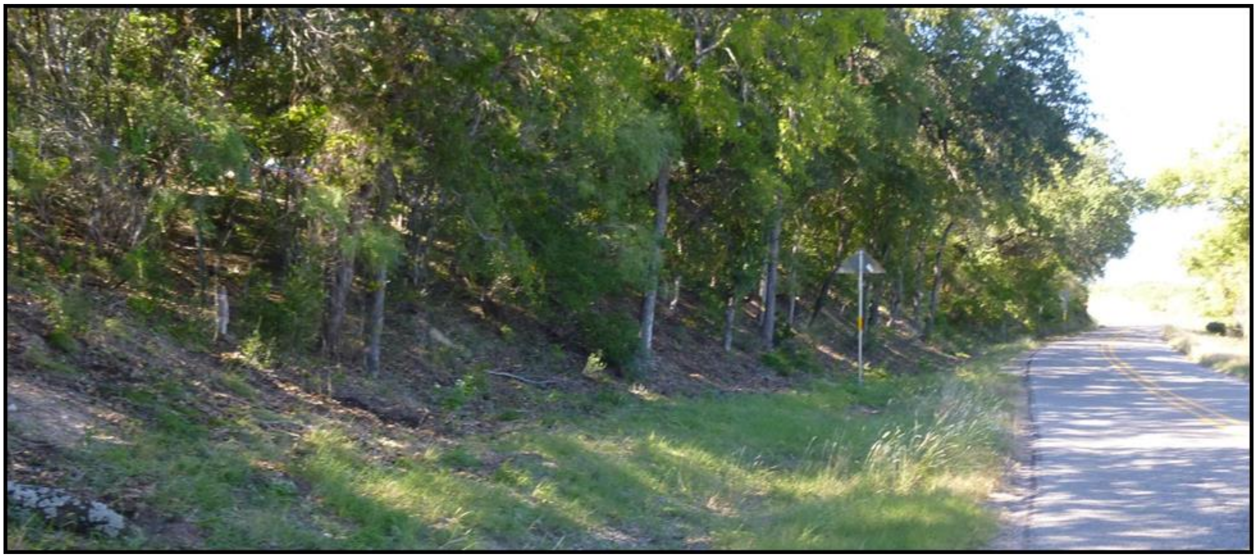


Figure 1-2. TxDOT road rising up from Llano River valley depicting steep, treed slope on western (left) side, which contains the Slippery Slope site (41MS69) adjacent the Llano River.

1.3 SITE BACKGROUND

The landowner adjacent to the roadway reported to TxDOT that looting of a lens of cultural burned rocks along the top of the road cut directly above the roadway was a safety concern. Looting had undermined several very large oak trees growing at the top of the road cut and hang over the roadway creating the potential for trees to fall on the roadway below (Figure 1-3). Erosion is occurring along the steep slope and burned rocks are scattered on the slope below the looted areas. Just north of the APE, TxDOT had reduced and stabilized the slope by removing trees and planting grasses. At that time, TxDOT was devising a plan to stabilize the slope from that point southward to the unnamed creek.

This prehistoric site had not been previously recorded. The fieldwork included recording and mapping the part of the site in the existing TxDOT right-of-way. A barbed wire fence line across the top of the slope and parallel to the road below was thought to mark the western boundary of the TxDOT right-of-way. The fence line varied in distance from 2 to 5 m west of the steep eroding edge of the right-of-way. The narrow 2 to 5 m wide top of the road cut was covered in trees including junipers (*Juniperus* sp.), Texas persimmons (*Diospyros texana*), and very large oaks (*Quercus* sp.) that hang over the roadway (Figure 1-3). Apparently the original roadway construction removed the eastern side of the terrace. The eastern edge of the existing right-of-way is low and intersects the Llano River floodplain, which is covered in diverse vegetation, large rocks, and flood debris.

Dr. Owen Lindauer (then director of the Environmental Affairs Division at TxDOT), Jon Budd (TxDOT district archeologist), and Mike Quigg (TRC principal investigator), visited the APE on April 26, 2004. Areas of looting were obvious along the top 1 m of the steep road cut deposits. The general strategy for site assessment was discussed and strategized during this field visit, including the testing of the steep road cut and flat terrace east of the fence. The adjacent landowner visited during the June 2004 field investigation and provided clarification that the existing fence line had been moved back from the eroding edge sometime in the past. Consequently, the 2 to 5 m area east of the fence along the more or less flat top terrace was probably private land.

Figure 1-3. Looter diggings under large oak tree caused safety concerns for the roadway below.

1.4 REPORT ORGANIZATION

This report is divided into 11 chapters and 12 appendices. Following this introduction, Chapter 2.0 provides an overview of the modern environmental setting for the project area followed by a review of the projected regional paleoenvironment. Chapter 3.0 provides an archeological background and cultural history focused on the Middle Archaic period for Texas and Oklahoma. Chapter 4.0 presents the final research design for analysis. Chapter 5.0 discusses the field and laboratory methods employed by TRC investigations. Geoarcheological information obtained during the eligibility assessment is presented in Chapter 6.0. Archeological results are in Chapter 7.0. A summary of the findings and conclusions are in Chapter 8.0. Chapter 9.0 presents TRC's recommendations concerning the site's eligibility for listing on the NRHP and designation as a SAL. This is followed by the references cited in Chapter 10.0. A glossary of technical and unusual terms is provided in Chapter 11.0.

Twelve appendices provide methodologies, results, and interpretations from diverse technical analyses performed following the eligibility and evaluation excavations. Radiocarbon results from Beta Analytic, Inc. and the University of Georgia accelerated mass spectrometry (AMS) laboratories are provided in Appendix A. This is followed by the diatom feasibility study by Dr. Barbara Winsborough in Appendix B. Appendix C presents the instrumental neutron activation analysis (INAA) by the University of Missouri, Archaeometry Laboratory. Presence/absence analysis of pollen and phytoliths are presented in Appendices D and E respectively by Dr. Steven Bozarth of the University of Kansas. Appendix F presents macrobotanical results by Dr. Phil Dering of Shumla Archeobotanical Services. Dr. Bruce Hardy of Kenyon College in Ohio presents high-powered use-wear analysis on stone tools in Appendix G. This is followed by lipid residue procedures and results by Dr. Mary Malainey and Mr. Figol in Appendix H. Procedures and results from the Dr. Linda Perry's starch grain analysis are in Appendix I. The following appendix presents detailed phytolith analysis by Dr. Byron Sudbury of J. S. Enterprises, Inc. in Ponca City, Oklahoma. Appendix K presents the lithic debitage analysis of materials associated with Features 1 and 2. Finally, Appendix L contains data on the projectile points recovered from 41MS69, following TxDOT 2010 protocols.

This page intentionally left blank.

2.0 ENVIRONMENTAL SETTING

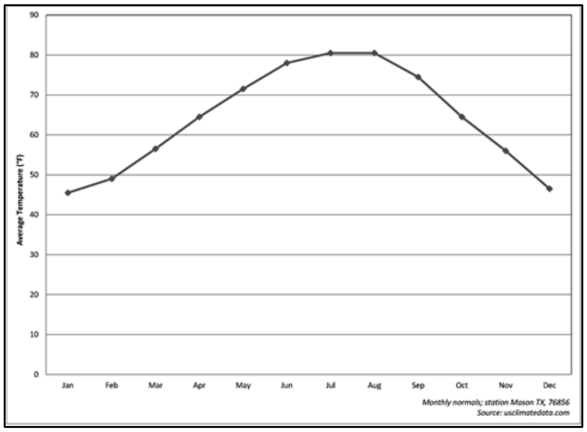
J. Michael Quigg and Paul M. Matchen

2.1 INTRODUCTION

This section first describes the modern environment for the broader project area in Mason County in west central Texas (see Figure 1-1). These modern environmental conditions provide a general foundation in hypothesizing the settings prehistoric populations potentially experienced. However, the majority of the cultural materials recovered from this archeological investigation date to a timeframe within the middle Holocene period (between 8,000 to 5,000 years ago). Therefore, following the modern environmental conditions and potential resources available, an in-depth review of the projected paleoenvironment is presented for the broad middle Holocene period across Texas and the adjacent regions. This background provides a probable backdrop for the lifeways of those middle Holocene populations.

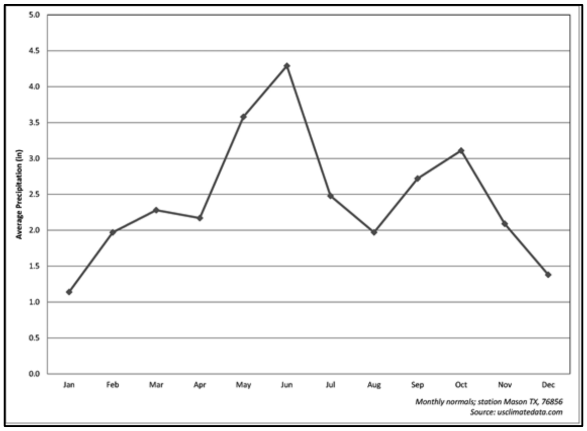
2.2 MODERN CLIMATE

Mason County has a subhumid climate characterized by hot summers and mild dry winters. Winter temperature average is 8.9 degrees Celsius (°C) or 48 degrees Fahrenheit (°F). The average daily temperature is 1.1°C (34°F) (Figure 2-1) (McCormick 2011). Average summer temperature is 27.2°C (81°F), whereas the average daily temperature is 33.9°C (93°F). The total annual precipitation is about 71.1 cm (28 inches). Nearly 78 percent or about 55.9 cm (22 in.) falls from March through October (Figure 2-2). Thunderstorms occur about 40 days each year, most often in May (McCormick 2011). The sun shines about 72 percent of the time in the summer and only about 48 percent in winter (McCormick 2011). Wind blows generally from the south-southeast and is most frequent in April.



Monthly normals; station Mason TX, 76856
Source: usclimatedata.com

Figure 2-1. Regional average temperature for Mason County, Texas.



Monthly normals; station Mason TX, 76856
Source: usclimatedata.com

Figure 2-2. Regional average precipitation for Mason County, Texas.

2.3 HYDROLOGY

The Llano River, a major tributary to the Colorado River, flows west to east across the middle of Mason County draining eastward from two split headwaters, one to the southwest in Edwards County and one further west in Sutton County (see Figure 1-1; Figure 2-3). A major tributary to the Llano River is the James River that flows northward from Kimble County into the Llano River about 7.5 km east of 41MS69. Many smaller drainages, some named and some unnamed, enter the Llano River in the vicinity of 41MS69.

Figure 2-3. The Llano River in the vicinity of 41MS69 (photograph by M. Quigg).

Two very short unnamed drainage channels flowing from the uplands immediately west of the site are at either end of the APE. There are also two named lateral tributaries in the general vicinity. Honey Creek enters the Llano River from the north just downstream of 41MS69 and Mill Creek enters the river from the south across from Honey Creek. No major lakes are in Mason County (McCormick 2011) and no springs are listed by Brune (1981). Site 41MS69 lies within the Llano River valley below the more pronounced contour at 426.7 m (1,400 ft.).

2.4 GEOLOGY

The geologic deposits in this region are quite complex as this site is within the southwestern boundary of the Llano Basin or Uplift (Figure 2-4). The basin is a roughly circular geologic dome of Precambrian rock and is an uplifted region over which the geological formations younger than about 300 million years have eroded away to form a topographic basin. Within the basin, the rock types are unique to that area and include granites, schists, marble, sandstone, and other igneous and metamorphic rocks. The larger outcrops of granites and schists are further east in Llano County. These rocks are unlike the dominate limestone across most of the surrounding Edwards Plateau. Extensive faulting in the region has created complexity in the geologic formations. The region immediately surrounding the site reveals numerous formations that include the Wilberns (labeled Cws and Cwp) of the Upper Cambrian, Tanyard (Ot) of the Lower Ordovician, Gorman (Og) of the Lower Ordovician, and narrow bands of Smithwick (IPsw) of the Pennsylvanian (Barnes 1981). Further west and beyond the Llano Basin in the Edwards Plateau are major regions of the Hensell Sand (Kh) and Fort Terrett Member (Ktf) of the Edwards Limestone all of the Lower Cretaceous. Many formations in the Edwards Plateau contain chert, limestone, and dolomite. The Gorman Formation just west of the site was sampled for chert. Selected samples were submitted for neutron activation analysis to compare with the more recognized and widely studied Edwards chert.

2.5 SOILS

Soils in and adjacent to 41MS69 are limited in diversity and aerial extent. The actual bottom of the Llano River valley along the northern edge of the site is classified as Riverwash rock (RCC) and is often flooded (Figure 2-5) (McCormick 2011). The rock in this zone includes diverse types that include metamorphic, igneous, sedimentary, and quantities of knappable chert. Soils immediately along the northern and southern borders of the Llano River are classified as Oakalla loam (OaB) and are

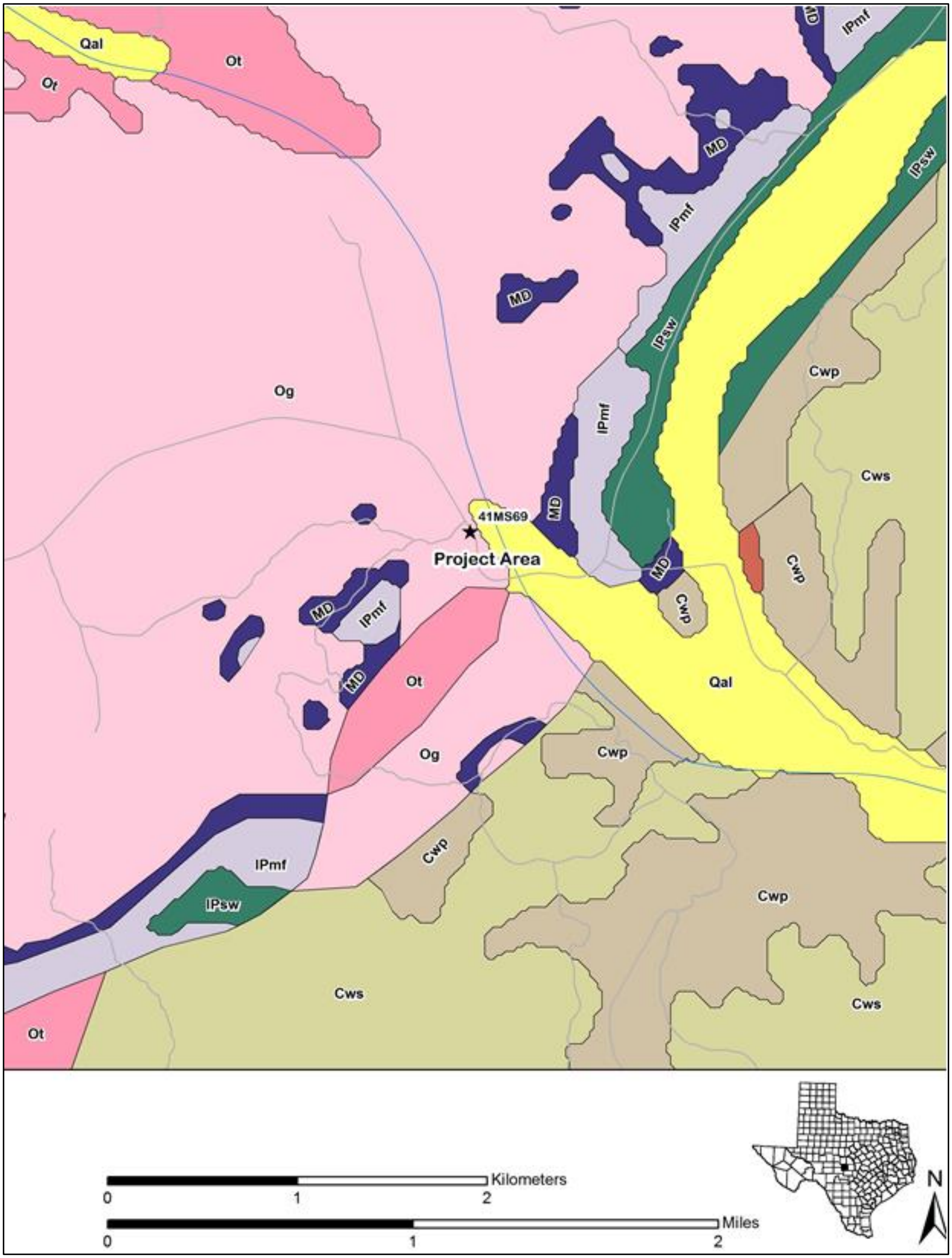


Figure 2-4. Bedrock geology in the vicinity of 41MS69.

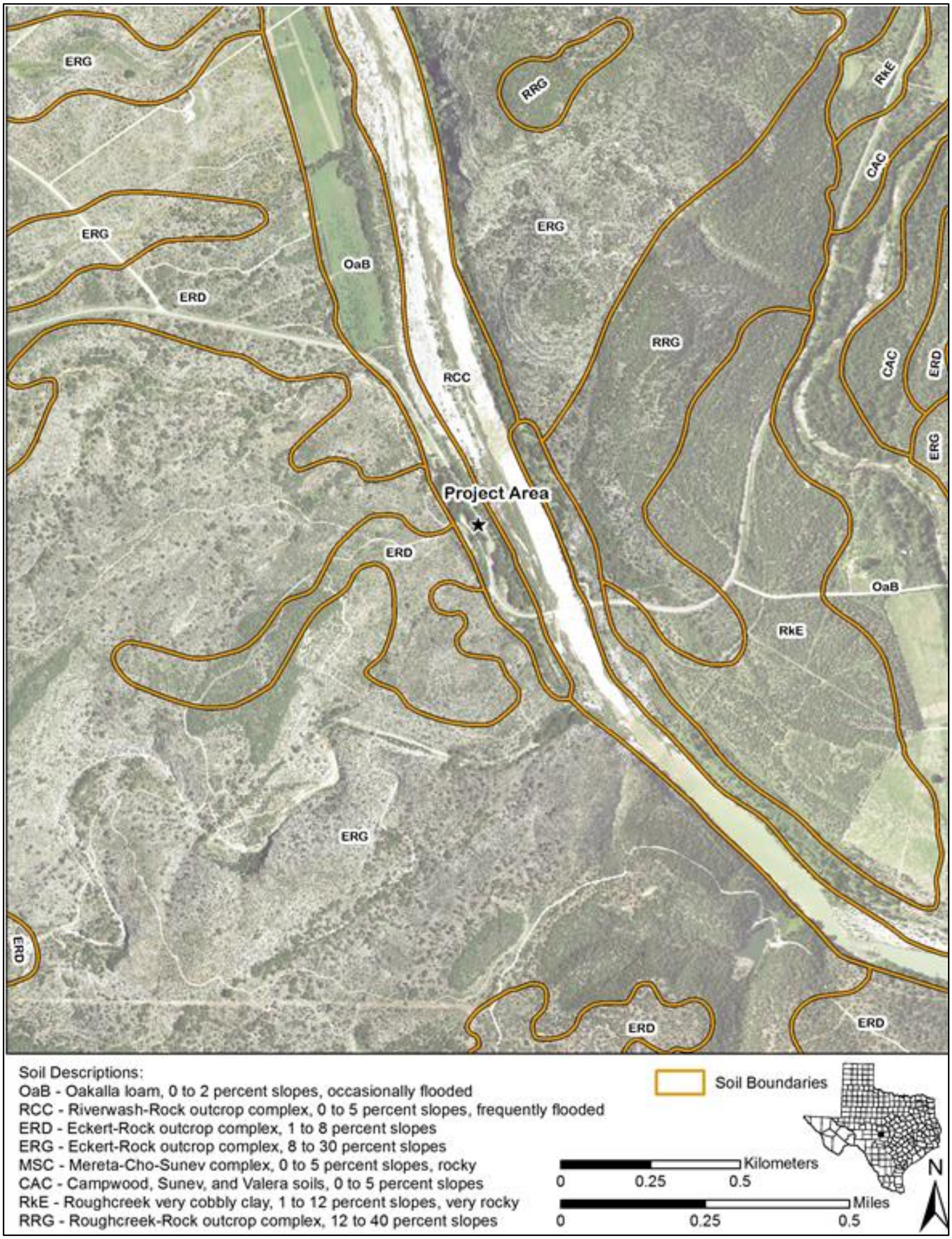


Figure 2-5. Soil types in vicinity of 41MS69.

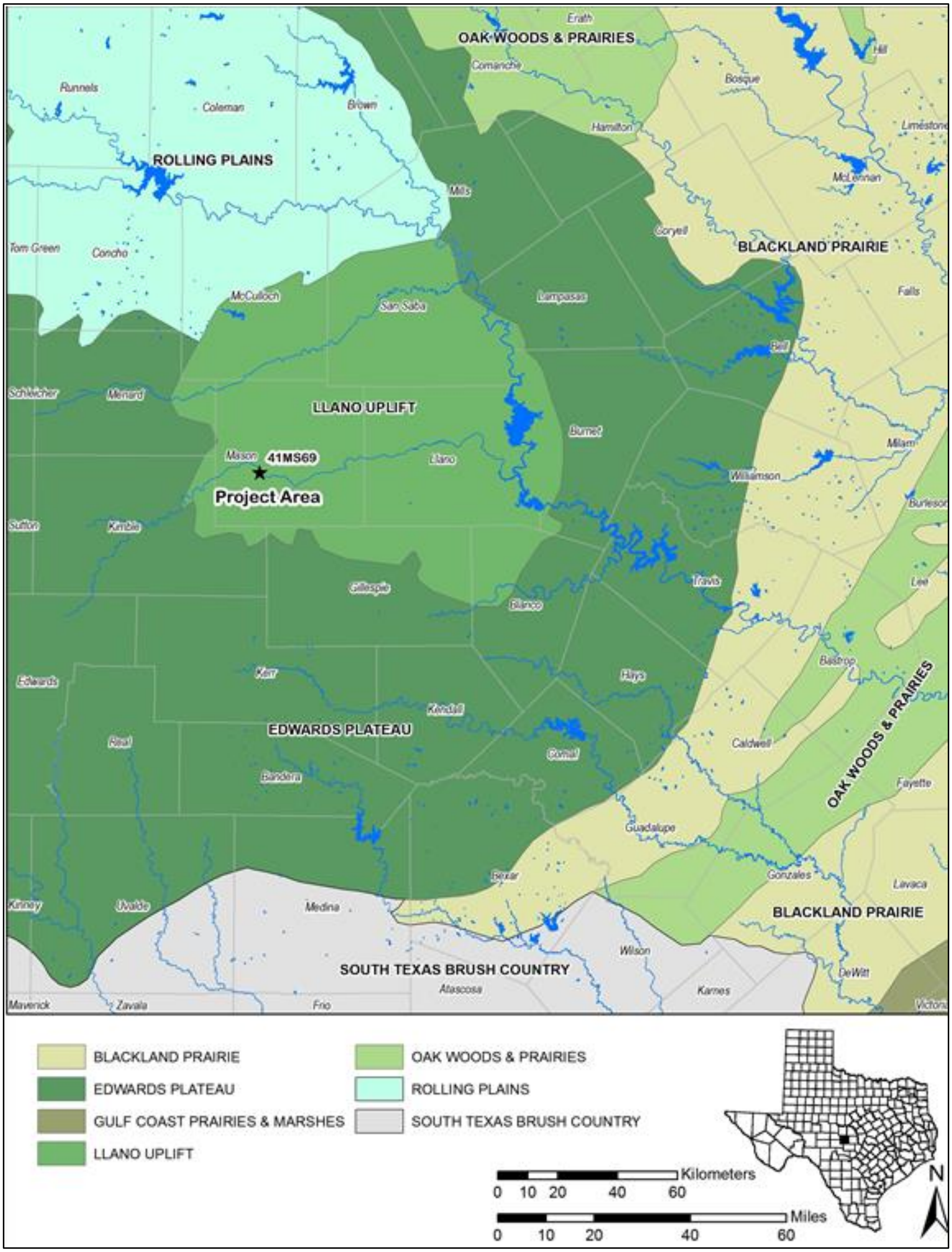


Figure 2-6. **Location of 41MS69 in relation to several physiographic/ecological zones within or extending into central Texas area.**

occasionally flooded. The Oakalla series are floodplains of perennial streams and formed in alluvium. The top 30 cm (0 to 12 in.) is slightly alkaline loam with the next 30 to 94 cm (12 to 37 in.) is very similar with clay increasing with depth. Below that is a moderate alkaline clay loam (McCormick 2011:96). The Slippery Slope site deposits are within the Oakalla series deposits. The upland areas west 41MS69 are classified as Eckert-rock (ERD and ERG) with slight differences depending on the slope and are generally considered part of the Edwards Plateau. The Eckert-rock is characterized with 30 cm (0 to 12 in.) of slightly alkaline cobbley loam, which overlies indurated limestone.

2.6 BIOTA

Site 41MS69 is situated in the heart of the Balconian biotic province (Blair 1950) with the massive mesquite (*Prosopis* sp.) grassland of the Kansan province to the north, the more mesic Texan province to the east, and the semiarid Tamaulipan with its brush land to the south (Figure 2-6). These provinces are distinguished by their ecological associations, plants and animals. Over time these probably changed depending on climate conditions. The Balconian province includes the Edwards Plateau, the Lampasas Cut Plains, the Llano Basin/Uplift or Central Mineral regions (Blair 1950). Mason County also falls within the Texas Parks and Wildlife Division (TPWD 2015) Edwards Plateau ecological region.

2.6.1 Flora

The regional vegetation is dominated by Mexican cedar (*Juniperus mexicana*) and Texas oak (*Quercus texana)* savanna across the uplands with oak (including stunted live oak) and hickory (*Carya* spp.) woodlands mixed with a variety of other trees and grasses (Blair 1950). Various oak species include stunted live oak (*Quercus virginiana*), post oak (*Quercus stellata*), and blackjack oak (*Quercus marilandica*) are abundant along with other minor species such as Texas persimmon (*Diospyros texana*). The more common juniper (*Juniperus mexicana)* is associated with much of the surrounding limestone region is limited. Sotol (*Dasylirion* spp.), prickly pear (*Opuntia* spp.), and various yuccas occur across the southern part of the county and further west and south. Much of the region is a mosaic of vegetation communities. Along the major rivers the arboreal species dominate and more species may be present. These can include the pecan (*Carya illinoinensis*), American elm (*Ulmus americana*), and black willow (*Salix nigra*).

Vegetation in the Oakalla loam is generally characterized with little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), yellow Indiangrass (*Sorghastrum nutans*), Canada wildrye (*Elymus canadensis*) (Figure 2-7), dropseed (*Sporobolus* spp.), eastern grama (*Tripsacum dactyloides*), sideoats grama (*Bouteloua curtipendula*), and Texas wintergrass (*Stipa leucotricha*) (McCormick 2011).

One plant resource that is increasingly identified in archeological assemblages from central Texas, specifically in burned rock features, are geophytes such as wild onions (*Allium canadensis*), Eastern camas or wild hyacinth (*Camassia scilloides*), rain

Figure 2-7. Canada Wildrye grass with mature seed heads (photograph by M. Quigg).

Figure 2-8. Wild onion bulbs (left) and winecup tubers (right) (photographs by M. Quigg).

lily (*Zephyranthes*), Prairie celestial (*Nemastylis geminiflora*), winecup (*Callirhoe involucrate*), and others (Figure 2-8) (Acuna 2010). These bulbs and tubers appear in the macrobotanical remains from excavated cultural features in the Edwards Plateau and in the adjacent Blackland Prairie (e.g., Acuna 2006; Boyd et al. 2004a, 2004b; Brownlow 2004; Dering 1997, 1998, 2003, 2004, 2006, 2011; Karbula et al. 2011; Quigg et al. 2011b).

During historic times, cedar has become the dominant plant species causing a previously diverse and healthy landscape to become a "cedar break" in many areas with very little plant diversity on the landscape across the Edwards Plateau (TPWD 2015).

2.6.2 Fauna

Blair (1950:101) considers this central Texas region part of the Balconian biotic province and lists 57 species of mammals in the widespread Balconian faunal assemblage. This includes raccoon (*Procyon lotor*), rock squirrel (*Spermophilus variegates*), and nine banded armadillo (*Dasypus novemcinctus*). No species are totally restricted to this province and most range into adjacent provinces, which creates a transitional region for most mammals. Minimally 15 species of frogs and toads are known, 36 species of snakes, only one land turtle, and 16 species of lizards. Blair (1950) indicates the density of the mammals was usually lower than in the adjacent Tamaulipan province. A relatively greater diversity of plant and animal species, plus relatively abundant surface water combined with a range of rock and mineral resources, probably drew prehistoric human populations to this region.

Of considerable importance to prehistoric people were probably; bison (*Bison* sp.), white-tailed deer (*Odocoileus virginianus*), pronghorn (*Antilocapra americana*), coyote (*Canis latrans*), black-tailed jackrabbit (*Lepus californicus*), fox squirrel (*Sciurus niger*), gray fox (*Urocyon cinereoargenteus scotti*), and eastern cottontail (*Sylvilagus floridanus*). Other than the gray fox and coyote, predators are relatively uncommon, although coyote and bobcat documented historically. Wild turkey (*Meleagris gallopavo*), and turtles (*Terrapene* sp.) are apt to have provided other utilized resources. Species no longer in the area include wolf (*Canis* sp.), black bear (*Ursus americanus*), jaguar (*Panthera onca*), lesser prairie chicken (*Tympanuchus* sp.), and Carolina Parakeet (*Conuropsis carolinensis*) (McCormick 2011).

2.7 LITHIC RESOURCES

The economic use of lithic resources by prehistoric people is usually restricted to the acquisition of cherts or other fine-grained materials to manufacture stone tools, plus locally available limestone, dolomite, conglomerates, and other fossiliferous rocks for use in cooking and other tasks. The two categories (tool manufacturing and cooking materials) are briefly discussed below.

Cherts are associated with the Fort Terrett and Segovia members of the Edwards Group formations. These occur over a wide area of central Texas plus more restricted formations such as the Wilberns and Gorman Formations as part of the Llano Uplift region and along the Cretaceous limestone of the Balcones Escarpment (Barnes 1981; Frederick and Ringstaff 1994:140). Information obtained during systematic surveys across Fort Hood revealed many exposures roughly coincide with the Edwards Group formation of the Manning surface buttes and mesas. Those chert exposures are not continuous nor can they be correlated from one butte to the next. In places, lenticular nodules of chert have eroded from softer limestone and mantle the ground surface. Elsewhere, bedded chert nodules occur in limestone and extend for distances as seam exposures. Amorphous nodules of chert erode from limestone bedrock. Even though chert nodules occur in secondary lag gravels along streams across the installation, vast areas of Fort Hood do not contain high quality cherts.

Considerable lateral variability is evident in the form, texture and color of cherts from various Edwards Group exposures across Texas. Initial attempts to characterize Edwards chert in Fort Hood identified seven high quality cherts for knapping purposes (Dickens 1993). A subsequent classification of Fort Hood cherts recognized 17 varieties of high quality chert (Frederick and Ringstaff 1994). More recent studies have expanded the number of high quality chert types to 38. Many of these additional types are not correlated to known exposures, nor are detailed descriptions presently available (Mehalchick et al. 2002:17). As a means of ascertaining the sources of cherts employed by prehistoric groups, and perhaps the movements of people or trading networks, four chert source provinces were identified across Fort Hood (Abbott and Trierweiler 1995). These consist of the west province, the southeastern province, the north province, and the Cowhouse Creek province (composed mostly of lag gravels). Cherts from these four identified chert provinces were potentially transported westward and used by those occupying 41MS69.

Alternatively, both the headwaters of the Llano and James Rivers are in the Edwards Plateau and cut through chert rich formations allowing these river systems to transport eroded chert cobbles downstream. Stream rounded chert cobbles are present in gravels adjacent to or in the vicinity of 41MS69. Limestone rocks, which constitute so many cultural features in archeological sites were probably derived from locally available sources across central Texas within a few hundred meters of sites.

2.8 PALEOENVIRONMENT AND INDICATIONS OF PALEOCLIMATE DURING THE MIDDLE HOLOCENE

Paleoenvironmental studies across Texas and adjacent states are spotty and incongruent especially for the middle Holocene period (Figure 2-9). Sound reconstructions are a very complex endeavor with many interpretative pitfalls, potential problems and interpretative biases to overcome. Reconstructive interpretations of paleoenvironmental conditions vary due to a range of geographical factors. These include the research setting within specific ecoregions and proximity to ecotonal boundaries, the localized topo- edaphic setting, and the mosaic of habitats represented in the immediate regions of the study area. The paleoenvironmental reconstructions are based on one or more environment indicators or proxies. These rely on localized sediments (e.g., geomorphological setting, depositional rates, and pedogenic developments), macrobotany and microbotany (e.g., pollen, phytoliths), macrofaunal bone elements and microfaunal remains (e.g.,

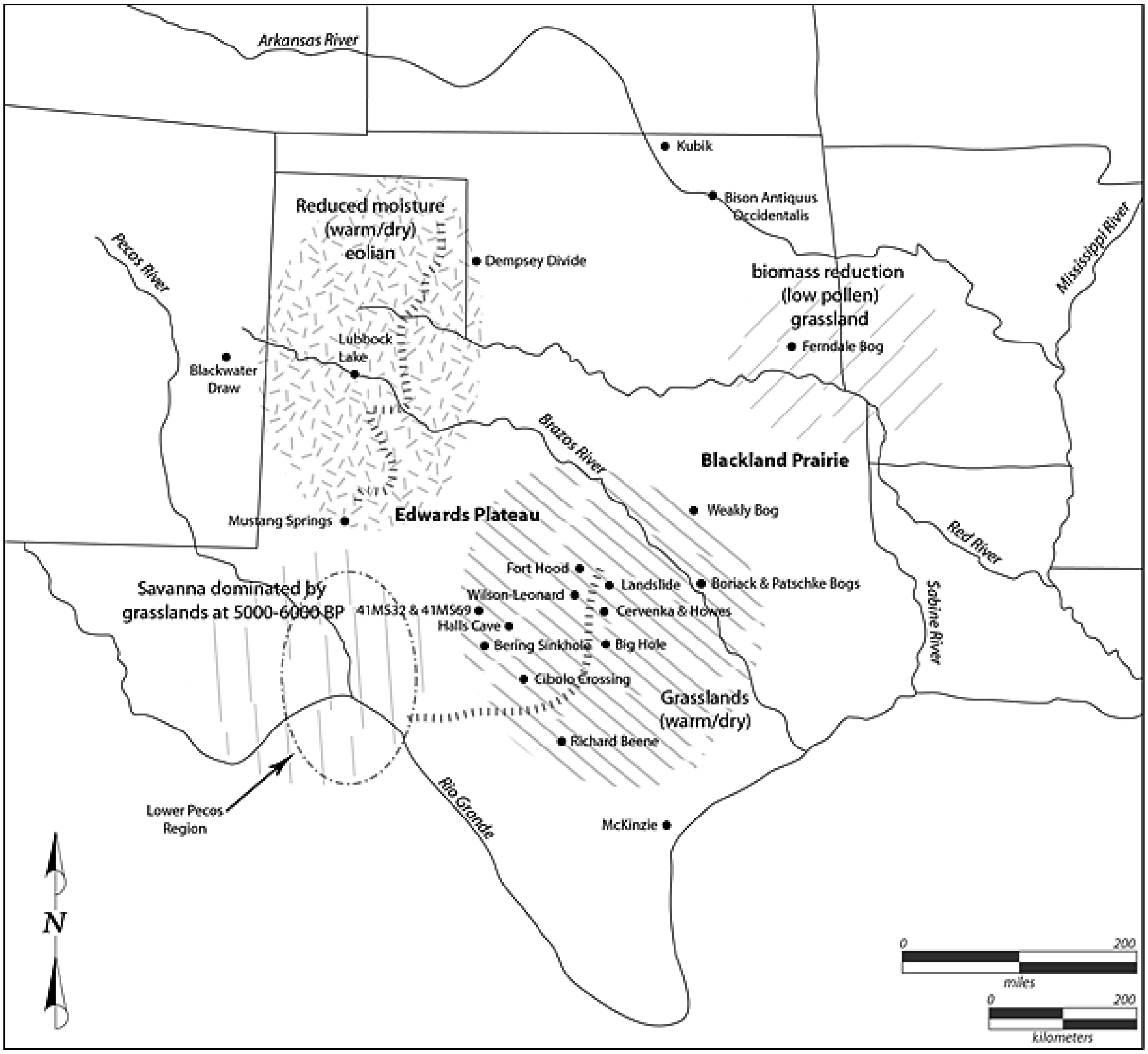


Figure 2-9. Map depicting generalized interpretations of the middle Holocene paleoenvironment and data collection areas.

diatoms, foraminifera), as well as carbon and nitrogen isotopic signatures in soils, plants and animals arising from plant decomposition or ingestion fractionation resulting in concentrations of carbon isotopes in the food chain.

Considerations must also account for the context and integrity of recovered proxy samples (e.g., a single event episode, hearth feature, random charcoal, composite/dispersed charcoal, a broad geological zone, single or multiple samples, or vertical column. Context relates to the genesis of deposit matrix and proxy samples of interest. Specific proxy indicators such as wind-borne pollens or bones and soil humates in alluvial settings can travel scores to hundreds of kilometers from their primary setting of origin. Other types of proxy indicators remain at or near the site of origin. Similarly, the study of faunal or macrobotanical remains inside rockshelters, caves, and sinkholes have to distinguish between the remains of resident occupants, and those proxy remains, which washed into those settings along with older sediments from the surrounding surfaces.

If the results of a particular proxy study are to be combined with other lines of paleoenvironmental proxy evidence, then the context and ages of the respective proxy samples should be acquired to ensure the integrated results are based on contemporaneous periods. Dating is especially critical even within single sites due to differential rates of sediment deposition. Unfortunately, too often sequences with high resolution paleoenvironmental results or trends are inadequately dated, so reliable comparisons are not possible. Worse yet are instances where paleoenvironmental data lack adequate dating points so researchers engage in circular reasoning exercises and extrapolate comparable environmental trends with an unknown degree of reliability or validity. Further chronological considerations must address the kinds of dateable materials selected (e.g., chunk or dispersed charcoal, carbonates, pedogenic humate carbonates, annual verse perennial plant parts, carbonate genesis and fractionation of animal bones, and snails, etc.), the validity of the association of the date to the studied environmental proxy samples (including considerations of old dead wood, and cross-sectional effects), and the accuracy and precision of the chronometric methods.

These and other factors affect the usefulness, data reliability and interpretative potential facing efforts to reconstruct the paleoenvironmental record. This chapter summarizes multiple paleoenvironmental studies conducted in Texas and adjacent areas for the middle Holocene period to provide an interpretative context, which potentially influenced the adaptive responses of prehistoric populations to the region.

For the Great Plains and western United States, geologist E. Antevs (1955) proposed in very general terms that the climatic period comparable to the middle Holocene (roughly 7,000 to 4,500 B.P.) was a time of drier and warmer conditions compared to the present and labeled this period the Altithermal. Antevs' model is based on evidence of erosional and depositional cycles observed in geologic strata across the western United States. In the eastern United States the contemporaneous period from ca. 7,000 to 4,000 B.P. correlates to the warm Hypsithermal interval (Deevey and Flint 1957). Ever since Antevs' (1955) publication, more interest has been directed towards understanding past environmental and climatic conditions in general and specifically for the middle Holocene period. Early research indicated the Great Plains were drier and/or warmer during this period than today (Webb and Bryson 1972). Subsequently, Reeves (1973) argued the short grass Plains expanded during the middle Holocene and offered potentially a larger region for grasses to support bison populations. The paleoenvironment plays a major role in the formation of human ecological models created to understand past human behaviors. These models are based on the assumption the environment influenced human behavior, social organization, resource procurement strategies, activities, and even technologies.

Paleoenvironmental reconstruction is often based on collaborative trends evident in diverse data sets (e.g., aspects of geomorphology, frequency and diversity of pollen, short cell phytolith ratios, spores, charcoal, diatoms, faunal remains, snail types, and changes in stable carbon and oxygen isotope values, etc.) with diverse specialists employing different analytical techniques to extract specific kinds of information to reconstruct paleoenvironmental facets. Many have proposed changes in the environment or speculated on climatic conditions from narrowly selected data sets. In most instances these data sets represent second, third, or higher order extrapolations from the paleoenvironmental condition (Caran 1998). Quaternary deposits provide context from which various proxy data sets are extracted. A clear and accurate understanding of the context and age of the deposits are critical for interpretations of proxy data. The following discussions present diverse paleoenvironmental proxy data sets and interpretations by researchers from across the Southern Plains. It is also probable regional variation occurred across the Plains and may provide different or even conflicting regional interpretations depending upon preservation conditions and the kinds of data used relative to the paleo ecoregions boundaries.

2.8.1 Paleoenvironmental Conditions in Central and Southeastern Texas

In central Texas, specifically across the Edwards Plateau and along its eastern margins in the adjacent Post Oak Savanna region, paleoclimatic records are better known in comparison to available from adjacent regions (Figure 2-10). For example, proxy data for reconstructing the paleoenvironment is derived from pollen cores from several bogs in the Post Oak Savanna (Bousman 1998; Bryant 1977; Holloway et al. 1987; Larson et al. 1972), geomorphic data from river valleys (Abbott 1994; Blum 1987; Blum and Valastro 1989; Frederick 2011; Johnson 1995; Johnson and Goode 1994; Mear 1998; Nordt 1992; Toomey et al. 1993), and microtine mammal remains from cave deposits (Toomey 1993).

Bousman (1998) recounted previously reported pollen results from Boriack and Weakly bogs in the oak-woodlands region of eastern Texas to obtain a 16,000 year sequence of grass-arboreal pollen fluctuations that indicate shifts between forest, woodland, and open plant communities. Bousman's interpretations based on his recalculations indicate open plant communities were present during the Late Glacial Maximum and between 13,000 and 12,000 B.P., 10,000 and 9,000 B.P., and 8,000 and 2,500 B.P. (see Figure 2-10). A key factor in understanding shifts in vegetation communities is the mesic (moist) woody species invaded grassland regions during moist climate intervals. In contrast, woody species died during extended xeric (drought) periods (Coupland 1958). Other factors may include fire suppression and disturbances.

Apparently, between 8,000 and 7,000 B.P., the Post Oak region of central Texas died back and grassland became more prominent. Bousman (1998) presents pollen data to indicate a possible two phased, middle Holocene dry interval, with extremes recorded at ca. 6,500 B.P. and 5,000 B.P. Limited evidence exists in the pollen data for a brief arboreal pollen event at 6,000 B.P., which supports a hiatus in the long drying event or sort impulses of moisture. Bousman also stated that concurrent with the pollen spikes, alluvial pedogenesis occurred at the same time as pollen spikes in the Weakly Bog. Therefore, Bousman interprets dry, grassy intervals are associated with alluvial landscape stability and pedogenesis in eastern Texas. This is a key point when interpreting geomorphic deposits. During the period from roughly 6,000 B.P. to 5,000 B.P. the pollen record documents extreme changes with the arboreal cover changing from about 25 percent to 0 percent during that 1,000 year period.

Nordt (1992) presents geoarcheological data combined with stable carbon isotope values on stream sediments in the Fort Hood area, located in Bell and Coryell Counties of central Texas and in the Edwards Plateau. He identified a specific Fort Hood alluvium under the T_1 surface, which radiocarbon dates between 8,000 and 4,800 B.P. This depositional unit is characterized by fine-grained sedimentation from meandering and abrading streams. Paleosols (buried soils) are absent from this ca. 10 m thick alluvium, which indicates a moderately rapid deposition that lacked long periods of stability. Nordt (1993) and Nordt et al. (1994) interprets vegetation changes for this middle Holocene depositional unit using stable carbon isotope data from dated alluvial deposits. In these studies, the C_4 warm season grasses increase from 65 to 70 percent prior to 6,000 B.P. to between 85 and 95 percent of the total vegetation during a period from 6,000 to 4,000 B.P. Nordt (1993) and

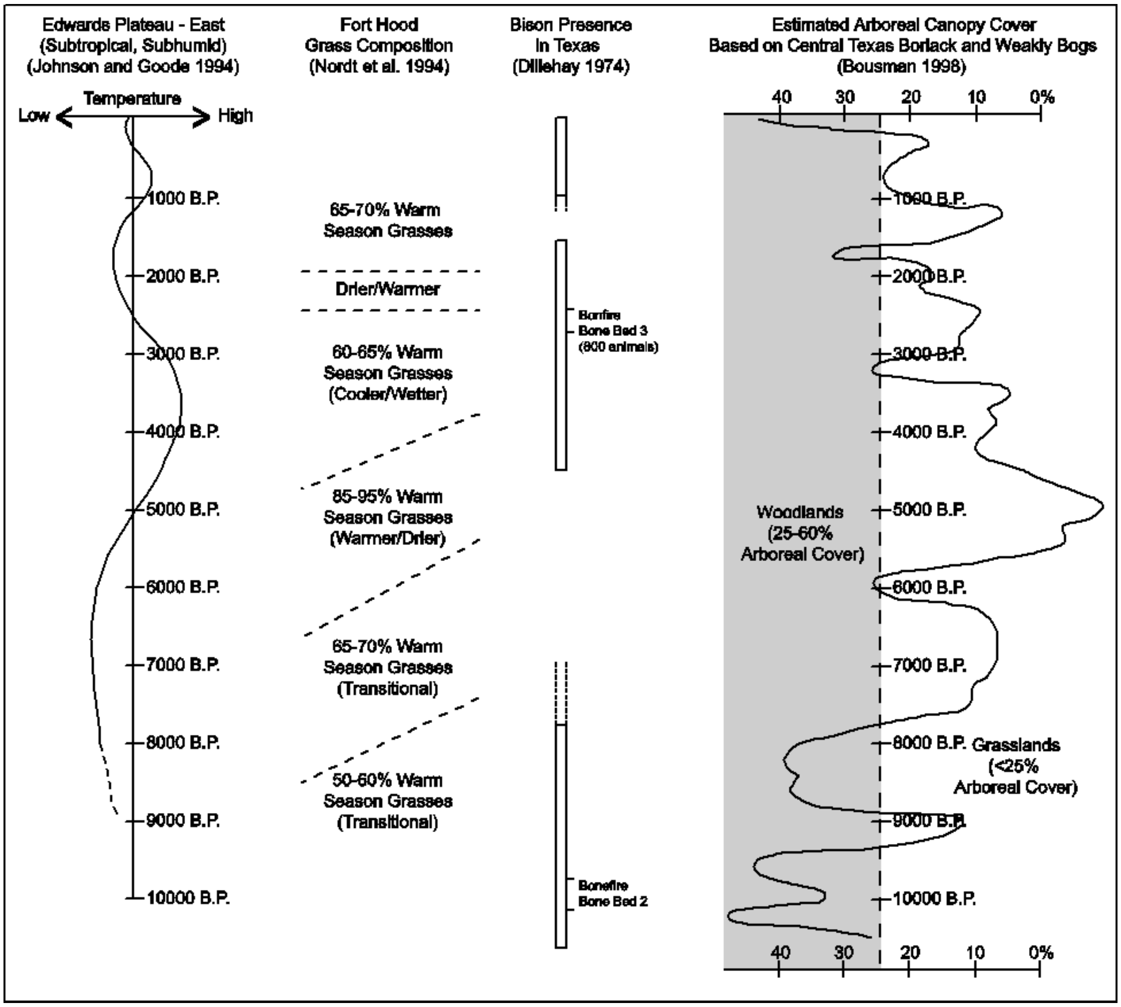


Figure 2-10. Comparison of multiple interpretations of changing environments in central Texas using different data sets.

Nordt et al. (1994) interpreted this isotopic data as a sign the climate was warmer and dryer than today. This generally supports the pollen findings resented by Bousman (1998).

Other stable isotope data reflects slightly different conditions. For example, at O. H. Ivie Reservoir at the confluence of the Concho and Colorado rivers in the northwestern edge of the Edwards Plateau, in Coleman County, a radiocarbon date from humate sediments yielded a stable carbon isotopic signal interpreted as reflecting a 60 percent C_4 plant contribution to the soil matter at 6,000 B.P. (Lintz et al. 1993). This single isotope value supports isotope data from Fort Hood. The amount of C_4 warm season grasses is 20 to 30 percent less than those documented at Fort Hood for this same time. The isotope value obtained from O. H. Ivie is less, although the value does support the dominance of short grass vegetation at that specific time. This value and the extrapolation of the C_4 grasses reflect a general warm period with C_4 grasses dominating local vegetation.

Stable carbon isotopic data from middle Holocene sediments (IIIb deposits, ca. 6,000 to 4,000 B.P.) at the Wilson-Leonard site (41WM235) in Williamson County of central Texas reflect little change in the amount of C_4 matter into the sediments. However, the $\delta^{13}C$ values of ca. -23‰ are unusually negative and reflect nearly 90 percent C_3 vegetation during this 2,000 year time span

(Fredlund and Tieszen 1998). This is opposite the stable isotope data from nearby Fort Hood and reflects a very low percentage of C_4 warm season grasses for that time, as well as limited change from the proceeding period.

The findings from Fort Hood do not support the data from the Wilson-Leonard site. It is the first author's opinion the stable carbon isotope values from the Wilson-Leonard site are suspect, since they also contradict the phytolith record from the Wilson-Leonard site for this same period. If the Fort Hood data set more accurately reflects the past environment, then that environment was dominated by C_4 grasses, which increased during extended periods of warm and dry climates.

Recent research that employed stable carbon and nitrogen isotope data from 61 radiocarbon dated bison bones across central and south Texas has revealed relative temperature and moisture conditions during four time intervals defined by four bone date clusters (Lohse, Madsen et al. 2014). These interpretations were derived from central Texas bison bones with $\delta^{13}C$ values that range from -9.4‰ through -11.9‰ with an outlier at -19.0‰. The $\delta^{15}N$ values range from 5.7‰ to 9.59‰ with no apparent outliers (Lohse, Madsen et al. 2014). The earliest bone date cluster identified, a Calf Creek interval (ca. 5120 to 5205 B.P.) is represented by elevated $\delta^{15}N$ values to indicate the driest of the four periods. The $\delta^{13}C$ values indicate the coldest of the four periods. The authors used their data to reconstruct mean annual temperature for that period at $14.87 \pm 1.13\,^{\circ}C$ ($58.8\,^{\circ}F$) based on stable carbon isotope data (Lohse, Madsen et al. 2014). Employing the $\delta^{15}N$ results based on a linear regression model they derive precipitation approximations at ca. 40 to 45 cm per year. The data relevant to the Calf Creek interval was therefore characterized by cool but dry conditions. The authors also suggest the data indicates this period was more volatile, with greater variation in rainfall over short periods. They summarize by providing a broad climate reconstruction with other stable isotope data to reveal a broad cold period across North America just prior to the Calf Creek interval, which was the coldest and driest of the three subsequent periods (Lohse, Madsen et al. 2014).

The $\delta^{13}C$ isotope values on a column of organic carbon from sediments through the Medina pedocomplex (Unit A5, about 7,000 to 4,400 B.P.) along the Medina River just south of San Antonio indicate a steady increase in the amount of C_4 organic plant matter from about 40 percent at 7,000 B.P. to about 62 percent at 5,000 B.P. Following this latter period the C_4 isotope values decrease to about 50 percent at 4500 B.P (Figure 2-11) (Mandel et al. 2007). This isotope data provides support for a warmer climatic period peaking at around 5,000 B.P. These values are roughly 30 to 40 percent less than isotope values obtained from farther north in the Fort Hood alluvium for this same period, although they still reflect dominance of short C_4 grasses. However, that same isotope data also reveals support for Johnson and Goode's (1994) Edwards Interval with even greater peaks in C_4 values slightly later in time with a peak near 75 percent C_4 grasses between ca. 3,000 and 1,500 B.P. The dates from the Medina pedocomplex are not in total agreement with Johnson and Goode (1994). The increase in C_4 plants does support a drying interval following the Altithermal period.

In geomorphic studies directed towards the upper Colorado River drainage across the Edwards Plateau, Blum (1992) interprets the broad depositional sequence dating from 11,000 to 5,000 B.P. as slow accumulation with slow valley widening through lateral migration. Deposition was dominated by sediments from relatively proximal (close) sources within the drainage, and sediment supply that exceeded transport capacity. At O. H. Ivie Reservoir the middle Holocene deposits occur at the confluence of the Concho and Colorado River channels aggrading with gravel and sand deposits. Around 5,000 B.P. the channels terraces were incised to bedrock and floodplain

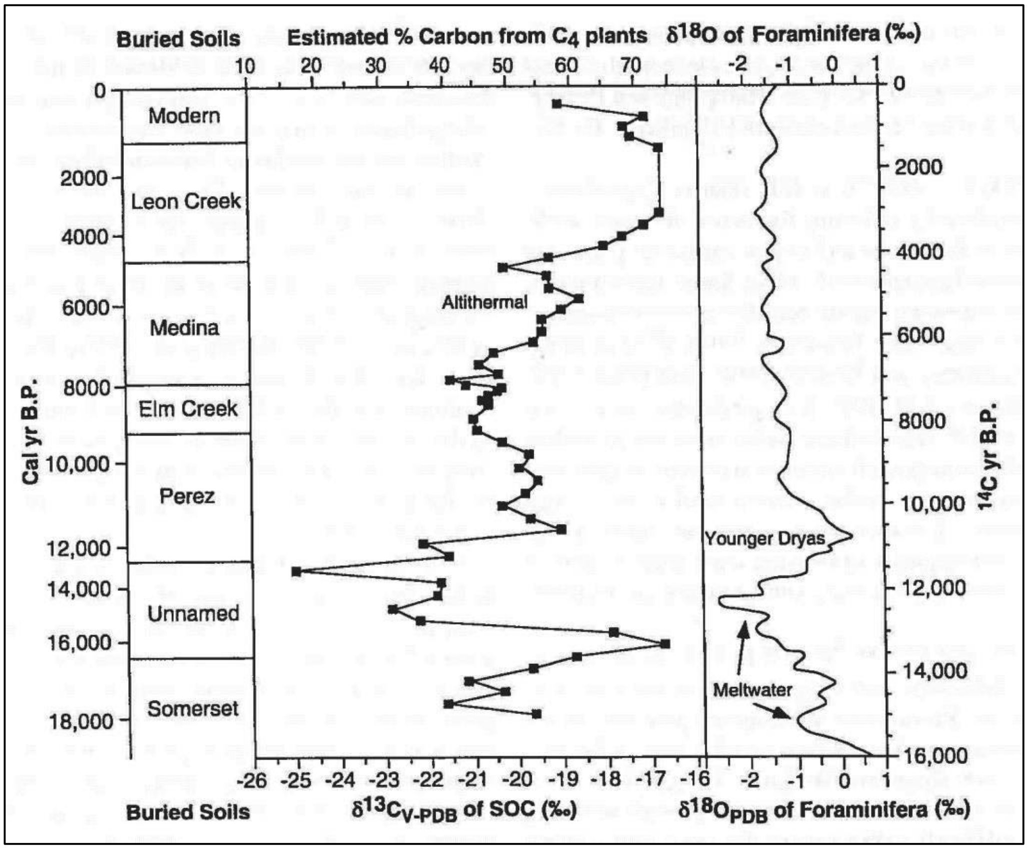


Figure 2-11. Carbon isotope values of soil organic carbon (SOC) in the sequence of buried soils at the Richard Beene site in southern Texas (from Mandel et al. 2007, Figure 3.20).

deposition temporarily ceased. This was interpreted to represent a serve arid period (Blum and Lintz 1993). Blum's work in the Pedernales River valley, south of the Colorado River and also in the Edwards Plateau observed changes in channel sediments, which revealed a middle Holocene erosional unconformity. Blum and Valastro (1989) interpreted this to reflect a dry climate around 4500 B.P. Near the eastern boundary of the Edwards Plateau and upstream from the Big Hole site, the Onion Creek valley deposits near Buda, revealed an erosionally truncated B soil horizon of a 20 cm thick paleosol radiocarbon dated by soil humates to 5310 ± 90 B.P. (Abbott 1994). Further south along the southern boundary of the Edwards Plateau, Mandel et al. (2007) defined the Medina pedocomplex (Unit A5) in geomorphic studies along the Medina River just south of San Antonio. This is a cumulic soil under development from about 7,000 B.P. to about 4400 B.P. This soil was buried soon after 4400 B.P. The Medina pedocomplex was 4.5 m thick and characterized by an Ak-ABk-Bk soil profile. The particle size does not change significantly throughout this period. This consistency in texture generally reflects a long stable environment over the 2,600 year period, in which periodically flooded occurred on a regular basis. The consistence text also prevented the identification of identifiable erosional episodes.

At Hall's Cave near the center of the Edwards Plateau in Kerr County and just northwest of San Antonio, Unit 3 deposits ranged from 1 to 1.5 m in-depth were consistent, and horizontally stratified with a sharp base and distinctive top (Toomey et al. 1993). This deposit is radiocarbon dated between 7,320 and 4,850 B.P. Unfortunately, this deposit lacks sufficient radiocarbon dates to document changes at specific times. The authors conclude during this early to middle Holocene period the upland soil mantles were undergoing progressive dissection and/or down wasting and became darker, thinner, and stonier. This is based on rates of vertical accretion at Hall's Cave that were twice the previous period with the amount of clays decreasing, soil color changes, and the percentage of transported limestone clasts increases (Toomey et al. 1993). Toomey et al. (1993), reviewed accumulated data from central Texas, and sees the early-to-middle Holocene dominated by a protracted decrease in effective moisture that reflects conditions somewhat drier than modern times. This xeric trend persisted until roughly 2500 B.P., a much later date than most previous researchers have proposed.

To date, geomorphic research has not clearly demonstrated whether flood plain aggradation is related to dry periods or too moist conditions (Johnson and Goode 1994). However, Blum and Valastro (1989) and Blum and Lintz (1993) support the notion fluvial systems reflect channel aggrading during more humid periods, and incision following a transition to drier conditions.

Insights gleaned from sparse middle Holocene faunal assemblages have been employed to characterize paleoenvironmental conditions. For example, at the Wilson-Leonard site, Baker (1998) did not identify any bison remains from the Middle Archaic deposits. This trend is also apparent in the period ca. 7,000 to 3,000 B.P., Unit IIIb at the Wilson-Leonard site. The representative faunal inventory was dominated by rabbits and medium size mammals along with fish, snakes, and turtles (Baker 1998). The Wilson-Leonard data supports the assertion the period from 8,000 to 4,500 B.P. was a period of bison absence or scarcity based on data from 28 paleofaunal assemblages across Texas (Dillehay 1974). If it is assumed bison frequency is environmentally influenced, then frequency of bison in archeological deposits potentially serves as a gross indicator of paleoenvironmental conditions. Conflicting interpretations concerning bison ecology, however, has identified both wet and dry conditions as suitable scenarios for bison herd populations in a particular area (Collins 1995, 2004; Johnson and Goode 1994), leaving the distinction unclear.

In direct contrast to the Wilson-Leonard faunal data and Dillehay's (1974) earlier work, the Spring Lake site (41HY160) data from Hays County south of Austin documents bison presence between 5060 and 5,180 B.P. based on 11 δ^{13}C corrected radiocarbon dates on bison bones from a 50 cm thick zone (Lohse, Culleton et al. 2014; Lohse et al. 2013). This zone also yielded turtles, deer, pronghorn (*Antilocapra americana*), Canidae, cottontail rabbits (*Sylvilagus*), bird, fish, and snake.

During a period from 10,500 to 5,000 B.P. the faunal record from Hall's Cave reveals a progressive extirpation of microvertebrate taxa with higher moisture requirements, such as the eastern mole (*Scalopus aquaticus*), mole salamanders (*Ambystoma* sp.) and the short-tailed shrew (*Blarina* sp.); along with an increasing importance of species such as the desert shrew (*Notiosorex crawfordi*) that tolerate drier conditions (Toomey 1993; Toomey et al. 1993). The faunal records from Hall's Cave are superb. The deep deposits represent a long depositional history, however, they lack sufficient reliable radiocarbon dates. Their presence would add importance and specific timing to changes in this faunal record.

Indicators of plant resources within dated deposits also provide insight into paleoenvironmental conditions. For example, indirect plant data via fossilized plant silicates (i.e., phytoliths) from the Wilson-Leonard site implies a significant increase in the rate of grassland expansion around 8,700 B.P. Grassland composition during the period from ca. 8,700 to 6,000 B.P. (Fredlund 1998) is similar to existing conditions. The phytolith record indicates a relatively stable period between about 6,000 and

4,000 B.P. dominated by grasslands, with most grasslands peaking just after about 4,000 B.P. Fredlund (1998) also theorizes the overall vegetation composition of central Texas reached its modern balance of woodlands and grassland by about 4,000 B.P.

Few macrobotanical records are published for the middle Holocene period from central Texas. One record from the Wilson-Leonard site dates between ca. 7,000 and 3,000 B.P. revealed live oak (*Quercus* sp.), juniper (*Juniperus* sp.), walnut (*Juglans nigra*), elm (*Ulmus alata*), and mulberry (*Morus* sp.) trees (Dering 1998). Macrobotanical remains from other archeological sites are nearly nonexistent, as evident from the lack of carbonized organic remains from the excavated components at the Landslide site (Sorrow et al. 1967) and Cibolo Crossing sites (Kibler and Scott 2004) among other locations that reflect this period.

In summarizing the central Texas area, the collective body of diverse proxy data presented above indicates a drying trend during the middle Holocene all across central and southeastern Texas, which roughly corresponds to Antevs' (1955) Altithermal period. These diverse studies reveal expressions of the Altithermal and reflects variability across the mosaic of microhabitats of Edwards Plateau and through time (see Figure 2-10). Johnson and Goode (1994) project no long-lasting, dry Hypsithermal (their term for the Altithermal) climate in the eastern Edwards Plateau based largely on the faunal data derived from Hall's Cave and geomorphic data from Cow House and San Geronimo Creek valleys. They propose, however, the existence of a dry Edwards Interval separate from the Altithermal period that peaked around ca. 4,000 B.P. and lasted from ca. about 5,000 to 3,000 B.P. This time frame is based on 50 calibrated wood charcoal radiocarbon assays from archeological and geomorphic context in the Jonas Terrace site (41ME29) along the San Geronimo Creek and Fort Hood Military Reservation. Johnson and Goode (1994) interpret little change in the climate record between the Early and Middle Archaic cultural periods. They also propose bison were present in central/southeastern Texas during the Middle Archaic based on very limited bison data from questionable contexts, contradicting the data presented by Dillehay (1974). The proposed dry conditions are postulated to have promoted the spread of yuccas and sotol (C_4 and CAM plants). It was these xeric-adapted plants that were collected by humans and cooked long periods in large burned rock ovens during Middle Archaic times (Johnson and Goode 1994).

Data from the Texas Gulf Coast near Corpus Christi indicates the sea level was rapidly rising between about 6,700 and 6,000 B.P (Ricklis and Blum 1997). Ricklis and Cox (1998) interpreted the stratigraphic evidence to indicate widespread erosion of upland margins prior to 5,000 B.P. This implies sparse vegetation cover and possibly patterns of relatively low precipitation. This also implies a probable regional, if not global, warming trend that supports Antevs' (1955) Altithermal model, and the timing of this event. Ricklis (1993) presents archeologically-derived radiocarbon dates and faunal evidence to indicate a middle Holocene period of relative aridity with an ocean still-stand in the Corpus Christi area. This still-stand was accompanied by shell fishing by the human population between roughly 6,000 and 4,000 B.P. Nordt et al. (2002) suggested little association between marine and adjacent continental ecosystems as a result of reduced glacial meltwater entering the Gulf of Mexico during the Holocene, and a shift in global circulation patterns. With the waning meltwater flow, C_4 production generally increased throughout the Holocene, culminating in peak warm intervals at ca. 5,000 and 2,000 B.P.

Also towards the coast along the Guadalupe River south of Victoria, Texas the Buckeye Knoll site (41TV98) yielded a long pollen sequence. Albert (2012) interpreted the middle Holocene to indicate a dry period similar to central Texas (i.e., Collins 2004; Johnson and Goode 1994), though it was interrupted by a wet period from ca. 5,500 to 5,000 B.P.

2.8.2 Paleoenvironments in Northern Texas, Oklahoma and Adjacent Areas

Areas north of the Edwards Plateau encompass several different biotic regions, which include the short grass plains (Texas and Oklahoma panhandles), the mixed grass prairies (north central Texas and central Oklahoma), and the Cross Timbers (eastern Texas and Oklahoma). Few archeological and geomorphic studies have encountered middle Holocene deposits across this expansive region. From published data, the more prominent investigations include work by Albert (1981); Albert and Wyckoff (1984); Ferring (2001); Hall (1988); Haynes (1995); Holliday (1985b, 1989); Humphrey and Ferring (1994); Johnson and Holliday (1986); and Meltzer (1999). These studies are presented to illuminate the overall paleoenvironmental picture of the middle Holocene.

Hall (1988), in discussing environmental conditions across much of Oklahoma derived from geomorphic data, states the middle Holocene (ca. 7,000 to 5,000 B.P.) climate was exceptionally dry and characterized by stream valley erosion. His assertion supports previous work in a comprehensive evaluation of river response to Holocene climates by Knox (1983) who notes "between 6,000 and 4,500 B.P. significant erosion of early Holocene alluvial fills was occurring that in most regions". They both contend stream valley erosion would have removed middle Holocene sediments and associated archeological sites from the record, and this extensive area wide erosion account for their low density of middle Holocene sites across the region. In western Oklahoma paleoenvironmental reconstruction was developed from four datasets from the riparian setting along the Bull Creek site (34BV176) in the panhandle. Diverse data reflects more effective moisture in the pollen samples (46 and 47). A mixed-grass phytolith assemblage dominated by C_3 grasses (ca. 60 percent) indicate a moist condition at roughly 6200 B.P., although trending toward drying conditions (Bement et al. 2007). This locality also revealed a nearly 80 cm thick deposit of loess (Unit III) dated between 8670 ± 90 and 6200 ± 90 B.P. to demonstrate the area received eolian sediments during this early period (Bement et al. 2007).

Multiple pollen records from Ferndale Bog on the western edge of the Ouachita Mountains in southeastern Oklahoma provide a significant, well-studied and dated source for the Holocene from which to reconstruct the paleoenvironment (Albert 1981; Albert and Wyckoff 1984). At Ferndale Bog the lowest dated zone is close to 12,000 B.P. (Bryant and Holloway 1985). The pollen record following the Pleistocene documents a loss of pine (*Pinus*) and oak (*Quercus*) with very minor amounts of hickory (*Carya*) combined with significant increases in grasses (Poaceae) and weeds (Ambrosineae). It is not clear if these changes document the short Younger Dryas with a return to a cold period that saw the return of glaciers between 11,000 and 10,000 B.P. During the early Holocene/Early Archaic pine and hickory pollen remained very limited. Oak pollen peaked at some point following a spike in the grasses. Both the later peaks in pine, oak and weeds continued to decline into the middle Holocene. Prior to about ca. 5,200 B.P. Albert's (1981) core reveals a significant dominance of non-arboreal pollen over arboreal pollen with oaks the dominate tree. Accordingly, in southeastern Oklahoma a grassland region with scattered oaks was established by Calf Creek horizon times. Subsequently, oaks gradually increased as did the overall arboreal composition. In light of the postulated grasslands in southeastern Oklahoma by minimally 5200 B.P., the vegetation further west was probably grassland as well.

The Aubrey site in north-central Texas contributes geomorphic and isotopic data to the paleoenvironmental discussion (Ferring 2001; Humphrey and Ferring 1994). From that data, Humphrey and Ferring (1994) suggest the middle Holocene (8,000 to 4,000 B.P.) experienced a decrease in C_3 plant composition as revealed in the floodplain stable carbon isotope record. Ferring and Yates (1997) consider the middle Holocene as a transitional period between the prior period with its high pollen representing prairie-step vegetation and the later low pollen amounts representing mixed forest vegetation based on data from Ferndale Bog in southeastern Oklahoma. They suggest the very low pollen influx during the middle Holocene, especially between 6500 and 5500 B.P. reflects a significant biomass reduction and presume this was caused by lower annual precipitation (Ferring and Yates 1997).

In northwestern Texas at the edge of the High Plains is the intensively investigated site of the Lubbock Lake site (41LU1; Holliday 1985a, 1985b, 1989, 1995a, 1995b; Johnson and Holliday 1986; and others). Multiple analyses directed at diverse data sets contribute significant data to the paleoenvironment there and the surrounding region. At the Lubbock Lake site the weakly developed Yellowhouse Soil (Substratum 3l) formed at the top of Stratum 3 dated between 6,300 and 5,000 B.P. (Holliday 1985b). The Yellowhouse Soil has a weak A-C profile which developed over an estimated 500 years in calcareous lacustrine and sandy eolian deposition sediments with and subsequent pedogenesis. Holliday (1995b) indicates the water table was high during this period of soil formation. Sediments similar to the Yellowhouse Soil are widespread in Southern High Plains and support an interpretation for a regional wide climate change toward conditions of increased eolian activity, reduced effective moisture, and possibly warmer temperatures. Johnson and Holliday (1986; Johnson 1987b:99) report the Middle Archaic was mostly a dry period from roughly 6,300 to 4,500 B.P. with a slightly cooler and more moist period with a cessation of blowing dust lasting for 500 years, between 5,500 and 5,000 B.P. as represented by the Yellowhouse Soil (Johnson 1987b:99). They interpret the 500 year moist period to coincide when bison were present. Holliday (1995a) documented intensive deflation between 6500 and 4500 B.P., probably due to reduction in plant cover, which allowed for considerable eolian activity.

Faunal remains can also be indicators of the environment and potentially reflect environment conditions. Johnson and Holliday (1986) indicate the archeological record from the Southern Plains is scarce for this estimated 2,000 year Middle Archaic period from 6,400 to 4,500 B.P. The Middle Archaic cultural events at the Lubbock Lake site reflect small groups of people subsisting on sparse bison remains. With the lack of excavated sites or components dated to the Altithermal period, faunal records are also nearly nonexistent. Between 5500 and 5,000 B.P. the limited faunal assemblage at the Lubbock Lake site indicates a period of landscape stability (Johnson 1987a:95, Table 8.2). Other faunal remains from the Middle Archaic period (ca. 6300 to 4500 B.P.) at the Lubbock Lake site includes the presence of frogs (*Rana*), yellow mud turtles (*Kinosternon flavescens*), box turtles (*Terrapene* sp.), Texas horned lizards (*Phrynosoma cornutum*), bullsnakes (*Pituophis melanoleucus*), blacktail jackrabbits (*Lepus californicus*), blacktail prairie dogs (*Cynomys ludovicianus*), pocket gophers (*Geomys*), rats, coyotes (*Canis latrans*), and pronghorn (*Antilocapra americana*) (Johnson 1987a). Most species except rats, gophers, coyotes, and the previously mentioned bison were recovered from noncultural contexts. Therefore, most of these species may be considered to be natural background fauna from the general site environment. No extinct species are apparent in the Lubbock Lake faunal assemblage. As expected the faunal assemblage reflects the grassland dominated, water-edge habitats of the site setting. Bison are documented for this middle Holocene period at the Lubbock Lake site in the Texas Panhandle, however, specific bone dates were not obtained to pinpoint precisely when bison were present at the Lubbock Lake site.

The gastropod assemblage from the Lubbock Lake site provides excellent clues to the paleoenvironmental conditions. Specifically Substratum 3l, the buried A horizon referred to as the Yellowhouse Soil, from ca. 5,500 to 5,000 B.P., yielded a gastropods assemblage markedly different from the more mesic strata 1 and 2. The terrestrial species is essentially a modern population, with 86 percent derived from six very tolerant and drought-resistant species making their first appearance (Pierce 1987). Another indication of a severely altered environment was the very limited occurrence of aquatic gastropods as represented by only six species. Pierce (1987) interpreted the assemblage as reflecting an environment with the possibility of higher temperatures and less effective moisture. This pattern potentially resulted from decreased rainfall or increased evaporation. He projected an environment similar to southeastern New Mexico with a probable average annual precipitation less than 40 cm per year.

Pollen studies conducted at the Lubbock Lake site reveal varying degrees of success due to differential preservation and low densities of recovered pollen (Bryant and Schoenwetter 1987). Researchers agreed the pollen record is so suspect the pollen should not be employed to reconstruct the local paleoenvironment (Bryant and Schoenwetter 1987). No other well-dated pollen records exist from northern Texas due primarily to poor pollen preservation.

Hall (1997) has made multiple attempts to recover pollen from late Quaternary valley fills in the Southern High Plains. Again, poor pollen preservation is characterized by low pollen concentrations, low taxa diversity, and high proportions of corroded grains. This makes interpretations of paleoenvironmental conditions based on pollen proxy data impossible.

Holliday (1989) utilized geomorphic data to indicate the Altithermal period was present in the western United States between 7,500 and 5,000 B.P. Stratigraphic data from many Southern Plains draws indicate eolian deposits date to about 5,000 B.P. Other research regards significant portions of dune fields in the Great Plains were created between 7,000 and 4,000 B.P. (Arbogast and Muhs 2000; Forman et al. 2001; Holliday 1989; Miao et al. 2005). In western Oklahoma evidence exists for stabilized surfaces buried by dune deposits (Brady 1989; Thurman and Wyckoff 1994; Wyckoff 1990).

In contrast with the poor pollen record in the High Plains region, Hinds Cave in southwestern Texas provided a good pollen record for much of the Holocene. In discussing pollen for the period from 7,000 to 4,000 B.P. Dering (1979) proposed widespread grasslands, which replaced the juniper-oak (*Juniperus*-*Quercus*) stands became restricted to erosional breaks. Xerophytic shrubs and semi-succulents probably were scattered thinly throughout the grasslands (Dering 1979).

Winsborough (1997) conducted diatom analysis from ten localities within draws across northwestern Texas. She discovered similar assemblages in all draws and suggested a great similarity in the draws lacustrine habitats. She claims evidence for synchronous, region wide deterioration of aquatic habitat associated with drying conditions occurred between about 8,000 and 6,500 B.P.

The Clovis type site of Blackwater Draw (LA3224) in northeastern New Mexico provides significant soil stratigraphy data to indicate paleoenviromental changes on the Southern High Plains. During the middle Holocene a large blowout remained exposed in the top of Unit F from roughly 8,500 to 6,500 B.P. The blowout was filled by reddish brown dune sand of Unit G (the Jointed Sands) and bracketed by radiocarbon dates on bulk soil of 4855 ± 90 B.P. at the top of Unit G and four dates from the Unit F/G contact range from 8730 ± 90 to 6720 ± 80 B.P. (Seeback 2002). After approximately 5,000 B.P. the depression filled with eolian sand of Unit G; and the presence of a weak brown paleosol at the top of

Unit G indicates dune stabilization by vegetation under conditions slightly more mesic than today (Haynes 1995). This paleosol is truncated in places by the deflational contact with overlying Unit G2 dune sand. Burned bison bone dated to 4950 ± 150 B.P. documents the presence of bison (Haynes 1995). During the dry period, which persisted from ca. 8,000 to 5,000 B.P., Archaic peoples apparently utilized the blowout as a place to trap and kill bison (Haynes 1995). The prehistoric water wells at the Clovis site described by Evans (1951) and Green (1962) were excavated from the surface of this blowout. The presence of water wells indicate a drop in the water table and presents compelling evidence for the dry Altithermal period proposed by Antevs (1955), an interpretation also emphasized by Meltzer and Collins (1987) and Holliday (1989).

The Mustang Springs site (41MT2) northeast of Midland in extreme Southern High Plains also makes significant contribution to the early to middle Holocene environment via prehistoric water well data (Meltzer 1999). Excavations there yielded a relatively fine-grained record of middle Holocene environments and climate (Meltzer and Collins 1987; Meltzer 1991, 1995, 1999). The site contains over 60 Altithermal age (7,000 to 4,500 B.P.) water wells hand-excavated by humans into the bottom of a dry Mustang Draw stream bed to obtain underground fresh water. Less than 50 non-culturally diagnostic artifacts were recovered from the Altithermal surface and no other recognizable cultural features were associated with the wells. The wells at the Mustang Springs site plus other documented wells across the Southern Plains (Evans 1951; Green 1962; Honea 1980; Quigg et al. 1994; Smith et al. 1966) reflect definite use of a clear adaptive human strategy to the region during dry periods when the water table is thought to have dropped by about 3 m. The shallowest wells are the earliest, which indicates the water table dropped and the wells got deeper. Most water wells at the Mustang Spring site were dug over a 200 year period from 6600 to 6800 B.P., during what Meltzer considers the maximum dryness. Meltzer speculates the well digging reflects a generalized strategy by highly mobile people as, an adaptive response to the drying environment. Meltzer (1999) postulates a reduction in effective moisture, surface water, and resource abundance, and an increase in resource patchiness, sediment weathering, erosion, and eolian activity.

Stable carbon isotope data from the middle Holocene period across northern Texas and Oklahoma is very limited and such kinds of information from well-dated, stratified contexts is absent. Isotope results are available from several draws across northwestern Texas, although isotope data directly related to this targeted period is limited to only a few samples from the Lubbock Lake site (Holliday 1995b).

Macrobotanical remains from archeological features dating to the Altithermal are nearly nonexistent for this region as excavated sites or components dated to this period are extremely rare. In most instances, the few excavations did not conduct flotation of feature sediments to acquire macrobotanical remains. The plant assemblage from the Middle Archaic Stratum 4 at the Lubbock Lake site was considered too small to be regarded as significant (Thompson 1967).

Well-dated, extensive phytolith analyses for the middle Holocene period across northern Texas and the adjacent Oklahoma regions have not been conducted. A feasibility study directed towards extracting fossil biosilicates was conducted in the northwestern part of Texas (Bozarth 1995). Five of eight investigated localities yielded good phytolith preservation dating to minimally 8300 B.P. Diatom preservation was also good in all eight samples. However, no samples dated between 6500 and 4500 B.P. (Bozarth 1995).

Morgan playa in the Rolling Plains of northwest Texas yielded a 220 cm deep sediment column that provided a well-represented phytolith record. Unfortunately only a single radiocarbon date was obtained to chronologically place the phytolith assemblages (Fredlund et al. 1998). Warm season shortgrass phytoliths dominate the profile from 15 to 145 cmbs. Despite the lack of dates to determine the rate of sedimentation, the authors divided the column into four parts and interpreted the different zones. Zone B, a period estimated to date between 5600 and 7900 B.P., significantly reflects more mesic conditions than today. This is at odds with other lines of environmental data and potentially reveals dating problems. On the other hand, the relatively high percentage of *Aristida*-type phytoliths indicates increased surface disturbance and aridity (Fredlund et al. 1998). Interpretations are not time specific as they lack solid chronological control. The analysis demonstrates the merit of phytolith analysis for the Southern Plains.

Stafford (1981) studied the geomorphology of valleys crossing the Texas High Plains to demonstrate certain periods had significantly different archeological potential. He indicated sediments dating from 6,000 to 2,000 B.P. have a distinctly lower archeological potential.

As in other areas, the environmental record for the Altithermal period across Kansas is sparse. Stites (2006) summarizes the environmental data and draws heavily on Grueger's (1973) pollen sequences spanning the last 25,000 years from two marshes in Atchison County, northeastern Kansas. "Prairie vegetation, with perhaps a few trees along the valleys, covered the region until about 5,000 years ago, when a reexpansion of deciduous trees began in the lowlands" (Grueger 1973:239). Subsequently, quantities of ragweed (*Ambrosia*) and sagebrush (*Artemisia*) combined with sparse deciduous tree pollen signaled brush that marks the end of the prairie interval.

Mandel (1992, 1995) interprets the Kansas Altithermal geomorphic data as marked by upland erosion and sediment removal from low-order streams valleys and sediment increases in high-order stream valleys. This generally supports early interpretations by Haynes (1967) where he observed arroyo cutting after 7,500 B.P. and channel filling between 6,000 and 4,000 B.P.

In Missouri, the remains of prairie faunal taxa are common in western Missouri archeological sites (Wolverton 2002). Interestingly, no reported prairie taxa such as bison are from sites or components in the northern Ozark Highlands of Missouri. Wolverton indicates new data reveals prairie taxa inhabited central Missouri during the warm and dry middle Holocene (8,500 to 5,000 B.P.).

Studies concerning the middle Holocene environment on Northern Plains and its margins are many and wider spread than those in the Southern Plains. It is not the intention of this summary to cover the broad Northern Plains region. However, one excellent example from that region reveals the common theme most studies have revealed. In a high resolution study of diatom assemblage sediments from Moon Lake in southwestern North Dakota served as a gauge for water salinity changes to infer past climatic conditions (Laird et al. 1996). The researchers interpreted their data to reflect high salinity during the middle Holocene from 7300 to 4700 B.P. as evidence of a period of low effective moisture.

In summary, the diverse proxy data sets overwhelmingly reflect a mostly warm, dry Altithermal period between ca. 7,000 to 4,500 B.P. in the more northerly regions of Texas, in Oklahoma, and across the plains. However, the lack of tight chronological control for many reported records hinders correlation of precise timing for the onset and duration of this warm, dry period or the potential for reversion to short moist period(s) within this long, arid period. Lack of well-dated assemblages also prevents researchers from refining the probable short-term fluctuations within the Altithermal period. The best evidence for the peak in the dry period may be from the datedhand-dug water wells at the Mustang Springs site, which places the principal well digging period between ca. 6800 and 6500 B.P.

2.8.3 Regional Context and Discussion

The following discussion considers environmental reconstructions and interpretations of paleoenvironments by multiple researchers, which employed diverse data sets gathered from across Texas and adjacent regions. It is unclear as to which specific data set or analytical technique best represents the middle Holocene paleoenvironment.

The use of different kinds of proxy data and the ambiguities in chronological controls probably account for slightly different interpretations and the slightly different ages. Johnson's and Goode's (1994) temperature shift projections contradict Bousman's (1998) canopy cover estimates and other studies in central Texas. This contradiction is difficult to resolve since Johnson's and Goode (1994) employed calibrated radiocarbon dates in contrast to the dates presented by all other researchers. The radiocarbon assays from humates or bulk soils may be a major factor underlying the different ages of interpreted events as humate dates are from composite soils that do not reliably date specific events (e.g., Brock et al. 2010; Collins 1994; Frederick 2011). More precise dating through the use of wood charcoal or even carbonized annual seeds from specific context provide more precision in the timing of events.

If the period of paleoenvironmental interest, roughly ca. 6,000 to 4,800 B.P., was arid, then the dry conditions probably caused great variation in types and density of vegetation as documented by empirical ground-cover observation during droughts in Kansas when large areas became devoid of plants (Weaver and Albertson 1956). The above ground net production of both C_3 and C_4 grasslands is strongly influenced by the amount and distribution of annual precipitation (Sala et al. 1988). The number, height and diversity of many grasses decline during drought phases. However, erosion and forbs increase and limited fuel would reduce the importance of fire (Clark et al. 2002). When precipitation is less than 37 cm per year, sandy soils with low water holding capacity are more productive than loamy soils with higher water holding capacity (Sala et al. 1988). Short grasses (C_4 photosynthetic pathways species) growing on stable lands would be the first to manifest drought effects, with many mesic plants (C_3 photosynthetic pathway species) disappearing completely. Bluestem grasses would decrease rapidly in two years of drought and would give way to C_4 grama grasses that increase during drought (Weaver and Albertson 1956). Various weeds would also start growth promptly and develop vigorously. The reduced vegetation cover would cause excessive runoff when infrequent rains occurred. The reduced carrying capacity would adversely affect Plains bison and pronghorn ranges which would undoubtedly disperse into smaller herds and reduce in number. Reduction in herbivore numbers has been postulated by Dillehay's (1974) documentation of bison absence or scarcity during the dry periods of the Altithermal (ca. 7,000 to 4,500 B.P.). Collins (1995:384, 2004:120) indicated the "climate during the cultural interval reflected by the Bell/Andice/Calf Creek projectile points was somewhat mesic" and a time when bison were hunted. He equates bison with moist mesic periods. Recently, Lohse, Culleton et al. (2014) radiocarbon dated 13 bison bones from Bell/Andice/Calf Creek interval components across Texas and demonstrated their presence during a very narrow 200 year period between 5,060 through 5,205 B.P. (cal 5,815 through 5,955 B.P.).

McDonald (1981) also projected a general reduction in frequency of bison across the Plains during the middle Holocene, which is generally supported by their scarcity or absence at many localities. Bamforth (1987) states bison migrate from place to place: to search for food and water, to search for other members of their species, and to escape dangerous circumstances. The distribution of relatively high quality forage in a region at any given time forms a mosaic of patches of varying forage quality, with the distribution of high quality patches largely controlled by spatial distribution of available moisture. Thus, the distribution of high quality food patches control where bison would move. If moisture was limited, then bison were undoubtedly dispersed across the landscape and directed towards isolated patches of good forage. Better range conditions would have probably occurred along major river valleys and around large water bodies, and therefore, provided suitable range for bison present in a given region.

The above data strongly indicates dry and warm conditions existed across the Southern Plains, which includes most of Texas during a period from ca. 7,000 to 4,500 B.P. Across this region short C_4 grasses that flourish in warm dry environments would dominate. Increased warming and drying is documented, although the intensity probably varied across space and through time. This sets the broad climate and paleoenvironmental conditions affecting human populations. Human populations living during this general period, and using a Bell/Andice/Calf Creek point technology were operating within and adapting to a relatively open grassland region during a warm and dry period. Bison were present during this period, although apparently in relatively low numbers. The limited number of prehistoric sites radiocarbon dated to the period between 6700 and 6500 B.P. across the Northern Plains (Walker 1992), combined with the radiocarbon dated 200 year long period from ca. 6700 to 6500 B.P. for the hand-dug water wells at the Mustang Springs site in west Texas (Meltzer 1991, 1999) may mark the period of greatest aridity during the Altithermal.

Multiple local researchers (Albert 2012; Bousman 1998; Collins 2004; Holliday 1985a; Hudler 2000; Johnson and Holliday 1986; Nordt et al. 1994 and Nordt et al. 2007) have suggested a two peak Altithermal with a possible moist period between. The Yellowhouse Soil at the Lubbock Lake site reflects a humid/moist or stable period, which occurred between two dryer events reflecting a two drought interval. Similar floodplain stability as reflected by soil development around 5,100 and 5,000 B.P. for the east-central Plains states of Kansas, Nebraska, Missouri, and Oklahoma supports a brief moist period in the late Altithermal (Johnson and Martin 2010).

Two rapid sea level rises discussed by Ricklis and Blum (1997), one between 7,000 and 6,000 B.P. and a later one between 4,000 and 3,000 B.P. support the notion of a two drought interval. In the Estancia basin of central New Mexico, the eolian landforms studied reveal two episodes of extreme drought and low groundwater levels during the middle Holocene (ca. 7,000 to 5,400 B.P.) followed by a rise in the water table through the late Holocene (Menking and Anderson 2003). Still, the pollen records from Boriack and Weakley bogs reveal a single peak in grass pollen right at ca. 5,000 B.P. (Bousman 1998) (see Figure 2-10). This peak in grass pollen occurs at the time Lohse et al. (2014) documents bison in central Texas at 5,000 to 5,100 B.P. Indirectly, the bison presence during that time combined with the grass spike in pollen at the bogs may support a moist period around the 5,000 to 5,100 B.P. period. Consequently, some data sets correlate, although many mixed signals exist in the proxy data. Additional research is required to address questions concerning the middle Holocene warm period and specifically when it occurred.

Seldom addressed are the causal factors underlying the warm and dry period. Diffenbaugh et al. (2006) examined the effects of summer precipitation during the middle Holocene causing insolation-forced and insolation-induced changes in sea surface temperatures. Using a high-resolution nested climate modeling system, they concluded the middle Holocene prolonged sun ray forced situations results in drier than present conditions over the central continental U.S. and northern Rocky Mountains, as well as wetter than present conditions over the Atlantic seaboard and northwestern Great Plains. Drier than present conditions over the central U.S. are associated with enhanced anticyclonic circulation aloft over the mid-continent and reduced low-level moisture content over the Gulf of Mexico and south-central U.S. The similar patterns indicate insolation was the strongest determinant of middle Holocene summer aridity in the continental U.S.

Paleoclimatologists have a much better understanding of the root cause to middle Holocene aridity. Changes in the Earth's orbit have altered the amount of solar radiation reaching each latitudinal bond on earth (National Oceanic and Atmospheric Administration 2007). By calculating these changes, the northern hemisphere was probably warmer than today during the middle Holocene in the summer and cool in the winter. Nordt et al. (2007) presented the first comprehensive late Quaternary temperature record for the Great Plains by assessing trends of 64 published stable carbon isotopic values from buried soils. The estimated temperature was +1.0ºC (1.8ºF) above modern July temperatures for the middle Holocene between 6,000 and 4,500 B.P.

In contrast Poore et al. (2005) analyzed variations in the planktic foraminifera (unicellular organisms) from Gulf of Mexico sediment cores to indicate these organisms are an environmental proxy for the southwest monsoon on millennial and submillennial time scales. The marine record indicates monsoon circulation, or summer rainfall in the Gulf of Mexico, was enhanced in the middle Holocene (ca. 6500 to 4500 B.P.).

Most data supports a dryer and warmer period across much of the Southern Plains for the middle Holocene/Middle Archaic period, with a cool period identified towards the end of the Altithermal ca. 5100 and 5300 B.P. (Lohse, Madsen et al. 2014). To what degree and how dry in different regions are yet to be clearly determined. With those dry and probably warmer conditions the climate had a profound effect on the foraging patterns employed by Bell/Andice/Calf Creek populations. This not only effected their subsistence patterns, but their overall lifeways. Studies have shown a correlation between effective moisture and forage quality and bison herd size as periods of high effective moisture were times of large bison herds as reflected by extensive bison kills in Wyoming (Reher 1977). It also stands to reason the opposite occurred, when periods of low moisture dominated such as was apparent during the Altithermal, bison herds were small and more dispersed. It is clear from the diverse data sets and variable interpretations concerning paleoenvironmental conditions that more specific data sets, better context, and more precise dating are needed from middle Holocene deposits. Further knowledge must also be gained about environmental episodes before and after the middle Holocene to further refine interpretations about past climatic conditions and human responses to the changes.

3.0 BELL/ANDICE BACKGROUND AND CONTEXT

J. Michael Quigg and Paul M. Matchen

3.1 INTRODUCTION

The following sections present what is understood concerning the background of the Bell/Andice (Calf Creek in Oklahoma) interval for this very important and poorly represented period. First we present a background and brief history of what is known of this cultural manifestation in Texas, Oklahoma, and the Southern Great Plains and beyond. This is followed by discussions of the geographic distribution, chronometric age, cultural assemblage, lithic procurement strategies, material use, knapping observations, cooking technologies and processes, subsistence base, site selection and mobility, possible trade and exchange interactions, and treatment of their dead. These documented materials are assumed to represent the cultural remains of various human activities and their lifeways, which is the foundation for continuing attempts to interpret human behavior. Finally, we summarize the findings.

3.2 BACKGROUND AND HISTORY

This background and history section provides a broad overview of what was known about this interval/horizon/culture across Texas and Oklahoma and surrounding states by about 2008 with some recent updates. Culture is defined here as the spatial and temporal co-occurrence of particular traits within assemblages of archeological materials. In order to fully interpret the materials recovered, the following facts and observations can be viewed as part of the foundation to construct a research framework. A research framework that could encompass a variety of research topics from which one could employ various techniques and methods to extract information concerning human behavior using data from diverse sites and other contemporaneous occupations in the region.

As will be demonstrated below, much of what is reported concerns artifacts recovered from surface sites, especially in Oklahoma. Few extensive archeological excavations across Texas and Oklahoma have encountered deposits assigned to this cultural construct. In fact, less than two dozen tested or excavated archeological sites or components can be directly attributed to these specific populations. Surface collected materials may lack primary context and are frequently mixed with other cultural events/times as represented by diagnostic artifacts. Limited excavations have severely constrained our existing understanding of this cultural construct. Much of what is known or perceived concerning this population has focused on the characteristic projectile points considered diagnostic of these groups (Figure 3-1). In the few sites tested or excavated the context of encountered material was frequently unclear and/or questionable as the artifacts were recovered from broad zones and generally not from well-defined occupation layers with sterile deposits between layers. That is, the association of the diagnostic artifacts and other material remains recovered from areas leave doubt concerning what materials belong with the Bell/Andice diagnostic projectile points and therefore representative of these populations.

3.3 BELL/ANDICE IN TEXAS

In Texas, the Bell projectile point was first reported from the Landslide site and described by Sorrow et al. in 1967 and was listed as a provisional type at that time. This identification developed from the recovery of ten similarly crafted basally-notched projectile points from Stratum III-b at the Landslide site in Bell County of central Texas. Stratum III-b was roughly 30 to 40 cm thick and yielded two Bulverde and two triangular projectile points. Four cultural features (Features 1, 6, 8, and 9) were present in this stratum. Feature 2, a circular mass

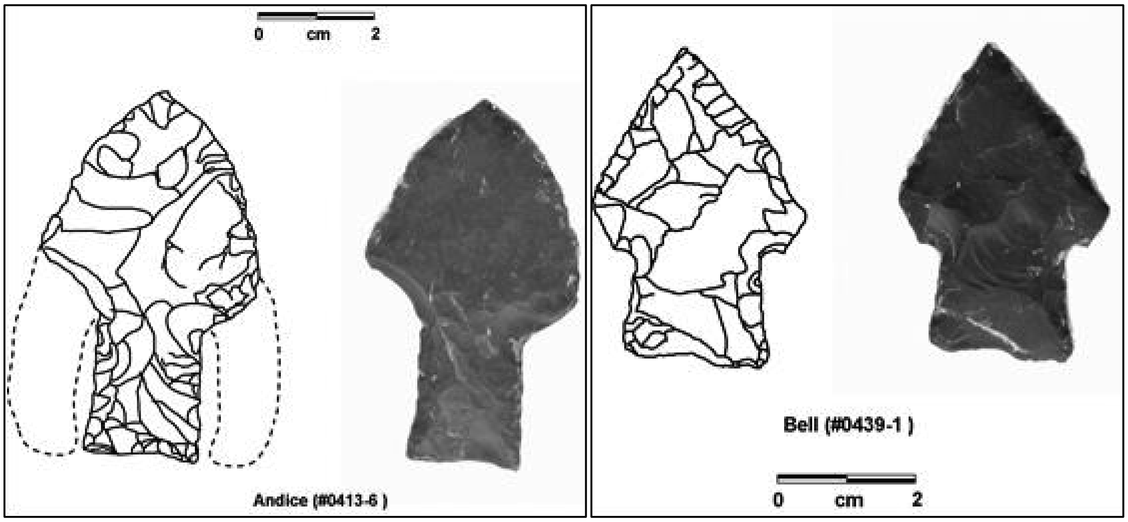


Figure 3-1. **Characteristic diagnostic Andice and Bell point examples (from Quigg et al. 2011b).**

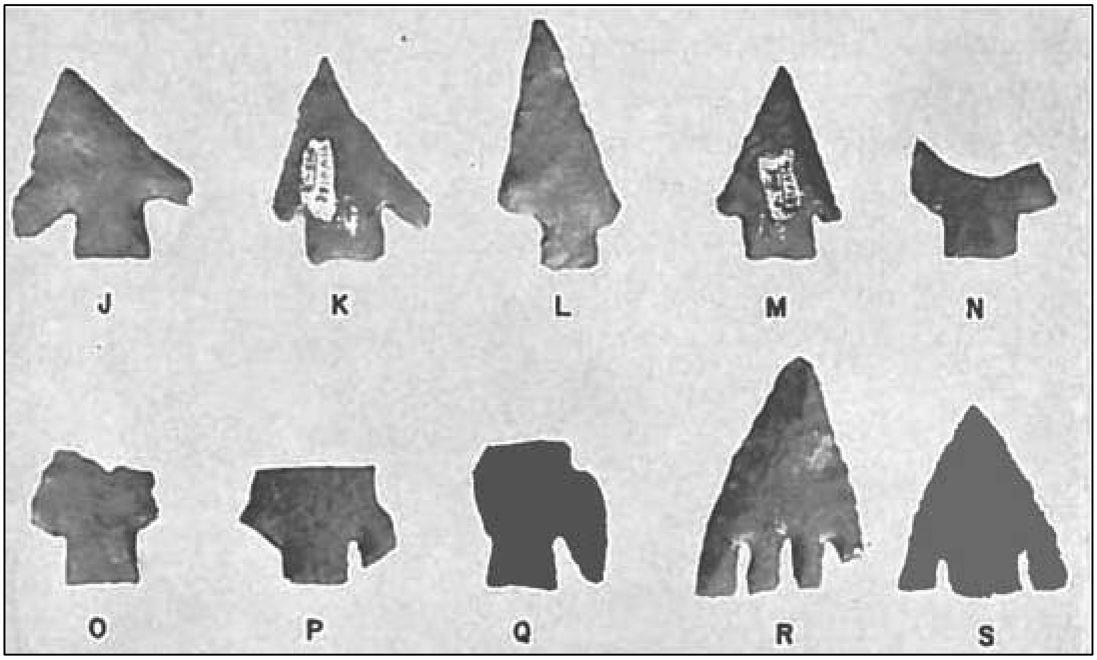


Figure 3-2. **Johnson's "Early Barbed" points from Devil's Mouth site (Johnson 1964, Figure 11; E. Prewitt 1981 considers Bell/Andice).**

of burned rock with bison bones on top and a Bell point possibly associated, was in Stratum IV. This lower stratum yielded a mixture of projectile points that included two Bell, one Martindale, and one Merrell point. Bison bones from Feature 2 were radiocarbon dated to >3520 B.P. (Tx-289) and lacking a δ^{13}C correction value. It is also unclear if this was a collagen derived date.

The Landslide site was the first to report the Bell point in Texas, although excavations in 1959 and again in 1961-1962 at the Devil's Mouth site (41VV188) in the Lower Pecos of southwestern Texas yielded ten basal-notched points very similar to Bell points in 1964 (Johnson 1964). These points were designated as "Early Barbed" and exhibit long barbs formed by basal notches, many with asymmetrical blades and primarily rectangular stems (Figure 3-2) (Johnson 1964, Figure 11). These "Early Barbed" points were recovered from the deepest part of the Early Archaic deposits (Levels 17 through 21 in Area A), just above the Paleoindian points, and just below Pandale points (Johnson 1964). Johnson reported these "Early Barbed" styles had not been reported previously in Texas or adjacent regions. Associated with these "Early Barbed" points (considered Bell/Andice by Prewitt 1981) were bifaces, side scrapers, drills, burin and burin spalls, core tools, manos and metates, scratched pebbles, and edge-modified flakes.

In his Ph.D. dissertation, Weir (1976) reviewed and revised the central Texas Archaic. He divided the Archaic into five named phases: San Geronimo, Clear Fork, Round Rock, San Marcos, and Twin Sisters based on specific projectile point types (Figure 3-3). In this review he lists only two sites that yielded Bell points. He assigned Bell points to the San Geronimo phase along with minimally four other point types that include Gower, Martindale, Uvalde, and Tortugas (sometimes referred to as Baird and Taylor points). He comments that "[Bell type] does seem to be associated with the Tortugas Type" (Weir 1976:115).

In an article reviewing the cultural chronology and summarizing identified phases of central Texas, Prewitt (1981) presented Bell and Andice points along with his introduction for the newly named Jarrell phase (Figure 3-3). Prewitt (1981) used the term Andice, even though this point type was not formally defined until 1983 (Prewitt 1983; see discussion below). He assigned the Jarrell phase to represent part of the Early Archaic.

The Jarrell phase also included Martindale and Uvalde dart point types. He did not list burned rock middens as a key index marker for this phase, although large flat hearths were listed under feature types. In addition to the deep basally-notched projectile points, Clear Fork gouges, bifaces, scrapers, hammer stones, and grinding stones are listed as representative artifacts. Prewitt (1983) listed the Landslide site (41BL85), the Gault site (41BL323), site 41TV17, the Tombstone Bluff site (41WM165), the Merrell site (41WM2), the La Jita site (41UV21), and the Jetta Court site (41TV151), as representative components for the Jarrell phase. No radiocarbon dates were provided in that article, but Prewitt estimated the phase age at ca. 6,000 to 5,000 B.P. Chronologically, he assigned Gower, Hoxie, and Wells types for the preceding San Geronimo phase. He assigned the Baird and Taylor triangular forms to the following Oakalla phase. Prewitt (1981) also indicated Bell and Andice types are possibly related to the same tradition represented by the Calf Creek points in northeastern Oklahoma, northwestern Arkansas, and southwestern Missouri. From that time forward many Texas archeologist employed this chronological and projectile point related sequence, even though radiocarbon dates were absent. Also in 1981, McKinney (1981) provided a distribution map of selected sites with Bell or Bell-like points. In that presentation, seven sites are listed as having yielded Bell points and another nine sites with Bell-like points. Their geographical range of occurrence was concentrated along the Balcones Escarpment in central and west Texas and southeast to the Texas coast. One exception to that distribution is Bell points from Crosby County on the eastern edge of the Llano Estacado near the head waters of the Brazos River (Parker and Mitchell 1979). McKinney comments Bell points appear to have a wider distribution than the earlier Gower points. More recently Wyckoff (2005) reports a single point surface collected from near Monahans, in Ward County in far west Texas.

Prewitt (1983) documented, described, and coined the term Andice for Texas and recognized it as an Early Archaic projectile point type. This type was recognized by Prewitt previously, but this documentation is the formal published definition of the Andice point type. His Andice specimens were

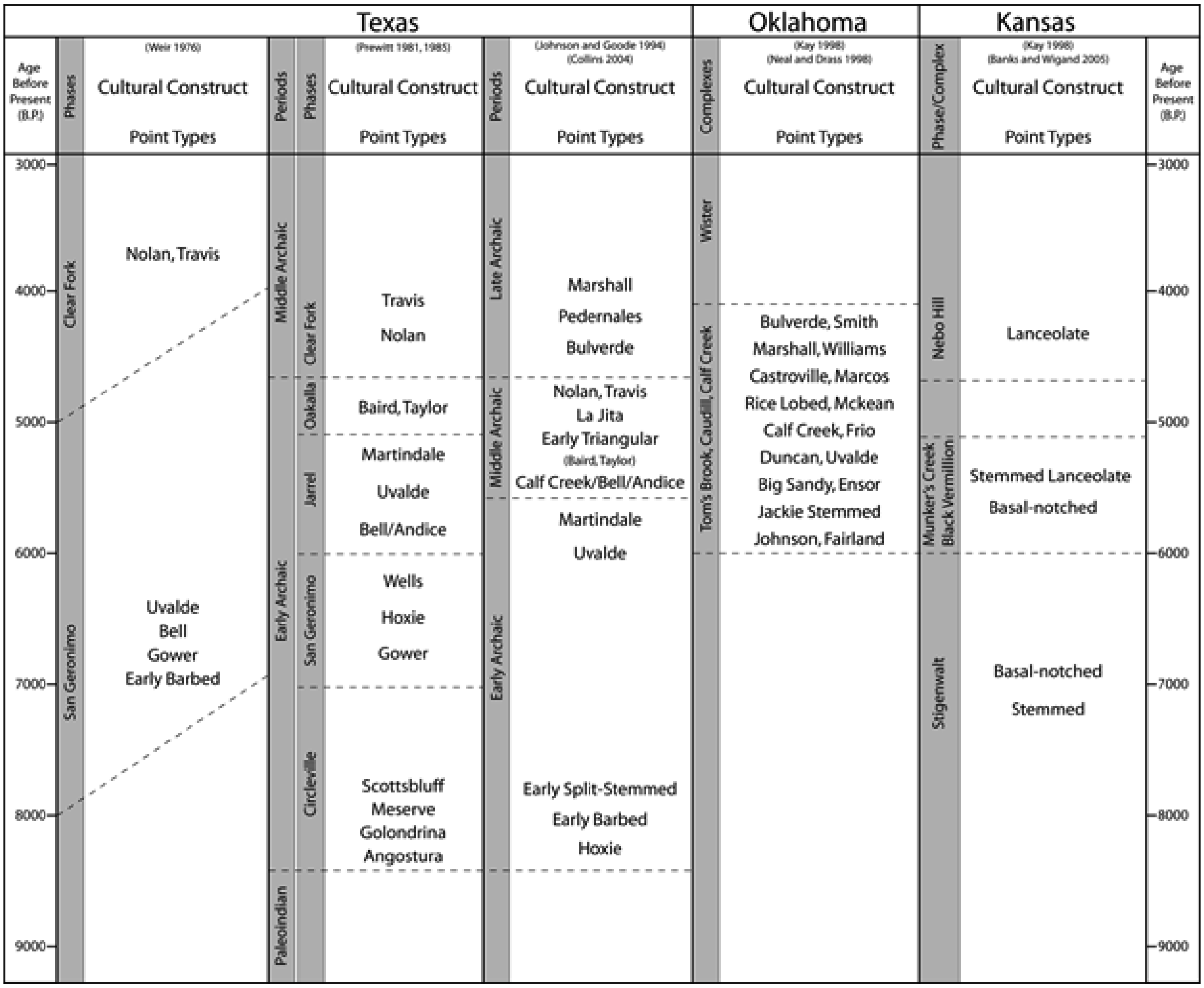


Figure 3-3. **Middle Holocene cultural construct for the Southern Plains region.**

excavated by J. E. Pearce in 1929 from the Gault Farm site (41WM323), which Prewitt considers the type site for this form. He presented attributes, greater size, stem length, and barb length that allow the distinction between the very similar Bell points. In general, the primary difference between the two types is stem length with Bell points having shorter stems. He acknowledged both types may be related to the Calf Creek type of eastern Oklahoma and western Arkansas as measurements of those points are mid-range between the Texas Bell and Andice types. Prewitt (1983) states Andice points are frequently misidentified as Bulverde type.

In a qualitative analysis of Bell and Andice projectile points, Weber and Patterson (1985) determined these two point types are statistically distinct based on stem length and blade thickness. Therefore, they can be classified into two groups. Based on similarity in form and a general understanding of their similar distribution patterns and presumed ages, they concluded the two forms may represent a "single technological continuum" (Weber and Patterson 1985). They also point out there may be a close technological relationship with Calf Creek point type in Oklahoma and other states. In a subsequent analysis using discriminant function, Andice and Bell points were determined not to support the existing typological separation (Weber 1986). These two point types have been assigned separate names in Texas, although they were statistically demonstrated to represent the same point with slight variations during their use life that can be documented metrically.

In 1985 Prewitt (1985) published 147 radiocarbon dates to support his earlier 1981 chronology for central Texas. In that report, he provides just two assays for his Jarrell phase, which both were from Williamson County. One date was 5285 B.P. from 41WM73 and the other date was 4970 B.P. from Feature 19 at the Cervenka site (41WM267). With these two dates in hand, he projected the Jarrell phase for a period from about 6100 to 5100 B.P. The date from the Cervenka site was on charcoal from Feature 19 (ca. 93.5 m in elevation) in Area D, about 5 cm above an undated Feature 26, which yielded bison bones. In Area A at the Cervenka site (nonfeature context), one Andice point (97.0 m in elevation) was recovered in Level 22 (Peter et al. 1982). The Andice point appears roughly 350 cm above dated Feature 19 based on the provided elevations.

In a synthesis of the Texas Archaic, Johnson and Goode (1994) place the Calf Creek/Bell types into the first part of the Middle Archaic and project a starting date of ca. 5600 B.P. (see Figure 3-3). Lacking any commentary on the subject, Johnson and Goode equate Calf Creek and Bell point types together, although they failed to mention the Andice point type. They thought the first part of the Middle Archaic was moderately moist, but drying. They also suggest this population represents an influx of bison hunting groups from the Eastern Woodland margins and also link bison to this region for a brief period. They state the Early Triangular types (Baird and Taylor) are about the same age as the Calf Creek points or slightly more modern (Johnson and Goode 1994).

A more recent synthesis of central Texas prehistory by Collins (1995, 2004) links Bell/Andice/Calf Creek types together as Johnson and Goode (1994) did, and places these types into one style interval in the first part of the Middle Archaic, a period from ca. 6,000 to 5,000 B.P. (see Figure 3-3). The ages put forth were estimated given no specific radiocarbon dates are supplied to support this stated period. For this period, Collins claims the Landslide site, with a Bell/Andice component, to have high integrity. No sites were considered to have moderate integrity. He places the triangular Taylor point type into a second style interval that follows the Bell/Andice/Calf Creek types in time. These first two style intervals reflect a shift in lithic technology from what had prevailed earlier. Collins states these two styles would serve equally well as knives or as tips of lances, spears, or darts. He states the Bell/Andice/Calf Creek period was somewhat mesic, a time when bison were hunted. As Johnson and Goode (1994) surmised, Collins also sees these thin bifaces as part of a specialized bison hunting weaponry, probably brought into the region by peoples moving southwesterly from the prairie, prairie margins, and woodlands west of the Ozarks.

Since those synthesis a few more Bell/Andice sites/components have been excavated, some with moderate to excellent context and associations (i.e., Kibler and Scott 2000; Quigg et al. 2007) and other with questionable stratigraphy and poor context (e.g., Collins 1994, 1998; Decker et al. 2000; Houk et al. 2008; Johnson 1991; Lohse et al. 2013). These sites are briefly discussed below to provide an understanding of context and material remains involved.

Collins (1994) presents data recovery excavation (104 m^2) results from a mixed or palimpsest of Early Archaic materials at Area B, at the Barton site (41HY202-B) in Hays County. This shallow, less than 50 cm deep component accumulated on a stable or slowly aggrading clay loam surface that overlaid sterile gravels. These mixed materials yielded uniformly patinated cherts, nine Early Archaic features, lithic debitage (N = 15,468), and chipped stone tools (N = 98). The diagnostic artifacts are predominantly the Bell/Andice group (11 of 23) with all other point types represented by four or fewer specimens that include; Uvalde (N =

4), Early Triangular (*N* = 3), Wilson (*N* = 1), Gower (*N* = 1), Angostura (*N* = 1), and unknown (*N* = 2). Feature 19 included 2,055 chert debitage pieces concentrated over an area 100-by-85 cm in diameter. No diagnostic artifacts were recovered from this lithic concentration. The authors however, recognized Bell/Andice/Calf Creek "notching flakes" (*N* = 4) they thought were derived from the creation of the deep basal-notches characteristic of this point type (Collins 1994). Together with similar attributes and stratigraphic position, this feature was inferred to represent this cultural interval. Here, Collins (1994) suggests Prewitt's (1981, 1985) Jarrell phase be split into with an earlier interval for which Uvalde and Martindale style dart points are diagnostic and a later interval for which Bell/Andice dart points are diagnostic.

Excavations (69.1 m^3 or 49 m^2) at the Cibolo Crossing site (41BX377) in Bexar County near San Antonio yielded a Bell/Andice component in a deep, stratified creek terrace context (Kibler and Scott 2000). Seven components were arbitrarily identified with little to no obvious separation or sterile zones between assigned components. A series of 20 radiocarbon dates, 4 derived from sediment and 16 on charcoal provide a general chronological sequence for the deposits and associated materials. The Bell/Andice component (59 m^2 or 16.8 m^3) was defined just above a Martindale component and just below a Late Archaic component with Castroville, Ensor, and Frio points. The Bell/Andice component provides significant data that includes a chipped stone tool assemblage (*N* = 55), lithic debitage (*N* = 897), cultural features (*N* = 12), sparse animal bones (*N* = 41), quantities of burned rocks (715 kg), and stratigraphic information supported by radiocarbon dates concerning this rare and poorly known interval. The eight radiocarbon dates from the Bell/Andice component are widely variable with obvious intrusive charcoal and sediment dates minimally 1,000 years too young for the projected age of the component. Three charcoal dates corrected for $\delta^{13}C$ are 4420 ± 50 B.P. (Beta-126362), 4400 ± 60 B.P. (Beta-126364), and 4370 ± 80 B.P. (Beta-126367) were from burned rock discard pile Feature 19, which contained two Bell points and an Andice barb. The dates are accepted by the authors as reasonable ages for this component (Kibler and Scott 2000:74). Seven calendrical dates were derived from mean D-alloisoleucine/L-isoleucine (A/I) values derived from *Rabdotus* snail shells and range from 4528 to 5503 B.P. Four dates projected from *Rabdotus* snail A/I values from Feature 19 are 5128 B.P., 5128 B.P., 5165 B.P. and 4528 B.P. (Kibler and Scott 2000:74). Diagnostic projectiles include nine Bell fragments, one Andice barb, two triangular Baird points, and one untyped midsection. Researchers may argue the identification of some Bell points. Cooking is inferred from multiple burned rock features in which two are interpreted as basin shaped, however direct evidence of what was cooked is limited to a few unidentifiable bone scraps and one freshwater mussel shell. The authors also provide metric data on stone tools (i.e., points, bifaces, and unifaces), descriptions and discussion of features, brief discussions of the unmodified debitage, raw material types employed, and discussions on site function and interpretations for this hunting group that occupied this locality (Kibler and Scott 2000).

Another Bell/Andice component was excavated (38.5 m^3) at the Big Hole site (41TV2161) in Travis County in central Texas (Quigg et al. 2016). This Bell/Andice component was isolated between roughly 220 and 245 cmbs and yielded a limited suite of chipped and ground stone artifacts that included two Bell and one Big Sandy point, 8 small burned rock features plus scattered burned rocks, a cluster of ground stone tools, a rare faunal assemblage, and multiple radiocarbon dates. The 12 radiocarbon dates on diverse materials document an occupation around 5300 B.P. (Quigg et al. 2016) The multidisciplinary technical analyses include phytolith, starch grain, diatom, high-powered microwear, macrobotanical, neutron activation, and lipid residue analyses, which shed significant new light on the lifeways of Bell/Andice populations in central Texas (Quigg et al. 2007). Significant aspects to this component include a preserved faunal assemblage that lacks bison bones, but yielded fish, Canidae, cottontail (*Sylvilagus*), jackrabbit (*Lepus*), and deer remains (Quigg et al. 2016). Lipid residues from multiple burned rocks from multiple burned rock features document animal residues in 20 percent, plant residues in 30 percent, with conifer residues (probably from heating the rocks) in all samples (Malainey and Figol 2014). The latter probably juniper or possibly cypress is this region.

Neutron activation was conducted on multiple natural chert samples from a nearby upland local gravel deposit adjacent to the site and cultural pieces from both components, which includes a Bell and a Big Sandy point. Results indicate all cultural samples were manufactured from the local cherts from the upland gravel (Boulanger and Glascock 2014).

Starch analysis on the Big Hole materials focused on burned rocks and yielded diverse plant use that included; lenticular grass grains probably from wildrye, grains from the true lily family (*Lilium*), and unidentified other grass starches. Importantly, ground stone tools yielded five damaged grass grains from grinding and processing. Burned rocks yielded five gelatinization grains and lily starch from cooking with heat and water (Perry 2014). No gelatinized grains were on the ground stone tools. Importantly, no lily starch was on the ground stone. One edge-modified flake yielded intact lenticular grass starch to imply cutting and processing grasses, which were then processed by grinding, followed by cooking (Perry 2014). A few eroded grains were also present. Significantly, no starch was found in the sediment samples, which indicate starches documented represent cultural activities.

The Ticket Kiosk excavations at the Spring Lake site (41HY160) in Hays County just south of Austin yielded a sample of two Bell/Andice projectile points from a 50 cm thick cultural zone in limited excavations (Lohse et al. 2013). Excavations documented a more or less continuous occupation sequence spanning from the Early Archaic to the latest Late Prehistoric period supported by 14 radiocarbon dates derived from mammal bones combined with 59 projectile points and point fragments (Table 3-1). The Bell/Andice/Calf Creek component was identified between roughly 135 and 185 cmbd with one Bell point between 145 and 155 cmbd and another between 175 and 185 cmbd in association with six other points (3 Merrell, 1 Martindale, and 2 Uvalde). The faunal assemblage assigned to this 50 cm zone includes bison, turtles (Testudines), deer (*Odocoileus*), pronghorn (*Antilocapra americana*), Canidae, cottontail rabbits (*Sylvilagus*), bird, fish, and snake. Ten δ^{13}C corrected radiocarbon dates on bison bones from this thick zone range between 5060 B.P. and 5180 B.P. at the two sigma range (Lohse, Culleton et al. 2014).

As an example of a site with questionable stratigraphy and context the Gatlin site (41KR621) along the upper Guadalupe River in Kerr County, Texas yielded 46 wood charcoal and two bulk soil radiocarbon dates, 18 of which fall between 5570 and 4930 B.P. with four of those from Feature 2 (Houk et al. 2008:7-7 through 7-10). The latter feature was directly associated with three Martindale and one Gower points. Most dates were generally associated with multiple point types such as Bandy, Gower, and Martindale. At least two of the 18 dates were directly associated with bison bones. Most dates were derived from cultural features, although none of the dated features yielded Bell/Andice projectile points. However, 18 Bell and Andice points (includes 2 “Early Barbed” points Prewitt refers to as Western Bell) were among the 342 typed points recovered from the roughly 145 m^3 excavation. The authors indicate an admixture of temporal indicators in compressed stratigraphy. The subjectively defined, four occupation zones or analytical units were broad, not always distinguishable, and definitely not vertically separated by clear divisions of sterile levels (Houk et al. 2008). Most radiocarbon dates overlap two zones. Sixteen Bell/Andice points were recovered from the top three occupation zones with the two Early Barbed points from the lowest occupation zone.

As more excavations encounter Bell/Andice sites and components in good context across Texas and more technical analyses are directed to those assemblages, we anticipate significant increases in our knowledge and understanding of this poorly known cultural interval in this state. How these relate to similar populations in the broader region remains unknown and needs thorough investigations.

3.4 BELL/ANDICE IN OKLAHOMA

In Oklahoma the term Calf Creek is employed to describe essentially the same projectile point type as referred to with the Bell and Andice types in Texas (Perino 1968). *The Prehistory of Oklahoma,* edited by Bell (1984), provides a synthesis of Oklahoma prehistory up to 1984. By 1984, only three general Archaic period (ca. 9,000 to 1,400 B.P.) sites in western Oklahoma had been extensively excavated (Hughes 1984). These sites yielded only four radiocarbon dates, therefore little is known about the Archaic period as a whole. The Calf Creek point type was not mentioned in the discussion on the Archaic period. In the eastern half of the state, hunter-gatherers employed notched points to kill modern game animals (Wyckoff 1984). More archeological investigations and scrutiny have occurred in the eastern half of Oklahoma. Consequently, more is known about the archeological manifestations in that region. Thirteen sites in eastern Oklahoma yielded 75 radiocarbon dates. No dates were reported for the period between ca. 9400 and 4700 B.P. The Tom's Brook complex lacks radiocarbon dates, although it is postulated to represent a period from 5,000 to 6,000 B.P (Wyckoff 1984). This complex, however, is composed of many projectile point types, probably to indicate a very long period of use. Included in this complex are occasional Calf Creek, Bulverde, and Big Sandy point types. This poorly defined complex extends into Arkansas with minimally two sites revealing similar materials.

In the mid-1990s, the Oklahoma Anthropological Society published two volumes dedicated to the Calf Creek horizon, Volume XL (1994) and XLII (1995). Materials attributed to this horizon were presented from across the state by a host of researchers. These two volumes presented updated information concerning Calf Creek artifacts, behavioral models, and several Calf Creek sites documented across Oklahoma. Much of the understanding of the Calf Creek horizon in Oklahoma is from those two volumes. Unfortunately, nearly all the information presented in those two volumes is derived from surface collections, with only occasional limited hand-excavation data presented (*N* = 5 sites). Limited salvage excavations conducted at the Arrowhead Ditch site (34MS174) targeted an eroding hearth (Wyckoff, Morgan et al. 1994). Hand-excavations of 24 test units were conducted at the Hester/Adams site (34ML83) in a disturbed upland setting (Cestaro and Carrell 1994). In 1941, the Works Progress Administration (WPA) conducted excavations at the Lamar site (34BR8), presently under Lake Texhoma, and encountered a lithic tool cache with a questionable association to badly deteriorated remains of a single human skeleton (Neal 1994a).

Salvage recovery in the Bellcow Creek drainage was at three sites (34LN10, 34LN29 and 34LN90) in central Oklahoma. Excavations at the Bellcow site (34LN29) included multiple backhoe trenches, eight test pits and two blocks of units with a total of 37 units at the base of sandstone bluff. Previously,

Table 3-1. Radiocarbon Dates for Sites Associated with and attributed to Bell/Andice/Calk Creek horizon.

Site Name and No.	Uncalibrated (B.P.)	Laboratory Number	Associated Point Types	Reference	Context and Comments
OKLAHOMA					
Arrowhead Ditch, 34MS174	5730 ± 160 *	Beta-28192	Indirectly 1 Calf Creek	Wyckoff, Morgan et al. 1994	Point was 50 cm above charcoal date, date from salvaged Feature 2 (burned rock oven) , 290-320 cmbs
Near Tulsa, OK	5120 ± 25	UCI AMS-11696	1 Calf Creek	Bement et al. 2005	*Petrous bone from Bison antiquus occidentalis* skull with Calf Creek point
Kubik site, 34KA354	5050 ± 60	Beta-98146	No points	Neal 1999, 2002	Level 16, Unit 0,0, charred nut husk, same sample as below, split
Kubik site, 34KA354	5020 ± 120	NZA-6602	No points	Neal 1999, 2002	Level 16, Unit 0,0, charred nut husk, same sample as above, split
Kubik site, 34KA354	4990 ± 100	NZA-6601	No points	Neal 1999, 2002	Level 15, Unit 0,0, scattered charred wood
Bellcow, 34LN29	4190 ± 80 *	Beta-31404	6 Calf Creek point fragments	Girard and Carr 1994	All bone from 140 to 160 cmbs in northern trench, collagen was of poor quality for dating,
TEXAS					
Devils Rockshelter, 41VV264	7430 ± 240 *	TX-314	Bell	Prewitt 1966	Charcoal from Zone V I Test Pit 2, which contained "Early Barbed" points that Prewitt now calls "western" Bell
Arenosa Shelter, 41VV99	5360 ± 170	TX-313	4 Early barb, Early Triangular	Dibble 1967, 1997	Looks like Martindale, but not directly associated, scattered charcoal near base of Stratum 32
41WM73	5285 ± 726	UGa-2482	1 Bulverde-like, 1 Nolan, 1 Group 2,	Peter & Hays 1982, Johnson 1987, Sorrow et al. 1987	In stratum 6, a compact yellowish brown clayey matrix, charcoal from stratum, Level 19, Area B, initial occupation of site
Big Hole, 41TV2161	5770 ± 50 *	Beta-216370	2 Bell, 1 Big Sandy	Unpublished	6 *Rabdotus* shells from N71 E82 at 235-241 cmbs
Big Hole, 41TV2161	5290 ± 40	Beta-214482	No points	Quigg & Frederick 2005	Charcoal from Feature 3 Test Unit 3 at 223-229 cmbs
Big Hole, 41TV2161	5280 ± 30	Beta-398642	2 Bell, 1 Big Sandy	Unpublished	Charcoal from Feature 24, 218-230 cmbs
Big Hole, 41TV2161	5370 ± 30	Beta-398643	2 Bell, 1 Big Sandy	Unpublished	Charcoal from Feature 24, 220-230 cmbs

Table 3-1. Radiocarbon Dates for Sites Associated with and attributed to Bell/Andice/Calk Creek Horizon (continued).

Site Name and No.	Uncalibrated (B.P.)	Laboratory Number	Associated Point Types	Reference	Context and Comments
Big Hole, 41TV2161	5240 ± 30	Beta-398646	2 Bell, 1 Big Sandy	Unpublished	Charcoal from Feature 28, 212-230 cmbs
Big Hole, 41TV2161	5290 ± 30	Beta-398648	2 Bell, 1 Big Sandy	Unpublished	Charcoal from nonfeature, 241 cmbs
Big Hole, 41TV2161	5340 ± 30	Beta-398656	2 Bell, 1 Big Sandy	Unpublished	Charcoal from Feature 29, 230-235 cmbs
Big Hole, 41TV2161	5370 ± 30	Beta-398657	2 Bell, 1 Big Sandy	Unpublished	Charcoal from Feature 29, 230-235 cmbs
Spring Lake, 41HY160	5050 ± 20	UCIAMS-111178	1 Nolan	Lohse et al. 2013:51	Mammal bone from Unit 3, 125-135 cmbd
Spring Lake, 41HY160	5140 ± 20	UCIAMS-106473	1 Bell, 1 Martindale	Lohse et al. 2013:51	Bison bone from Unit 4, 145-155 cmbd
Spring Lake, 41HY160	5140 ± 20	UCIAMS-106468	1 Merrell	Lohse et al. 2013:51	Bison bone from Unit 3, 155-165 cmbd
Spring Lake, 41HY160	5145 ± 20	UCIAMS-106469	1 Merrell	Lohse et al. 2013:51	Bison bone from Unit 3, 155-165 cmbd
Spring Lake, 41HY160	2415 ± 20*	UCIAMS-106470	1 Merrell	Lohse et al. 2013:51	Bison bone from Unit 3, 155-165 cmbd
Spring Lake, 41HY160	5290 ± 20	UCIAMS-111178	1 Bell, 1 Merrell, 2 Uvalde	Lohse et al. 2013:51	Mammal bone from Unit 4, 175-185 cmbd, specimen below Calf Creek Zone
Spring Lake, 41HY160	5060 ± 40	UCIAMS-80999		Lohse et al. 2014, Lohse et al. 2014	Bison bone from Unit 9, level 14
Spring Lake, 41HY160	5110 ± 15	UCIAMS-95717	1 Bell, 1 Martindale	"	Bison bone from Unit 14, Level 13
Spring Lake, 41HY160	5115 ± 20	UCIAMS-80139		"	Bison bone from Unit 7, Level 14
Spring Lake, 41HY160	5120 ± 20	UCIAMS-80136		"	Bison bone from Unit 7, Level 15
Spring Lake, 41HY160	5120 ± 20	UCIAMS-80998		"	Bison bone from Unit 7, Level 14
Spring Lake, 41HY160	5155 ± 15	UCIAMS-81000		"	Bison bone from Unit 16, Level 13
Spring Lake, 41HY160	5165 ± 15	UCIAMS-81001		"	Bison bone from Unit 16, Level 13
Spring Lake, 41HY160	5180 ± 15	UCIAMS-80997		"	Bison bone from Unit 7 , Level 9
Stinnet Pool, 41HC220	4950 ± 40	Beta-169973	1 Bell	Unpublished	Bison bone date thought to be associated with Bell point

Table 3-1. Radiocarbon Dates for Sites Associated with and attributed to Bell/Andice/Calk Creek Horizon (continued).

Site Name and No.	Uncalibrated (B.P.)	Laboratory Number	Associated Point Types	Reference	Context and Comments
Devils Mouth, 41VV188	4900 ± 100	TX-525	10 Bell	Sorrow 1968	Flecks of charcoal from in and around Feature 3 in Stratum N, in Area D, just below Group 3-Early Barbed (Prewitt =Bell) points
Cervenka, 41WM267	4970 ± 90	TX-3684	1 Andice, not directly	Peter et al. 1982	Stratum 5, charcoal from hearth Feature 19 near bison bones, Level 117/118, Area D, Andice point from Area A
Cervenka, 41WM267	5135 ± 20	UCIAMS-129248	No points	Lohse et al. 2014, Lohse et al. 2014	Bison bone from Area D, Unit E-6, 120-121 cmbd, at hearth Feature 26
Granberg II, 41BX271	4770 ± 110	TX-3606	1 Bell	Black & McGraw 1985, Munoz et al. 2011	charcoal, Stratum V
Panther Springs Creek, 41BX228	4720 ± 170	TX-3912	Numerous types	Black & McGraw 1985	Area A, 84 cmbs
Cibolo Crossing, 41BX377	4420 ± 50, 4400 ± 60, 4370 ± 80	Beta-126362, Beta-126364, Betta-126367	9 Bell, 2 Baird, 1 Andice	Kibler & Scott 2000	Bell component, *Rabdotus* snail A/I ratio projected dates
McKinzie, 41NU221	4450 ± 90*	Tx-5263	1 Bell, 1 Cantan, 1 Tortugas	Ricklis 1988	Raw date from *Rangia flexuosa* shells from Zone III, roughly between 37-55 cmbs in shell midden on top of tan B horizon, Pleistocene clay, possible reservoir error
McKinzie, 41NU221	4630 ± 90*	Tx-5264	1 Bell, 1 Cantan, 1 Tortugas	Ricklis 1988	Raw date from *Rangia flexuosa* shells from Zone III, roughly between 37-55 cmbs in shell midden on top of tan B horizon, Pleistocene clay, possible reservoir
McKinzie, 41NU221	4410 ± 90*	Tx-5265	1 Bell, 1 Cantan, 1 Tortugas	Ricklis 1988	Raw date from *Rangia flexuosa* shells from Zone III, roughly between 37-55 cmbs in shell midden on top of tan B horizon, Pleistocene clay, possible reservoir
41ME147	5205 ± 20	UCIAMS-111182	??	Lohse et al. 2014,	Bison bone from N802 E631 Level 4
Landslide, 41BL85	> 3520 *	TX-289	2 Bell/Andice, 1 Martindale, 1 Merrell	Sorrow et al. 1967	Bison bones from Feature 2, Horizon IV, Stratum IIIa with a mixture of point types, organic fraction of bone, not comparable

* = Date is rejected as not associated. ** = date not associated with Bell/Andice/Calf Creek points; cmbs = centimeters below surface; cmbd = centimeters below datum.

this bluff was probably a small rockshelter or overhang. Colluvial deposits yielded a Calf Creek point and other artifacts between 130 and 180 cm below the surface. A small sample of multiple bison bones from 140 to 180 cm below surface were radiocarbon dated on collagen to 4190 ± 80 (Beta-31404). The collagen was of poor quality and potentially contaminated (Girard and Carr 1991, 1994). In 1992, limited hand-excavations (5 squares) at the Red Clay site (34HS29) targeted a buried sediment anomaly, which ended up being of natural origin (Neal et al. 1994).

Since the mid-1990s, a few short articles on Calf Creek finds were presented in various journals (i.e., Andrews 1999; Bement et al. 2004, 2005; Duncan 1996; Neal 1999, 2002; Wyckoff 1993, 2005) followed by Neal and Drass (1998) presenting a summary of the Middle Archaic period that included a discussion on the Calf Creek and Thurmond and Wyckoff (1999) presenting an over view of Calf Creek in the Plains Anthropologist. Andrews (1999) analyzed 808 Calf Creek points and point fragments from across Oklahoma. As Wyckoff (1995) before him, he discovered raw material exploitation regions across the state. Also, in examining the metric measurements, point outlines, basal outlines, stem forms, and resharpening frequencies he determined no morphological difference in Calf Creek points across Oklahoma. Excavated and reported sites concerning the Calf Creek horizon from good context remains limited in Oklahoma. However, sporadic excavations were conducted at the Kubik site (34KA354) in 1996, 1998 and 2002 with a few radiocarbon dates reported (Duncan 1996; Neal 1999, 2002; Neal and Duncan 1998). Unfortunately the final report is not yet available. Neal (2002) reports five notching flakes, one late stage preform, bifaces, flakes and bison bones were recovered from the Calf Creek levels. One possible feature (Feature 02-14) was present at 2.3 m below laser datum. Neal (2002) presents a table with 11 radiocarbon dates from the Kubik site that includes the material type and provenance locations (unit, level, and feature) with three dates at ca. 5020 B.P. he says are associated with the Calf Creek artifacts (Neal 1999:1).

3.5 BELL/ANDICE IN THE SOUTHERN GREAT PLAINS AND BEYOND

After first noted by Adams (1958) in southwestern Missouri and again by Roberts in 1965 at Tick Creek Cave in Missouri the Calf Creek point was subsequently described by Dickson (1968) as a provisional type based on projectiles recovered from the Calf Creek Cave in Searcy County, in northwestern Arkansas. The stratum from which these new points were recovered was not directly radiocarbon dated. The points occurred below a zone which yielded Rice (wide corner-notched), Big Sandy (early side-notched) and Searcy (stemmed lanceolate) dart points. The names and forms of those points were subsequently discussed and illustrated by Perino (1968:14) and became type names from then on. Perino describes Calf Creek points in the following manner:

> "… deep but narrow basal notches and barbs which are usually aligned with the base of the parallel-sided to slightly expanding stems. Bases vary from straight to slightly convex in outline. A slight angle is usually formed where the parallel sides of the barbs and the triangular shaped blade unite, but some point edges are convex or recurved due to resharpening of damaged specimens. Calf Creek points were roughly formed by percussion and excellently finished by a pressure flaking technique that often produced delicate serrations along the edges of the blade and barbs. In cross section, the points range from very thin to medium lenticular, the thicker specimens being made from

> poor grades of flint. The base and sometimes the edges of the stems were usually smoothed by grinding or dulling. Most specimens are resharpened; ranging from 43 to 63 mm in length" (Perino 1968:14).

In 1989, Hofman provided a region-wide synthesis of hunter-gatherer culture history for the Southern Plains. In his Archaic discussion, he states the region saw a use of a diverse array of modern species in a diffuse foraging pattern. The cultural assemblages denoted local resource usage and included a variety of diagnostic notched and stemmed projectile points/knives. He observed some tool forms did occur across extensive regions and does mention the distinctive Calf Creek point type. This may indicate widespread sharing of ideas and technological advances (Hofman 1989). Another important technology was the intentional use of thermal alteration of cherts to improve flaking quality. Hofman lists five assumptions thought to be common characteristics of the Archaic groups across the Southern Great Plains region, which include: 1) seasonally varied economies; 2) flexible group structure with periods of aggregation and dispersal; 3) seasonally variable needs such as fuel, shelter, clothing; 4) a variety of site types which result from diverse economic, social, and maintenance activities; and 5) a variety of alternative strategies for coping with seasonal, or yearly, economic shortfalls or windfalls (Hofman 1989). He briefly describes selected complexes defined across the region. Only those complexes, pertinent to the period from ca. 6,000 to 4,500 B.P., are presented below.

The Black Vermillion phase was defined by Schmits (1978 as cited in Hofman 1989) for components at the Coffey site, in northeastern Kansas. The Coffey site provides a range of radiocarbon dates between 5700 to 4900 B.P. This phase is distinguished by triangular basal- and corner-notched dart points/knives (Figure 3-4). The Coffey site yielded a wide range of plant and animal resources that included; weedy plants, fish, reptiles, birds, small animals, deer, and bison (Hofman 1989). Blackmar and Hofman (2006) indicate a similar age for this phase, from 5650 to 4850 B.P. The basally-notched points from Horizons III-5 and III-7 at the Coffey site were stratigraphically linked to a variety of corner-notched forms (Schmits (1976, 1978). Apparently, these three phases overlap in time, which indicate interaction probably occurred. Different projectile point types were recovered from the same components at the Coffey site reflecting potential interactions.

The Munkers Creek phase is delineated for northeastern and east-central Kansas and is dated to 5,500 to 5,000 B.P. (Blackmar and Hofman 2006; Witty 1969, 1982). The economy of this group was apparently based on hunting and foraging, with deer and small animals the primary meat sources. Distinctive artifacts include the Munkers Creek gouges, Munkers Creek bifaces, chipped double bitted axes, and long and narrow lanceolate dart points with small, broad stems and primarily straight bases (Figure 3-5) (Witty 1982). The Coffey site components were originally assigned to the Munkers Creek phase. Blackmar and Hofman (2006) revised that assignment of the Coffey site components and currently attribute the different components to Munkers Creek, Black Vermillion, El Dorado, and Walnut phases. They indicate the age for Munkers Creek ranges from 5800 to 4950 B.P. In a recent reassessment of the radiocarbon age determinations from the Munkers Creek phase, Banks and Wigand (2005) included new radiocarbon dates to derive an average age of 5259 ± 26 B.P. with a three sigma range of 5180 to 5338 B.P. thought to have occurred during the Altithermal period. The economy included the use of bison, deer, antelope, smaller mammals, and mussels (Hofman 1989). The tool assemblage includes end scrapers and a variety of side-notched triangular projectile points with basal grinding.

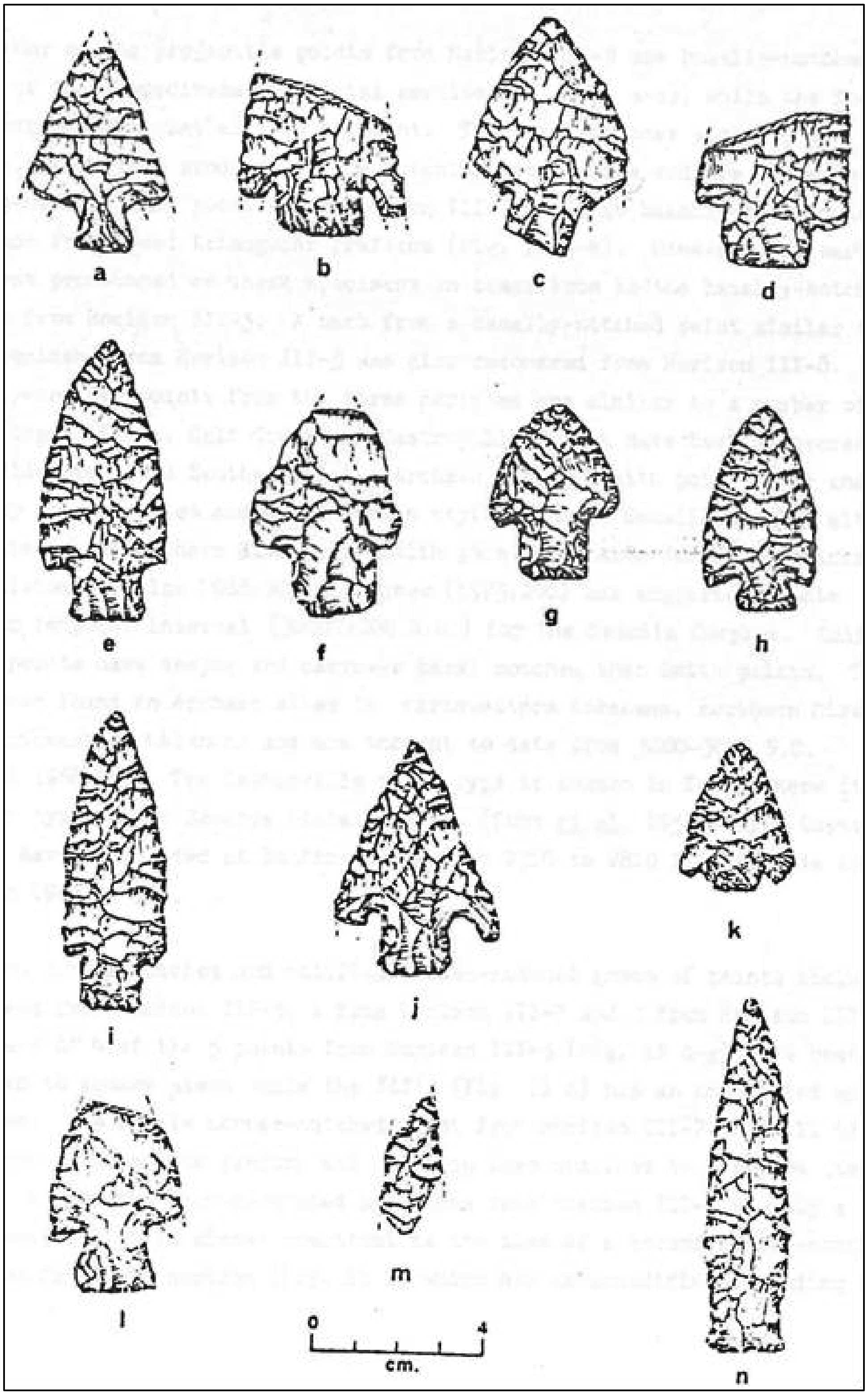


Figure 3-4. Projectile points from the Coffey site in Kansas (from Schmits 1976, 1978). Top two rows (a-h) from Horizon III-5, next row (i-k) from Horizon III-7, and bottom row (l-n) from Horizon III-8.

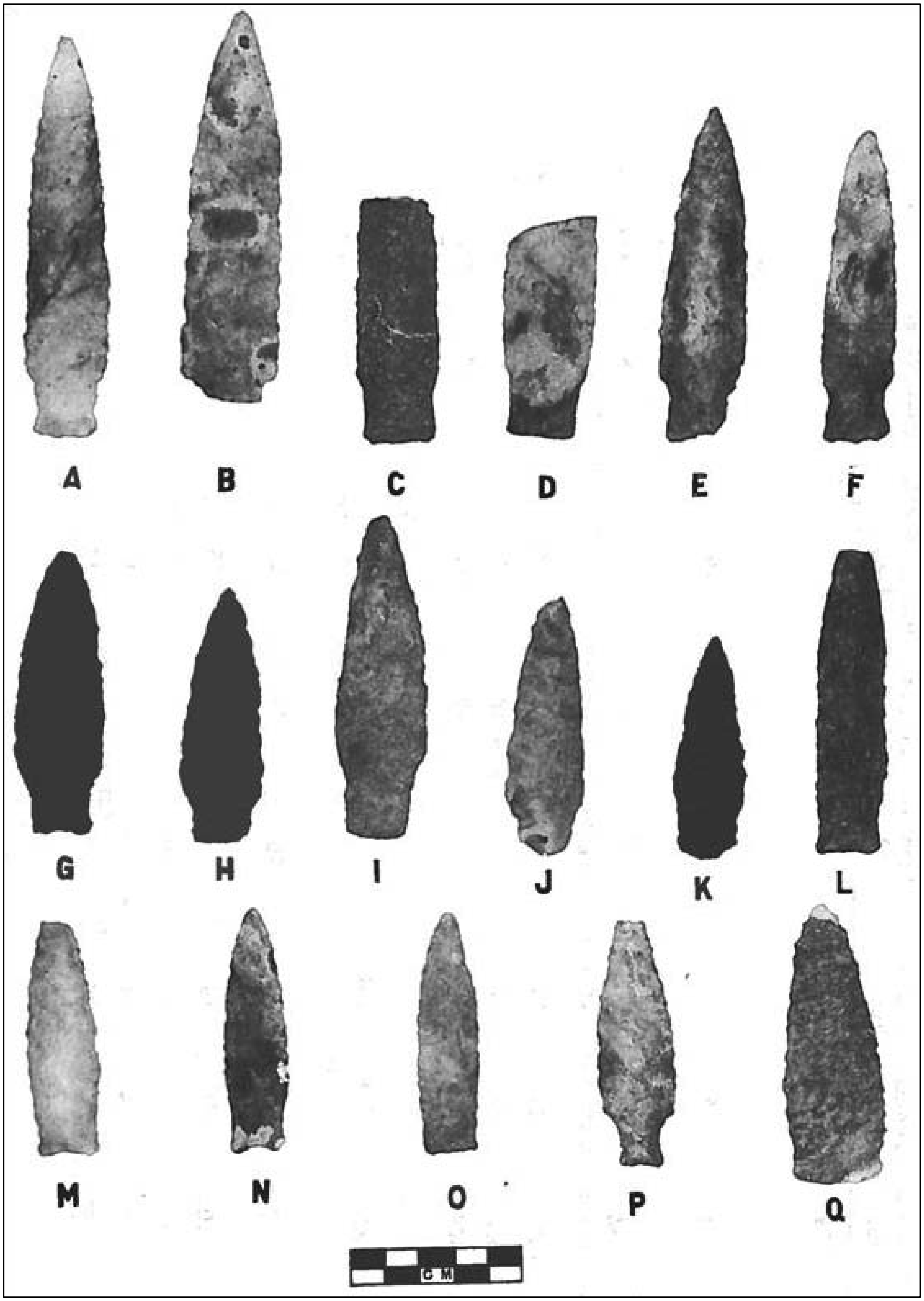


Figure 3-5. Munkers Creek points from Witty (1982:171).

Hofman (1989) makes several general statements pertaining to the Southern Plains region. One is the data employed by Hofman reveals bison were not abundant in the region between 7,000 and 3,500 B.P. In summarizing the Archaic period, he states this long period has not been well-studied and lacks radiocarbon dates for a period of considerable climatic change. Thus, few answers are available to the many questions.

Stites (2006) summarizes the Calf Creek complex in Kansas and reviews information from several key sites such as the Coffey site, William Young, and Site 98. He also acknowledges the lack of formal research on this complex in Kansas. His distribution map of known sites with Calf Creek points in Kansas is restricted to the southeastern corner of the state. What little is known about the technology in Kansas is similar to that further south in Oklahoma. The Logan Creek phase is defined for a broad region across Nebraska, the northern Flint Hills of Kansas, and into Iowa (Hofman 1989). The age of this phase ranges from 6300 to 5200 B.P.

In summary, the broad regions of Texas, Oklahoma, and neighboring states have yielded significant data concerning the diagnostic projectile points. Very limited data concerning the overall Bell/Andice/Calf Creek interval and the lifeways of those populations is currently known. Lack of information stems primarily from the paucity of excavation data. Until additional sites with isolatable components in good context are intensively excavated, analyzed, and reported, this cultural phenomenon will probably be discussed in broad, general terms, as researchers focus on technological aspects of the more accessible and numerous projectiles (e.g., Anderson 1999; Ayala 2014a, 2014b; Weber 1986, 1991, 2000, 2002; Weber and Patterson 1985; Wyckoff 1995; Wyckoff and Neal 1994; Wyckoff and Shockey 1994, 1995).

In the Central and Northern Plains, more extensive investigations have provided additional information on this general period. In broad terms, the characteristic projectile point style of this same period is the broad side-notched form, as characteristic of the Logan Creek phase, and many other similar point types (i.e., Hawken, Gowen, Mount Albion, Blackwater, and Northern) assigned to the Early Archaic period (Buckner 1980; Frison 1991; McCracken 1978; Walker 1992; Wood 1998). Walker (1992) provides a list of 115 sites for this Early Archaic period and a thorough discussion concerning the different early side-notched projectiles. Walker's distribution map (1992) clearly depicts most sites with early side-notched forms ends in Kansas (Figure 3-6). For the Northern Plains, Walker (1992) sees fewer sites before 6700 B.P. and more sites after 6400 B.P.

The lack of sites between 6700 and 6500 B.P. may reflect the period of maximum aridity. Sites include bison kills, processing localities, and habitation sites. The latter are frequently limited in extent with sparse cultural assemblages. Virtually all sites are very close to water. Walker (1992) does not detect a shift to a foraging subsistence pattern. In Texas, a similar broad side-notched point is referred to as the Big Sandy (Turner et al. 2011). Prewitt's (1995) distribution map of Big Sandy points reveal only seven counties in Texas with 1 to 11 points recovered with those counties scattered across the eastern half of the Texas.

In his early study of the northeastern Plains, Buckner (1980) concluded the Altithermal hunters' response to changes in the availability and distribution of potable water and various floral and faunal resources focused more intensively on regions with better resources along the grassland margins (forests), areas of higher elevations (topographic outliers), and/or areas with perennial water.

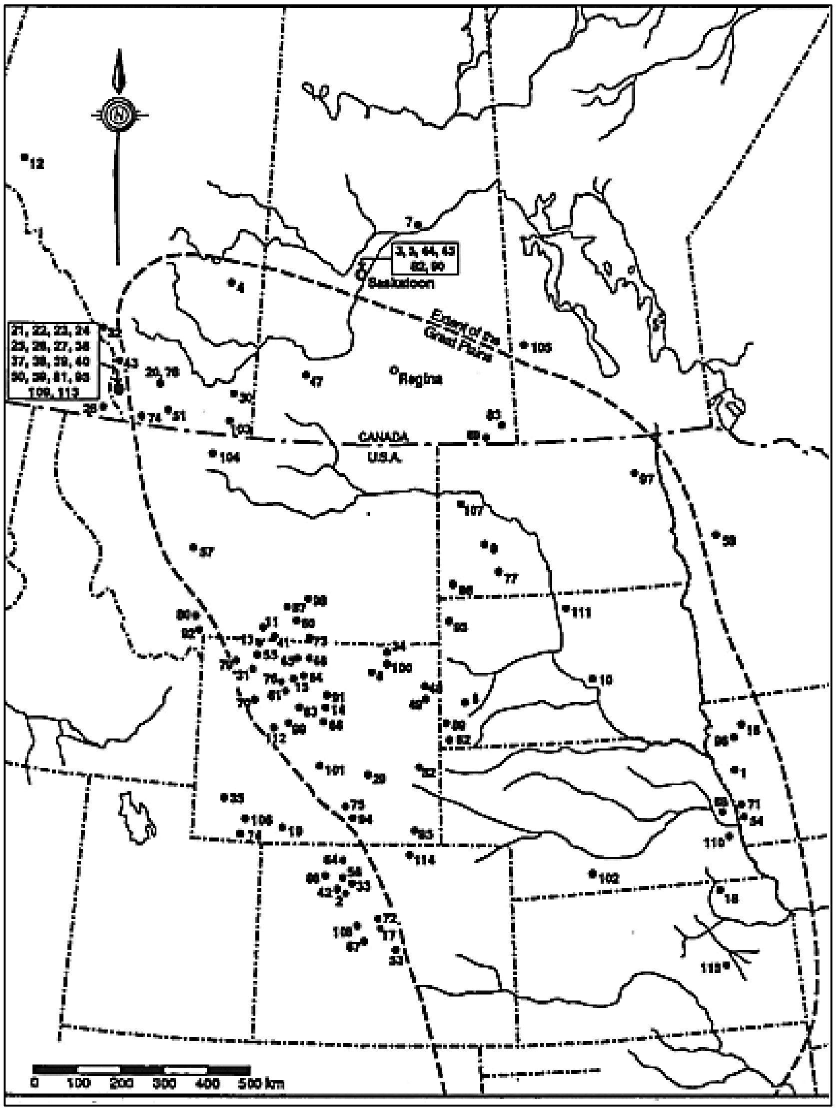


Figure 3-6. Distribution of Early Middle Prehistoric period sites that yielded broad side-notched projectile points across the Plains (after Walker 1992:126).

Based on the following regional background and history concerning Bell/Andice/Calf Creek projectile points (here discussed as one group) and associated sites, the following provides a broad summary of specific aspects what is known for this horizon/complex/phase.

3.6 GEOGRAPHICAL DISTRIBUTION

Bell/Andice/Calf Creek projectile points have been recovered from across most parts of Texas, which include the Lower Pecos region, specifically at Zones IV, V, VI in the Devils Rockshelter (Prewitt 1966) and the lowest levels at the Devils Mouth site (Johnson 1964), with limited materials from south Texas and the Texas Panhandle region (Calame et al. 2002; Hester and McReynolds 2003; McReynolds 2002; Prewitt 1995) (Figure 3-7), all across Oklahoma, northwestern Arkansas, southern Missouri, southeastern Kansas, and possibly into eastern Colorado, and northeastern New Mexico (Figure 3-8). A synthesis of Colorado archeology by Cassells (1997) does not mention the Calf Creek projectile points. However, Rhoton (1995)

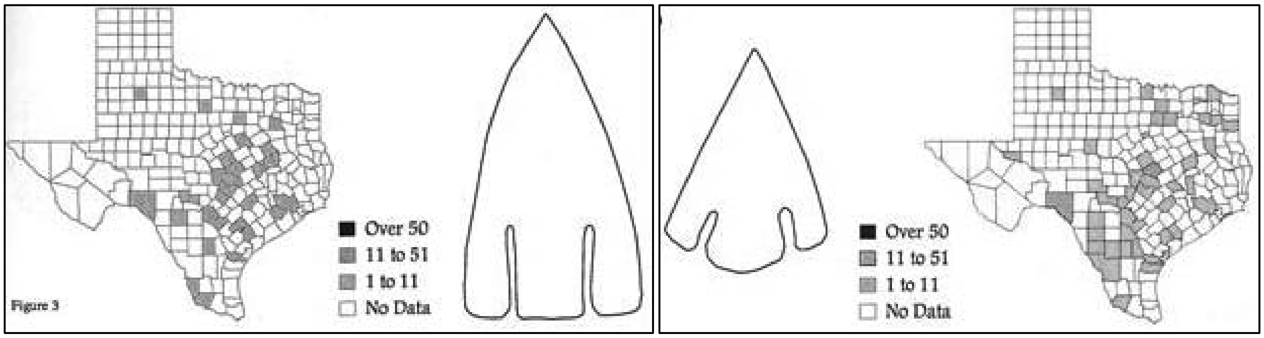


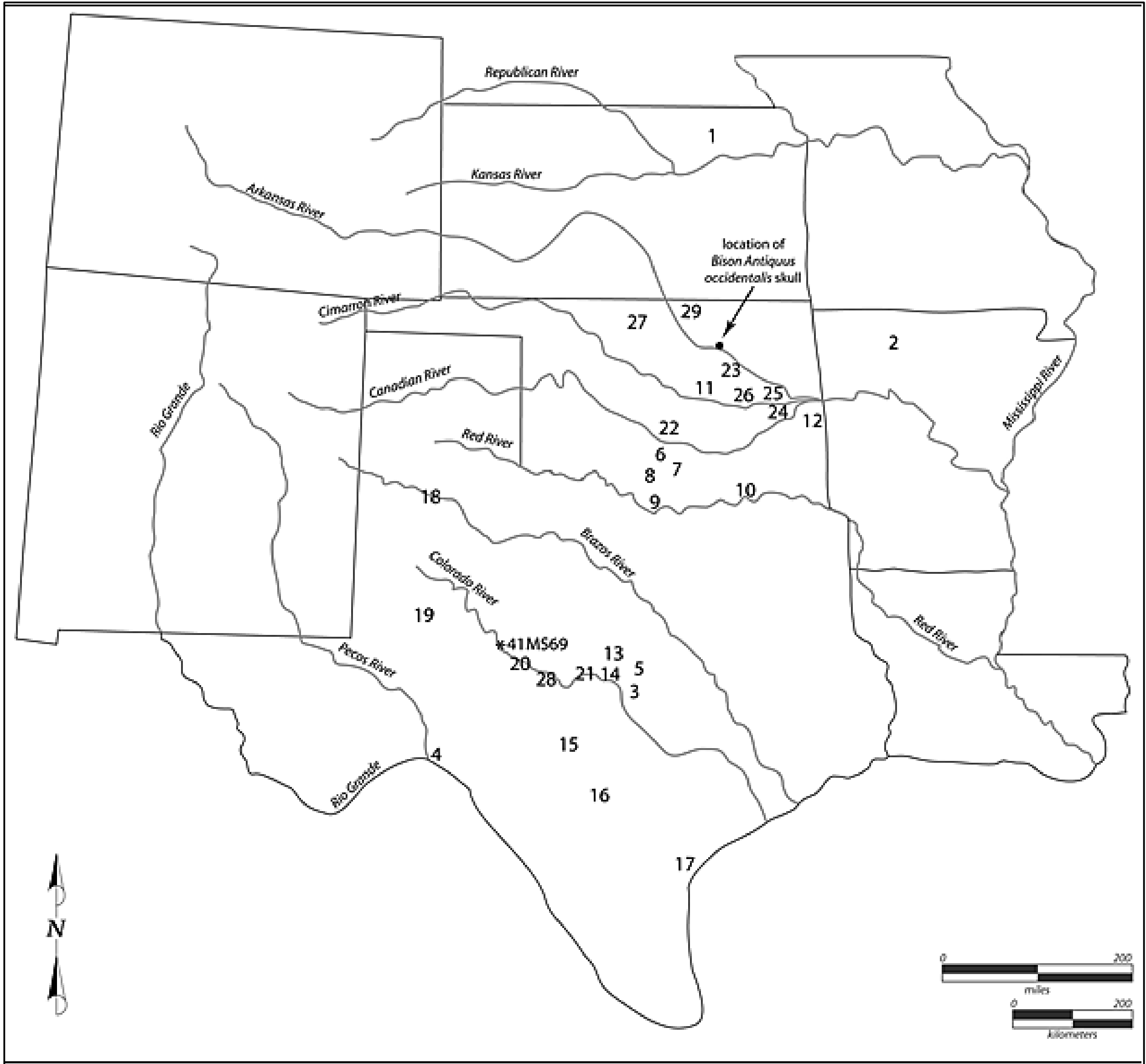
Figure 3-7. Distribution of Andice (left) and Bell (right) points across Texas (after Prewitt 1995).

indicates he knows of three surface collected specimens from Baca County in southeastern Colorado. These points appear most widely distributed across Oklahoma and Texas with significant decreases stretching northward and eastward from Kansas, and appear quite limited in northern New Mexico and most of Colorado. In sheer number, these points appear less frequent in northwestern Texas and the Oklahoma panhandle regions (Thurmond and Wyckoff 1999).

The existing distribution is undoubtedly biased and reflects surface visibility, since so few sites and/or components with these point types has been recovered. Consequently, even though certain areas lack these point styles, this may reflect poor surface visibility in particular regions. On the other hand, many sites of this age may be deeply buried rather than visible on the surface. Calf Creek sites are frequent enough and widespread across much of Oklahoma, enabling Wyckoff (1995) to divide the observed clusters of reported surface sites into four major geographical regions across Oklahoma. Using distribution data from two volumes of reported site data published in the Oklahoma Anthropological Society Bulletins XL and XLII, Wyckoff (1995) sees regional differences, especially in the use of different raw materials for the manufacture of their stone tools. Preferentially employed lithic materials in different areas across Oklahoma provide insight of different groups using specific territories. He outlines and discusses four territories in Oklahoma that include: 1) the Arbuckle Mountains in south-central Oklahoma; 2) the Arkoma Basin in east-central Oklahoma; 3) the Osage Plains and Osage Hills in north-central Oklahoma; and 4) the western Osage Plains and Southern High Plains in southwestern Oklahoma. These four regions or territories are focused on and delineated by unique local raw lithic materials, specific to each of the four regions. These local resources were readily available and predominately employed in each of those four regions.

3.7 THE CHRONOMETRIC AGE

Presently, the age of the Bell/Andice/Calf Creek projectile points is documented and/or bracketed by 61 assays. Table 3-1 provides a list of published radiocarbon dates to reveal a broad time range for this point type. Potentially a minimum of 16 percent of the dates appear nonassociated. Several dates are questionable because of poor or unreliable context, poor association, mixed assemblages, and/or materials dated. For example, the radiocarbon dates on bones (not identified) from the Bellcow Shelter in Oklahoma yielded a date of 4190 B.P. This date appears too recent in comparison to most other dates, although the sample of available dates remains quite small. This date was based on collagen of poor quality to begin with (Girard and Carr 1994). Therefore, preservation issues probably caused problems with the obtained date. At the Arrowhead Ditch site (34MS174) the Bell



1. Coffey - 14PO1
2. Calf Creek Cave -
3. Landslide - 41BL85
4. Devil's Mouth - 41VV188 &
   Devil's Rockshelter - 41VV264
5. Cervenka - 41WM267
6. Primrose - 34MR65
7. Stilman - 34MR71
8. Williams Orchard - 34GV37
9. Frazier - 34JF43
10. Lamar - 34BR8
11. Bellcow - 34LN29
12. Red Clay - 34HS29
13. Fort Hood - various sites
14. Wilson-Leonard - 41WM235
15. Cibolo Crossing - 41BX377
16. Richard Beene - 41BX831
17. McKinzie - 41NU221
18. Lubbock Lake - 41LU1
19. Mustang Springs - 41MT2
20. O.H. Ivie Reservoir - various sites
21. Gault - 41WM9
22. Hester/Adams - 34ML83
23. Brandon - 34TU82
24. Mckellips - 34MI136
25. Arrowhead Ditch - 34MS174
26. Woodard-Benefield - 34MS258
27. Hunter - 34GT6
28. Big Hole - 41TV2161
29. Kubik - 34KA354

Figure 3-8. Location of key Bell/Andice/Calf Creek sites in the Southern Plains region.

point was 50 cm above the date. Therefore, the obtained date probably does not directly reflect the age of the Bell point.

Another questionable bone date was retrieved from Feature 2, Stratum IV at the Landslide site, which yielded an assay of >3520 B.P. (Sorrow et al 1967:9). Not only is the date imprecise, it was said to have been based on organic fraction (Valastro et al. 1967). Later Valastro indicated to the first author he only ran apatite dates in his laboratory (personal communication 1989). Another example is the 5770 B.P. date derived from six *Rabdotus* shells from the Big Hole site in central Texas. These and probably other dates are considered suspect and do not precisely document the true age range of these populations. To strengthen the reliability of the assignment of the age range for Bell/Andice/Calf Creek occupation in Texas, many of these dates should be reassessed.

In general terms, Bell/Andice/Calf Creek projectile points generally range from ca. 5800 to 5200 B.P. in Oklahoma. In Texas, existing dates form Bell/Andice component at the Cibolo Crossing site provide indications as to the ages on multiple materials from components attributed to this point type. Three charcoal dates from Feature 19 assigned to this component range from ca. 4370 to 4420 B.P. These charcoal dates contrast with seven calendrical dates derived from mean amino acid epimers D-alloisoleucine/L-isoleucine (A/I) values derived from *Rabdotus* snail shells. The seven calendrical dates range from 4528 to 5390 B.P. (Kibler and Scott 2000). Three bulk organic sediment ages from Features 9, 10, and 11, assigned to the Bell/Andice component, are at least 1,000 years younger than the charcoal dates from Feature 19. These bulk sediment derived dates do not appear useful, or as accurate as charcoal dates from these same contexts, if all the dated features were properly assigned to this component.

Bement et al. (2004, 2005) provide one of the best contexts for dating the Calf Creek complex. They dated the inner ear of a bison skull with a broken Calf Creek point embedded in the skull. The obtained date was 5100 B.P. from a young *Bison antiquus occidentalis*. This date fits nicely with the majority of existing dates (see Table 3-1). However, the identification of this species is quite interesting as it postdates what was generally considered *B. occidentalis* presence in the Southern Plains at this time. In addition, it indicates a co-existence with modern bison with occidentalis during this time.

The Coffey site in northeastern Kansas yielded a range of dates from Horizon III-5 between 5100 and 4800 B.P. (Schmits 1976, 1978). The original Munkers Creek dates attributed to basal-notched points similar to the Bell/Andice/Calf Creek point types were reevaluated by Banks and Wigand (2005). Their reevaluation indicates an age centered on ca. 5240 B.P. with a smaller concentration of dates at ca. 5640 B.P. The earliest age is ca. 6250 B.P., with the ending age around 4850 B.P.

More precise direct radiocarbon dating of known or newly discovered components with good context will enable a more refined timeframe for the use of these styles of projectile points. As more dates become available from sites or components across this broad use region, archeologists can pursue the possibility of contemporaneity of cultural artifacts and the rate of spread of these peoples across the region. Precise dating will also allow researchers to explore regional settlement patterns of population differences during this period.

3.8 THE CULTURAL ASSEMBLAGE (ARTIFACTS)

Much of what is known about this phase/complex/horizon is based on diagnostic projectile points with their characteristic deep basal notches creating a rectangular stem and long, broad barbs. The original description of Bell points in Texas was from the Landslide site as follows:

> "The distinctive attributes of these specimens are their large barbs and overall thinness. They have been fashioned by chipping two deep, narrow notches into the base of an otherwise trianguloid blade. The resulting barbs (when present) extend into line with the basal corners. Stems generally expand faintly and the often broad blades have straight or less often convex lateral edges. The blade on one specimen is asymmetrical (Fig. 10. i). On the specimens with straight blade edges, the barbs are wider at the tip (Fig. 10; a, b, c, h). By contrast, the barbs are pointed on the examples with convex lateral edges and are wider at the pint in line with the inception of the base (Fig. 10, e). The blade edges of one specimen are serrated (Fig. 10, c). Bases on all are very carefully thinned and are either convex, or less frequently straight. Workmanship is excellent" (Sorrow et al. 1967:12).

Bell and Andice projectile points have received separate names in the Texas literature. In 1986 Weber (1986) employed a discriminant function analysis to document statistically the data does not support the separation into separate constructs. It has yet to be demonstrated the Bell/Andice are typologically identical to Calf Creek points. Visually limited differences are apparent. Prewitt (1983) pointed out the Calf Creek type is mid-range between the Andice and Bell morphological series. Wyckoff (1994) and other authors generally agree the Bell, Andice, and Calf Creek forms generally overlap and are part of a single biface form. The differences observed and detected are generally related to different amounts of resharpening and reworking during the life cycle of the artifact. It is important to note morphological variations in projectile points remain the primary method for determining archeological groupings or complexes and comparing assemblages

At a minimum three excavated Bell components in Texas, at the Cibolo Crossing site (Kibler and Scott 2000), the Landslide site (Sorrow et al. 1967), and potentially the Barton site Area B (Collins 1994), yielded triangular dart points potentially in association with the Bell points. At the Coffey site in Kansas, Horizon III-5 yielded five corner-notched points and four basal-notched forms. In all four instances, these assemblages may represent possible mixed events, or may reflect possible trade and interaction with other groups, which employed different point types contemporaneous with the Bell/Andice/Calf Creek occupations. Triangular points potentially overlap in time and at least in Texas may overlap territorially as well. Their relationships with the Bell/Andice interval is an important question with more research is necessary to identify that relationship. That research is beyond the scope of this site assessment.

Most information, especially from the Oklahoma sites, was derived from surface collections. Therefore, assignment of tools, other than the deep basal-notched bifaces to this construct is often difficult and may be questioned. Broader tool assemblages include ground stone (e.g., the Bellcow site), chipped stone, and bone tools are sometimes associated with these projectiles (e.g., the Bellcow site) and are rarely known for this population. Other recognized tools include; unnotched ovate and rectangular bifaces, end scrapers, drills, cores, "practice pieces", edge-modified flakes, gouges, choppers, burin spalls, hammer stones, the occasional adz (Wyckoff 1995), and rare pitted stones. The broader tool assemblages are frequently from excavated context, where problems with association and mixing of assemblages are also real possibilities. One excavated component, the roughly 40 cm thick Stratum III-b at the Landslide site, yielded a broader array of stone tools in apparent association with the basal-notched projectiles. This includes 72 utilized flakes, 3 hammer stones, 2 gouges, many burins and burin spalls, 2 choppers, 1 quartzite mano, and 1 sandstone grinding slab (Sorrow et al. 1967). However, the context of this presumed associated assemblage is questionable, as these materials were from a thick zone with more than one point type represented and may be mixed.

In much of the Oklahoma literature concerning the Calf Creek points, the points are often referred to as bifacial projectile points and/or knives (Thurmond and Wyckoff 1999). These characteristic artifacts frequently exhibit multiple resharpening and breakage episodes, which shorten and narrow the original blade and often shorten or remove the broad barbs. The young *Bison antiquus occidentalis* skull embedded with the broken Calf Creek point (Bement et al. 2004, 2005) is irrefutable evidence this broad bladed, basal-notched biface was employed as a projectile. How it was propelled, attached to a dart shaft or a spear is not clear. Functional interpretation of the use of this tool as a knife is primarily based on the extensive resharpenings. No detailed high-powered use-wear studies have been conducted to verify if this was truly the case.

Unnotched bifaces constitute a considerable percentage of many assemblages. If the Stilman cache is a representative sample of late stage bifaces for this population, then the overall shapes are ovate to roughly triangular. These pieces reveal thicknesses primarily between 11 and 15 mm. Frequently, broken bifaces exhibit resharpened areas and/or bending stress breaks (Wyckoff, Neal et al. 1994). Broken specimens in caches indicate the items had not completed their life cycle with further use still projected.

Scrapers are a common tool type in many Oklahoma sites as documented at the Arrowhead Ditch site (Wyckoff, Morgan et al. 1994) and the Hunter site (Brooks 1995). One is circular and manufactured from heat treaded Keokuk chert (Wyckoff, Morgan et al. 1994). Others are of various shapes, generally with one steeply worked distal end. In Texas only a single side scraper is reported, which is from the Cibolo Crossing site (Kibler and Scott 2000). Brooks (1995) examined 53 scrapers from surface context at the Hunter site (34GT6) in north-central Oklahoma he attributed to a Calf Creek occupation. He observed extensive edge crushing, smoothing, polishing, and step fracturing on the worked edges. He interpreted these observations to indicate these tools were employed for dry-hide processing, and presumes they were employed on bison hides (Brooks 1995). All the scrapers are oval to rectangular in outline, generally with thick cross sections, are unifacially worked, and exhibit steeply retouched and modified edges. A few have spokeshave and graver functions (Brooks 1995). Scrapers were manufactured from regionally available tabular nodules of Florence-A chert. Flakes that were fashioned into scrapers were initially removed from near the exterior of cobbles as 42 percent exhibit cortex. Wear patterns on nine specimens (17 percent) indicated they were hafted, whereas three exhibit adhesive substance (Brooks 1995).

Several other tool types have been assigned or recognized for this population. A few chipped stone drills have been recovered from a few surface sites (e.g., Primrose, Arrowhead Ditch) in Oklahoma (Wyckoff, Morgan et al. 1994; Wyckoff, Neal et al. 1994), however, the contexts of most is questionable. Those reported appear bifacial in the bit and base areas. The bits are generally long, tapered, and pointed. Bases are irregular in outline, slightly expanding, and lack hafting modifications. Gouges are relatively rare in most assemblages. Excavations at Stratum II-b at the Landslide site yielded two specimens referred to as gouges (Sorrow et al. 1967). Hammer stones have been infrequently identified in a few sites (Sorrow et al. 1967). Edge-modified flakes are reported from many sites. These expedient tools exhibit many shapes and sizes with one or more modified edges. This artifact category receives minimal attention in the literature. Their functions have yet to be carefully examined. Cobble tools of various shapes and sizes were identified at the few excavated sites (e.g., Kibler and Scott 2000; Sorrow et al. 1967). Cores are relatively common at many components and in many surface collections. Most are multidirectional cores with limited number of platforms, with no obviously prepared cores reported.

So called "practice pieces" or "eccentric" artifacts are attributed to these populations or minimally the Early Archaic (Hester 1990). These unique specimens are usually well-executed notches knapped into various pieces such as a broken bifaces, point fragments, or flakes (Collins 1994; Hester 1990). These well-executed notches resemble the deep, narrow notches observed on completed Bell/Andice/Calf Creek projectile points (see Weber and Collins 1994). These notched pieces are interpreted as how knappers developed the skill to execute the very narrow and deep notches on projectile points. Hester (1990) and Collins (1994) illustrate selected "practice pieces" from Texas and the Gault site (41BL323) respectively. Practice pieces are also found in Oklahoma (Duncan 1994) as illustrated by specimens from the Primrose site (Wyckoff, Neal et al. 1994).

Ground stone is nearly nonexistent in reported Oklahoma and Texas sites. Girard and Carr (1994:203) state ten pieces were recovered from the Calf Creek zone at the Bellcow site. A single quartzitic sandstone slab assumed part of a grinding slab and a single mano were from Stratum III-b at the Landslide site (Sorrow et al. 1967). No ground stone implements were reported from the excavations at the Bell/Andice component at the Cibolo Crossing site (Kibler and Scott 2000). Multiple metate and mano fragments are associated with the Bell component at the Big Hole site and were documented for grinding plants (Quigg et al. 2007).

Thus far, bone tools are nearly nonexistent from sites in the Texas and Oklahoma assemblages. This is probably a function of poor preservation and the lack of excavated components. Various bone tools were recovered from the Calf Creek zone at the Bellcow site (Girard and Carr 1994:203). However, if the three main horizons at the Coffey site are included in this discussion, those three assemblages yielded several bone tools. Bone flakers, bone tubes, bone punches, and a bone awl were recovered in limited numbers (Schmits 1976, 1978).

Shell tools are also nonexistent, with one exception. Zone III, with one broken Bell, a Catan dart, and two unnamed, unnotched points similar to Catan were part of a *Rangia* shell midden at the McKinzie site near Corpus Christi yielded at least two culturally altered shell specimens (Ricklis 1988). One is a complete perforated oyster shell, and the other is a rectangular shaped oyster shell (Ricklis 1988:18). These specimens may reflect a mixed assemblage. Fresh water mussel shell tools are lacking from other excavated Bell/Andice/Calf Creek components.

Several stone tool caches have been recovered in southern Oklahoma. The Lamar site in south-central Oklahoma yielded a small, 50 cm diameter by 15 cm deep cache with 38 stone implements (Calf Creek points, bifaces, scrapers, and modified flakes) (Neal 1994a). The Stilman Pit site (34MR71) also in south-central Oklahoma yielded a cache of 21 large bifaces and 8 large flakes (Bartlett 1994). None of the many caches in Texas have been assigned to these populations.

3.9 LITHIC PROCUREMENT AND KNAPPING OBSERVATIONS

Numerous raw material source areas are known across Oklahoma and Texas (i.e., Duncan 1995; Holliday and Welty 1981; Shaeffer 1958; Shideler 1970). Many different raw materials were employed by these groups. However, actual quarrying techniques and/or pits cannot be directly linked to the Bell/Andice/Calf Creek groups. We do know they removed quantities of selected cherts from source areas and transported materials distances to manufacture their stone tools. As an example, the Primrose site lies about 35 km east of the main Frisco bedrock exposures, residue clasts, and gravel-bearing source areas (Wyckoff, Neal et al. 1994). The Primrose assemblage assigned to the Calf Creek horizon allows observations concerning human behaviors relating to the selection, procurement, movement, and processing of the raw material. The Primrose site yielded over 40 kg of Frisco flint with pieces of residual tabular cobbles (primary and secondary flakes), preliminary shaped bifaces made from large flakes removed from boulders or bedrock sources, and large flakes were all brought to the site. Wyckoff, Neal et al. (1994) state the largest pieces exceed 100 g result from secondary and tertiary decortification. Bifacial preforms, unworked spalls, and cobbles were also cached for future use at the Primrose site. The 21 bifaces from the Stilman Pit cache (34MR71) represent late stage bifaces manufactured from Frisco chert (Bartlett 1994). Weber and Collins (1994) report the Bell/Andice/Calf Creek component at the Gault site (41BL323) in central Texas yielded many interior biface thinning flakes, in contrast, primary reduction flakes were few. These differences prompted them to infer the raw materials were brought into the site in the form of large flakes and/or core bifaces.

The excavated Bell component at the Cibolo Crossing site exhibited all stages of the reduction process (Kibler and Scott 2000). The authors identified multidirectional cores, unmodified debitage of complete flakes, flake fragments, chips, chunks, and bifaces in various stages of reduction, and completed formal and informal tools (Kibler and Scott 2000). They interpreted biface reduction was a major activity and accomplished through the reduction of fully corticated cobbles. In central Texas, the peoples represented by the Bell/Andice component at the Cibolo Crossing site employed the use of local Edwards chert for the production of their tools (Kibler and Scott 2000). The authors make no reference to the use of heat treatment of Edwards chert or use of nonlocal materials.

The 16 Bell/Andice points from the Gatlin site (41KR261) in the Edwards Plateau of central Texas were manufactured from local Edwards chert (Houk et al. 2008). In fact one would be hard pressed to fine one of these diagnostic points made from something other than Edwards chert.

The production of Bell/Andice/Calf Creek projectile points result from a very precise sequence of production steps particularly late in the primary trimming and throughout the secondary trimming steps (Weber and Collins 1994). Webber and Collins (1994) consider both qualitative and quantitative attributes important to understanding manufacturing behavior as evidenced on prehistoric specimens. They present a series of manufacturing steps based on observations made from a collection of nearly 400 Bell/Andice points, then Weber experimentally duplicated identical points. In doing so, Weber systematically isolated flake scar attributes into two groups, those resulted from manufacture and those imparted through use and damage. That detail study of attributes provides in-depth analyses and insights into the manufacturing of Bell/Andice/Calf Creek projectile points and the tool kit employed to produce this particular point style. The flintknapper had to be a skilled craftsman to produce large, pressure-flaked bifaces with very narrow notches (Weber and Collins 1994). Weber and Collins also interpret this as evidence for very early use of indirect percussion for notching. Notching and stem attributes have also been studied by Ayala (2014a, 2014b).

Debitage analysis was conducted on Feature 19, a lithic concentration at the Barton site (41HY202-B) in Hays County, Texas. This feature was assigned to the Bell/Andice interval based on the recognition of four tiny notching flakes in Feature 19 (Collins 1994). The 2,055 pieces (9.2 kg), ranging in size from less than 1 cm to greater than 10 cm, were sorted into subjective morphological categories and the results indicate multiple large weathered nodules of local Edwards chert were knapped into multiple bifaces with minimally one Andice point manufactured. Based on Collins's (1994) observations full biface reduction sequence was represented. Direct percussion was employed during the decortification stages, followed by direct billet percussion during biface thinning, and finishing with precise pressure flaking. During the biface thinning stage, platforms were carefully prepared by grinding. Based on the 96 bifacial thinning flakes Collins estimates minimally 4 to 8 preforms potentially thinned at this work station. No mention was made of heat treating the chert in this assemblage.

After points were used and dulled, they were frequently resharpened along lateral blade edges and sometimes so extensive the original form is nearly obliterated (Collins 1994; Weber 2000). The overall debitage and stone tool assemblage reflects the use of soft-hammer, bifacial thinning that employed strongly prepared, multifaceted platforms (Weber and Collins 1994; Collins 1994).

Weber (2000) included 13 qualitative attributes to reflect the Andice/Bell resharpening technique and provided many observations. He discussed resharpening in three general stages; early, moderate, and late. He concluded not every artifact was employed in the same manner and many were employed as knives. Also the extensive resharpening of tools indicates a conservation strategy.

Weber (2002) also studied fracture patterns of 371 Bell/Andice points to reveal clues to their use. Discriminant function value groups indicate very similar breakage patterns for these two point styles. Often broken specimens were reworked for further use as projectiles of other tools such as knives, or infrequently as drills. "Damage to stems varies by stem length and stem shape. Long stems are more likely snapped from the blade. Sever stem damage is relatively rare; most damage is to blades and barbs" (Weber 2002:44). He interprets most specimens were employed as projectile points based on breakage patterns observed.

Production of Calf Creek end scrapers from the Hunter site (34GT6) in Oklahoma were projected to be derived from tabular nodules with flakes removed from near the exterior surface (Brooks 1995). Forty-two percent reveal cortex with an average of 13 percent of the dorsal surface covered by cortex. Scrapers were manufactured on thick flakes (mean thickness of nearly 13 mm) with 40 percent greater than 10 cm. Lengths vary with most between 40 and 60 mm. Striking platforms reveal few (15 percent) double or multifaceted platforms implying a single blow removed the flake from the partial nodule. A statistical test indicated a 0.85 correlation between striking platforms with bulbar characteristics with a resulting pattern indicative of soft-hammer percussion. Another pattern observed by Brooks (1995) was the intentional removal of the striking platform and the bulb of percussion. Thirty-two percent reveal evidence of heat treatment to improve knapping.

Heat treating chert was a common practice in the Oklahoma Calf Creek assemblages. Heat treated tools manufactured from Frisco chert dominate the documented tools from the Primrose site, the Stilman Pit site, the Williams' Orchard site, and the Lamar site in south-central Oklahoma. As an example all 6 of the Calf Creek points, all 21 bifaces, and 3 of the 8 flakes from the Stilman Pit cache manufactured from Frisco chert were heat treated (Bartlett 1994). The different stages of cobble reduction, biface, and point manufacture reveal heat treatment, which indicates multiple heating episodes of a single piece. Heat treatment was conducted early on in the biface manufacturing as evidenced by various reduction stages of bifaces that exhibit heat treatment (Wyckoff, Neal et al. 1994). Heat treatment was frequently conducted between the manufacturing stages. From experimental heat treatment, Wyckoff, Neal et al. (1994) observed changes in luster and color on artifacts probably occurred after two or three heating episodes. Heat treatment was not restricted to Frisco chert since Duncan and Wyckoff (1994) documented Calf Creek bifaces manufactured from Johns Valley chert, Boone chert, Keokuk, and Novaculite from the McKellips site in eastern Oklahoma were all heat treated. Neal et al. (1994) also documented heat treated artifacts manufactured from various Ozarks chert at the Red Clay site in eastern Oklahoma. Florence-A/Kay County chert was also heat treated (George 1995; Sullivan 1995). Powell (1995) and subsequently Thurmond and Wyckoff (1999) documented Calf Creek artifacts of Alibates agatized dolomite, Edwards chert, and Ogallala chert were all heat treated.

Collins (1994) sees great skill and great effort in the production of these very thin bifaces with the long deep, narrow notches on the projectile points. He claims these skill levels were not and could not be possessed by everyone. He argues status is achieved by the skilled production of these chipped objects, which brings about status to the artisan, and possible intrinsic value to the object produced. In turn, this may influence how an object was treated and may help explain why these projectile points undergo such extensive refurbishing to complete depletion prior to discard.

3.10 COOKING PROCESSES

Cooking is represented by various concentrations and clusters of burned rocks designated as features (Table 3-2). However, no detailed analyses of the features, the sediments, or the burned rocks have been conducted to conclusively demonstrate their use or determine what foods resources were processed in features.

A few different types of features are recognized despite only a few sites having been tested and fewer have received extensive excavations. In eastern Oklahoma, a nearly 2 m diameter rock lined feature (Feature 2) was identified at 260 to 330 cmbs at the Arrowhead Ditch site (34MS174) (Wyckoff, Morgan et al. 1994). This salvaged rock feature consisted of two layers of 86 sandstone pieces that completely lined a shallow (10 to 13 cm deep) basin. Numerous bits and chunks of charcoal were between and below the rocks. Charcoal from Feature 2 was radiocarbon dated to 5730 ± 160 B.P. The authors interpreted Feature 2 as a roasting pit that represents this Bell/Andice/Calf Creek point using population (Wyckoff, Morgan et al. 1994).

Stratum III-b at the Landslide site contained four recognizable features that reflect possible heating, cooking, and/or dumping activities (Sorrow et al. 1967). Three of the latter were dominated by burned and fractured rock and one (Feature 10) was an irregular stain associated with burned rocks that might represent a type of general *in situ* warming facility. However, two triangular dart points were associated with Feature 10, therefore, this feature may not be part of the Bell/Andice population. Those authors offer little in the way of interpretation of individual features.

At the Cibolo Crossing site (41BX377) near San Antonio, Texas, 12 burned rock features were identified in the Bell/Andice component (Kibler and Scott 2000). These features varied in shape, size, outline, contents, and were interpreted to reflect different types of cooking facilities (rock hearths and rock grills) and dumping activities (Kibler and Scott 2005). Those with recognizable basins, filled with quantities of broken rocks, were interpreted as evidence for plant food cooking over a long period. Features that lacked recognizable

Table 3-2. Excavated Bell/Andice Feature Data.

Site No. and Name	Feature No.	Feature Type	Feature Size (cm)	Profile	Stained Matrix	Depth (Cm) Below Surface	Burned Rock Counts/ Wts. (g)	δ^{13}C Corrected C14 Date B.P.
41TV2161 Big Hole[1]	3	Burned rock filled hearth	100	Shallow basin	Charcoal	230	201	Charcoal 5290 ± 40
	16	Burned rock hearth	30 x 30	Shallow basin	Charcoal	247-254	10/1766	
	17	2 manos	24 x 20	Flat	None	230-239	Apr-00	-
	22	Burned rock dump	25 x 40	Flat		220-230	13/1272	-
	24	Hearth	50 x 60	Flat	Dark stain	216/233	41/13,100	Bone = 5580 ± 30, charcoal = 5370 ± 30, 5280 ± 30, sediment = 5540 ± 40
	27	Burned rock dump	60 x 40	Flat	None	212-217	15/1329	-
	28	Burned rock dump	40 x 45	Flat	None	218-231	11/676	Charcoal = 5280 ± 30
	29	Burned rock filled hearth	100 x 70	Shallow saucer basin 10 cm	Dark mottles, charcoal	230-242	44/10,000	Charcoal = 5340 ± 30, 5370 ± 30 , Sediment = 5360 ± 40
	30	Burned rock hearth	30 x 70	Basin	None	229-238	6/1303	Sediment = 5680 ± 50
	32	Burned rock hearth	120 x 83	Flat	Dark stain	226-234	37/7520	-

Table 3-2. Excavated Bell/Andice Feature Data (continued).

Site No. and Name	Feature No.	Feature Type	Feature Size (cm)	Profile	Stained Matrix	Depth (Cm) Below Surface	Burned Rock Counts/ Wts. (g)	δ^{13}C Corrected C14 Date B.P.
41BX377 Cibolo Crossing[2]	9	Burned rock concentration	260x160+	Sloping		100.07-99.83 m	205/46,000	Sediment = 3550 ± 70 B.P.
	10	Burned rock concentration	210x100+	Flat, sloping		99.83-9948 m	111/3,225	Sediment = 3510 ± 80 B.P.
	11	Burned rock	43x47	Shallow basin		99.86-9978 m	27/7,250	Sediment = 3060 ± 70 B.P.
	18	Burned rock scatter	380x240	Shallow basin in middle		100.12-99.85 m	403/124,500	
	19	Burned rock concentration	400x275	flat, sloping		99.95-99.21 m	1,574/280,000	Charcoal= 4420 ± 50, 4400 ± 60, 4370 ± 80 B.P.
	24	Burned rock cluster	110x65	Unreported		99.95-99.78 m	/28500	
	25a	Burned rock cluster	80x35	Unreported		99.95-99.83 m	23/4500	
	25b	Burned rock cluster	40x30	Unreported			15/4000	
	27	Burned rock cluster	71x65			99.70-99.50 m	21/8,000	
	28	Burned rock cluster	100x100	Unreported		99.85-99.67 m	16/3,000	
	29	Burned rock cluster	140x100+	Flat		99.71-99.52 m	/4,750	
	30	Burned rock cluster	80x20+	Unreported		99.64-99.5 m	4/	
41HY202-B Barton Area B[3]	19	Debitage concentration	100x85	Shallow pit, 10 cm thick	Shallow basin	Unreported	2,055 flakes	4 notching flakes

Table 3-2. Excavated Bell/Andice Feature Data (continued).

Site No. and Name	Feature No.	Feature Type	Feature Size (cm)	Profile	Stained Matrix	Depth (Cm) Below Surface	Burned Rock Counts/ Wts. (g)	$\delta^{13}C$ Corrected C14 Date B.P.
41BL85 Landslide[4] Stratum III-b	1	Burned rock concentration	80x30+	Unreported	Heat stained, charcoal flecks	Unreported	Unreported	
	2	Burned rock hearth	150x150	Unreported	Unreported	Unreported	Unreported	Bison bone = >3520 B.P.
	6	Burned rock concentration	Unreported	Slight basin	No charcoal	Unreported	Unreported	
	8	Burned rock concentration	45x45	Flat	No charcoal or burned soil	Unreported	Unreported	
	108	Burned rock hearth	150x150	Unreported	Dark stained	Unreported	Unreported	
34MS174, Arrowhead Ditch[5]	2	Rock lined feature, two layers	200x200	Shallow 10-13 cm basin	Charcoal	290 to 320 cmbs	86/?	Charcoal = 5730 ± 160 B.P.

1 = Quigg et al. 2007 and Quigg et al. 2015; 2 = Kibler and Scott 2005; 3 = Collins 1994; 4 = Sorrow et al. 1967; 5 = Wyckoff, Morgan et al. 1994.

basins or pits and were essentially flat-lying structures comprised of several large flat slabs or tabular burned rocks were interpreted as grills and broilers. Small burned rocks clusters that lacked intact core or internal structure, observable charcoal, or oxidized sediment were interpreted as dumps or discard piles (Kibler and Scott 2005).

Nine burned rock features plus one cluster of two manos were excavated at the Bell/Andice component at the Big Hole site in central Texas (Table 3-2). Six appeared to represent rock filled hearths with shallow basins, which lacked preserved charcoal, although a few exhibited black stained sediment. None revealed deep basins or oxidation rinds to indicate long-term heating episodes to indicate oven cooking (Quigg et al. 2007). Three irregular outlined features that lacked basins and charcoal or carbon staining were interpreted as dumps or discarded rocks. No circular stained areas indicative of warming hearths were identified. So far, no massive burned rock middens or mounds are directly attributed to those populations.

The relatively small, different sized and shaped cooking facilities were probably were directed towards processing and cooking different food resources that required certain types of heat or heat controls to properly prepare the food (see Wandsnider 1997 for discussion concerning cooking requirements on different foods). No direct evidence from specific technical analyses is available to support the interpretations of various types of cooking processes perceived by these various facilities. Future technical research (e. g., lipid residues and starch grain analyses) may potentially link certain foods to specific types of cooking facilities.

One principal byproduct of cooking is the fractured burned rocks employed to cook and transfer heat to foods, and includes boiling, roasting, and steaming in an oven. This class of artifact is not normally curated and therefore accumulates from this process and can be subjected to multiple analyses. After rocks no longer provided the necessary heat retention qualities for their intended use, choices had to be made concerning what to do with the rocks. It is postulated many of the irregular clusters of randomly positioned burned rocks were the result of discarding those rocks no longer suitable, and they were removed from the primary *in situ* cooking facility and dumped. This discard process, if accurately reflecting this human behavior, allows archeologists to interpret a separate activity of cleaning and maintaining a cooking feature or area.

3.11 SUSBSISTENCE BASE

Direct evidence for the subsistence base is limited. This stems from few sites having been excavated and reported in detail, plus lack of organic preservation in those excavated from Texas and Oklahoma. The faunal and floral remains from excavated sites (i.e., Bellcow, Cibolo Crossing, and Landslide) were very sparse because of poor preservation. As an example, only 41 unidentifiable bone fragments were recovered from the Bell/Andice component excavated at the Cibolo Crossing site (Kibler and Scott 2000). Bison remains have been recovered from a few sites such as the Bellcow site (Girard and Carr 1994), the Frazier site (Spivey et al. 1994), the Snyder site, the Landslide site, and the *Bison antiquus occidentali* skull with the Calf Creek point embedded in it from the Arkansas River in northeastern Oklahoma (Bement et al. 2004, 2005). Bison remains from the Frazier site represent a single adult animal (species unknown) that apparently had been butchered, evidenced by the association of a Calf Creek point and a bison scapula. Bison leg bones *(B. bison*) (Valastro et al. 1967) were from Stratum IV/Occupational Phase 3 that was 18 to 25 cm thick at the Landslide site with a mixed point assemblage of two Bell, one Martindale, and one Merrill (Sorrow et al. 1967). Questions exist about the age of the bison bones and association with the points. At the Bellcow site the reported faunal remains from Middle Archaic Phase I levels include a broad assortment of species such as fish, birds, mussel shells, turtles, snakes, small mammals, deer, and bison (Girard and Carr 1994:205). If all the faunal remains reported from the Phase I levels are directly associated with the Calf Creek component, then this reveals a very broad, diverse subsistence pattern. Bison bones were recovered from the three main horizons at the Coffey site in northeastern Kansas. Apparently a few bison were in Kansas and Oklahoma during the Middle Archaic period. Presently in central Texas, bison bones are radiocarbon dated to ca. 5,120 B.P. in questionable association with Bell points at 41HY160 in San Marcos (Lohse et al. 2013).

At the Cervenka site in central Texas, in a zone attributed to the middle Holocene period, a diverse faunal assemblage was identified and indicates a diffuse foraging subsistence strategy through the presence of aquatic, grassland, and woodland species. Prairie chicken, turkey, quail, bison, pronghorn, deer, and rabbits are represented. Mammals (71%), birds (1.7%), reptiles (25%), amphibians (0.6%), and fishes (1.8%) were represented with 12 percent of the assemblage burned (Peter et al. 1982). Based on the presence of bison bone in Feature 26 and the radiocarbon date of 4970 B.P. from nearby Feature 19, bison were present in that area of Texas at that time. Recently the bison bones from Feature 26 were directly radiocarbon dated to 5135 B.P. (Table 3-1).

Poor preservation cannot account for the lack of bison in assemblages from this period. The thickness of cortical walls on bison long bones would enable preservation of these elements/pieces longer than thinner cortical walls on bones of small animals. Multiple middle Holocene period (ca. 7,000 to 4,000 B.P.) occupations at the Wilson-Leonard site in central Texas yielded limited faunal assemblages (Baker 1998). The assemblages represented include a broad range of smaller species such as small mammals, turtles, rodents, and fish remains. If bison populations (the a highest ranked resource) across the Southern Plains were significantly reduced in number during this period, then the human population, which preyed on bison, would have had to adjust and broadened their diet to include lower ranked resources (e. g., deer, small mammals, turtles, rodents, fish, etc.).

Broader bison distribution was not evident across Southeastern United States since Newman (1983) concluded bison probably did not expand significantly eastward, past Oklahoma and Texas, during the warm and drying period of the middle Holocene. McDonald (1981) sees an overall reduction in the number of bison during the middle Holocene across the Plains. At the Lubbock Lake site in northwestern Texas Johnson and Holliday (1986) indicate few bison were present during the middle Holocene. Only localized individual bison kills and processing areas were represented in Stratum 4A and 4B of the Middle Archaic. Unfortunately few diagnostic artifacts were present in those Archaic assemblages (Johnson and Holliday 1986). They also point out the archeological record for the period from 8500 to 4500 B.P. is scarce.

Mussel shells lack the preservation problems of bones and were minimally represented in the excavated Bell component at the Cibolo Crossing site where only one shell was recovered. In Stratum III-b at the Landslide site, many mussel and snail shells were present, and were assumed a food resource (Sorrow et al. 1967). Mussel shells have not often been reported from surface collections across Oklahoma. A possible mixed Bell component, a 10 to 15 cm thick shell midden designated Zone III at the McKinzie site near Corpus Christi, yielded quantities (N = 12,722) of marine clams (*Rangia flexuosa*). At least two other point types were represented in his same Zone III and therefore the association with the Bell point may be questioned. Zone III at the McKinzie site also yielded marine fish otoliths (N = 32), which minimally reflect six different fish species. These aquatic remains are unique for Bell/Andice assemblages. If the otoliths were a direct reflection of the Bell population there, it complements the diversity of the subsistence base. Based on the otoliths the seasonality reflects a late fall-winter occupation (Ricklis 1988).

Researchers must assume Middle Archaic hunter-gatherers were similar to most other hunter-gatherers groups who relied on plant foods to some degree. Direct evidence from good context has yet to be recovered, with a few exceptions. In Oklahoma, lack of excavated sites is the primary reason for the void. The few excavated and tested sites in Texas have revealed poor preservation from most Bell/Andice/Calf Creek assemblages (Kibler and Scott 2000). Consequently, food evidence is lacking in the macrobotanical material. It is not clear if investigations at the Landslide site explored the features for macrobotanical remains, but none are reported (Sorrow et al. 1967).

If one includes the three main horizons at the Coffey site in northeastern Kansas, with their basal-notched points, then the faunal and floral assemblages are greatly expanded. The Coffey site floral assemblage is also wide-ranging with goosefoot, smartweed, hackberry, bulrush, grape, and Solomon's Seal all represented (Schmits 1976, 1978). These very diverse data sets indicate those populations exploited a wide range of species in a couple of different habitats. In other words, populations during this general period were broad-based consumers rather than specialized bison hunters.

Poor preservation in most excavated sites combined with questionable context and/or association in other excavated sites prevents establishment of a solid foundation for determining what the subsistence base was at most locations. Lack of preserved faunal and floral assemblages hinders any across site and/or regional comparisons. Preserved faunal and macrobotanical assemblages are rare and are of utmost importance in determining the subsistence base and to help establish seasonal occupation of sites. Regional and/or seasonal differences in the subsistence base probably occurred across the broad regions utilized by these populations. If poor bone and macrobotanical preservation continues and even if it does not, technical analyses such as starch grain and lipid residues provide different data sets that can and should be employed to address subsistence and potentially seasonality issues.

3.12 SITE SELECTION AND MOBILITY

We assume most hunter-gatherer groups traveled across the landscape and it is possible movements occurred primarily along waterways through the different regions. Identified site locations across broad regions of Oklahoma and Texas provide information that can address group or population movements. Thus far, sites have been identified along large rivers and small creeks, in terrace deposits (e.g., the Arrowhead Ditch site [Wyckoff, Morgan et al. 1994]; the Cibolo Crossing site [Kibler and Scott 2000]; the Landslide site [Sorrow et al. 1967]; site 41MS69 [Quigg and Frederick 2005]; the Big Hole site [Quigg et al. 2007]), in sand dunes (e.g., the Primrose site [Wyckoff, Neal et al. 1994], and site 34GT6 [Wyckoff 1995]), on high ridges (e.g., Cestaro and Carrell 1994; Thurmond and Wyckoff 1999), out on the open short grass plains of western Oklahoma (e.g., Rhoton 1995; Thurmond and Wyckoff 1999), near springs (e.g., the Hester/Adams site [Cestaro and Carrell 1994]), and even rockshelters (e.g., the Bellcow site [Girard and Carr 1994]). The diverse topographic settings indicate broad use of the landscape rather than rigid use of specific landforms. Different site settings may reflect individual choices, or seasonally determined localities for hunting, camping, plant gathering, and/or raw material acquisition.

Different topographic settings occupied by these populations contain a wide range of biotic resources. Multiple biotic regions such as the short grass plains, mixed grass prairies, tallgrass prairies, and post oak forests in Oklahoma were all occupied. Known sites in central Texas are concentrated along the Balcones Escarpment where biotic ecotones occur along with diverse resources. Examples like the McKinzie site (41NU221) near the coast at Corpus Christi and the Devil's Mouth site (41VV188) in the Lower Pecos region just west of Del Rio, Texas reveal even greater diversity in landforms and biotic regions. These settings imply the populations accessed diverse environments and accessed diverse plant, animal and lithic resources in the different regions.

Thurmond and Wyckoff (1999) explored known occurrences of Calf Creek artifacts across northwestern Oklahoma and discovered seven widely scattered localities with isolated finds and no sizeable campsites documented between the Caprock Escarpment to the west and the Oklahoma and Texas line. Not only were these artifacts rare, they were mainly high in the landscape, along major east-west interfluvial divides. They postulated Calf Creek bands employed interfluves as travel routes between the Southern High Plains to the west and the Redbed Plains to the east.

Wyckoff (1995) lumped Calf Creek sites in Oklahoma into four geographical regions and refers to these regions as territories based on use of similar local knappable stone in the four regions. The quantities of regional collections generally reveal regionally positioned raw material resources (identified chert types and quartzites). In other words, specific tool stone was selected for tool manufacture in different localities across Oklahoma. These four different territories were localized and surround a particular known tool stone source locality. Wyckoff (1995) sees the diminishing sizes of implements made from preferentially used material as indication of the approximation of territories. Researchers frequently use movement of lithic materials as a reflection of group mobility and movement patterns. Therefore, in Oklahoma, regional groups appear centered around local raw material source areas and movement was potentially restricted to resource regions.

The five lithic caches from three sites in south-central Oklahoma (Primrose, Stilman, and 34MA4) reveal a storage technology directed towards leaving raw materials at specific locations across the landscape to collect and use at a later time. The archeological recovery of cached stone resources indicates groups did not always recover this valued material. Items in these five caches represent a variety of unfinished stone tools, which include large bifaces in various stages of reduction, scrapers, and large flakes that could be fashioned into tools. These caches contained items manufactured from Frisco cherts, which were from the Frisco chert source area not far from the caches. These caches occur within the territory that Wyckoff identified as Arbuckle Mountains in south-central Oklahoma. The caching behavior indicates those peoples clearly understood the landscape and potentially had predetermined travel routes through regions as they moved around seasonally.

Some researchers interpret direct procurement of chert as a logistical procurement strategy associated with a collector strategy. Bartlett (1994) claims the majority of evidence reveals a foraging strategy. Sites such as Area B at the Barton site (Collins 1994) in central Texas, which lacked a broad range of tool types may be interpreted as a task specific camp of short-term durations. The Hunter site in north-central Oklahoma yielded a high percentage of end scrapers (Brooks 1995) and may also support the remains of a task specific activity. Sites like Primrose in south-central Oklahoma appear intensively occupied over and over as campsites with the intention of returning to that same locality (Wyckoff, Neal et al. 1994).

If the single Bell point in the Zone III *Rangia* shell midden at the McKinzie site is representative of a Bell/Andice/Calf Creek group occupation rather than a single individual, then this one component reveals a fall season occupation. The relatively few excavated sites have reveled very limited seasonal data to help track seasonal movement patterns. This single location may hint at part of the broader seasonal round employed for one or more groups.

Duncan (1995) examined three Oklahoma surface sites and determined most documented site types for the Calf Creek groups primarily support a foraging mobility strategy where the entire group moved and "mapped onto" the exploitable resources. The projects lithic resources were obtained during normal movement patterns, an embedded strategy. Duncan states this is supported by resharpening and recycling of broken tools since tool stone source areas were restricted in size and geographically scattered across the landscape.

3.13 TRADE AND INTERACTIONS

Our understanding concerning possible trade and/or interactions of Bell/Andice/Calf Creek populations, both internally and with external groups, is quite limited. Understanding these complex interactions and human behaviors is yet to be clearly documented. What information can be gathered on the introduction of nonlocal materials into the everyday existence of middle Holocene groups is through the diversity of lithic artifact raw materials and/or other exotic materials. For example, the Primrose site in the heart of the Frisco chert resource area in south-central Oklahoma has yielded imported cherts (Johns Valley Flint, *N* = 6; or <1 percent of the total assemblage) far to the east along the western edge of the Ouachita Mountains and Edwards chert (*N* = 66, or 6 percent) far to the south in central Texas (Wyckoff, Neal et al. 1994). Edwards and Tecovas cherts have been recovered from surface sites in central Oklahoma (Carrell 1994; Cestaro and Neal 1994b; Duncan 1995; Powell 1995; Wyckoff, Morgan et al. 1994). Alibates agatized dolomite from the Texas Panhandle was employed to manufacture tools from sites in the Oklahoma Panhandle (Thurmond and Wyckoff 1999; White 1995), central Oklahoma (Powell 1995), and very northern Oklahoma in Kay County (Sullivan 1995). Alibates cobbles occur in the Canadian River drainage as far east as the present-day Lake Eufaula (Kraft 1997; Wyckoff 1993). Alibates material was moved northward into Oklahoma even though Oklahoma has quantities of local usable cherts. Projectile points manufactured from Florence (Kay County) chert from 250 km east in the southern Flint Hills of northern Oklahoma were recovered in northwestern Oklahoma (Thurmond and Wyckoff 1999).

Duncan (1995) traced raw material from the Anthony site (34CD295) in Caddo County in central Oklahoma, which yielded minimally 246 Calf Creek points, to minimally seven different chert source areas all across Oklahoma and two source areas in Texas. From these diverse chert resources, apparently coexisting groups interacted and exchanged chert resources from different regions, or participated in forays to directly procure these resources.

Another example is the Bell point from the Stinnet Pool site (41HC220) in Hutchinson County, in the Texas Panhandle. The point was manufactured from a gray opaque, dull, and fossiliferous non-local material. Similar materials are from Foraker or Wreform Formations, the former in northeastern Oklahoma and the latter from Flint Hills in southeastern Kansas. Obviously this point traveled a great distance westward and probably reflects trade or movements of people.

In Oklahoma different regions have different chert source areas that dominate the local Calf Creek assemblages. Small percentages of raw materials from outside regions occur in these local assemblages. Regardless what part of the territory these populations occupied, local chert sources were known and extensively employed to manufacture their tools. Wyckoff postulates the low frequency of nonlocal cherts in the different territories provides evidence for exchange among coexisting groups. Where high quality chert was not immediately available in a region, local Ogallala quartzite was employed (Thurmond and Wyckoff 1999). Employment of local raw materials is also evident at excavated Bell/Andice/Calf Creek components in central Texas, which are dominated by central Texas Edwards chert (Collins 1994; Kibler and Scott 2000).

To date, no obsidian has been directly associated with the Bell/Andice/Calf Creek materials, with one possible exception. A single obsidian flake was from a *Rangia* shell midden in Zone III at the McKinzie site (Ricklis 1988) near Corpus Christi. Zone III yielded two other identified point types in addition to a single broken Bell point, therefore this component may reflect a mixture of groups or assemblages. Lack of obsidian tools and debitage associated with Calf Creek across Oklahoma probably reflects lack of contact and/or travel westward to various obsidian sources in the northern New Mexico region and/or northwest ward across the Northern Plains.

3.14 TREATMENT OF THE DEAD

Virtually no human remains have been directly associated with the Bell/Andice/Calf Creek points. A partial human skeleton from the Lamar site (34BR8) in Bryan County, Oklahoma, just north of the Red River was encountered during Works Progress Administration (WPA) investigations in 1941. The partial skeletal remains (i.e., skull, long bone fragments, and possible vertebrae) of a single individual assigned Burial #14, were scattered and slightly above a cache of tightly clustered diverse chipped stone tools (Neal 1994). The human remains were not retained and no formal study was conducted. Artifacts, which represent the Calf Creek horizon were recovered from the deposits and the cache, although it is not clear if Burial #14 was associated with this material.

The Buckeye Knoll site (41TV98) in Victoria County in far south Texas has yielded an early cemetery with 13 of 69 human interments directly radiocarbon dated human bones and teeth to between 5,470 and 6,075 B.P. (Table 3-2) (Ricklis et al. 2012). No Bell/Andice artifacts were directly associated with any of these interments. Other associated point types and artifacts reflect other affiliations. However, six Bell/Andice point fragments were in nonmortuary context (Ricklis 2012a:189). These interments were part of a large cemetery with minimally 116 individuals identified from a knoll top overlooking the Guadalupe River in the coastal plains environment. The evidence reflects intensive occupations surrounding the Buckeye Knoll site, as the knoll was employed as a cemetery during this specific period (Ricklis 2012b). Even though those individuals represent a broader population and were not directly assigned to the Bell/Andice horizon, it indicates other populations were in the same region as them and potentially contacted or even interacted with them.

Researchers have no conception of appearance or cultural diversity within groups which represent the Bell/Andice/Calf Creek interval as human remains are absent. Based on the expansive territory recorded, it is probable multiple groups were involved. As a result, researcher speculate regional differences probably existed. Lack of human remains also prevents researchers from pursuit of questions concerning burial practices and rituals, social status, or health conditions.

3.15 SUMMARY

The combined Oklahoma Anthropological Society Bulletins XL and XLII provides a wealth of information concerning many aspects of the Bell/Andice/Calf Creek interval, and includes site distribution across Oklahoma, landform utilization, raw material use and lithic technology, and diverse aspects of the diagnostic artifacts. Most data was derived from roughly 50 separate archeological surface sites with no clear stratigraphic context, therefore many sites lack solid association of objects. This creates difficulties in identifying the broader cultural assemblage and addressing many specific aspects of human behavior beyond information derived from the tools. The few excavations have contributed other aspects to our understanding the broader cultural lifeways.

Excavations across Texas have encountered Bell/Andice/Calf Creek components and added diverse information to this poorly known interval. They have yielded information concerning the broader tool kit, insights into subsistence, aspects concerning food processing and the cooking processes. The problem stems from most associations are questionable as context has often yielded mixed assemblages. Most sites and components are undated, although recent excavated components have been radiocarbon dated and the broad temporal framework is slowly coming into focus and narrowed.

Existing radiocarbon dates reveal these point types generally occurred between 5050 and 4990 B.P. in Oklahoma and between 5770 and 4720 B.P. in Texas. Multiple dates, however, appear as potential outliers and/or questionable dates as they are both older and younger than the majority of results. Apparent outliers may be eventually verified through more dates or represent population expansion into different regions across the vast expanse of the projected territory. The few dates from Kansas are very similar to those in Texas. Existing data is not sufficient to document population movements across the broad landscape.

This period is projected as part of the broad Altithermal climatic period, a generally warm and dry period across the Southern Plains region. If climatic conditions can be verified, this must have had a significant influence on how these populations operated and what choices they made in their everyday lifeways and the animal and plant resources available to them. After reviewing the archeological and environmental record from the middle Holocene, Meltzer (1999) lists several key points. First, there are fewer archeological sites from this period throughout the Plains. Second, sites occur widely scattered in space and time, and hence few localities or areas provide fine-grained evidence of adaptive change through time. Third, the adaptive strategies evident in these sites vary across the Plains. Forth, the apparent effects of the Altithermal are most evident on the Southern Plains.

Consequently, Meltzer (1999) sees several trends in human subsistence, technology, settlement, and demographics attributed to forger responses to Altithermal climates. The responses included: 1) an expansion of the diet breath to incorporate a variety of animals and plants in the diet; 2) the advent of new technologies to cope with diminished food and water; 3) large scale settlement shifts, from the Plains to the western foothills and mountains or to local refugia (springs and watercourses on the Plains; 4) reduced settlement mobility (marked by increasing reliance on local stone sources and construction of residential pithouses; and 5) an overall decline in human population density.

In order to continue to expand our understanding of the diverse aspects of human behavior that characterize these populations of hunter-gatherers, more in-depth excavations of Bell/Andice/Calf Creek cultural deposits, with clear stratigraphy and dateable organic materials are needed, followed by detailed and critical analyses of multiple artifact classes and human processes are necessary across broad areas of Oklahoma, Texas and beyond. Much remains to be understood concerning this period and the human populations, and how these groups operated during those environmental conditions. Contributions in the following chapters will advance our pursuit of greater understanding.

4.0 FINAL RESEARCH DESIGN FOR ANALYSIS AND REPORTING, SITE 41MS69, MASON COUNTY, TEXAS

Robert A. Ricklis, J. Michael Quigg, and Paul M. Matchen

4.1 BACKGROUND: THE SITE AND THE TESTING CONDUCTED BY TRC

Due to the limited extent of the excavations, many aspects of the archeological record that might normally be represented by findings from a more extensive excavation simply do not exist here, a fact which inevitably limits research potential. Thus, we propose that our report on this site be *largely of a descriptive nature*, with descriptions focusing on a review of field methods, a discussion of observed stratigraphy and subsurface features, plus a discussion of the radiocarbon dating of features and a basic description of associated cultural materials. This research design was written and approved by TxDOT in 2012.

A single research question, stated further on in this document, was directed toward a single analytical unit comprised of two relatively well-defined and more or less contemporaneous features (Features 1 and 2), and inferably associated materials from immediately surrounding matrices. This research question was of a generalized nature, and it was our intention to conduct a limited set of technical analyses that would target this question using the data acquired.

The Slippery Slope site saw recurrent occupations over several millennia (e.g., the eight recovered dart as point types span the Middle and Late Archaic periods, which represent a time interval between roughly 6,000 and 2,000 cal B.P.). Only a single period within the Middle Archaic was represented by stratigraphically and horizontally isolatable features. These were the aforementioned Features 1 and 2, which have yielded multiple radiocarbon dates that range from 3,910 to 5,140 B.P. and 4,730 to 5,420 B.P. (cal 3990-3635 B.C. and cal 3640-3585 B.C.), respectively. Both features were within the same sedimentary depositional unit (Unit 3) (Figure 4-1) in contiguous TUs 5 and 6, plus a limited extension of TU 5. These two features were toward the southern end of the APE. Both consisted primarily of more or less tight concentrations of fire-cracked limestone rocks. A Middle Archaic Andice point was in proximity to Feature 1 at the same depths as the feature rocks and just 90 cm west of the feature boundary. This association was inferred, and is supported by the radiocarbon ages from both features. Later occupations are represented by a few dart points of known Late Archaic age (Marcos, Montell, Pedernales points) or later Middle Archaic age (a Travis point). These point types cannot be assigned to discrete features or stratigraphically definable archeological components.

Geoarcheological investigations documented a basic alluvial stratigraphy comprised of three different sediment units (see Figure 4-1): Unit 1, estimated to date to greater than 9,120 B.P.; Unit 2, estimated to have been deposited between 7,990 and 5,200 B.P.; and Unit 3, with an estimated age of between 5,200 and 1,600 B.P. Examination of the profiles created by the hand-excavations, in conjunction with observations of the sediment profile created by the road cut, revealed multiple lenses of cultural material toward the southern end of the site, where as many as 12 apparent occupational layers were observable to a depth of 250 cmbs. Toward the north, the sediment profile became thinner and more compressed, which reflected a lesser net accumulation of alluvium over the long-term (Figure 4-1); the various lenses of cultural material, marked largely by fragments of burned rock, tended to merge into a single stratum

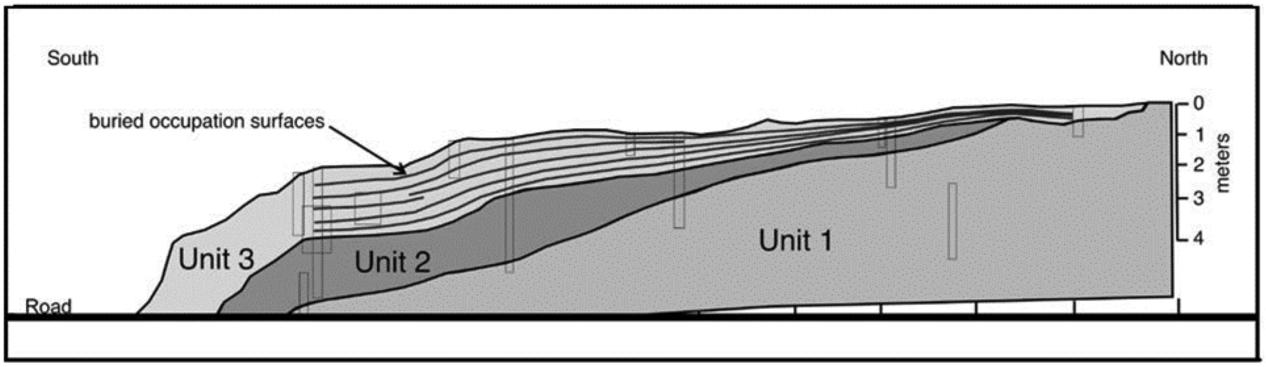


Figure 4-1. **Schematized profile of 41MS69, looking west. Note thinning and compression of the deposits and buried occupation surfaces, from south to north.**

of burned rock (having the appearance of a typical central Texas burned rock midden) contained within a vertical range of no more than 150 cm. Sediment Units 1 and 2 were devoid of archeological materials, and all cultural remains were found at various depths within Unit 3, the uppermost of the three alluvial stratigraphic units.

4.2 FEATURES 1 AND 2 AS AN ANALYTICAL UNIT

Features 1 and 2 were exposed by hand-excavation of TUs 5 and 6, and a small extension of TU 5, in the southern part of the APE. Both features consisted of largely intact concentrations of burned rock apparently sealed in primary contexts within Unit 3 alluvial sediments. While evidence for Middle to Late Archaic occupation was discovered elsewhere in the APE, these two features represent the only cultural deposits in clear and discretely definable stratigraphic and chronological contexts.

Feature 1 was a rock-lined/filled heating element, between 136 and 157 cmbs, with a slightly basin shaped profile (see Figure 4-2). Due to the limited horizontal extent of the hand-excavations, overall dimensions could not be determined. A distinct and possible shape was indicated by a clearly defined western margin. Excavations documented the feature had a minimal east-west dimension of at least 100 cm and a minimal north-south dimension of at least 200 cm. Despite its basin shaped profile, no concentration of charcoal or marginal oxidized (burned) rim was observed. Burned rocks from within the exposed portion of the feature (*N* = 254) had a total weight of 124,575 g. A few pieces of lithic debitage and two freshwater mussel shells were in direct association with this feature. A broken Andice point was at the exact same depth as the burned rocks at 146 cmbs and just 90 cm from the western boundary of the feature in TU 5. A biface fragment and edge-modified flake were in the upper part of the feature.

Feature 2 rested below Feature 1, with associated rocks distributed from 163 to 177 cmbs in sloping deposits, while carbon stained sediments extended to 200 cmbs. As depicted in Figure 4-2, the two features, while in close vertical proximity, were clearly separated by roughly 15 cm of relatively rock-free or stained sediment. Feature 2 measured at least 170 cm east-west and 200 cm north-south. In profile, it was basin shaped. The bottom portion of the basin was filled with dark, charcoal-stained sediment, which indicate an *in situ* thermal feature, perhaps a cooking facility. A total of 928 burned rocks, weighing 247,334 g, were documented in association with Feature 2.

A total of 15 radiocarbon dates have been obtained on sediment and charcoal. Seven samples from Feature 1 provide a combined conventional date range from 3890 to 5140 B.P. (2-sigma calibrated date range of 2490 to 3990 B.C.), while eight

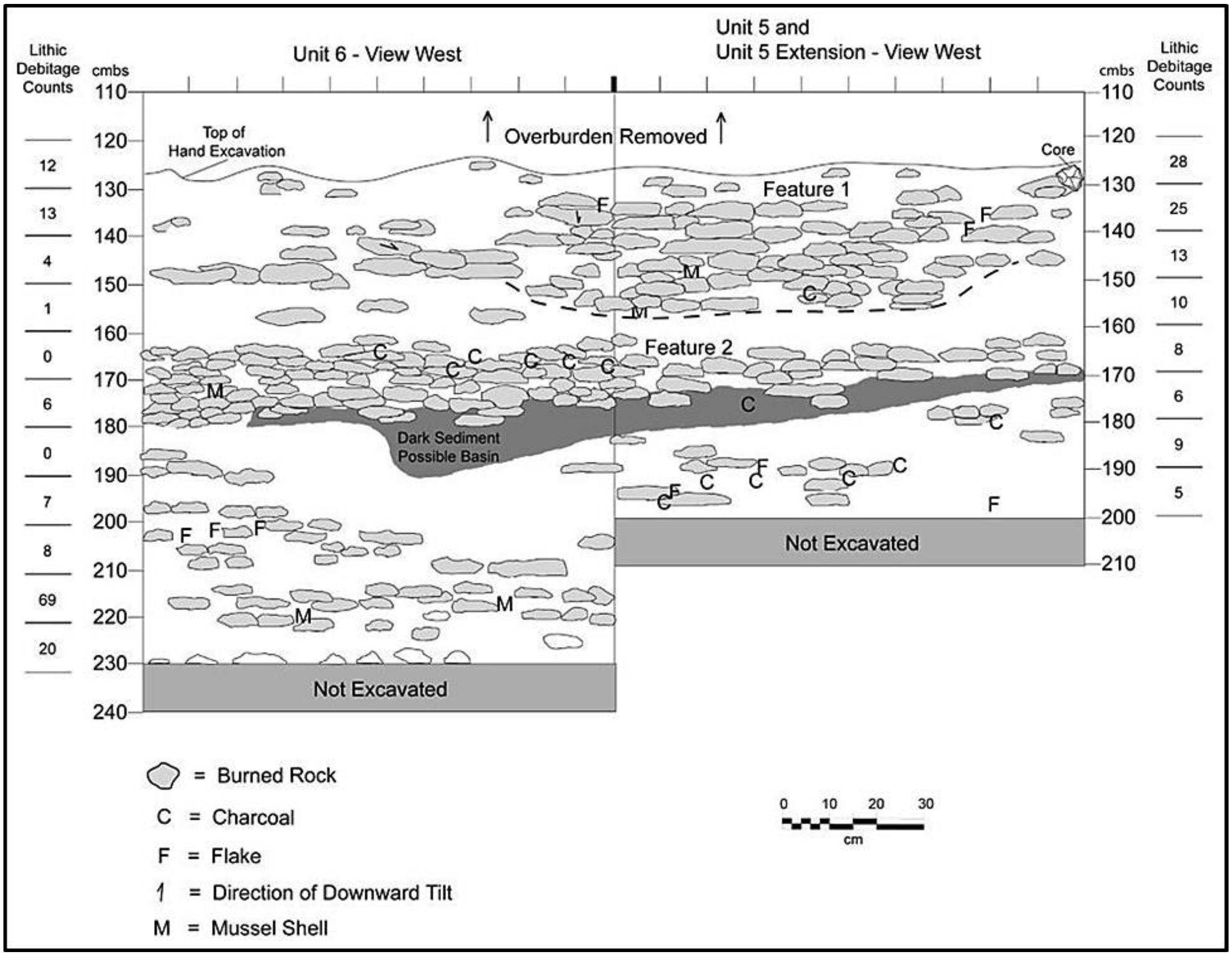


Figure 4-2. Profile drawing of Test Units 5, 6, and 5-extension, depicting cross-sectional morphologies and stratigraphic relationships of Features 1 and 2.

samples from Feature 2 have a combined conventional date range from 4550 to 5420 B.P. (2-sigma calibrated range of 4340 to 3370 B.C.). Both features pertain to essentially the same period during the middle Holocene, and the date ranges document a slightly earlier age for Feature 2, which is expected given its slightly deeper vertical position. These radiocarbon results are congruent with the presence of an Andice point in association with Feature 1 (Andice points have a temporal placement at ca. 5,000 to 6,000 B.P. (cal 3,100 to 4,100 B.C.) in Prewitt's [1985] central Texas culture chronology). Consequently, both features are considered to pertain to Middle Archaic occupations of 41MS69 between ca. 3890 to 5420 B.P. (2-sigma calibrated range of 2490 and 4340 B.C.,). These are treated as a single analytical unit for our present purposes.

4.3 RESEARCH ORIENTATION

In a letter report sent to TxDOT in June, 2011, we formulated a succinct research orientation, stated in terms of a research hypothesis, to guide analysis of the materials and data from 41MS69 (Ricklis et al. 2011), as follows:

Features 1 and 2 at 41MS69 represent Middle Archaic occupations during which the site inhabitants procured and processed a range of food resources, most importantly, plant resources.

As we noted in the letter report, this hypothesis may seem highly generalized, perhaps even to the point of being trivial, since it is a given hunter-gatherer groups exploited a range of plant and animal resources according to availability within their operational areas. However, our key concern here, as is implied in the stated hypothesis, is to contribute to an understanding of the relative importance that populations in central Texas, living during the climatically dry period of the middle Holocene, placed on plant resources, which potentially had a greater economic and dietary significance than animal food resources. In the letter report, we formulated this inquiry by posing the question: *Did a general drying trend in regional climate lead to an increased emphasis on procurement and processing of plant resources on the part of human populations, in response to an overall reduction in available animal biomass?*

The limited database obtained from 41MS69 is not, in itself, sufficient to answer this fundamental question. At the same time, limited, carefully targeted analyses on materials from Features 1 and 2 provided insight into the adaptive strategies that were operating at this particular site in the middle Holocene, and therefore provides useful comparative data for further inquiry, at a regional scale, into this question.

The proposition that the period between ca. 7500 cal B.P. and 5500 cal B.P., (ca. 5500-3500 B.C.) saw relatively dry climatic conditions is supported by several reconstructions of Holocene climatic trends, based variously on palynological and microfaunal data, plus shifts in the proportions of C_3 and C_4 plants within environmental mosaics. These reconstructions of long-term climatic trends are presented here in Figure 4-3, and include pollen records from two east-central Texas bog sites (Bousman 1998), dated sediment cores from the lower Guadalupe River floodplain in Victoria County, (Albert 2007), the record of long-term changes in microfauna from Halls Cave on the Edwards Plateau (Toomey et al. 1993), and fluctuating representations of C_4 plants from the Richard Beene site just south of San Antonio (Thoms 2007). Also included in this figure is a reconstruction proffered by LeRoy Johnson, based on a variety of data sets from the central Texas region (Johnson and Goode 1994, 1995). While none of these long-term climate models are identical, they all posit dry conditions during the period of 7500-5500 cal B.P. The sole exception is Johnson's model, which indicates the period of dryness beginning after ca. 7,000 B.P.

The preponderance of evidence, then, is the period of interest was in fact relatively dry. Following from this, we may postulate a degree of reduced environmental primary productivity and a resultant decline in overall animal biomass and, by extension, a shift in human adaptive strategies that placed an increased emphasis on exploitation of plant food resources, a trend that should be detectable in the archeological record. The analytical approaches to the materials from 41MS69 are geared toward addressing these issues at the site specific scale.

For reasons already stated, both Features 1 and 2 appear to represent the same period of prehistory and, therefore, as susceptible to inclusion within a single analytical unit. We proposed to address the above-stated hypothesis by applying the following analytical approaches to this unit of analysis:

- *Starch Grain Analysis.* This analysis will be performed on samples of fire-cracked rock and sediment from Features 1 and 2, as well as any expedient lithic tools that may also be associated with these features. The results can be expected to contribute to understanding the kinds of plant foods potentially processed and cooked in these features.

- *Lipid Residue Analysis.* This kind of analysis can be expected to indicate whether the features served to processand

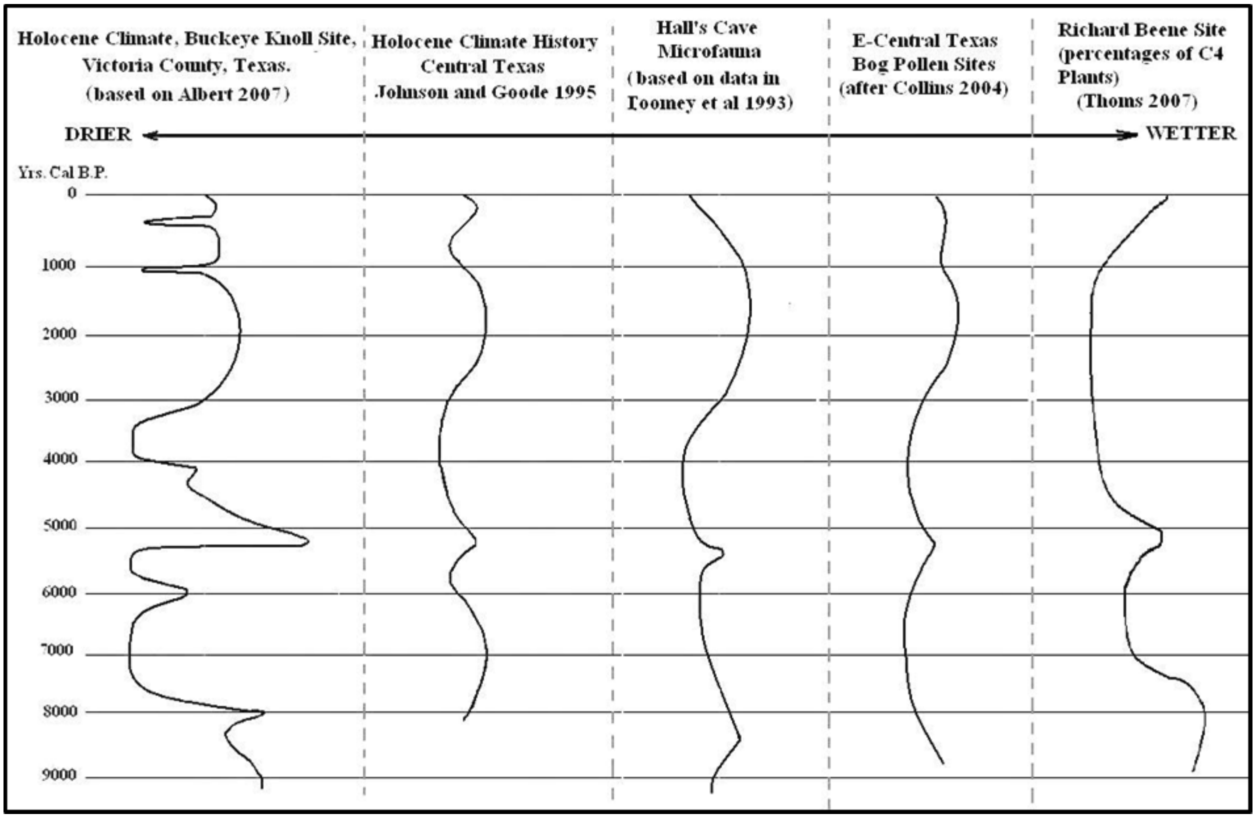


Figure 4-3. Five presentations of basic patterns of Holocene climate fluctuations (relatively dry to relatively moist) based on pollen studies (Albert 2007; Bousman 1998, as summarized in Collins 2004) shifts in microfaunal species in cave deposits (Toomey et al. 1993), and fluctuations in percentages of C_4 plants, based on carbon isotope values (Thoms 2007). The Holocene climate history presented by Johnson and Goode (1994, 1995) draws upon various data sets, including sediment stratigraphy's that reflect shifting hydrological conditions related to climate change.

cook animal or plant foods, or both animal and plant foods. This analysis will be performed on samples of fire-cracked rock and sediment from Features 1 and 2. In light of the research questions articulated above, we should expect to see a significant or even preponderant representation of plant residues.

- *Use-Wear Analysis, Stone Tools.* This will be applied to formal tools, including the Andice point associated with Feature 1 and surrounding sediment, as well as debitage specimens that represent expedient tools associated with the two features. The goal in this work will be to ascertain the kinds of tasks accomplished with the tools and, in particular, to assess the relative importance of tasks oriented toward hunting and subsequent butchering of animal carcasses, as opposed to tasks related to processing of plant materials. While the samples of such materials are small, it is hoped that some useful information can be thus obtained.

- Instrumental neutron activation analysis is to be conducted on a suite of lithic tools and debitage from the two features to assess the use of local versus nonlocal chert resources, and to examine how lithic technological organization operated within the relevant adaptive system.

Several other analytical techniques were proposed in an earlier version of this research design (Ricklis et al. 2011), including phytolith analysis, macrobotanical analysis, diatoms, and debitage analysis. Following results from feasibility studies of these techniques, only the phytolith analysis yielded insufficient data to proceed with further analysis. We do note, however, that in accord with TxDOT recommendations (TxDOT 2011), samples for each of these kinds of analyses were prepared for permanent curation, in the event they could prove useful for comparative purposes in future studies.

5.0 METHODS

J. Michael Quigg

5.1 FIELD METHODS

Dr. Owen Lindauer, previous director of ENV Affairs Division, TxDOT district archeologist Jon Budd, and Mike Quigg archeologist for TRC visited the site on April 26, 2004. Areas of previous looting in a burned rock lens or midden deposit were observed under numerous large oak trees along the top 1 m of the steep road cut deposits (see Figure 1-3). During this visit, the general strategy for eligibility assessment was discussed and agreed upon. Subsequently, the Work Authorization (WA #57512SA006) was finalized and signed, followed by prefieldwork that included obtaining a THC permit, completing the site form, and obtaining a trinomial site number from the Texas Archeological Research Laboratory (TARL).

Fieldwork was initiated June 16 with the excavation of initial four 1-by-1 m hand-excavated test units (TUs 1 through 4) widely distributed along the relatively flat, and very narrow strip of what was thought to be TxDOT right-of-way. This narrow strip was the top of the terrace above the steeply sloping deposits (Figure 5-1). These four test units were excavated from the ground surface to various depths to assess the general nature of the upper part of the deposits where a burned rock lens or midden appeared concentrated based on the exposures in the top of the road cut (Figure 5-2).

As hand-excavations progressed, geoarcheologist Dr. Charles Frederick, documented the natural deposits in the road cut. The exposed road cut, a roughly 100 m long, nearly 5.5 m tall exposure was considered the APE, also provided a window in which the stratigraphy was examined and recorded. No backhoe trenches were excavated at this location because of the lack of room and safety concerns. To remove the slumping sediments and gain a clear window into the buried deposits, five vertical columns (Columns 1 through 5) were hand-excavated from the top of the road cut down through the deposits at different intervals along the 100 m exposure. Columns were excavated in stair-step benches to allow access to the steep slope, and were generally excavated into the eroded exposure at least 30 cm (Figure 5-3). In places such as along the road shoulder, roughly 1 m of slump was removed in order to access the intact deposits. Columns varied from 40 to 85 cm in width and provided windows that geoarcheologist Dr. Charles Frederick used to view and record the depositional units. He created a sketch map and photo mosaic of the roughly 100 m long by nearly 5.5 m tall road cut section that exposed the cultural deposits (see Chapter 5.0 below for details).

Subsequently, Columns 1 and 2 became access points for hand-excavated and screened columns of sediment to document the cultural materials at those localities. At these two locations 25-by-25 cm or larger columns were hand-excavated in 20 cm thick levels. The excavated sediments were screened through 6.4 mm (¼-inch) wire-mesh screens beginning from the ground surface to depths of 220 and 160 cm below surface (cmbs) respectively. Screened Columns 2 and 3, combined with subsequent hand-excavated and screened TUs 5 through 10 along the steep road cut permitted assessment of the much deeper cultural deposits (Figure 5-3).

During the excavations, the adjacent landowner, TxDOT archeologist Jon Budd, and the TRC crew determined TUs 1 through 4 had been excavated on private land. The north-south fence was thought to be marking the western boundary of the existing TxDOT right-of-way was stated to have previously been moved back from the eroding edge and was presently 3 to 4 m west of the TxDOT right-of-way on private land (see Figure 5-1). It was determined the true western boundary of the TxDOT right-of-way, the APE, was near the actual edge of the sloping road cut. Consequently upon discovery, TUs 1 through 4 were terminated at depths of 70,

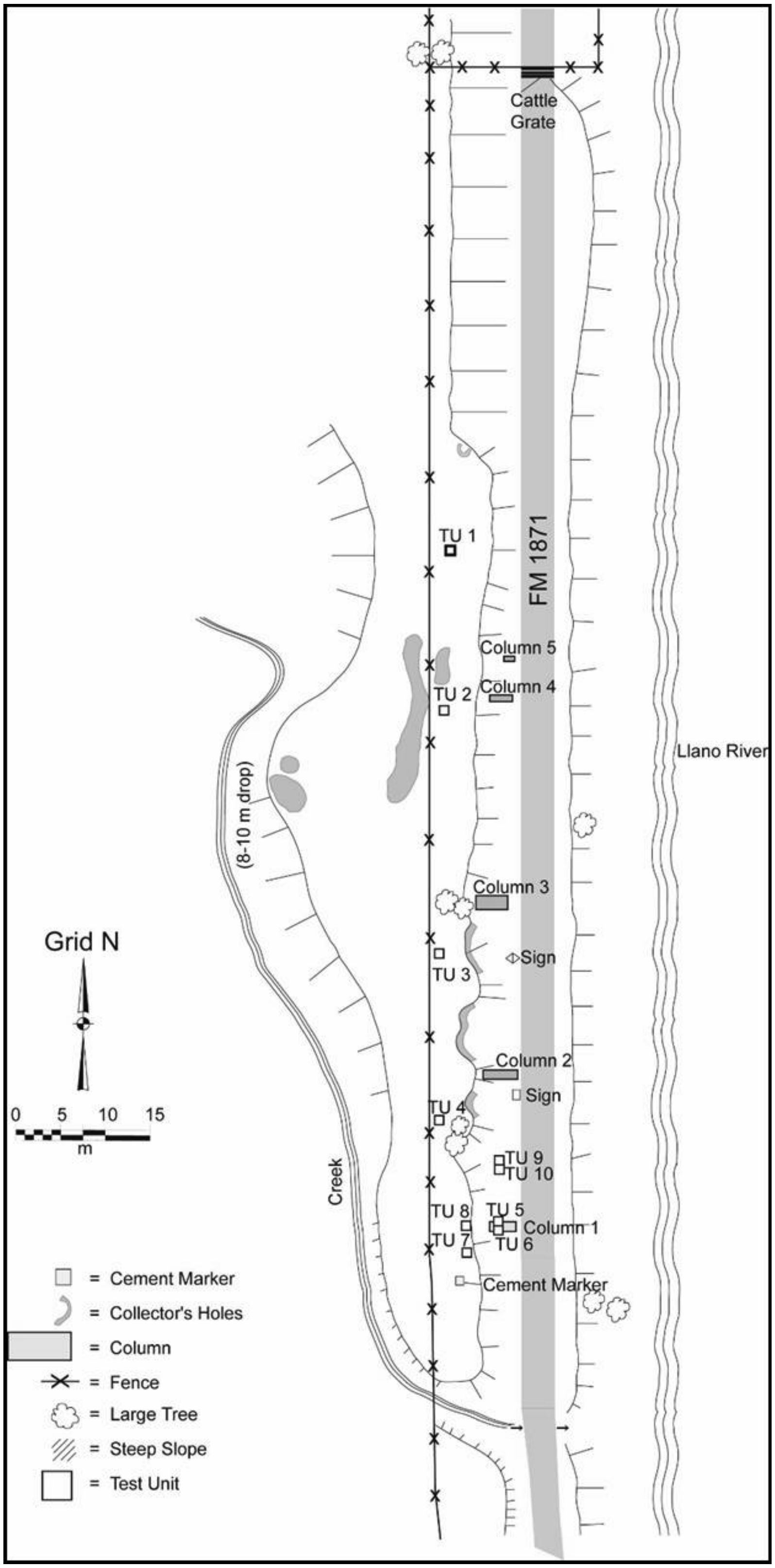


Figure 5-1. Plan map of the site 41MS69 along the narrow area of potential effect depicting areas investigated.

Figure 5-2. Example of test units excavated into alluvium on flat area of the terrace above the steep sloping road cut.

Figure 5-3. Column 1 depicting stair-stepped hand-excavation in steep sloped road cut.

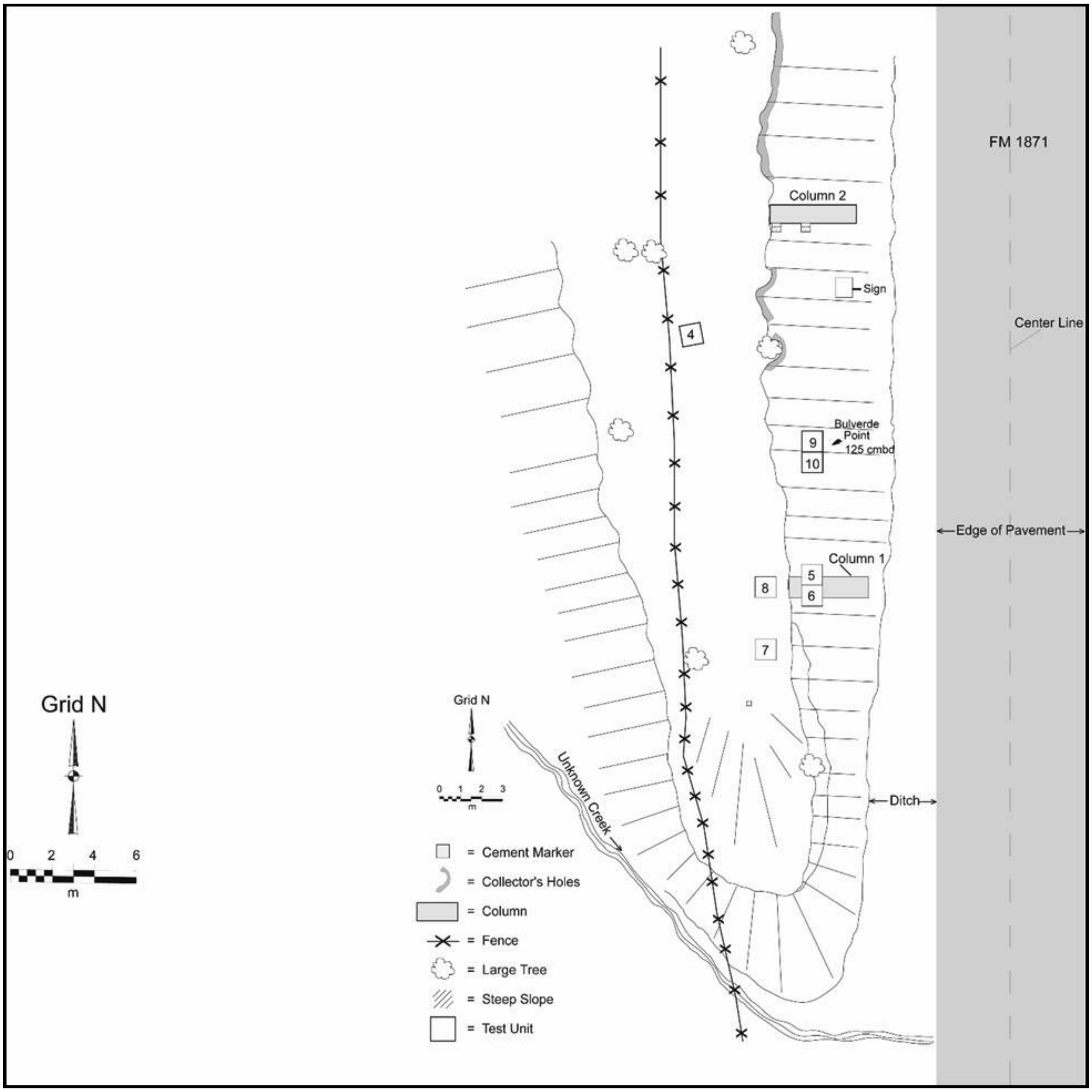


Figure 5-4. Southern end of 41MS69 depicting areas investigated and landform variations.

100, 60, and 90 cmbs respectively, and backfilled that same day. It appeared the area of TUs 7 and 8 was probably in the TxDOT right-of-way (Figure 5-4).

Investigations then shifted to target cultural deposits exposed in the steeply sloping road cut at two areas that exhibited potential cultural features. Test Units 5 and 6 were placed side-by-side to create 1-by-2 m working space near the middle of the slope to target one or more potential burned rock features exposed between 150 and 200 cmbs on the face of Column 1 (Figures 5-4 and 5-5). Screening of sediment from TUs 5 and 6 began at depths of 120 cmbs on the slope. The sloping sediments above were removed by hand without screening to create a flat starting surface at ca. 120 cmbs. Test Units 5 and 6 were then hand-excavated to depths of 200 and 230 cmbs at which point the top of natural gravels were encountered.

Test Units 7 and 8 were excavated at the very western boundary of the projected TxDOT right-of-way, at the southern end of the exposure and just west of Column 1 (Figure 5-4). These units sampled cultural bearing deposits detected in the top part of Column 1 above those features targeted by TUs 5 and 6. Test Units 7 and 8 were excavated from the ground surface to depths of 110 and 150 cmbs, respectively.

Test Units 9 and 10 were excavated about 6 m north of Column 1 to assess a cluster of large rocks with the potential to be a deeply buried cultural feature (Figures 5-4 and 5-6). Similar to TUs 5 and 6 these two units were side-by-side creating a 1-by-2 m long sample unit in the lower portion of the sloping road cut. Screening began at depths of 60 and 70 cmbs, respectively, on the slope with the overlying sloping sediments removed by hand without screening to create a flat working surface at 70 cmbs. Test Units 9 and 10 were excavated to depths of 130 cmbs and penetrated into an intact, very sandy, gravelly deposit at the bottom of each unit.

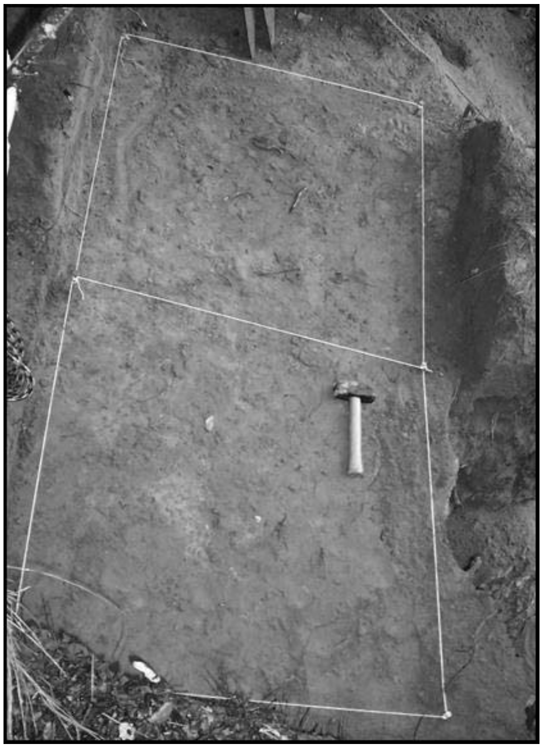


Figure 5-5. Configuation of Test Units 5 (top) and 6 (bottom) over buried burned rock features below that surface and exposed in original Column 1.

On the last day of the fieldwork in an attempt to expose as much of the targeted features as possible, TU 5-extension, a 100 cm north-south by about 70 cm east-west unit, was excavated immediately east of TU 5. Test Units 5 and 6 exposed only the very western edge of Feature 1 and did not further clarify the nature of Feature 2. Test Unit 5-extension was anticipated to further expose Features 1 and 2 and clarify their association.

The sediment from TU 5-extension was not screened, although a bulk sample was collected for processing in the laboratory. In total, ten hand-excavated test units sampled 8.9 m^3 of site deposits.

The hand-excavated 1-by-1 m units were excavated in roughly 10 cm levels with excavated sediment screened through 6.4 mm (¼-inch) wire-mesh screens. The four units excavated on the sloping road cut were much more challenging as the working space was limited and excavated rocks and sediments were bucketed and hauled down slope to the screen below (Figure 5-7). When sizable pieces of cultural material or features were encountered *in situ* in the level, most artifacts were piece plotted for the level record. Separate level records were completed for each screened level to document the particulars of that level, which included what was observed and collected. Cultural materials (except burned rocks) were bagged by unit and level, and returned to the laboratory for assessment. Burned rocks were generally counted and weighed by previously established size categories and then discarded in the field. Often samples of 1 to 4 burned rocks were collected from features and/or particular levels and brought to the laboratory for potential analysis. Samples including bulk sediment from Features 1, 2, and 3, macrobotanical, carbon-14, snails, fine-screen, flotation, and burned rocks were collected when necessary during the

Figure 5-6. Position and configuration of Test Units 9 (right) and 10 (left) over potential cultural rocks.

excavations. These samples were collected according to the judgment of the investigators with the primary goals of identifying data content and placing site deposits in a chronological framework, addressing subsistence issues, and projecting paleoenvironmental conditions.

5.2 LABORATORY PROCEDURES AND TECHNICAL ANALYSES

Back in the TRC Austin laboratory, artifact processing began with the washing, sorting, and labeling most cultural materials, except burned rocks and mussel shells. Prior to washing, all bags of lithic debitage were macroscopically examined for formal and informal tools. All identified stone tools were pulled from the level bags and bagged separately without washing or further handling. On unwashed specimens, a portion of one surface was cleaned to allow an archival stable ink label to be placed on the artifact. Nitrile gloves were worn when handling these selected tools.

All cultural materials were assigned Provenience Numbers (PNUMs) and entered into an electronic database. These unique PNUMs were assigned to individual excavation levels, as well as other proveniences. All provenience information available and pertinent data from the collection bags and level records were entered into a Microsoft Access format database.

TRC's cataloging system assigns strings of numbers to artifacts that encode information on provenience, artifact class, a unique identifier, and samples removed from the artifact or lot for specialized analyses. The PNUMs (e.g., #155) were assigned to lithic debitage, stone tools, and burned rocks. PNUMs are sequential numbers that designate the overall provenience unit (i.e., excavation unit, backhoe trench, modern ground surface) and level, or depth, within that provenience unit and can be cross-referenced to a master list of PNUMs. Within each PNUM, various artifact classes were assigned a secondary designation referred to as the artifact class number: lithic debitage (001), faunal bone (002), burned rock (003), soil (004), feature (005), shell (006), macrobotanical remains (007), ceramic sherds (008), and historic material (009). Individual tools and other unique items were assigned unique artifact numbers starting with the number 10 within the same unit and level designated by the PNUM.

Figure 5-7. Example of excavation procedures on steep slope.

Thus, each tool and unique specimen was assigned a PNUM and an artifact number (e.g., #155-10, #155-11, and #155-12).

About one in ten items (10 percent) occurring in bulk material classes (e.g., chert debitage) within specific provenience units (e.g., a level) were individually labeled as per curation guidelines. Specimen size was also a major consideration for labeling purposes, as many lithic pieces are less than 1 cm in diameter and were not labeled. Artifact labeling consisted of inscribing the State of Texas Archeological Site Trinomial (41MS69) and the catalog number on designated artifacts using black indelible ink. After the ink was dry, the artifact labels were coated with clear Acryloid B-72 with reagent-grade acetone solvent to preserve the inscriptions.

Permanent paper tags were included with each individually bagged artifact or class of artifacts collected from a single provenience. These tags include the site trinomial, provenience information (unit and depth), the class or type of artifact(s), the date of excavation, the excavator's initials, and the quantity of items in the bag. These permanent tags were printed on acid free, 30.4 kg (67 lb.) card stock and filled out with pencil.

5.2.1 Analytical Methods

Artifacts were subjected to different metric, nonmetric, typological, and several specialized analyses. A set of predefined attributes for each material class were first encoded on paper, and then entered into TRC's electronic database management system utilizing Microsoft Access 2010 software, which constitutes the master database for the investigations at 41MS69. A copy of this database is provided on the CD-ROM attached to the back cover of this report. The specific data recorded for each class of artifact are presented below. Analytical methods pertinent to each data class and various secondary suites of software employed for specialized analyses are discussed in detail in the appropriate parts of this report.

5.2.1.1 Chipped Stone Artifact Analysis

A protocol for analysis of debitage and chipped stone tools has been developed by TxDOT archeological staff (TxDOT ENV 2010) in an effort to standardize data collection and presentation in analytical and interpretive chapters of archeological reports sponsored by TxDOT. When possible, terminological and taxonomic uses follow those terms for this assemblage (Figure 5-8).

Bifaces

Bifacial tools, whether finely or crudely produced, have completed the manufacturing process. This is evidenced by secondary retouch, edge straightening, hafting preparation, notching, and similar characteristics. Bifaces are defined predominantly on the basis of morphological characteristics, although they may also have functional associations (e.g., cutting, piercing, chopping, and drilling). Bifacial tools exhibit purposeful, usually patterned, flake removals on

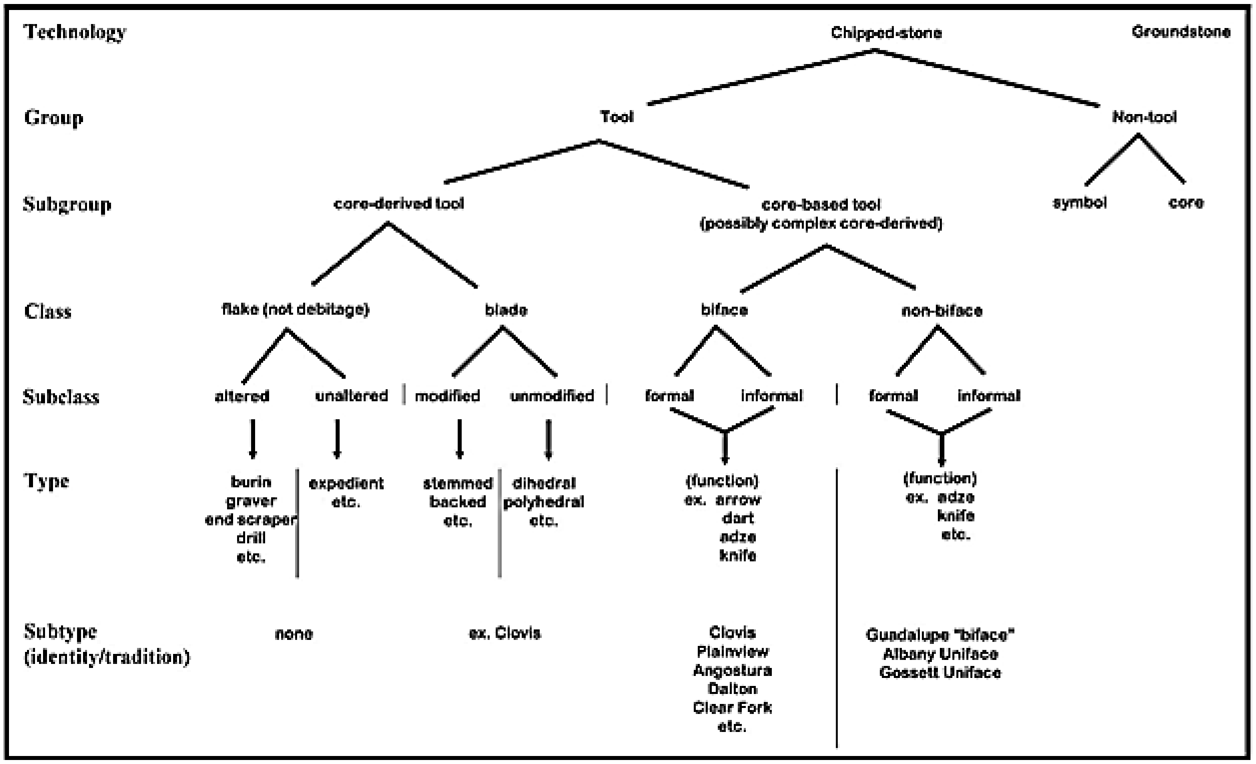


Figure 5-8. Chipped stone artifact analysis flowchart.

both faces (ventral and dorsal). Most or all of both faces may be covered with flake scars, and occasionally one face may be completely modified, whereas the opposite face exhibits only partial modification. Bifaces may be fashioned either from large bifacial cores or from flakes. Included within this overall morphological category are diverse functional groups such as projectile points (see below).

Projectile Points

Projectile points are a functional subset of the biface class specifically designed to be hafted to the distal end of a shaft employed in stabbing, throwing, or shooting to penetrate animal hides and flesh and kill the animal. Projectile points are bifacial tools given their final form by means of fine secondary retouch, usually with basal modification in the form of notching, stemming, or thinning of the proximal end for purposes of hafting. Dart points, arrow points, and indeterminate dart/arrow points are all classes of projectile points. Dart points are those employed to tip hand-held darts or spears, arrow points are used to tip arrows, and indeterminate points are, as the name implies, of uncertain usage. Dart points are usually manufactured from bifacial preforms, arrow points are often manufactured on thin flakes.

Projectile points were assigned to recognized types whenever possible. In traditional archeological literature, projectile points are normally referred to by their typological designation, which are usually based on a set of morphological characteristics, shared in common by groups of similar points, which generally focus on the hafting modification. Point classifications were conducted by TRC's personnel in reference to established point typologies in use in Texas archeology (Suhm and Jelks 1962; Turner et al. 2011).

Scrapers

Scrapers are a specific type of unifacial tool that have at least one intentionally modified working edge. In a few instances, bifacial modification may be present, and in such instances the intentional retouch tends to be on the dorsal flake surface. The ventral surface tends to exhibit primarily use-related flake scars. Based upon the location of the primary working edge, scrapers are subdivided into end, side, or combination types. End scrapers are pieces with retouch, restricted primarily to either the distal or proximal end of the flake blank, generally producing a convex working edge. The opposing end of the piece may bear minimal retouch, presumably to facilitate hafting. Side scrapers are pieces with retouch present on one or both lateral edges of the flake blank. Working edges may be convex, straight, or concave. On combination scrapers, marginal retouch may appear along the end as well as along one or more lateral edges of the blank. As implied by the name of this tool, the primary function of scrapers is presumed to relate to scraping relatively soft materials such as animal hides or vegetable matter, or slightly harder materials, such as wood or possibly antler or bone.

Unifaces

Unifaces are those tools that exhibit flake scars on one face only. Like bifaces, unifaces are defined based on morphological characteristics, and tend to have functional associations (e.g., scraping, planing, cutting, engraving). Unifacial tools exhibit purposeful flaking across most or all of one face. The opposite face most often remains flat and unmodified. Unifaces may be fashioned from cobbles or flakes and include such functionally diverse groups as scrapers, gouges, edge-modified flakes, gravers, and spokeshaves. One or more edges of a unifacial tool may exhibit manufacture and/or use-related flake removals that may be patterned or random. To a degree, unifacial tools form a continuum ranging from formal tools exhibiting intentional, patterned, and manufacture-related edge flaking to informal, expedient tools that exhibit only use-related edge scarring. The former tend to fall within the scraper and gouge categories, whereas the latter are generally classified as edge-modified flakes.

Edge-Modified Flakes

Edge-modified flakes are minimally modified flakes, flake fragments, or pieces of angular debris that are characterized by one or more areas of flake scarring along margins. The edge flaking may be patterned or unpatterned, continuous or discontinuous, and may result from use-related activities or from intentional pressure retouching to prepare an edge for use. Many edge-modified flake tools exhibit combinations of these characteristics, and many have more than one working edge. The modifications, however, usually are restricted to the edges and do not significantly alter the original flake form. Such edge modifications may be either unifacial or bifacial. Edge-modified flakes are usually considered ‘expedient’ tools, pieces of raw or minimally modified material that are utilized for a short time, and subsequently discarded soon after use.

5.2.1.2 Lithic Debitage Analysis

Lithic debitage is unmodified debris created as a result of stone tool manufacture and maintenance activities. During the analysis process, each piece was visually inspected to identified tool fragments or informal tools. Pieces that exhibit any sign of use-wear or intentional modification were assigned to the appropriate tool category. All debitage from TUs 1 through 10 were counted.

A selected sample of lithic debitage was analyzed according to TxDOT Lithic Protocol Version 2.1 (protocol, TxDOT ENV 2010) to extract information and general character of this middle Holocene assemblage. Test Units 5, 5-extension, and 6 with 193 pieces of lithic debitage or eight percent of the total debitage, were targeted for analysis as these three units contained age controlled Features 1 and 2. The other 92 percent was widely distributed across multiple scattered units and lacked age control and association.

The protocol includes; technology, core group, flake group, flake type, platform type, size grade, completeness, cortex percentage, thermal alteration, lithology, total count, and weight. In addition, extent of thermal alteration, cortex texture, and ultraviolet (UV) florescence color were added to the analyses.

The lithic debitage was first size graded as specified by screen manufacturer Gilson Company, Inc. into 6.3, 12.5, 19.0, and 26.5 mm size groups. Each specimen was then sorted into platform bearing and nonplatform bearing groups. Nonplatform bearing specimens were treated as shatter and weighed in bulk by provenience (specific to Level and TU). Platform–bearing specimens were examined individually and sorted into one of four classes: flat, multifaceted, crushed, and cortical. Other attributes documented include the presence/absence of heat alteration, cortex percentage (i.e., none, 1 to 25 percent, 26 to 50 percent, 51 to 75 percent, and 75 to 100 percent) and raw material type. Specimens were then weighed and findings entered into a database spreadsheet. Those that lacked a platform were grouped together on a single line, counted and weighed.

The thermal alteration provided comments on the type of heating, either slow heating in a carefully designed feature to improve knapping qualities of the stone or intentional discarding pieces into fires as a discard process. The latter pieces are characterized by potlidding and crazing. The former generally exhibit redding and a higher luster.

The type of cortex was observed to indicate the material source or origin. If the cortex is worn smooth, it indicates the piece was water worn and probably originated from stream or creek gravels. If the cortex was rough and textured the assumed originated was from a bedrock source.

The UV florescence color observations provide a quick means to determine if the piece originated from the Edwards Plateau. Edwards chert generally fluoresces yellow to light orange. Non-Edwards chert reflects a dark color. This allows assessment of use of local or nonlocal material use.

The protocol requires that all debitage with platforms be analyzed extensively with every category. However, flakes without platforms are considered shatter. Shatter is grouped together by material type within size grades, counted, and then weighted together. Each analytical line is given a specimen number within the provenience number and curated to retain analytical integrity.

Core Reduction Flakes

This category includes flakes, flake fragments, and pieces of angular debris associated with initial core preparation activities, such as test flakes that were removed to determine the quality of raw material within a cobble as well as to decorticate a cobble for further reduction. Items in this category tend to have cortex covering greater than 50 percent of their dorsal surfaces. By definition, most of these items tend to be relatively large (smaller flakes with dorsal cortex often fall within other categories, such as early and late stage biface flakes or indeterminate flakes, depending on their diagnostic characteristics). Core preparation flakes may or may not exhibit pronounced platforms, bulbs of percussion, or ventral concussion rings, though most do have one or more of these characteristics.

Biface Thinning Flakes/Flakes with Complex Platforms

Biface manufacture flakes were classified primarily based on the presence of complex striking platforms, multidirectional dorsal flake scars, parallel to slightly expanding flake margins, and slight to moderate longitudinal curvatures. This category was subdivided into early and late stage biface manufacture flakes. Early stage biface flakes tend to be slightly larger than late stage biface flakes, have fewer and larger dorsal flake scars, and may retain a considerable amount of cortex on their dorsal surfaces. As employed in this analysis, early stage biface flakes correlate roughly with Callahan's (cf. 1979) revised Stage 1, 2, and 3 bifaces ("blank," "rough out," and "primary preform" stages). Late stage biface flakes correlate with Callahan's revised Stage 4 and 5 bifaces ("secondary preform" and "final preform" stages). In practice, Stage 1 ("blank") flakes more than likely to fall in the core preparation flake category due to the lack of clear diagnostic characteristics on many such specimens. Final percussion thinning, pressure thinning, and retouch flakes that do not clearly exhibit biface manufacture characteristics due to their small size would probably be included in the tertiary thinning/retouch flakes category. The early and late stage biface flake categories may contain complete flakes, proximal and distal flake fragments, and/or small pieces of angular debris that exhibit clear characteristics of the biface manufacturing process (in practice, the latter type of debitage—angular debris bearing bifacial traits—is rare in the biface manufacture flake categories).

Tertiary Thinning/Retouch Flakes

This category includes flakes and proximal and dorsal flake fragments resulting from the final stages of tool manufacture, including final percussion thinning and any subsequent pressure retouch. By definition, flakes in this category tend to be quite small, and it is difficult to distinguish whether they result from biface manufacture, uniface manufacture, or resharpening.

Angular Debris

Angular debris, or "shatter," includes angular pieces of lithic raw material that break away from the core as flakes are struck. In contrast to flakes, angular debris does not generally retain any diagnostic characteristics of the flint knapping process (i.e., platforms, bulbs of percussion, concussion rings, and definable dorsal or ventral surfaces). In this analysis, those few pieces of angular debris that exhibit characteristics diagnostic of biface manufacture were included in the appropriate biface manufacturing category (i.e., early versus late stage biface flakes).

Indeterminate Flakes

This category includes flakes and flake fragments that lack diagnostic traits that would permit their placement into one of the other categories. Generally, these flakes are small fragments of flakes and/or thin pieces of angular debris that do not display clear evidence of a platform, concussion rings, or flake scar patterning on their dorsal surfaces. This category also includes a small number of potlid flakes and fractured heat spalls resulting from thermal alteration of raw materials.

Cores

A core is a cobble, pebble, or other mass of lithic raw material with one or more platforms and flake scars resulting from the systematic removal of flakes by flint knappers (Parry and Kelly 1987). Technically, any chipped stone tool may properly be classified as a core as it is the object created through the removal of flakes from the exterior surface of the original mass of lithic material. In common terms, however, cores are generally considered to be those masses of material from which one or more flakes were removed. In other words, cores do not exhibit any intentional or use-related flake scarring along any of their edges, though scars resulting from platform preparation may be evident, and a core might be expediently employed as a tool (e.g., extensive crushing damage along one or more thick edges of a core would probably result in classification of the object as a chopper).

Various types of cores are recognized according to the degree of knapping and the flake removal strategy. Four basic types of cores are unifacial, bifacial, multidirectional, and blade core. The last named type often has a distinctive conical polyhedral shape, the result of the repeated, parallel removal of long, narrow flakes known as prismatic blades.

A unifacial core has flake scars removed from only one face. The flake removals may be in various directions and exhibit no pattern or structure to the removals. There are usually only one or two platforms.

A bifacial core exhibits flake removals from both faces and again these may be in multiple directions. The parent or objective rock is generally a cobble with two detectable faces. The flakes were driven from the lateral edges; thus, the platforms are along the edges.

The multidirectional core is generally a chunk of raw material that does not necessarily exhibit two obvious faces. Generally, several platforms from which flakes were removed are present. Most often, the flakes are removed in different directions.

Blade cores are chunks of raw material intentionally prepared to facilitate the removal of a specific kind of desired flake. These generally exhibit two or more parallel scars driven from the same platform in the same direction with the same overall shape.

5.2.1.3 Ground Stone Tools

This broad artifact class includes pieces of natural rock that have been modified by grinding, pecking, or battering, either to intentionally shape an implement or as a byproduct of use. Ground stone tools are recognized by the presence of intentional abrasions, grooves, and striations and/or smoothing. Significant rounding, flattening, and/or pitting of utilized surfaces can also be identified. Categories of ground stone tools can include hammer stones, manos, metates (milling stones or grinding slabs), abraders or shaft smoothers, and edge-ground cobbles.

The edges and surfaces of each potential ground stone tool were macroscopically examined for signs of use as a tool. If battered, smoothed, unnaturally flattened, pitted, ground, striated, incised, or pecked areas were identified, then the artifact was assigned to a morphological and/or functional category based on general form and inferred function. Sets of observations were recorded for the tool classes recovered. The following subsection provides a definition of major tool class identified.

Manos and Metates

Manos and metates are generally employed together to grind friable materials (nuts, seeds, other vegetal matter, and occasionally pigments) into powder. A mano is a hand-held grinding stone, generally characterized by a round to ovate shape, usually of hard, dense siliceous rock such as quartzite, dolomite, or sandstone. One or more surfaces exhibit a smooth or polished, and/or possibly flattened area caused by grinding action against another hard surface (the metate). In a few instances, the edges exhibit crushed or pitted areas to indicate possible use as hammer stones as well. Occasionally one or both faces may be pitted, which results from the user trying to rough up the smooth surface to facilitate the grinding. Generally, these are water worn cobbles that exhibit no other alterations to the natural cobble.

A metate is often a large slab of a dense siliceous rock such as sandstone, limestone, or dolomite, which served as the base on which the mano is employed to grind materials. The grinding action most often wears the natural surface and creates a shallow concave face that is smoothed and/or polished. Extensive and continued use creates a deeper concave basin and in most instances, both faces potentially served as a base for grinding. Occasionally, the edges of metates are artificially shaped, usually by direct percussion that removed flakes along the margins. Metric and nonmetric observations were recorded for manos and metates. Measurements of dimensions were recorded only when the dimension in question was completely represented and/or could be reasonably estimated.

5.2.1.4 Mussel Shell Analysis

Recovered mussel shells were compared to TRCs extensive modern and prehistoric comparative collection assembled, identified and individually labeled. Original identifications were performed by Dr. R. G. Howells. To confirm identification, each specimen was compared to other modern pictures. Habitat data were obtained from literature sources (e.g., Howells et al. 1996).

5.2.2 Flotation Procedures

Bulk sediment samples of roughly 35 liters were collected from Features 1, 2, and 3. Initially in 2007, about 4.5 liters from Feature 1 and nearly 15 liters from Feature 2 were sent to Dr. Phil Dering for his processing and identification. Subsequently, in 2013 another 2.6 liters from Feature 1, 10.4 liters from Feature 2, and 2.45 liters from Feature 3 were mechanically floated by TRC archeologist. The latter flotation was conducted at the TRC south Austin facilities using the Dousman flotation system (Figure 5-9). Prior to floating, the dry sediment was first measured for volume, provenience information was recorded, and then samples gradually poured into the churning water.

Figure 5-9. Dousman flotation system employed to float sediment samples (light fraction in tray).

After about 20 to 30 minutes of water agitation, depending on sediment conditions, the light and heavy fractions were collected separately, set out to dry, then after they are dry, bagged and tagged.

Back in the Austin laboratory, each heavy fraction was spread across a clean white paper and the remains sorted into general artifact classes such as flakes, shells, burned rock fragments, charcoal, bone, etc. The sorting was facilitated with the aid of magnification. The frequencies and weights of different classes were recorded on a form and results incorporated into appropriate the feature discussions. The recovered materials were bagged by class and provenience tags were placed with each class. In the laboratory, light fractions were scanned under magnification searching for charred seeds, charcoal, and other possible identifiable cultural materials. No charcoal chunks or charred materials were observed. The light fractions obtained from Features 1 and 2 were analyzed by archeobotanist Dr. Phil Dering.

5.2.3 Analytical Techniques

Multiple classes of artifacts and suits of artifacts were selected and outsourced for specific analytical techniques that included; radiocarbon dating, starch grain analysis, phytolith analysis, diatom analysis, lipid residue analysis, instrumental neutron activation analysis, and macrobotanical analysis. These diverse techniques were performed to obtain greater insights into, and understanding of, the ages of the deposits and associated cultural materials and provide indications as to the foods potentially employed in these occupations, and other aspects of the previous occupants.

Each technical analyses performed is discussed below to provide the reader a general understanding of what was conducted. Separate technical reports are presented in the Appendices A through J and provide details concerning methods and procedures, analytical results, and interpretations. Those results are incorporated into the body of this report.

5.2.3.1 Radiocarbon Dating Analysis

Charcoal, the preferred material for radiocarbon dating, was sparse at best. Other organic substances such as snail shells, bones, and seeds were also rare. Consequently, sediment samples were dated to obtain an indication of the radiocarbon age of the deposits represented. Often the charcoal and sediment samples were paired from the same provenience to compare results. Direct dating soil humates have been conducted at many archeological sites with mixed results (see Frederick 2011 for recent problems with dating humates). Consequently, one must view the humate dates as general ballpark dates rather than a narrowly definable point in time. TRC archeologists selected 31 samples; 19 wood charcoal samples, 8 humate samples, 3 ashy sediment samples, and 1 bone for direct radiocarbon dating and requested approval from TxDOT geoarcheologist Dr. James Abbott. After approved, TxDOT submitted all 31 samples to the laboratory for dating. The initial 20 samples were sent to the University of Georgia (UGA), Center for Applied Isotope Studies (CAIS) in Athens for dating by the AMS technique. The subsequent 11 samples were submitted to Beta Analytical Inc., (Beta) in Miami for AMS dating.

Beta dates are reported as radiocarbon years before present (B.P.), with “present” being A.D. 1950 using the Libby ^{14}C half-life of 5,568 ± 30 years. Each sample was measured for Carbon-13 verses Carbon-12 ratios ($^{13}C/^{12}C$) expressed as the delta 13 carbon ($\delta^{13}C$) and calculated relative to the internationally standard Cretaceous Belemnite Formation at Peedee, South Carolina (PDB or VPDB). Beta’s individual laboratory reports with specific details concerning each sample are presented in Appendix A. Individual sample results are also presented and discussed throughout the body of this report.

The CAIS laboratory operates a 500 kilovolt compact AMS unit for precise analyses of carbon isotopes Carbon (C)-12, C-13, and C-14 at extremely low (parts per quadrillion) concentration levels. The National Electrostatics Corporation Model 1 5SDH-1 Pelletron AMS provides the means to directly count the number of C-14 atoms in a sample, so even extremely small (microgram size) samples can be used for quantitative determinations of very low-level isotopic concentrations. Precision of C-14 measurements is better than 0.3 percent. The sensitivity of the instrument is comparable to much larger units, with theoretical detection limits as low as 4 attomoles (4 x 10-18 moles) of C-14. Geological graphite $^{14}C/^{12}C$ ratios average 7.5 x 10-16.

The charcoal samples were pretreated by CAIS with acid, alkali and acid, the shells were treated with mild acid, and the collagen was extracted from the bone sample prior to processing for AMS dating. The derived dates are reported as radiocarbon years before present (B.P.), with "present" being A.D. 1950 using the international convention Libby ^{14}C half-life of 5,568 ± 30 years. Each sample was measured for C-13 verses C-12 ratios ($^{13}C/^{12}C$) expressed as the delta 13 carbon ($\delta^{13}C$) and calculated relative to the internationally standard Cretaceous Belemnite Formation at Peedee, South Carolina (PDB or VPDB). The CAIS individual laboratory reports concerning each sample are presented in Appendix A. Individual sample results are also presented and discussed throughout the body of this report. Two submitted samples (41MS69-32-7-1a and 41MS69-112-7a) were lost when quartz tubes with each sample cracked during combustion process. Two other samples (41MS69-106-7 and 41MS69-109-7) provided insufficient material after standard acid-base-acid treatment to remove contaminants.

5.2.3.2 Diatom Analysis

As an introduction, diatoms are single-celled algae with a siliceous cell wall. They grow in a wide range of aerophilous habitats, including damp soils, wet plants and rocks, marshes, wetlands and mudlands, as well as in all types of aquatic habitats. Their silica cells are often preserved in sedimentary deposits. Because individual taxa have specific requirements and preferences with respect to water chemistry, hydrologic conditions, and substrate characteristics, the presence of diatoms in natural and/or archeological contexts can provide information about the nature of the local environments, such as water quality and paleoenvironments. Water orientated diatoms, when present, indicate the use of water and provide a proxy measure of water quality, degree of pollution, and ultimately certain aspects of the paleoenvironment. In addition to the latter information we are exploring the use of water with cultural features to better understand the functions of specific features.

In 2007, ten samples were selected for analysis, four sediment and six burned rocks, and sent to Dr. Barbara Winsborough of Winsborough Consulting in Austin, for diatom analysis. The four sediment samples were from Features 1 and 2 and two from just above and below the features. The six burned rocks were from Features 1 and 2. Dr. Winsborough's detailed processing methods, individual sample results, and interpretations concerning the past environmental conditions and use of water with burned rocks, are presented in Appendix B.

5.2.3.3 Instrumental Neutron Activation Analysis (INAA)

During the 2004 fieldwork natural chert samples from gravel deposits along the adjacent Llano River were collected as were small chert samples from the Gorman Formation exposed in road cuts just west of the project. These were to potentially use for neutron activation analysis along with cultural artifacts from 41MS69. In 2007, a total of 60 chert samples were submitted to the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR) in Columbia under the direction of Dr. Michael Glascock. The elemental composition of these samples was to inform as to the different sources from which these samples came or establish an elemental characterization of formation cherts. The data also allows researchers to address the possible direction from which occupants came or had trading connections.

The INA samples focused on 39 cultural artifacts associated with Features 1 and 2 (TRC 319-357) and a few other individual tools from 41MS69, plus a selection of 10 natural samples of chert we randomly collected from the Gorman Formation (TRC 369-378) just to the northwest of 41MS69, one natural sample from the Marble Falls Formation (TRC 368), and ten natural chert samples randomly collected from the gravel deposits (probably representing Edwards chert) along the margins of the Llano River at 41MS69 (TRC 358-367). The details concerning sample preparation, irradiation, elements detected, results, interpretations and comparisons with Edwards cherts already in the MURR system are presented in Appendix C. MURR analysis compares the 39 cultural samples from 41MS69 with the 21 local source samples to those 100s of Edwards chert samples already in their database from Texas.

5.2.3.4 Pollen Analysis

In 2007 the presence/absence of pollen was sought to determine the value of pursuing this analytical technique. Six sediment samples from 41MS69 were selected and analyzed for presence/absence of pollen. These include samples from geologic zones 8 (#107), 9 (#108), and 11 (#109), and different depths in Features 1 (#505 and #507) and 2 (#511). Samples were sent to Dr. Steven Bozarth at the University of Kansas for analysis. His procedures, findings and recommendations are presented in Appendix D.

5.2.3.5 Starch Grain Analysis

Starch grain analysis is becoming more widely employed in Texas archeology to identify plant resources employed by the inhabitants (see Quigg 2011; Perry and Quigg 2011; Quigg et al. 2010, 2011a, 2012, 2013a, 2013b). A brief introduction is provided here as background to this discipline for those unfamiliar with this technique.

Starch grains are microscopic granules that serve as the principal food storage mechanism of plants (Figure 5-10). These grains are in most plants that include roots and tubers (e.g., crow poison, rain lilies, false garlic, wine cup, and spring beauty), and in the seeds of legumes and grasses, where they are often produced in abundant numbers (Perry personal communication 2008). Starch grains from different plants possess a large variety of species-specific forms that have been previously recognized.

Distinctive features of starch grains are genetically controlled and when carefully observed, can reflect specific plant taxa. At least 300 species and varieties of important economic plants from around the world have been described and can be preserved in archeological contexts (Piperno and Holst 1998; Piperno et al. 2000). Researchers around the world (particularly in the neotropics and in Australia) have been using these techniques with excellent results (Perry personal communication 2007). Starch grain remains have significantly increased the knowledge of plant domestication and crop-plant dispersal in various regions (Perry et al. 2006:76-77). Researchers have employed starch grain analyses to study diet, plant processing, plant domestication and cultivation, tool use, and uses of ceramic vessels. Starch grains have been extracted from soil samples, ceramics, and chipped and ground stone tools to address questions of resource procurement and preparation of foods. Intact starch grains have been extracted from formal and informal chipped stone tools, both washed and unwashed (Perry personal communication 2007). Heat alone does not destroy starches, as they are in ceramic cooking vessels and in burned rocks (Quigg et al. 2010; Perry and Quigg 2011).

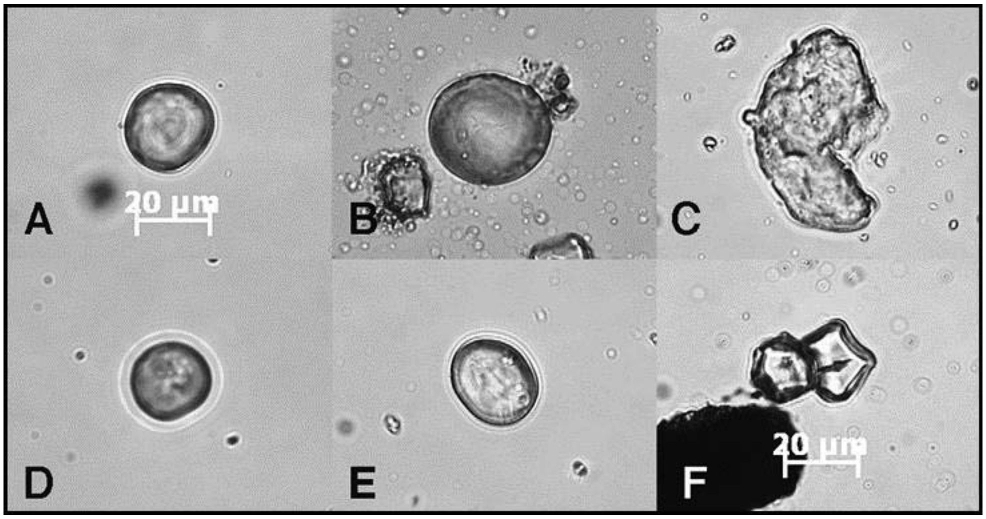


Figure 5-10. Examples of starch grains of wildrye grass recovered from burned rocks at a Texas archeological site (photograph by L. Perry).

In 2007, ten samples, nine burned rocks and one mano, were sent to Dr. Linda Perry of the Archaeobiology Program at the Smithsonian National Museum of Natural History in Washington for presence/absence of microfossils. She discovered all ten samples yielded microfossils and included nine with starch, nine with unidentified plant parts, and eight with phytoliths. She stated very well-preserved, identifiable starch residues were extracted from five burned rocks, phytoliths were also well-preserved, and the fibrous plant materials was probably identifiable (Perry personal communication August 28, 2007).

Form these very positive findings, a suite of 15 burned rocks and five sediment samples were selected from Features 1 and 2 for analysis and sent to Dr. Perry, Executive Director of The Foundation for Archeobotanical Research in Microfossils in Virginia, in 2013. The selection process targeted the two most important features (Features 1 and 2) to investigate possible foods involved in these ca. 4,800 to 5,500 year old cooking features. It is notable most burned rocks were relatively large limestone cobbles, with submitted sample sizes varying from 49 to 364 g. The five sediment samples, 10 to 30 g per sample, were analyzed from Features 1 and 2 plus two other samples were employed for control from above and below the features. Dr. Perry's methods, results, and interpretations are presented in Appendix I. Individual sample results are also presented and discussed in the body of this report.

5.2.3.6 Macrobotanical Analysis

Initially, 17 individual charcoal samples were sent to Dr. Dering of Shumla Archeobotanical Services in Comstock in 2004 for identification following the fieldwork. Then in 2007, about 19.5 liters of sediment from Features 1 and 2 were sent to Dr. Dering for processing and identification of the recovered remains. In 2013, two additional individual charcoal samples and two light fractions from Feature 2 were submitted to Dr. Dering. All his procedures and identifications of individual samples and the results from the light fractions are presented in Appendix F.

5.2.3.7 Use-Wear Analysis

Formal chipped stone tools are generally categorized by overall form, with an assumed function, such as projectiles for tipping arrows or dart shafts and scrapers for scraping hides, etc. This generalized classification strategy was employed throughout this report. However, to gain greater insights into the actual tool function of certain tool classes, a suite of 17 chipped stone tools from 41MS69 was selected and sent for high-powered microscopic use-wear and microfossil analysis. Most tools selected were originally washed, although a few remained unwashed. Each artifact was archivally labeled in ink with the site and provenience number in a small area and then the label was coated with B-72 to preserve it. These artifacts were submitted to Dr. Bruce Hardy at Kenyon College in Gamber, Ohio.

The 17 artifacts selected include 10 edge-modified flakes, 4 bifaces, and 3 projectile points, which includes 1 Bell/Andice point (#33-10). Edge-modified flakes were intensively sampled as they presumably served in multiple ways (e.g., cutting, scraping, engraving, whittling, etc.) on multiple materials (e.g., skins, wood, bone), thus providing an opportunity to document a broad range of activities performed. Dr. Hardy's analytical methods, individual observations, illustrations, and results are presented in Appendix G. Use-wear results are also incorporated into appropriate sections within the body of this report.

5.2.3.8 Lipid Residue Analysis

Previous research in Texas since about 2000 (Malainey 2000; Quigg and Cordova 2000; Quigg et al. 2000, 2001) and in other regions using this chemical approach has successfully demonstrated organic residues are present and can be extracted and generally interpreted from burned rocks employed by prehistoric peoples to process foodstuffs (cf. Malainey 2003; Malainey and Malisza 2004, 2008, 2011). Interpretations generally provide only a general indication of what is chemically represented (i.e., plants, animals, or plant and animal products) rather than precise species or taxa. This proxy line of investigation is critical when environmental conditions lack preservation of primary organic data, such as macrobotanical and faunal remains. If the analyzed rocks are from specific features it allows researchers to interpret what types of food were cooked in specific features. The fatty acid analysis provides chemical results to help identify the types of general food groups or types of resources cooked by burned rocks.

This general technique has been performed for over 15 years. However, since 2010 this technique has been enhanced and upgraded to permit <u>specific</u> identifications for the presence of plant and animal residues. Before about 2010, results often provided ambiguous interpretations on some samples and did not reflect specifically plant or animal products present. However, over the last few years the techniques employed in lipid analysis have improved significantly with new analytical procedures. These new procedures have greatly reduced the level of interpretive ambiguity. Improvements include the use of high temperature (HT) gas chromatography (GC) to enable identification of specific biomarkers, which permit precise identification of plant verse animal residues with much greater levels of confidence (e.g., biomarker cholesterol is indicative of animal residue; biomarkers sitosterol, stigmasterol and campersterol are indicative of plants, and dedydroabietic acid indicates conifer residues). Improvements in interpretive results are indicated by greatly reduced percentages of ambiguous sample interpretations. Those samples previously interpreted or had ambiguous results as plants <u>or</u> animals, are presently identified specifically to either plant, animal, or plants <u>and</u> animals, (the last indicative of multifunctional use of thermal features, rather than ambiguity as to whether plants <u>or</u> animals were cooked). This has significantly enhanced what was cooked with the rocks. More recent investigations from multiple sites at Landis (Malainey and Figol 2010) yielded only four percent ambiguous results. The Root-Be-Gone site (41YN452, Malainey and Figol 2011) and prehistoric site 41MI96 yielded no ambiguous results (Malainey and Figol 2013). Listed in the chronological order of their completion, the results from these three projects document a significant improvement over the previous pre2010 work represented with the implementation of the HT-GC and the use of biomarkers.

In 2007, an initial 17 burned rock fragments were submitted to Dr. Malainey in Winnipeg, Manitoba, for analysis and processed. In 2013 another eight burned rocks, split equally between Features 1 and 2 were submitted. Dr. Malainey reanalyzed the initial 2004 17 samples in conjunction with newer samples to provide results derived from the newer processing techniques to all samples. Twenty-five burned rock fragments, most from Features 1 and 2 with a couple from elsewhere, were analyzed utilizing the new improved HT-GC with biomarkers. The individual pieces submitted for lipid residue analysis were broken from a parent rock and weighed from 28 to 191 g (Figure 5-11). The parent rock was retained and curated for future reference.

Dr. Malainey and Mr. Figol present the background to identification of fatty acids, detailed methods, results obtained on all individual burned rocks, and interpretations for all samples are in Appendix H. Their results have been incorporated into the appropriate sections within the body of the text.

5.2.3.9 Phytolith Analysis

Opal phytolith studies are important in reconstructing a general profile of grassland flora in plains setting with the added potentially to enable specific identification of the use of various domesticated such as maize (corn) have diagnostic phytoliths. Opal silicate bodies are produced in multiple shapes and sizes and comprise the phytoliths entities from within plant cells. The distinctiveness of various types of bodies varies according to cellulose structure. In grasses, phytoliths exhibit diversity and are distinct for grass species. The presence of certain short cell phytoliths (e.g., Panicoid, Festucoid, and Chloridoid) in the paleoenvironmental record provides a record of general vegetative communities, such as forested versus open grassland prairie, and the grasslands constituents. Nongrass monocots also produce numerous taxonomically valuable phytoliths. Water orientated plants such as bulrush (*Scripus pallidus*) and sedges (*Cyperus*) exhibit distinctive types. Phytoliths are also formed in woody and herbaceous dicotyledons. Diagnostic phytoliths are rarely formed in edible fruits and nuts. However, common beans (*Phaseolus vulgaris*), specific species in the sunflower family (Asteraceae), rinds of selected varieties of squash (*Cucurbita species*), and maize (*Zea maize*) all yield recognizable phytoliths (Bozarth and Woodburn 2010). Phytolith analysis was conducted to extract data for reconstructing the broad vegetation communities in at 41MS69 during the primary occupations. The identification of phytoliths will complement the starch grain and lipid residue analyses and potentially help elevate the lack of macrobotanical analysis.

Figure 5-11. Technical equipment empolyed in the lipid analysis (photograph provided by Dr. Malainey).

Following the eligibility assessment, a phytolith assessment on six sediment samples from 41MS69 was conducted in 2007 by Dr. Steven Bozarth from the University of Kansas Palynology Laboratory. His presence/absence results indicated phytoliths were adequately preserved in all six samples and C_3 and C_4 grass phytoliths, plus arboreal phytoliths, were present (Appendix E). In his professional opinion, the phytolith assemblages would provide interpretable paleoenvironmental and archeological

Table 5-1. Sediment Samples Selected for Phytolith Analysis.

Catalog No,	Column	Unit	Depth (cmbs)	Feature No.	Material
107-4-1b	1	Zone 8	224-228		sediment
109-4-1b	1	Zone 11	395-397		sediment
505-4-1b	1	5 Ext	151-154	1	sediment
507-4-1b	1	6	134	1	sediment
511-4-1b	1	5	177	2	sediment

data (Bozarth personal communication 2007). Given the positive assessment results and recommendations, TRC petitioned and was granted permission by TxDOT in 2013 to continue to pursue a limited phytolith analysis. In 2013, five sediment samples, three from Features 1 and 2, plus two control samples of different ages were selected and sent to Dr. Byron Sudbury in Oklahoma for complete phytolith analysis and interpretations (Table 5-1). Dr. Sudbury's extraction methods, phytolith counts, identifications, and interpretations are presented in Appendix J.

5.3 CURATION

Artifacts collected from this assessment were temporarily curated at the office of TRC in Austin from 2004 through 2015. Cultural artifacts from Test Units 1 through 4 were sent to TxDOT for determination of their final destination as their ownership was still in question. All stone tools, lithic debitage, burned rocks, and other cultural materials, from Test Units 5 through 11, plus all field records and photographs are to be permanently curated at Center for Archaeological Studies, Texas State University at San Marcos. Individual artifacts and artifact lots, including all stone tools, lithic debitage, and burned rocks are in clear, zip-locking four millimeter thick polyethylene bags according to provenience. Each polyethylene bag contains an archival-quality, acid free curation tag, which lists the site number, provenience data, date of excavation, excavator(s) name, artifact type, and quantity in pencil. Digital photographs were submitted on CDs and a contact sheet and placed in archival photo sleeves for curation. All original field records are on acid free paper and were placed in acid free reinforced file folders for curation.

6.0 GEOARCHEOLOGICAL RESULTS: HOLOCENE ALLUVIAL STRATIGRAPHY AT 41MS69

Charles D. Frederick

6.1 INTRODUCTION

This chapter describes the results of geoarcheological investigations at 41MS69. The fieldwork documents a series of alluvial deposits exposed by a road cut situated near the right (or south) bank of the Llano River and near the alluvial valley-bedrock upland interface. Initial construction of the road removed some Holocene and Pleistocene age alluvial deposits, and the present paved road is situated at the point where these deposits would have met the modern floodplain of the Llano River.

Today, nearly the entire valley floor is a channel bar that local informants stated was rejuvenated by a catastrophic flood in the 1930's, which ripped out an extensive nearly valley-wide floodplain pecan (*Carya* sp.) grove. This would have been the June 1935 flood that remains the largest flood on record at the Llano River gauging station near Mason, which had a recorded peak discharge of 380,000 cubic feet per second (United States Geological Survey, open file data) and for which Tinkler (2001) documents on the James River, which joins the Llano River just upstream from the gauge and downstream from 41MS69. This flood apparently resulted from a 20.3 to 45.7 cm (8 to 18 in.) rainfall in a 12 hour period in the Llano and James river catchments that fell onto saturated ground in early June (Tinkler 2001:243).

Because the road apparently affected the interface between the existing floodplain surface (T_0) and the Holocene terrace (T_1), the estimated heights of these surfaces should be considered very tentative. The floodplain fragment upon which the road is constructed, appears 2 to 3 m above the lowest parts of the adjacent channel, and places the T_1 surface, which the 41MS69 occupies, at around 8 to 9 m above the channel. Geomorphic work for this project only occurred at the site, which has a modified nature. These elevations should not be considered as representative of surfaces in this part of the Llano River valley.

The T_1 surface in this location, in reality, represents a narrow peninsula of alluvium separated from the nearby upland by the erosional channel of a small upland tributary that has incised at the contact between the late Pleistocene alluvium and the bedrock. This tributary channel forms the southern boundary of the APE depicted on Figure 4-1 where the ground surface dips to the level of the road. Just north of this pointed fragment of land, this peninsula is approximately 7 m wide, and broadens to about 25 m wide immediately south of Unit 2. The majority of this area lying on private land, the other side of the property fence that borders the highway.

6.2 METHODS

6.2.1 Stratigraphic Exposures and Descriptions

The stratigraphic setting of the APE was determined by examination of five manually-excavated vertical columns. These tall columns, roughly 30 cm wide were at intervals along the road cut on the west side of the road. They were excavated in stair-step benches and generally removed sediment without screening to view the stratigraphy. The profiles were then cleaned and described. Descriptions generally, but not always, followed guidelines established in Schoeneberger et al. (2002), and are provided on Table 6-1.

Table 6-1. Column Descriptions.

Column 1

Geologic Units:	Unit 3 resting on Unit 2 resting on Unit 1
Cultural material:	Multiple occupation surfaces in Unit 3
Comments:	* Zones 5 and 6 are very localized phenomena, being restricted to a series of prehistoric features; but they are technically anthropic A horizons.

Zone	Horizon	Depth (cmbs)	Depositional Unit	Description
1	O	0-2	--	Black (10YR 2/1, moist) partially decomposed leaf litter
2	A	2-26	Unit 3	Very dark grayish brown (10YR 3/2, moist) silt loam to loam, very friable, moderate medium to coarse subangular blocky structure, clear, smooth boundary
3	Bk	26-95	Unit 3	Brown-pale brown (10YR 5.5/3, moist) silt loam, very friable, moderate medium subangular blocky structure, gradual smooth boundary, few to many (3-25%) calcium carbonate filaments decreasing in frequency with depth, prehistoric occupations denoted by horizontal accumulations of burned rock, mussel shell and debitage at 50-55 cm and 90-95 cm and possibly at 25 cm as well
4	BC	95-132	Unit 3	Brown (10YR 5/3, moist) silt loam-loam, very friable, weak medium to coarse subangular blocky structure, abrupt smooth boundary, few (1-3%) calcium carbonate filaments, base of zone is defined as the top of two stacked prehistoric features (Features 1 and 2) although this zone clearly infiltrates into the interstitial spaces of Feature 1
5	Ab*	132-163	Cultural feature within Unit 3	Dark grayish brown (10YR 4/2, moist) silt loam, very friable, weak, medium subangular blocky structure, abrupt smooth boundary, this is a feature fill that surrounds Features 1 and 2; charcoal from Feature 1 was dated 4890 ± 40 B.P. (UGA-14116) and 5120 ± 40 B.P. (UGA-14110)
6	Ab2*	163-177	Cultural feature within Unit 3	Black (10YR 2/1, moist) silt, very friable, weak medium subangular blocky structure, abrupt, smooth boundary, this is a pit-like fill beneath Feature 2, and it was radiocarbon dated 4740 ± 40 B.P. (UGA-14107)
7	C	177-216	Unit 3	Brown to light brown (7.5YR 5/4-6/4, moist) silt loam, friable, weak to moderate, medium subangular blocky structure, abrupt smooth boundary, few (1-3%) calcium carbonate filaments, seems to have abundant reworked ash in places, a prehistoric occupation surface is present at 195-200 cm, denoted primarily by burned rock. A charcoal radiocarbon sample from this occupation was lost by the University of Georgia Lab

Table 6-1. Column Descriptions (continued).

Zone	Horizon	Depth (cmbs)	Depositional Unit	Description
8	2C	216-275	Unit 2	Brown (7.5YR 4/4, moist) slightly gravelly to gravelly clay loam, friable, weak to moderate subangular blocky structure, abrupt smooth boundary, 30-60% coarse fragments with greatest density in top 20 cm of zone. A bulk sediment sample from near the top of this zone yielded a radiocarbon date of 5250 ± 60 B.P. (UGA-14099)
9	2Bk	275-305	Unit 2	Brown (7.5YR 4/4, moist) slightly gravelly clay loam, firm, strong medium angular blocky structure parting to strong fine granular structure, abrupt smooth boundary, many (>50%) calcium carbonate filaments on dry ped faces (but not visible on moist peds). A bulk sediment sample from the middle of this zone yielded a radiocarbon date of 4640 ± 50 B.P. (UGA-14100) and is rejected as inaccurate
10	2C’	305-360	Unit 2	Brown (7.5YR 4/3, moist) extremely gravelly clay loam, friable to loose, single grained structure, abrupt, smooth boundary, ~60-80% coarse fragments, could be subdivided into multiple beds
11	2C	360-400	Unit 2	Brown (7.5YR 4/3, moist) silty clay loam, friable, moderate to strong coarse prismatic structure, abrupt smooth boundary, ~1% coarse fragments (< 2 cm diameter, widely dispersed), few (1%) calcium carbonate filaments. A bulk sediment sample from the base of this zone yielded a radiocarbon date of 8070 ± 60 B.P. (UGA-14101) and a piece of charcoal submitted for radiocarbon dating from the same depth was lost by the University of Georgia Lab
12	3C	400-420+	Unit 1	Brown (7.5YR 4/4, moist) silt loam to silty clay loam, friable, moderate medium subangular blocky structure, few (1%) calcium carbonate filaments

Table 6-1. Column Descriptions (continued).

Column 2

Geologic Units:	Unit 3 over Unit 2 over Unit 1
Cultural material:	Multiple prehistoric occupations stratified within Unit 3

Zone	Horizon	Depth (cmbs)	Depositional Unit	Description
1	O	0-4	--	Black (10YR 2/1, moist) partially decomposed leaf litter
2	A	4-36	Unit 3	Very dark grayish brown (10YR 3/2, moist) silt loam, very friable, weak to moderate fine subangular blocky structure, clear smooth boundary
3	Bk	36-130	Unit 3	Dark grayish brown (10YR 3/2, moist) silt loam, very friable, moderate medium subangular blocky structure, gradual smooth boundary, common to many (10-25%) calcium carbonate filaments, at least three prehistoric occupations are present in this zone, one at 48-52 cm, another at about 80-90 cm denoted by an ash filled basin hearth (Feature 3), and one at 120-125 cm. A piece of charcoal from the middle occupation yielded a radiocarbon age of 3500 ± 50 B.P. (UGA-14118). A piece of charcoal from the lowest occupation in this zone yielded an age of 3480 ± 40 B.P. (UGA-14114) and a bulk sediment sample from the same depth as this charcoal sample yielded an age of 2410 ± 40 B.P. (UGA-14102) and is rejected as an accurate age for the time of deposition
4	C	130-174	Unit 3	Brown (10YR 5/3, moist) silt loam, very friable, weak to moderate, medium to fine subangular blocky structure, clear smooth boundary. At least two prehistoric occupations are present in this zone, one at 130-134 cm and another at 146-150 cm
5	2C	174-216	Unit 2	Dark yellowish brown - yellowish brown (10YR 4.5/4, moist) very gravelly silt loam, very friable to loose, single grained structure, abrupt smooth boundary, 50-60% coarse fragments (subangular to subrounded limestone)
6	2C	216-257	Unit 2	Brown (7.5YR 5/4, moist) extremely gravelly sand, loose, single grained, abrupt smooth boundary, >80% coarse fragments (mostly 1-3 cm subangular to subrounded limestone gravel)
7	2Ck	257-270	Unit 2	Light yellowish brown (10YR 6/4, moist) silt loam, very friable, weak to moderate, medium subangular blocky structure, abrupt wavy boundary. This appears to be a carbonate-rich mud, possibly a marl

Table 6-1. Column Descriptions (continued).

Zone	Horizon	Depth (cmbs)	Depositional Unit	Description
8	2C	270-300	Unit 2	Brown (7.5YR 4/4, moist) very gravelly sandy loam, loose, single grained structure, abrupt smooth boundary, approximately 50% coarse fragments
9	3Ab	300-310	Unit 2	Dark brown-brown (7.5YR 3.5/4, moist) slightly gravelly silty clay loam, friable, moderate fine angular blocky structure parting to moderate fine granular structure, abrupt smooth boundary, approximately 10% coarse fragments. Weakly developed buried A horizon. A bulk sample for radiocarbon dating returned an age of 7480 ± 60 B.P. (UGA-14113)
10	3C	310-430	Unit 2	Reddish brown (5YR 5/4, moist) extremely gravelly sandy clay, firm, massive structure, abrupt smooth boundary. A piece of charcoal from the base of this zone yielded a radiocarbon age of 6300 ± 50 B.P. (UGA-14115) and a bulk sediment sample from the same depth yielded a radiocarbon age of 3190 ± 40 B.P. (UGA-14104). The latter age is rejected as unreliable
11	3C	430-455	Unit 2	Brown (7.5YR 4/4, moist) silty clay loam, friable, weak to moderate medium subangular blocky structure, clear smooth boundary
12	4Bk	455-500	Unit 1	Brown (7.5YR 5/4, moist) silt loam to silty clay loam, very friable, weak to moderate medium subangular blocky structure, few (1-3%) patches of diffuse calcium carbonate

Table 6-1. Column Descriptions (continued).

Column 3

Geologic Units:	Unit 3 over Unit 2, over Unit 1
Cultural material:	Several occupation surfaces stratified within Unit 3

Zone	Horizon	Depth (cmbs)	Stratigraphic Unit	Description
1	O	0-4	--	Black (10YR 2/1, moist) partially decomposed leaf litter
2	A	4-30	Unit 3	Black (10YR 2/1, moist) sandy loam-loam, very friable, weak to moderate fine subangular blocky structure, clear smooth boundary. One prehistoric occupation surface around 15-20 cm in-depth
3	Bk	30-150	Unit 3	Brown (10YR 5/4, moist) loam-silt loam, very friable, moderate to strong coarse prismatic structure parting to strong medium angular blocky structure, abrupt smooth boundary, few (1-3%) calcium carbonate filaments inside peds, many (20-50% on ped faces forming prominent but discontinuous coats. At least two prehistoric occupation surfaces, one at 55-60 cm depth and a second at 95-105 cm
4	2C	150-186	Unit 2	Brown (7.5YR 4/4, moist) extremely gravelly clay loam, very friable, single grained structure, abrupt smooth boundary, inversely graded with numerous large clasts (>30 cm diameter) at the top of the zone
5	3Bk1	186-195	Unit 1	Brown (7.5YR 4/4, moist) slightly gravelly loam, friable, weak fine subangular blocky structure, abrupt smooth boundary, common (5-10%) vertically oriented patches of diffuse carbonate
6	3Bk2	195-220	Unit 1	Brown (7.5YR 4/4, moist) extremely gravelly clay loam, friable, single grained structure, abrupt smooth boundary, >75% coarse fragments, common (5-10%) vertically oriented patches of diffuse carbonate
7	3Bk3	220-300	Unit 1	Brown (7.5YR 4/4, moist 7.5YR 5/4, dry) loam (base) to silty clay loam (top), friable, weak coarse prismatic structure parting to strong medium subangular blocky structure, gradual smooth boundary, common to many (15-20%) vertically oriented patches of diffuse filamentous calcium carbonate (linear, vertical to subvertically oriented patches 2-8 cm wide, rarely indurated or nodular)
8	3Bk4	300-360+	Unit 1	Reddish yellow (7.5YR 7/6, moist; 7.5YR 8/4, dry) loam-silt loam, very friable, weak coarse subangular blocky structure, seems to have abundant diffuse calcium carbonate, few (1-3%)) weakly cemented nodules of calcium carbonate

Table 6-1. Column Descriptions (continued).

Column 4

Geologic Units:	Unit 3 over Unit 2 over Unit 1, but majority of exposure here is Unit 1
Cultural material:	Burned rock midden within unit 1

Zone	Horizon	Depth (cmbs)	Depositional Unit	Description
1	Ap	0-12	Unit 3	Black (10YR 2/1, moist) loam, friable, moderate coarse subangular blocky structure parting to strong medium to fine granular structure, abrupt irregular boundary, few burned rocks throughout (5-10% coarse fragments, all anthrogenic).
2	A	12-50	Cultural feature within Unit 3	Black (N 2/0 to 10YR 2/1, moist) sandy loam to loam, friable, weak to moderate, medium to coarse granular structure, abrupt smooth boundary. This is the burned rock midden.
3	Bk1	50-73	Unit 3	Brown (10YR 5/3, moist) silt loam, very friable, moderate medium to coarse subangular blocky structure, abrupt smooth boundary, many (20%) calcium carbonate filaments on ped faces.
4	Bk2	73-117	Unit 2	Brown (7.5YR 4/4, moist) slightly gravelly to gravelly silt loam, friable, massive structure, abrupt smooth boundary, common (10-15%) calcium carbonate filaments, 20-40% coarse fragments.
5	2Bk	117-153	Unit 2	Brown (7.5YR 5/4, moist) slightly gravelly silt loam, friable, moderate medium subangular blocky structure, abrupt smooth boundary, ~10% coarse fragments, many (20-40%) calcium carbonate filaments on ped faces.
6	3K	153-203	Unit 1	Pink (7.5YR 7/4, moist) silt loam, very friable, weak coarse subangular blocky structure, abundant diffuse calcium carbonate, few to common (3-5%) distinct hard coarse calcium carbonate nodules. A bulk sediment sample from the middle of this zone yielded an age of 2580 ± 40 B.P. (UGA-14105) and this date is rejected as an accurate estimate of the time of deposition. This is clearly a Pleistocene deposit and this sample is stratigraphically beneath all of the other dated material at the site.

Table 6-1. Column Descriptions (continued).

Column 5

Geologic Units:	Unit 1, beneath profile 4 - this is not a complete section
Cultural material:	None observed
Comments:	This section was cleaned in order to collect a radiocarbon sample from low in the Pleistocene age Unit 1.

Zone	Horizon	Depth (cmbs)	Stratigraphic Unit	Description
1	Bk1	300-420	Unit 1	Light brown-reddish yellow (7.5YR 6/5, moist; 10YR 7/4, dry), sandy loam, very friable, massive structure, gradual smooth boundary, abundant diffuse calcium carbonate, few (1-3%) coarse, hard, light yellowish brown (10YR 6/4) calcium carbonate nodules, numerous small snail shell fragments
2	Bk2	420-490+	Unit 1	Brown-strong brown (7.5YR 5/5, moist) sandy loam, very friable, massive structure, numerous small snail shell fragments (1-2 mm in diameter), few (1-3%) vertically oriented patches of dense filamentous calcium carbonate, few (1%) coarse (1-2 cm) hard calcium carbonate nodules, <1% coarse fragments. A bulk sediment sample collected from 4.7-4.75 m in this zone yielded an age of 9170 ± 70 B.P. (UGA-14106) but this date is rejected as an accurate date for the deposition of this unit

6.2.2 Dating

Samples for dating the sequence consisted of tiny charcoal in association with cultural features or scattered in the deposit with no clearly discernible cultural affiliation, or bulk sediment or soil samples. The results of the radiocarbon dating were problematic, with most bulk sediment samples yielding ages significantly younger than the paired charcoal samples at similar depths, which is opposite that what is normally encountered by dating bulk sediment organic matter in contexts similar to this. The most extreme example of this was a matched pair of charcoal and sediment samples collected from near the base of Unit 2. The charcoal yielded a corrected age of 6,330 B.P. and the bulk sediment dated to 3,190 B.P., an approximate 3,140 age error.

6.2.3 Stratigraphic Observations

Three different aged unconformities bounded alluvial stratigraphic units (or allostratigraphic units) are present in the road cut adjacent to the roadway at 41MS69. The core of the road cut is a Pleistocene age deposit that has been partially truncated by erosion from a tributary cutting across these deposits from roughly west to east toward the main channel of the Llano River. Two Holocene age alluvial fills drape this eroded surface, one dating to the early to middle Holocene, and another dating from the middle to late Holocene. These alluvial units are distinguishable on the basis of the soils formed in them, and the color of the deposits.

6.3 GEOARCHEOLOGY OF TEXT UNITS

6.3.1 Unit 1: Late Pleistocene >9,170 B.P.

This deposit forms the core of the road cut and is overlapped on the southern end by the two Holocene alluvial fills. It ranges in texture from a sandy loam at depth to a loam and silt loam, and exhibits a prominent calcic soil. The deposit is rubified, with a pink to light yellowish brown color prevailing when dry (7.5YR 7/4 to 7.5YR 6/5) in the core of the outcrop (at depth) and slightly darker colors present near the surface, primarily a brown (7.5YR 4/4). In every exposure examined, this deposit was draped by Unit 1, and a complete soil of late Pleistocene age was not observed in any vertical profile. It is possible one might be present at the extreme northern end 41MS69, but this was not examined in detail. The dominant soil horizon present in this deposit was a Bk horizon with abundant diffuse calcium carbonate, subvertically oriented powdery concentrations, within which there were found occasional hard, indurated calcium carbonate nodules up to 2 cm in diameter. The stratigraphic position and degree of pedogenic alteration of this deposit is consistent with Pleistocene age alluvial deposits dated elsewhere in Texas.

Two bulk sediment radiocarbon samples were collected from this unit: one near its interface with Unit 2 in Column 4 at a depth of about 178 cm, and a second within the core of the deposit in Column 5 at 475 cm depth. The upper sample yielded an age of 2580 ± 40 B.P. (UGA-14105) and the lower one dated 9170 ± 70 B.P. (UGA-14106). Neither is considered an accurate depositional age, rather, both are unexpectedly young, and inconsistent with the degree of soil development. Furthermore, both samples are stratigraphically below all of the cultural occupations that are confidently dated to greater than 5,140 B.P. on the basis of charcoal dates associated with cultural material in Unit 3. The 9,170 B.P. date obtained from 475 cm is considered a minimum age for the deposition of this deposit.

6.3.2 Early to Middle Holocene ca. 8,070 to 5,200 B.P.

Unconformably resting upon Unit 1 was a brown (7.5YR 4/4 to 7.5YR 5/4), but occasionally reddish brown (5YR 5/4) deposit that consisted of interbedded coarse deposits (gravelly and extremely gravelly sands, silt loam, and clay loam) (Figure 6-1) and relatively thin, fine deposits (primarily silt loam and silty clay loam). In Column 2 there was a weak buried soil formed in one of the finer textured deposits (an A- C profile) as well as what appeared to be a thin marl deposit. The top of this unit appeared to have been truncated by erosion prior to the deposition of Unit 3, and no complete soil was observed within the top of this deposit (Figure 6-2). Compared with the overlying Unit 3 or the underlying Unit 1, this is a relatively coarse textured unit, but this may be more a function of facies preserved in this location and probably is not representative of this deposit as a whole.

On the basis of its stratigraphic position and general appearance, this deposit was assumed in the field to be of early to middle Holocene age. Several samples were collected from this deposit for radiocarbon dating in order to bracket the period of its deposition. The interface with Unit 1 was dated in Column 1 and Column 2; and in both places we collected pairs of charcoal and bulk sediment. The bulk sediment from Column 1 yielded a radiocarbon age of 8070 ± 60 B.P. (UGA-14101). The paired piece of charcoal, which was submitted for radiocarbon dating from Column 1, was lost by the University of Georgia Laboratory.

In Column 2 the charcoal from the base of this zone yielded a radiocarbon age of 6330 ± 50 B.P. (UGA-14115). The bulk sediment sample from the same depth yielded a radiocarbon age of 3190 ± 40 B.P. (UGA-14104). The latter age is rejected as unreliable. Together, these samples indicate deposition of Unit 2 probably occurred as early as 8,070 B.P. and certainly it was underway by 6,330 B.P.

Samples from the middle of Unit 2 deposit yielded widely divergent radiocarbon ages. Stratigraphically above the 6,330 B.P. date in Column 2, a bulk soil sample from the weakly developed buried soil returned a radiocarbon age of 7480 ± 60 B.P. (UGA-14113). A bulk sediment sample from a fine-grained bed within the middle of Unit 2 in Column 1 yielded an age of 4640 ± 50 B.P. (UGA-14100) and is rejected as inaccurate given that this age is younger than the dated charcoal from cultural features in Unit 3 more than a meter higher in this section. It is hard to understand how two samples from roughly similar stratigraphic positions could yield such divergent dates.

Figure 6-1. Example of gravelly deposits in Unit 2.

Cessation of Unit 2 sedimentation can be estimated by comparing samples on either side of the Unit 1/Unit 2 interface. In Column 1, a bulk sediment sample from near the top of Unit 2 yielded a radiocarbon date of 5250 ± 60 B.P. (UGA-14099). The two oldest dated charcoal pieces from cultural contexts were 5100 ± 40 B.P. (UGA-14111) and 5240 ± 40 B.P. (Beta-370494) obtained

Figure 6-2. Example of upper limits of Unit 2 just below cultural Feature 2 on top.

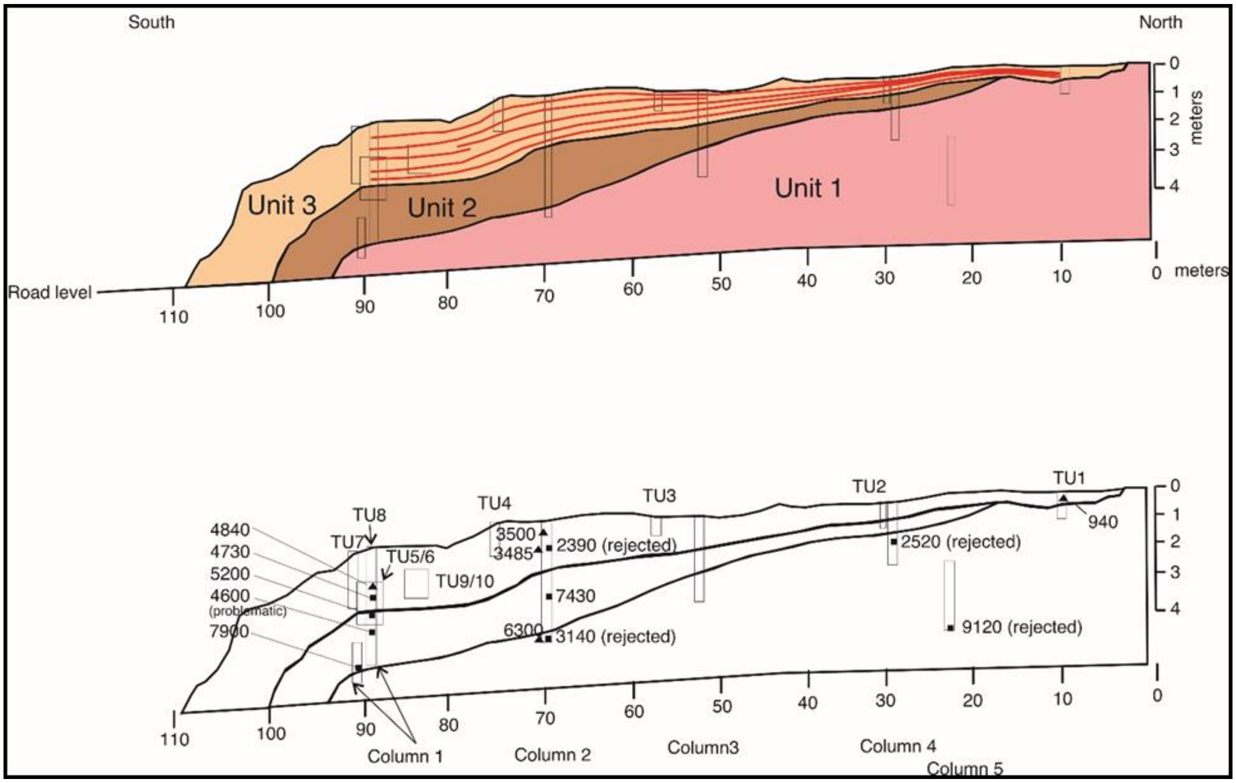
from the lowest cultural stratum in TU 6. A piece of charcoal from the lowest cultural surface in Column 1 was lost by the University of Georgia laboratory, but two radiocarbon dates from Features 1 and 2 (which were vertically superimposed 40 to 80 cm above the Unit 1/Unit 2 interface) yielded radiocarbon ages 4890 ± 40 B.P. (UGA-14116) and 5120 ± 40 B.P. (UGA-14110); and a sample of dark, charcoal rich feature fill sediment from Feature 2 yielded an age of 4740 ± 40 B.P. (UGA-14107). Hence, it appears that deposition of Unit 2 ceased around 5,240 B.P. and was followed almost immediately by deposition of Unit 3.

No cultural material was observed within Unit 2, but given its apparent age, it is theoretically possible to find Early Archaic and possibly Late Paleoindian occupations within this depositional unit.

6.3.3 Unit 3: Middle to Late Holocene 5400

The youngest stratigraphic unit identified at 41MS69 is designated Unit 3. Column 1 consists of more than 2 m of brown to pale brown (10YR 5/3, 10YR 5/4, and 10YR 5.5/3) silty loam within which a weak A-Bk-C soil has formed. The thickness of this unit decreased northward where it drapes most, if not the entire Unit 1 core of this landform (Figure 6-3). All cultural occupations observed at 41MS69 were situated within Unit 3. These occupation surfaces, of which there appeared to be at least five distinct ones, were compressed together at the northern end of the road cut, and expanded to the south where Unit 3 was the thickest. This general relationship is illustrated on Figure 6-3, which was compiled by correlating the radiocarbon dated occupation surfaces within each of the column profiles. Although the drawing of all five-occupation surfaces as correlates of the midden in the north end of the exposure is speculative, the compression of the different occupation surfaces was clearly evident in Columns 1 through 3.

The age of Unit 3 was determined by radiocarbon dates on charcoal and bulk sediment samples from a variety of stratigraphic locations. Deposition of Unit 3 appears to begin sometime around 5240 ± 40 B.P. and continued until at least 3480 ± 40 B.P. (UGA-14114) to 3500 ± 50 B.P. (UGA-14118). Another 120 cm of sediment accumulated after this date (Figure 6-4). If we assume that the occupation at a depth of about 100 cm is contemporaneous with the occupation at 80 cm in Column 2, which dates to 3,500 B.P., and it is assumed that the last meter of Unit 3 aggraded at approximately the same rate as the first meter, then the end of Unit 3 deposition would have occurred sometime around 1,600 B.P.



Dates are in uncorrected radiocarbon years B.P.
▲ = Triangles are charcoal samples
▬ = Bars are bulk sediment samples
– = Lines correlate occupation surfaces observed in the columns

Figure 6-3. Generalized alluvial stratigraphy and cultural strata 41MS69.

Figure 6-4. Example of alluvial sediments at the top of Unit 3 at TU 8.

6.4 STRATIGRAPHIC SUMMARY

The Holocene part of this sequence bears chronological similarities to stratigraphic sequences on the Colorado River (Blum and Valastro 1992) and at Fort Hood by Nordt (1992). However, caution should be used in comparing these results to more complete stratigraphic sequences because this sequence represents one exposure and Holocene deposits are both lapping onto an older surface rather than present at their maximum thickness. The latter point is important because the earliest phase of sedimentation may not be adequately represented. This is probably the case for Unit 2, which is represented in this sequence by channel related facies (either channel bars or near channel overbank facies) which would have required the channel to be several meters higher than today. If the phase of incision inferred between Unit 1 and Unit 2 removed sediment from the valley floor to bedrock, then it is probable that it required some time before the channel was able to flood this high, and if the case, the earliest phase of Unit 2 aggradation is not represented here. The Unit 3 deposits appear to be entirely overbank facies and therefore are less problematic in this regard because they merely require flooding to this level, not the elevation of channel related processes to this level.

A younger alluvial unit should be present in this sequence, but it was not observed in any of the column profiles and therefore not described. This deposit presumably is preserved beneath the existing highway. It may also be present immediately adjacent to the channel of the small tributary at the southern end of the site.

6.5 COMMENT ON THE CONTEXTUAL INTEGRITY OF THE DEPOSITS

In general terms, this site beautifully exemplifies how dynamically aggrading alluvial environments may yield highly interpretable archeological occupations. Based on the scatters of burned rock and debitage observed when describing the column profiles, Unit 3 contains at least five discrete occupations and probably more given that the test units appeared to encounter several occupations high in the profile (some in the A horizon) that had lesser archeological visibility (only scatters of debitage and little burned rock) than those correlated in Figure 6-3. These occupations span the period between roughly 5,400 B.P. and estimated to be around 940 B.P. Indeed, TU 8, positioned behind and 1 m west of Column 1 recorded approximately nine discrete cultural events. Those occupations are separated by sterile sediment where Unit 3 is the thickest (Columns 1 and 2, and to the south of Column 1). The vertical separation between those occupations decreases to the north where Unit 3 thins dramatically and laps up onto Unit 1. North of TU 3, the area of the disturbed burned rock midden, it was increasingly difficult to distinguish discrete occupation surfaces. With only one seemingly accurate charcoal date from the disturbed midden (940 B.P., UGA-14109) which postdates most of the Unit 3 occupations, it is difficult to be certain, but it seems apparent that one or more of these occupations stratified within Unit 3 are contemporaneous with the midden's use and creation (assuming it significantly predates 940 B.P.). In the immediate proximity of the midden it is impossible to separate or recognize discrete occupation surfaces, but it is quite easy to separate events to the south where Unit 3 thickens.

6.6 SUMMARY

Two Holocene age alluvial deposits (Units 2 and 3) are present in the road cut at 41MS69, but only Unit 3 contains prehistoric occupations. The lower half of Unit 3 was radiocarbon dated to the middle to late Holocene between approximately 5,400 and 3,500 B.P. The cessation of Unit 3 sedimentation has been estimated to be around 1,600 B.P. by assuming a constant sedimentation rate for the unit. At least 12 prehistoric occupations are present within Unit 3. These surfaces are easily separated from one another in the southern part of the road cut and APE, and become increasingly compressed northward, where they apparently merge with the disturbed burned rock midden.

Unit 3 rests unconformable upon an early to middle Holocene age alluvial deposit termed Unit 2, which was radiocarbon dated to the period approximately between 8,000 and 5,400 B.P. It is likely that deposition of this deposit began earlier than 8,000 B.P., but was not demonstrated here. Unit 2 rested unconformably upon a late Pleistocene alluvial deposit named Unit 1, and the age of this deposit is unknown, but it is greater than 9,170 B.P.

7.0 ARCHEOLOGICAL FINDINGS AND RESULTS

J. Michael Quigg

7.1 INTRODUCTION

This chapter presents the findings from archeological evaluation assessment within the APE. The later a narrow, 100 m long, a few meters wide, by 5.5 m tall road cut along the western edge of TxDOT FM 1871. Cultural features are described and results from technical analyses concerning them are presented in Section 7.2. Classes and frequencies of cultural materials are presented Section 7.3, followed by presentation of the vertical distributions of those cultural materials in Section 7.4. Finally, Section 7.5 provides the radiocarbon results for the buried cultural events encountered and for the depositional deposits encountered in this assessment.

7.2 CULTURAL FEATURES

Limited sections of three prehistoric features, Features 1, 2 and 3, were recognized and sampled in the 8.9 m^3 of hand-excavations. These were vertically distributed across different cultural events with Features 1 and 2 stratigraphically above one another near the bottom of cultural deposits in Column 1 at the southern end of the APE. Feature 3 was higher in the road cut in Column 2, more towards the central part of the exposure. Each feature is presented in detail below.

7.2.1 Feature 1

Feature 1 was first observed during hand-excavation of geomorphic Column 1 at the southern end of the exposed road cut (see Figure 5-3). This feature appeared as a line of burned rocks between roughly 150 and 160 cmbs in the roughly 85 cm wide Column 1 (Figure 7-1). Following exposure of Feature 1, two 1-by-1 m test units (TUs 5 and 6), which formed a 1-by-2 m unit oriented north-south, were individually hand-excavated immediately behind the face of Column 1. Test Units 5 and 6 were initiated at roughly 130 cmbs (measured from the top of the road cut and terrace surface projected as the original surface) and terminated at depths of 200 and 230 cmbs respectively, below a second burned rock feature (Feature 2). Test Units 5 and 6, Levels 14 through 16 (130 through 160 cmbs), revealed the very western edge of a much larger, dense burned rock concentration (Feature 1) (Figures 7-2 through 7-5). A tight cluster of eight or nine relatively large burned rocks were detected along the eastern 20 cm of TUs 5 and 6, with only a few smaller burned rocks scattered across the remaining levels. On the last field day, TU 5-extension was established and rapidly hand-excavated immediately east of TU 5 along the sloping edge to more fully delineate the nature of this concentration (Figure 7-6). Previous road construction and slumping sediments removed the majority of Feature 1, not allowing the original feature size and shape to be determined.

Hand-excavations demonstrated Feature 1 was minimally 100 cm east-west by 200 cm north-south, with a dense concentration of relatively large burned rocks (see Figures 7-2 through 7-6). The very western edge of the burned rock concentration was well-defined with tightly spaced larger burned rocks in TU 5 and 6. In contrast, the northern and southern edges were not encountered and the eastern side was gone.

At least 254 burned rocks, which weighed about 124,575 g, or about 490 g per rock, constituted the excavated part of Feature 1 (Table 7-1). Approximately 18 pieces, less than 10 percent of the total count, mostly towards the margins with a few near the middle, were angled or tilted in various directions (see Figure 7-3).

Some of the largest burned rocks and a few of those tilted appeared along the western margin to indicate a possible rock lining. Burned rock depths varied

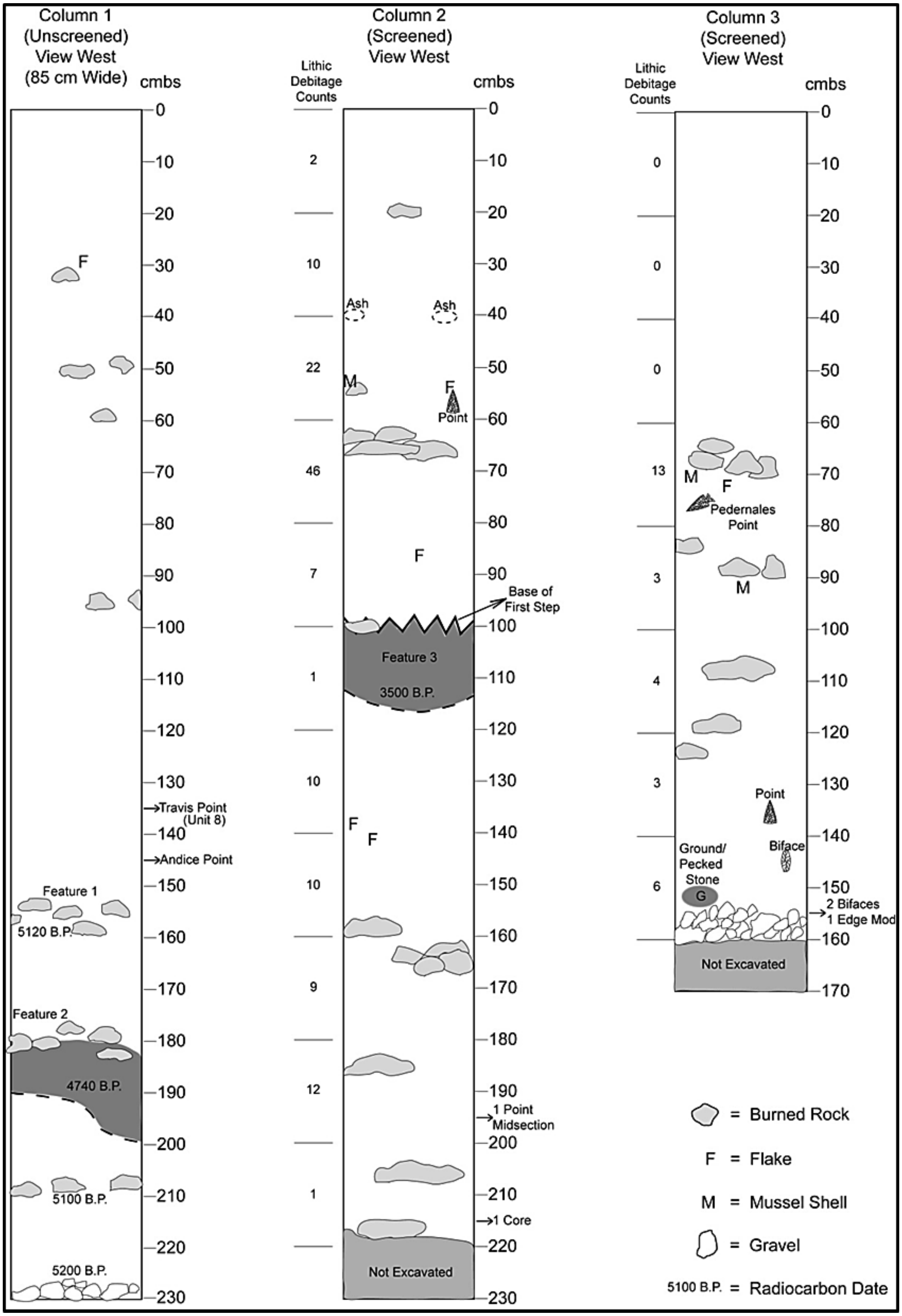


Figure 7-1. **Columns 1, 2, and 3 depicting depths of cultural materials exposed.**

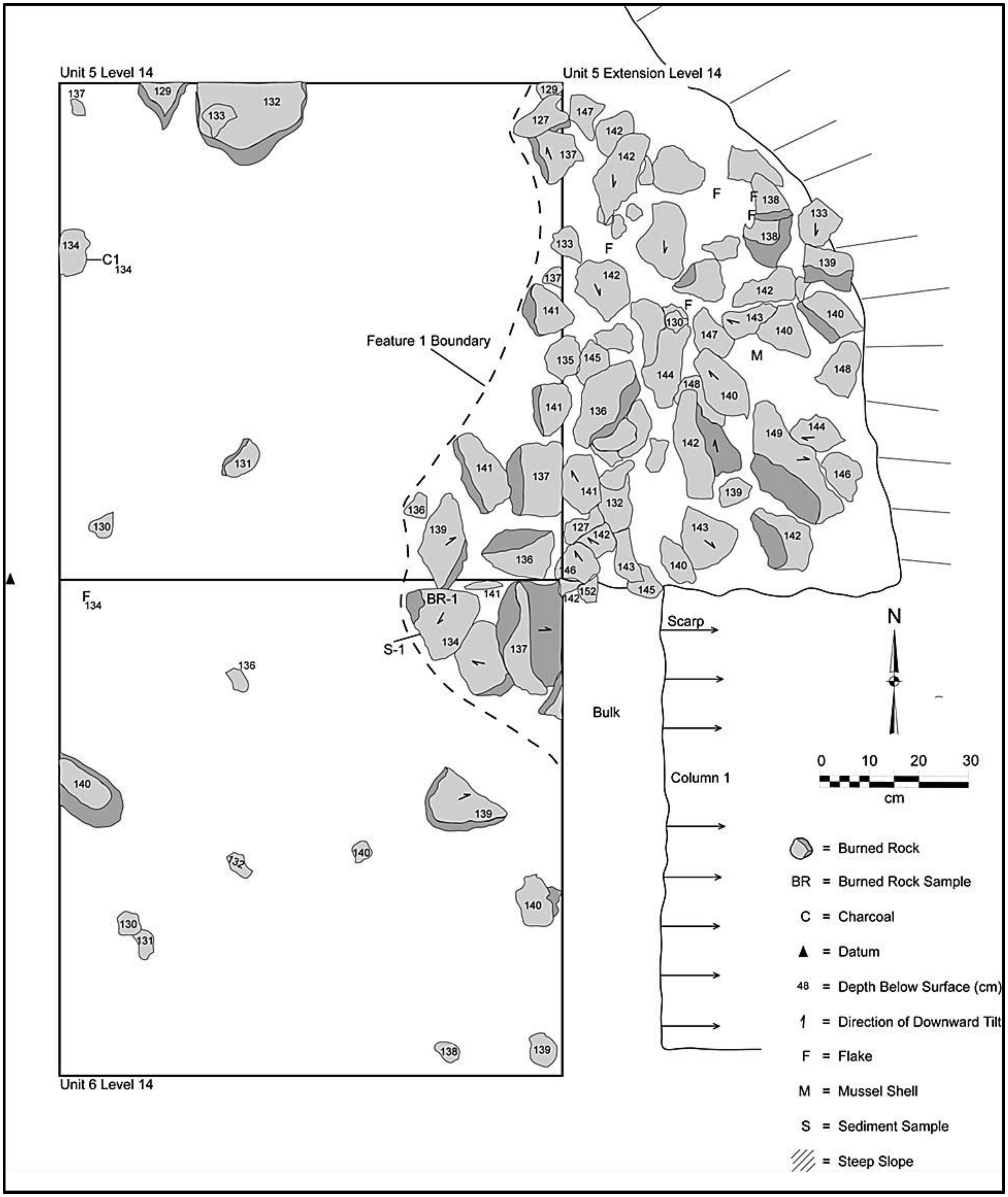


Figure 7-2. **Plan view of Feature 1, TUs 5, 6, and 5-Extension, 130 to 140 cmbs.**

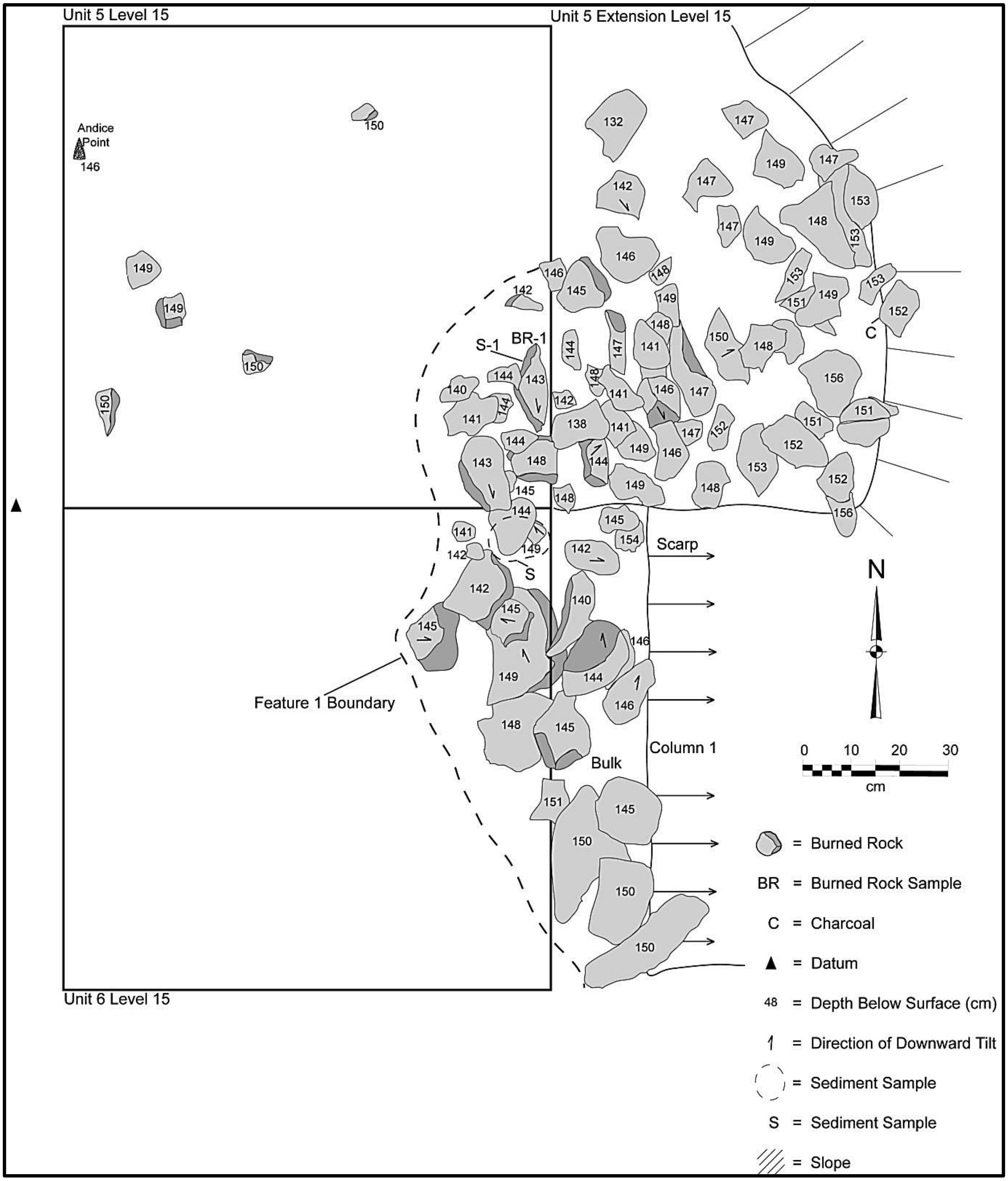


Figure 7-3. Plan view of Feature 1 in TUs 5, 6, and 5-Extension, 140 to 150 cmbs.

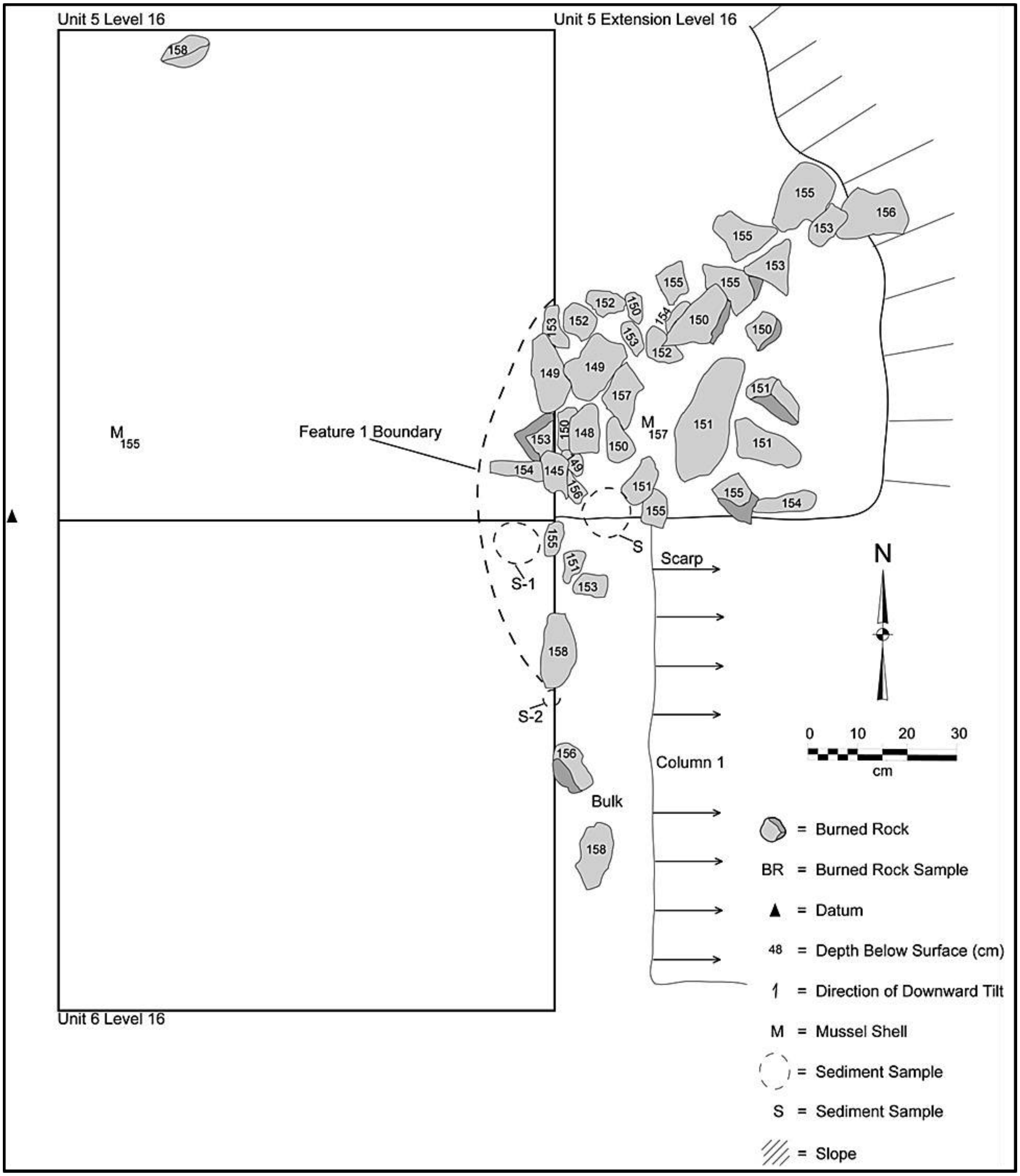


Figure 7-4. Plan view of Feature 1 in TUs 5, 6, and 5-Extension, 150 to 160 cmbs.

Figure 7-5. View down at western edge of Feature 1 exposed at 140 to 150 cmbs on eastern edge of TU 6 with Column 1 and steep slope east and downslope of rocks at top of photograph.

Figure 7-6. Feature 1 exposed at 130 to 140 cmbs in TU 5-extension depicting the position and nature of the rocks. Note: western edge of TU 5 in foreground with steep slope and roadway pavement at top.

Table 7-1. Burned Rock Characteristics from Feature 1.

Test Unit	Level	Cat. No.	Size (cm) and Weight (g)								Total Count	Total Wt. (g)
			0-4	Wt.	4.1-9	Wt.	9.1-15	Wt.	>15.1	Wt.		
5	15	501			6	750	3	275			**9**	**1,025**
5	16	502					2	1,000			**2**	**1,000**
5 Ext.	14-16	504	46	2,500	53	12,000	48	39,000	26	34,750	**173**	**88,250**
6	15	508	6	300	18	325	20	3,375	6	22,500	**50**	**29,000**
6	16	509	15	300					5	5,000	**20**	**5,300**
Feature 1 Totals			**67**	**3,100**	**77**	**13,075**	**73**	**43,650**	**37**	**62,250**	**254**	**124,575**

from 136 to 157 cmbs with the deepest rocks clustered towards the perceived middle of the cluster. This depth difference created what was probably a shallow, rock filled basin. The projected central area exhibited three layers of burned rocks. No obvious or well-defined basin edge was detected in the limited excavations. No oxidation lens or even patches, or charcoal concentrations were detected, and only small, localized and slight sediment color changes were observed within the burned rock concentration. The sediment surrounding the rocks in Feature 1 was generally a brown (7.5YR 4/3, moist) fine silty sand. One dark grayish-brown (10YR 4/2, moist) sediment sample was collected from near the feature's western boundary in the northeastern corner of TU 6 at 145 to 150 cmbs from beneath a burned rock.

Below burned rocks along the eastern edge of TU 6, a small 15 cm diameter area contained a few pieces of lithic debitage near 158 cmbs (Table 7-2). A few pieces of lithic debitage, a couple of small mussel shell valve fragments, a biface fragment, and an edge-modified flake were recovered from the upper part of this burned rock concentration. Multiple sediment samples that totaled nearly 4.1 kg included one larger bulk sample and at least 12 burned rock samples were collected from Feature 1. Immediately below this burned rock concentration was a dark yellowish-brown (10YR4/4, moist) silty sand with few small burned rocks.

Over the lengthy time of this project, two bulk sediment samples, light fractions and individual charcoal samples from Feature 1, were submitted to Dr. Dering for macrobotanical analysis. Details of his findings are presented in Appendix F, which are summarized below. Individually collected charcoal samples from Feature 1 are mostly unidentifiable charcoal flecks (#509-4) with a single piece (#508-4) of indeterminate wood. Two small float samples (#508-4 and #509-4, 0.9 liters) failed to yield any wood charcoal or carbonized seeds. No materials other than a few small fragments of burned rocks were in the heavy fraction (Appendix F).

Seven samples for radiocarbon dating were selected from Feature 1 and those results are presented in Table 7-3. The youngest assay resulted from dark ashy bulk sediment from between the burned rocks.

Table 7-2. Material Classes in Feature 1.

Cultural Material Classes	Counts
Biface fragment	1
Edge-modified flake	1
Lithic debitage	13
Mussel shells	3
Burned rocks	254

Table 7-3. Radiocarbon Dates Associated with Feature 1.

Catalogue No.	Unit No.	Depth (Cmbs)	Feature No.	Material Dated	Weight of Material (g)	Lab. No.	Measured Age	13C/12 C Ratio (‰)	Conventional Age (B.P.)	2 Sigma Calibration Range
505-4-1d	5 Ext	151-154	1	Ashy Sediment		Beta-370497	3890 ± 40	-23.8	3910 ± 40	Cal 2490 to 2290 BC
505-7-1a	5 Ext	152	1	Charcoal	0.1	UGA 14116	4840 ± 40	-21.7	4890 ± 40	Cal 3770 to 3540 BC
41-7	6	130-140		Charcoal		Beta-370495	4930 ± 40	-25.4	4920 ± 40	Cal 3780 to 3640 BC
505-7-1h	5 Ext	151-154	1	Charcoal		Beta-370496	4970 ± 40	-25.8	4960 ± 40	Cal 3890 to 3880 BC
505-7-2	5 Ext	152	1	Charcoal	0.1	Beta-233355	4950 ± 40	-21.7	5000 ± 40	Cal 3950 to 3700 BC
32-7-1c	5	134	1	Charcoal	0.1	Beta-233352	5090 ± 40	-26.1	5070 ± 40	Cal 3970 to 3770 BC
32-7-1a	5	134	1	Charcoal	0.1	UGA 14110	5140 ± 40	-25.0	5120 ± 40	Cal 3990 to 3790 BC

This date is rejected as it is significantly younger than six charcoal dates and probably contains younger organics that filtered downward. The six wood charcoal dates range from 4890 to 5120 B.P., and encompasses a 230 year period. The six wood charcoal dates average 4993 B.P., which is acceptable for the age of Feature 1. The differences between the six charcoal dates presumably is due to use of dead wood from multiple sources and therefore may be slightly older than the actual use event. If the charcoal represents old wood, potentially the younger sediment date may more closely reflect the specific age of the event.

Two sediment samples from the feature, one (#507-4) from 134 cmbs and one (#505-4) from 151 to 154 cmbs were submitted and subjected to phytolith analysis. Dr. Sudbury's procedures, results and interpretations are in Appendix J. Overall, the biogenic silica was poorly preserved and the phytolith assemblage appears incomplete and skewed due to differential particle dissolution. This was probably caused by the cambic character of the Oakalla soil and pH soil environment (Appendix J). What was recovered and identified from the two samples include; two burned hackberry seeds, 20 well-preserved sponge spicules, some hot weather Chloridoids grass phytoliths (30 percent burned), traces of charcoal, burned silica globs, tree phytoliths, and a single gourd phytolith. Short cell phytoliths were present in very low numbers and represent all three grass subfamilies with Chloridoids dominant. Recovered data and interpretations indicate a probable late summer or fall use event based on the gourd phytolith and burned hackberry seeds. The presence of sponge spicules may be indicative of water use with Feature 1.

Small chunks (less than 100 g) of 11 burned rocks were submitted for lipid residue analysis. Eight yielded positive interpretable results with all except one (#507-3-1e) yielding combinations of plant and animal products. Four were dominated by plants and one dominated by meat (#508-3-5). Larger herbivore meat (i.e., deer, pronghorn, or bison) was only present on one rock (#507-3-1e) (Appendix H). All eight positive results yielded conifer residues as well, which probably indicate the wood employed to heat the rocks. The residue probably represents local juniper or possibly cypress trees.

Chunks of the same burned rocks employed for lipid analysis (#505-3-2b, #507-3-1d and #508-3-3b) plus seven other burned rocks and two sediment samples (#505-4-1g and #507-4-1d) were subjected to starch analysis (Appendix I). Dr. Perry's results are summarized here. Sediment samples analyzed did not yield any starch grains. Therefore starches from the burned rocks are considered definitely cultural. Eight of the 10 burned rocks yielded 13 starch grains. Of those, three were lenticular grass grains typical of those derived from grasses in the Triticeae, the group includes wildrye and little barley. Four grains from two rocks (#507-3-1d and #508-3-3b) (Figure 7-7) are of an unidentified legume. Six damaged unidentified grains were also present. Damaged grains include four gelatinized (altered by heat and water) and two with indeterminate damage (Appendix I).

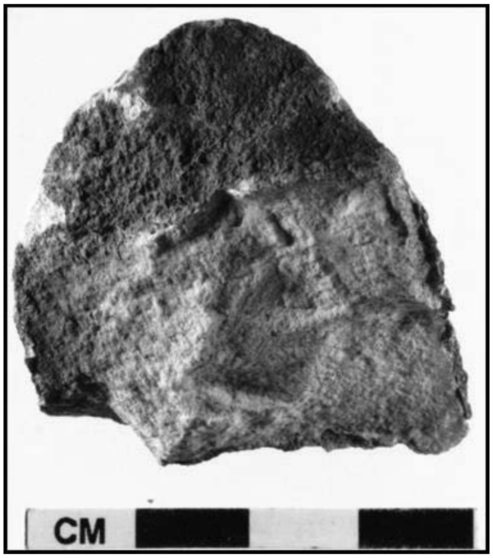


Figure 7-7. Burned rock fragment that yielded starch grains.

Two burned rocks (#508-3-1c and #508-4-1a) and a single sediment sample (#505-4-1c) were submitted for diatom analysis to Dr. Winsborough. Her processing methods and individual results from the initial sample assessments in 2007 are presented in Appendix B. Two rocks yielded only five diatom cells, which are typical of rivers, streams and ponds. Not much can be said with such a limited assemblage. Individual cells were in good condition and did not exhibit signs of having been transported any great distances. This probably supports the use of water in this feature.

Only a very small segment of Feature 1 was excavated. The characteristics observed and documented indicate this was *in situ* rock lined and rock filled, basin shaped feature, potentially an oven employed to cook bulk foods. The grasses present were potentially part of foods along with the legumes and meat products, or the grasses potentially served as lining or packing in conjunction with the targeted foods (e.g., unidentified legumes, meats, etc.). Grasses potentially were introduced as tinder to start fires to heat the rocks.

7.2.2 Feature 2

Feature 2 was also first detected during the hand-excavation of geomorphic Column 1 at the southern end of the exposed road cut. Feature 2 initially appeared as a two rock, thick lens overlying and sometimes in a dark grayish-brown (10YR 4/2) sediment that appeared part of a basin hearth (see Figures 7-1 and 7-8). This burned rock lens was approximately 15 cm below the irregular line of burned rocks in Feature 1. In Column 1, the tops of the burned rocks in Feature 2 were at roughly 175 cm with the bottom of the dark brown (7.5YR 3/2, moist) sediment near 200 cmbs. These burned rocks sloped gently down toward the south, across the 85 cm wide exposed Column 1.

As discussed above, TUs 5 and 6 were hand-excavated immediately behind the face of

Figure 7-8. Profile of Feature 2 exposed in Column 1, view west.

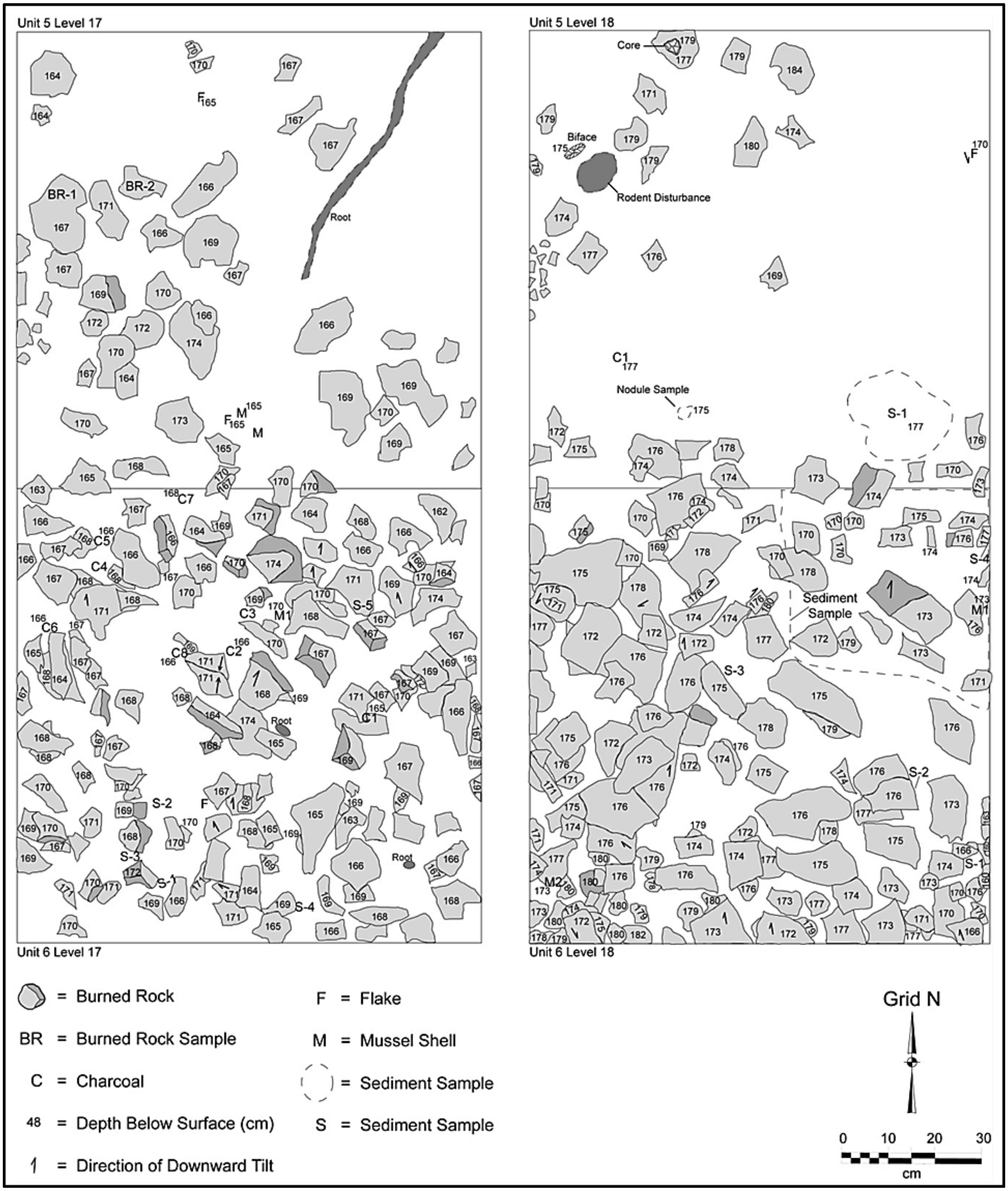


Figure 7-9. Two plan views of the northern edge of Feature 2 in TUs 5 and 6 at 170 and 180 cmbs.

Column 1 to investigate the nature of Features 1 and 2. Test Units 5 and 6, Levels 17 and 18, encountered a portion of a much larger burned rock feature (possibly the northern edge) with dark organic stained sediment below the rocks and mixed with the rocks in parts of Feature 2 (Figures 7-9 through 7-11). Test Unit 5-extension contributed to delineate Feature 2.

The road cut and slumping deposits removed most of Feature 2. This fact combined with limited excavations, the original size and shape could not be determined. The thickness was variable and the bottom was uneven and at variable depths across the two units. As exposed during excavation, Feature 2 measured at least 170 cm east-west by 200 cm north-south. It was characterized by a dense concentration of burned rocks in at least two layers in TU 6 (Figure 7-9). Burned rock density decreased rapidly northward across TU 5 with the lens decreasing in thickness to a single rock. In TU 5 the burned rock lens was between 163 and 177 cmbs. A definite slope southward was detected for the entire burned rock lens. No pattern or structure was detected in the burned rocks exposed as they extended beyond the margins of TU 6 and decreased in frequency across TU 5. Test Units 5 and 6 yielded a total of 928 burned rock pieces that weighed 247,334 g, or about 267 g per rock (Table 7-4).

The deeper burned rocks, those ca. 175 to 177 cmbs, rested in the top of the very dark gray sediment. The bottom of this dark sediment was not even and varied from roughly 175 to 185 cmbs. A poorly defined edge, which possibly marked a shallow basin, was evident by the dark brown (7.5YR 3/2, moist) sediment towards the southern side, and most obvious in the face of Column 1. The base of that dark sediment tapered up towards the northern end of TU 5 with burned rocks contained therein. No definable edges were detected as the rocks extended across the two entire levels, and the eastern side was gone. Burned rocks were across the top part of the dark brown sediment and decreased in number towards the northern end.

The dark sediment below the burned rocks contained the occasional small, less than 4 cm burned rock fragment. It lacked charcoal chunks, lithic debitage, snails, or other cultural materials. No charcoal lens or oxidation rim was detected. The occasional small chunk of charcoal and the occasional mussel valve fragment were scattered between the burned rocks.

Several sediment samples totaling 26.3 kg included one larger bulk sediment sample (80 liters) of dark brown sediment (#513) that weighed nearly 12.2 kg, plus minimally 22 burned rock samples, were collected from Feature 2. Individual piece plotted macrobotanical and float samples were submitted to Dr. Dering for macrobotanical analysis. His findings are in Appendix F, which are summarized here. The individual samples include hackberry and oak wood fragments, plus charred

Table 7-4. Burned Rock Characteristics from Feature 2.

Test Unit	Level	Cat. No.	Size (cm) and Weight (g)								Total Count	Total Wt. (g)
			0-4	Wt.	4.1-9	Wt.	9.1-15	Wt.	>15.1	Wt.		
5	17	510	107	5,800	9	1,1250	9	6,000			**125**	**23,050**
5	18	511	52	2,184	9	1,350	3	2,000			**64**	**5,534**
6	17	514	148	4,100	123	4,500	33	33,700	3	3,250	**307**	**45,550**
6	18	515	154	4,200	231	85,200	44	79,300	3	4,500	**432**	**173,200**
Feature 2 Totals			**461**	**16,284**	**372**	**102,300**	**89**	**121,000**	**6**	**7,750**	**928**	**247,334**

Figure 7-10. Exposed top of Feature 2 at 170 cmbs in TU 6 (Note portion of Feature 1 above in profile at upper right corner).

Figure 7-11. Close-up profile of dark stained sediment and burned rocks in Feature 2 in southwestern corner of completed TU 6 (Note three burned rocks as part of Feature 1 above Feature 2 in profile at top edge and minor turbation that moved dark sediment downward below the rocks).

hackberry nutlets. Most organic samples (#511-4, #512-4, #514- and #515) were indeterminate to species. Again, no carbonized seeds or other edible plant parts were present. Only a few small pebbles were in the heavy fractions (Appendix F).

A chunk of wood charcoal (#511-7-1a) from 177 cmbs in TU 5, surrounded by burned rocks was radiocarbon dated. This charcoal yielded a δ^{13}C (-27.4‰) corrected AMS date of 110.8 ± .4 pMC or modern age (UGA-14117) (Table 7-5). This age is inconsistent with other radiocarbon dates from this feature and was rejected as a reliable age for Feature 2. A 283 g sample of the dark brown sediment (#513-4a) yielded a δ^{13}C (-24.5‰) corrected AMS date of 4740 ± 40 B.P. (UGA-14107). A fine dark ashy sediment sample (#512-4-b) was also submitted and yielded a δ^{13}C (-23.9‰) corrected AMS date of 4550 ± 40 B.P. (Beta-370492). The six wood charcoal dates range over 320 years from 5100 to 5420 B.P. with an average of 5305 B.P. The two dates derived from the bulk sediments are younger by at least 360 years than the averaged six wood charcoal dates. These bulk sediments are less likely to represent the actual age of Feature 2 if younger organic matter filtered downward into the feature. Potentially these two sediment dates may represent the use period, if the charcoal dates were derived from old wood. Two charcoal samples were stratigraphically immediately below Feature 2 and probably represent minor displacement downward over time. The six wood charcoal dates are accepted as the use period of Feature 2 in keeping with most researchers accepting wood charcoal over sediment dates. The average age for Feature 2 is roughly 312 years older than the average wood charcoal dates from Feature 1, roughly 15 cm higher in the profile. The radiocarbon dates on charcoal derived from Features 1 and 2 are stratigraphically consistent and document the age of two large burned rock cooking features used during the Middle Archaic period as defined by Collins (2004).

Chunks of 12 parent burned rocks were submitted for lipid residue analysis. Lipid residue results were generally combinations of plants and animals with the exception of one. Four were dominated by plants and two were dominated by meat (Appendix H). A single sample (#512-3-4a) yielded large herbivore meat residues (i.e., deer, pronghorn, and/or bison). Nine of the 11 samples also contained conifer product residues from burning wood, locally juniper or possibly cypress, employed to heat the rocks (Appendix H).

Parts of the same three burned rocks sent for lipid residue analysis (#501-3-1b, #501-3-2b, and #501-3-3b), plus ten other burned rocks and a single sediment sample (#511-4-1d) from between 170 and 180 cmbs were subjected to starch analysis. Dr. Perry's procedures and results are in Appendix I with only a summary present here. The sediment sample did not yield any starch grains, therefore starches from the burned rocks are considered cultural. Of the 13 burned rocks analyzed, only 6 yielded 10 starch grains, plus several damaged grains. Of those identified, two are lenticular grass grains typical of those derived from grasses in the Triticeae. The latter group includes wildrye and little barley. One other is a grass grain unlike those in the Triticeae family. Six grains of an unidentified legume (all on rock #510-3-2b or BR-2 in TU 5) (Figure 7-12), plus at least five damaged and unidentified grains. Those damaged include three gelatinized grains (altered by heat and water), one parched grass grain, and one with undetermined damage (Appendix I). Minimally, wildrye-type grass seeds and as yet unidentified legume "bean" were probably cooked in this feature.

Two burned rocks (#515-3-1c and #515-3-4a) and a single sediment sample (#511-4-1c) were submitted for diatom analysis to Dr. Winsborough. Her processing methods and individual results from the initial sample assessments in 2007 are presented in Appendix B. The three samples did not yield any diatoms and no further diatom analysis was conducted.

Table 7-5. Radiocarbon Dates Associated and Immediately below Feature 2.

Catalogue No.	Unit No.	Depth (cmbs)	Feature No.	Material Dated	Weight of Material (g)	Lab. No.	Measured Age	13C/12C Ratio (‰)	Conventional Age (B.P.)	2 Sigma Calibration Range
511-7-1a	5	177	2	Charcoal	0.1	UGA 14117	110.8 ± .4 pMC	-27.4	Modern	Modern
513-4a	5 Ext	180	2	Black sediment	283.0	UGA 14107	4730 ± 40	-24.5	4740 ± 40	Cal 3640 to 3370 BC
512-4-b	5	170-174	2	Ashy Sediment		Beta-370492	4530 ± 40	-23.9	4550 ± 40	Cal 2480 to 3100 BC
36-7-3	5	189	2	Charcoal	0.1	Beta-233354	5340 ± 50	-26.4	5320 ± 50	Cal 4320 to 4030 BC
514-7-2	6	166	2	Charcoal	0.1	Beta-233356	5340 ± 40	-23.5	5360 ± 40	Cal 4330 to 4050 BC
36-7-1	5	180	2	Charcoal	0.1	Beta-233353	5390 ± 40	-24.7	5390 ± 40	Cal 4340 to 4160 BC
511-7-1h	5	177	2	Charcoal		Beta-370493	5420 ± 40	-25.3	5420 ± 40	Cal 4340 to 4230 BC
45-7a	6	190-200	lowest cultural	Oak Charcoal	0.1	UGA 14111	5110 ± 40	-25.9	5100 ± 40	Cal 4460 to 4250 BC
37-7-3a	5	192		Charcoal		Beta-370494	5250 ± 40	-25.9	5240 ± 40	Cal 4230 to 4090 BC

Figure 7-12. Burned rock (#510-3-2b) which yielded unidentified legumes and at least five damaged starch grains.

A single sediment sample (#511-4-1c or S-1 in TU 5) from 177 cmbs in Feature 2 was analyzed for the phytoliths to further investigate materials in the feature. Overall, the biogenic silica was poorly preserved, so the phytolith assemblage was definitely incomplete and skewed due to differential particle dissolution. Again, poor preservation was probably caused by the cambic character of the Oakalla soil and pH soil environment (Appendix J).

What was recovered and identified include; three burned hackberry seeds, a sponge spicule, few hot weather Chloridoids grass phytoliths, microdebitage, a large snail population, charcoal flecks, burned unidentified black granular particles, two burned microbone fragments, and tree phytoliths. Short cell phytoliths were present in very low numbers and represented all three grass subfamilies with Chloridoids dominant. The recovered phytolith data and their interpretations indicate a possible late summer or fall event (Appendix J).

Feature 2 is interpreted to represent the remains of a large burned rock cooking feature, possibly an oven, as evident through the dark stained basin with the burned rocks removed and discarded around this probable basin-like heating element. Interestingly, 85 percent of the rocks are less than 9 cm in size. This relatively small size indicates these rocks had been subjected to multiple heating and cooling events. Multiple grass starches, burned hackberry nutlets and unidentified legume starches were in this feature. The single parched grass starch may support the precursor to grinding and the hypothesis grasses were part of the food resource or potentially part of the packing material surrounding other foods. However, the small sample of starch grains could also have been introduced into the feature through the use of grass as tinder. Gelatinized starch grains also support water was used in this feature.

7.2.3 Feature 3

Feature 3 was first detected during hand-digging the upper 1 m section of geomorphic Column 2 towards the southern end of the road cut (see Figure 7-1). Feature 3 first appeared as a small pocket of whitish sediment near 100 cmbs, where the first step/bench of Column 2 was created. Following the digging of Column 2, a subsequent hand-excavated and screened column was excavated to the southern side of the exposure (Figure 7-13). The upper section of the screened column stopped at 100 cmbs, the observed top of the detected color change. At 100 cmbs the size of the screened column was about 30-by-40 cm. At that depth the screened column was moved 190 cm to eastward and excavation continued downward from that depth.

Following completions of Column 2, sediment at the first step/bench at 100 cmbs was hand-troweled. This revealed a dark grayish-brown (10YR 4/2) ashy, silty sandy loam over an area at least 65 cm east-west and nearly 70 cm north-south. Three small burned rocks were in the very top of this ashy sediment. Two separate profiled sections revealed the ashy sediment was in a 16 cm deep basin with steep sidewalls (Figure 7-14). No oxidation rim or charcoal lens was observed. The ashy sediment

Figure 7-13. Profile of screened section in top of Column 2.

was very clean with no visible signs of rodent, root disturbances or scattered charcoal. About 3.2 kg of ashy sediment (#516) was collected and returned to the TRC Austin laboratory. A single chunk of wood charcoal (#516-7-1) was identified by Dr. Dering as oak wood (Appendix F).

The tiny chunk of oak charcoal (#516-7-1a) from just below Feature 3 at 111 cmbs was radiocarbon dated. This charcoal yielded a $\delta^{13}C$ (-24.8‰) corrected AMS date of 3500 ± 50 B.P. (UGA-14118). This age is generally appropriate with cultural materials from this APE; and therefore, it is accepted as the approximate age of Feature 3.

No other technical analyses were conducted on samples from Feature 3. Feature 3 represents the remains of an intense hearth or heating element, which completely consumed the fuel wood leaving only ash. Limited excavations revealed this ash deposit filled an *in situ* basin dated to 3500 B.P.

7.2.4 Another Burned Rock Feature

An extensively looted burned rock midden or lens was observed across the northern end of the APE (Figure 7-15). Because the majority was west of the APE (see Figure 4-1) and had extensive vegetation cover and considerable disturbance, it was not recorded in detail. The horizontal and vertical dimensions and its general association to the burned rock lenses observed along the road cut are unknown. Test Unit 1 was thought to be north of this surface observed midden, although at least two 10 cm thick levels yielded more than 50 pieces of burned rocks, so the association is not clear (Figure 7-16). Test Unit 2 was excavated in the area of this disturbed midden with no observed surface burned rocks. Quantities of burned rocks were throughout the unit and continued to the end of the unit at 100 cmbs (Figure 7-16). The midden-like deposits yielded chert flakes (*N* = 141), bone fragments (*N* = 57), mussel shell fragments (*N* = 6), and formal stone tools (*N* = 5). The formal tools include; a dart point midsection (#9-10) between 20

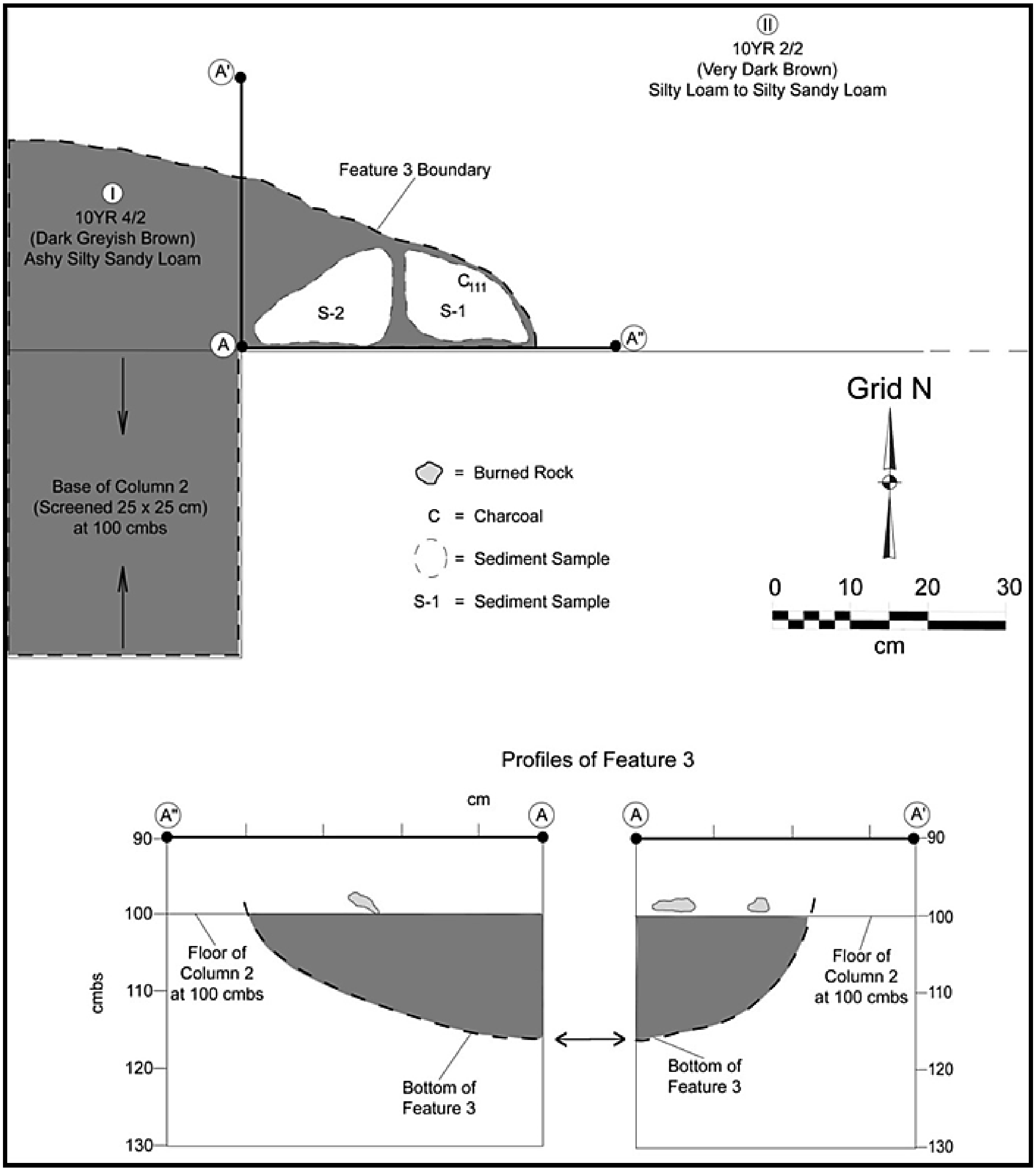


Figure 7-14. Plan and Profile of Feature 3, Column 2 with top of Feature at 100 cmbs.

Figure 7-15. Overgrown looters hole in burned rock midden at the north end of road cut.

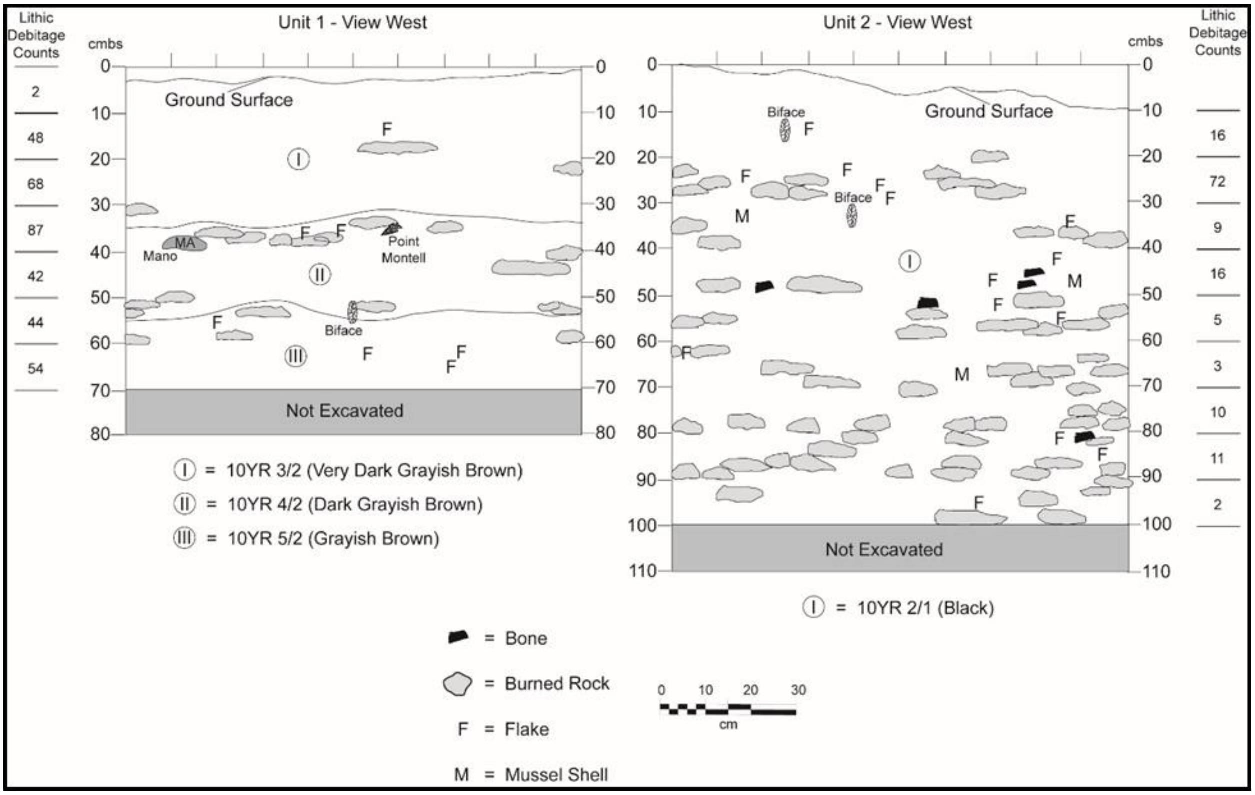


Figure 7-16. Profile of Test Units 1 and 2 ddepicting the vertical distribution of plotted burned rocks in profile.

Table 7-6. Summary of Feature Data from 41MS69.

	Feature 1	**Feature 2**	**Feature 3**
Column	1	1	2
Unit	5, 5 Ext., 6	5, 5 Ext., 6	None
Depth Below Surface (cm)	136-157	163-200	100-116
Radiocarbon Age (B.P.)	7 = ca. 4993	9 = ca. 5305	1 = 3500
Feature Type	Rock filled basin/?oven	Rock filled basin/?oven	Ash pit
Shape	Undetermined	Undetermined	Circular
Profile	Shallow basin	Deep basin	Deep basin
Length (cm)	100+	200+	70
Width (cm)	200+	170+	65
Thickness (cm)	21	15-35	16
Mussel Shells	3	6	None
Charcoal	Sparse	Sparse	Very sparse
Lithic Debitage	13	14	None
Stone Tools	1 biface, 1 edge-modified flake	1 biface	None
Burned Rock Count	254	928	3
Burned Rock Weight (g)	124,575	247,334	Unrecorded
Burned Rock Type	Multiple	Multiple	Unrecorded
Lipid Analysis	11	12	None
Starch Analysis	12	14	None
Phytolith Analysis	2	1	None
Macrobotanical Identification	Multiple	Multiple	None
Diatom Analysis	3	3	None

and 30 cmbs, a biface fragment (#10-10) between 30 and 40 cmbs, a second dart point midsection (#12-10) between 50 and 60 cmbs, a third dart point midsection (#14-10) between 70 and 80 cmbs, and another biface fragment (#16-10) between 90 and 100 cmbs. Test Unit 2 deposits appeared part of a much larger, and at least, a partially disturbed midden.

7.2.5 Summary of Features

Only three cultural features were partially documented through very limited hand-excavations and all three were radiocarbon dated (Table 7-6). Minimally one other extensive burned rock midden or lens was observed towards the northern end of the APE. The latter was possibly associated with multiple undocumented lenses of burned rocks observed in the top of the road cut under large oak trees.

Hand-excavations of Column 1 encountered two dense burned rock concentrations, Features 1 and 2, and were partially explored with 2.5 m^2 hand-excavated units. The efforts directed towards Features 1 and 2 and subsequent technical analyses directed on materials from those two features, yielded significant data to understand and interpret those features. Features 1 and 2 represent a period in which archeologists know very little about across Texas. Only a few other Bell/Andice/Calf Creek cultural features have been documented across Texas (i.e., the Cibolo Crossing site [Kibler and Scott 2000]; the Spring Lake site (Lohse et al. 2013]; the Stillhouse Hollow site [Sorrow et al. 1967]; the Big Hole site [Quigg et al. 2007]).

Features 1 and 2 potentially represent burned rock ovens, and may indicate cooking multiple plants (at least grasses and legumes) for this previously thought of bison hunting population. Lipid residue analysis of 23 burned rocks from those two features yielded interpretable lipid residues on 83 percent. Lipid results indicate most rocks were employed to cook both plant and animal products based on specific biomarkers cholesterol and β-sitosterol. At least eight rocks were dominated by plant residues and another three dominated by animal residues. Two rocks yielded large herbivore meat residues (Appendix H). Technical analyses reveal those two Middle Archaic features cooked or heated both plant and animal products similar to most other hunter-gatherer populations. Rocks also yielded conifer wood residues, probably local juniper or possibly cypress employed to heat the rocks.

7.3 MATERIAL CLASSES AND FREQUENCIES

This section presents the classes and frequencies of cultural material recovered with general observations. This includes not only the item counts, but also the horizontal distribution and density for the 8.9 m^3 excavated across nearly 100 m long APE road cut exposure. In a few instances, materials recovered from multiple cultural events and components exhibited good stratification in the southern end. Presumably those multiple events merged to a relatively thin and probably mixed cultural deposit at the northern end. The lowest cultural events at the southern end are radiocarbon dated between roughly 3,000 B.P. to at least 5,200 B.P., with potentially younger undated events above those.

7.3.1 Lithic Debitage

The 8.9 m^3 area excavated yielded 2,312 pieces of lithic debitage with a 10 cm level yielding an average of nearly 26 pieces. However, the debitage frequency varied tremendously both vertically and horizontally and was not evenly distributed across each level. Horizontal variability is reflected in TUs 7 and 8, which were only 2 m apart. Test Unit 7 yielded 34 pieces for an average of 3.0 pieces per 10 cm level. Test Unit 8 yielded 278 pieces for an average of 18.5 pieces per 10 cm level. Both units yielded a peak in debitage frequency in the 80 to 90 cm level. This indicates a broad horizontal distribution of debitage at that particular level. Test

Table 7-7. Material Class Summary by Unit for APE at 41MS69.

Material Classes	**Test Units**												**Surface Column**	**Unit Totals**
	1	**2**	**3**	**4**	**5**	**5 Ext**	**5 & 6**	**6**	**7**	**8**	**9**	**10**		
Stone Tools	7	5	5	7	10	2	1	10	4	15	11	4	13	**94**
Ground Stone	1	0	0	2	0	0	0	0	0	0	0	2	3	**8**
Lithic Debitage	347	141	387	547	110	21	1	109	34	278	70	97	159	**2301**
Mussel Shells	1	7	5	7	2	8	0	5	0	3	2	3	9	**52**
Charcoal	2	0	2	0	17	3	0	11	0	0	0	0	10	**45**
Feature nos.	0	0	0	0	1 & 2	1 & 2	1 & 2	0	0	0	0	0	F3	**3**
Burned Rocks	334	540	132	108	533	209	0	1057	31	329	292	142	191	**3898**
Bone Fragments	2	57	0	25	0	0	0	1	0	0	0	1	0	**86**
Snail Shells	125	0	0	0	74	9	0	2	0	0	0	67	31	**308**
Totals	**819**	**750**	**531**	**696**	**746**	**252**	**2**	**1195**	**69**	**625**	**375**	**316**	**416**	**6795**
Volume Excavated (m²)	0.7	1	0.6	0.9	0.8			1.1	1.1	1.5	0.7	0.6		8.9

Unit 7, the most southern unit excavated was apparently near the southern end of most occupations within the upper 100 cm of the surface. There the only obvious cultural event centered between the 80 and 90 cm. Test Units 1 through 4, also excavated from the top terrace surface, sampled roughly the upper 100 cm or so. These units yielded higher debitage densities compared to TUs 5, 6, 9, and 10, although the later units sampled deposits deeper events in the road cut deposits (Table 7-7).

Near the northern end of the APE, TU 2 was excavated through a thick part of the disturbed burned rock midden. One level, between 20 and 30 cmbs, yielded relatively moderate frequencies of lithic debitage (*N* = 65). The entire 1.0 m^3 excavated in TU 2 yielded only 140 pieces. Test Units 1 and 3, north and south of TU 2, yielded more than double the debitage frequencies in shallower deposits than in TU 2 (Table 7-7). Test Unit 4, south of the disturbed burned rock midden deposit, yielded the highest frequencies and greatest density of lithic debitage for the entire APE. The upper 50 cmbs yielded quite low densities at only eight items per 10 cm level. The lower 40 cmbs yielded high densities at 127 items per 10 cm level. Test Units 5 and 6, which were side-by-side near the midslope at the southern end, yielded relatively low quantities of lithic debitage, with densities of 14 and 13 pieces, respectively, per 10 cm level. Four meters north, and again in the midslope, TUs 9 and 10 also yielded relatively low densities of debitage at 11 and 16 items, respectively, per 10 cm level.

A small percentage of the chert flakes from within the burned rock midden encountered in TU 2 exhibit heat spalls caused from exposure to heat. Heat-spalled pieces were not restricted to the burned rock midden and occured in low frequencies in most units across the investigated area. This distribution may relate to camp maintenance and episodes of dumping. A high percentage of debitage in TU 2 reflects cortex in primary and secondary reduction stages, plus core manipulation with some biface thinning.

Vertical debitage distribution in TU 4 revealed levels below about 40 cmbs yielded cherts spotted with calcium carbonate adhering to them, in contrast to those in the upper 40 cm that did not. Test Unit 4 materials are generally small pieces of chert debitage, especially deeper in the unit.

Nearly 94 percent of the lithic debitage consists of chert, which includes very high quality brown and dark gray colors with few to no internal flaws. A single small quartz crystal resharpening flake (#19-1) was recovered from 30 to 40 cmbs in TU 3. Unfortunately, its age and cultural association is unknown. This piece was associated with 133 pieces of chert and 49 burned rocks. The five phytolith sediment samples analyzed, two greater than 5,000 B.P. and three directly associated with ca. 5,000 year old Features 1 and 2 yielded 42 microflakes of quartz (Appendix J, Figure J-7). Between 33 and 55 percent of the debitage does not fluoresce in the known yellowish to orange color range for Edwards chert. Those pieces exhibit a very dark purple or mauve fluorescence indicative of non-Edwards chert. The Gorman Falls Formation outcrops on the higher landform surface less than a kilometer north of 41MS69 (Barnes 1981). This formation yields some whitish chert, with banding and mottling not often observed in most Edwards cherts. The Tanyard Formation is also in the immediate area and contains undescribed chert. Multiple pieces exhibit water worn cortex, which were probably collected from the nearby Llano River gravels or other secondary context such as upland gravels. Many non-Edwards pieces are quite small indicting they were from larger tools or cores or the natural pieces were small to begin with. Most non-Edwards pieces are visibly a different color with different textures than the Edwards cherts.

Nearly 92 percent of lithic debitage was from scattered test units and lacks chronological control. Excavation levels in different units could not be confidently correlated with other units. Consequently, time and effort was not expended to conduct detailed analysis on scattered debitage not assigned to a specific period or identified cultural event.

Lithic analysis focused on materials from in and around Features 1 and 2, assigned to the Bell/Andice assemblage of the Middle Archaic period according to Collins (2004). A total of 193 pieces of lithic debitage weighing 480.3 g from levels associated with Bell/Andice Features 1 and 2 in TUs 5 and 6, and 5-Extension were subjected to analyses. These pieces were analyzed primarily following the TxDOT Lithic Protocol Version 2.1 for debitage analysis (TxDOT 2010). This limited debitage assemblage combined with the multiple categories employed during the analysis yields low numbers per individual category. Therefore, conclusions from this analysis may be skewed and misrepresent our understanding of the broader cultural processes involved if a much larger assemblage were analyzed. We trust the following information provides at least some insights into the broader knapping trajectories and strategies employed around these two similar features by the occupants.

Visual raw material assessment reveals near complete use of chert, which accounts for nearly 94 percent. Remaining materials include orthoquartzite (3.6 percent) and chalcedony (2.3 percent). Nearly 61 percent of the chert was identified as Edwards chert based on colors, color patterns and UV fluorescence. Under the short wave UV light the non-Edwards chert generally reveals a dark fluorescence, mottled dark colors and/or a mauve or dark mauve appearance. A single small piece has the appearance similar to Alibates, but potentially is an outlier of Edwards chert. In addition to this one questionable piece, no nonlocal material was detected. Given the very low frequency of nonchert, these pieces were incorporated into the rest of the analysis as part of the analyzed assemblage.

The 193 pieces were assessed for completeness. Thirty-two percent were complete or had platforms still present. The remaining 68 percent lacked platforms and are considered shatter. The relatively small percentage of complete flakes limits our overall understanding of the strategies employed. The shatter may reflect human trampling around the features.

The majority of the debitage is quite small, and as size increased, the frequency decreases sharply. Employing the nested sieves as directed (TxDOT 2010), 71 percent of the debitage fell in the 6.4 mm (¼ in.) sieve, with 17.6 percent in the 12.8 mm (½ in.) sieve, 8.2 percent in the 19.2 mm (¾ in.) sieve, and only 3.1 percent were retained in the 25.6 mm (1 in.) sieve. As expected, the smallest size category contained the highest percentage of whole flakes (44 percent) followed by those in the 12.8 mm (½ in.) size category (26 percent). The small size of most whole flakes may reflect resharpening of tools as individuals attended to the features.

Cortex was documented in 25 percent increments. Eighty percent of the debitage lacks cortex. About 10 percent has between 1 and 25 percent cortex with the other 10 percent roughly divided between the other three categories. The 20 percent with cortex has nearly twice as many pieces with rough cortex compared with smooth, water worn cortex. The latter probably reflects rounded cobbles from a secondary context, such as upland gravels or river beds. The rough exterior pieces imply probable extraction directly form a primary context such a as limestone bed, which in this case is most likely represented by the Gorman materials.

Thermal alteration was observed on only 23 percent, with nearly 89 percent of the thermally atlered pieces exhibiting crazing and/or potlidding. These latter pieces had been subjected to extreme heat, possibly as accidental or intentional discard into fires. Only about 11 percent may reflect possible heat treatment to improve flaking. Of the five pieces with possible heat treatment appearance, three are of Edwards chert and two are unidentified cherts. Crazed and potlidded pieces are nearly equally divided between Edwards and other cherts. As expected, after subjected to extreme heat, pieces often were reduced in size with half of those heat altered, in the smallest size category.

Ninety-nine pieces exhibit some type of platform. Nearly 54 percent were considered multifaceted, followed by 28 percent with flat platforms, 9 percent have crushed, 5 percent with cortical, and 4 percent with single faceted platforms. Single faceted platforms exhibit no cortex followed by crushed platforms with the second least in small amounts. Cortical platforms have the greatest amount per piece and are quite infrequent. Flat and multifaceted platforms exhibit the highest number of pieces with cortex, mostly in amounts less than 50 percent.

From the above analysis, Edwards chert was selected for and/or most readily available in this limited assemblage. It was almost never heat treated (three pieces) to improve workability. Multiple chert cobbles were reduced in the vicinity as evident by pieces with two types of cortex. Lack of cortex in most pieces, in combination with the overall small size of the vast majority probably reflects resharpening of tools or breakage of informal tools in the vicinity of Features 1 and 2. The absence of abraded platforms is also an indirect indication formal tool manufacturing was not conducted immediately adjacent to these cooking features. Lack of complex platforms indicates most resharpening and reduction did not target bifacial tools. Knapping tasks around Features 1 and 2 created opportunities for pieces to be incorporated into features and/or hot context in which pieces became crazed and potlidded. The high frequency of broken pieces may also relate to intense human activity around these cooking features during the occupation.

Thirty other pieces were judgmentally selected from associations with Features 1 and 2 and subjected to INAA (TRC319 through TRC348). Details of the chemical procedures and results are presented in Appendix C with a summary of results presented here. Chemical results represent 4 of MURR's 14 existing chemically identified compositional groups in the Texas chert database (Table 7-8; Appendix C). Forty-three percent of 41MS69 pieces are chemically similar to general Edwards chert scattered across the broader Edwards Formation outcrop. Thirty percent are similar to Edwards chert from Wright Creek in Kerr County (Appendix C). Twenty percent are similar to Gorman Formation cherts from the immediate area. Roughly seven percent are chemically similar to the Edwards chert from the Llano River gravels sampled immediately below 41MS69 (Table 7-8).

7.3.2 Chipped Stone Tools

The 8.9 m^3 hand-excavated area yielded 94 chipped stone tools, which include: 52 edge-modified flakes, 21 projectile point fragments, 18 bifaces, 2 scrapers, and 1 uniface (#73-12). The average density was less than one tool per 10 cm level. One complete Pedernales point (#102-10) was between 60 and 100 cmbs without exact provenience from the road cut surface at Column 3. Other diagnostic points include; one Marcos, one Montell, two additional Pedernales, one Bulverde (#103-10), one Andice (#33-10) (Figure 7-17), and one Travis, (#71-10) (Figure 7-18) (Turner et al. 2011). Data for all projectile point fragments is listed in Appendix L.

The shallowest and youngest point identified was the Marcos point (#23-10) from 20 to 30 cmbs in TU 4. The Marcos point was slightly above a Montell point (#4-10) from 36 cmbs in TU 1 towards the northern end. The Montell point appeared near the top of the burned rock midden. It was associated with 87 pieces of lithic debitage and 52 burned rocks in the same level. Two Pedernales points were from deeper context. One Pedernales stem section (#26-10) was between 50 and 60 cmbs in TU 4, which was stratigraphically below the Marcos point. A second Pedernales stem (#73-10) was between 70 and 80 cmbs in TU 9. This latter stem also appeared stratigraphically in context. The Bulverde point (#103-10) was collected *in situ* from the exposed road cut at 125 cmbs just below the base of TU 10 and just above the highest natural gravel lens. In TU 8, stratigraphically below the Pedernales point, a Travis point (#71-10) was discovered at 138 cmbs. The Bulverde point was above the Travis point, although the deposits sloped up between these two points. The sloping deposits create doubt concerning their positions in relationship to one another. The Bulverde point was manufactured from Edwards chert, which

Table 7-8. INAA Results on Lithic Debitage associated with Bell/Andice Assemblage Features 1 and 2 (data from Appendix C).

Test Unit	Depth (cmbs)	TRC PNUM	Feature Association	MURR ID. NO.[1]	Wright Creek[2]	Gorman Formation[3]	Edwards Formation[4]	Llano River Gravels[5]
5	130-140	32-1-1	1	TRC319	**70.843**[6]	14.213	23.539	7.102
5	130-140	32-1-2	1	TRC320	**28.297**	9.253	24.246	8.292
5	130-140	32-1-3	1	TRC321	8.371	37.64	**58.439**	3.596
5	130-140	32-1-4	1	TRC322	59.341	12.024	**59.41**	9.116
5	140-150	33-1-1	1	TRC323	1.421	**78.115**	27.733	14.272
5	140-150	33-1-2	1	TRC324	7.037	7.176	3.58	**10.46**
5	140-150	33-1-3	1	TRC325	61.77	17.928	**83.941**	6.407
5	140-150	33-1-4	1	TRC326	29.184	**53.294**	7.902	1.799
5	160-170	35-1-1	2	TRC327	10.15	5.279	**15.25**	1.246
5	160-170	35-1-2	2	TRC328	11.024	26.237	**36.349**	4.949
5	160-170	35-1-3	2	TRC329	**42.189**	11.542	12.664	0.456
5	160-170	35-1-4	2	TRC330	**56.223**	7.226	1.176	0.387
5	160-170	35-1-5	2	TRC331	1.282	**17.408**	7.916	1.685
5	160-170	35-1-6	2	TRC332	**78.485**	16.807	43.282	0.526
5	160-170	510-1	2	TRC333	0.071	**20.785**	9.306	2.446
5	170-180	511-1	2	TRC334	12.659	6.307	**51.782**	6.809
5	170-180	511-2	2	TRC335	17.059	36.596	**61.463**	3.651
5	170-180	511-3	2	TRC336	11.6	22.121	**59.401**	2.578
5, Exten.	160-170	39--1-1	2	TRC337	65.368	15.381	**71.853**	49.775
5, Exten.	160-170	39-1-2	2	TRC338	6.185	16.868	**75.83**	5.861
5, Exten.	130-140	503-1-1	1	TRC339	**65.355**	22.811	57.988	1.182
5, Exten.	130-140	503-1-2	1	TRC340	59.993	19.08	**86.82**	3.23
5, Exten.	130-140	503-1-3	1	TRC341	0.494	27.233	**40.408**	2.035
5, Exten.	130-140	503-1-4	1	TRC342	**73.978**	18.518	46.205	0.751
6	140-150	42-1-1	1	TRC343	0.262	**7.661**	0.013	1.337
6	140-150	42-1-2	1	TRC344	**44.141**	12.275	40.668	0.815
6	140-150	42-1-3	1	TRC345	3.137	15.475	**33.317**	0.543
6	170-180	515-1-1	2	TRC346	**47.769**	21.674	44.876	2.191
6	170-180	515-1-2	2	TRC347	0.489	21.472	36.922	**39.262**
6	170-180	515-1-3	2	TRC348	1.131	**24.126**	10.952	3.686

[1] University of Missouri laboratory number

[2] Wright Creek in Kerr County, Texas is variation of Edwards chert by Hudler 1998

[3] Present study

[4] Fort Hood study by Frederick et al. 1994

[5] Present study

[6] Bold numbers equal percentage of probability in that group (see Appendix C)

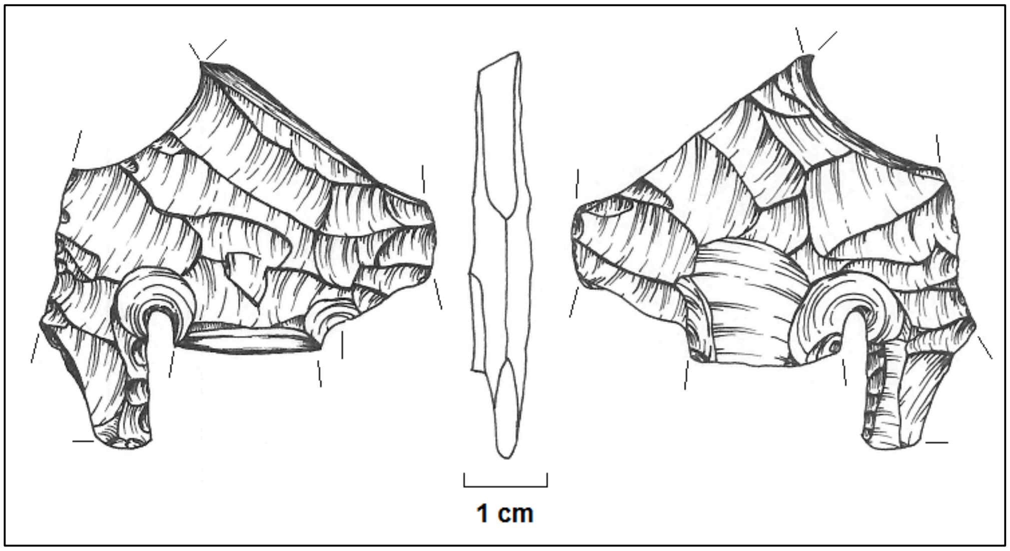


Figure 7-17. Line drawing of Andice point fragment from next to Feature 1 (drawing by Meghan Bruckse-Bury).

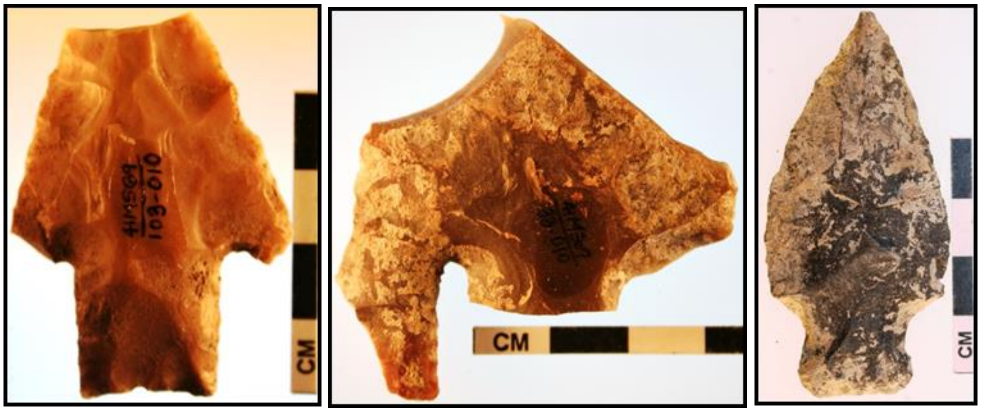


Figure 7-18. Unwashed dart points: Bulverde base (#103-10), Andice midsection (#33-10), and complete Travis (#71-10).

apparently was collected from the Llano River gravels adjacent to the site based on INAA (TRC355) (Appendix C).

The broken Andice point (#33-10) was from 146 cmbs in TU 5 and in immediate proximity with the basin hearth Feature 1, as it was about 90 cm west of the feature margin. The Andice point was manufactured from very dark gray (7.5YR 3/0)Edwards chert that fluoresces a yellow, which chemically resembles Edwards chert form Wright Creek in Kerr County based on INAA (TRC354, Appendix C). This piece has a fine texture, a dull luster, and no apparent heat treatment, or cortex. High-powered use-wear was conducted with no evidence of use or residues. Lack of wear probably indicates it had a short use life (Appendix G).

The Andice point was slightly lower in the vertical profile than the Travis point, although the points were from separate units roughly 2 m apart. The Travis point and one complete Pedernales point from Column 3 did not fluoresce a bright yellow like other Edwards chert pieces. These latter two points were manufactured from non-Edwards Plateau chert based on visual appearances. These

Figure 7-19. Small unnotched biface/arrow point (#19-11).

diagnostic dart points were from generally intact, stratified cultural deposits and document use a period from about 4,800 to 2,000 B.P. based on Collins's (2004) chronology.

A single relatively small unnotched, triangular biface (#19-11; from 30 to 40 cmbs in TU 3) might fit into an arrow preform category size range, as it is similar in outline to Fresno points of the Late Prehistoric period (Figure 7-19). Its function is not clear, although it probably did not served as a projectile. It was in a level with 49 burned rocks, 2 mussel shells, and 134 pieces of lithic debitage.

Nothing remarkable was observed about the other chipped stone tools, with the possible exception of one long narrow biface (#30-10) that is steeply beveled on opposite edges (Figure 7-20). Unfortunately, this biface was from overburden context above TUs 5 and 6. Two bifaces, one each from near Features 1 and 2 (#38-10 and #511-10, respectively), were sourced through INAA and determined chemically similar to Edwards Formation cherts (TRC 356 and TRC357) (Appendix C). Biface #38-10, a crude or early stage biface, contained hair and collagen residues along with soft polish, which is interpreted as having served in cutting or butchering hides (Appendix G). Biface #511-10 had bark wood and hard/high silica polish and was thought to reflect cutting wood (Appendix G).

A single broken scraper fragment (#36-11) was from TU 5 between 180 and 190 cmbs (Figure 7-21). This context was just below Feature 2 in a yellowish-brown (10YR 5/4) sediment along with an edge-modified flake (#36-10) and scattered burned rocks. This tools age is probably greater than 5400 B.P. if it did not get displaced downward from Feature 2. This broken piece measures 35.5

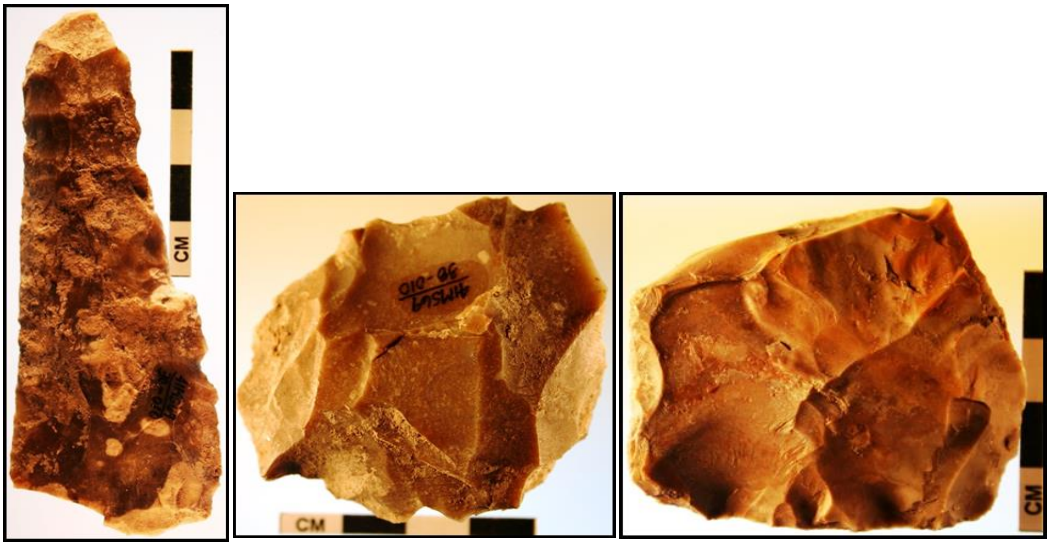


Figure 7-20. Long narrow biface (#30-10, left), proximal biface fragment (#38-11, middle), and crude complete biface (#38-10, right).

Table 7-9. Edge-Modified Flake Data from in and around Features 1 and 2.

PNUM	Test Unit	Depth (cmbs)	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Weight (g)	Edge Angle 1 (degrees)	Edge Angle 2 (degrees)	Portion	Failure or Discard	Material Type	Technology Observations	Technical Analytical Results
31-11	5	120-130	52.0	43.1	6.8	10.8	42	41	Complete	Indet	Edwards Chert	Yellow Edwards UV,	Use-wear
31-12	5	120-130	19.4	36.0	10.1	4.1	66	0	Distal	Hinge / Step	Unknown Chert	Dark mauve UV, calcium carbonate build-up	Use-wear
32-10	5	130-140	21.2	25.2	4.5	1.7	59	0	Proximal-medial	Hinge / Step	Unknown Chert	Mottled mauve UV, calcium carbonate build-up	None
36-10	5	180-190	17.8	28.1	6.7	2.1	66	0	Complete	Indet	Fort Hood Chert # 31 Indeterminate mottled Chert	Off white opaque banding with lighter browns as well as darker browns, water worn cortex dorsal side, bright yellow UV	Use-wear
37-10	5	190-200	67.2	71.9	18.0	51.5	61	0	Complete	n/a	Fort Hood Chert # 31 Indeterminate mottled Chert	Off white opaque banding with lighter browns as well as darker browns, water worn cortex dorsal side, Yellow UV	Use-wear
38-11	5 Ext.	120-130	54.4	54.9	10.5	33.8	60	58	Distal-medial	Snap / end shock	Fort Hood Chert # 31 Indeterminate mottled Chert	Mottled with light gray, dark gray, tan, brown and reddish colors with crystalline inclusions. Not Edwards, Mottled Mauve UV, calcium carbonate build-up	Use-wear

Table 7-9. Edge-Modified Flake Data from in and around Features 1 and 2 (continued).

PNUM	Test Unit	Depth (cmbs)	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Weight (g)	Edge Angle 1 (degrees)	Edge Angle 2 (degrees)	Portion	Failure or Discard	Material Type	Technology Observations	Technical Analytical Results
41-10	6	130-140	70.9	52.3	12.3	36.9	49	0	Complete	n/a	Fort Hood Chert #35 Indeterminate dark brown Chert	TRC 350 INAA, Mottled yellow, cortex is rough	Use-wear
41-11	6	130-140	33.3	48.2	13.2	23.0	55	65	Proximal-medial	Snap / end shock	Fort Hood Chert #35 Indeterminate dark brown Chert	TRC 351 INAA, Yellow UV	Use-wear
42-11	6	140-150	27.7	29.9	12.6	10.1	66	0	Proximal-medial	Snap / end shock	Fort Hood Chert #35 Indeterminate dark brown Chert	TRC 352 INAA, Mottled Yellow UV, smooth cortex	Use-wear
42-12	6	140-150	25.8	29.3	4.0	3.0	64	0	Proximal-medial	Snap / end shock	Fort Hood Chert #34 Indeterminate light brown Chert	TRC 353 INAA, Mottled mauve and purple UV, Not Edwards, banded light brown and white with light brown small inclusions	Use-wear
47-10	6	210-220	61.5	49.1	8.8	24.9	57	47	Proximal-medial	n/a	Fort Hood Chert #35 Indeterminate dark brown Chert	Yellow UV, light inclusions	Use-wear

Table 7-9. Edge-Modified Flake Data from in and around Features 1 and 2 (continued).

PNUM	Test Unit	Depth (cmbs)	Maximum Length (mm)	Maximum Width (mm)	Maximum Thickness (mm)	Weight (g)	Edge Angle 1 (degrees)	Edge Angle 2 (degrees)	Portion	Failure or Discard	Material Type	Technology Observations	Technical Analytical Results
47-11	6	210-220	34.2	19.7	6.7	4.7	62	69	Distal-medial	Snap / end shock	Fort Hood Opalite # 29 Indeterminate white Opalite	Mottled mauve UV, Not Edwards possibly Opalite, white, gray and tan banding	Use-wear
47-12	6	210-220	29.9	42.4	12.5	12.2	62	0	Distal-medial	Indet	Fort Hood Chert # 36 Indeterminate black Chert	Mottled orange UV, Not Edwards dark brownish black with light gray inclusions	Use-wear
47-13	6	210-220	12.0	10.0	1.9	0.2	53	0	Medial	Indet	Edwards Chert	Yellow UV	None
48-11	6	220-230	17.0	10.1	5.2	0.7	60	0	Complete	Indet	Unknown chert-chalcedony blend	Dark mauve UV	None
511-11	5	179	47.6	20.7	9.4	9.3	70	69	Complete	Indet	Unknown chert-chalcedony blend	Mottled mauve UV	None

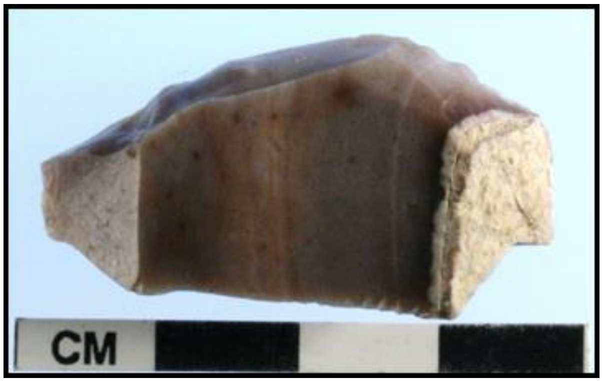


Figure 7-21. Scraper Fragment (#36-11).

Figure 7-22. Mano (#104-10) from surface of road cut next to Feature 2, submitted for starch grain analysis.

mm long, 21.4 mm wide, 8.0 mm thick, and weighs 6.7 g, with only a 10.6 mm long worked edge remaining with one broken side opposite the worked area. Adjacent to the worked area is what appears as an intentional removal of the steep working edge as a potential rejuvenation. The ventral surface is flat as is most of the dorsal surface with steep lateral edges. This scraper was manufacture from banded Edwards chert that fluoresces a bright yellow.

Fifty-two edge-modified flakes were identified with 16 from in and around Features 1 and 2 analyzed (Table 7-9). Five edge-modified flakes (#31-10, #41-10, #41-11, #42-11, and #42-12) from near Feature 1 in TU 6, between 130 and 150 cmbs were sourced through INAA. All five (TRC350 through TRC354) are chemically similar to Edwards Formation cherts (Appendix C). The other is also Edwards chert with a chemical signature similar to Wright Creek in Kerr County (Appendix C). Three of the ten edge-modified flakes (#38-11, #41-11, and #47-11) subjected to high-power use-wear exhibited no microscopic resides or use-wear and therefore, had unknown functions (Appendix G). The other seven pieces were employed on hard and soft materials and included minimally whittling hard plants (#37-10), cutting hard, high silica plants (#47-12), and cutting hide and/or butchering (#42-11 and #42-12) (Appendix G).

About 35 percent of the recognized chipped stone tools, which include; bifaces, points, and edge-modified pieces, do not fluoresce a bright yellow color similar to known Edwards chert pieces. Apparently, non-Edwards Plateau chert was not extensively used. These pieces are probably dominated by the local Gorman Formation cherts, as obvious nonlocal materials were not identified.

7.3.3 Ground Stone Tools

This category contains eight items, two metate fragments that refit, three manos, two hammer stones, and one combination mano/hammer stone. Ground stone is relatively infrequent in most central Texas sites and is assumed to represent plant processing. One relatively small, complete mano (#104-10) (Figure 7-22) was in the road cut profile at 186 cmbs just south of Feature 2, which was dated to roughly 5305 B.P. This is the only ground stone tool from dated context. The mano measures 85.6 mm long, 78.9 mm wide, 59.4 mm thick, and weighs 604 g. It has one nearly flat face that measures roughly 66 mm across with a very slight convex surface. The remaining sides and surfaces appear purposefully shaped with small pecked indentations across all surfaces, except the flattened face. Starch grain analysis yielded no starch grains (Appendix I).

The two refit metate sections were vertically displaced by 11 cm in TU 4. A mano from TU 1 was in the same 10 cm level as the Montell point and associated with burned rocks. It is not clear if the latter piece last served as a burned rock or a mano. No ground stone tools were associated with Feature 1.

7.3.4 Cores

Eight chert cores were identified and most exhibit water-rounded cortex. The majority are multidirectional cores with two to four platforms. In one instance at least two platforms are opposite one another to indicate bipolar flake removal. A single core (#6-12) was identified in the six units started from the top of the terrace. Four cores were recovered from 90 to 110 cmbs in TUs 9 and 10. Four cores do not fluoresce a similar color to known Edwards chert pieces and probably reflect local cherts from other formations. Only two of the eight cores are assigned a general period of use and are those associated with Features 1 and 2, dated to the Middle Archaic period. These two assigned cores are discussed in greater detail below.

Two cores were recovered from TU 5 with one (#511-11) associated with Feature 2 and the other (#31-001) from 129 cmbs associated with Feature 1. This latter core measures 88.1 mm long, 87.2 mm wide, 27.4 mm thick, and weighs 186.5 g. This is a multiple directional core bifacially reduced (Figure 7-23). Cortex was completely removed from one face and covers roughly 50 percent of the opposite face. The face with cortex also reveals two sizable potlids in the cortex. This bifacial core is of gray (10YR 6/1) Edwards chert with white (7.5YR 8/0) spots, and a mottled yellowish-orangish fluoresces. A piece of the core was chemically analyzed with results similar to Edwards cherts from Wright Creek in Kerr County (TRC349) (Appendix C).

The other core (#511-11) measures 40.9 mm long, 39.2 mm wide, 32.1 mm thick, and weighs 52.9 g.

Figure 7-23. Edwards chert core (#31-11).

Figure 7-24. Small core (#511-11) of non-Edwards chert.

This small mottled piece has bands of reddish-yellow (5YR 6/6) to yellowish-red (5YR 5/6) on dominate light brown (7.5YR 6/4) chert. It also reveals rough cortex on two opposite sides (Figure 7-24). This piece apparently represents chert extracted from a bed or lens rather than a water worn cobble. This is not Edwards chert and it fluoresces a dark color under UV light. Two platforms are present, opposite each other and initiated from the cortex area. Flake scars are limited with a few fractured along internal fracture lines. The small size and fracture plans may account for it limited use.

7.3.5 Faunal Remains

The 8.9 m^3 hand-excavations yielded 86 bone fragments and most are small unidentifiable fragments. A nearly complete, severely root and acid etched astragalus/talus and calcaneus from a large ungulate (e.g., cow, bison, etc.) were identified (Figure 7-25). These elements were mixed with dense burned rocks in the burned rock midden context in TU 2 at 49 cmbs. The calcaneus was radiocarbon dated and yielded a $\delta^{13}C$ (-24.2‰) corrected AMS date of 114.8 ± .5 pMC (UGA-14108) or modern age. Apparently this was a modern cow element displaced nearly 50 cm into this burned rock midden deposit. The element age combined with the $\delta^{13}C$ value reveals a very dominant C_3 plant consumer. The latter indicative of a modern cow rather than a C_4 grazing bison. Consequently, the other 55 bone fragments from TU 2, and potentially the cow bones, were probably displaced rather than originally associated with the midden burned rocks. This date combined with the depth of the modern cow element indicates at least the top 50 cm of this much thicker burned rock deposit represents disturbed midden deposits. Test Unit 2 was beyond the apparent disturbed midden, and the specific location appeared intact when excavations began.

A small concentration of badly weathered bone fragments ($N = 25$ fragments or 28.7 percent of the total recovered bones) was between 10 and 20 cmbs in TU 4. These appear to represent the partial remains of a cottontail. It is not clear if these bones were the result of the cultural activity or natural. In support of a cultural origin, a small calcined bone fragment of a rabbit size long bone was from 40 to 50 cmbs in TU 1. Another small calcined long bone fragment of a medium size mammal was from 80 to 90 cmbs in TU 10. A fragment of a partially burned turtle shell was from 200 to 210 cmbs in TU 6. Most bone fragments, except for the calcined pieces, exhibit extensive root and acid etching, common in this existing treed environment. Other animal bones were potentially part of the occupations. Poor preservation conditions have probably destroyed most bones, except when burned or calcined. No animal bones were associated with Features 1 and 2.

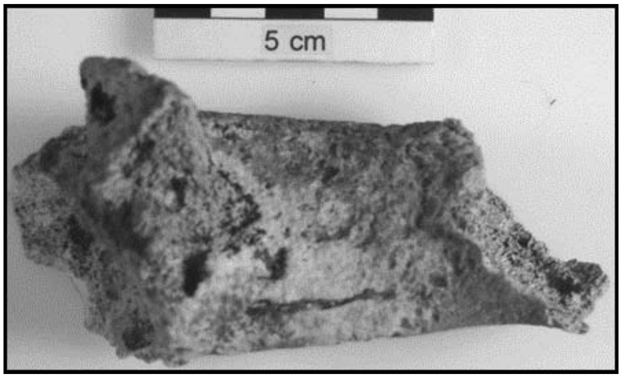


Figure 7-25. Large, weathered ungulate calcanium radiocarbon dated to modern times.

7.3.6 Mussel Shell

The 8.9 m^3 hand-excavations yielded 52 partially complete shell values, a few with hinges, but most without. These shells ranged in-depth from 10 to 20 cmbs in TU 1 to 230 cmbs in TU 6. No shell concentrations were encountered. Individual fragments were associated with multiple cultural events. No shell fragments appear intentionally modified by humans to form tools or decorations. Four shells were directly associated with Feature 1 and six with Feature 2 and range in time from 4800 to 5400 B.P. (Table 7-9). A few shells from Column 1, which cut through Features 1 and 2 were probably associated with one of these two features (Table 7-10). One unidentified shell fragment (#506-6) from Feature 1 is burned to a dark color documenting its cultural use. If mussels were part of the occupant's food resources during the events at Features 1 and 2, they served a very minor role.

Eleven shell fragments appeared in the burned rock midden or lens in the top of the terrace in TUs 2 and 3. The fragments were scattered over nine of the ten test units and two of the five columns. At least four species are represented and include: Smooth

Table 7-10. Observations on Mussel Shell Pieces from in and around Features 1 and 2.

PNUM	Unit	Depth (cm)	Feature	Species	Count	Weight (g)	Portion	Heat Altered
34	5	155	1	Texas Lilliput	1	2.5	Complete	No
38	5 Ext.	120-130	1	Smooth Pimpleback	1	3.6	Hinge	No
39	5 Ext.	163-170	2	Smooth Pimpleback	1	2.9	Hinge	No
39	5 Ext.	163-170	2	Indeterminate	1	0.8	Fragments	No
39	5 Ext.	163-170	2	Texas Pimpleback	1	21.1	Complete	No
47	6	210-277		Texas Pimpleback	1	3.3	Hinge	No
48	6	210-277		Smooth Pimpleback	1	3.8	Hinge	No
503	5 Ext.	141	1	Smooth Pimpleback	1	3.4	Hinge	No
506	5 Ext.	150	1	Indeterminate	1	1.0	Hinge	Yes
510	5	165	2	Indeterminate	5	2.7	Tooth	No
514	6	170	2	Smooth Pimpleback	2	5.5	Hinge	No
515	6	176	2	Smooth Pimpleback	1	9.0	Complete	No

Figure 7-26. Examples of mussel shells from 41MS69 (three Smooth Pimpleback and one Texas lilliput- right).

Pimpleback (*Quadrula houstonensis*), Texas Pimpleback (*Quadrula petrina*), Threeridge (*Amblema plicata*), and Texas lilliput (*Toxolasma parvus*) (Figure 7-26).

7.3.7 Charcoal

The 8.9 m^3 excavations yielded 45 samples of what appear as wood charcoal. These pieces were from 20 to 428 cmbs within five different excavation units and extracted from the columns. Test Units 1 through 4 yielded the fewest pieces. Almost no charcoal was directly associated with the northern burned rock midden (Table 7-11). Culturally associated charcoal was directly dated between 940 and 5120 B.P. A piece of charcoal from 428 cmbs and below the cultural materials, which is part of sediment Zone 10 near the base of Column 2, yielded $\delta^{13}C$ (-23.4‰) corrected AMS date of 6330 ± 50 B.P. (UGA-14115). This indicates charcoal can and did survive at this site for a long period. This date provides a maximum age for cultural components above that zone.

Seventeen potentially identifiable charcoal samples were submitted to Dr. J. Phil Dering. All samples contained wood charcoal with Texas persimmon (two samples), oak (nine samples), and woody legume (two samples) identified (see Table 7-11). Oak wood was associated with Features 2 and 3. No juniper was identified, although it is prevalent in the area today. This might indicate a cultural selection process, differential preservation of wood types, or the treed environment has changed over the years.

Table 7-11. Charcoal Identifications, 41MS69.

Catalog No.	Feature. No.	Taxon	Common Name	Part	Count	Weight. (g)
36-007-2	--	*Diospyros texana*	Texas persimmon	Wood	3	+
37-007-1	--	*Quercus* sp.	Oak	Wood	5	+
110-007	--	Indeterminate hardwood	NA	Wood	2	+
516-007-1	3	*Quercus* sp.	Oak	Wood	9	0.2
514-007-2	--	*Quercus* sp.	Oak	Wood	11	0.1
45-007	--	*Quercus* sp.	Oak	Wood	10	0.1
37-007-4	--	Indeterminate hardwood	NA	Wood	20	0.1
514-007-4	2	Indeterminate hardwood	NA	Wood	9	+
36-007-1	--	*Quercus* sp.	Oak	Wood	9	0.6
511-007-1	--	Indeterminate hardwood	NA	Wood	8	+
37-007-3	--	*Diospyros texana*	Texas persimmon	Wood	32	1
36-007-6	--	*Quercus* sp.	Oak	Wood	9	0.1
100-007	--	*Quercus* sp.	Oak	Burl-wood	5	0.5
36-007-3	--	Fabaceae	Woody legume-type	Wood	7	0.1
41-007	--	*Quercus* sp.	Oak	Wood	2	0.1
18-007	--	*Quercus* sp.	Oak	Wood	8	1.1
3-007	--	Fabaceae	Woody legume-type	Wood	3	0.1

7.3.8 Burned Rocks

The hand-excavations yielded 3,898 burned rocks that weighed 1,430,022 g. Nearly all were limestone. Most burned rocks were measured and counted for the different size classes in the field and then discarded. These varied in size from about 2 to 20 cm in diameter, with the 4.1 to 9 cm size class dominating. The burned rock midden at the northern end, Feature 1 and Feature 2 account for 7, 3.2, and 11.8 percent, respectively, of the total count of burned rocks. These three features account for about 22 percent of the burned rocks by count or 29 percent by weight. Burned rocks in the northern midden from TU 2 averaged about 77 g, compared to the average weight of the rocks in hearth Feature 1 at 490 g and Feature 2 at 267 g. Burned rock frequency exhibited extreme variability between units (see Table 7-5) and in vertical provenience. Depths of individual burned rocks were depth indicators of the various occupations and/or events, since they tend to move much less than the smaller cultural items. Burned rock samples from selected proveniences, Features 1 and 2, were collected and returned to the laboratory for potential analyses. Forty-one burned rocks were subjected to starch grain (N = 18) and lipid residue (N = 23) analyses to gain understanding of potential food residues cooked in Features 1 and 2. Selected samples will be curated for future analyses.

7.3.9 Snail Shells

About 308 complete snail shells were collected, with more noted on the level records and discarded in the field. Rough counts were documented in the field and limited samples were collected. Samples from TUs 1, 5, and 10, plus Column 2, were collected for potential analysis. These samples are dominated by *Helicina* species with very few *Rabdotus* shells present. No snail shells were recovered from the nearly 80 cm thick burned rock midden in TU 2. *Helicina* shells were more common than *Rabdotus* shells in the deeper levels such as level 80 to 90 cmbs in TU 10, and were dominate in Features 1 and 2. In TU 1 the highest density of snail shells was between 30 and 40 cmbs and was associated with a moderate frequency of burned rocks.

7.3.10 Summary of Material Classes

The multiple artifact classes indicate diverse activities occurred in the APE at the Slippery Slope site. These activities include, but not limited to; cooking, stone tool manufacturing and resharpening, animal processing, and camp cleaning and discard activities. Horizontal dispersion of the cultural materials and features reflect different use areas during each occupation. Vertical differences in the cultural materials from the northern to the southern end reflect the structure of the alluvial deposits as they thinned away from the river and how they preserved at this 100+ m long location. These diverse activities occurred sporadically over the last 5,400 years by mobile hunter-gatherers who occupied different parts of this terrace overlooking the river. The local environment obviously provided essential resources necessary to sustain their lifeways.

7.4 VERTICAL MATERIAL DISTRIBUTION

The following discussion focuses on the vertical distribution of cultural materials within the alluvial deposits exposed in this 5.5 m tall road cut and detected in the test units. This assessment phase employed ten test units dispersed across this 100 m long, narrow APE, which permitted identification of multiple stratified events. Through this strategy and the aid of the geoarcheological work, major vertical differences were detected between the two ends of the APE. Multiple cultural events were well-stratified in the southern end, and appeared compressed towards the northern end. Consequently, individual events could not be traced horizontally because of the vertical assessment strategy employed in this assessment.

The southern end of the exposure exhibited cultural deposits as deep as 250 cmbs within alluvial Unit 3. In TU 1 at the very northern end of the exposure, the cultural deposits were roughly 100 cm deep within alluvial Unit 3. Cultural events in the southern end slope upward and pinch out or became compressed toward the northern end. Cultural materials identified in the APE at 41MS69 were confined to alluvial Unit 3. This deposition period began around 5,400 B.P., but has a poorly defined termination date at roughly 2,000 B.P. No notched or stemmed diagnostic arrow points were recovered. Only one radiocarbon date of 940 B.P. (Table 7-12, Figure 7-27) falls within the Late Prehistoric period. This young radiocarbon date was 20 to 30 cmbs near the top of the burned rock midden in TU 1 at the northern end, and the dated charcoal may be intrusive. The latter is assumed since none of the identified events yielded Late Prehistoric diagnostic items. However, many occupations in the upper part of the profile across the southern end did not yield diagnostic projectile points or were dated directly through radiocarbon analyses. Consequently, Late Prehistoric occupations may be present, but not identified.

The top of the road cut across the northern half of the steep exposure had an irregular and somewhat vertical exposure. This roughly 1 m tall, mostly vertical face exhibited a 10 to 60 cm thick burned rock lens or midden with irregular thickness. This was the area where looting had occurred (see Figure 5-1). Obvious cultural events in addition to the looted burned rock lens were not exposed in the lower road cut deposits, although a few scattered burned rocks were observed below the burned rock lens in the tall slumping profile. The five vertical Columns, 1 through 5, exposed not only the natural deposits, but cultural events as well. Near the very southern end Column 1 revealed a two partial clusters of cultural materials (Features 1 and 2), subsequently explored by hand-excavations. Column 2, also in the southern end, exposed Feature 3. A burned rock lens or midden was exposed towards the north half of the APE in the top 1 m of the road cut and in at least TUs 1 and 2 and possibly TU 3 (Figure 7-28 and 7-29).

The burned rock lens or midden exposed along the top of the road cut at the northern end extended sporadically for at least 75 m along the northern two-thirds of the exposure. This lens did not appear present in screened Column 3 deposits (see Figure 7-1). Column 3 did not yield any lithic debitage and only three small burned rock fragments in the upper 60 cm. Multiple burned rocks, 13 pieces of lithic debitage, and a Pedernales point base, were between 65 and 77 cmbs in Column 3. It is not clear if this culturally productive zone sloped up to become part of the burned rock midden or not. Exact thickness of the exposed burned rock lens was difficult to isolate as many burned rocks were scattered across the slope from looting activities and slumping. This lens appeared to vary from 10 to 60 cm thick in various looted exposures. No investigations were conducted west of the existing north-south fence line. Observations west of the fence indicated the midden continued, was much more extensive, and exhibited extensive looting west of the fence.

Test Unit 2 and possibly TU 3 appeared to penetrate this looted burned rock lens or midden. In TU 2, a thick burned rock zone was present from 10 to at least 100 cmbs, or at least 90 cm thick (Figure 7-28). Nearly 28 m south of TU 2 in TU 3, potentially that same burned rock midden deposit, was roughly 20 cm thick with the highest frequencies of burned rock between 20 and 40 cmbs. It is unclear if the bottom of this burned rock lens was encountered in these two units, since TUs 2 and 3 were terminated prior to encountering sterile deposits. Test Units 1 and 4 exhibited multiple thin lenses of burned rocks, and were not considered the same lens (Figures 7-28 and 7-29). It is possible, although not demonstrated, the burned rock lenses detected in TUs 1, 3, and possibly 4 merged into the thick midden deposit encountered in TU 2. No horizontal or vertical

Table 7-12. Site 41MS69 Radiocarbon Data and Results.

Catalogue No.	Unit No.	Depth (Cmbs)	Feature No.	Material Dated	Weight of Material (g)	Lab. No.	Measured Age	13C/12 C Ratio (‰)	Conventional Age (B.P.)	2 Sigma Calibration Range
3-7a	1	20-30	BRM	Oak Charcoal	0.1	UGA 14109	940 ± 40	-25.0	940 ± 40	Cal AD 1010 to 1190
11-2	2	48	BRM	Bone		UGA 14108	114.8 ± .5 pMC	-24.2	Modern	Modern
106-7	Column 1	205		Charcoal	0.1	UGA 14112	lost			
107-4a	Column 1	224		Sediment	1000	UGA 14099	5200 ± 60	-22.0	5250 ± 60	Cal 4250 to 3950 BC
108-4a	Column 1	292		Sediment	1000	UGA 14100	4600 ± 50	-22.7	4640 ± 50	Cal 3630 to 3160 BC
109-4a	Column 1	395		Sediment	1000	UGA 14101	7990 ± 60	-20.0	8070 ± 60	Cal 7350 to 6700 BC
109-7	Column 1	395		Charcoal	0.1	UGA 14113	lost			
110-4a	Column 2	118		Sediment	1000	UGA 14102	2390 ± 40	-23.55	2410 ± 40	Cal 770 to 390 BC
110-7a	Column 2	122		Charcoal	0.1	UGA 14114	3480 ± 40	-25.2	3480 ± 40	Cal 1890 to 1680 BC
111-4a	Column 2	300		Sediment	1000	UGA 14103	7430 ± 60	-21.9	7480 ± 50	Cal 6430 to 6230 BC
112-4a	Column 2	427		Sediment	1000	UGA 14104	3140 ± 50	-22.2	3190 ± 50	Cal 1610 to 1310 BC
112-7a	Column 2	428		Charcoal	0.1	UGA 14115	6300 ± 50	-23.4	6330 ± 50	Cal 5470 to 5140 BC
113-4a	Column 4	176-180		Sediment	1000	UGA 14105	2520 ± 40	-21.21	2580 ± 40	Cal 830 to 540 BC
114-4a	Column 5	475		Sediment	1000	UGA 14106	9120 ± 70	-22.0	9170 ± 70	Cal 8560 to 8260 BC
516-7-1a	Column 2	111	3 ash	Oak Charcoal	0.1	UGA 14118	3500 ± 50	-24.75	3500 ± 50	Cal 1950 to 1680 BC
505-4-1d	5 Ext	151-154	1	Ashy Sediment		Beta-370497	3890 ± 40	-23.8	3910 ± 40	Cal 2490 to 2290 BC

Table 7-12. Site 41MS69 Radiocarbon Data and Results (continued).

Catalogue No.	Unit No.	Depth (Cmbs)	Feature No.	Material Dated	Weight of Material (g)	Lab. No.	Measured Age	13C/12 C Ratio (‰)	Conventional Age (B.P.)	2 Sigma Calibration Range
505-7-1a	5 Ext	152	1	Charcoal	0.1	UGA 14116	4840 ± 40	-21.7	4890 ± 40	Cal 3770 to 3540 BC
41-7	6	130-140		Charcoal		Beta-370495	4930 ± 40	-25.4	4920 ± 40	Cal 3780 to 3640 BC
505-7-1h	5 Ext	151-154	1	Charcoal		Beta-370496	4970 ± 40	-25.8	4960 ± 40	Cal 3890 to 3880 BC
505-7-2	5 Ext	152	1	Charcoal	0.1	Beta-233355	4950 ± 40	-21.7	5000 ± 40	Cal 3950 to 3700 BC
32-7-1c	5	134	1	Charcoal	0.1	Beta-233352	5090 ± 40	-26.1	5070 ± 40	Cal 3970 to 3770 BC
32-7-1a	5	134	1	Charcoal	0.1	UGA 14110	5140 ± 40	-25.0	5120 ± 40	Cal 3990 to 3790 BC
511-7-1a	5	177	2	Charcoal	0.1	UGA 14117	110.8 ± .4 pMC	-27.4	Modern	Modern
513-4a	5 Ext	180	2	Black sediment	283.0	UGA 14107	4730 ± 40	-24.5	4740 ± 40	Cal 3640 to 3370 BC
512-4-b	5	170-174	2	Ashy Sediment		Beta-370492	4530 ± 40	-23.9	4550 ± 40	Cal 2480 to 3100 BC
36-7-3	5	189	2	Charcoal	0.1	Beta-233354	5340 ± 50	-26.4	5320 ± 50	Cal 4320 to 4030 BC
514-7-2	6	166	2	Charcoal	0.1	Beta-233356	5340 ± 40	-23.5	5360 ± 40	Cal 4330 to 4050 BC
36-7-1	5	180	2	Charcoal	0.1	Beta-233353	5390 ± 40	-24.7	5390 ± 40	Cal 4340 to 4160 BC
511-7-1h	5	177	2	Charcoal		Beta-370493	5420 ± 40	-25.3	5420 ± 40	Cal 4340 to 4230 BC
45-7a	6	190-200	lowest cultural	Oak Charcoal	0.1	UGA 14111	5110 ± 40	-25.9	5100 ± 40	Cal 4460 to 4250 BC
37-7-3a	5	192		Charcoal		Beta-370494	5250 ± 40	-25.9	5240 ± 40	Cal 4230 to 4090 BC

BRM = Burned rock midden; UGA = Univewrsity of Georgia AMS laboratory number; B = Beta Analytic laboratory number: Ext = Extension

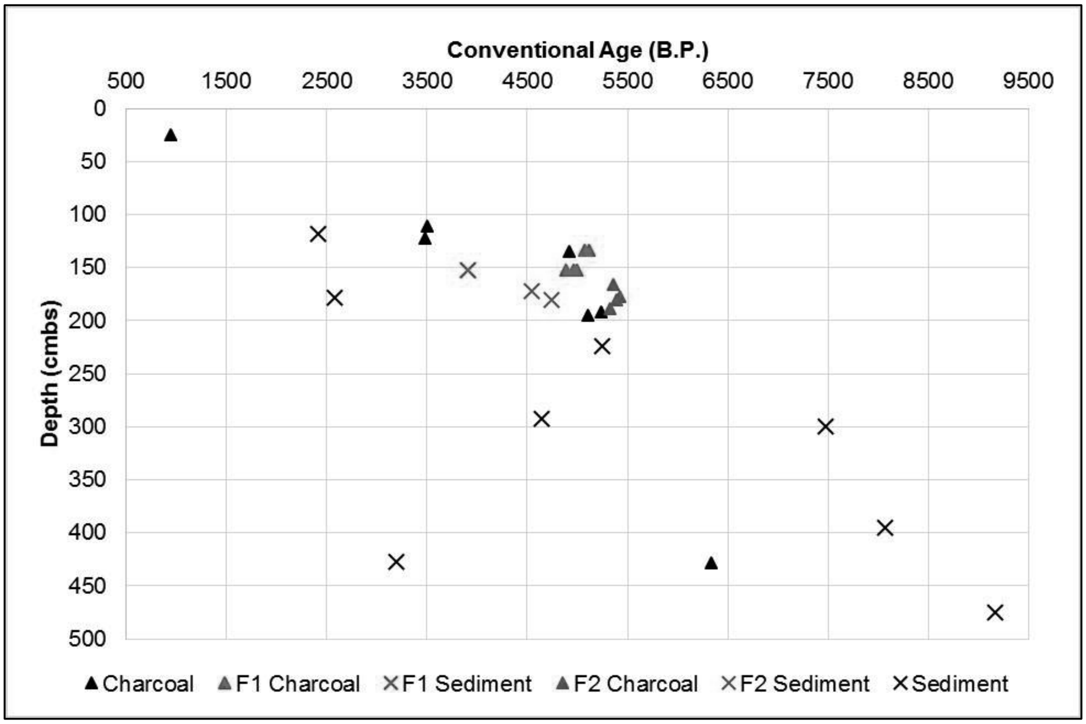


Figure 7-27. Graphic display of radiocarbon dates from 41MS69.

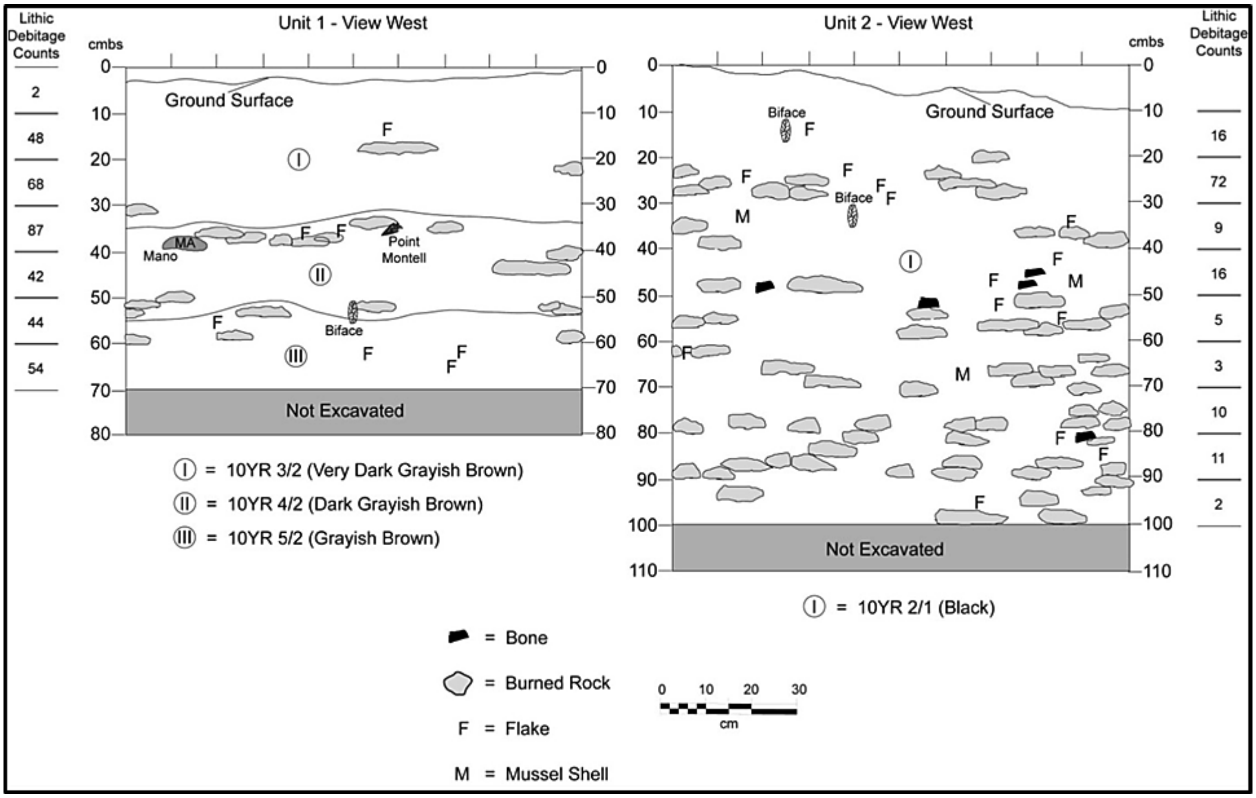


Figure 7-28. Vertical patterning of in situ plotted materiasl in TUs 1 and 2.

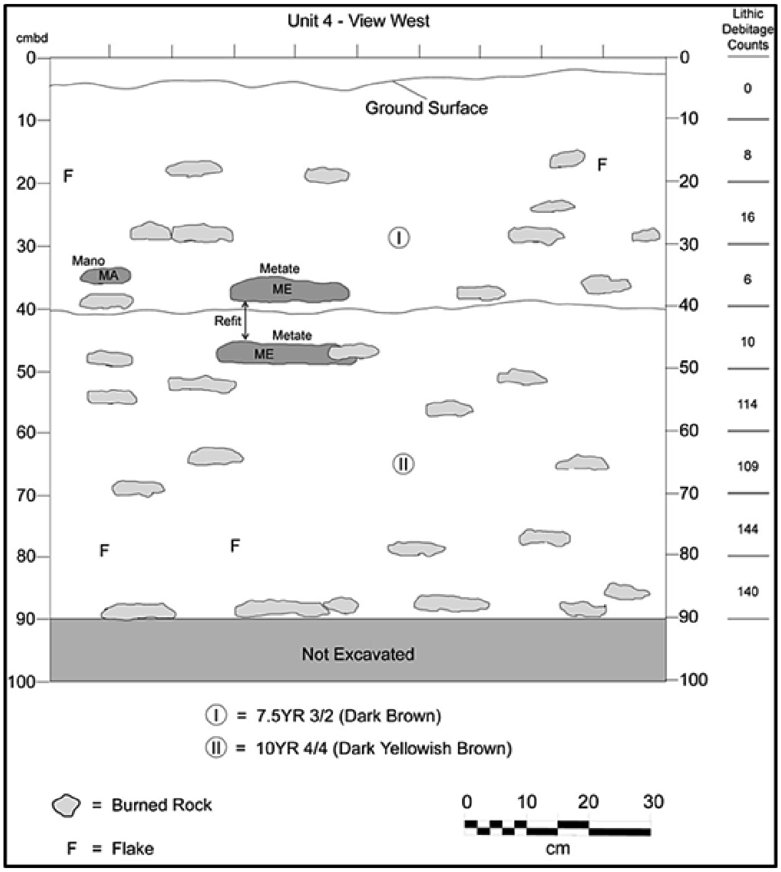


Figure 7-29. Vertical patterning of *in situ* plotted Material in TU 4.

boundary was defined for this burned rock midden deposit near the top of the road cut at the northern end. At least parts of the upper 50 cmbs of the burned rock lens or midden are disturbed, since a large mammal bone from 49 cmbs in TU 2 yielded a modern radiocarbon date.

South of TU 4, the ground surface gently slopes southward, with the slope significantly increasing over the last 15 m prior to encountering the unnamed creek (see Figure 6.3). Investigations along the southern third of the road cut exposed numerous horizontal to slightly southward sloping lenses of burned rocks, which represent multiple events dating back to about 5400 B.P. Eight or nine horizontal zones of mostly burned rocks and lithic debitage were detected in 90 cm of deposits in TU 4, as depicted in the back plots (see Figure 7-29). About 7 m further south, the 150 cm of deposits in TU 8 yielded at least eight more or less vertically definable events (Figure 7-30). Two meters further south in TU 7, only one obvious cultural event was represented in the top 110 cmbs. The southward sloping nature of the cultural and natural deposits creates uncertainty to exactly how many individual events are represented, especially since each event was not individually traced or dated. One cannot assume events recognized in one test unit correlate with events represented in other tests unit unless the two units were side-by-side, as in TUs 5 and 6 and TUs 9 and 10.

Test Units 5 and 6, stratigraphically below TU 8, yielded four or five more stratified cultural events that contained minimally burned rock Features 1 and 2 (Figure 7-31). At least 12 stratified cultural events were represented in the vicinity of Column 1. Test Units 9 and 10, about 4 m north of TUs 5 and 6, revealed a completely different vertical distribution of cultural events (Figure 7-32).

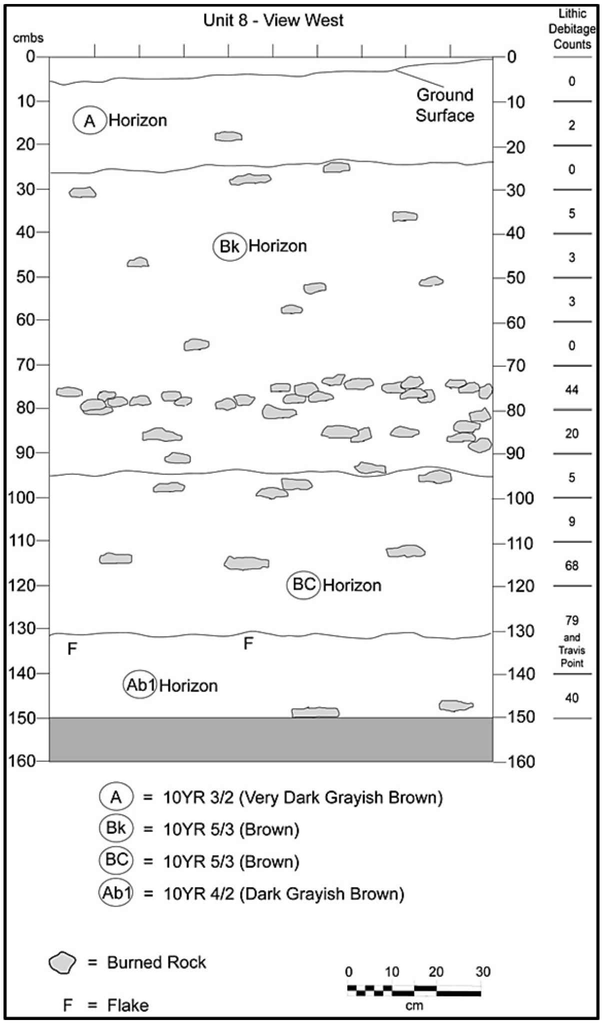


Figure 7-30. Vertical patterning of *in situ* plotted materials in TU 8.

Burned rocks and lithic debitage were present, although they were not easily separated into well-defined horizontal lenses. Lack of charcoal and diagnostic artifacts hinders cultural and age assignment of the cultural events into specific periods and prevents direct connection to events represented in TUs 5 and 6.

In summary, at least 12 cultural events were irregularly and vertically dispersed over about 250 cm of alluvial deposits in the very southern end. These cultural deposits slope upward and pinch out, or merge, to create two or three components in compressed deposits at the northern end of the road cut. Consequently, a 30 m long section near the southern end revealed well-stratified cultural deposits with detectable separation. The northern 60 to 70 m long section contained poorly stratified deposits with compressed stratigraphy. The vertical difference result from complexity within the alluviation with the younger alluvial deposit lapping up and pinching out against the higher, older deposit within this road cut exposure.

7.5 AGES AND ASSOCIATION OF THE CULTURAL DEPOSITS

Twenty-nine radiocarbon dates were obtained from the stratified cultural and natural deposits exposed in the nearly 100 m long, by 5.5 m tall road cut APE, which exposed a vertical section of the eastern side of 41MS69 (see Table 7-11). Sixteen radiocarbon dates reveal specific ages for the earliest cultural events represented by burned rock Features 1 and 2 with a single date on latter Feature 3. Ten other dates provide indications to the general ages of the natural depositional units and the broader chronological framework for the cultural events represented. Two dates are modern and document intrusive wood charcoal to the earlier cultural events.

In collecting samples from the natural deposits for possible dating. The goal was to retrieve an individual charcoal sample from the exact location as each bulk sediment sample to obtain a greater understanding of the potential downward movement of organic matter within these deposits by comparing the results from the two types of material dated. Unfortunately, two charcoal samples collected in association with two older sediment samples were accidentally destroyed at the radiocarbon laboratory. The detailed geoarcheological results and ages of those deposits are presented in Chapter 3.0. Briefly, those results indicate the ages of three general alluvial deposits designated Units 1, 2 and 3. Unit 1 is a late Pleistocene deposit(s) greater than 9,120 B.P. Unit 2 is an early Holocene deposit(s) dated between ca. 5,500 and 7,990 B.P. Unit 3 is middle

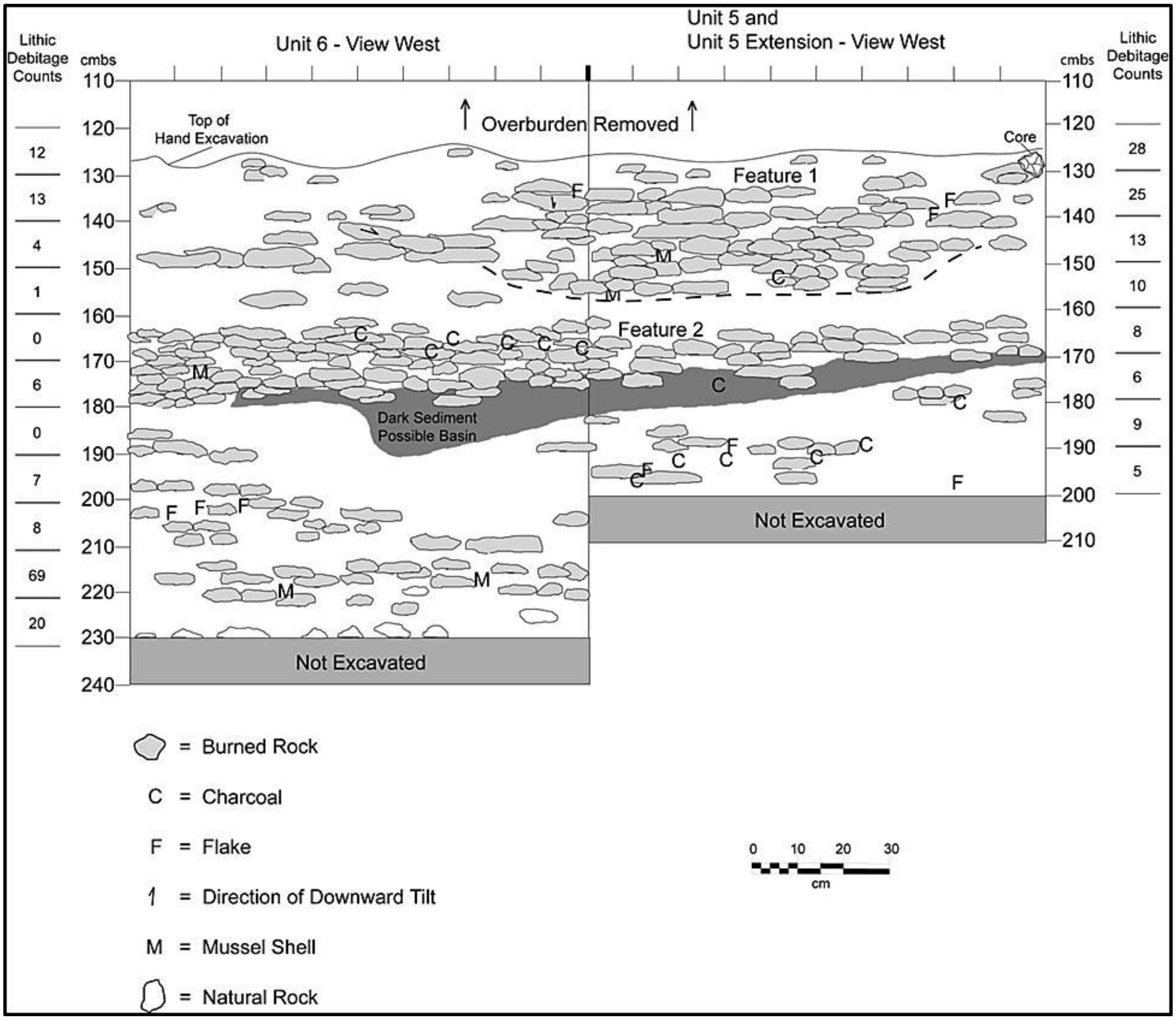


Figure 7-31. Vertical patterning of *in situ* plotted materials in TUs 5, 6, and 5-Extension.

to late Holocene deposit(s) that dates from ca. 5,500 B.P. to less than 3,480 B.P., possibly to around 1,600 B.P.

No cultural materials were detected in depositional Units 1 and 2. All cultural material encountered in Unit 3 is younger than roughly 5,500 B.P. The lowest cultural event identified was represented by scattered burned rocks below Feature 2 near the southern end of the road cut in Column 1 and in the bottom of TU 6 (Figure 7-33). Feature 2, between 163 and 200 cmbs, reflects the second deepest and oldest radiocarbon dated cultural event detected in Column 1 and encountered in TUs 5 and 6. Six wood charcoal dates average 5,305 B.P. and document the probable age of Feature 2 (Figure 7-34).

Stratigraphically and 15 cm above Feature 2 was burned rock Feature 1, which was encountered between 140 and 160 cmbs. Six wood charcoal dates provide an average age of 4,993 B.P., which is stratigraphically consistent with the older dates from Feature 2 below (Figure 7-34). These Feature 1 dates document the age of the Andice dart point directly associated with Feature 1. Bell/Andice/Calf Creek components are postulated for this general Middle Archaic period, although only a few radiocarbon dates in good context are available for this rare point type in central Texas.

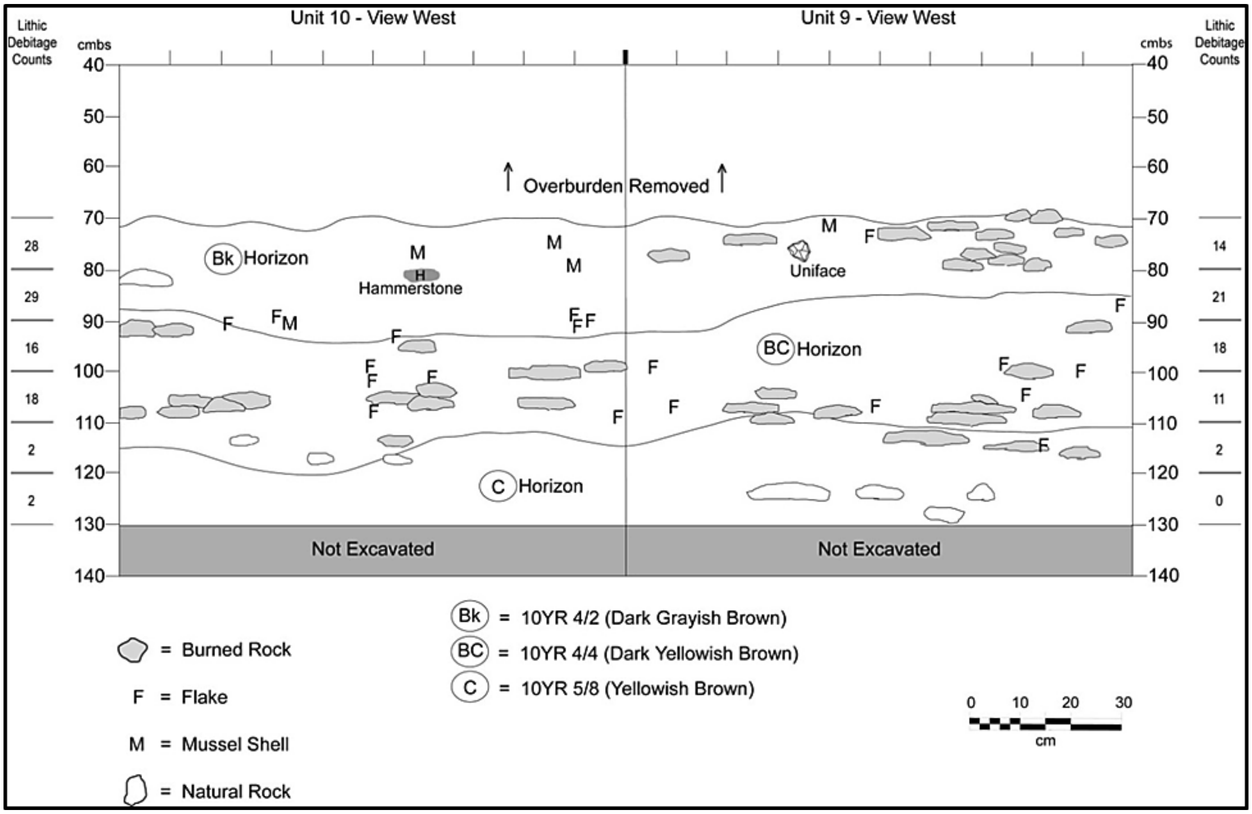


Figure 7-32. Vertical patterning of *in situ* plotted materials in TUs 9 and 10.

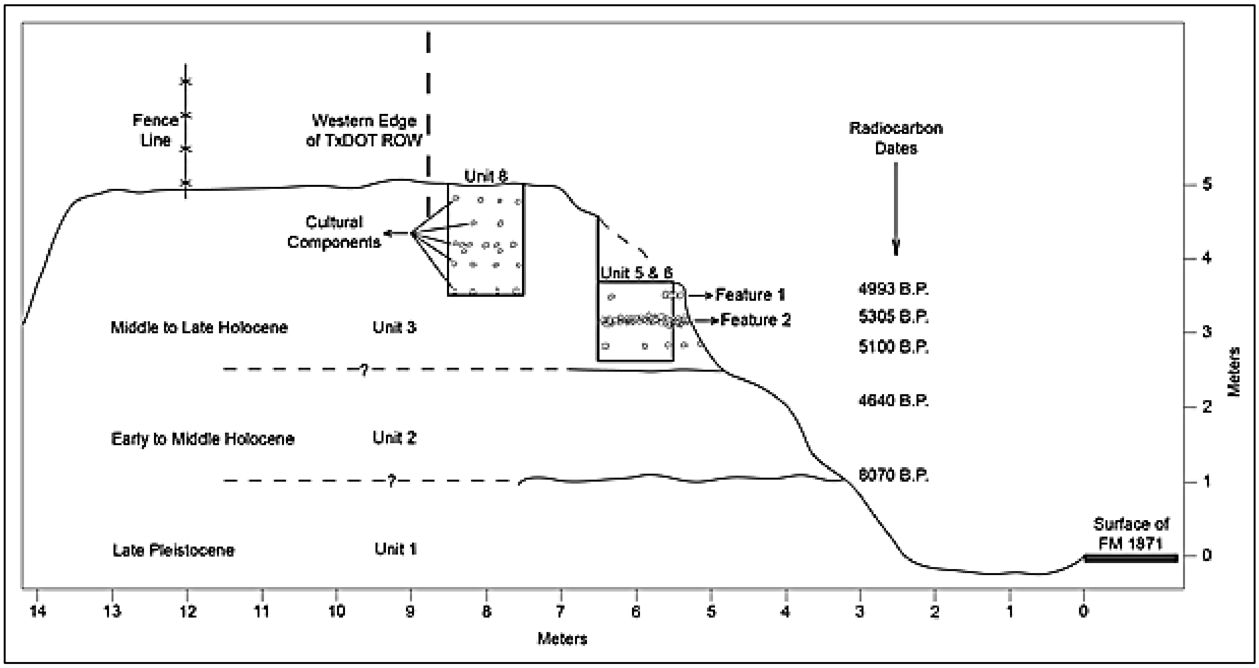


Figure 7-33. Schematic profile at southern end depicting age and relationships of the deposits.

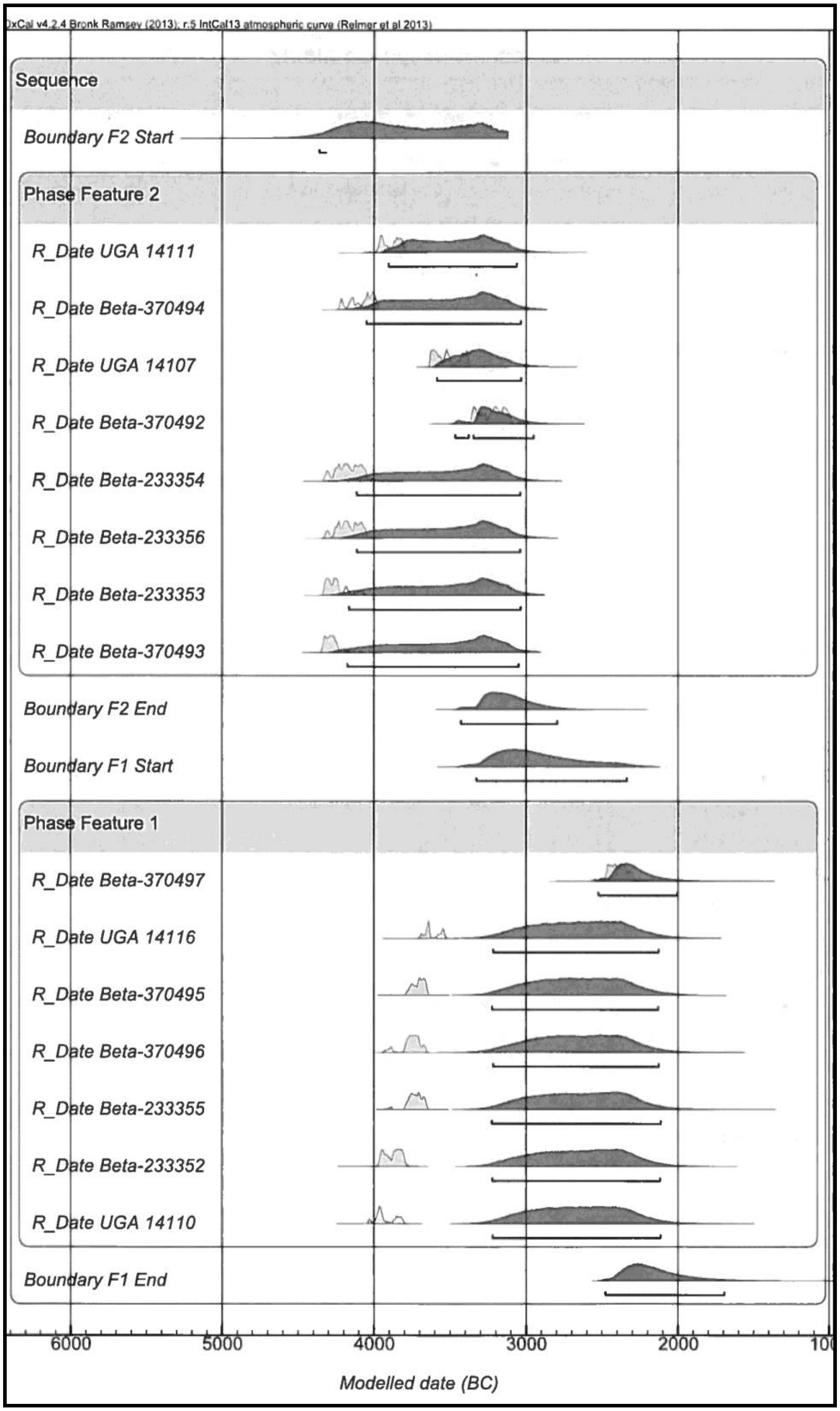


Figure 7-34. **Plot of calibrated radiocarbon dates from Features 1 and 2 using OxCAL model (graphic provided by Pletka of TxDOT).**

A complete Travis dart point (#71-10) (see Figure 7-17) from 138 cmbs in TU 8 was stratigraphically above the Andice point at Feature 1. Here, no radiocarbon dates are directly associated with this Travis point. Collins (2004) places the Travis and Nolan dart points between about 4,000 and 4,500 B.P. based primarily on a single radiocarbon date of 3750 ± 90 (UGA-2473) from the Hawes site (41WM56) in Williamson County, Texas (Peter et al. 1982). Actually two dates are available from the Hawes site, with a second being 3615 ± 60 (UGA-2485), both of which were associated with Bulverde, Travis, and Nolan points (Peter et al. 1982). It is assumed the Travis point generally represents this age span and apparently was in good stratigraphic context.

A Bulverde dart point (#103-10) (see Figure 7-18) was *in situ* from the exposed road cut at 125 cmbd just below the base of TU 10 and just above the highest natural gravel lens. The Bulverde point was slightly above the Travis point in deposits that sloped upward between these two points. This creates doubt as to their relationship to one another. The Bulverde point was not associated with any radiocarbon dates in this APE. It is projected to be younger than the Nolan and Travis points, roughly 4,000 to 3,500 B.P. on the basis of Collins (2004) chronological framework.

Only a single radiocarbon date was obtained from deposits near the middle of the vertical profile, which yielded at least three Pedernales points, one Marcos point, and one Montell point. These three Late Archaic dart point types are associated with a period from roughly 3,200 to 1,800 B.P. (Collins 2004; Johnson and Goode 1994; Prewitt 1985). Cultural Feature 3, the large ash filled basin at 100 cmbs in Column 2, yielded a wood charcoal radiocarbon date of 3500 ± 50 B.P. This date may potentially be associated with the Pedernales points.

No arrow points were recovered to indicate Late Prehistoric use of the APE for this part of 41MS69. However, a screened oak wood charcoal sample (#45-7a) between 20 and 30 cmbs in TU 1; and near the projected top of the burned rock lens, yielded a δ^{13}C (-25.0‰) corrected AMS date of 940 ± 40 B.P. (UGA-14109). It is unclear what this date was originally associated with, since it was only a few centimeters above an older Montell dart point. It is possible this was intrusive charcoal, since that general area experienced looting and disturbances. One relatively small unnotched, triangular biface (#19-10) from 30 to 40 cmbs in TU 3 is small enough to fall within the arrow point size range. The outline is similar to triangular Fresno arrow points of the Late Prehistoric period, but is not as well-manufactured as most finished arrow points.

In summary, the oldest cultural material, scattered burned rocks roughly at 220 cmbs in TU 6, was below the radiocarbon dated Feature 2 at roughly ca. 5,300 B.P. Limited vertical testing and widely scattered test units employed in this evaluation and assessment did not yield diagnostic projectile points or radiocarbon dates for most of the multiple and well-stratified cultural events. The infrequent projectile points from various context, the 29 radiocarbon dates derived primarily from Features 1 and 2, with some defining the geomorphology are not all directly associated. Therefore, specific ages cannot be directly assigned to particular projectile point types, although inferences can be presented. The exception is the age of the Andice dart point in direct association with Feature 1 radiocarbon dated to an average of 4,993 B.P. This is one of the rare instances in Texas that provides a well-documented radiocarbon age for a Bell/Andice cooking feature and the Andice point. The identification of cooking features dated to the Bell/Andice interval is also rare and informative. The last cultural use period projected for this part of 41MS69 is between roughly 1,600 and 2,000 B.P. The investigated APE, part of site 41MS69, was quite limited. Minimally this section was sporadically occupied over minimally a 3,000 year period during the Middle and Late Archaic periods. Stratified sites with these age deposits are relatively rare across central Texas.

This page intentionally left blank.

8.0 SUMMARY, DISCUSSIONS, AND CONCLUSIONS

J. Michael Quigg

8.1 INTRODUCTION

A private landowner reported cultural materials in a TxDOT right-of-way were being looted along a steep road cut on the southwestern side of FM 1871 along the southwestern edge of the Llano River, south of Mason (CSJ: 1111-04-002). The landowner expressed safety concerns the looting had undermined large oak trees and the trees might fall directly on the roadway below. Since the looting occurred within TxDOT right-of-way, the landowner's concerns prompted TxDOT to initiate stabilization plans along this section of roadway. This in turn required immediate documentation of this previously unrecorded prehistoric site, and the NRHP and SAL eligibility assessment, prior to any further actions by TxDOT. In June 2004 an archeological team from TRC conducted documentation of the APE, geoarcheological investigations, and hand-excavations to assess the value of cultural materials in the APE for their eligibility to NRHP and as a SAL and make recommendations for further actions. The APE was a steeply sloped 5.5 m tall road cut, roughly 100 m long and 2 to 5 m wide, on the western edge and directly above TxDOT pavement.

8.2 SUMMARY OF INVESTIGATIONS

Prehistoric site 41MS69, the Slippery Slope site, lies along the right bank (southwestern side) of the Llano River in southern Mason County, about 12 km south of Mason. Five hand-cut vertical columns/windows of various heights were judgmentally spaced and opened along the APE to allow geoarcheological insights into the deposits. The geoarcheologist documented three time distinctive alluvial units based on sediment characteristics and radiocarbon assays results. The impressive depositional sequence consists of a single late Pleistocene unit (Unit 1) greater than 9120 B.P., which underlies two Holocene age alluvial deposits (Units 2 and 3). Unit 2 is early to middle Holocene in age from ca. 8,000 to 5,400 B.P. and rests unconformably on the late Pleistocene alluvial deposit. Unit 3 is the only unit to contain cultural materials and was radiocarbon dated between 5,400 and at least 3,500 B.P. At least 12 occupational events are present in Unit 3. These events were nicely separated from one another in the upper 1.5 m of deposits at southern end of the APE. These became increasingly compressed moving toward the northern end, where they appeared to merge with a looted burned rock midden in the upper meter.

A total of 8.9 m^3 of hand-excavation was conducted across this very narrow north-south APE of the steeply sloping section of 41MS69. The relatively flat 2 to 5 m wide tree covered top of the terrace, at the top of the steep road cut, was sampled through six dispersed 1-by-1 m excavation units totaling 5.8 m^3. These units penetrated up to 150 cm of Unit 3 deposits. Subsequently, two areas at the southern end of the APE road cut exhibited deeply buried cultural deposits in the midslope were investigated through hand-excavation of 3.1 m^3 up to 230 cmbs. These latter hand-excavations documented multiple stratified cultural deposits in the southern end with apparent compression of cultural events across the northern section.

The northern half of the exposed APE exhibited an overgrown, looted and pothole-marked burned rock midden deposit concentrated in the upper 150 cm of the surface. This midden appeared to have compressed stratigraphy with at least the upper 50 cm extensively disturbed. Precise age and cultural affiliation of this northern midden was not determined. The southern half of the roughly 5.5 m vertical exposure exhibited at least 12 distinguishable cultural events with two burned rock features in the earliest events. At least several cultural events were associated with Marcos, Montell, Pedernales, Bulverde, Travis, and Andice projectile points all recovered from questionable contexts, with the exception of the Andice point.

In general, the dispersed nature of the test units, combined with relative few diagnostic projectiles *in situ* and radiocarbon dates, created circumstances, which did not facilitate assignment of materials and events to specific periods or individual components. Recovered cultural materials include: 52 pieces of mussel shells, 86 animal bone fragments, 94 chipped stone tools, 8 ground stone tools, 2,301 pieces of lithic debitage, and at least 3,898 burned rocks that weighed 1,430,022 g. The stone tools include: 52 edge-modified flakes, 18 bifaces and fragments, 21 point and point fragments, 2 scrapers, 3 manos, 3 hammer stones, 3 metate fragments, and 1 uniface. Three cultural features, two well-defined partially destroyed concentrations of burned rocks (Features 1 and 2) and one ash filled basin (Feature 3) were identified, sampled, and radiocarbon dated.

Feature 1, a partially preserved circular rock filled and possibly rock lined hearth, and Feature 2, a partial burned rock lens/oven and associated dark ashy stained fill, discovered in Column 1 became the principal target of the hand-excavations and subsequent analyses. Only the 2.5 m^2 units (TUs 5, 5-extension and 6) that targeted Features 1 and 2 were identified to a cultural event. That event represented the Bell/Andice/Calf Creek interval of the Middle Archaic following Collins (2004). An Andice point fragment was *in situ* 90 cm west and at the same elevation, 146 cmbs, as Feature 1. Six wood charcoal dates from Feature 1 range from 4890 to 5120 B.P. (cal 3540 and 3990 B.C.) for an average age of 4993 B.P. Fifteen to 20 cm below Feature 1 was Feature 2, which was radiocarbon dated by six wood charcoal dates to between 5320 and 5420 B.P. (cal 4340 and 4030 B.C.) with an average age of 5305 B.P. At least Feature 1, and probably Feature 2, are part of the rare and poorly known Bell/Andice/Calf Creek interval in Texas. These 12 radiocarbon ages and two features contribute significant data to place this poorly known cultural assemblage into a specific period in the middle Holocene.

Sparse lithic debitage, stone tools, and mussel shells were in direct association with Features 1 and 2, whereas animal bones and macrobotanical remains were absent. Analyses of 193 pieces of lithic debitage associated with Features 1 and 2 indicates the use of nearly all local cherts, representing both Edwards (*N* = 61 percent) and Gorman Formation (*N* = 32 percent) cherts. The Andice projectile was manufactured from Edwards chert and chemically determined by INAA as similar to Edwards cherts documented from Wright Creek in Kerr County, Texas. Lithic debitage associated with the two Bell/Andice features (Features 1 and 2) include primarily small flakes and shatter from tool resharpening and breakage of flakes with minor core reduction.

Multiple technical analyses were directed towards Features 1 and 2 sediments and burned rocks in an attempt to identify what resources were in those apparent cooking facilities. Overall, microfossils and macrofossils were poorly preserved. Phytolith preservation was poor and contributed little to what plants were in the two features. A wild gourd (*Cucurbit*) phytolith was recovered from Feature 1. Both features yielded burned and melted phytoliths, and a few identifiable and unidentifiable phytoliths from grasses and trees. Macrobotanical remains were also poorly preserved as demonstrated with no substantial recovery from three floated samples from Features 1 and 2 as organic pieces were highly degraded. No wood species were identified from Feature 1. Oak and hackberry woods were in Feature 2. Similarly, lipid residues were poorly preserved. Fortunately they did yield information as to what types of foods were cooked with the rocks from Features 1 and 2. Ninety percent of the rocks with sufficient residues for interpretations yielded both plant and animal residues. Of those, seven were dominated by plants and three were dominated by animal residues. Two rocks had mostly large herbivore (deer, bison, and/or pronghorn) meat present. Chemical biomarkers present in the lipid analysis indicate conifer products were present, and here would have probably been juniper or possibly cypress, employed to heat the rocks. Starch grain analysis on burned rocks yielded minimally two types of grasses, an unknown legume, and ten damaged grains to indicate grass seeds were parched and the cooking process included heat and water. The latter gelatinized starches may indicate stone boiling or baking. High-powered use-wear on a few formal and informal tools indicate 71 percent were employed in a cutting motion, both on hard and soft materials (e.g., hide). Microscopic residues of hair, bone collagen, plant tissue, and wood were all observed. These results support diverse activities occurred and minimally represents working wood and hides, which includes working high silica plants.

Column 3 revealed a partial ash filled basin (Feature 3) radiocarbon dated on charcoal to 3500 B.P. The cultural events and features detected in the southern half of the APE were within rapidly accumulated alluvial fines dated from Middle to Late Archaic periods, ca. 5,400 to 2,000 B.P.

Based upon onsite verbal communication with the landowner during our June 2004 field assessment, it was determined the 5.8 m^3 excavated in TUs 1 through 4 at the top of the terrace were actually on private land. We were informed the existing fence line had been moved back from the eroding edge of the road cut.

8.2.1 Gorman Formation Description

The Gorman Formation is a thickly to thinly bedded limestone and dolomite dominated formation in the region. Very light gray aphanitic limestone is predominantly in the upper part. The microgranular to fine-grained, pink, gray, and yellowish-gray dolomite is predominately in the lower part. The latter is very sparsely fossiliferous. Chert nodules are common in a bed near the middle (Figure 8-1). The formation is roughly 129.5 to 149.4 m (4215 to 490 ft.) in thickness and in places overlain by the Honeycut Formation. This is part of the Lower Ordovician period (Barnes 1981).

Nine pieces of chert from the Gorman Formation were collected from the surface near the site and submitted for INAA (MURR No. TRC370 through 378). Table 8-1 provides pertinent information concerning visible descriptions of each piece submitted, their observed colors, and the UV fluorescence's. Their visual colors range from light gray (2.5Y 6/0) to white (2.5YR 8/0) and are easily distinguishable from Edwards chert. Seven of the nine pieces were chemically similar and formed a group. Two pieces (TRC375 and TRC378) were slightly different chemically, but similar to other previously analyzed Edwards chert sources. A single piece was similar to the Llano River gravels and another similar to the broader Edwards Formation cherts.

Most Gorman Formation pieces are visually distinguishable from Edwards chert and generally have a dark mauve or purple appearance under the UV light. However, this does not hold true for all pieces as four of the nine have similar UV responses as presumed Edwards pieces. Also, chemically a few pieces that visually appear different from Edwards chert, are chemically similar. Five (14 percent) of the 35 analyzed cultural flakes were chemically identified as representing the Gorman Formation. These five had various UV responses and include; light yellow, two dark brown, purple, and one mottled brown and orangish. Only a single piece has a rough cortex. The INAA indicates Gorman Formation pieces were chemically distinguishable from other various sources of Edwards chert over a broader region. Gorman Formation material was recognized and collected for possible stone tool use, it was not intensively utilized by the inhabitance at this location. The Gorman Formation is restricted to the margins of the central Texas mineral region and should generally be visually and chemically recognizable from Edwards chert in cultural assemblages.

Figure 8-1. **Gorman Formation chert sample with interior and cortex-left (sample TRC375 sent for INAA) and right are other Gorman Formations cherts sampled.**

8.3 DISCUSSIONS

The discovery of two vertically separated burned rock features (Features 1 and 2), which radiocarbon date to the Middle Archaic and specifically to the poorly understood and known period between ca. 5500 and 4800 B.P., is significant and an important discovery. This period is part of what is referred to as the Altithermal or a very dry climatic period in the Plains (see Chapter 2.0). In general, this period in central Texas is thought by most researchers to be affiliated with the Bell/Andice/Calf Creek interval (e.g., Collins 1995, 2004; Johnson and Goode 1994). Few sites or components which represent this time are known in Texas, and fewer have been tested with no substantial excavated and analyzed components available in the literature, with the exception of the Big Hole site (Quigg et al. 2007; Quigg et al. 2016; see Chapter 3.0 for further discussions). Consequently, researchers know very little about this interval other than a large, thin, well-made broad bladed dart point was the prime killing instrument thought to have killed bison (Johnson and Goode 1994). Johnson and Goode (1994:25) thought the groups that employed these points were intrusive to central Texas and probably followed bison into the region under moderately moist but drying conditions. The discovery and through documentation of a Calf Creek projectile imbedded in a bison skull from central Oklahoma testifies these points were for killing bison (Bement et al. 2005).

The near absence of excavated components associated with this period and/or point types in central Texas, and even across adjoining Oklahoma, severely limits our understanding of their lifeways and other possible resource utilizations. Multiple technical analyses directed towards cultural materials associated with Features 1 and 2 sought to investigate foods cooked, how foods were prepared, and lithic resource use and technology. Features 1 and 2 are some of the first well-defined cooking features definitively associated with those populations. For the first time we document a partial list of probable plant food resources utilized beside bison.

Also INAA documented the utilization of local high quality chert resources, a pattern similar to Bell/Andice/Calf Creek populations in Oklahoma (Wyckoff 1995). One significant difference between the Oklahoma and central Texas stone tool assemblage is the local cherts utilized here, mostly high quality Edwards varieties, were not intentionally heat treated prior to the knapping process. This is in direct contrast to the nearly total heat treatment of multiple lithic resources in Oklahoma by Calf Creek point using groups (Wyckoff 1995).

Data obtained from Features 1 and 2 significantly increases our understanding of the group(s) represented by Bell/Andice/Calf Creek projectiles in Texas and their exploitation of plant resources.

Table 8-1. Description of Gorman Formation Samples Analyzed with INA at MURR.

MURR No.	Material Type	Texture	Structure	Luster	Translucent (mm)	Cortex	Patina	Weight (g)	Visual Description, Munsel Color	UV Fluorescence
TRC369	chert							2.3	Offwhite/white. 7.5YR 8/0	Mottled orange
TRC370	chert	Medium	Impurities - crystals	Dull	Translucent - 2.40	Absent	None	7.0	Offwhite and very light tan, banded. 10YR 6/2	Mottled orange
TRC371	chert	Fine to Coarse	Bands and impurities - vugs	Dull	Translucent - 0.77	Present - rough, 7.5YR 7/0	None	6.2	White to light gray, bands & vugs. 2.5YR 8/0	Mottled orange
TRC372	chert	Fine to Medium	Impurities - crystals, vugs and mottles	Dull to Chalk	Translucent - 4.64	Absent	None	9.1	White and light gray mottled with phenocrysts, mottled. 2.5YR 8/0 to 2.5Y 6/0	Mottled orange
TRC373	chert	Medium	Mottled and spotted.	Dull	Translucent - 2.17	Absent	None	3.8	Light gray with blue mottles, spotted. 2.5YR 8/0	Mottled orange
TRC374	chert	Medium to Coarse	Spotted with vugs & crystals	Dull	Translucent - 1.14	Absent	None	1.1	White with orange-tan specks. 2.5YR 8/0 spots 10YR 8/6	Dark purple
TRC375	chert	Medium to Coarse	Spotted with vugs & crystals	Dull	Translucent - 1.60	Absent	None	10.0	White with tan specks, crystals & vugs.2.5YR 8/0 spots 10YR 8/6	Dark purple
TRC376	chert	Medium	Solid	Dull	Translucent - 1.73	Present - smooth,	None	3.6	White with cortex. 2.5YR 8/0	Dark purple
TRC377	chert	Medium to Coarse	Impurities - vugs & crystals	Dull	Translucent - 1.76	Absent	None	5.2	White with dark brown specks, vugs & crystals. 5Y 8/1	Dark purple
TRC378	chert	Medium to Coarse	Impurities - vugs & crystals	Dull	Translucent - 1.48	Absent	None	5.6	White with tan specks, vugs & crystals. 2.5Y 8/0 spots 10YR 8/6	Dark purple

Some lithic technology issues were also identified. These two cooking apparatus document a new technology not well-known or represented prior to this. These two features greatly expand our understanding of food processing activities and reveal these bison hunters supplemental their meat resource.

8.4 CONCLUSIONS

Texas Department of Transportation's proposed stabilization of the steeply sloping road cut in the existing TxDOT right-of-way along the western side of a segment of FM 1871 for safety reasons threatened to directly impact a multiple component, prehistoric site (41MS69). Cultural resource evaluation of the long, narrow and sloping APE yielded partial remains of multiple cultural events between roughly 2,000 and 5,400 B.P. Some events were stratified towards the southern end, whereas those towards the northern end appeared compressed. Investigations documented an occupation period dated between 4,800 to 5,500 B.P. through two partially preserved and excavated burned rock features (Features 1 and 2). Analysis of feature data contributed significantly to our understanding of subsistence practices and cooking technologies of the poorly known Bell/Andice/Calf Creek interval of Collins (2004) Middle Archaic period.

The research design in Chapter 4.0 proposed the following generalized hypothesis to guide analysis of the materials and data from 41MS69. The hypothesis*: Features 1 and 2 at 41MS69 represent Middle Archaic occupations during which the site inhabitants procured and processed a range of food resources, most importantly, plant resources.*

As stated, this hypothesis is supported as both Features 1 and 2 were directly radiocarbon dated by wood charcoal to a period between ca. 4890 to 5420 B.P. within the Middle Archaic of the middle Holocene. Microfossil analyses on feature rocks from these two partial burned rock features identified multiple grasses, gourds, and unknown legume starches, plus plant and meat lipid residues. The Bell/Andice interval is noted for bison hunting; therefore, the presence of large burned rock cooking features, which cooked plants and probably only some meat, significantly contributes to and broadens our understanding of the Bell/Andice populations. Poor preservation of most microfossils does not allow one to specifically address the associated environment. If the existing understanding of the Altithermal holds true, then these features were in use towards the end of that climatic period and potentially reflects a broadening of the diet breath or a seasonally specific use.

Important cultural data was recovered from Features 1 and 2, and multiple other prehistoric events were identified. The remaining cultural deposits within the APE contain very limited cultural materials in good context. It is unlikely that significant cultural deposits remain within the right-of-way to be targeted for additional data collection through a data recovery program.

9.0 RECOMMENDATIONS

J. Michael Quigg

9.1 INTRODUCTION

In June 2004, documentation and eligibility assessment was conducted on a portion of prehistoric site 41MS69 within the presumed TxDOT right-of-way. This assessment was in anticipation of TxDOT contouring a steep road cut within the existing right-of-way of FM 1871 (CSJ: 1111-04-002) in Mason County. These efforts complied with state guidelines (Antiquities Code of Texas of 1977 [revised 1987], Title 9, Chapter 191, VACS, Art. 6145-9), to assess the value of cultural remains in the APE to contribute to the body of knowledge of Texas prehistory. The investigations also allow TRC to make recommendations of eligibility to National Register of Historic Places (NRHP) and as a State Antiquities Landmark (SAL).

According to the NHPA (Section 106) and Federal Regulations (36 CFR 60.4), a site's significance is evaluated based on criteria identified by the National Park Service (1995:2). Cultural resources are eligible for listing on the NRHP and therefore worthy of avoidance, protection, or mitigation through data recovery, if they are significant in American history, architecture, engineering, or cultural history. Significant properties are those that possess integrity of location, design, setting, materials, workmanship, feeling, and association and:

A. That are associated with events that have made a significant contribution to the broad patterns of our history; or

B. That are associated with the lives of persons significant in our past; or

C. That embody the distinctive characteristics of a type, period or method of construction, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

D. That have yielded, or may be likely to yield, information important in prehistory or history.

The criteria for determining the eligibility of a prehistoric or historic cultural property for designation as an SAL are presented in Chapter 191, Subchapter D, and Section 191.092 of the Antiquities Code of Texas. These criteria are similar to the criteria used in assessing the eligibility of a property for inclusion in the NRHP:

Sites, objects, buildings, artifacts, implements, and locations of historical, archeological, scientific, or educational interest including those pertaining to prehistoric and historical American Indians or aboriginal campsites, dwellings, and habitation sites, their artifacts and implements of culture, as well as archeological sites of every character that are located in, on, or under the surface of any land belonging to the State of Texas or to any county, city, or political subdivision of the state are SAL and are eligible for designation (Section 191.092[a]).

The archeological assessment of 41MS69 within TxDOT right-of-way consisted of five hand-excavated vertical columns or windows dispersed along the sloping road cut to expose the alluvial deposits and identified potential cultural deposits. Subsequently, 8.9 m^3 were hand-excavated across a very narrow north-south APE of the steeply sloping section of 41MS69. The relatively flat 2 to 5 m wide tree covered terrace top above the steep road cut was sampled through six, dispersed 1-by-1 m excavation units, which totaled 5.8 m^3 and penetrated up to 150 cm of deposits. Two areas at the southern end of the road cut exhibited two buried and partially preserved burned rock cooking features (Features 1 and 2) in the midslope between

150 to 220 cmbs. The two features were investigated through the hand-excavation of 3.1 m^3 up to 230 cmbs. Investigations documented the presence of multiple stratified cultural deposits in the southern section, which converged and were compressed across the northern section.

9.2 TRC RECOMMENDATIONS

Significant information was extracted from cultural Features 1 and 2 that contributed important cooking technology and subsistence practices to a poorly known Middle Archaic period, specifically the Bell/Andice cultural interval. The remaining cultural deposits in the steeply sloped APE however, contained very limited cultural materials in very restricted space, much in poor context with limited integrity. The assessment excavations effectively sampled the APE with the highest degree of preservation and stratigraphic integrity. It is unlikely that significant cultural deposits remain for subsequent data collection through a data recovery program.

Therefore, TRC recommends the portion of 41MS69 remaining in the narrow APE is not eligible for NRHP listing under Criterion D, 36 CFR 60.4. Furthermore, it is also recommended this same area is not eligible for SAL designation under Criteria 1 and 2 of the Rules of practice and procedures for the Antiquity Code of Texas, 13 TAC 26.8.

10.0 REFERENCES CITED

Abbott, J. T.
1994 Geomorphic Context of the Barton Site (41HY202) and the Mustang Branch Site (41HY209). In *Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas—Volume 2*, by R. A. Ricklis and M. B. Collins, pp. 353-379. Studies in Archeology, No. 19. Texas Archeological Research Laboratory, The University of Texas at Austin.

Abbott, J. and W. N. Trierweiler
1995 *NRHP Significance Testing of 57 Prehistoric Archaeological Sites on Fort Hood, Texas*. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 34.

Acuna, L. I.
2006 The Economic Contribution of Root Foods and Other Geophytes in Prehistoric Texas. Unpublished Master's thesis, Texas State University-San Marcos.

2010 Plant Remains from Site 41CV389, Fort Hood, Coryell County, Texas. In *Data Recovery Investigations on the Cowdog Crossing Site: A Study of the End of the Archaic, Fort Hood, Coryell County, Texas*, by S. Carpenter, C. T. Hartnett, J. D. Lowe, and K. A. Miller, pp. 143-1154. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 56.

Adams, L. E.
1958 Archaeological Investigations of Southwestern Missouri. *The Missouri Archaeologist* 20.

Albert, B. M.
2012 Appendix B: Pollen Analysis. In *Archaeology and Bioarchaeology of the Buckeye Knoll Site (41TV98), Victoria County, Texas*, edited by R. A. Ricklis, R. A. Weinstein and D. G. Wells, pp. 779-822. Prepared by Coastal Environments, Inc., Corpus Christi, for U.S. Army Corps of Engineers, Galveston District.

Albert, L. E. and D. G. Wyckoff
1984 Oklahoma Environments: Past and Present. In *Prehistory of Oklahoma*, edited by R. E. Bell, pp. 1-43. Academic Press, Inc., Orlando.

Andrews, B.
1999 Regional Variation in Calf Creek Projectile Points from Oklahoma. *Bulletin of the Oklahoma Anthropological Society* Volume XLVIII:113-124.

Antevs, E.
1955 Geologic-Climate Dating in the West. *American Antiquity* 20(4):317-335.

Arbogast, A. F. and D. R. Muhs
2000 Geochemical and Mineralogical Evidence from Eolian Sediments for Northwesterly Mid-Holocene Paleowinds from Central Kansas, USA. *Quaternary International* 67:107-118.

Ayala, S.
2014a Technology and Typology of the Calf Creek Horizon. Paper presented at the 79th Annual Meeting, Society of American Archaeology, Austin.

2014b Technology and Typology of the Calf Creek Horizon. Paper presented at the 72nd Annual Meeting of the Plains Anthropological Society, Fayetteville.

Baker, B. W.
1998 Vertebrate Faunal Remains from the ¼-inch and 1/8-inch Screens. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter Gatherers in Central Texas. Volume V: Special Studies*, assembled by M. B. Collins, pp. 1463-1509. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin and Archeological Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division.

Bamforth, D. B.
1987 Historical Documents and Bison Ecology on the Great Plains. *Plains Anthropologist* 32(115):
1-16.

Banks, W. E. and P. E. Wigand
2005 Reassessment of Radiocarbon Age Determinations for the Munkers Creek Phase. *Plains Anthropologist* 50(194):173-183.

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

Bartlett, R.
1994 Calf Creek Component at the Stilman Pit Site (34MR71) and its Relation to Calf Creek Caching Strategy. *Bulletin of the Oklahoma Anthropological Society* XL:69-90.

Bell, R. (editor)
1984 *Prehistory of Oklahoma*. Academic Press, Inc., Orlando.

Bement, L. C., E. L. Lundelius Jr. and R. A. Ketchum
2004 Get the Point? Point of No Return, Driving Home the Point, A Data Package from the Arkansas River, Pointing out the Obvious, A Pointed Comment, Point Taken, *Oklahoma Archeological Survey Newsletter* 23 (4):1-3.

2005 Hoax or History: A Bison Skull with Embedded Calf Creek Projectile Point. *Plains Anthropologis*t 50(195):221-226.

Bender, M. M.
1971 Variations in the C13/C12 Ratios of Plants in Relation to the Pathway of Photosynthetic Carbon Dioxide Fixation. *Phytochemistry* 10:1239-1244.

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*. Archaeological Survey Report, No. 100, Center for Archaeological Research, The University of Texas at San Antonio.

Blackmar, J. M. and J. H. Hofman
2006 The Paleoarchaic of Kansas. In *Kansas Archaeology,* edited by R. J. Hoard and W. E. Banks, pp. 46-75. University of Kansas, Lawrence.

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

Blum, M. D.
1987 Late Quaternary Sedimentation by the Upper Pedernales River, Central Texas. Unpublished Master's thesis, The University of Texas at Austin.

1992 Modern Depositional Environments and Recent Alluvial History of the Colorado River, Gulf Coastal Plain of Texas. Unpublished Ph.D. Dissertation, The University of Texas at Austin.

Blum, M. D. and C. Lintz
1993 *Late Quaternary Geology in the Reservoir Basin. In Cultural Resource Investigations in the O. H. Ivie Reservoir, Concho, Coleman, and Runnels Counties, Texas, Volume I: Project Introduction, Setting, and Methods*, by C. Lintz, W. N. Trierweiler, A. C. earls, F. M. Oglesby, M. Blum, P. L. O'Neill, J. Kuhl, R. Holloway, L. Scott-Cummings, and D. Scurlock, pp. 280-314. Mariah Associates, Inc., Technical Report No. 346-1.

Blum, M. D. and S. Valastro, Jr.
1989 *Response of the Pedernales River of Central Texas to Late Holocene Climate Change*. Annals of the Association of American Geographers 79(3):435-456.

1992 Quaternary Stratigraphy and Geoarchaeology of the Colorado and Concho Rivers, West Texas. *Geoarchaeology*, 7:419-448.

Bohrer, V.
1987 The Plant Remains from La Ciudad, A Hohokam Site in Phoenix. In *Specialized Studies in the Economy, Environment and Culture of La Ciudad*, edited by J. A. E. Kisselburg, G. E. Rice, and B. Spears, pp. 67-202. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Boulanger, M. T. and M. D. Glascock
2014 *Chert Sourcing for the Big Hole (41TV2161) Project, Compositional Analyses of Chert Gravels and Artifacts.* Report on file with TRC Environmental Corporation, Austin.

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

Boyd, D. K., C. W. Ringstaff, and G. Mehalchick
2004a Analysis and Interpretations of the Cultural Occupations at the Firebreak Site. In *Shifting Sands and Geophytes: Geoarcheological Investigations at Paluxy Sites on Fort Hood, Texas*, by G. Mehalchick, D. K. Boyd, K. W. Kibler, and C. H. Ringstaff, pp. 129-198. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 48.

Boyd, D. K., C. W. Ringstaff, and G. Mehalchick
2004b Rethinking Paluxy Site Archeology. In *Shifting Sands and Geophytes: Geoarcheological Investigations at Paluxy Sites on Fort Hood, Texas*, by G. Mehalchick, D. K. Boyd, K. W. Kibler, and C. H. Ringstaff, pp. 199-224. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 48.

Bozarth, S.
1995 Fossil Biosilicates. In *Stratigraphy and Paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains*, by V. T. Holliday, pp. 47-50. Geological Society of America, Inc., Memoir 186, Boulder.

Bozarth, S. and T. Woodburn
2010 Appendix D, Paleoenvironmental Reconstruction at West Amarillo Creek, Potter County, Texas, Based on Biosilicate Analysis

and Palynology. In *Landis Property: Data Recovery at Three Prehistoric Sites (41PT185, 41PT186, and 41PT245) in Potter County, Texas*, by J. M. Quigg, C. D. Frederick, P. M. Matchen and K. G. DuBois, pp. 695-733. TRC Technical Report 150832. Manuscript on file with TRC in Austin and Bureau of Land Management, Santa Fe.

Brock, F., D. G. Froese, and R. G. Roberts
2010 Low temperature (LT) combustion of sediments does not necessarily provide accurate radiocarbon ages for site chronology. *Quaternary Geochronology* 5:625-630.

Brooks, R. L.
1995 Trying to Scrape Up Some Answers: An Analysis of Scraping Tools from a Calf Creek Assemblage at the Hunter Site, 34GT6. *Bulletin of the Oklahoma Anthropological Society* XLII:53-88.

Brownlow, R. K.
2004 *Data Recovery Investigations at the Holt Site (41YHY341), San Marcos, Hays County, Texas.* HJN 040032 AR, Prepared for Fairfield Residential, LLC, by Horizon Environmental Services, Inc., Austin.

Brune, G.
1981 *Springs of Texas*. *Volume I.* Brance-smith, Inc., Fort Worth.

Bryant, V. M., Jr.
1977 A 16,000 Year Old Pollen Record of Vegetation Change in Central Texas. *Palynology* 1:143-155.

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 America Sediments*, edited by V. M. Bryant, Jr. and R. G. Holloway, pp. 36-70. American Association of Stratigraphic Palynologist Foundation, Dallas.

Bryant, V. M., Jr. and J. Schoenwetter
1987 Pollen Records from Lubbock Lake. In *Lubbock Lake: Late Quaternary Studies on the Southern High Plains*, edited by E. Johnson, pp. 36-40. Texas A&M University Press, College Station.

Buckner, A. P.
1980 *Cultural Responses to Altithermal (Atlantic) Climate Along the Eastern Margins of the North American Grasslands 5500 to 3000 B.C.* National Museum of Canada, National Museum of Man, Mercury Series, Archaeological Survey of Canada, Paper No. 97, Ottawa.

Calame, D. Sr., C. Weber, L. Banks, and R. McReynolds
2002 Projectile Points of the Calf Creek Horizon from Frio, Medina, and Uvalde Counties, Texas. *La Tierra* 29(2):29-38

Callahan, E.
1979 The Basics of Biface Knapping in the Eastern Fluted Point Tradition: A Manual for Flintknappers and Lithic Analysts. *Archeology of Eastern North America* 7:1-180.

Caran, S. C.
1998 Quaternary Paleoenvironmental and Paleoclimate Reconstruction: A Discussion and Critique, with Examples from the Southern High Plains. *Plains Anthropologist* 43(164):111-124.

Cestaro, G. C. and M. H. Carrell
1994 The Hester/Adams Site: 34ML83, McClain County, Oklahoma. *Bulletin of*

the Oklahoma Anthropological Society XLII:107-130.

Clark, J. S., E. C. Grimm, J. J. Donovan, S. C. Fritx, D. R. Engstrom, and J. E. Almerndinger
2002 Drought Cycles and Landscape Responses to Past Aridity on Prairies of the Northern Great Plains, USA. *Ecology* 83(3):595-601.

Collins, M. B.
1994 Evidence of Early Archaic Occupation. In *Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas*, by R. A. Ricklis and M. B. Collins, pp. 67-100. Studies in Archeology 19, Texas Archeological Research Laboratory, The University of Texas at Austin.

1995 Forty Years of Archeology in Central Texas. *Bulletin of the Texas Archeological Society* 66:361-400.

1998 *Wilson-Leonard, An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas.* 5 Volumes. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin and Texas Department of Transportation, Environmental Affairs Department, Archeology Studies Program, Report 10.

2004 Archeology in Central Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 101-126. Texas A&M University Press, College Station.

Coupland, R. T.
1958 The Effects of Fluctuations in Weather Upon the Grasslands of the Great Plains. *The Botanical Review* 24(5):273-317.

Decker, S. 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.* Studies in Archeology 33, Texas Archeological Research Laboratory, The University of Texas at Austin and Texas Department of Transportation, Environmental Affairs Department, Archeology Studies Program, Report 14.

Deevey, E. S. and R. F. Flint
1957 Postglacial Hypsithermal Interval. *Science* 125:182-184.

Dering, J. P.
1997 Appendix D: Macrobotanical Remains. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas, Volume II*, by S. L. Black, L. W. Ellis, D. G. Creel, and G. T. Goode, pp. 571-600. Texas Archeological Research Laboratory, The University of Texas at Austin, Studies in Archeology 22, and Texas Department of Transportation, Environmental Affairs Department, Archeology Studies Program, Report 2.

1998 Carbonized Plant Remains. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter Gatherers in Central Texas. Volume V: Special Studies*, assembled by M. B. Collins, pp. 1609-1636. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin and Archeological Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division.

2003 Appendix C: Plant Remains from Rice's Crossing (41WM815). In *Archeological Investigations at 41WM815, A Backland Prairie Site, Williamson County, Texas*, by

R. K. Brownlow, pp. 113-120. Studies in Archeology 36, Texas Archeological Research Laboratory, The University of Texas at Austin and Archeological Studies Program, Report 23, Environmental Affairs Division, Texas Department of Transportation, Austin.

2004 Appendix B: Analysis of Macrobotanical Remains form Three Paluxy Sites on Fort Hood, Texas. In *Shifting Sands and Geophytes: Geoarcheological Investigations at Paluxy Sites on Fort Hood, Texas*, by G. Mehalchick, D. K. Boyd, K. W. Kibler, and C. H. Ringstaff, pp. 245-257. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 48.

2006 Plant Remains. In *Prehistoric Encampments at the Shepherd Site: Testing and Data Recovery at 41WM1010, Williamson County, Texas*. Prepared for Texas Department of Transportation, by PBS&J, Austin.

2011 Appendix A: Plant Remains form 41TV410 and 41TV540. In *Results of Archeological Significance Testing at 41TV410 and 41TV540 and Associated Geomorphological Investigations on a Segment of Onion Creek in Travis County, Texas*, by A. Figueroa, R. Mauldin, C. Frederick, S. A. Tomka, and J. L. Thompson, pp. 159-164. Archaeological Report No. 420, Center for Archaeological Research, The University of Texas at San Antonio.

Dibble, D. S.
1967 *Excavations at Arenosa Shelter, 1965-66.* Texas Archeological Salvage Project, The University of Texas at Austin.

1997 *Excavations at Arenosa Shelter, 1965-66.* Reprinted by the Texas Archeological Research Laboratory, The University of Texas at Austin.

Dickens, W. A.
1993 Lithic Analysis. In *Archaeological Investigations in Bull Branch: Results of the 1990 Summer Archaeological Field School*, edited by D. L. Carlson, pp. 75-111. United States Army Fort Hood, Archeological Resource Management Series, Research Report Number 19.

Dickson, D.
1968 Two Provisional Projectile Point Types. *The Arkansas Amateur* 7(6):5-7. Fayetteville.

Diffenbaugh, N. S., M. Ashfaq, B. Shuman, J. W. Williams, and P. J. Bartlein
2006 Summer Aridity in the United States: Response to Mid-Holocene Changes in Insolation and Sea Surface Temperature. *Geophysical Research Letters,* 33, L22712:1029.

Dillehay, T. D.
1974 Late Quaternary Bison Population Changes on the Southern Plains. *Plains Anthropologist* 19(65):180-196.

Duncan, M.
1994 The Williams' Orchard Site: An Analysis of Lithic Procurement. *Bulletin of the Oklahoma Anthropological Society* XL:91-106.

1995 Calf Creek Foragers: Mobility on the Southern Plains During the Altithermal. *Bulletin of the Oklahoma Anthropological Society* XLII:89-144.

1996 Test Excavations at the Kubik Site, 34KA354, *Oklahoma Anthropological Survey Newsletter* 15(4):3.

Duncan, M. and D. G. Wyckoff
1994 The McKellips Site: An Analysis of the Calf Creek Component. *Bulletin of the Oklahoma Anthropological Society* XL:257-276.

Evans, G. L.
1951 Prehistoric Water Wells in Eastern New Mexico. *American Antiquity* 17:1-9.

Evershed, R.P.
2000 Bimolecular Analysis by Organic Mass Spectrometry. In *Modern Analytical Methods in Art and Archaeology,* Chemical Analysis Series, Vol. 155, edited by E. Ciliberto and G. Spoto, pp. 177-239. John Wiley & Sons, Inc., New York.

Evershed, R. P., C. Heron and L. J. Goad
2001 Analysis of Organic Residues of Archaeological Origin by High Temperature Gas Chromatography and Gas Chromatography-Mass Spectroscopy. *Analyst* 115:1339-1342.

Ferring, C. R.
2001 *The Archaeology and Paleocology of the Aubrey Clovis Site (41DN479), Denton County, Texas.* Center for Environmental Archaeology, Department of Geology, University of North Texas, Denton.

Ferring, C. R. and B. C. Yates
1997 *Archaeological Investigations at Five Prehistoric Sites at Lewisville Lake, Denton County, Texas*. Center for Environmental Archaeology, University of North Texas, Denton.

Forman, S. L., R. Oglesby and R. S. Webb
2001 Temporal and Spatial Patterns of Holocene Dune Activity on the Great Plains of North America: Megadroughts and Climate Links. *Global and Planetary Change* 29:1-29.

Frederick, C. D.
2011 Chapter 8: Late Quaternary Alluvial Stratigraphy of the Lower Onion Creek Valley. In *Results of Archeological Significance Testing at 41TV410 and 41TV540 and Associated Geomorphological Investigations on a Segment of Onion Creek in Travis County, Texas*, by A. Figueroa, R. Mauldin, C. Frederick, S. A. Tomka, and J. L. Thompson, pp. 69-95. Center for Archaeological Research, The University of Texas at San Antonio, Archaeological Report No. 420 and Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report No. 134, Austin.

Frederick, C. D. and C. Ringstaff
1994 Lithic Resources at Fort Hood: Further Investigations. In *Archaeological Investigations on 571 Prehistoric Sites at Fort Hood, Bell, and Coryell Counties, Texas*, edited by W. N. Trierweiler, pp. 125-181. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 31.

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

Fredlund, G.

1998 Phytolith Analysis. In *Wilson-Leonard: An 11,000-year Archeological Record of Hunter Gathers in Central Texas. Volume V: Special Studies*, assembled by M. B. Collins, pp. 1637-1651. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin and Archeological Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Fredlund, G. G. and L. L. Tieszen

1998 Stable Carbon Isotope Analysis of Soil Organic Matter. In *Wilson-Leonard An 11,000-year Archeological Record of Hunter-Gatherers in Central Texas. Volumes I-V*, assembled and edited by M. B. Collins, pp. 1653-1656. Studies in Archeology 31, Texas Archeological Research Laboratory, The University of Texas at Austin, and Archeology Studies Program, Report 10, Texas Department of Transportation, Environmental Affairs Division, Austin.

Fredlund, G. G., C. B. Bousman, and D. K. Boyd

1998 The Holocene Phytolith Record from Morgan Playa in the Rolling Plains of Texas. *Plains Anthropologist* 43(164):187-200.

Frison, G. C.

1991 *Prehistoric Hunters of the High Plains*. 2nd edition, Academic Press Inc., San Diego.

Girard, J. and H. S. Carr

1991 *Archeological Investigations at the Bellcow Site (34LN29), Lincoln County, Oklahoma*. Oklahoma Conservation Commission, Archaeological Research Report 15, Oklahoma City.

1994 Calf Creek Bifaces and Middle Archaic Period Occupations in the Bellcow Creek Drainage, Central Oklahoma. *Bulletin of the Oklahoma Anthropological Society* XL:195-208.

Hall, S. A.

1988 Environment and Archaeology of the Central Osage Plains. *Plains Anthropologist* 33(120):203-218.

1997 Pollen. In *Stratigraphy and Paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains*, by V. T. Holliday, pp. 53-54. Geological Society of America, Inc., Memoir 186, Boulder.

Haynes, C. V.

1967 Geochronology of Late-Quaternary Alluvium. In *Means of Correlation of the Quaternary Successions*, edited by R. B. Morrison and H. E. Wright, vol. 8, pp. 591-631. Proceedings VII Congress International Association for Quaternary Research.

1995 Geochronology of Paleoenvironmental Change, Clovis Type Site, Blackwater Draw, New Mexico. *Geoarchaeology* 10:317-188.

Hester, T. R.

1990 Notes on South Texas Archeology: 1990-3: Early Archaic "Eccentric" Lithic Artifacts in Southern and Central Texas. *La Tierra* 17(3):1-5.

Hester, T. R. and R. L. McReynolds

2003 A Look Back at the Contributions of C. K. Chandler to the Study of South Texas Archaeology. *La Tierra* 30(3 & 4):5-14.

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

Holliday, V. T.
1985 Archaeological Geology of the Lubbock Lake Site, Southern High Plains of Texas. *Geological Society of American Bulletin* 96:1483-1492.

1989 Middle Holocene Drought on the Southern High Plains. *Quaternary Research* 31:74-82.

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

1995b Stable Isotopes. In *Stratigraphy and Paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains*, by V. T. Holliday, pp. 54-58. Geological Society of America, Inc., Memoir 186, Boulder.

Holliday, V. T. and C. M. Welty
1981 Lithic Tool Resources of the Eastern Llano Estacado. *Bulletin of the Texas Archeological Society* 52:201-214.

Holloway, R. G., L. M. Raab, and R. Stuckenrath
1987 Pollen Analysis of Late-Holocene Sediments from a Central Texas Bog. *The Texas Journal of Science* 39(1):71-79.

Honea, K.
1980 Marks Beach, Stratified Paleoindian Site, Lamb County, Texas: Preliminary Report. *Bulletin of the Texas Archeological Society* 51:243-269.

Houk, B. A., K. A. Miller, and E. R. Oksanen
2008 *The Gatlin Site (41KR621): Investigating Archaic Lifeways on the Southern Edwards Plateau of Central Texas.* Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report No. 108, and SWCA Environmental Consultants, SWCA Cultural Resources Report No. 2008-149, Austin.

Howells, R. G., R. W. Neck, and H. D. Murray
1996 *Freshwater Mussels of Texas*. Texas Parks and Wildlife Department Press, Austin.

Hughes, D. T.
1984 The Foragers: Western Oklahoma. In *Prehistory of Oklahoma*, edited by R. E. Bell, pp. 109-118. Academic Press, Inc., Orlando.

Humphrey, J. and C. R. Ferring
1994 Stable Isotopic Evidence for Late Pleistocene to Holocene Climatic Change, North-Central Texas. *Quaternary Research* 41: 200-213.

Johnson, E.
1987a Vertebrate Remains. In *Lubbock Lake: Late Quaternary Studies on the Southern High Plains* edited by E. Johnson, pp. 49-89. Texas A&M University Press, College Station.

1987b Paleoenvironmental Overview. In *Lubbock Lake: Late Quaternary Studies on the Southern High Plains* edited by E.

Johnson, pp. 90-99. Texas A&M University Press, College Station.

Johnson, E. and V. T. Holliday
1986 The Archaic Record at Lubbock Lake. *Plains Anthropologist* 31(114) Part 2:7-54. Memoir 21.

Johnson, L. Jr.
1964 *The Devil's Mouth Site: A Stratified Campsite at Amsted Reservoir Val Verde County, Texas.* Archeology Series, Number 6, Department of Anthropology, The University of Texas, Austin.

1995 *Cultures and Climates at the Jonas Terrace Site, 41ME29 of Medina County, Texas*. Office of the State Archeologist Report 40. Texas Department of Transportation and Texas Historical Commission, Austin.

Johnson, L. Jr. and G. T. Goode
1994 A New Try at Dating and Characterizing Holocene Climates, as Well as Archeological Periods, on the Eastern Edwards Plateau. *Bulletin of the Texas Archeological Society* 65:1-51.

1995 *Cultures and Climates at the Jonas Terrace Site, 41ME29 of Medina County, Texas*. Office of the State Archeologist Report 40. Texas Department of Transportation and Texas Historical Commission, Austin.

Johnson, W. C. and C. W. Martin
2010 Holocene Alluvial-stratigraphic Studies from Kansas and Adjoining States of the East-central, Plains. Electronic document, http://www.kgs.ku.edu/Publications/Bulletins/GB5/Johnson/index.html Accessed December 17 2014.

Karbula, J. W., J. A. Campbell, and B. M. Jones
2011 The Berdoll Site: An Early Archaic Camp on Onion Creek, Travis County, Texas. *Bulletin of the Texas Archeological Society* 82:135-173.

Kay, M.
1998 The Central and Southern Plains Archaic. In *Archeology on the Great Plains,* edited by W. R. Wood, pp. 173-200.

Kibler, K. W. and A. M. Scott
2000 *Archaic Hunters and Gatherers or the Balcones Canyon Lands: Data Recovery at the Cibolo Crossing Site (41BX377), Camp Bullis Military Reservation, Bexar County, Texas*. Reports of Investigations, Number 126, Prewitt and Associates, Inc., Austin.

Knox, J. C.
1983 Responses of River Systems to Holocene Climates. In *Late Quaternary Environments of the United States*, edited by H. E. Wright, pp. 26-41. University of Minnesota, Minneapolis.

Kwiatkowski, S.
1992 The Rye Creek Flotation and Macrobotanical Analyses. In *The Rye Creek Project: Archaeology in the Upper Tonto Basin. Volume 2: Artifact and Specific Analyses*, pp. 325-375. Anthropological Papers No. 11. Center for Desert Archeology, Tucson.

Laird, K. R., S. C. Fritz, E. C. Grimm, and P. G. Mueller
1996 Century-Scale Paleoclimate Reconstruction from Moon Lake, A Closed-basin Lake in the Northern Great Plains. *American Society of Limnology and Oceanography, Inc.*, pp. 890-902.

Larson, D. A., V. M. Bryant, and T. S. Patty
1972 Pollen Analysis of a Central Texas Bog. *The American Midland Naturalist* 88(2):358-367.

Lintz, C., W. N. Trierweiler, A. C. Earls, F. M. Oglesby, M. Blum, P. L. O'Neill, J. Kuhl, R. Holloway, L. Scott-Cummings, and D. Scurlock
1993 *Cultural Resource Investigations in the O. H. Ivie Reservoir, Concho, Coleman, and Runnels Counties, Texas—Volume I: Project Introduction, Setting and Methods*. Technical Report No. 346-I, Mariah Associates, Inc., Austin.

Lohse, J. C., B. J. Culleton, and D. J. Kennett
2014 Dating Calf Creek Bison in Texas. Paper presented at the Society of American Archeology 79th Annual Meeting, Austin.

Lohse, J. C., A. E. Reid, D. M. Yelacic, and C. L. Timperley
2013 *Data Recovery and Analysis at the Texas State University Ticket Kiosk Project, Located at 41HY160, Spring Lake, Hays County, Texas*. Archaeological Studies Report No. 32, Center for Archaeological Studies, Texas State University-San Marcos.

Lohse, J. C., D. B. Madsen, D. J. Kennett, and B. J. Culleton
2014 Isotope Paleoecology of Episodic Mid-to-Late Holocene Bison Population Expansions in the Southern Great Plains. *Quaternary Science Reviews* 101 (2014), 1e13, Elsevier Ltd.

Malainey, M. E.
2000 Appendix K: Analysis of the Fatty Acid Compositions of Burned Rock Residues from Site 41ZP364, Zapata County, Texas. In *Data Recovery at 41ZP364: An Upland Campsite at Falcon Reservoir, Zapata County, Texas*, by J. M. Quigg and C. Cordova, pp. 331-352. Technical Report No. 22317, TRC Mariah Associates Inc., Austin.

2003 Appendix F: Analysis of the Fatty Acid Compositions of Archeological Residues from 41MM340. In *Data Recovery Excavations at 41MM340: A Late Archaic Site along Little River in Milam County, Texas*, by R. B. Mahoney, S. A. Tomka, R. P. Mauldin, H. J. Shafer, L. C. Nordt, R. D. Graves, and R. R. Galdeano, pp. 235-244. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report No. 54, Austin, and The University of Texas at San Antonio, Center for Archaeological Research, Archaeological Survey Report No. 340, San Antonio.

Malainey, M. E. and K. L. Malisza
2004 Appendix C: Analysis of Fatty Acid Compositions of Archeological Residues from 41CV595. In *Shifting Sands and Geophytes: Geoarcheological Investigations at Paluxy Sites on Fort Hood, Texas*, by G. Mehalchick, D. K. Boyd, K. W. Kibler, and C. H. Ringstaff, pp. 259-270. United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 48.

2008 Appendix G, Analysis of the Fatty Acid Compositions of Archaeological Pottery and Rock Residues from the Varga Site (41ED28). In *The Varga Site: A Multicomponent, Stratified Campsite in the Canyonlands of Edwards County, Texas*, by J. M. Quigg, J. D. Owens, P. M. Matchen, G. D. Smith, R. A. Ricklis, M. C. Cody, and C. D. Frederick, pp. 951-983. Texas Department of Transportation

Environmental Affairs Division, Archeological Studies Program Report No. 110 and TRC Environmental Corporation, Austin, Technical Report No. 35319.

2011 Analysis of the Fatty Acid Composition of Archeological Burned Rock Samples from 41CV413, Central Texas. In *Cultural Resource Investigations to Offset Mechanical Impacts to the Clear Creek Golf Course Site (41CV413), Fort Hood, Texas*, by J. M. Quigg, C. Lintz, G. Smith, D. DeMar and J. D. Owens, pp. 169-183. United States Army Fort Hood, Archeological Resource Management Series, Resource Report No. 60.

Malainey, M. E. and T. Figol

2010 Appendix G, Analysis of Lipids Extracted from Archaeological Burned Rock and Pottery Residues from Sites in Potter County, Texas. In *Landis Property: Data Recovery at Three Prehistoric Sites (41PT185, 41PT186, and 41PT245) in Potter County, Texas, Volume II,* by J. M. Quigg, C. D. Frederick, P. M. Matchen, and K. DuBois, pp. 791-831. TRC Technical Report No. 150832. Manuscript on file with TRC, Austin and Bureau of Land Management, Santa Fe.

2011 Appendix H, Analysis of the Lipid Compositions of Archeological Burned Rock Residues from Site 41YN452. In *Data Recovery at 41MI96 in Mills County, Texas*, by J. M. Quigg, R. A. Ricklis, P. M. Matchen, and J. T. Abbott, pp. 177-194. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 150 and TRC Environmental Corporation, Technical Report No. 192832, Austin.

2013 Appendix D, Analysis of the Lipid Compositions of Archeological Burned Rock Residues from Site 41MI96. In *Root-Be-Gone (41YN452): Data Recovery of Late Archaic Components in Young County, Texas, Volume II*, by J. M. Quigg, P. M. Matchen, C. D. Frederick and R. A. Ricklis, pp. 581-604. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 135 and TRC Environmental Corporation, Technical Report Nos. 50907 and 171219, Austin.

2014 Analysis of the Lipid Compositions of Archeological Burned Rock and Tool Residues from Site 41TV2161 in Travis County, Texas. Report on file with TRC Environmental Corporation, Austin.

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

2005 Geomorphic Investigations at the Richard Beene Site. In *Archaeological and Paleoecological Investigations at the Richard Beene Site 41BX831: South-Central Texas, 2005,* 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.

Martin, P. S.

1963 *The Last 10,000 Years: A Fossil Pollen Record of the American Southwest*. Tucson: University of Arizona Press, Tucson.

McCormick, J. A.

2011 *Soil Survey of Mason County, Texas*. United States Department of Agriculture, Soil Conservation Service in cooperation with Texas AgriLife Research, Natural Resource Conservation Service.

McCracken, H., editor
1978 *The Mummy Cave Project in Northwestern Wyoming*. Buffalo Bill Historical Center, Cody.

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

McKinney, W. W.
1981 Early Archaic Adaptations in Central and Southwestern Texas: The Problem of the Paleoindian-Archaic Transition. *Bulletin of the Texas Archeological Society* 52:91-120.

McReynolds, R.
2002 Calf Creek Horizon Points from Wilson County, Texas. *La Tierra* 29(2):39-44.

Mear, C. E.
1998 Terrace Deposits and Late Quaternary Climate, South-Central Edwards Plateau, Texas. *Bulletin of the Texas Archeological Society* 69:79-88.

Mehalchick, G., K. Killian, K. W. Kibler, and D. K. Boyd
2002 *Geoarcheological Investigations at the Clear Creek Golf Course Site (41CV413), Fort Hood, Texas.* United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 46.

Mehalchick, G., D. K. Boyd, K. W. Kibler, and C. H. Ringstaff
2004 *Shifting Sands and Geophytes: Geoarcheological Investigations at Paluxy Sites on Fort Hood, Texas.* United States Army Fort Hood, Archeological Resource Management Series, Research Report No. 48.

Meltzer, D. J.
1991 Altithermal Archeology and Paleoecology at Mustang Springs, on the Southern High Plains of Texas. *American Antiquity* 56:236-267.

1995 Modeling the Prehistoric Response to Altithermal Climates on the Southern High Plains. In *Ancient Peoples and Landscapes*, edited by Eileen Johnson, pp. 349-368. Texas Tech University Press, Lubbock.

1999 Human Responses to Middle Holocene (Altithermal) Climates on the North American Great Plains. *Quaternary Research* 52:404-416.

Meltzer, D. J. and M. B. Collins
1987 Prehistoric Water Wells on the Southern High Plains: Clues to Altithermal Climate. *Journal of Field Archaeology* 14:9-28.

Menking, K. M. and R. Y. Anderson
2003 Contributions of La Nina and El Nino to Middle Holocene Drought and Late Holocene Moisture in the American Southwest. *Geology* 31(11):937-940.

Munoz, C. M., R. P. Mauldin, J. L. Thompson, and S. C. Caran
2011 *Archeological Significance Testing at 41BX17.271, The Granberg Site: A Multi-Component Site along the Salado Creek in Bexar County, Texas.* Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report 135 and Center for Archaeological Research, The University of Texas at San Antonio, Archaeological Report No. 393, Austin.

National Parks Service

1995 *How to Apply the National Register Criteria for Evaluation.* National Register Bulletin 15. United States Department of Interior, National Parks Service, National Register Division, Washington, D.C.

National Oceanic and Atmospheric Administration

2007 A Paleo Perspective on Global Warming: The Mid-Holocene "Warm Period". Electronic document, http://www.ncdc.noaa.gov/paleo/globalwarming/holocene.html, accessed April 12, 2013.

Neal, L.

1994a A Calf Creek Component from the Lamar Site, 34BR8, Bryan County. *Bulletin of the Oklahoma Anthropological Society* XL:139-180.

1994b The Brandon Site, 34TU82, Tulsa Oklahoma. *Bulletin of the Oklahoma Anthropological Society* XL:209-250.

1999 Dating the Kubik Site. *Newsletter of the Oklahoma Archeological Survey*, The University of Oklahoma 19(2):1-3.

2002 Activities at the Kubik Site, 2002. *Oklahoma Archeology* 50(3):5-7.

Neal, W. L. and R. R. Drass

1998 Middle Holocene Archeology in Northeastern Oklahoma. *Oklahoma Anthropological Society Bulletin* XLVII:39-61.

Neal, W. L. and M. Duncan

1998 Mid-Holocene Radiocarbon Dates from the Kubik Site (34KA354). *Oklahoma Archeological Survey Newsletter* 18(1):2.

Neal, L., D. Morgan, B. Ross, and D. G. Wyckoff

1994 The Red Clay and Island Locations in Haskell County: Eastern Oklahoma Manifestations of the Calf Creek Horizon. *Bulletin of the Oklahoma Anthropological Society* XL:277-306.

Nordt, L. C.

1992 *Archeological Geology of the Fort Hood Military Reservation Ft. Hood, Texas*. United States Army Fort Hood, Archeological Resource Management Series, Research Report Number 25.

1993 *Additional Geoarcheological Investigations at the Fort Hood Military Reservation, Ft. Hood, Texas*. United States Army Fort Hood, Archeological Resource Management Series, Research Report Number 28, Addendum to Research Report Number 25.

Nordt, L. C., J. von Fisher, and L. Tieszen

2007 Late Quaternary Temperature Record from Buried Soils of the North American Great Plains. *Geological Society of America* 35(2):159-162.

Nordt, L. C., T. W. Boutton, C. T. Hallmark, and M. R. Waters

1994 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 Production and Climate-CO_2 Variations in South-Central Texas during the Late Quaternary. *Quaternary Research* 58(2):182-188.

Parker, W. and J. Mitchell
1979 Notes on Some Bell Points from a Site in Crosby County, Texas. *La Tierra* 6(2):26-27.

Perino, G.
1968 *Guide to the Identification of Certain American Indian Projectile Points*. Special Bulletin No. 3, of the Oklahoma Anthropological Society.

Perry, L.
2014 Starch Analysis of 74 Samples from Site 41TV2161, Travis County, Texas. Report on file with TRC Environmental Corporation, Austin.

Perry, L. and J. M. Quigg
2011 Starch Remains and Stone Boiling in the Texas Panhandle, Part I: The Pipeline, Corral, and Pavilion Sites. *Plains Anthropologist* 56(218):95-107.

Perry, L., D. Sandweiss, D. R. Piperno, K. Rademaker, M. Malpass, A Umire, and P. de la Vera
2006 Early Maize Agriculture and Interzonal Interaction in Southern Peru. *Nature* 440(2):76-78.

Peter, D. E., D. Prikryl, O. F. McCormick, and M. Demuynck
1982 Site Excavation Reports: Primary Contract. In *Archeological Investigations at the San Gabriel Reservoir District, Central Texas*, compiled and edited by T. R. Hays, pp. 8-241 to 8-297, Volume I. Archaeology Program, Institute of Applied Sciences, North Texas State University, Denton.

Pierce, H. G.
1987 The Gastropods, with Notes on Other Invertebrates. In L*ubbock Lake: Late Quaternary Studies on the Southern High Plains*, edited by E. Johnson, pp. 41-48. Texas A&M University Press, College Station.

Piperno, D. R. and I. Holst
1998 The Presence of Starch Grains on Prehistoric Stone Tools from the Humid Neotropics: Indications of Early Tuber Use and Agricultural in Panama. *Journal of Archeological Science* 25:765-776.

Piperno, D. R., A. J. Ranere, I. Holst, and P. Hansell
2000 Starch Grains Reveal Early Root Crop Horticulture in the Panamanian Tropical Forest. *Nature* 407:894-897.

Poore, R. Z., M. J. Pavich, and H. D. Grissino-Mayer
2005 Record of the North American Southwest Monsoon from Gulf of Mexico Sediment Cores. *Geological Society of America* 33(3):209-212.

Powell, V.
1995 Bifaces of the Calf Creek Horizon: A Collection from Cedar Canyon, Oklahoma. *Bulletin of the Oklahoma Anthropological Society* XLII:45-166.

Prewitt, E. R.
1966 Preliminary Report on the Devil's Rockshelter. *Texas Journal of Science* 18(2):206-224.

1981 Cultural Chronology in Central Texas. *Bulletin of the Texas Archeological Society* 52:65-89.

1983 Andice: An Early Archaic Dart Point Type. *La Tierra* 10(3):1-6.

1985 From Circleville to Toyah: Comments on Central Texas Archeology. *Bulletin of the Texas Archeological Society* 54:201-238.

1995 Distribution of Typed Projectile Points in Texas. *Bulletin of the Texas Archeological Society*66:83-173.

Quigg, J. M.
2011 Use-Wear and Starch Residue Analyses on an *In Situ* Corner-Tang Knife from the Texas Panhandle: Towards an Understanding of Function. *Plains Anthropologist* 56(217):37-44.

Quigg, J. M. and C. Cordova
2000 *Data Recovery at 41ZP364: An Upland Campsite at Falcon Reservoir, Zapata County, Texas*. TRC Technical Report No. 22317, TRC Mariah Associates Inc., Austin.

Quigg, J. M. and C. D. Frederick
2005 *Assessment of TxDOT Right-of-Way at 41MS69 in Mason County, Texas: An Interim Report*. Prepared for Texas Department of Transportation, Environmental Affairs Division by TRC Environmental Corporation, Austin.

Quigg, J. M., C. D. Frederick, and C. Lintz
1994 *Sulphur Springs Draw: Geoarchaeological and Archaeological Investigations at Sulphur Draw Reservoir, Martin County, Texas.* Prepared for Colorado River Municipal Water District, Big Springs, Texas. Mariah Technical Report No. 776, Mariah Associates, Inc., Austin.

Quigg, J. M., C. Lintz, G. Smith, and S. Wilcox
2000 *The Lino Site: A Stratified Late Archaic Campsite in a Terrace of the San Idelfonzo Creek, Webb County, Southern Texas*. Technical Report No. 23756, TRC Mariah Associates Inc., and Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report No. 20., Austin.

Quigg, J. M., M. Malainey, R. Przybylski, and G. Monks
2001 No Bones about It: Using Lipid Analysis of Burned Rock and Ground Stone Residues to Examine Late Archaic Subsistence Practices in South Texas. *Plains Anthropologist* 46(177):283-303.

Quigg, J. M., P. M. Matchen, C. D. Frederick, and E. Schroeder
2007 *Data Recovery at 41TV2161, Travis County, Texas: Interim Report.* Prepared for Texas Department of Transportation, Environmental Affairs Division by TRC Environmental Corporation, Austin,

Quigg, J. M., C. D. Frederick, P. M. Matchen, and K. DuBois
2010 *Landis Property: Data Recovery at Three Prehistoric Sites (41PT185, 41PT186, and 41PT245) in Potter County, Texas*. TRC Technical Report No. 150832. Manuscript on file, TRC, Austin and Bureau of Land Management, Santa Fe.

Quigg, J. M., P. M. Matchen, C. D. Frederick and R. A. Ricklis
2011a *Root-Be-Gone (41YN452): Data Recovery of Late Archaic Components in Young County, Texas.* Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 135 and TRC Environmental Corporation, Technical Report Nos. 50907 and 171219, Austin.

Quigg, J. M., R. A. Ricklis, P. M. Matchen, and J. T. Abbott

2013a *Data Recovery at 41MI96 In Mills County, Texas*. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 150 and TRC Environmental Corporation, Technical Report No. 192832, Austin.

Quigg, J. M., C. Lintz, G. Smith, D. DeMar and J. D. Owens

2011b *Cultural Resource Investigations to Offset Mechanical Impacts to the Clear Creek Golf Course Site (41CV413), Fort Hood, Texas*. United States Army Fort Hood, Archeological Resource Management Series, Resource Report No. 60.

Quigg, J. M., P. M. Matchen, C. D. Frederick, B. Gregory, and R. A. Ricklis

2014 *Barrett Site (41MM382) Assessment, Milam County (CSJ: 0590-05-027), Texas.* Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report no. 163 and TRC Environmental Corporation, TRC Technical Report Nos. 192919 and 211462, Austin.

Quigg, J. M., P. M. Matchen, R. A. Ricklis, S. Gray, E. Schroeder, and C. D. Frederick

2016 *Big Hole (41TV2161): Data Recovery of Two Stratigraphically Isolated Middle Holocene Components in Travis County, Texas*. Draft report in progress for Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Austin.

Quigg, J. M., P. M. Matchen, C. D. Frederick, R. A. Ricklis, B. Gregory, D. Maki and M. Bateman

2013b *Long View (41RB112): Data Recovery of Two Plains Village Components in Roberts County, Texas, Volumes I and II*. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 147 and TRC Environmental Corporation, Technical Report Nos. 50907 and 171219, Austin.

Ramsey, C. B.

2009a Bayesian Analysis of Radiocarbon Dates. *Radiocarbon* 51(1):337-360.

2009b Dealing with Outliers and Offset in Radiocarbon Dating. *Radiocarbon* 51(3):1023-1045.

Reimer, J. P., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C., B. Ramsey, C. E. Buck, H. Cheng, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, H. Haflidason, I. Hajdas, C. Hatté, T. J. Heaton, D. L. Hoffmann, A. G. Hogg, K. A. Hughen, K. F. Kaiser, B. Kromer, S. W. Manning, M. Niu, R. W. Reimer, D. A. Richards, E. M. Scott, J. R. Southon, R. A. Staff, C. S. M. Turney, and J. van der Plicht

2013 IntCal13 and Marine 13 Radiocarbon Age Calibration Curves 0-50,000 Years cal B.P. *Radiocarbon* 55(4):1869-1887

Rhoton, C.

1995 Calf Creek on the High Plains, Part II: Finds from Cimarron County, Oklahoma, and Adjacent Parts of Colorado and Texas. *Bulletin of the Oklahoma Anthropological Society* 41:171-177.

Ricklis, R. A.

1988 Archeological Investigations at the McKinzie Site (41NU221), Nueces County, Texas: Description and Contextual Interpretations. *Bulletin of the Texas Archeological Society* 58:1-76.

1993 *A Model of Holocene Environmental and Human Adaptive Change on the Central*

Texas Coast, Geoarchaeological Investigations at White's Point, Nueces Bay, and Surrounding Area. Coastal Archaeological Studies, Inc., Corpus Christi.

2012a Chapter 7: Non-Mortuary Artifacts. In *Archaeology and Bioarchaeology of the Buckeye Knoll Site (41TV98), Victoria County, Texas*, edited by R. A. Ricklis, R. A. Weinstein and D. G. Wells, pp. 163-254. Prepared by Coastal Environments, Inc., Corpus Christi, for U.S. Army Corps of Engineers, Galveston District.

2012b Chapter 19: Cultural and Ecological Change. In *Archaeology and Bioarchaeology of the Buckeye Knoll Site (41TV98), Victoria County, Texas*, edited by R. A. Ricklis, R. A. Weinstein and D. G. Wells, pp. 679-700. Prepared by Coastal Environments, Inc., Corpus Christi, for U.S. Army Corps of Engineers, Galveston District.

Ricklis, R. A. and M. D. Blum

1997 The Geoarchaeological Record of Holocene Sea Level Change and Human Occupation of the Texas Gulf Coast. *Geoarchaeology: An International Journal* 12(4):287-314.

Ricklis, R. A., J. M. Quigg, and P. M. Matchen

2011 Research Design for Analysis and Reporting, Site 41MS69, Mason County, Texas. Letter report by TRC Environmental for Texas Department of Transportation, Environmental Affairs Division, Austin.

Ricklis, R. A., R. A. Weinstein and D. G. Wells (editors)

2012 *Archaeology and Bioarchaeology of the Buckeye Knoll Site (41TV98), Victoria County, Texas*. Prepared by Coastal Environments, Inc., Corpus Christi, for U.S. Army Corps of Engineers, Galveston District.

Roberts, R. G.

1965 Tick Creek Cave: An Archaic Site in the Gasconade River Valley of Missouri. *The Missouri Archaeologist* 27(2).

Sala, O. E., W. J. Parton, L. A. Joyce, and W. K. Lauenroth

1988 Primary Production of the Central Grassland Region of the United States. *Ecology* 69(1):40-45.

Schmits, L. J.

1976 *The Coffey Site: Environment and Cultural Adaptation at a Prairie Plains Archaic Site*. Kansas University, National Park Service, Denver, Interagency Archeology Services.

1978 The Coffey Site: Environment and Cultural Adaptation at a Prairie Plains Archaic Site. *Mid-Continental Journal of Archaeology*, 3:69-185.

Schoeneberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson (editors)

2002 *Field Book for Describing and Sampling Soils. Version 2.0.* Natural Resources Conservation Service, National Soil Survey Center, Lincoln.

Shaeffer, J. B.

1958 The Alibates Flint Quarry, Texas. *American Antiquity* 24:189-191.

Shideler, G. L.

1970 Provenance of Johns Valley Bounders in Late Paleozoic Ouachita Fancies, Southeastern Oklahoma and Southwestern Arkansas. *The American Association of*

Petroleum Geologists Bulletin 554(5):789-806.

Shockey, D., P. Benefield, and D. G. Wyckoff
1994 Calf Creek on the Cherokee Prairie, Part II: The Woodard-Benefield Site (34MS258). *Bulletin of the Oklahoma Anthropological Society*, XL:329-346.

Smith, B. N. and W. V. Brown
1973 The Kranz Syndrome in the Gramineae as Indicated by Carbon Isotope Ratios. *American Journal of Botany* 60:505-513.

Smith, C., J. Runyon, and G. Agogino
1966 A Progress Report on a Pre-Ceramic Site at Rattlesnake Draw, Eastern New Mexico. *Plains Anthropologist* 11:302-313.

Sorrow, W. M., H. J. Shafer, and R. E. Ross
1967 *Excavations at Stillhouse Hollow Reservoir*. Papers of the Texas Archeological Salvage Project, No. 11, Austin.

Spivey, T., F. Freeze, and D. G. Wyckoff
1994 The Frazier Site: A Calf Creek-Bison Association in the Southern Osage Plains, South-Central Oklahoma. *Bulletin of the Oklahoma Anthropological Society*, XL:131-137.

Stafford, T., Jr.
1981 Geology and Archeological Potential of the Texas Southern High Plains. *American Alluvial Antiquity* 46(3):548-565.

Stites, M. D.
2006 The Calf Creek Complex: Preliminary Research on the Lithic Technology in Kansas. *Oklahoma Archeology* 54(4):10-42.

Stuiver, M. and P. J. Reimer
1993 Extended 14C Database and Revised CALIB Radiocarbon Calibration Program. *Radiocarbon* 35:215-230.

Suhm, D. A. and E. B. Jelks
1962 *Handbook of Texas Archeology: Type Descriptions*. The Texas Archeological Society, Special Publication Number One and The Texas Memorial Museum Bulletin Number Four, Austin.

Sullivan, M. J.
1995 Calf Creek in North-Central Oklahoma. *Bulletin of the Oklahoma Anthropological Society*, XLII:41-52.

Texas Department of Transportation (TxDOT)
2010 TxDOT Lithic Protocol Version 2.1, Chipped Stone Analytical Protocol, TxDOT Archeological Studies Program, On File with Environmental Affairs Division, Texas Department of Transportation, Austin.

Texas Parks and Wildlife Division (TPWD)
2015 Edwards Plateau Ecological Region. Electronic document, https://tpwd.texas.gov/landwater/land/habitats/cross_timbers/ecoregions/edwards_plateau.phtml, accessed May 12, 2015.

Thompson, J. L.
1967 Modern, Historic, and Fossil Flora. In *Lubbock Lake: Late Quaternary Studies on the Southern High Plains*, edited by E. Johnson, pp. 26-35. Texas A&M University Press, College Station.

Thurmond, J. P. and D. G. Wyckoff
1999 The Calf Creek Horizon in Northwestern Oklahoma. *Plains Anthropologist* 44(169):231-250.

Tinkler, K. J.
2001 The Case of the Missing Flood: The Unrecorded Flood of 1935 on the James River, Mason County, Texas. *Geomorphology* 39:239–250.

Toomey, R. S. III
1993 Late Pleistocene and Holocene Faunal and Environmental Changes at Hall's Cave, Kerr County, Texas. Unpublished Ph.D. dissertation, The University of Texas at Austin.

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

Turner, E. S., T. R. Hester, and R. McReynolds
2011 *Stone Artifacts of Texas Indians*. Completely revised Third Edition. Taylor Trade Publishing, London, New York.

Valastro, S., F. J. Pearson, and E. M. Davis
1967 University of Texas Radiocarbon Dates. *Radiocarbon* 9:445.

Walker, E. G.
1992 *The Gowen Site: Cultural Responses to Climate Warming on the Northern Plains (7500-5000 B.P.*) Archaeological Survey of Canada, Mercury Series Paper No. 145, Ottawa. Canadian, Museum of Civilization, Hull, Quebec.

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.

Weaver, J. E. and E. W. Albertson
1956 *Grasslands of the Great Plains*. Johnson Publishing, Lincoln.

Weber, C. D.
1986 An Analysis of Discriminant Function Values of Andice and Bell Points. *La Tierra* 13(3):32-38.

1991 Andice/Bell Projectile Point Notching Failures. *La Tierra* 18(4):23-38.

2000 Andice/Bell Resharpening Attributes. *La Tierra* 27(4):45-61.

2002 Andice/Bell Point Use Fractures. *La Tierra* 29(2):31-44.

Weber, C. D. and L. W. Patterson
1985 A Quantitative Analysis of Andice and Bell Points. *La Tierra* 12(2):21-27.

Weber, C. D. and M. B. Collins
1994 A Replication Technique for Andice/Bell Points. In *Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas, Volume 2, Tropical Studies*, by R. A. Ricklis and M. B. Collins, pp. 629-651. Studies in Archeology 19, Texas Archeological Research Laboratory, The University of Texas at Austin.

Weir, F. A.
1976 The Central Texas Archaic. Unpublished Ph.D. dissertation, Department of Anthropology, Washington State University, Spokane.

White, R. W.
1995 Calf Creek on the High Plains, Part I: Some Central Oklahoma Panhandle Finds. *Bulletin of the Oklahoma Anthropological Society* XLII:167-170.

Winsborough, B. M.
1997 Diatoms. In *Stratigraphy and Paleoenvironments of Late Quaternary Valley Fills on the Southern High Plains,* by V. T. Holliday, pp. 67-82. Geological Society of America, Inc., Memoir 186, Boulder.

Witty, T. A. Jr.
1969 Notes on Flint Hills Archeology. *Kansas Anthropological Association Newsletter* 14(8):1-5.

1982 *The Slough Creek, Two Dog, and William Young Sites, Council Grove Lake, Kansas.* Kansas State Historical Society, Anthropological Series Number 10, Topeka.

Wolverton, S.
2002 Zooarchaeological Evidence of Prairie Taxa in Central Missouri During the Mid-Holocene. *Quaternary Research* 58(2):200-204.

Wood, W. R., editor
1998 *Archeology of the Great Plains*. University Press of Kansas, Topeka.

Wyckoff, D. G.
1984 The Foragers: Eastern Oklahoma. In *Prehistory of Oklahoma*, edited by R. E. Bell, pp. 119-160. Academic Press, Inc., Orlando.

1993 Calf Creek: Traces of 6,000 year Old Hunting-Gathering Societies. *Oklahoma Archeological Survey Newsletter* 1:1-2.

1994 Introduction to the 1991 Bulletin. *Bulletin of the Oklahoma Anthropological Society* XL:1-8.

1995 A Summary of the Calf Creek Horizon in Oklahoma. *Bulletin of the Oklahoma Anthropological Society* XLII:179-210.

2005 A Calf Creek Potpourri. *Oklahoma Archeology* 53(1):20-28.

Wyckoff, D. G. and W. L. Neal
1994 Some Preliminary Conclusions about the Calf Creek Horizon in the Osage Savannah. *Bulletin of the Oklahoma Anthropological Society* XL:347-350
.

Wyckoff, D. G. and D. Shockey (editors)
1994 *Bulletin of the Oklahoma Anthropological Society* XL.

1995 *Bulletin of the Oklahoma Anthropological Society* XLII.

Wyckoff, D. G., D. Morgan, and L. Woodard
1994 Calf Creek on the Cherokee Prairie, Part I: The Arrowhead Ditch Site (34MS174). *Bulletin of the Oklahoma Anthropological Society* XL:307-328.

Wyckoff, D. G., W. L. Neal, and M. Duncan
1994 The Primrose Site, 34MR65, Murray County, Oklahoma. *Bulletin of the Oklahoma Anthropological Society* XL:11-67.

This page intentionally left blank.

11.0 GLOSSARY OF TECHNICAL TERMS

A Horizon: The near surface horizon of a natural soil. This is a carbon rich soil horizon characterized by an accumulation of partially decomposed to decomposed organic matter and eluvial loss of constituents such as clays and carbonates, which tend to accumulate in the deeper B horizon. The A horizon represents the upper solum of a soil. Lower case letters with the upper case letter A indicate specific characteristics of the A horizon. An Ab designation indicates the A horizon is buried. An Ap designation indicates a disturbed or anthropically modified soil such as in a plow zone.

Accelerated Mass Spectrometry (AMS): A laboratory technique that separates and identifies ions based on their mass to charge ratios. This technique is used in radiocarbon dating tiny particles of carbon in organic remains and residues.

Acidic: Containing acid bearing pollutants.

Acryloid B-72: This is a conservation material employed to stabilize or glue artifacts together. It is an ethyl methacrylate copolymer.

A.D.: Anno domini in Latin. “In the year of our Lord.” For example, A.D. 1000 is 1,000 years After Christ (A.D.). This is generally used when a B.P. radiocarbon date is calibrated to the tree ring results with a calibration formula.

Aerophilic Diatoms: These depend on free oxygen or air.

Agavaceae: A plant family name that refers to fiber, vascular bundle, or the central stem sections, which cannot be specifically identified as agave (*Agave*), yucca (*Yucca*) or sotol (*Dasylirion*).

Allostratigraphic Unit: Depositional unit made up of sediments dating to a similar period of deposition.

Alluvium: Clastic sediments, such as sand, silt, or clay deposited by a flowing stream, either in the channel or beyond the channel during overbank flooding.

Antiquities Code of Texas: This is the state law passed in 1977 to protect and preserve prehistoric and historic cultural resources on lands owned by the State and its political subdivisions (i.e., cities, towns, municipalities, and parks).

Argillins: These are clay coatings on ped- or pore surfaces.

Azelaic Acid: This is a chemical biomarker in lipid residue analysis and a short chain dicarboxylic acid associated with the oxidation of unsaturated fatty acids. Its presence may indicate plant seed processing.

B.C.: The abbreviation for Before Christ, in contrast to After Christ (A.D.).

Beta-Sitosterol: This is one of several phytosterols with chemical structures similar to that of cholesterol. Sitosterols are white, waxy powders with a characteristic odor. They are hydrophobic and soluble in alcohols.

Biface or Bifacial: A stone tool that has two distinct sides or faces, both of which have been substantially worked and/or flaked. The biface may take the form of many shapes and sizes and utilized in diverse activities.

B Horizon: The lower solum of a natural soil. A B horizon is a mineral soil horizon characterized by an accumulation of constituents such as clays, carbonates or salts, or organic complexes that have been translocated from the A horizon. Common subordinates include lowercase letters such as *t* as Bt, which indicates accumulation of illuvial clays. The lowercase k (Bk) indicates accumulation of carbonate. The lower case w indicates structural or color changes with no significant accumulations of alluvial material.

Biomarker: This is in lipid residue analysis, a molecular associated with a narrow range of substances, or the presence and distribution of certain types of lipids that enables a residue to be identified with a high degree of precision.

Bioturbation: The churning and mixing of sediments by living organisms, including burrowing rodents, insects, worms, and plant roots.

Biplot: A biplot is a special type of graph following from principal component analysis on which both the samples and elements are displayed. Examination of a biplot from the principal component analysis of ceramic specimens often leads to identification of the analyzed elements responsible for differentiating groups of specimens from one another.

B.P.: An abbreviation for before present, which in radiocarbon dating is referenced to the standard year A.D. 1950, which is considered "present". Generally B.P. dates have not been tree ring corrected using one of the calibration formulas.

β-sitosterol and Stigmasterol: These are sterols associated with plant products, which can be detected during lipid analysis. Its presence indicates plant residues.

Burned Rock Dump: A loose cluster of previously heated rocks with no horizontal patterning to the positions of the rocks and lacks indications of *in situ* heating/burning, such as a prepared basin, lenses of charcoal or ash, and/or the absence of an oxidation rim. Scattered charcoal or other cultural items may be present between or around the burned rocks.

Burned Rock Midden: An accumulation of a large quantity of discarded burned rocks previously employed in multiple cooking activities. These accumulations were the results of long extensive cooking episodes generally in association with rock ovens.

C_3 Plants: A photosynthetic pathway that most trees and flowering bushes use to assimilate carbon dioxide into their systems. The average carbon isotope of C_3 matter is -26.5‰ with a range from about -19.0‰ to -34.0‰.

C_4 Plants: A photosynthetic pathway employed by most arid (xeric) grasses and maize (corn) to assimilate carbon dioxide into their systems. The average carbon isotope of C_4 matter is -12.5‰ with a range of -6‰ to -19‰. These plants are more resistant to stress due to lack of water, but more susceptible to cold temperatures.

C Horizon: Weathered, but relatively unaltered parent material at the base of a soil profile, generally below the B horizon. This term is roughly synonymous with subsoil, although the latter term is often utilized to encompass the lower B horizon.

Calcareous: Rocks, minerals, or sediment containing calcium carbonates.

Calcic Horizon: This is a mineral soil horizon of secondary carbonate enrichment that is >15 cm thick, has a $CaCO_3$ equivalent of >150 g kg^{-1}, and has at least 50 g kg^{-1} more calcium carbonate equivalent than the underlying C horizon.

Calcite: A mineral consisting only or mainly of calcium, the principal mineral of limestone and marble.

Calcium: A chemical element with the symbol Ca and atomic number 20. Calcium is a soft gray alkaline earth metal, and is the fifth most abundant element by mass in the Earth's crust. Calcium is also the fifth most abundant dissolved ion in seawater by both molarity and mass, after sodium, chloride, magnesium, and sulfate.

Caliche: A more or less cemented deposit of calcium carbonate in soils of warm-temperate, subhumid to arid areas. Caliche, normally white, occurs as soft, thin layers in the soil or as hard, thick beds just beneath the solum, or it is exposed at the surface by erosion.

CAM Plants: A photosynthetic pathway for assimilating carbon dioxide into plants that can change from C_3-like to C_4-like pathways depending on the diurnal (day or night) cycle. Most succulent plants such as cactus have crassulacean acid metabolism (CAM) pathways. The carbon isotope values of most CAM plants in Texas such as *Agave lechuguilla* and *Opuntia englmannii* are similar to the values in C_4 plants (see Eickmeier and Bender 1976).

Cambic Horizon: This is a nonsandy, mineral soil horizon that has soil structure rather than rock structure, contains weatherable minerals and is characterized by the alteration or removal of mineral material.

Campesterol: This and stigmasterol and sitosterol are sterols in plant tissue, which can be detected during lipid analysis. Its presence indicates plants were processed.

Carbonates: These are rock or mineral classes such as imestone, calcite, ooids, and bioclasts. White carbonate filaments are often observed in C horizons of soils.

Chalcedony: A cryptocrystalline variety of quartz or chert. Chalcedony is often a component of other cherts. It may be translucent or semitranslucent, has a wax-like luster, and generally is white, pale blue, gray, blown, or black in color.

Cheno-am: A term used in botanical classification that includes the plant family of Chenopodiaceae (goosefoot) and the genus *Amaranthus* (pigweed), with tiny charred seeds indistinguishable from each other.

Chloridoid: These are short cell phytoliths that are squat and tall saddle-shaped, and occur primarily in C_4 grasses such as grama grass (*Bouteloua* sp.) and buffalo grasses (*Bouchloe* sp.). These plants thrive in warm, arid to semiarid regions in which the available soil moisture is very low, and therefore thrive in the shortgrass prairies during the hot summers.

Cholesterol: This is the major sterol in animal tissue, which can be detected during lipid analysis. Its presence indicates animal residues.

Clast: Any detrital particle of sediment created by the weathering and disintegration of a larger rock mass and transported by water, wind, or ice. Clasts also include discrete particulates created and deposited by volcanic action.

Clay: This is mineral sediment particles less than 0.002 millimeters in diameter. As a soil textural class, soil mineral that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Cluster Analysis (CA): A type of numerical classification that uses the value of attributes to cluster data. Clustering is the classification of objects into groups so objects from the same cluster are more similar to each other than to objects from different clusters. Often similarity is defined according to a distance measure. Clustering is a common technique for statistical data analysis, which is employed employed in many fields for data mining, pattern recognition, image analysis and bioinformatics.

Colluvium: Soil material, rock fragments, or both, moved by creep, slide, or local wash, which is deposited at the base of steep slopes.

Complex: A group of archeological sites that date to the same time and contain similar artifacts. This term expresses a relationship of common cultural or technological traits in assemblages within widespread geographic area.

Component: An archeological site or portion of a site that is spatially and chronologically discrete from other accumulations of artifacts. These can be horizontally or vertically differentiated.

Conifers: Any member of the order Pinales, woody plants that bear their seeds and pollen on separate, cone-shaped structures. They constitute the largest division of gymnosperms, with more than 550 species. Most are evergreen, upright trees and shrubs. They grow throughout North American and prefer temperate climate zones. Conifers include the pines (*Pinus*), junipers (*Juniperus*), spruces (*Picea*), hemlocks (*Tsuga*), firs (*Abies*), larches (*Larix*), yews (*Taxus*), cypresses (*Cupressus*), bald cypresses (*Taxodium*), Douglas firs (*Pseudotsuga*), and related groups. The trees are the source of resins, volatile oils, turpentine, tars, and pharmaceuticals.

Context: The association and position of artifacts, materials, and cultural features employed by archeologists to interpret space, time, and culture.

Cumulic Soil: A soil formed in a setting experiencing relatively slow deposition, so freshly introduced sediment is incorporated into the A horizon, leading to over thickening of the surface horizon. Cumulic soils are common in alluvial overbank and colluvial settings.

D-alloisoleucine: This is an amino acid that through the racemization process of snail shells converts the amino acid L-isoleucine to this amino acid. The ratio of the D-alloisoleucine to the L-isoleucine is expressed as the A/I value. This is a measure of relative age.

Dehydroabietic Acid: This is a biomarker that indicates the presence of conifer products, which probably was introduced from firewood, resins or other conifer products. This acid can be detected in lipid residue analysis.

Dendrite: An oxide of manganese that has crystallized in a branching pattern as in the dark inclusions in moss agate.

Deposition: The accumulation of sediments or gravels laid down by natural agencies such as moving water, or artificial agencies such as dumping.

Diatoms: These are single-celled algae whose cellular contents are enclosed between two valves of silica preserved when the organism dies. Often these are preserved in ponds, streams, and important to stream ecology. These are useful in reconstructing aquatic paleoenvironments.

Eraillure Scar: A small enigmatic flake formed between the bulb of force and the bulbar scar.

Erosional Unconformity: A significant break or gap in the geological or depositional record, indicative of removal of the older unit prior to renewed deposition.

Ester: This is an organic compound that contains a carbonyl group linked to an alkyl group through an oxygen atom; organic compounds synthesized from a carboxylic acid and an alcohol in the presence of water.

Fabaceae: This is commonly known as the legume, pea, or bean family, is a large and economically important family of flowering plants. It includes trees, shrubs, and perennial or annual herbaceous plants, which are easily recognized by their fruit and their compound, stipulated leaves.

Facies: A definable subdivision of a formal or informal stratigraphic unit.

FAMES: This is an abbreviation for fatty acid methyl esters (FAMES) and is prepared by treating the dry lipid with 3 mL of 0.5 N anhydrous hydrochloric acid in methanol (68°C; 60 min). This is part of the lipid residue analysis.

Fatty Acids: The major constituents of fats and oils (lipids) that occur in nature in plants and animals. They are insolubility in water and relatively abundant compared to other classes of lipids. Fatty acids may be absorbed into porous archeological materials during cooking, including heated rocks and ceramics, or ground into manos, metates, or mortar holes. Some of the major fatty acids are referred to as C12:0, C14:0, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1w9, C18:1w11, C18:2.

Floodplain: A nearly level alluvial plain that borders a stream or river and is subject to periodic flooding.

Gas Chromatography (GC): This highly technical measuring instrument that separates and measures the amount of elemental components of a specific sample by the measurement of light passed through gas at regulated temperatures, which allows the detection of fatty acids at the nonogram (1 X 10^{-9} g) level. High temperature gas chromatography is utilizeed to separate and assess a wide range of lipid components, including fatty acids, long-chain alcohols and hydrocarbons, sterols, waxes, terpenoids and triacylglycerols (Evershed et al. 2001). The molecular structure of separated components is elucidated by mass spectrometry (Evershed 2000).

Gas Chromatography-Mass Spectrometry (GC-MS): This is an analytical technique that enables the mass analysis and identification of components separated from a sample by gas chromatography; an analytical technique that combines gas chromatography with mass spectrometry.

Gelatinization: In regards to starch grains this is a morphological change (distortion of the original shape) in the grain caused by the exposure to heat and water when starches are cooked.

Geomorphology: That part of geography concerned with the form and development of the landscape.

Geophytes: These are plants with underground storage organ such as bulbs (e.g., onions, camas, and false garlic), tubers, roots, and rhizomes that are a reserve of carbohydrates, nutrients, and water. These storage organs can be collected, cooked, and eaten as part of the human diet. The study of these geophytes from an archeological site aids in determining the diet of the past occupants.

Glume: Pertains to small dry membranous chaffy bract at the base of a grass spikelet or each flower in a sedge or related plant.

Gorget: These are usually a polished stone, sometimes of shell or limestone, with holes drilled in it. These are presumably worn as jewelry by natives.

Graticule: A device within a microscope to measure the size of items under magnification.

Hard/High Silica Polish: This is a residue from the material that a stone tool came in contact with. This type of polish is generally produced when processing soft plants with high silica content in the plant tissues such as grasses, wood, reeds, and potentially soil. This polish was detected during high-powered microscopic use-wear studies conducted during stone tools analysis.

HCL: Hydrochloric acid, which is the solution of hydrogen chloride (HCl) in water. It is a highly corrosive, strong mineral acid and has major industrial uses.

Heating Element: This is an intentional, intact and localized spot were a human created a fire in an archeological site or component. This is generally evidenced by quantities of wood charcoal, prepared basin, lenses of charcoal or ash, and possibly an oxidation rim often accompanied by intentionally placed rocks, either lining the margins or directly amongst the charcoal. The function of this fire may reflect many different things, such as for heat to warm a person, to cook on, or to heat rocks for other uses. The specific contents may provide clues as to a more specific function or length of use.

High Temperature-Gas Chromatography (HT-GC): This instrument is used to separate and assess a wide range of lipid components, including fatty acids, long-chain alcohols and hydrocarbons, sterols, waxes, terpenoids and triacylglycerols (Evershed et al. 2001). This is used with mass spectrometry (MS) to elucidate the molecular structure of separated components. Triacylglycerols, diacylglycerols and sterols can be used to distinguish animal-derived residues, which contain cholesterol and significant levels of both triacylglycerols, from plant-derived residues, indicated by plant sterols, such as β-sitosterol, stigmasterol and campersterol, and only traces of triacylglycerols.

Hilum: The scar on a seed, such as a bean, which indicates the point of attachment to the funiculus. The nucleus of a starch grain.

Holocene: Geological period spanning roughly the last 10,000 years before present. The Holocene is roughly equivalent to the post-glacial period, and often referred to as the "Recent" period in geology. Many investigations consider the Holocene to be an interstadial in the ongoing Pleistocene epoch.

Horizon: A discrete, relatively uniform layer in a soil profile typically parallel with the surface and formed as the result of pedogenic process.

Humates: These are substances formed from the biological and chemical breakdown of animal and plant life over time. Humates are made up of compounds and materials that plant life on earth absolutely needs for growth. Humates contain a mixture of organic acids, including humic acids, fulvic acids, macromolecules of amino acids, amino sugars, and peptides. The chemistry of humate is so complex it cannot really be broken down.

Humus: A dark, organic-rich substance consisting of decomposed organic material (animal or vegetable) and found in the soil.

In Situ: An artifact in its original position that was placed or deposited within the landscape.

Integrity: This refers to the degree of intactness of archeological deposits, components, features, or artifacts.

Inulin: This is a carbohydrate, a fructan is not digestible via acid hydrolysis, the typical way we digest carbohydrates such as starch.

Isomers: These are compounds with the same molecular formula that differ with respect to how the atoms are joined. Structural isomers differ with respect to the order in which atoms are joined. Stereoisomers differ with respect to the arrangement of atoms in space but the order in which the atoms are attached is identical.

Isotope: An atom of an element. One of two or more forms of a chemical element, differentiated by the number of neutrons contained in the nucleus.

Jasper: A dense, cryptocrystalline, opaque to slightly translucent variety of chert associated with iron oxide impurities that give the rock various colors. Most often red, but can be yellow, green, grayish-blue, brown, or black.

Knapping: A term used to describe the manufacturing of prehistoric chipped stone tools using different techniques, such as pressure and/or percussion methods, to chip/flake a target mass of material to form a useful tool.

L-isoleucine: This is an amino acid that is converted over time to D-alloisoleucine as part of the racemization process with snail shells. This is contained in the protein of the shellsof living snails.

Lamellae: This is a thin plate-like structure, often one amongst many lamellae very close to one another, with open space between.

Legume: A plant that produces a bean or seedpod in various forms consisting of one cell and/or two valves. Common legume plants across Texas include such plants as; mesquite, Texas ebony, various acacia, retama, *Dalea* sp., mimosa, and rattlebush.

Lipids: These are hydrophobic constituents of living tissues including fatty acids, alcohols, triacylglycerols, sterols, bile acids, and waxes. Lipids are present in tissues of all living organisms in varying proportions. These are insoluble in water, relatively easy to extract, and are readily amenable to separation and characterization.

Lithic: Means “of stone”. This term is used by archeologists to refer to stone artifacts and the debris derived from the manufacture of stone artifacts.

Lithology: The scientific study and description of rocks, especially at the macroscopic level, in terms of their color, texture, and composition. The gross physical character of a rock or rock formation.

Little Barley: This is a short winter annual bunch grass with a scientific name of *Hordeum pusillum* in the Poaceae grass family. It has a rapid growth period with a brown seed that develops after spring and is available in the early summer. The seed head consists of flattened spikes. It is considered low in protein and is intolerant to shade. This grass has a low drought tolerance but can grow with only 10 inches of rain per year. It is considered a C_3 grass (-26.7‰; Smith and Brown 1973) adapted to fine and medium soil (http://plants.usda.gov 2011).

Loam: This is soil composed of sand, silt, and clay in relatively even concentration (about 40-40-20% concentration respectively). Loam soils generally contain more nutrients and humus than sandy soils, have better drainage and infiltration of water and air than silty soils, and are easier to till than clay soils.

Macrobotanical: These are remains of plant tissues, such as wood, charcoal, and seeds that one can observed with the naked eye.

Maize or Zea Mays: The scientific name for corn, which is a water-efficient C_4 plant with a shallow root system. The corn cob is also known as a rachis, which have alignments of cupules that are weakly jointed. The term Indian corn presently refers specifically to multi-colored "field corn" (flint corn) cultivars. There are many forms of maize, such as flint corn, popcorn, Dent corn, sweet corn (modern), and others.

Mano: This is a hand-held stone, usually sandstone or quartzite, used to grind plants such as corn, nuts, seeds, or other vegetable matter and sometimes other rocks. It is used in conjunction with a stone metate that plants are placed on to perform the grinding.

Manuport: An object, usually a rock, transported by humans to the place it was recovered, but its macroscopic appearance does not indicate it had been artificially altered to form a specific tool or other kind of artifact.

Mass Spectrometer (MS): This is an instrument used to produce molecular and elemental ions, sort them according to mass and detect abundances to establish the composition, determine molecular structure or measure isotopic ratios of specific elements.

Matrix: Refers to the sediments in which the artifacts at an archeological site are encased, or surrounds.

Mesic Condition: A relatively moist interval of time generally used in the context of climatic conditions.

Metate: A slab of rock in which vegetable matter is placed upon for the purpose of grinding. The natural surface becomes polished and a concave depression forms on the metate surface from continued grinding. The grinding stone used with the metate is called a mano.

Microdebitage: Any stone or lithic material from the manufacture of stone tools that is less than 4.0 mm in diameter. Microdebitage is often recovered in sieving or floating sediments from archeological deposits.

Microfossils: These include a variety of very tiny residues including such things as starch grains, diatoms, phytoliths, pollen, and organic remains that are only detectable and visible under high-powered microscopes.

Midden: This is somewhat of a catch-all term. It generally refers to an accumulation of cultural material such as a zone of burned rocks, and it is often used to refer to a thick accumulation of mixed cultural material in a vertical zone.

Migmatite: This is a rock at the beginning between igneous and metamorphic rocks. These rocks form under extreme temperature conditions during volcanic activity, prograde metamorphism.

National Historic Preservation Act: This is the federal law passed in 1966 that establishes a program for the preservation of significant historic properties throughout the United States.

National Register of Historic Places: This is the federal list of significant historic properties maintained by the National Parks Service (1995).

Organic: Compounds that contain carbon and are associated with living organisms. Materials or objects that contain organic carbon can be radiocarbon dated.

Overbank Deposits: The deposition of fine silts and clay particles that are left on terrace tops and banks when water in creeks exceeds the capacity of the channel and drops the suspended sediments in the lower energy environment. Overbank depositional processes usually cause minimal movement to large objects on the terrace top.

Oxidation: A chemical process wherein oxygen is added to minerals or other compounds; weathering oxidizes minerals; burning wood and rusting metal are types of oxidation.

Paleoenvironment: Ancient or past environment.

Paleosol: Generally refers to a soil that developed an A horizon and was subsequently buried by younger deposits.

Palimpsest: Archeologically, refers to the inability to distinguish and separate material remains from repeated occupations by a succession of cultural events of different ages due to their deposition and intermixing over time on relatively stable surfaces. Some palimpsest assemblages are buried following a long period of exposure.

Panicoid: A group of short cell grass phytoliths derived from tall C_4 grasses and are taxonomically diagnostic of switch grass (*Panicum*), big and little bluestem (*Andropogon* sp.), and Indian grass (*Sorghostrum*). These grasses do well in warm, moist environments and are a major species in the tallgrass prairies. These include basic morphotypes that include simple lobate, panicoid-type, cross, and other lobate forms.

Ped: A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes.

Pedogenesis: The dynamic process of soil formation and development, which typically leads to the formation of a darkened, organic-rich A horizon at or near the surface, and the downward movement of fine clays into, and/or the formation of carbonate nodules within, the underlying B horizons.

Pedoturbation: A general term used to describe soil that has been mixed.

Pee Dee Belmnite: A limestone in Southern Carolina used as the international standard for various compositional (carbon and oxygen isotopic and elemental) analyses.

Phase: A group of related archeological traits (e.g., artifacts, features) that contain similar cultural material and date to one relatively narrow period within a limited region.

Phytolith: These are microscopic, inorganic siliceous bodies/residues that form in plant cells and frequent mirror parent cell shape. They are produced in multiple shapes and sizes. After the plant dies, the silica bodies become part of the mineral component of soils. A single plant may produce many different phytolith forms. A single phytolith form may be produced by several plant taxa. Phytoliths may survive for thousands of years and provide evidence of past plants. Phytoliths are generally incorporated in the silt fraction of the soil (2-50 micron particle size) as are most specimens of diatoms and statospores.

Planktonic foraminifera: These are unicellular organisms with a complex cell (Eukaryotes), and genetic material within a cell nucleus.

Pleistocene: The first epoch, which along with the Holocene Epoch constitutes the Quaternary period, spanning the time between roughly 2.0 or 1.65 million years ago and 10,000 years ago. Characterized by repeated continental glaciations, the Pleistocene witnessed the evolution of modern humans.

Poaceae: This, also called Gramineae or true grasses, is a large and nearly ubiquitous family of monocotyledonous flowering plants. There are more than 10,000 domesticated and wild species, the Poaceae represent the fifth-largest plant family. The three Poaceae subfamilies include Pooids, Panicoids, and Chloridoids.

Polyunsaturated Fatty Acids: Pertaining to long-chain carbon compounds (e.g., C18:2) like fats with multiple double bonds. These fats are very unstable and degrade very rapidly over time. These are detected in archeological samples during lipid residue analysis.

Pooids: A group of phytoliths from mostly cool-moist C_3 grasses such as fescue (*Festuca* sp.), Canadian wildrye (*Elymus* sp.), Foxtail barley (*Hordeum* sp.), and western wheatgrass (*Agropyron* sp.). These grasses often grow in shaded areas and in riparian environments. Basic morphotypes for Pooids include keeled, conical, pryramidal, and crenate forms.

Potlid: A planoconvex flake created from differential expansion and contraction of the chert exposured to exstreme heat. This leaves a distinctive concave scar on the parent piece.

Pressure Flaking: A method used to shape stone tools through the application of force applied by pushing rather than striking. This is generally part of the final stages of finishing a stone tool.

Principal Component Analysis (PCA): This is a pattern recognition technique used for reducing the dimensionality of multivariate data, similar to factor analysis. It uses all the variables measured in a sample and calculates the variation among those variables.

Profile: A cross-sectional exposure of the sequence of horizons that make up a soil or a sequence of sedimentary deposits. It can be the result of either natural erosional down cutting or an artificial excavation.

Provenience: The specific vertical and horizontal location of where an object is recovered.

Quaternary: The second period, which along with the Tertiary Period, make up the Cenozoic Era, encompassing the Pleistocene and Holocene epochs; roughly the last 2.0 or 1.65 million years.

Radiocarbon Dating: The process of determining the age of a sample based on the amount of radioactive carbon (carbon 14) retained in that object.

Raphides: Needle-shaped crystals in a plant cell, typically of calcium oxalate. These are small (30 to 500 µm) crystals, generally with points on the ends and of similar lengths. They are often in plants of the Agavaceae family such as sotol, yucca, agave, and lechuguilla. They are not diagnostic of any particular plant. Bohrer (1987) and Kwiatkowski

(1992) believe that only agave contain these crystals. In contrast, Dering (2003) claims raphides occur in a variety of Agavaceae including sotol, yucca, agave, and beargrass.

Retouch: A technique of chipped stone artifact manufacture in which pressure flaking is used to detach small flakes to sharpen or otherwise modify the edge of a stone tool.

Saturated Fatty Acids: Each carbon in the chain is connected to its neighboring carbon by a single bond, which makes them relatively stable. The most abundant saturated fatty acids have chain-lengths of either, 14, 16, or 18 carbons. Mammal fats consist primarily of saturated fatty acids and are solid at room temperature. These are detected in archeological samples during lipid residue analysis.

Section 106 Process: This is the federal process to assess whether or not a project will have effects on historic properties. The basic steps include establishing the parameters of the development/undertaking, identifying the historic properties within the undertaking, if historic properties are affected then assess the effects, and resolve the adverse effects. The assessment is generally done in terms of evaluating/testing, whereas resolving the adverse effects is through avoidance or data recovery/mitigation.

Silt: A particle size that has a range from 0.06 mm to 0.002 mm. These are smaller than sand grains and larger than clay particles.

Siliceous: Pertaining to silica, as in silicon dioxide, the most common chemical constituent on earth, and the dominant component of chert and quartz.

Site Structure: The spatial distribution of features, artifacts, and debris across a single occupation (or within a component) of an archeological site that is used to reconstruct manufacturing, maintenance, processing, production, and disposal activities at specific loci, and the spatial ways prehistoric groups organized their space at a site.

Sitosterols: These are white, waxy powders with a characteristic odor. They are hydrophobic and soluble in alcohols.

Slackwater: Water that is essentially still/unstressed or with no movement either way.

Soil Horizon: A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons an upper case letter (i.e., A, B, C, R, and O) represents the major horizons with A at the top. Lower case letters that follow the upper case letters represent subdivisions of the major horizons.

Sponge Spicules: Spicules are structural elements in most sponges. They provide structural support and deter predators. Large spicules that are visible to the naked eye are referred to as megascleres, while smaller, microscopic ones are termed microscleres. Megascleres are large spicules measuring from 60-2000 µm. Spicules are found in a range of symmetry types. Sponges can be calcareous, siliceous, or composed of organic substance called spongin. The composition, size, and shape of spicules are one of the largest determining factors in sponge taxonomy.

Sponge Gemmoscleres: Gemmoscleres are important for sponge species survival. They are part of the sponge's reproductive mechanism. Gemmules--which are spheres with the axially aligned gemmoscleres forming the outer "wall" of the gemmule as a layer or shell protecting the sponge larvae inside--are released from adult sponges to establish new sponge colonies.

Starch: Starch is produced by all green plants for energy storage and is a major food source for humans. Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. Starch can be used as a thickening, stiffening or gluing agent when dissolved in warm water, giving, for example, wheat paste. In photosynthesis, plants use light energy to produce glucose from carbon dioxide. The glucose is stored mainly in the form of starch granules. Toward the end of the growing season, starch accumulates in twigs of trees near the buds. Fruit, seeds, rhizomes, and tubers store starch to prepare for the next growing season.

State Antiquities Landmark (SAL): This is any archeological site on county or municipal property, according to the Antiquities Code of Texas (Texas National Resources Code of 1977, Title 9, Chapter 191 as amended). State Antiquities Landmarks with high research potential may be designated by the Texas Historical Commission.

Statospores: These are the resting phase cysts of certain algae. These are the remains after the death of the plant or organism that produced it and in a terrestrial environment is incorporated into the soil mineral fraction.

Sterols: These are structural lipids that are present in cell membranes and contain the perhydrocyclopentanophenanthrene ring system. Sterols are a special king of alcohol that serves as precursors to a wide variety of products known as steroids. The cholesterol is the major sterol in animal tissue. Campersterol, stigmasterol and sitosterol are sterols in plant tissue.

Stigmasterol: This and sitosterol are sterols in plant tissue and can be detected in lipid analysis.

Stratigraphy: The study of layering in rocks and/or sediments, and how the layers correlate to each other.

Striae: These are tiny, thin, narrow grooves, channels, or lines, often called striations. Here, they were observed during high-powered microscopic use-wear analysis on stone tools and are an indication of the direction of the movement of the tools during their use. They were observed under high magnification in the residues left on the tools.

Terrace: In geologic terms this is an old alluvial plain that is generally flat and borders a river, stream, lake, or sea. Terraces are recognized by different elevations and generally designated T_0, T_1 and T_2 from lowest to highest.

Triacylglycerol (TAGs): This is a glycerol molecule to which three fatty acids are bounded through ester connections. These can be detected in lipid analysis.

Triticeae: This is a tribe within the Pooideae subfamily of grasses that includes genera with many domesticated species. Major crop genera are in this tribe including wheat, barley, and rye; crops in other genera include some for human consumption and others used for animal feed or rangeland protection. Seed storage proteins in Triticeae are implicated in various food allergies and intolerances.

Turbation: Disturbance to natural matrix deposits generally caused by biological agents (burrowing rodents, insects, worms, and plant roots) and natural (soil creep, desiccation crack displacement, frost heaving, landslides, etc.) processes. These actions tend to move cultural objects in the ground.

Tuber: This is the thick, fleshy underground stem of a plant. This stem serves as the primary storage organ of nutrients that stores food over winter and produces new growth in spring.

Type: This is a group of similar items (ceramic sherds or projectile points) all of which are more or less the same.

Ultraviolet Light: The wave length of light above that is usually detected by the human eye and that fluoresces various kinds of minerals and emits distinctive colors. Here, a multiband light source (UV light 254/366 nm Model UVGI-58) was used to investigate the visual fluorescence of culturally modified stones to help in identifying their source and detect new/recent scars from old flake scars.

Unconformity: Stratigraphic term for a boundary or break created by a depositional hiatus. This boundary separates younger strata from older strata. An unconformity is usually caused by erosion and therefore deposits are missing.

Unsaturated Fatty Acids: These types of fatty acids contain at least one carbon-carbon double bond or point of unsaturation. That point of unsaturation is susceptible to additional reactions. Unsaturated fatty acids are the primary constituents of plant and fish oils and tend to be in liquid-state at room temperature. Their chain-lengths vary with a minimum of 12 carbons but most common ones contain at least 18 carbons.

Use-wear: The high-powered microscopic evidence on a stone tool created from sustained use. The wear may appear as striations, tiny nicks, abrasive particles, polish, rounding, soluble inorganic residues, etc. The accompanying use-wear study used magnification between 100x and 500x to observe wear and edge-modification on selected artifacts. This detailed analysis contributes to our understanding of the function of tools and potentially substances that tools were used on.

Waxes: These are long-chain fatty acids and long-chain alcohols that form protective coatings on skin, fur, feathers, leaves and fruit, also resist decay. These can be detected in lipid analysis.

Wildrye (*Elymus* sp.): A common grass throughout the Plains of the United States, from Mexico to Canada and is all across Texas. The seeds of this genus are large and it possesses a large distinctive starch grain. This is a cool season C_3 grass (ca. -27.6‰, -27.1‰, Bender 1971) that produces short cell phytoliths. The seeds are available during the summer and fall.

Xeric Condition: A dry or relatively arid condition often in reference to climatic conditions.

Xerophic Plant**s:** These are plants that have adapted to survive in an environment that lacks water, such as a desert. These include cactus, sotol, yucca, agave, and lechuguilla, and others.

APPENDIX A
RADIOCARBON ASSAY RESULTS

Prepared for:

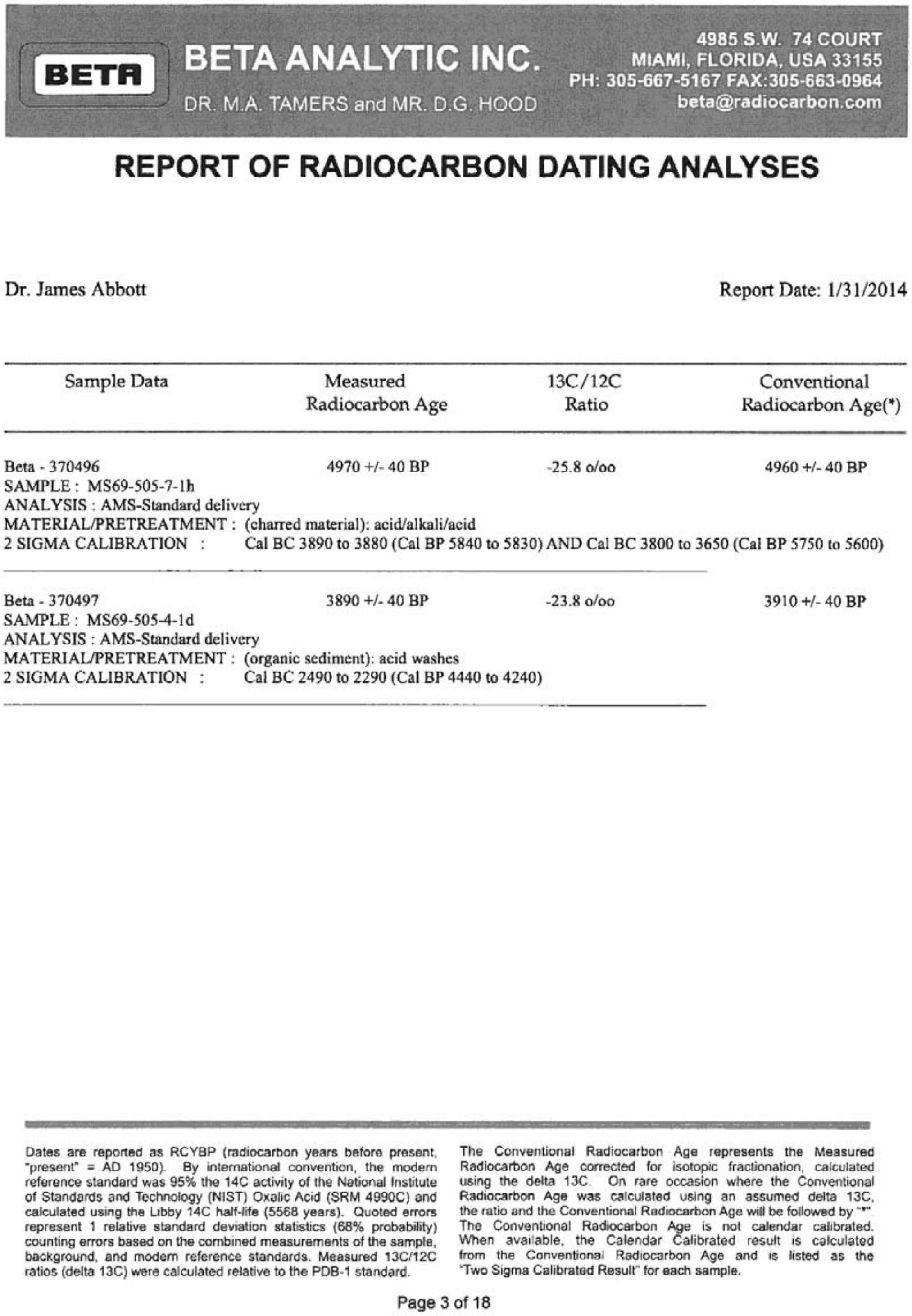
TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Alexander Cherkinsky, Ph.D.
The University of Georgia
Center for Applied Isotope Studies
120 Riverbend Road
Athens, Georgia 30602-4720

Darden Hood
Beta Analytic, Inc.
4985 S.W. 74 Court
Miami, Florida 33155

This page intentionally left blank.



BETA
BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. James Abbott

Report Date: 1/31/2014

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 370496	4970 +/- 40 BP	-25.8 o/oo	4960 +/- 40 BP

SAMPLE : MS69-505-7-1h
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal BC 3890 to 3880 (Cal BP 5840 to 5830) AND Cal BC 3800 to 3650 (Cal BP 5750 to 5600)

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 370497	3890 +/- 40 BP	-23.8 o/oo	3910 +/- 40 BP

SAMPLE : MS69-505-4-1d
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (organic sediment): acid washes
2 SIGMA CALIBRATION : Cal BC 2490 to 2290 (Cal BP 4440 to 4240)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

Page 3 of 18

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.9:lab. mult=1)

Laboratory number: **Beta-370492**

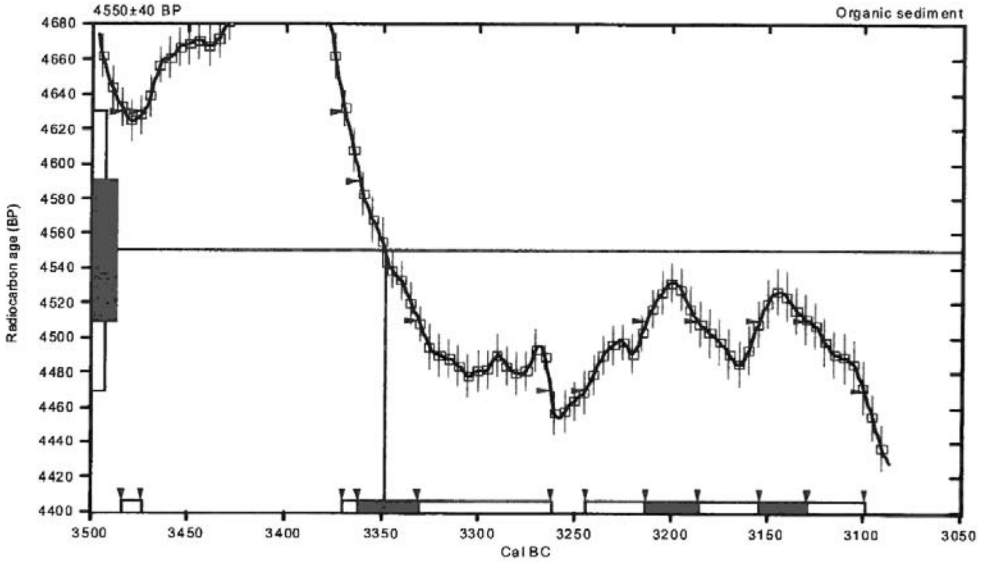
Conventional radiocarbon age: **4550±40 BP**

2 Sigma calibrated results: **Cal BC 3480 to 3470 (Cal BP 5430 to 5420) and**
(95% probability) **Cal BC 3370 to 3260 (Cal BP 5320 to 5210) and**
Cal BC 3240 to 3100 (Cal BP 5190 to 5050)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 3350 (Cal BP 5300)

1 Sigma calibrated results: Cal BC 3360 to 3330 (Cal BP 5310 to 5280) and
(68% probability) Cal BC 3210 to 3190 (Cal BP 5160 to 5140) and
Cal BC 3150 to 3130 (Cal BP 5100 to 5080)

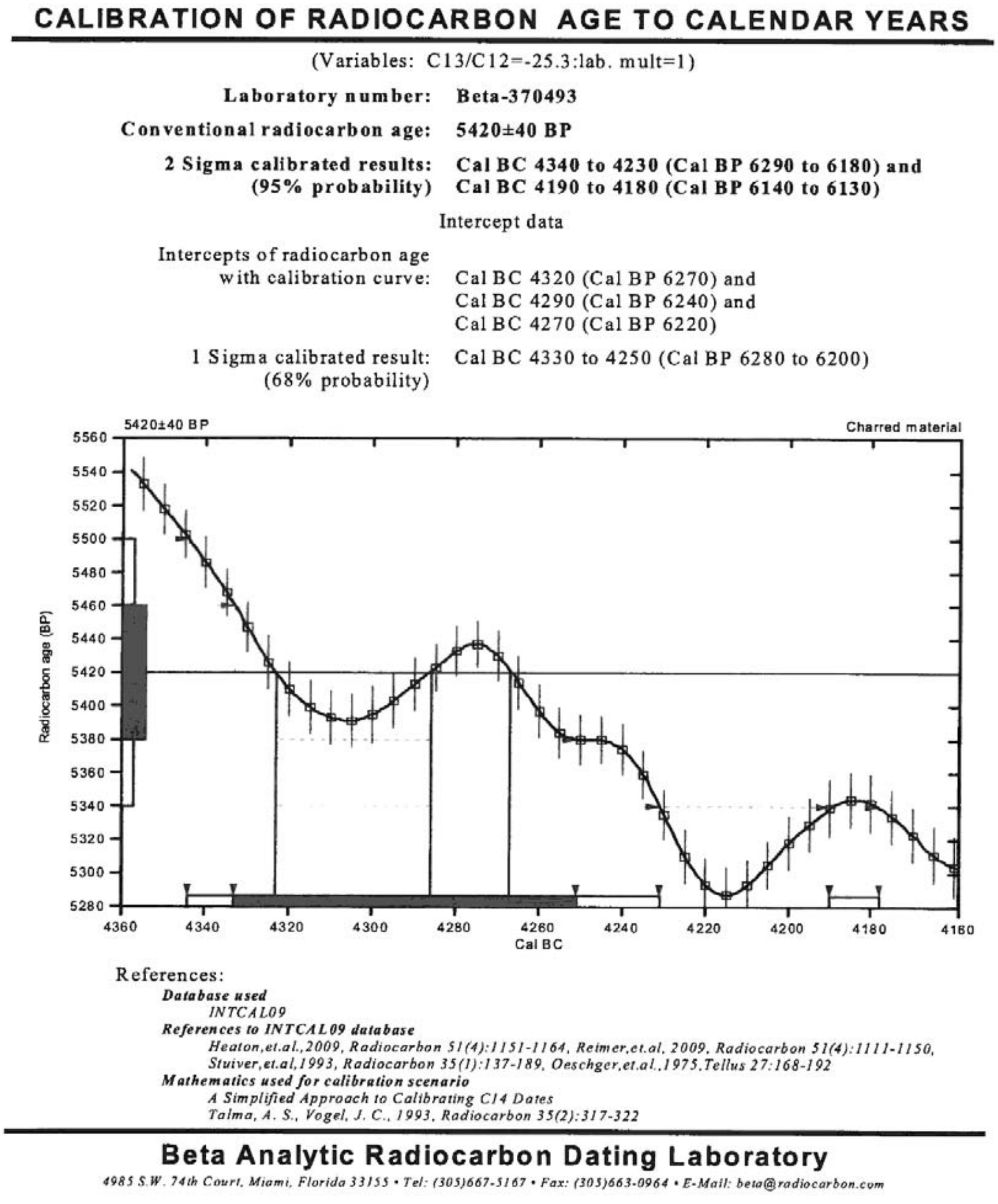


References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):1-244, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com



CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.3:lab. mult=1)

Laboratory number:	**Beta-370493**
Conventional radiocarbon age:	**5420±40 BP**
2 Sigma calibrated results: **(95% probability)**	**Cal BC 4340 to 4230 (Cal BP 6290 to 6180) and** **Cal BC 4190 to 4180 (Cal BP 6140 to 6130)**
	Intercept data
Intercepts of radiocarbon age with calibration curve:	Cal BC 4320 (Cal BP 6270) and Cal BC 4290 (Cal BP 6240) and Cal BC 4270 (Cal BP 6220)
1 Sigma calibrated result: (68% probability)	Cal BC 4330 to 4250 (Cal BP 6280 to 6200)

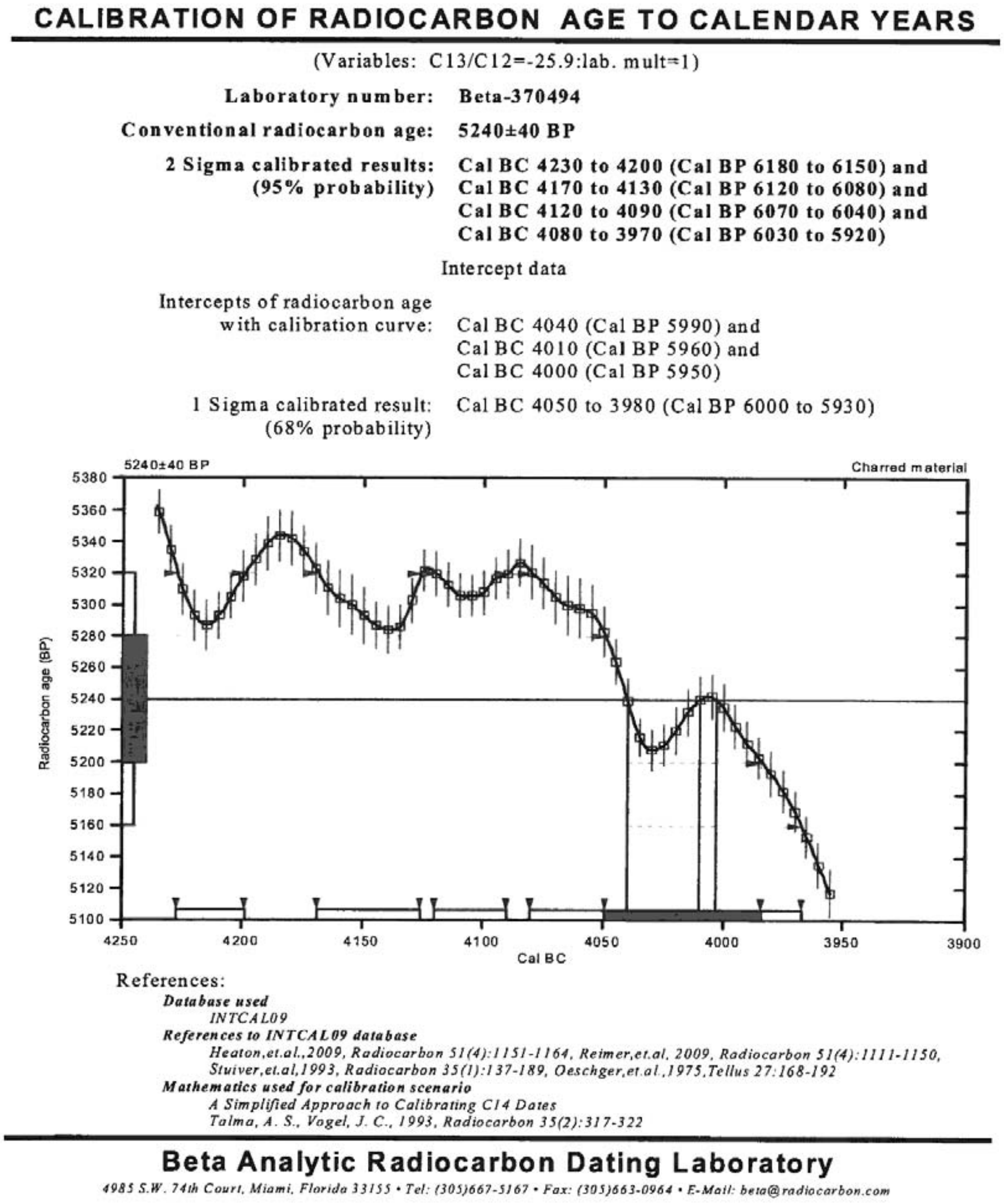
References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

Page 7 of 18



CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.9:lab. mult=1)

Laboratory number: **Beta-370494**

Conventional radiocarbon age: **5240±40 BP**

2 Sigma calibrated results:
(95% probability)
Cal BC 4230 to 4200 (Cal BP 6180 to 6150) and
Cal BC 4170 to 4130 (Cal BP 6120 to 6080) and
Cal BC 4120 to 4090 (Cal BP 6070 to 6040) and
Cal BC 4080 to 3970 (Cal BP 6030 to 5920)

Intercept data

Intercepts of radiocarbon age with calibration curve:
Cal BC 4040 (Cal BP 5990) and
Cal BC 4010 (Cal BP 5960) and
Cal BC 4000 (Cal BP 5950)

1 Sigma calibrated result: (68% probability)
Cal BC 4050 to 3980 (Cal BP 6000 to 5930)

References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

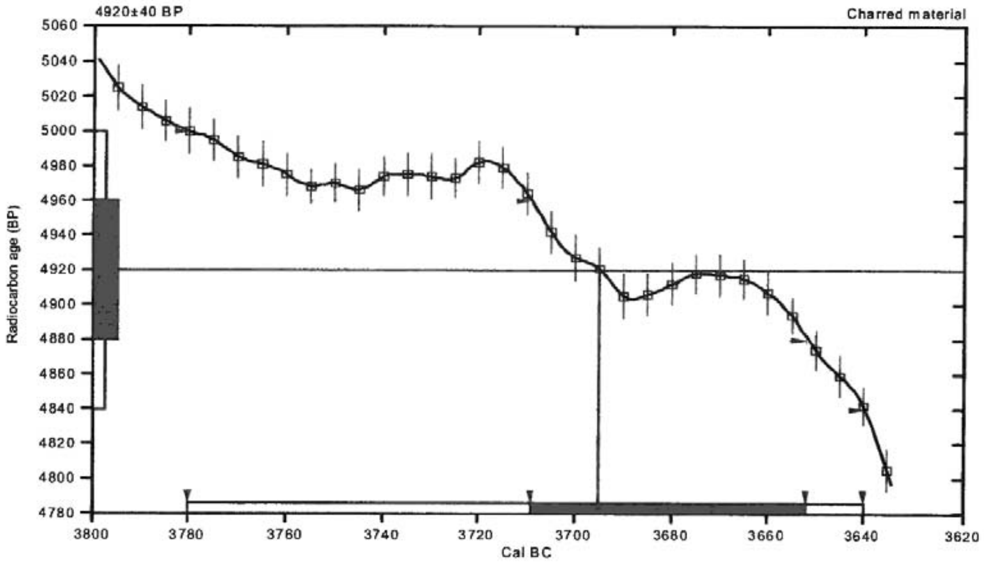
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.4:lab. mult=1)

Laboratory number:	**Beta-370495**
Conventional radiocarbon age:	**4920±40 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 3780 to 3640 (Cal BP 5730 to 5590)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 3700 (Cal BP 5640)
1 Sigma calibrated result: (68% probability)	Cal BC 3710 to 3650 (Cal BP 5660 to 5600)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

Page 9 of 18

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.8:lab. mult=1)

Laboratory number: **Beta-370496**

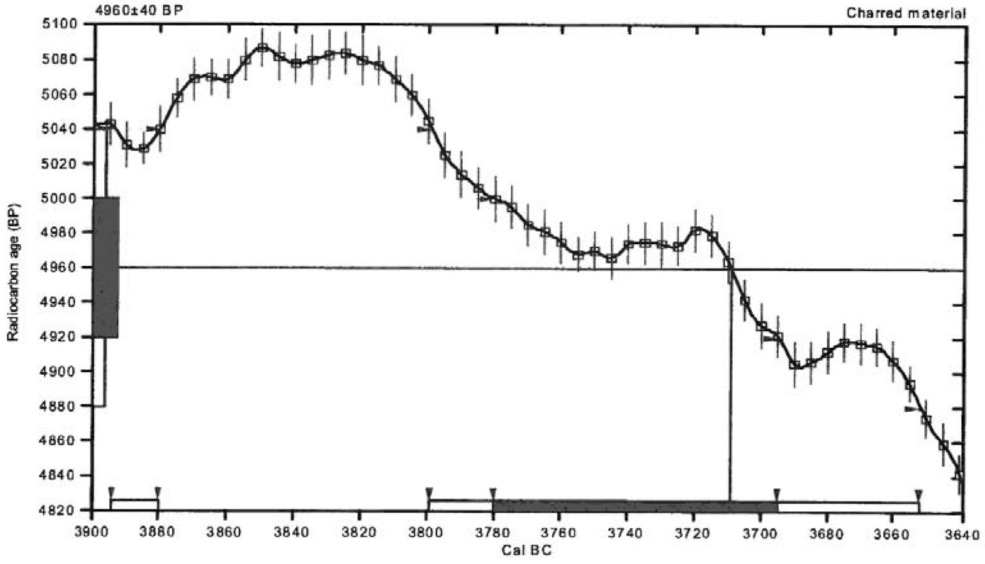
Conventional radiocarbon age: **4960±40 BP**

2 Sigma calibrated results: **Cal BC 3890 to 3880 (Cal BP 5840 to 5830) and**
(95% probability) **Cal BC 3800 to 3650 (Cal BP 5750 to 5600)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 3710 (Cal BP 5660)

1 Sigma calibrated result: Cal BC 3780 to 3700 (Cal BP 5730 to 5640)
(68% probability)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.8:lab. mult=1)

Laboratory number: **Beta-370497**

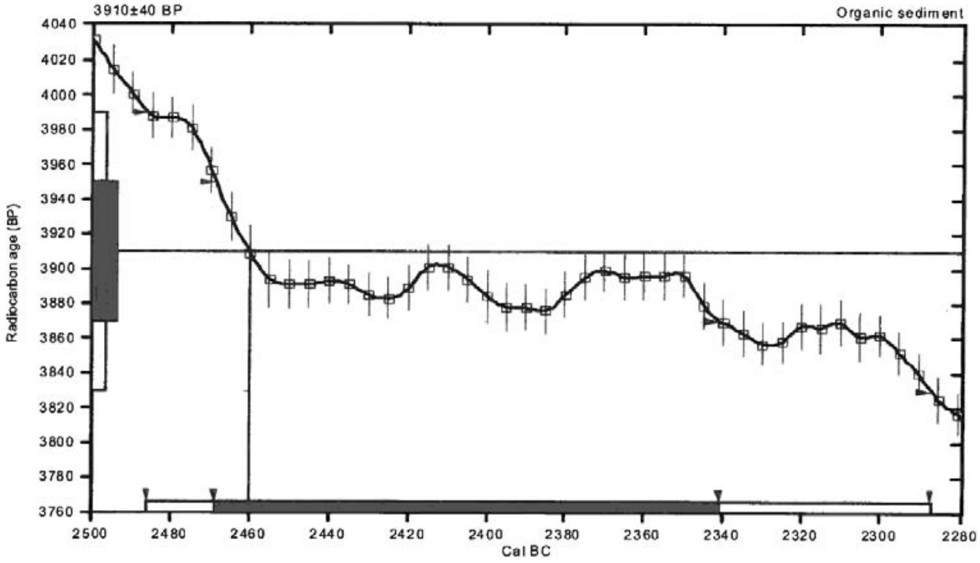
Conventional radiocarbon age: **3910±40 BP**

2 Sigma calibrated result: **Cal BC 2490 to 2290 (Cal BP 4440 to 4240)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 2460 (Cal BP 4410)

1 Sigma calibrated result: Cal BC 2470 to 2340 (Cal BP 4420 to 4290)
(68% probability)



References:

Database used
INTCAL09
References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):1-244, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

BETA
Consistent Accuracy
Delivered On Time.

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0964
beta@radiocarbon.com
www.radiocarbon.com

MR. DARDEN HOOD
Director

Mr. Ronald Hatfield
Mr. Christopher Patrick
Deputy Directors

TxDOT - ENV
Sep 0 2007
CRM

August 28, 2007

Dr. James Abbott
Texas Department of Transportation
Cultural Resource Management
Environmental Affairs Division
125 East 11th Street
Austin, TX 78701

RE: Radiocarbon Dating Results For Samples MS69/32-7-1C, MS69/36-7-1, MS69/36-7-3, MS69/505-7-16, MS69/514-7-2

Dear Jim:

Enclosed are the radiocarbon dating results for five samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

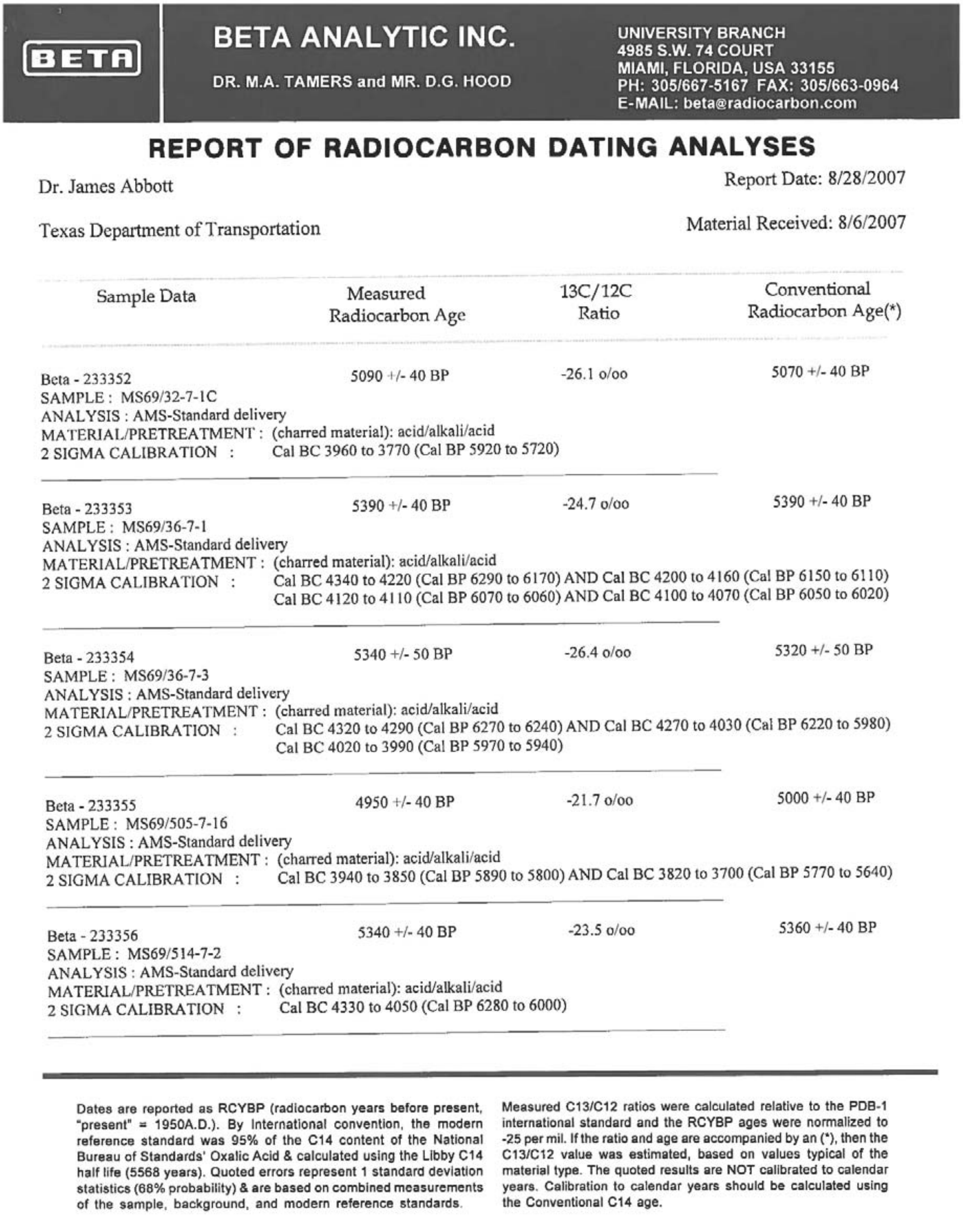
As always, no students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

If you have specific questions about the analyses, please contact us. We are always available to answer your questions.

Our invoice is enclosed. Please, forward it to the appropriate officer or send VISA charge authorization. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood



BETA
BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD

UNIVERSITY BRANCH
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305/667-5167 FAX: 305/663-0964
E-MAIL: beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. James Abbott
Report Date: 8/28/2007

Texas Department of Transportation
Material Received: 8/6/2007

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 233352 SAMPLE : MS69/32-7-1C ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 3960 to 3770 (Cal BP 5920 to 5720)	5090 +/- 40 BP	-26.1 o/oo	5070 +/- 40 BP
Beta - 233353 SAMPLE : MS69/36-7-1 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 4340 to 4220 (Cal BP 6290 to 6170) AND Cal BC 4200 to 4160 (Cal BP 6150 to 6110) Cal BC 4120 to 4110 (Cal BP 6070 to 6060) AND Cal BC 4100 to 4070 (Cal BP 6050 to 6020)	5390 +/- 40 BP	-24.7 o/oo	5390 +/- 40 BP
Beta - 233354 SAMPLE : MS69/36-7-3 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 4320 to 4290 (Cal BP 6270 to 6240) AND Cal BC 4270 to 4030 (Cal BP 6220 to 5980) Cal BC 4020 to 3990 (Cal BP 5970 to 5940)	5340 +/- 50 BP	-26.4 o/oo	5320 +/- 50 BP
Beta - 233355 SAMPLE : MS69/505-7-16 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 3940 to 3850 (Cal BP 5890 to 5800) AND Cal BC 3820 to 3700 (Cal BP 5770 to 5640)	4950 +/- 40 BP	-21.7 o/oo	5000 +/- 40 BP
Beta - 233356 SAMPLE : MS69/514-7-2 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 4330 to 4050 (Cal BP 6280 to 6000)	5340 +/- 40 BP	-23.5 o/oo	5360 +/- 40 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.1:lab. mult=1)

Laboratory number: **233352**

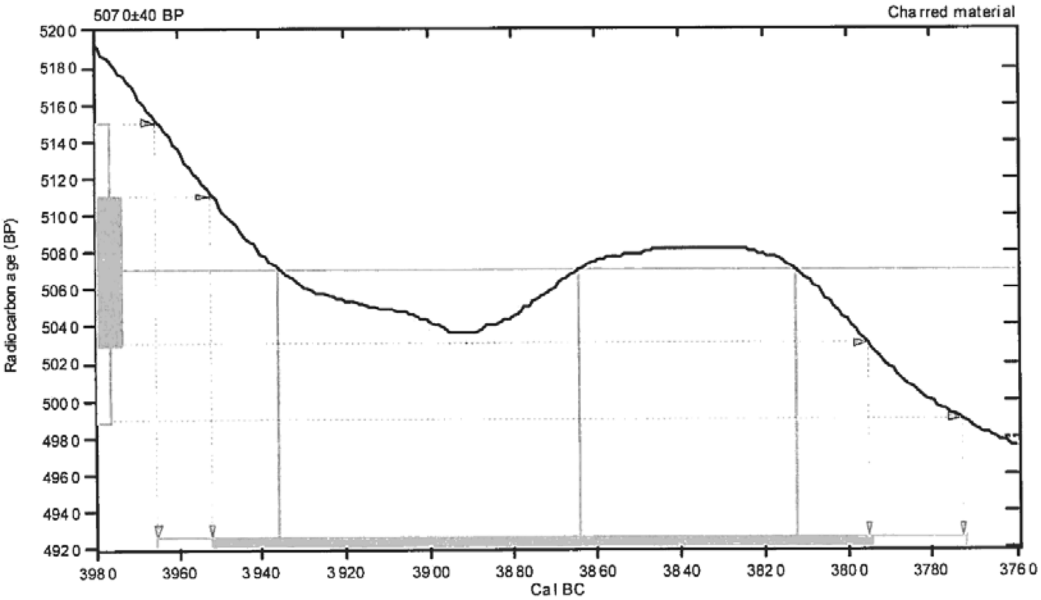
Conventional radiocarbon age: **5070±40 BP**

2 Sigma calibrated result: **Cal BC 3960 to 3770 (Cal BP 5920 to 5720)**
(95% probability)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 3940 (Cal BP 5890) and
Cal BC 3860 (Cal BP 5810) and
Cal BC 3810 (Cal BP 5760)

1 Sigma calibrated result: Cal BC 3950 to 3800 (Cal BP 5900 to 5740)
(68% probability)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.7:lab. mult=1)

Laboratory number: **233353**

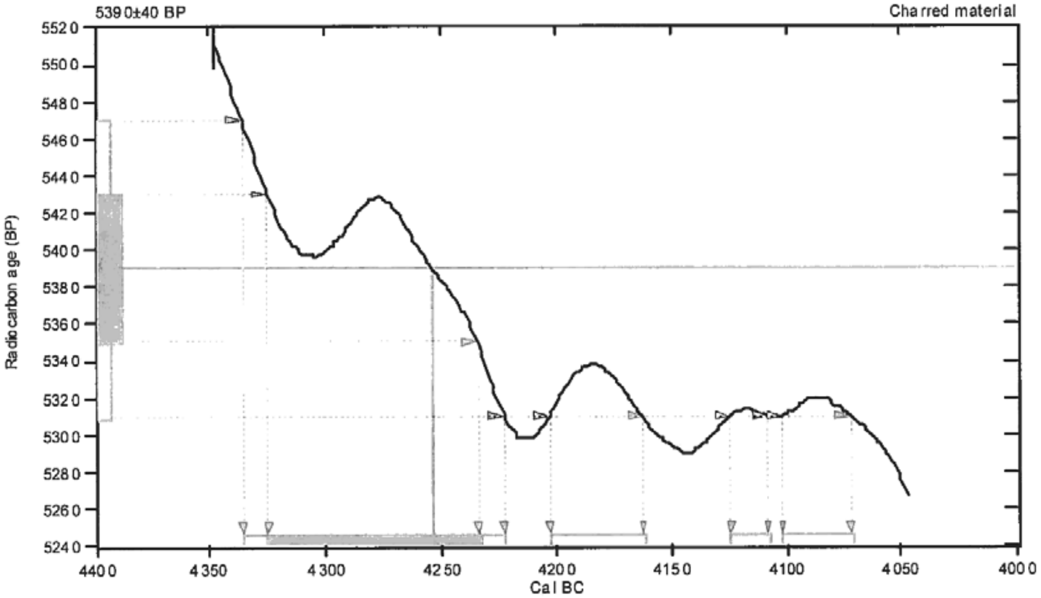
Conventional radiocarbon age: **5390±40 BP**

2 Sigma calibrated results: **Cal BC 4340 to 4220 (Cal BP 6290 to 6170) and**
(95% probability) **Cal BC 4200 to 4160 (Cal BP 6150 to 6110) and**
Cal BC 4120 to 4110 (Cal BP 6070 to 6060) and
Cal BC 4100 to 4070 (Cal BP 6050 to 6020)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 4250 (Cal BP 6200)

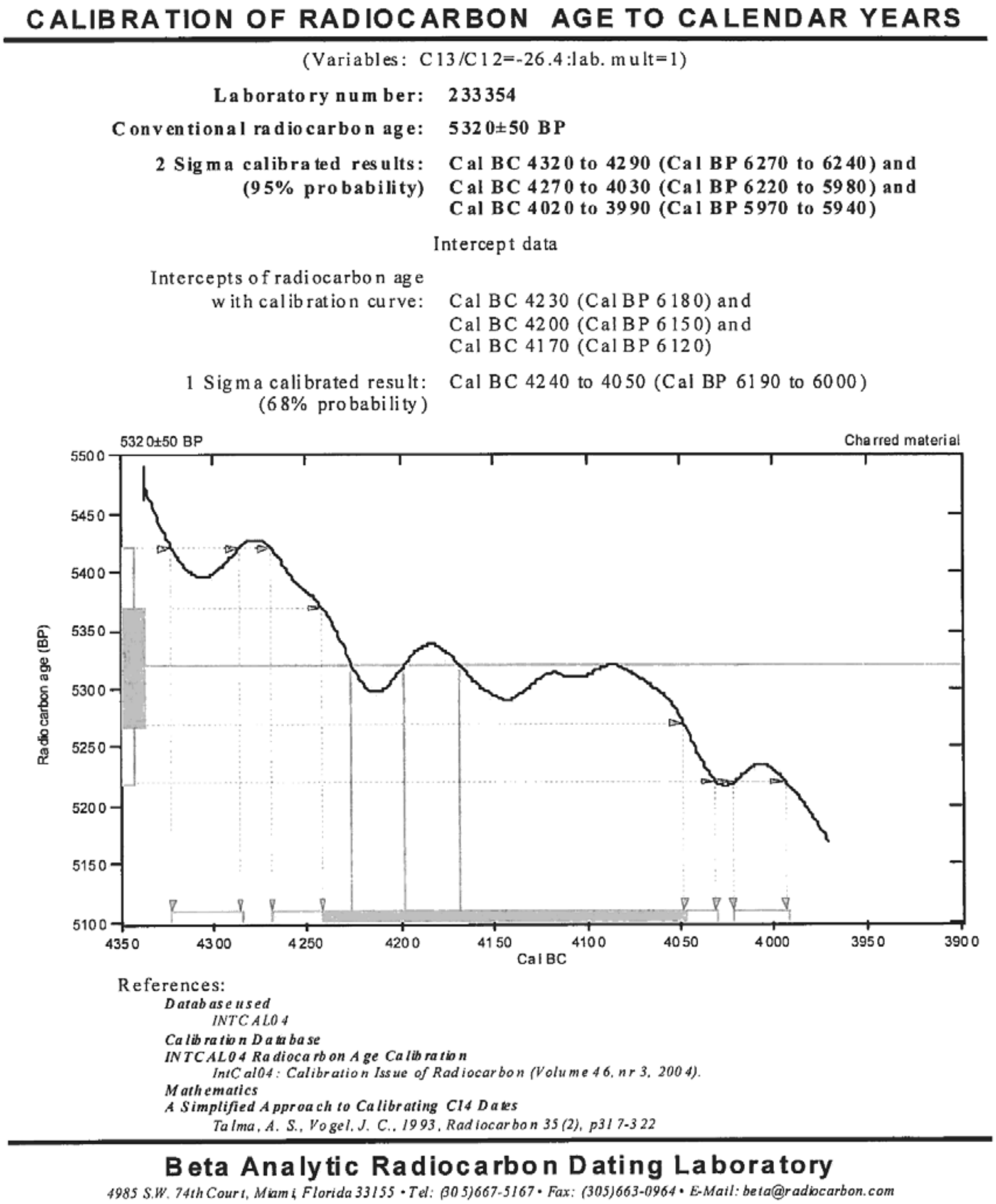
1 Sigma calibrated result: Cal BC 4320 to 4230 (Cal BP 6280 to 6180)
(68% probability)



References:
Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com



CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.4:lab. mult=1)

Laboratory number: **233354**

Conventional radiocarbon age: **5320±50 BP**

2 Sigma calibrated results: **Cal BC 4320 to 4290 (Cal BP 6270 to 6240) and**
(95% probability) **Cal BC 4270 to 4030 (Cal BP 6220 to 5980) and**
Cal BC 4020 to 3990 (Cal BP 5970 to 5940)

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal BC 4230 (Cal BP 6180) and
Cal BC 4200 (Cal BP 6150) and
Cal BC 4170 (Cal BP 6120)

1 Sigma calibrated result: Cal BC 4240 to 4050 (Cal BP 6190 to 6000)
(68% probability)

References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-21.7:lab. mult=1)

Laboratory number: **233355**

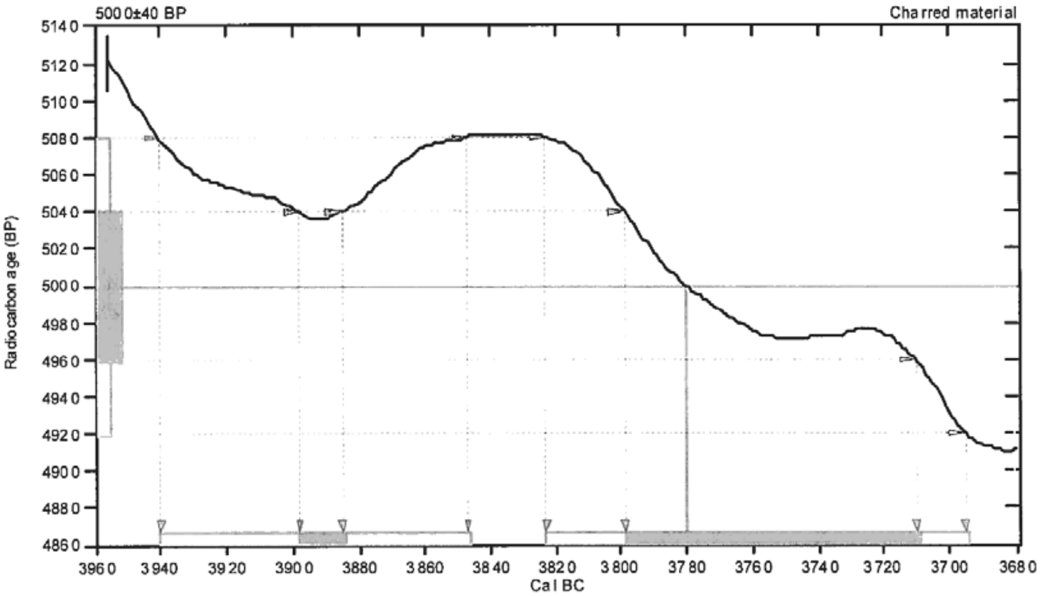
Conventional radiocarbon age: **5000±40 BP**

2 Sigma calibrated results: **Cal BC 3940 to 3850 (Cal BP 5890 to 5800) and**
(95% probability) **Cal BC 3820 to 3700 (Cal BP 5770 to 5640)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal BC 3780 (Cal BP 5730)

1 Sigma calibrated results: Cal BC 3900 to 3880 (Cal BP 5850 to 5840) and
(68% probability) Cal BC 3800 to 3710 (Cal BP 5750 to 5660)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com

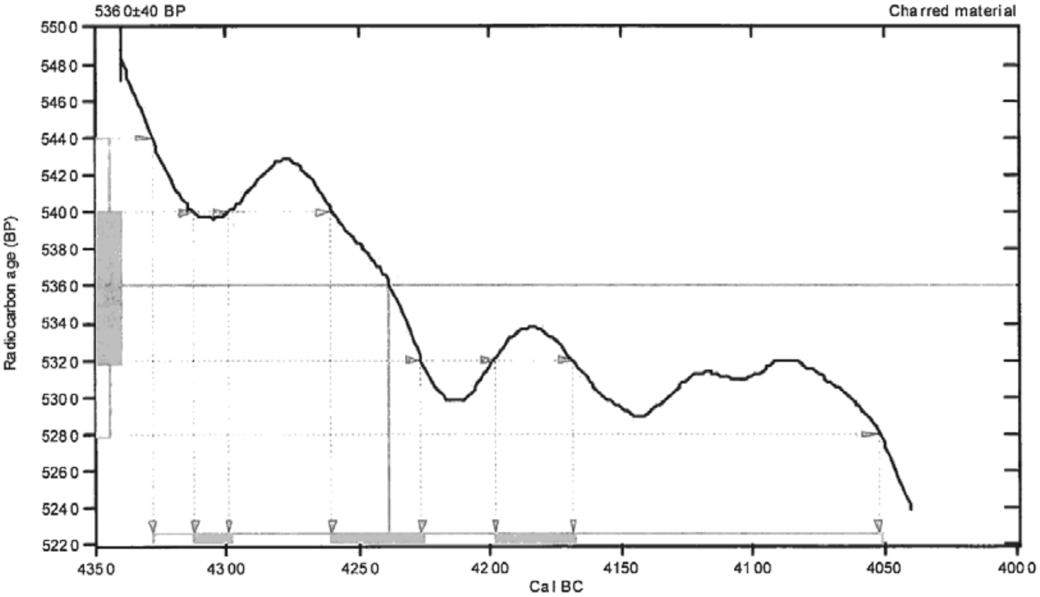
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.5:lab. mult=1)

Laboratory number:	**233356**
Conventional radiocarbon age:	**5360±40 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal BC 4330 to 4050 (Cal BP 6280 to 6000)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal BC 4240 (Cal BP 6190)
1 Sigma calibrated results: (68% probability)	Cal BC 4310 to 4300 (Cal BP 6260 to 6250) and Cal BC 4260 to 4230 (Cal BP 6210 to 6180) and Cal BC 4200 to 4170 (Cal BP 6150 to 6120)



References:

Database used

INTCAL04

Calibration Database

INTCAL04 Radiocarbon Age Calibration

IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).

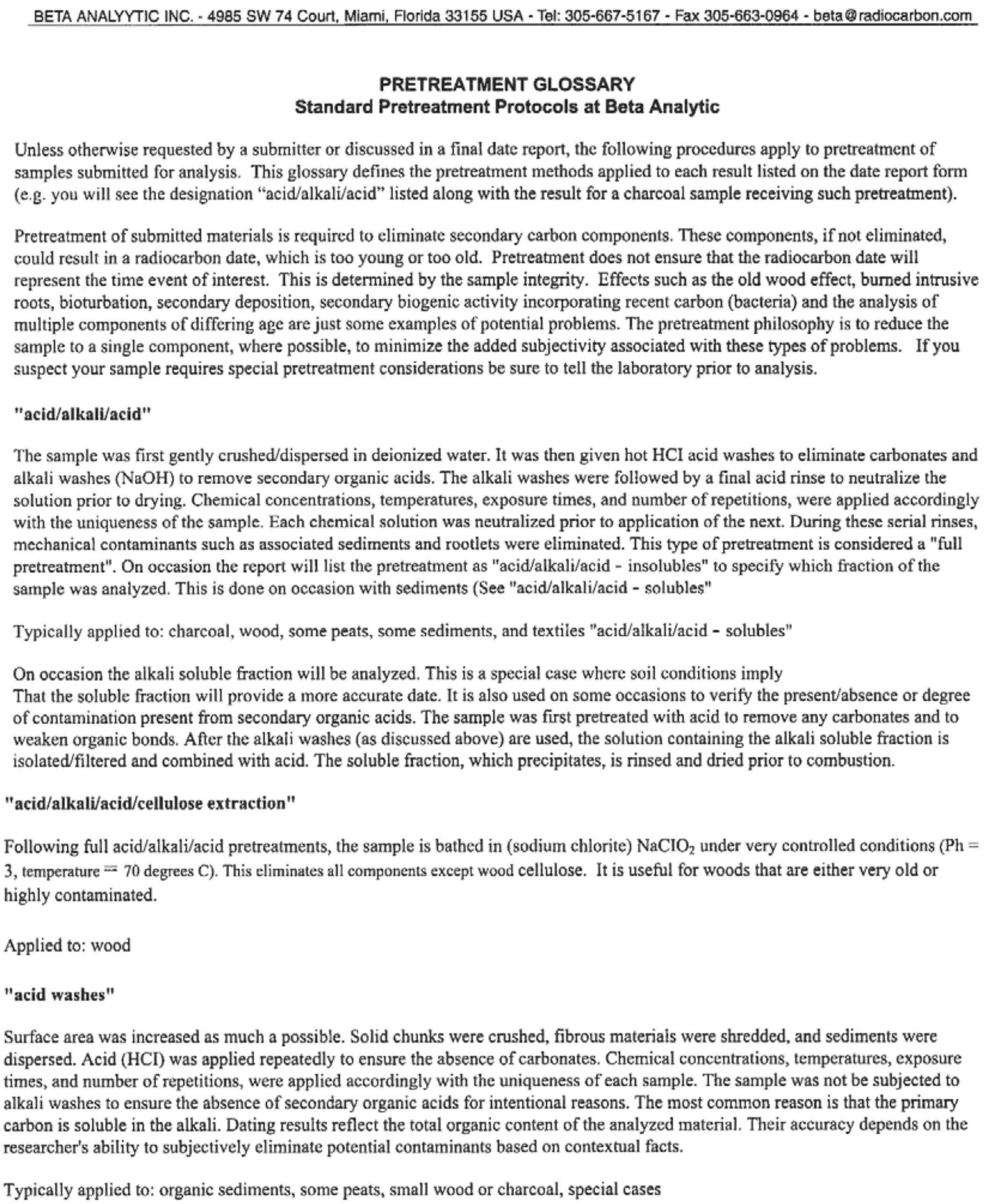
Mathematics

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-Mail: beta@radiocarbon.com



BETA ANALYYTIC INC. - 4985 SW 74 Court, Miami, Florida 33155 USA - Tel: 305-667-5167 - Fax 305-663-0964 - beta@radiocarbon.com

PRETREATMENT GLOSSARY
Standard Pretreatment Protocols at Beta Analytic

Unless otherwise requested by a submitter or discussed in a final date report, the following procedures apply to pretreatment of samples submitted for analysis. This glossary defines the pretreatment methods applied to each result listed on the date report form (e.g. you will see the designation "acid/alkali/acid" listed along with the result for a charcoal sample receiving such pretreatment).

Pretreatment of submitted materials is required to eliminate secondary carbon components. These components, if not eliminated, could result in a radiocarbon date, which is too young or too old. Pretreatment does not ensure that the radiocarbon date will represent the time event of interest. This is determined by the sample integrity. Effects such as the old wood effect, burned intrusive roots, bioturbation, secondary deposition, secondary biogenic activity incorporating recent carbon (bacteria) and the analysis of multiple components of differing age are just some examples of potential problems. The pretreatment philosophy is to reduce the sample to a single component, where possible, to minimize the added subjectivity associated with these types of problems. If you suspect your sample requires special pretreatment considerations be sure to tell the laboratory prior to analysis.

"acid/alkali/acid"

The sample was first gently crushed/dispersed in deionized water. It was then given hot HCI acid washes to eliminate carbonates and alkali washes (NaOH) to remove secondary organic acids. The alkali washes were followed by a final acid rinse to neutralize the solution prior to drying. Chemical concentrations, temperatures, exposure times, and number of repetitions, were applied accordingly with the uniqueness of the sample. Each chemical solution was neutralized prior to application of the next. During these serial rinses, mechanical contaminants such as associated sediments and rootlets were eliminated. This type of pretreatment is considered a "full pretreatment". On occasion the report will list the pretreatment as "acid/alkali/acid - insolubles" to specify which fraction of the sample was analyzed. This is done on occasion with sediments (See "acid/alkali/acid - solubles"

Typically applied to: charcoal, wood, some peats, some sediments, and textiles "acid/alkali/acid - solubles"

On occasion the alkali soluble fraction will be analyzed. This is a special case where soil conditions imply
That the soluble fraction will provide a more accurate date. It is also used on some occasions to verify the present/absence or degree of contamination present from secondary organic acids. The sample was first pretreated with acid to remove any carbonates and to weaken organic bonds. After the alkali washes (as discussed above) are used, the solution containing the alkali soluble fraction is isolated/filtered and combined with acid. The soluble fraction, which precipitates, is rinsed and dried prior to combustion.

"acid/alkali/acid/cellulose extraction"

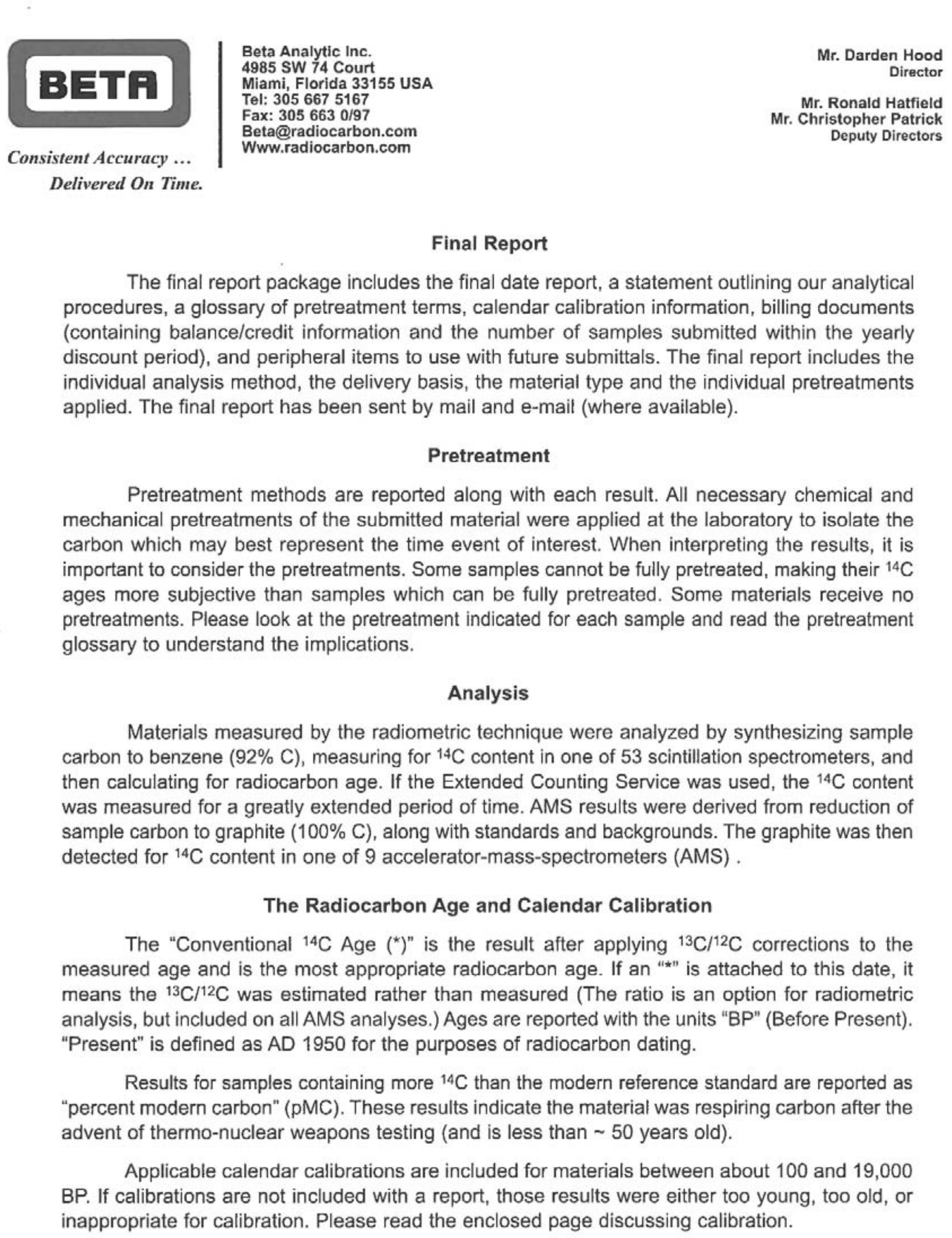
Following full acid/alkali/acid pretreatments, the sample is bathed in (sodium chlorite) $NaClO_2$ under very controlled conditions (Ph = 3, temperature = 70 degrees C). This eliminates all components except wood cellulose. It is useful for woods that are either very old or highly contaminated.

Applied to: wood

"acid washes"

Surface area was increased as much a possible. Solid chunks were crushed, fibrous materials were shredded, and sediments were dispersed. Acid (HCI) was applied repeatedly to ensure the absence of carbonates. Chemical concentrations, temperatures, exposure times, and number of repetitions, were applied accordingly with the uniqueness of each sample. The sample was not be subjected to alkali washes to ensure the absence of secondary organic acids for intentional reasons. The most common reason is that the primary carbon is soluble in the alkali. Dating results reflect the total organic content of the analyzed material. Their accuracy depends on the researcher's ability to subjectively eliminate potential contaminants based on contextual facts.

Typically applied to: organic sediments, some peats, small wood or charcoal, special cases



BETA

Consistent Accuracy …
Delivered On Time.

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0/97
Beta@radiocarbon.com
Www.radiocarbon.com

Mr. Darden Hood
Director

Mr. Ronald Hatfield
Mr. Christopher Patrick
Deputy Directors

Final Report

The final report package includes the final date report, a statement outlining our analytical procedures, a glossary of pretreatment terms, calendar calibration information, billing documents (containing balance/credit information and the number of samples submitted within the yearly discount period), and peripheral items to use with future submittals. The final report includes the individual analysis method, the delivery basis, the material type and the individual pretreatments applied. The final report has been sent by mail and e-mail (where available).

Pretreatment

Pretreatment methods are reported along with each result. All necessary chemical and mechanical pretreatments of the submitted material were applied at the laboratory to isolate the carbon which may best represent the time event of interest. When interpreting the results, it is important to consider the pretreatments. Some samples cannot be fully pretreated, making their ^{14}C ages more subjective than samples which can be fully pretreated. Some materials receive no pretreatments. Please look at the pretreatment indicated for each sample and read the pretreatment glossary to understand the implications.

Analysis

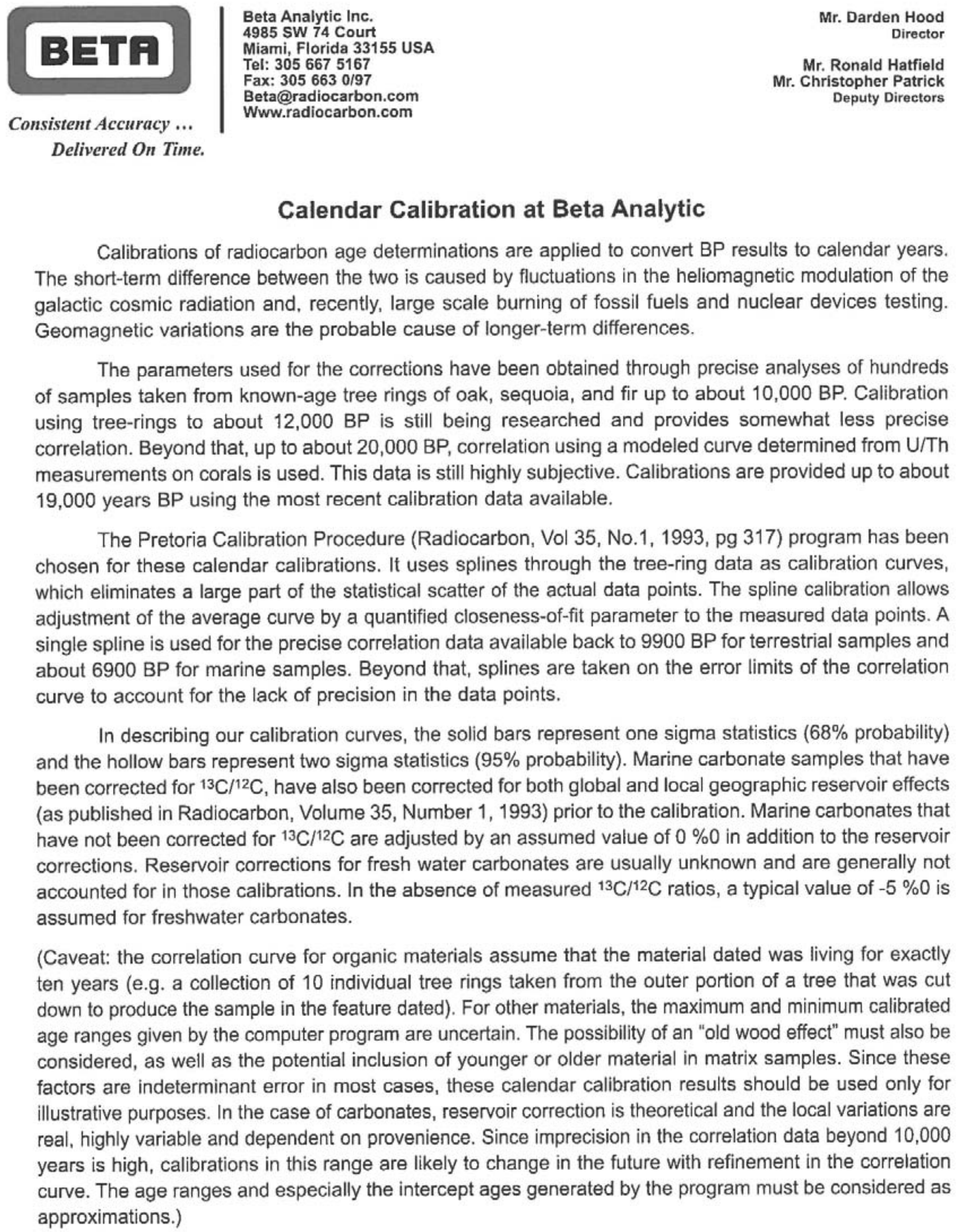
Materials measured by the radiometric technique were analyzed by synthesizing sample carbon to benzene (92% C), measuring for ^{14}C content in one of 53 scintillation spectrometers, and then calculating for radiocarbon age. If the Extended Counting Service was used, the ^{14}C content was measured for a greatly extended period of time. AMS results were derived from reduction of sample carbon to graphite (100% C), along with standards and backgrounds. The graphite was then detected for ^{14}C content in one of 9 accelerator-mass-spectrometers (AMS) .

The Radiocarbon Age and Calendar Calibration

The "Conventional ^{14}C Age (*)" is the result after applying ^{13}C/^{12}C corrections to the measured age and is the most appropriate radiocarbon age. If an "*" is attached to this date, it means the ^{13}C/^{12}C was estimated rather than measured (The ratio is an option for radiometric analysis, but included on all AMS analyses.) Ages are reported with the units "BP" (Before Present). "Present" is defined as AD 1950 for the purposes of radiocarbon dating.

Results for samples containing more ^{14}C than the modern reference standard are reported as "percent modern carbon" (pMC). These results indicate the material was respiring carbon after the advent of thermo-nuclear weapons testing (and is less than ~ 50 years old).

Applicable calendar calibrations are included for materials between about 100 and 19,000 BP. If calibrations are not included with a report, those results were either too young, too old, or inappropriate for calibration. Please read the enclosed page discussing calibration.



BETA
Consistent Accuracy …
Delivered On Time.

Beta Analytic Inc.
4985 SW 74 Court
Miami, Florida 33155 USA
Tel: 305 667 5167
Fax: 305 663 0/97
Beta@radiocarbon.com
Www.radiocarbon.com

Mr. Darden Hood
Director

Mr. Ronald Hatfield
Mr. Christopher Patrick
Deputy Directors

Calendar Calibration at Beta Analytic

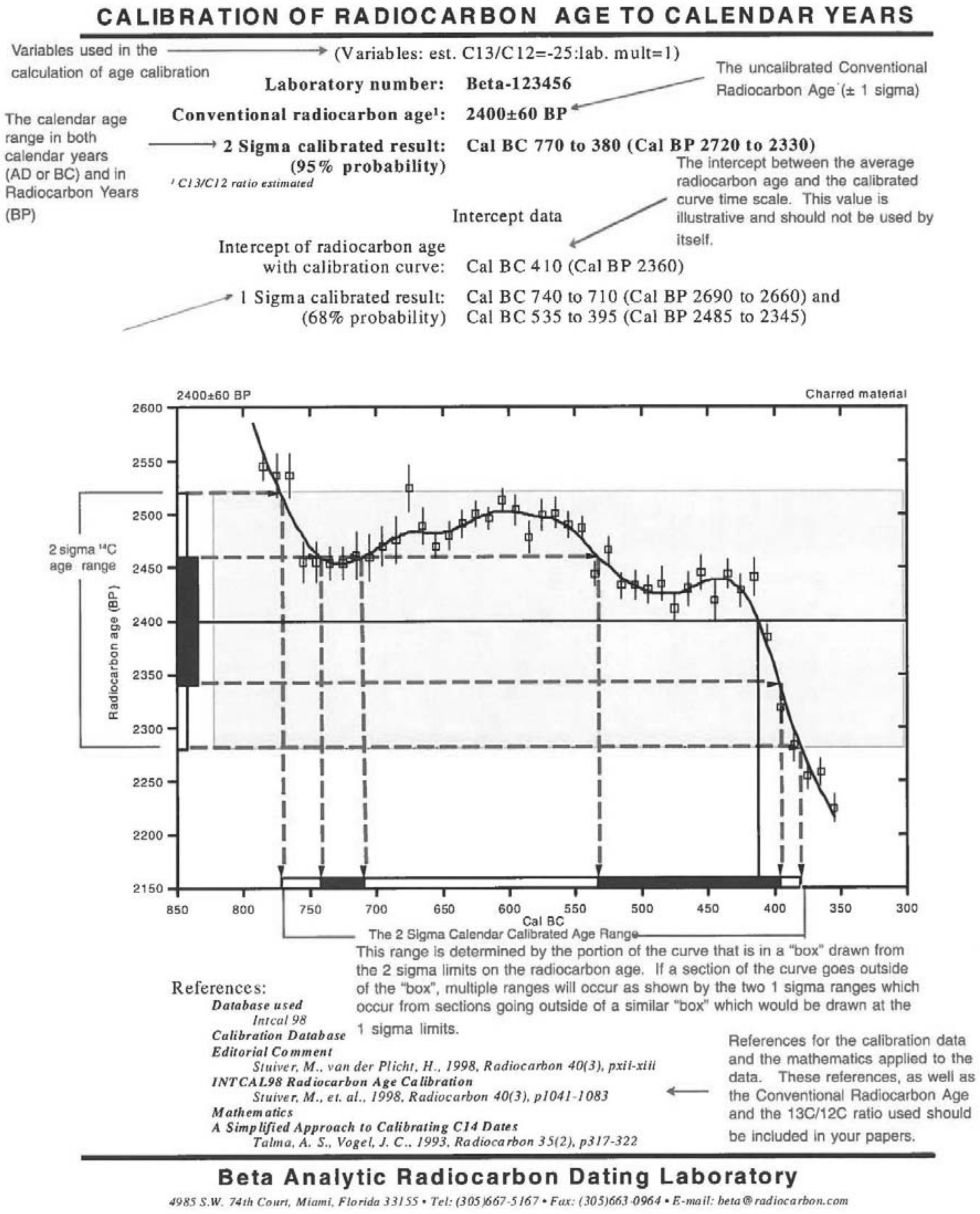
Calibrations of radiocarbon age determinations are applied to convert BP results to calendar years. The short-term difference between the two is caused by fluctuations in the heliomagnetic modulation of the galactic cosmic radiation and, recently, large scale burning of fossil fuels and nuclear devices testing. Geomagnetic variations are the probable cause of longer-term differences.

The parameters used for the corrections have been obtained through precise analyses of hundreds of samples taken from known-age tree rings of oak, sequoia, and fir up to about 10,000 BP. Calibration using tree-rings to about 12,000 BP is still being researched and provides somewhat less precise correlation. Beyond that, up to about 20,000 BP, correlation using a modeled curve determined from U/Th measurements on corals is used. This data is still highly subjective. Calibrations are provided up to about 19,000 years BP using the most recent calibration data available.

The Pretoria Calibration Procedure (Radiocarbon, Vol 35, No.1, 1993, pg 317) program has been chosen for these calendar calibrations. It uses splines through the tree-ring data as calibration curves, which eliminates a large part of the statistical scatter of the actual data points. The spline calibration allows adjustment of the average curve by a quantified closeness-of-fit parameter to the measured data points. A single spline is used for the precise correlation data available back to 9900 BP for terrestrial samples and about 6900 BP for marine samples. Beyond that, splines are taken on the error limits of the correlation curve to account for the lack of precision in the data points.

In describing our calibration curves, the solid bars represent one sigma statistics (68% probability) and the hollow bars represent two sigma statistics (95% probability). Marine carbonate samples that have been corrected for $^{13}C/^{12}C$, have also been corrected for both global and local geographic reservoir effects (as published in Radiocarbon, Volume 35, Number 1, 1993) prior to the calibration. Marine carbonates that have not been corrected for $^{13}C/^{12}C$ are adjusted by an assumed value of 0 %0 in addition to the reservoir corrections. Reservoir corrections for fresh water carbonates are usually unknown and are generally not accounted for in those calibrations. In the absence of measured $^{13}C/^{12}C$ ratios, a typical value of -5 %0 is assumed for freshwater carbonates.

(Caveat: the correlation curve for organic materials assume that the material dated was living for exactly ten years (e.g. a collection of 10 individual tree rings taken from the outer portion of a tree that was cut down to produce the sample in the feature dated). For other materials, the maximum and minimum calibrated age ranges given by the computer program are uncertain. The possibility of an "old wood effect" must also be considered, as well as the potential inclusion of younger or older material in matrix samples. Since these factors are indeterminant error in most cases, these calendar calibration results should be used only for illustrative purposes. In the case of carbonates, reservoir correction is theoretical and the local variations are real, highly variable and dependent on provenience. Since imprecision in the correlation data beyond 10,000 years is high, calibrations in this range are likely to change in the future with refinement in the correlation curve. The age ranges and especially the intercept ages generated by the program must be considered as approximations.)



CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

Variables used in the calculation of age calibration → (Variables: est. C13/C12=-25:lab. mult=1)

Laboratory number: **Beta-123456**

Conventional radiocarbon age¹: **2400±60 BP** ← The uncalibrated Conventional Radiocarbon Age (± 1 sigma)

The calendar age range in both calendar years (AD or BC) and in Radiocarbon Years (BP) → **2 Sigma calibrated result: (95% probability)** **Cal BC 770 to 380 (Cal BP 2720 to 2330)**

[1] *C13/C12 ratio estimated*

Intercept data

The intercept between the average radiocarbon age and the calibrated curve time scale. This value is illustrative and should not be used by itself.

Intercept of radiocarbon age with calibration curve: Cal BC 410 (Cal BP 2360)

1 Sigma calibrated result: (68% probability) Cal BC 740 to 710 (Cal BP 2690 to 2660) and Cal BC 535 to 395 (Cal BP 2485 to 2345)

The 2 Sigma Calendar Calibrated Age Range

This range is determined by the portion of the curve that is in a "box" drawn from the 2 sigma limits on the radiocarbon age. If a section of the curve goes outside of the "box", multiple ranges will occur as shown by the two 1 sigma ranges which occur from sections going outside of a similar "box" which would be drawn at the 1 sigma limits.

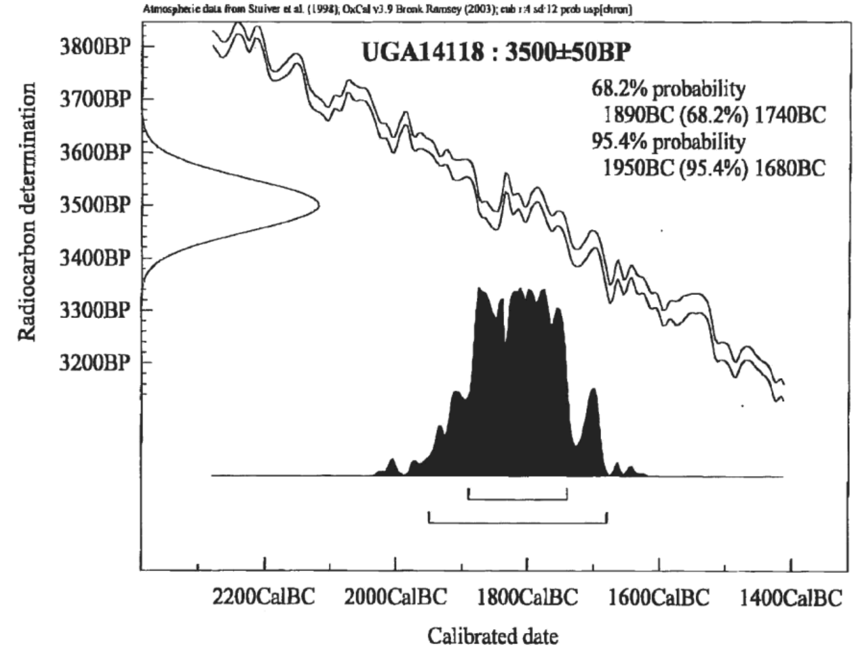
References:

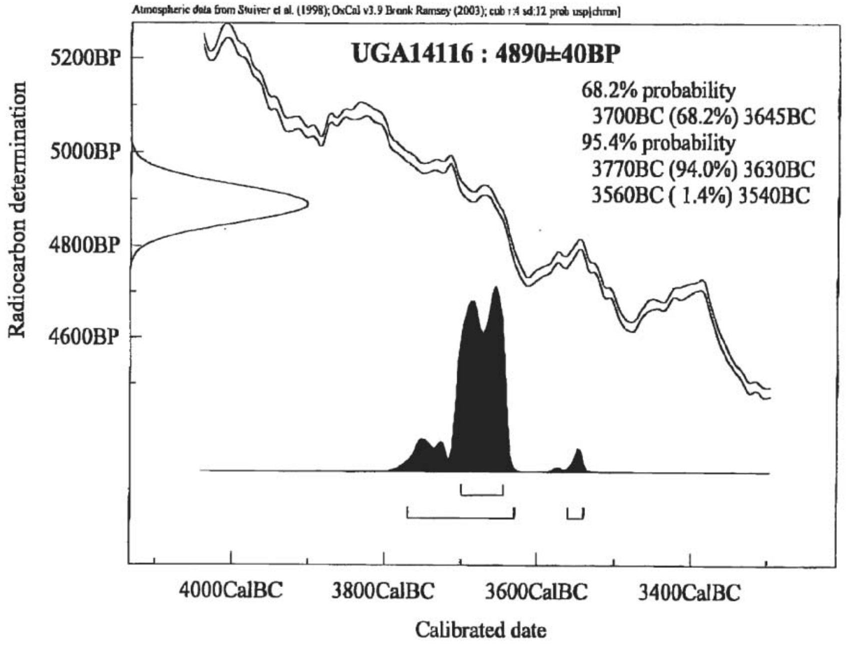
Database used
Intcal 98
Calibration Database
Editorial Comment
Stuiver, M., van der Plicht, H., 1998, Radiocarbon 40(3), pxii-xiii
INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

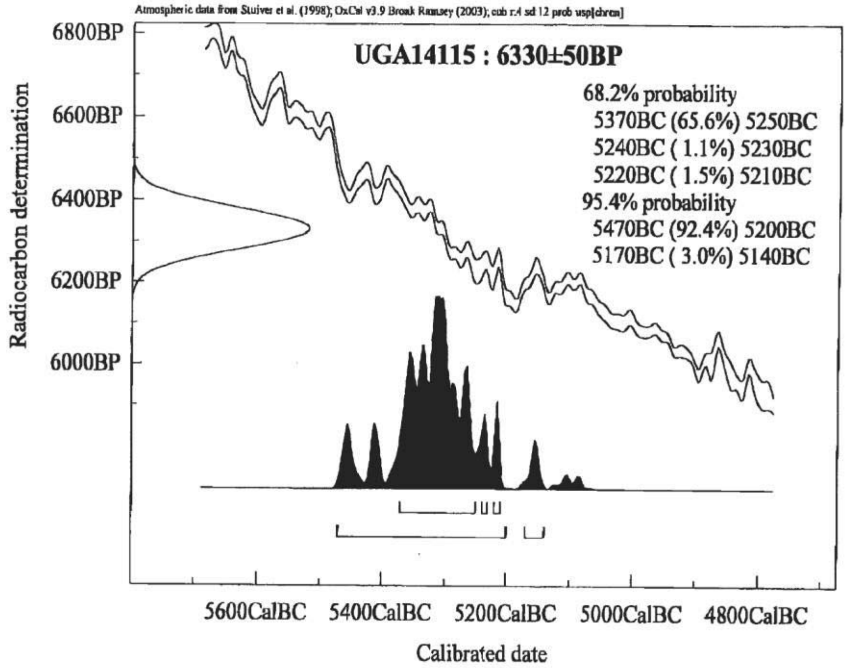
← References for the calibration data and the mathematics applied to the data. These references, as well as the Conventional Radiocarbon Age and the 13C/12C ratio used should be included in your papers.

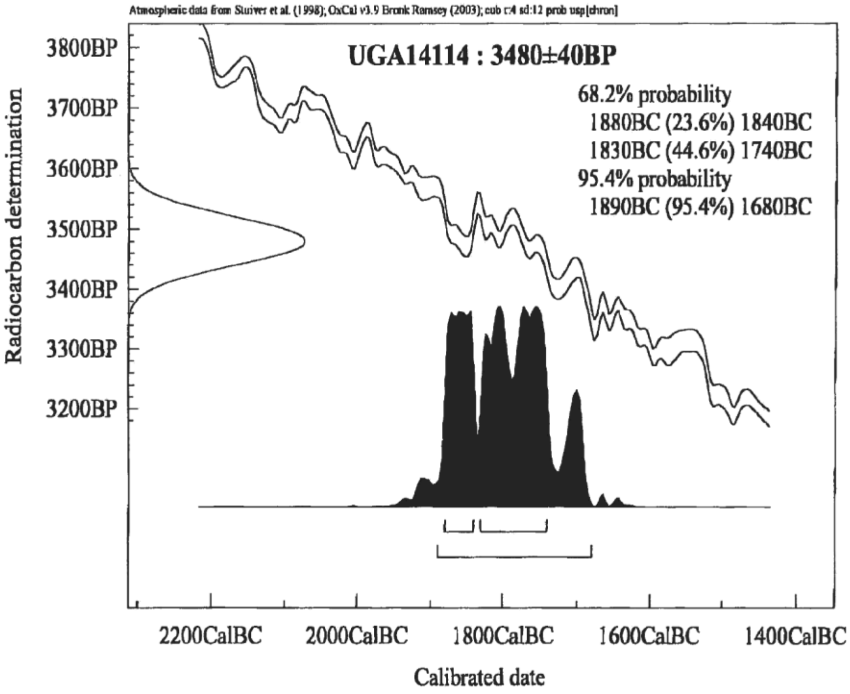
Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • E-mail: beta@radiocarbon.com

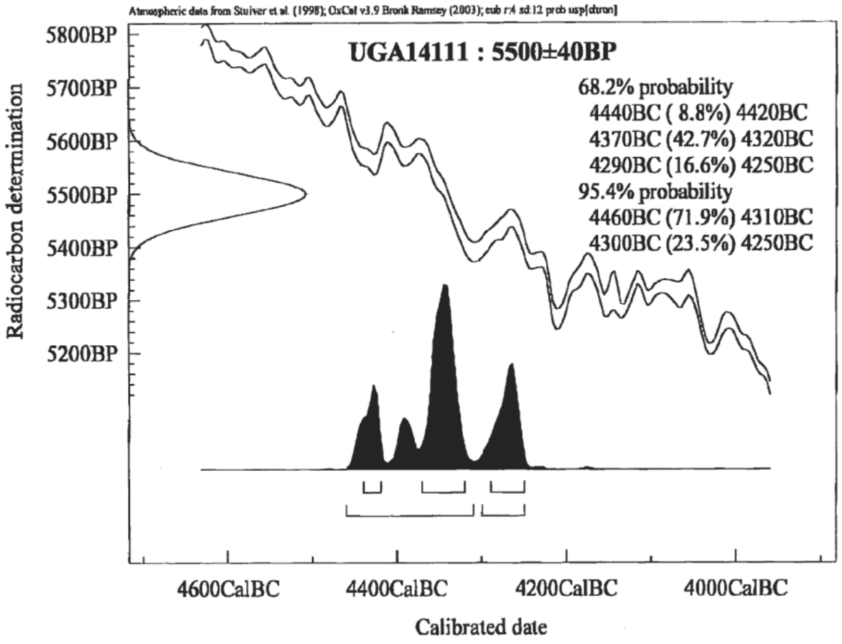

Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14118 : 3500±50BP
68.2% probability
1890BC (68.2%) 1740BC
95.4% probability
1950BC (95.4%) 1680BC
Radiocarbon determination
3800BP
3700BP
3600BP
3500BP
3400BP
3300BP
3200BP
2200CalBC
2000CalBC
1800CalBC
1600CalBC
1400CalBC
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14116 : 4890±40BP
68.2% probability
3700BC (68.2%) 3645BC
95.4% probability
3770BC (94.0%) 3630BC
3560BC (1.4%) 3540BC
5200BP
5000BP
4800BP
4600BP
Radiocarbon determination
4000CalBC
3800CalBC
3600CalBC
3400CalBC
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14115 : 6330±50BP
68.2% probability
5370BC (65.6%) 5250BC
5240BC (1.1%) 5230BC
5220BC (1.5%) 5210BC
95.4% probability
5470BC (92.4%) 5200BC
5170BC (3.0%) 5140BC
6800BP
6600BP
6400BP
6200BP
6000BP
Radiocarbon determination
5600CalBC
5400CalBC
5200CalBC
5000CalBC
4800CalBC
Calibrated date

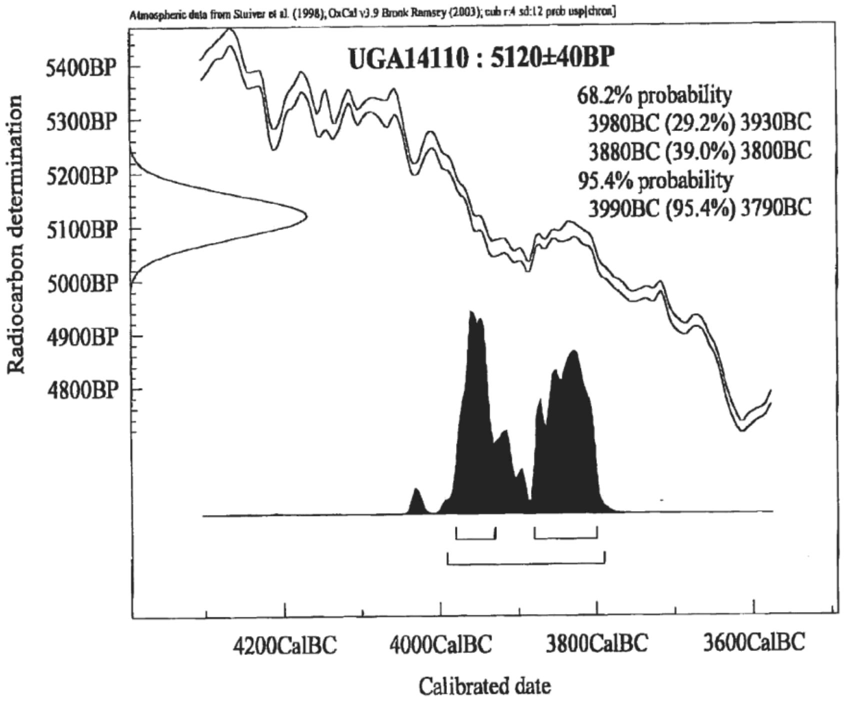

Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14114 : 3480±40BP
68.2% probability
1880BC (23.6%) 1840BC
1830BC (44.6%) 1740BC
95.4% probability
1890BC (95.4%) 1680BC
Radiocarbon determination
3800BP
3700BP
3600BP
3500BP
3400BP
3300BP
3200BP
2200CalBC
2000CalBC
1800CalBC
1600CalBC
1400CalBC
Calibrated date

08-16-2004 10:58AM FROM-CAIS UNIV of GA +7065426106 T-111 P.008/022 F-415

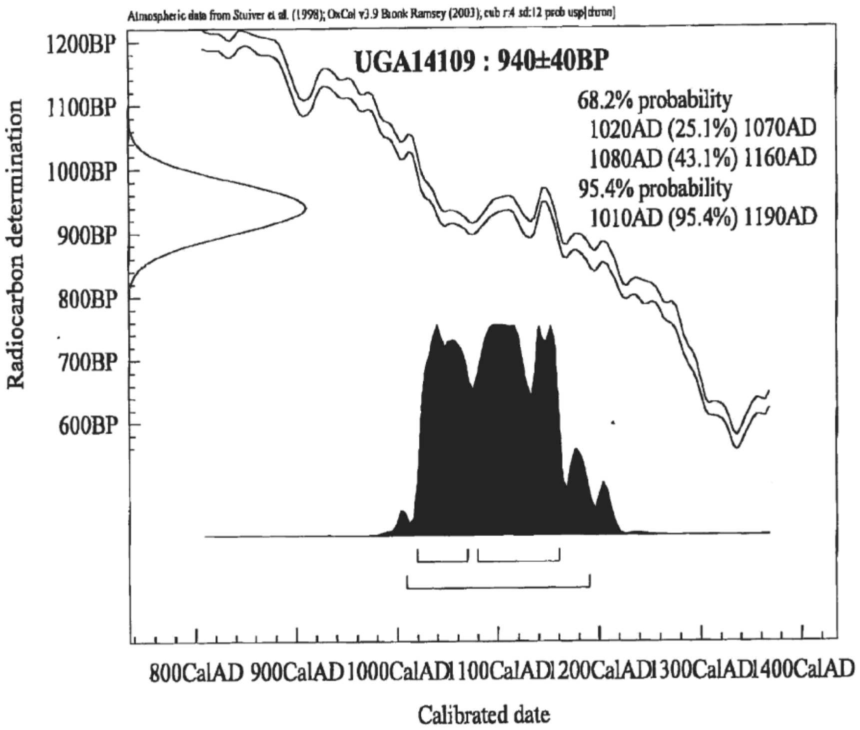


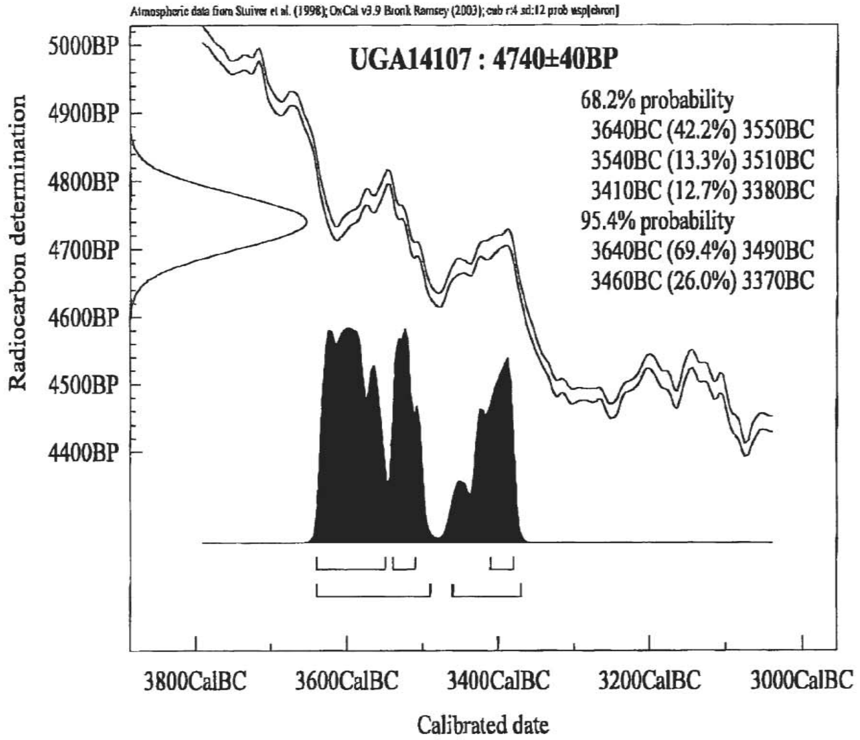
08/16/04 THU 09:54 [TX/RX NO 7889]

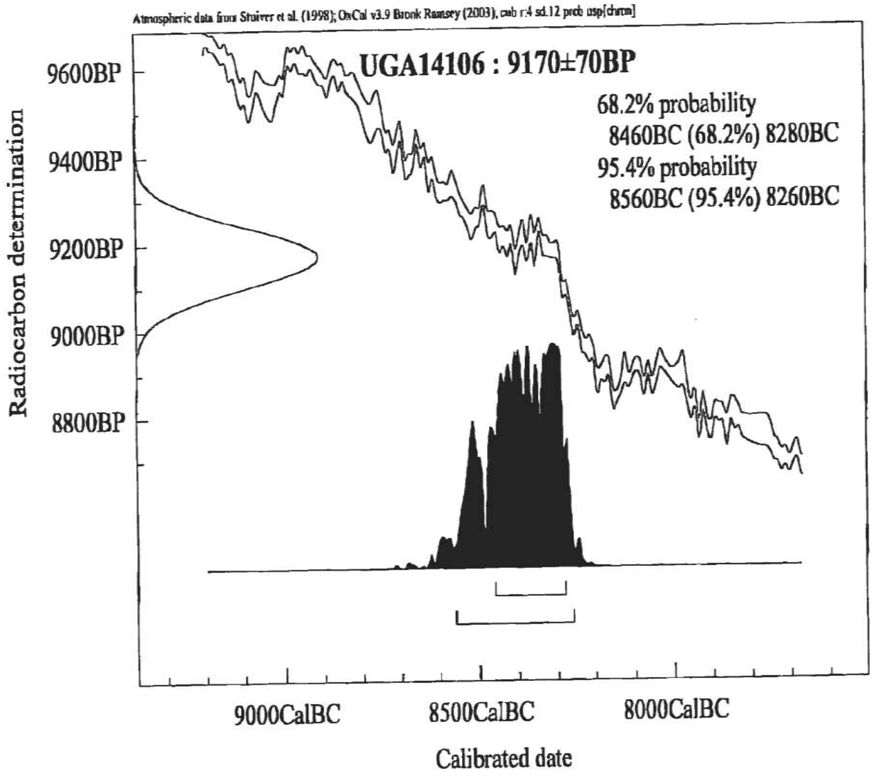
09-16-2004 10:59AM FROM-CAIS UNIV of GA +7065426106 T-111 P.008/022 F-416

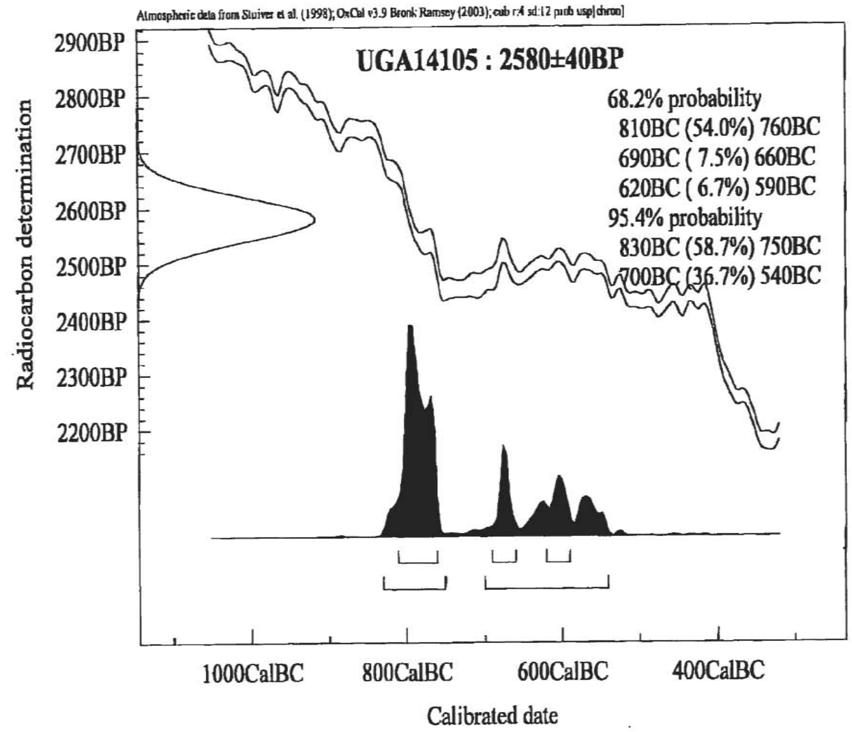


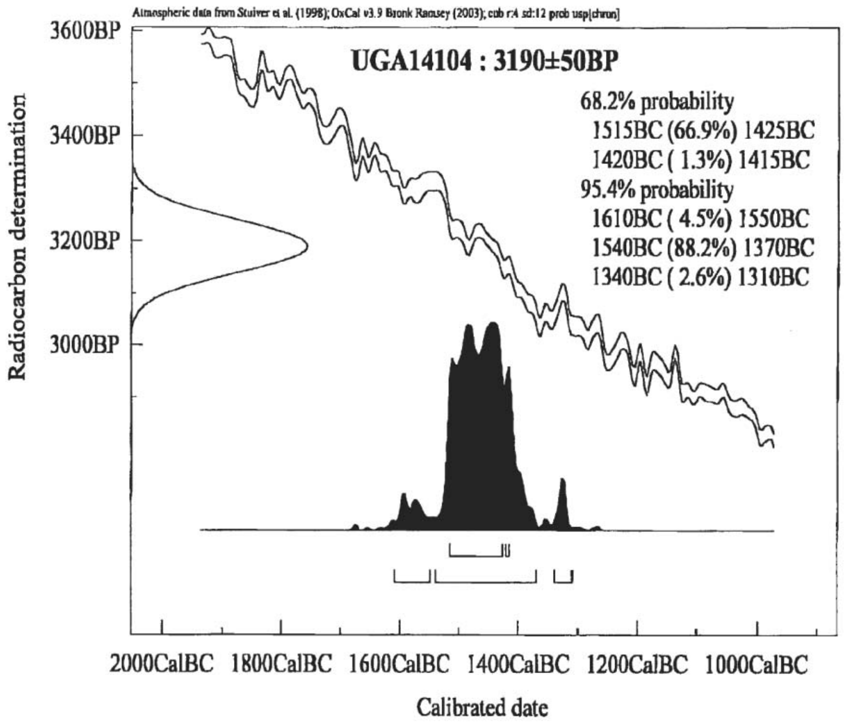
09/16/04 THU 09:54 [TX/RX NO 7889]


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14109 : 940±40BP
68.2% probability
1020AD (25.1%) 1070AD
1080AD (43.1%) 1160AD
95.4% probability
1010AD (95.4%) 1190AD
Radiocarbon determination
1200BP
1100BP
1000BP
900BP
800BP
700BP
600BP
800CalAD
900CalAD
1000CalAD
1100CalAD
1200CalAD
1300CalAD
1400CalAD
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14107 : 4740±40BP
68.2% probability
3640BC (42.2%) 3550BC
3540BC (13.3%) 3510BC
3410BC (12.7%) 3380BC
95.4% probability
3640BC (69.4%) 3490BC
3460BC (26.0%) 3370BC
Radiocarbon determination
5000BP
4900BP
4800BP
4700BP
4600BP
4500BP
4400BP
3800CalBC
3600CalBC
3400CalBC
3200CalBC
3000CalBC
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14106 : 9170±70BP
68.2% probability
8460BC (68.2%) 8280BC
95.4% probability
8560BC (95.4%) 8260BC
9600BP
9400BP
9200BP
9000BP
8800BP
Radiocarbon determination
9000CalBC
8500CalBC
8000CalBC
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14105 : 2580±40BP
68.2% probability
810BC (54.0%) 760BC
690BC (7.5%) 660BC
620BC (6.7%) 590BC
95.4% probability
830BC (58.7%) 750BC
700BC (36.7%) 540BC
Radiocarbon determination
2900BP
2800BP
2700BP
2600BP
2500BP
2400BP
2300BP
2200BP
1000CalBC
800CalBC
600CalBC
400CalBC
Calibrated date


Atmospheric data from Stuiver et al. (1998); OxCal v3.9 Bronk Ramsey (2003); cub r:4 sd:12 prob usp[chron]
UGA14104 : 3190±50BP
68.2% probability
1515BC (66.9%) 1425BC
1420BC (1.3%) 1415BC
95.4% probability
1610BC (4.5%) 1550BC
1540BC (88.2%) 1370BC
1340BC (2.6%) 1310BC
3600BP
3400BP
3200BP
3000BP
Radiocarbon determination
2000CalBC
1800CalBC
1600CalBC
1400CalBC
1200CalBC
1000CalBC
Calibrated date

Charcoal Model

The following model was run in OxCal. Like the previous model, I assumed that the two charcoal samples below Feature 2 date the same phase occupation.

```
Plot()
 {
  Outlier_Model("Charcoal", Exp(1, -10, 0), U(0,3), "t");
  Sequence()
  {
   Boundary("F2 Start");
   Phase("Feature 2")
   {
    R_Date("UGA   14111", 5110,40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-370494", 5250,40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("UGA   14107", 4730, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-370492", 4530, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-233354", 5340, 50)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-233356", 5340, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-233353", 5390, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-370493", 5420, 40)
    {
     Outlier("Charcoal", 1);
    };
    Span("Span of Feature 2 dates");
    Interval("Duration of Feature 2");
   };
   Boundary("F2 End");
   Boundary("F1 Start");
   Phase("Feature 1")
   {
    R_Date("Beta-370497", 3910, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("UGA   14116", 4840, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-370495", 4930, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-370496", 4970, 40)
    {
     Outlier("Charcoal", 1);
    };
```

Updated 20-Aug-15 2:34 PM

```
    R_Date("Beta-233355", 4950, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("Beta-233352", 5090, 40)
    {
     Outlier("Charcoal", 1);
    };
    R_Date("UGA   14110", 5140, 40)
    {
     Outlier("Charcoal", 1);
    };
    Span("Span of Feature 1 dates");
    Interval("Duration of Feature 1");
   };
   Boundary("F1 End");
  };
 };
```

The results from this model are illustrated on the following two pages.

Updated 20-Aug-15 2:34 PM

This page intentionally left blank.

APPENDIX B
DIATOM PALEOENVIRONMENTAL ANALYSIS OF SEDIMENT AND BURNED ROCK SAMPLES FROM ARCHEOLOGICAL SITE 41MS69, MASON COUNTY, TEXAS

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Barbara Winsborough, Ph.D.
Winsborough Consulting
Glen Ribbit
23606 Round Mountain Circle
Leander, Texas 78641

This page intentionally left blank.

DIATOM PALEOENVIRONMENTAL ANALYSIS OF SEDIMENT AND BURNED ROCK SAMPLES FROM ARCHEOLOGICAL SITE 41MS69, MASON COUNTY, TEXAS

Barbara Winsborough, Ph.D.

B.1 INTRODUCTION

Diatoms are unicellular, pigmented, photosynthetic algae distinguished by the possession of a silica cell wall. Diatoms can be found living in a wide variety of natural and man-made terrestrial and aquatic habitats, including seeps, wet walls, dry and damp soil, springs, streams, creeks, sloughs, lakes, rivers, canals, ponds, marshes, lagoons, estuaries, bays, and oceans. Most are cosmopolitan - found in many parts of the world under similar environmental conditions, and many species have predictable environmental requirements and pollution tolerances. Therefore water quality directly effects diatom species composition. Diatoms can be readily identified to species, and a large and growing body of information exists on the range of ecological tolerance of many common taxa. Large diatom data sets from various parts of the world have shown that living diatom communities provide reliable analogs for estimates of past salinity, depth, trophic (nutrient) level, pH, habitat, and (indirectly) climate. Since diatoms are sensitive to so many physical and chemical parameters, and are often found in large numbers in sedimentary deposits, they are well-suited for use in paleoenvironmental reconstruction.

Diatom life forms include free-floating planktonic (lives suspended in the water column) and tychoplanktonic (opportunistically planktonic during turbid periods) taxa; and benthic species, associated with sediment, microbial mats and vegetation at or near the floor of a stream or lake. Motile benthic forms glide through mud (epipelic), and others are firmly attached to macrophytes or larger algae (epiphytic), rock (epilithic) and sand (epipsammic). Related to the benthic diatoms, in terms of overlapping habitats, are the aerophilic (commonly found living exposed to air) or sediment diatoms that are adapted to damp or dry habitats.

This report presents the results of a diatom paleoenvironmental analysis of ten sediment samples from site 41MS69. The site is located in west central Texas, in rolling terrain along the southwestern bank of the Llano River in southern Mason County. It is about 12 km south of Mason along FM 1871 on the remnants of a prehistoric floodplain terrace. The area is within the Llano Uplift part of the Edwards Plateau. Regional geology consists mostly of Pre-Cambrian igneous and metamorphic rocks, with some isolated carbonates. Local outcrops are the Gorman and Tanyard formations that contain limestone, dolomite and chert. The time frame of these samples is from about 4800 to 5200 B.P. The samples include sediment, sediment from features and burned rocks from cultural features.

B.2 METHODS

Sediment samples were cleaned of organic material and soluble minerals in preparation for microscopic analysis by boiling first in hydrogen peroxide and then in nitric acid. Burned rocks were gently scraped to remove the organic coating that was then processed in the same manner as the sediments. The oxidized, decalcified material was rinsed repeatedly until a pH of about 7.0 was reached. A few drops of the cleaned material was air-dried onto 22 x 22 mm cover glasses and mounted onto glass slides using NAPHRAX© a synthetic resin with a high index of refraction, developed to aid in resolving the details of diatom cell wall morphology. A slide of each sample were scanned at 1500x until 500 cells were counted, or if fewer diatoms were present, the entire slide was scanned, and all diatoms and diatom fragments were recorded.

B.3 RESULTS

Diatoms were found in three of the ten samples. All of the diatoms were found in the organic coatings on burned rocks. The diatoms encountered during this investigation are tabulated on Table B-1. The presence of phytoliths or pollen is also noted on Table B-1. A total of nine diatom cells, representing four species, were recorded from the three diatomaceous samples. As can be seen from Table B-1, the number of diatoms in any one sample varied from 2 to 4. In all samples the diatoms were heavily diluted by insoluble residues consisting of quartz and other mineral grains. There was one planktonic or benthic, freshwater diatom, two benthic diatoms, and one aerophilic species. All of these species are cosmopolitan, well-known taxa.

B.4 DISCUSSION

The diatoms found in these samples are species typically found in rivers, streams, and ponds in the shallow areas around the edges, attached to vegetation, sand, pebbles or rocks. *Cyclotella meneghiniana* Kützing is common in many aquatic habitats in the region, where there is standing or flowing water. It is opportunistically planktonic (tychoplanktonic), blooming during or after floods. *Gomphonema rhombicum* Fricke and *Navicula veneta* Kützing are benthic diatoms common in central Texas limestone streams.

The aerophilic diatom, *Hantzschia abundans* Lange-Bertalot, is adapted to life on soil, mud, moss, damp or wet walls and other humid environments. It is found typically in the soil and mud of occasionally or temporarily wet habitats. It lives along the banks of streams and the upper margins of ponds and lakes and is often found together with the aquatic species in very shallow habitats with fluctuating water levels. In this case, the lack of a substantial aquatic diatom component suggests that the aerophil was living in an environment that was only wet or damp for brief time periods. Aerophilic diatoms characteristically bloom and produce large numbers of cells after being well soaked.

The aquatic and aerophilic groups of diatoms in these samples all have pH preferences that range from slightly acidic to definitely alkaline. The water probably had a moderate to somewhat high conductivity. Since there was only one planktonic diatom, the water was probably shallow, at least in parts, possibly vegetated, and clear enough to permit light to reach the bottom. The nutrient preferences of the diatoms suggest moderate trophic conditions (phosphate and nitrate concentrations). There is no evidence of polluted conditions. The diatoms are indifferent to moderate current velocity and the water may have been flowing or standing. The water in which these diatoms grew could have been seasonal, at least in flow volume. The extreme dilution with sediment could mean that at least the aquatic diatoms were deposited during a flood that covered the terrace. All of the diatoms were in reasonably good condition so they were not transported a long distance before being deposited.

B.5 SUGGESTIONS FOR FUTURE INVESTIGATIONS

The presence of diatoms in the burned rock samples is encouraging. An improved methodology for removing the organic rind without including the rock material itself could potentially yield better results. Modern diatom material from the streams in the area would provide comparable material to distinguish between present day and prehistoric water conditions.

Table B-1. Diatoms Abundance in Samples from Site 41MS69, Mason County, Texas.

	4-3-1b burned rock, Unit 1, 35 cmbs	4-3-2b burned rock, Unit 1, 37 cmbs	508-3-1c **Feature 1** burned rock, Unit 6, 140-150 cmbs	508-3-2c **Feature 1** burned rock, Unit 6, 140-150 cmbs	107-4-1d sediment. **Column 1,** Zone 8, 224-228 cmbs	515-3-1c **Feature 2** burned rock, Unit 6, 174 cmbs	515-3-4c **Feature 2** burned rock, Unit 6, 177 cmbs	507-4-1c **Feature 1,** sediment from feature, Unit 6, 134 cmbs	505- 4-1c **Feature 1,** sediment from feature, Unit 5 extension, 151-154	511-4-1c **Feature 2,** sediment from feature, Unit 5, 177 cmbs
		no diatoms phytoliths or pollen			no diatoms phytoliths or pollen	no diatoms phytoliths or pollen	no diatoms phytoliths or pollen	no diatoms & phytoliths & pollen rare	no diatoms phytoliths or pollen	no diatoms phytoliths or pollen
Cyclotella meneghiniana				1						
Gomphonema rhombicum	2									
Hantzschia abundans			2	2						
Navicula veneta	2									
Total counted	**4**		**2**	**3**						

This page intentionally left blank.

APPENDIX C

NEUTRON ACTIVATION ANALYSIS OF CHERT SAMPLES FROM THE LLANO RIVER GRAVEL, THE GORMAN FORMATION, AND THE MARBLE FALLS FORMATION

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Jeffrey R. Ferguson, Ph.D. and Michael D. Glascock, Ph.D.
Archaeometry Laboratory Research Reactor Center
University of Missouri
Columbia, MO 65211

This page intentionally left blank.

NEUTRON ACTIVATION ANALYSIS OF CHERT ARTIFACTS FROM 41MS69 AND OF GEOLOGICAL CHERT SAMPLES FROM THE LLANO RIVER GRAVEL,THE GORMAN FORMATION AND THE MARBLE FALLS FORMATION

Matthew T. Boulanger, Ph.D. and Michael D. Glascock, Ph.D.

C.1 INTRODUCTION

Sixty chert samples from archaeological and geological contexts in central Texas were characterized by neutron activation analysis (NAA) at the Archaeometry Laboratory, University of Missouri Research Reactor (MURR). Samples were obtained and submitted by Mike Quigg of TRC Environmental Corporation (TRC) in August of 2007. Samples in this study were analyzed as part of TRC assessment of site 41MS69 (106892/0003/0008) and were obtained from the following locations: 41MS69, a prehistoric archaeological site in Mason County, Texas (*N* = 39); secondarily deposited gravels of Edwards Formation chert from the Llano River (*N* = 10); from surface collections at or near two separate outcroppings of the Gorman Formation (*N* = 10), and one outcropping of the Marble Falls limestone (*N* = 1) (Figure C-1). Compositions of these samples are compared with those from other chert sources in Texas to determine chemical differences that may permit confident artifact-sourcing studies.

C.2 SAMPLE PREPARATION

Upon arrival at MURR, the source samples were washed in deionized water to remove all possible dirt and loose material from their surfaces. Samples for NAA were prepared by placing source specimens between two tool-steel plates and crushing them with a Carver Press. Several small 50–100 mg fragments were obtained from the crushed specimens. Fragments were examined under low-power magnification, and fragments with metallic streaks or crush fractures were eliminated from consideration. Several grams of the remaining fragments were obtained from each sample and temporarily stored in plastic bags.

Two analytical samples were prepared from each source specimen. Portions of approximately 200 mg of rock fragments were weighed into clean high-density polyethylene vials used for short irradiations at MURR. At the same time, 800 mg aliquots from each sample were weighed into clean high-purity quartz vials used for long irradiations. Individual sample weights were recorded to the nearest 0.01 mg using an analytical balance. Both vials were sealed prior to irradiation. Along with the unknown samples, standards made from National Institute of Standards and Technology (NIST) certified standard reference materials of SRM-1633a (Coal Fly Ash), SRM-278 (Obsidian Rock), and SRM-688 (Basalt Rock) were similarly prepared.

C.3 IRRADIATION AND GAMMA-RAY SPECTROSCOPY

Neutron activation analysis of most archaeological samples at MURR, which consists of two irradiations and a total of three gamma counts, constitutes a superset of the procedures used at most other NAA laboratories (Glascock 1992; Glascock and Neff 2003; Neff 2000). As discussed in detail by Glascock (1992), a short irradiation is carried out through the pneumatic tube irradiation system. Samples in the polyvials are sequentially irradiated, two at a time, for five seconds by a neutron flux of 8 x 10^{13} n cm^{-2} s^{-1} The 720-second count yields gamma spectra containing peaks for nine short-lived elements aluminum (Al), barium (Ba), calcium (Ca), dysprosium (Dy), potassium (K), manganese (Mn), sodium (Na), titanium (Ti), and vanadium (V).

The long-irradiation samples are encapsulated in quartz vials and are subjected to a 70–hour irradiation at a neutron flux of 5 x 10^{13} n cm^{-2} s^{-1}. This long irradiation is analogous to the single irradiation utilized at most other laboratories. After the long irradiation, samples decay for seven days, and then are counted for 1800 seconds (the "middle count") on a high-resolution germanium detector coupled to an automatic sample changer. The middle count yields determinations of seven medium half-life elements, namely arsenic (As), lanthanum (La), lutetium (Lu), neodymium (Nd), samarium (Sm), uranium (U), and ytterbium (Yb). After an additional three- or four-week decay, a final count of 8500 seconds is carried out on each sample. The latter measurement yields the following 17 long half-life elements: cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), europium (Eu), iron (Fe), hafnium (Hf), nickel (Ni), rubidium (Rb), antimony (Sb), scandium (Sc), strontium (Sr), tantalum (Ta), terbium (Tb), thorium (Th), zinc (Zn), and zirconium (Zr).

The element concentration data from the three measurements are tabulated in parts per million using Microsoft® Office Excel. Descriptive data for archaeological samples were appended to the concentration spreadsheet. The data are also stored in a dBase/FoxPro database file useful for organizing, sorting, and extracting sample information.

C.4 INTERPRETING CHEMICAL DATA

Analyses at MURR described previously produce elemental concentration values for 33 elements in most analyzed samples. However, cryptocrystalline silicates do not always have sufficient quantities of these 33 elements to be detectable using the above procedures. For example, less than 50 percent of the Llano River gravel samples contained detected values for Ti, Dy, Tb, Ni, and Lu. Of the 33 elements measured, 13 (As, Lu, Nd, Yb, Ni, Ta, Tb, Ca, Dy, K, Ti, and V) were eliminated because they were missing in greater than 50% of all samples from the newly analyzed chert sources as well as previously analyzed chert sources from Texas (Table C-1).

Statistical analyses were subsequently carried out on base-10 logarithms of concentrations on the remaining 20 elements. Use of log concentrations rather than raw data compensates for differences in magnitude between the major elements, such as sodium, and trace elements, such as the rare earth or lanthanide elements (REEs). Transformation to base-10 logarithms also yields a more normal distribution for many trace elements.

The interpretation of compositional data obtained from the analysis of archaeological materials is discussed in detail elsewhere (e.g., Baxter and Buck 2000; Bieber et al. 1976; Bishop and Neff 1989; Glascock 1992; Harbottle 1976; Neff 2000) and will only be summarized here. The main goal of data analysis is to identify distinct homogeneous groups within the analytical database. Based on the provenance postulate of Weigand et al. (1977), different chemical groups may be assumed to represent geographically restricted sources. For lithic materials such as obsidian, basalt, and cryptocrystalline silicates (e.g., chert, flint, or jasper), raw material samples are frequently collected from known outcrops or secondary deposits and the compositional data obtained on the samples is used to define the source localities or boundaries. The locations of sources can also be inferred by comparing unknown specimens (i.e., ceramic artifacts) to knowns (i.e., clay samples) or by indirect methods such as the “criterion of abundance” (Bishop et al. 1982) or by arguments based on geological and sedimentological characteristics (e.g., Steponaitis et al. 1996). The ubiquity of ceramic raw materials usually makes it impossible to sample all potential “sources” intensively enough to create groups of knowns to which unknowns can be compared. Lithic sourcestend to be more localized and compositionally homogeneous in the case of obsidian or compositionally heterogeneous as is the case for most cherts.

Compositional groups can be viewed as "centers of mass" in the compositional hyperspace described by the measured elemental data. Groups are characterized by the locations of their centroids and the unique relationships (i.e., correlations) between the elements. Decisions about whether to assign a specimen to a particular compositional group are based on the overall probability that the measured concentrations for the specimen could have been obtained from that group.

Initial hypotheses about source-related subgroups in the compositional data can be derived from non-compositional information (e.g., archaeological context, decorative attributes, etc.) or from application of various pattern-recognition technique to the multivariate chemical data. Some of the pattern recognition techniques that have been used to investigate archaeological data sets are cluster analysis (CA), principal components analysis (PCA), and discriminant analysis (DA). Each of the techniques has it own advantages and disadvantages which may depend upon the types and quantity of data available for interpretation.

The variables (measured elements) in archaeological and geological data sets are often correlated and frequently large in number. This makes handling and interpreting patterns within the data difficult. Therefore, it is often useful to transform the original variables into a smaller set of uncorrelated variables in order to make data interpretation easier. Of the above-mentioned pattern recognition techniques, PCA is a technique that transforms from the data from the original correlated variables into uncorrelated variables most easily.

Principal components analysis creates a new set of reference axes arranged in decreasing order of variance subsumed. The individual PCs are linear combinations of the original variables. The data can be displayed on combinations of the new axes, just as they can be displayed on the original elemental concentration axes. PCA can be used in a pure pattern-recognition mode, i.e., to search for subgroups in an undifferentiated data set, or in a more evaluative mode, i.e., to assess the coherence of hypothetical groups suggested by other criteria. Generally, compositional differences between specimens can be expected to be larger for specimens in different groups than for specimens in the same group, and this implies that groups should be detectable as distinct areas of high point density on plots of the first few components.

Principal components analysis of chemical data is scale dependent, and analyses tend to be dominated by those elements or isotopes for which the concentrations are relatively large. As a result, standardization methods are common to most statistical packages. A common approach is to transform the data into logarithms (e.g., base 10). As an initial step in the PCA of most chemical data at MURR, the data are transformed into log concentrations to equalize the differences in variance between the major elements such as Al, Ca and Fe, on one hand and trace elements, such as the rare-earth elements (REEs), on the other hand. An additional advantage of the transformation is that it appears to produce more nearly normal distributions for the trace elements.

One frequently exploited strength of PCA, discussed by Baxter (1992), Baxter and Buck (2000), and Neff (1994; 2002), is that it can be applied as a simultaneous R- and Q-mode technique, with both variables (elements) and objects (individual analyzed samples) displayed on the same set of principal component reference axes. A plot using the first two principal components as axes is usually the best possible two-dimensional representation of the correlation or variance-covariance structure within the data set. Small angles between the vectors from the origin to variable coordinates indicate strong positive correlation; angles at 90 degrees indicate no correlation; and angles close to 180 degrees indicate strong negative correlation. Likewise, a plot of sample coordinates on these same axes will be the best two-dimensional representation of Euclidean relations among the samples in log-concentration space (if the PCA was based on the variance-covariance matrix) or standardized log-concentration space (if the PCA was based on the correlation matrix). Displaying both objects and variables on the same plot makes it possible to observe the contributions of specific elements to group separation and to the distinctive shapes of the various groups. Such a plot is commonly referred to as a "biplot" in reference to the simultaneous plotting of objects and variables. The variable inter-relationships inferred from a biplot can be verified directly by inspecting bivariate elemental concentration plots.

Whether a group can be discriminated easily from other groups can be evaluated visually in two dimensions or statistically in multiple dimensions. A metric known as the Mahalanobis distance (or generalized distance) makes it possible to describe the separation between groups or between individual samples and groups on multiple dimensions. The Mahalanobis distance of a specimen from a group centroid (Bieber et al. 1976; Bishop and Neff 1989) is defined by:

$$D_{y,X}^2 = [y - \overline{X}]^t I_x [y - \overline{X}]$$

where y is the 1 x m array of logged elemental concentrations for the specimen of interest, X is the n x m data matrix of logged concentrations for the group to which the point is being compared with being it 1 x m centroid, and I_x is the inverse of the m x m variance-covariance matrix of group X. Because Mahalanobis distance takes into account variances and covariances in the multivariate group it is analogous to expressing distance from a univariate mean in standard deviation units. Like standard deviation units, Mahalanobis distances can be converted into probabilities of group membership for individual specimens. For relatively small sample sizes, it is appropriate to base probabilities on Hotelling's T^2, which is the multivariate extension of the univariate Student's *t*.

When group sizes are small, Mahalanobis distance-based probabilities can fluctuate dramatically depending upon whether or not each specimen is assumed to be a member of the group to which it is being compared. Harbottle (1976) calls this phenomenon "stretchability" in reference to the tendency of an included specimen to stretch the group in the direction of its own location in elemental concentration space. This problem can be circumvented by cross-validation, that is, by removing each specimen from its presumed group before calculating its own probability of membership (Baxter 1994; Leese and Main 1994). This is a conservative approach to group evaluation that may sometimes exclude true group members.

Small sample and group sizes place further constraints on the use of Mahalanobis distance: with more elements than samples, the group variance-covariance matrix is singular thus rendering calculation of I_x (and D^2 itself) impossible. Therefore, the dimensionality of the groups must somehow be reduced. One approach would be to eliminate elements considered irrelevant or redundant. The problem with this approach is that the investigator's preconceptions about which elements should be discriminate may not be valid. It also squanders the main advantage of multielement analysis, namely the capability to measure a large number of elements. An alternative approach is to calculate Mahalanobis distances with the scores on principal components extracted from the variance-covariance or correlation matrix for the complete data set. This approach entails only the assumption, entirely reasonable in light of the above discussion of PCA, that most group-separating differences should be visible on the first several PCs. Unless a data set is extremely complex, containing numerous distinct groups, using enough components to subsume at least 90 percent of the total variance in the data can be generally assumed to yield Mahalanobis distances that approximate Mahalanobis distances in full elemental concentration space.

Lastly, Mahalanobis distance calculations are also quite useful for handling missing data (Sayre 1975). When many specimens are analyzed for a large number of elements, it is almost certain that a few element concentrations will be missed for some of the specimens. This occurs most frequently when the concentration for an element is near the detection limit. Rather than eliminate the specimen or the element from consideration, it is possible to substitute a missing value by replacing it with a value that minimizes the Mahalanobis distance for the specimen from the group centroid. Thus, those few specimens which are missing a single concentration value can still be used in group calculations.

C.5 RESULTS AND DISCUSSION

The NAA results were entered into a spreadsheet and combined with the provided descriptive data to create a database for sorting and extraction of quarry subgroups. Table C-2 is extracted from this database, and it lists the measured concentrations in parts per million (ppm) for each element.

Data from prior studies of Texas cherts (Table C-1) were compared against the data generated in this study. As stated above, only 20 of a possible 33 elements were present in sufficient amounts in all samples to be useful for multivariate analysis. After transformation to base-10 logarithms, missing values were replaced in each of the identified subgroups. An RQ-mode principal components analysis (PCA) was conducted on the entire Texas chert dataset. Table C-3 lists the eigenvalues and percentages of variance explained by each of the eigenvectors in the PCA. The PCA demonstrates that greater than 90% of the cumulative variance in the dataset is subsumed by the first nine principal components. The first eigenvector is heavily loaded on transition metals (Mn, Co, Fe, Sc, Zn), The second eigenvector is most-heavily loaded in the negative direction by Cs, and the third is loaded on the following elements: Ba, Sm, and U.

Biplots of the source samples and element vectors based on the several of the first principal components are shown in Figures C-2 through C-4. These biplots demonstrate that samples obtained from the Llano River gravel bed are compositionally similar to other Edwards Formation chert samples from Texas. This result is not unexpected, as Quigg indicates that these gravels are in fact derived from the Edwards Formation (personal communication 2007). Of interest to future sourcing studies are the observations that chert samples from the Gorman Formation and from the Marble Falls limestone show some chemical differences from Edwards Formation cherts. In both cases, these differences appear to result from slightly higher amounts of transition metals, particularly Mn.

Mahalanobis distance-based probabilities for the Gorman Formation and Llano River Gravel source groupings were calculated in comparison to all other Texas chert compositional groups[1]. Due to the small number of samples in the newly analyzed groups (n = 10 samples each), the first eight principal components, subsuming 89.66% of the total variance in the dataset, were used in calculation of Mahalanobis distances (Table C-4 and Table C-5).

These probabilities demonstrate that, with the exception of two samples (TRC375 and TRC378), chert from the Gorman Formation can be

---

[1] The single sample of chert from the Marble Falls Limestone could not be included in this procedure because calculation of Mahalanobis distances requires at least two more variables (i.e., elements or principal components) than the total number of samples.

distinguished from all other compositional groupings. TRC378 is more similar to a highly variable compositional group defined by Frederick et al. (1994), and comprised of undifferentiated Edwards Formation chert samples collected at or near Fort Hood, Texas. Sample TRC375 is more similar to the compositional profile of the Llano River Gravel, some of which Quigg (personal communication 2007) identified visually as being derived from the Edwards Formation. Given that the Llano River samples were collected from a secondary geological context, it is quite possible that these samples are derived from multiple primary geological contexts (i.e., from multiple chert-bearing formations). If this is the case, it would not be unreasonable to find that at least some of the Gorman Formation chert is similar to the gravels collected within the Llano River bed. Consultation of detailed bedrock geology maps is necessary to determine if, in fact, the Llano River downcuts through the Gorman Formation, thereby providing a potential input of chert into the river.

All but four samples collected from the Llano River gravels appear to form a compositionally distinct group based upon Mahalanobis distance probabilities calculated from the first eight principal components. The four outlying samples are most closely associated either with the undifferentiated Edwards Formation groups defined by Frederick et al. (1994) or with samples of chert from Wright Creek submitted by Hudler in 1998. Two possible explanations are offered for this result. First, the Llano River Gravels are secondarily deposited geological materials, and therefore they likely contain chert nodules derived from multiple primary geological contexts (i.e., formations). It is possible, though unconfirmed, that the Llano River cuts through the same or a similar formation from which Hudler's Wright Creek samples originate. Second, the Llano River Gravel samples are believed, based upon visual identification, to be derived from the Edwards Formation. Chert from the Edwards Formation is quite heterogeneous, and many of the compositional groups are only subtly different. Similarities between Llano River samples and those from Wright Creek may therefore reflect real-world chemical similarity between the Edwards and Wright Creek formations, and not the presence of both cherts in the river gravel.

Mahalanobis distance-based probabilities of group membership were also calculated for the 39 chert artifacts from 41MS69. These probabilities are given in Table C-6, and group assignments are summarized in Tables C-7 and C-8. A majority of the artifacts (*N* = 20) are assignable to either the Llano River Gravel group or the undifferentiated Edwards Formation group defined by Frederick et al. (1994). A further 11 are assignable to the Wright Creek chert samples submitted by Hudler in 1998. Given that the samples comprising the Llano River Gravel group are compositionally similar to both the Wright Creek and undifferentiated Edwards groups, a conservative statement about the compositions of these artifacts is that they can be assigned to the heterogeneous chemical profile of Edwards Formation chert in central Texas. Eight artifact samples are closely associated with the compositional profile of chert from the Gorman Formation, and the relatively high probabilities of group membership suggest that assignments to this compositional group may be made confidently. None of the artifacts analyzed appear to be chemically similar to the single chert sample from the Marble Falls Limestone (Figures C-2 through C-4), although because only one sample from this geologic formation has been analyzed, rigorous testing of this statement is impossible.

C.6 CONCLUSIONS

Analysis of 10 chert samples from the Gorman Formation has led to the establishment of a compositional group tentatively associated with this specific geological material, and the compositions of 11 artifacts from 41MS69 are most-closely associated with this group. The chert samples obtained from the gravel bed of the Llano River are compositionally similar to samples from Wright Creek and to a highly variable compositional group comprised of Edwards Formation cherts collected in the vicinity of Fort Hood, Texas. This finding supports the conclusion that the Llano River gravels are primarily derived from the Edwards Formation, and suggests that cherts from other formations may also be present. The remaining 28 artifacts from 41MS69 are chemically similar to Edwards Formation cherts as well. Given that the nearest documented source of Edwards Formation chert appears to be the gravel bed of the Llano River, the most parsimonious explanation of these results is that Native Americans were primarily using chert nodules from the riverbed for tool manufacture, and that chert from the Gorman Formation was used as a secondary material. No evidence has been identified to indicate that Native Americans were using chert from the Marble Falls Limestone; however, only one sample of this material has been analyzed, and the full compositional variability of this chert has not been identified.

C.7 ACKNOWLEDGEMENTS

Corinne Rosania and Mark O. Beary were responsible for sample preparation and analysis of the chert samples by INAA. Any errors in interpretation are the responsibility of the authors.

C.8 REFERENCES

Baxter, Mike J.
1992 Archaeological Uses of the Biplot—A Neglected Technique? In *Computer Applications and Quantitative Methods in Archaeology, 1991*, edited by Gary Lock and Jonathon Moffett, pp. 141-148. BAR International Series. Vol. S577. Tempvs Reparatvm, Oxford.

1994 *Exploratory Multivariate Analysis in Archaeology*. Edinburgh University Press, Edinburgh.

Baxter, Mike J. and Caitlin E. Buck
2000 Data Handling and Statistical Analysis. In *Modern Analytical Methods in Art and Archaeology*, edited by Enrico Ciliberto and Giuseppe Spoto, pp. 681-746. John Wiley and Sons, New York.

Bieber, Alan M. Jr., Dorothea W. Brooks, Garman Harbottle and Edward V. Sayre
1976 Application of Multivariate Techniques to Analytical Data on Aegean Ceramics. *Archaeometry* 18:59-74.

Bishop, Ronald L. and Hector Neff
1989 Compositional Data Analysis in Archaeology. In *Archaeological Chemistry IV*, edited by R. O. Allen, pp. 576-586. Advances in Chemistry. vol. 220. American Chemical Society, Washington, D.C.

Bishop, Ronald L., Robert L. Rands and George R. Holley
1982 Ceramic Compositional Analysis in Archaeological Perspective. *Advances in Archaeological Method and Theory* 5:275-330.

Frederick, Charles D., Michael D. Glascock, Hector Neff and Christopher M. Stevenson
1994 *Evaluation of Chert Patination as a Dating Technique: A Case Study from Fort Hood, Texas*. Research Report No. 32, Archaeological Resource Management Series. United States Army, Fort Hood.

Glascock, Michael D.
1992 Characterization of Archaeological Ceramics at MURR by Neutron Activation Analysis and Multivariate Statistics. In *Chemical Characterization of Ceramic Pastes in Archaeology*, edited by Hector Neff, pp. 11-26. Prehistory Press, Madison, WI.

1995 A Report on the INAA Characterization of

Source Specimens from the Segovia Formation (Site 41HW52, Howard County, Texas) of the Edwards Group Chert. In *Cultural Resource Investigations of Three Lithic Procurement Sites (41RG39, 41RG40, and 41HW52) in Howard and Reagan Counties, Texas*, by Turnbow, Christopher A. and David P. Staley pp. D-1 through D16. For Cap Rock Electric Cooperative, Inc., Staton, Texas.

2001 *Letter report dated May 10, 2001, summarizing INAA of 30 chert samples from Leon Creek, Bluff, Texas*. Archaeometry Laboratory, University of Missouri Research Reactor. Submitted to Dale Hudler, Texas Archaeological Research Laboratory.

Glascock, Michael D. and Hector Neff
2003 Neutron Activation Analysis and Provenance Research in Archaeology. *Measurement Science and Technology* 14:1516-1526.

Glascock, Michael D. and Robert J. Speakman
2008a Instrumental Neutron Activation Analysis of Chert from the Varga Site (41ED28) in Southwest Texas. In *The Varga Site: A Multicomponent, Stratified Campsite in the Canyonlands of Edwards County, Texas, by J. M. Quigg, J. D. Owens, P. M. Matchen, G. D. Smith, R. A. Ricklis, M. C. Cody, and C. D. Frederick, pp. 885-899.* Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program Report No. 110 and TRC Environmental Corporation, TRC Technical Report No. 35319, Austin, TX.

2008b Instrumental Neutron Activation Analysis of Natural Chert from Gillespie County in Central Texas -- TRC Project 46843/0020. In *Cultural Resource Survey and Testing of Properties at Boot Ranch, Gillespie County, Texa*s, by Paul M. Matchen, J. Michael Quigg, and Angela Newman, pp. 89-109. TRC Technical Report No. 46832, Austin.
2008c *Instrumental Neutron Activation Analysis of Natural Chert from the Callahan Divide Area of North Central Texas -- TRC Project 49150*. In *Reconnaissance in Phase II East and Chert Collection Across Phase I and II East for FPL Energy's Horse Hollow Project, Taylor County, Texas*, by J. Michael Quigg, Michael Glascock and Robert J. Speakman, pp. 32-48. TRC Environmental Corporation, Technical Report No. 49150, Austin. For FPL Energy, Houston, TX. CONFIDENTIAL

Harbottle, Garman
1976 Activation Analysis in Archaeology. *Radiochemistry* 3(1):33-72.

Leese, Morven N. and Peter L. Main
1994 The Efficient Computation of Unbiased Mahalanobis Distances and their Interpretation in Archaeometry. *Archaeometry* 36:307-316.

Neff, Hector
1994 RQ-mode Principal Component Analysis of Ceramic Compositional Data. *Archaeometry* 36:115-130.

2000 Neutron Activation Analysis for Provenance Determination in Archaeology. In *Modern Analytical Methods in Art and Archaeology*, edited by Enrico Ciliberto and Giuseppe Spoto, pp. 81-134. John Wiley and Sons, New York.

2002 Quantitative Techniques for Analyzing Ceramic Compositional Data. In *Ceramic Source Determination in the Greater Southwest*, edited by Donna M. Glowacki and Hector Neff. Monograph 44. Cotsen Institute of Archaeology, Los Angeles.

Sayre, Edward V.
1975 *Brookhaven Procedures for Statistical Analyses of Multivariate Archaeometric Data*. Brookhaven National Laboratory Report BNL-23128.

Steponaitis, Vincas, M. James Blackman and Hector Neff
1996 Large-scale Compositional Patterns in the Chemical Composition of Mississippian

Pottery. *American Antiquity* 61(3):555-572.

Weigand, Phil C., Garman Harbottle and Edward V. Sayre

1977 Turquoise Sources and Source Analysis: Mesoamerica and the Southwestern U.S.A. In *Exchange Systems in Prehistory*, edited by Timothy K. Earle and J. E. Ericson, pp. 15-34. Academic Press, New York.

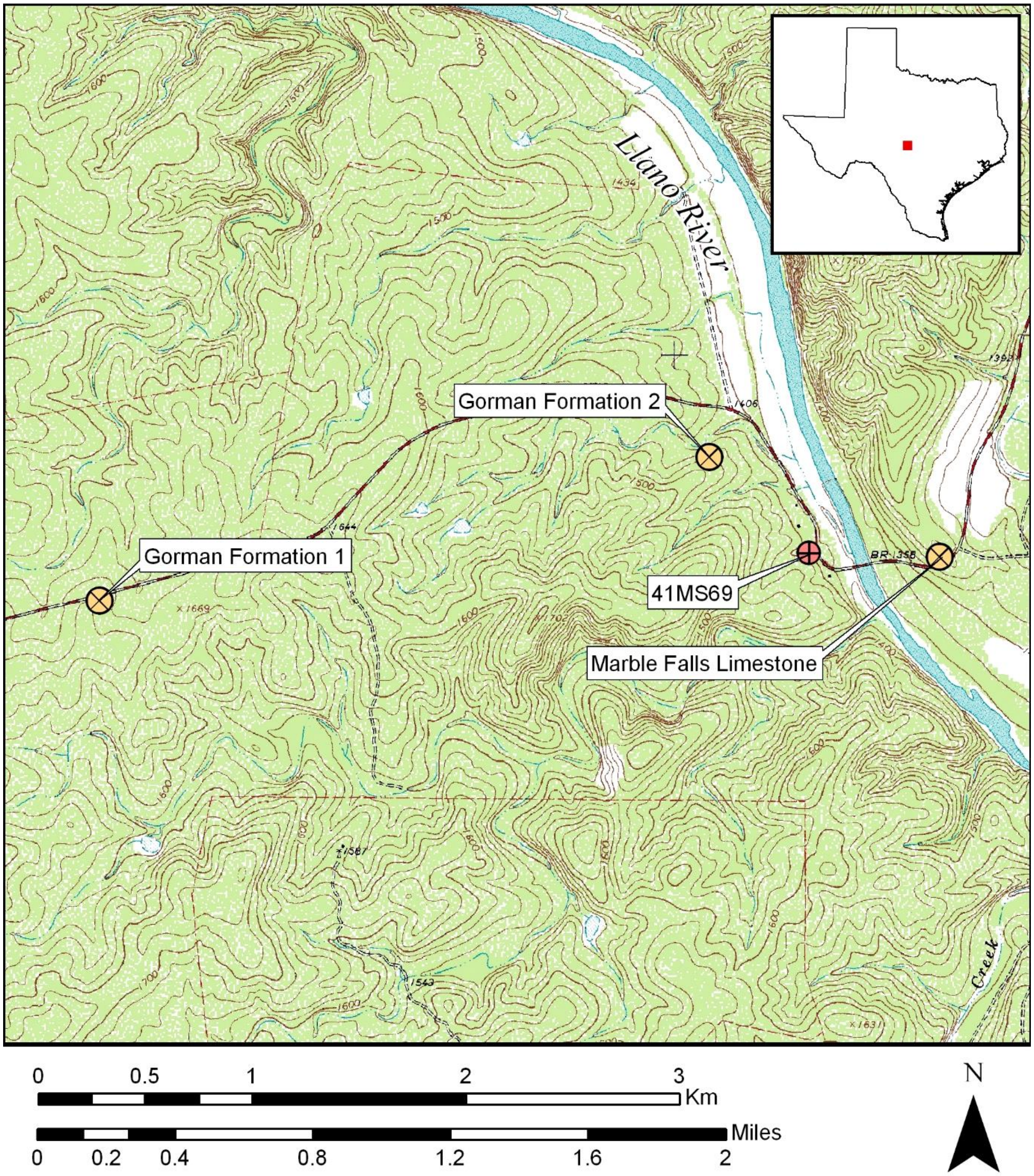


Figure C-1. Locations from which archaeological and geological samples were obtained for this study. All locations are within Mason County, Texas. Note that samples of chert from the Gorman Formation were obtained from two separate locations, one limestone sample was collected from the Marble Falls formation, and coordinates were not provided for samples collected from the Llano River bed. Basemap: 1968 USGS 7.5-minute Turtle Creek topographic quadrangle. Sample-collection locations provided by M. Quigg.

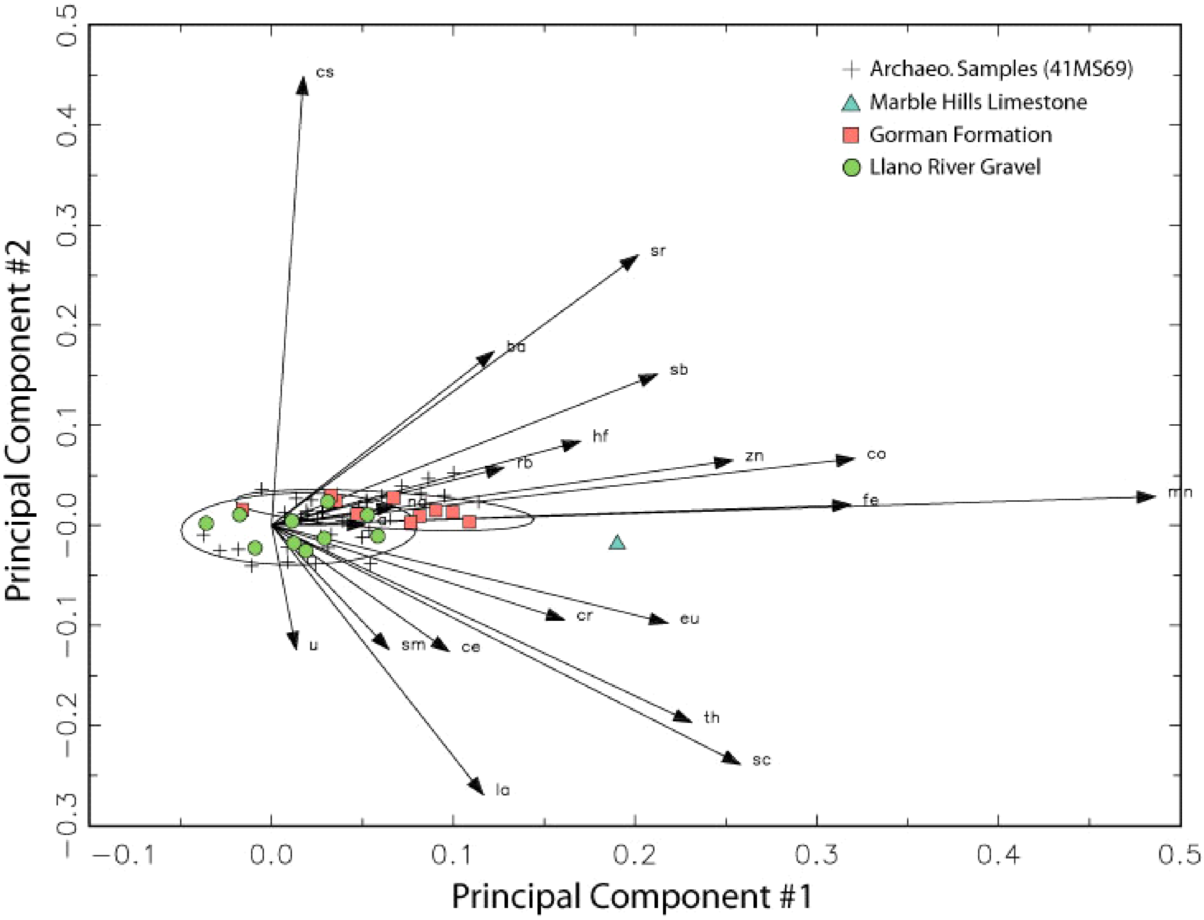


Figure C-2. Biplot showing the first and second principal components for the extant Texas chert database and samples analyzed in this study. Only the newly analyzed samples are shown. Element vectors are labeled, and ellipses represent 90% confidence interval for group membership. Note that the single sample from the Marble Hills limestone is distinct from all other samples in this study.

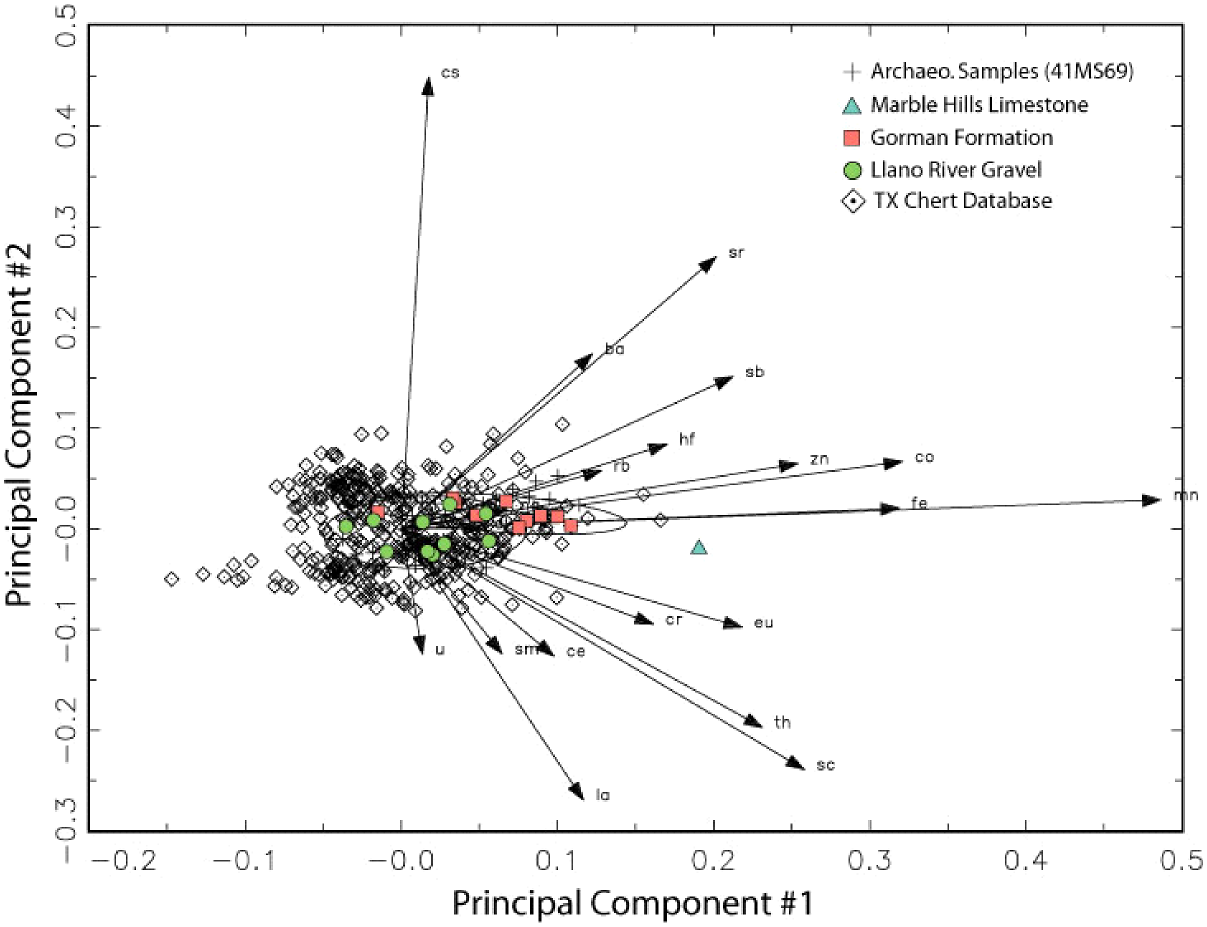


Figure C-3. **Biplot showing the first and second principal components for the extant Texas chert database and samples analyzed in this study. All samples in the database are shown. Element vectors are labeled, and ellipses represent 90% confidence interval for group membership. Note that the single sample from the Marble Hills limestone remains distinct from all previously analyzed samples.**

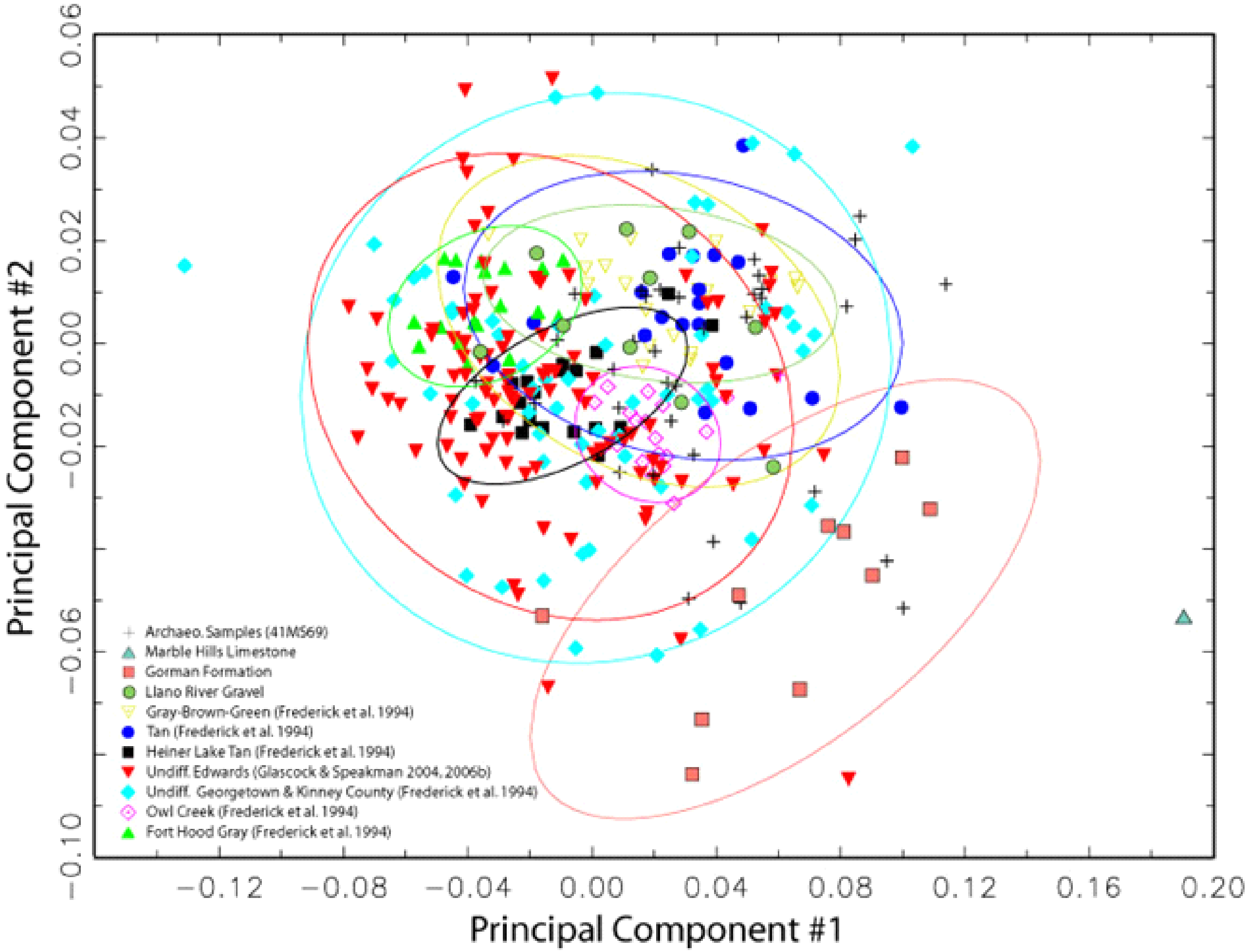


Figure C-4. Biplot showing the first and second principal components for the extant Texas chert database. Previously defined source groupings are indicated with the exception of the Novaculite group of Frederick et al. (1994). Element vectors are labeled, and ellipses represent 90% confidence interval for group membership. Note that the single sample from the Marble Hills limestone remains distinct from all other samples in this study.

Table C-1. Prior Studies of Texas Cherts Conducted by NAA at MURR.

Note that published reports for projects by Hudler (1998) could not be located at the time of this writing.

Investigator	Year	Formation or Chert Name	Location	Reference
C. Frederick	1994	Edwards	Fort Hood, TX	Frederick et al. 1994
C. Turnbull	1994	Edwards/ Segovia	Howard County, TX	Glascock 1995
D. Hudler	1998	Wright Creek	Kerr County, TX	
D. Hudler	2001	Leon Creek	Bluff, TX	Glascock 2001
M. Quigg	2004	Edwards Fmt.	SW, TX (multiple)	Glascock and Speakman 2008a
M. Quigg	2006	Glen Rose	Gillespie County, TX	Glascock and Speakman 2008b
M. Quigg	2006	Edwards Fmt.	Taylor County, TX	Glascock and Speakman 2008c

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR.

ANID	As	Ba	La	Lu	Nd	Sm	U	Yb	Ce
TRC319	0.3658	87.0	0.1133	0.0009	0.3883	0.1322	1.4020	0.0046	0.4589
TRC320	0.1823	34.0	0.2755	0.0000	0.8291	0.3923	4.3075	0.0033	1.2317
TRC321	0.4195	14.4	0.1307	0.0017	0.1538	0.0846	0.7781	0.0144	0.3492
TRC322	0.3922	57.1	0.2388	0.0000	0.7097	0.2873	3.0677	0.0079	0.9816
TRC323	0.1912	16.7	0.2206	0.0000	0.3283	0.1697	1.6318	0.0156	0.6707
TRC324	0.2579	41.5	0.2875	0.0000	1.0895	0.4105	4.5287	0.0000	1.3232
TRC325	0.1618	42.8	0.2848	0.0000	1.0174	0.3838	4.1962	0.0000	1.2408
TRC326	0.0000	5.0	0.1195	0.0008	0.2552	0.1108	1.1465	0.0000	0.4092
TRC327	0.6300	622.7	0.1538	0.0000	0.0000	0.1011	0.9436	0.0101	0.4466
TRC328	0.2990	27.3	0.1338	0.0013	0.3258	0.1391	1.4487	0.0074	0.4878
TRC329	0.3827	84.2	0.2460	0.0000	1.1555	0.3626	3.9516	0.0000	1.0878
TRC330	2.4100	115.2	0.2344	0.0018	0.6143	0.2394	2.4369	0.0083	0.8086
TRC331	0.1611	8.9	0.1424	0.0013	0.2450	0.1122	1.0899	0.0070	0.4819
TRC332	0.1939	148.2	0.2514	0.0000	0.8208	0.3228	3.4568	0.0000	1.0337
TRC333	2.0246	21.5	0.1624	0.0030	0.2623	0.0844	0.7264	0.0155	0.4326
TRC334	0.2917	63.3	0.5694	0.0000	2.4415	0.8167	8.9040	0.0000	2.4914
TRC335	0.4179	20.5	0.1993	0.0022	0.6080	0.1651	1.6710	0.0067	0.6541
TRC336	0.2759	23.9	0.0949	0.0014	0.4359	0.0853	0.8280	0.0045	0.3064
TRC337	0.2189	23.4	0.2647	0.0009	0.9814	0.3448	3.7065	0.0050	1.1216
TRC338	0.0718	17.7	0.1490	0.0000	0.2876	0.0911	0.8307	0.0076	0.4205
TRC339	0.2988	66.6	0.2938	0.0000	0.8043	0.3861	4.1691	0.0000	1.1757
TRC340	0.1656	43.4	0.2953	0.0000	0.9634	0.3858	4.1286	0.0037	1.1985
TRC341	0.7698	30.2	0.2370	0.0000	0.6097	0.1877	1.8478	0.0169	0.7538
TRC342	0.1895	170.0	0.2461	0.0005	0.8169	0.2962	3.1374	0.0000	0.9095
TRC343	0.0365	5.7	0.6279	0.0052	0.9328	0.1602	0.2180	0.0339	1.5938
TRC344	0.6469	142.6	0.1966	0.0000	0.8600	0.1792	1.7747	0.0086	0.6198
TRC345	1.6200	109.3	0.2850	0.0013	0.7290	0.3188	3.3490	0.0039	1.0157
TRC346	0.6472	29.6	0.1460	0.0008	0.3707	0.1674	1.7772	0.0030	0.5350
TRC347	0.3138	19.8	0.1579	0.0037	0.1867	0.0558	0.4629	0.0171	0.3637
TRC348	0.4920	21.9	0.1167	0.0018	0.1863	0.0575	0.4828	0.0139	0.3078
TRC349	0.6782	86.2	0.1491	0.0000	0.0000	0.1428	1.4306	0.0088	0.5733
TRC350	0.3167	62.0	0.6358	0.0000	2.7033	0.9049	9.6217	0.0000	2.9860
TRC351	0.4483	71.1	0.2180	0.0291	0.8334	0.2035	1.9472	0.0091	0.7859
TRC352	0.1795	64.4	0.1983	0.0000	0.0000	0.3055	3.2647	0.0000	0.9791
TRC353	0.1473	11.8	0.3388	0.0208	0.7506	0.2135	1.4666	0.0310	1.3138
TRC354	0.8246	58.9	0.2450	0.0000	0.8822	0.3209	3.3613	0.0072	1.1027
TRC355	0.1827	50.6	0.0683	0.0000	0.0000	0.0720	0.7010	0.0000	0.2671
TRC356	0.7598	216.5	0.4458	0.0000	2.1290	0.6960	7.3301	0.0000	2.4956
TRC357	0.2371	71.9	0.1322	0.0137	0.4500	0.0936	0.8202	0.0130	0.4531
TRC358	0.9295	58.0	0.2403	0.0000	0.9688	0.2444	2.2753	0.0138	0.9748

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	As	Ba	La	Lu	Nd	Sm	U	Yb	Ce
TRC359	0.1596	37.0	0.2221	0.0000	1.1572	0.3346	3.5197	0.0000	1.1007
TRC360	0.2785	53.1	0.1076	0.0000	0.6200	0.1333	1.3713	0.0000	0.4836
TRC361	0.3508	22.7	0.0861	0.0000	0.0000	0.1132	1.1695	0.0000	0.3651
TRC362	0.2274	23.3	0.1495	0.0121	0.5981	0.0889	0.8030	0.0150	0.4441
TRC363	0.1916	26.8	0.0754	0.0000	0.0000	0.0529	0.5035	0.0069	0.2539
TRC364	0.4039	27.2	0.2003	0.0000	0.5475	0.2613	2.5815	0.0073	0.8422
TRC365	0.5340	66.0	0.2485	0.0000	0.8293	0.3344	3.4769	0.0000	1.0712
TRC366	0.1900	47.3	0.1789	0.0000	1.0827	0.2662	2.7275	0.0000	0.8346
TRC367	0.2576	44.8	0.2315	0.0000	0.9674	0.3072	3.1414	0.0000	1.0260
TRC368	0.4261	20.3	3.8824	0.0520	3.5762	0.8128	1.6089	0.2285	3.3056
TRC369	0.1917	12.4	0.1925	0.0150	0.0000	0.1369	1.1725	0.0229	0.5203
TRC370	0.2110	20.4	0.2453	0.0000	0.9318	0.2319	2.1395	0.0159	0.8382
TRC371	0.3338	26.2	0.4909	0.0000	0.8167	0.2602	1.9531	0.0468	1.0307
TRC372	0.1837	40.2	0.3555	0.0000	0.5096	0.2289	1.9332	0.0248	0.9054
TRC373	0.1008	30.7	0.1833	0.0000	0.5275	0.2237	2.2551	0.0062	0.7381
TRC374	0.1802	10.9	0.2398	0.0096	0.0000	0.0788	0.4380	0.0317	0.5298
TRC375	0.3194	16.0	0.2522	0.0145	0.0000	0.0959	0.6481	0.0389	0.5417
TRC376	0.2411	8.9	0.2164	0.0092	0.2294	0.0703	0.3587	0.0250	0.3890
TRC377	0.5876	14.0	0.3967	0.0145	0.4399	0.1141	0.6344	0.0396	0.6414
TRC378	0.5492	14.8	0.2796	0.0134	0.3435	0.0858	0.5561	0.0483	0.4660

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	Co	Cr	Cs	Eu	Fe	Hf	Ni	Rb	Sb
TRC319	0.0384	0.5058	0.0091	0.0010	214.7	0.05	0.00	0.41	0.027
TRC320	0.0304	0.3375	0.0086	0.0000	109.0	0.007	0.00	0.13	0.025
TRC321	0.0669	0.5429	0.0150	0.0035	279.0	0.067	0.00	0.48	0.025
TRC322	0.0382	0.6673	0.0109	0.0016	200.9	0.031	0.00	0.29	0.032
TRC323	0.0373	0.5650	0.0508	0.0052	309.8	0.039	0.00	0.90	0.243
TRC324	0.0159	0.3871	0.0039	0.0005	150.4	0.02	0.00	0.28	0.011
TRC325	0.0102	0.2103	0.0076	0.0013	82.3	0.019	0.00	0.17	0.013
TRC326	0.0169	0.1222	0.0118	0.0014	57.0	0.012	0.00	0.25	0.006
TRC327	0.0903	2.9231	0.0605	0.0039	392.6	0.044	0.00	0.65	0.034
TRC328	0.1462	1.2928	0.0348	0.0016	272.2	0.067	0.00	0.46	0.012
TRC329	0.0332	0.2154	0.0243	0.0012	205.6	0.033	0.00	0.27	0.071
TRC330	1.1833	0.8264	0.0177	0.0041	1562.4	0.042	0.00	0.47	0.076
TRC331	0.0321	1.7359	0.0224	0.0020	133.8	0.03	0.00	0.42	0.493
TRC332	0.0407	0.4428	0.0410	0.0018	139.0	0.022	0.00	0.41	0.021
TRC333	0.3073	0.5816	0.0628	0.0037	883.3	0.13	3.36	1.36	0.487
TRC334	0.0158	0.3610	0.0054	0.0000	144.9	0.019	0.00	0.30	0.029
TRC335	0.0605	0.9381	0.0143	0.0026	214.3	0.056	0.00	0.51	0.018
TRC336	0.0117	0.7008	0.0292	0.0020	154.4	0.024	0.00	0.38	0.02
TRC337	0.0162	0.3288	0.0116	0.0019	110.4	0.015	0.00	0.24	0.025
TRC338	0.0297	0.6449	0.0154	0.0031	86.7	0.027	0.00	0.27	0.011
TRC339	0.0463	0.2094	0.0206	0.0012	216.2	0.06	0.00	0.27	0.011
TRC340	0.0091	0.1990	0.0074	0.0014	72.9	0.017	0.00	0.18	0.013
TRC341	0.2658	0.7300	0.0711	0.0032	956.6	0.113	2.75	1.63	0.042
TRC342	0.0235	0.1631	0.0413	0.0009	118.2	0.028	0.00	0.29	0.018
TRC343	0.0152	0.5067	0.0191	0.0278	37.5	0.029	0.00	0.41	0.024
TRC344	0.0810	0.5500	0.0271	0.0032	257.4	0.027	0.00	0.31	0.042
TRC345	0.1298	0.4710	0.0549	0.0017	852.0	0.132	0.00	0.99	0.061
TRC346	0.0289	0.1299	0.0348	0.0014	195.0	0.016	0.00	0.39	0.035
TRC347	0.0409	1.6023	0.0568	0.0028	290.3	0.105	0.00	0.90	0.019
TRC348	0.2970	0.5794	0.0346	0.0029	505.4	0.115	0.00	0.73	0.014
TRC349	0.0793	0.6095	0.0154	0.0029	277.0	0.034	0.00	0.29	0.037
TRC350	0.0143	0.3532	0.0081	0.0021	140.4	0.026	0.00	0.29	0.023
TRC351	0.0356	0.9287	0.0140	0.0033	181.0	0.035	0.00	0.37	0.018
TRC352	0.0158	0.8362	0.0098	0.0006	91.5	0.014	0.00	0.18	0.011
TRC353	0.0462	0.2422	0.0144	0.0146	186.1	0.025	0.00	0.27	0.235
TRC354	0.0350	0.4769	0.0087	0.0011	191.0	0.029	0.00	0.32	0.049
TRC355	0.0138	0.3194	0.0492	0.0009	115.0	0.019	0.00	0.35	0.017
TRC356	0.0194	0.5046	0.0035	0.0013	185.7	0.022	0.00	0.19	0.045
TRC357	0.0599	0.4915	0.0203	0.0037	177.3	0.072	0.00	0.51	0.01

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	Co	Cr	Cs	Eu	Fe	Hf	Ni	Rb	Sb
TRC358	0.0345	0.5041	0.0150	0.0042	441.7	0.044	0.00	0.34	0.07
TRC359	0.0113	0.2835	0.0076	0.0007	101.6	0.016	0.00	0.22	0.022
TRC360	0.0311	0.3543	0.0067	0.0010	131.8	0.041	0.00	0.18	0.019
TRC361	0.0314	0.1495	0.0093	0.0003	250.7	0.012	0.00	0.13	0.028
TRC362	0.0806	0.7312	0.0228	0.0026	285.2	0.074	0.00	0.58	0.01
TRC363	0.0984	0.2789	0.0206	0.0013	305.4	0.051	0.00	0.45	0.009
TRC364	0.0579	0.3403	0.0127	0.0013	294.7	0.023	0.00	0.18	0.039
TRC365	0.0291	0.4696	0.0050	0.0005	186.6	0.024	0.00	0.19	0.049
TRC366	0.0131	0.0862	0.0000	0.0000	80.7	0.014	0.00	0.00	0.022
TRC367	0.0271	0.3798	0.0059	0.0015	144.8	0.019	0.00	0.19	0.017
TRC368	0.1960	6.6102	0.0945	0.1396	844.3	0.068	3.78	1.18	0.083
TRC369	0.0147	0.8444	0.0800	0.0070	55.9	0.07	0.00	0.87	3.124
TRC370	0.0130	0.4919	0.0902	0.0080	106.7	0.057	0.00	0.82	0.938
TRC371	0.1462	1.1207	0.1058	0.0150	147.8	0.062	0.00	0.66	0.132
TRC372	0.0330	0.6872	0.0755	0.0091	336.2	0.103	0.00	0.74	0.536
TRC373	0.0069	0.2516	0.0567	0.0019	24.5	0.031	0.00	0.44	0.239
TRC374	0.0568	0.7188	0.0439	0.0072	112.4	0.071	0.00	0.91	0.151
TRC375	0.1622	0.7079	0.0559	0.0068	154.9	0.106	0.00	1.18	0.039
TRC376	0.0538	0.4968	0.0405	0.0062	85.1	0.076	0.00	0.86	0.311
TRC377	0.1794	0.7407	0.0591	0.0107	231.1	0.108	0.00	1.18	0.056
TRC378	0.1359	0.7537	0.0589	0.0066	195.7	0.093	0.54	1.15	0.046

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	Sc	Sr	Ta	Tb	Th	Zn	Al	Ca	Dy
TRC319	0.02700	6.94	0.0041	0.0000	0.0310	0.55	1889.9	3216.7	0.0000
TRC320	0.03260	2.19	0.0000	0.0008	0.0174	0.75	1110.5	240.3	0.0000
TRC321	0.04980	5.84	0.0064	0.0037	0.0363	0.75	1815.6	302.1	0.0000
TRC322	0.08440	6.55	0.0034	0.0000	0.0504	0.73	1395.8	1446.5	0.0000
TRC323	0.05370	7.23	0.0054	0.0046	0.0518	0.77	1792.6	1237.1	0.0000
TRC324	0.03360	1.39	0.0028	0.0000	0.0316	0.39	1338.5	143.4	0.0000
TRC325	0.04150	3.28	0.0024	0.0000	0.0192	1.34	1111.4	501.3	0.0000
TRC326	0.01610	1.26	0.0018	0.0010	0.0141	1.41	1058.0	260.1	0.0000
TRC327	0.07440	32.66	0.0055	0.0031	0.0573	1.23	1631.8	556.0	0.0000
TRC328	0.03740	21.62	0.0057	0.0000	0.0413	0.38	1634.6	13383.0	0.0000
TRC329	0.00950	8.10	0.0000	0.0000	0.0104	0.71	1570.7	261.1	0.0000
TRC330	0.02790	9.90	0.0044	0.0000	0.0362	0.87	1427.1	647.8	0.0000
TRC331	0.06740	5.56	0.0058	0.0023	0.0935	0.46	1125.8	2525.6	0.0000
TRC332	0.02700	8.60	0.0021	0.0000	0.0216	0.91	1631.2	656.8	0.0291
TRC333	0.06230	18.94	0.0119	0.0037	0.0604	3.02	3391.2	2942.5	0.0000
TRC334	0.05020	3.34	0.0040	0.0000	0.0294	0.67	1415.1	0.0	0.0000
TRC335	0.06000	5.96	0.0064	0.0000	0.0708	1.25	1801.0	500.0	0.0000
TRC336	0.04940	4.72	0.0045	0.0018	0.0401	1.11	1477.6	247.7	0.0000
TRC337	0.04510	1.96	0.0005	0.0000	0.0196	1.08	1062.2	0.0	0.0000
TRC338	0.02810	9.09	0.0032	0.0031	0.0335	1.31	1200.3	3500.4	0.0000
TRC339	0.01720	6.46	0.0000	0.0000	0.0147	0.80	1238.0	899.4	0.0000
TRC340	0.03910	3.13	0.0026	0.0010	0.0190	1.08	888.6	186.5	0.0000
TRC341	0.07240	12.20	0.0110	0.0046	0.0646	4.16	3462.9	1928.1	0.0000
TRC342	0.02050	7.55	0.0013	0.0000	0.0281	0.69	1521.6	671.9	0.0000
TRC343	0.03920	3.12	0.0070	0.0219	0.1007	0.44	1333.0	1186.7	0.0872
TRC344	0.06090	10.35	0.0030	0.0032	0.0488	2.12	1641.4	1084.6	0.0000
TRC345	0.02810	10.35	0.0127	0.0023	0.0189	1.79	2477.2	1132.3	0.0000
TRC346	0.01660	5.31	0.0016	0.0018	0.0182	0.42	1478.4	219.2	0.0000
TRC347	0.06070	11.35	0.0098	0.0040	0.0543	1.12	3135.3	797.9	0.0000
TRC348	0.05380	12.14	0.0079	0.0027	0.0691	1.34	2677.2	979.2	0.0000
TRC349	0.05030	7.67	0.0037	0.0016	0.0523	0.99	1477.0	377.7	0.0000
TRC350	0.04550	3.31	0.0032	0.0016	0.0238	0.75	1086.4	207.6	0.0000
TRC351	0.08030	8.73	0.0049	0.0020	0.0523	0.94	1247.3	16467.6	0.0000
TRC352	0.04220	231.01	0.0026	0.0000	0.0317	0.69	1224.1	0.0	0.0000
TRC353	0.06370	3.01	0.0064	0.0110	0.0964	0.39	1259.7	282.1	0.0311
TRC354	0.03250	3.41	0.0046	0.0012	0.0423	0.71	1297.0	619.9	0.0000
TRC355	0.02460	4.18	0.0027	0.0011	0.0278	0.72	1504.8	255.5	0.0000
TRC356	0.11750	7.49	0.0000	0.0000	0.0989	1.42	1198.1	1596.2	0.0000
TRC357	0.04220	6.02	0.0047	0.0025	0.0555	0.50	1091.7	311.9	0.0000

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	Sc	Sr	Ta	Tb	Th	Zn	Al	Ca	Dy
TRC358	0.11530	3.94	0.0080	0.0033	0.0739	2.13	1645.6	232.3	0.0000
TRC359	0.03360	2.29	0.0021	0.0000	0.0267	0.27	1107.6	392.1	0.0000
TRC360	0.03270	8.17	0.0023	0.0000	0.0308	0.50	1335.7	1026.5	0.0000
TRC361	0.02010	2.17	0.0010	0.0000	0.0120	0.31	915.2	106.9	0.0000
TRC362	0.05410	9.28	0.0078	0.0028	0.0754	0.97	2159.2	4253.7	0.0000
TRC363	0.04800	11.02	0.0045	0.0000	0.0583	0.43	1863.5	415.6	0.0000
TRC364	0.05570	2.54	0.0044	0.0014	0.0458	0.71	1218.3	337.8	0.0000
TRC365	0.04620	3.86	0.0052	0.0005	0.0288	0.52	1402.4	215.9	0.0000
TRC366	0.01470	3.61	0.0000	0.0000	0.0121	0.42	997.4	157.2	0.0000
TRC367	0.05440	4.29	0.0037	0.0000	0.0349	0.47	1251.7	298.0	0.0000
TRC368	0.45250	89.45	0.0161	0.1006	0.2970	13.84	2497.5	49484.1	0.5784
TRC369	0.05550	8.75	0.0139	0.0058	0.0973	0.39	1470.4	183.1	0.0000
TRC370	0.04880	10.54	0.0089	0.0051	0.0884	0.36	1890.5	387.8	0.0390
TRC371	0.10030	18.16	0.0099	0.0096	0.1188	0.81	2419.0	2412.6	0.0174
TRC372	0.04440	12.62	0.0083	0.0067	0.1021	1.53	1912.5	1377.2	0.0253
TRC373	0.04480	7.86	0.0079	0.0014	0.0977	0.22	1545.6	0.0	0.0000
TRC374	0.14100	3.36	0.0190	0.0053	0.1818	1.14	1790.2	9870.4	0.0416
TRC375	0.12060	7.25	0.0253	0.0071	0.2394	2.01	2453.2	452.1	0.0000
TRC376	0.05490	2.08	0.0192	0.0049	0.1229	0.67	1733.6	94.3	0.0000
TRC377	0.13360	5.02	0.0228	0.0087	0.2359	2.06	3027.7	2566.5	0.0000
TRC378	0.09920	5.87	0.0219	0.0071	0.1829	2.43	2822.7	5140.2	0.0715

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	K	Mn	Na	Ti	V
TRC319	549.3	3.00	296.9	0.00	2.82
TRC320	0.0	6.50	217.5	0.00	0.00
TRC321	505.5	0.74	250.7	135.06	2.36
TRC322	330.1	5.36	274.3	0.00	3.78
TRC323	352.8	1.13	171.4	0.00	1.19
TRC324	378.4	1.01	323.2	0.00	1.25
TRC325	167.7	0.40	194.1	0.00	1.38
TRC326	169.4	1.03	244.4	33.88	0.00
TRC327	228.7	4.33	319.6	0.00	5.89
TRC328	426.5	4.54	294.7	0.00	1.21
TRC329	0.0	10.33	224.8	0.00	2.13
TRC330	380.8	20.14	290.4	0.00	39.35
TRC331	245.2	1.75	111.6	26.58	0.72
TRC332	698.6	17.20	242.6	0.00	3.38
TRC333	982.0	2.15	388.0	57.83	8.56
TRC334	465.2	2.79	246.8	0.00	5.25
TRC335	525.6	0.66	345.3	0.00	3.36
TRC336	366.7	1.11	254.6	0.00	2.54
TRC337	226.2	2.35	206.6	0.00	2.46
TRC338	175.7	2.38	121.0	0.00	0.00
TRC339	200.5	2.41	205.7	0.00	0.46
TRC340	116.7	0.23	174.5	0.00	1.94
TRC341	825.8	2.39	411.8	88.93	5.39
TRC342	424.7	4.82	236.4	0.00	1.11
TRC343	221.3	2.03	152.4	57.57	0.00
TRC344	0.0	23.78	245.7	0.00	3.48
TRC345	394.8	2.51	213.5	121.94	1.18
TRC346	478.1	4.68	257.3	0.00	1.29
TRC347	675.5	5.10	419.7	0.00	3.85
TRC348	678.1	9.91	313.8	0.00	3.01
TRC349	162.9	3.91	224.2	0.00	2.75
TRC350	280.7	0.65	252.7	0.00	6.08
TRC351	341.2	5.46	271.1	0.00	3.35
TRC352	0.0	1.63	254.5	0.00	0.00
TRC353	200.3	0.54	166.7	0.00	1.00
TRC354	219.9	1.98	246.5	69.67	4.81
TRC355	464.1	1.84	237.4	0.00	1.87
TRC356	231.9	3.44	198.7	0.00	4.06
TRC357	429.9	1.34	272.7	0.00	0.00

Table C-2. Elemental Concentrations of Texas Chert Samples as Determined by INAA at MURR (continued).

ANID	K	Mn	Na	Ti	V
TRC358	282.2	1.53	301.3	0.00	4.71
TRC359	274.6	2.01	238.0	0.00	1.79
TRC360	270.4	2.02	209.0	0.00	2.13
TRC361	96.7	2.18	179.5	0.00	2.06
TRC362	397.7	3.58	373.3	69.48	2.61
TRC363	458.4	2.83	300.5	0.00	2.64
TRC364	186.3	2.05	244.8	0.00	2.43
TRC365	255.0	1.15	270.2	33.60	2.47
TRC366	160.7	0.50	155.4	0.00	2.13
TRC367	241.4	2.84	262.5	0.00	3.31
TRC368	450.9	19.96	367.3	58.50	3.22
TRC369	235.3	0.40	153.1	76.38	1.56
TRC370	356.1	0.53	253.1	0.00	0.83
TRC371	358.4	3.52	254.3	0.00	1.25
TRC372	285.4	0.64	283.9	0.00	0.96
TRC373	240.8	0.21	222.4	83.43	0.00
TRC374	420.1	8.07	183.3	95.88	2.30
TRC375	632.4	2.97	371.1	0.00	5.85
TRC376	229.7	2.49	176.6	53.02	0.00
TRC377	466.4	16.48	232.4	110.29	1.59
TRC378	443.2	19.56	225.3	113.76	2.13

Table C-3. Eigenvalues and Percentage of Variance Explained by Principal Components Analysis of the Database of all Texas Cherts Analyzed at MURR.

Principal Components	1	2	3	4	5	6	7	8	9
Eigenvalue	0.8791	0.5813	0.3832	0.2147	0.1759	0.1233	0.1014	0.0842	0.0676
%Variance	30.9968	20.4957	13.512	7.5697	6.2029	4.3479	3.575	2.9672	2.3837
Cum. %Var.	30.9968	51.4924	65.005	72.5742	78.777	83.125	86.7	89.6673	92.0509
Total Structure Coefficients									
Mn	**0.5185**	0.0378	0.0447	0.3858	**0.4429**	**0.5082**	0.1152	0.1166	0.1743
Co	0.342	0.0874	0.0782	0.0215	0.151	0.1425	0.0924	0.341	0.2629
Fe	0.3398	0.027	0.1219	0.0221	0.0425	0.2622	0.1009	0.2237	0.3084
Sc	0.275	0.3132	0.1929	0.0331	0.2098	0.0387	0.1802	0.0492	0.1517
Zn	0.2706	0.0852	0.0835	0.1912	0.0393	0.0177	0.2059	0.1771	**0.5264**
Th	0.2464	0.2587	0.2023	0.0764	0.3652	0.0304	0.0584	0.0542	0.3364
Eu	0.2324	0.1283	0.0369	0.038	0.1741	0.2841	**0.6132**	**0.44**	0.0162
Sb	0.2264	0.1983	0.1001	0.3874	0.3505	0.2765	0.3657	0.2139	**0.5335**
Sr	0.2149	0.3541	0.1654	0.2395	**0.4355**	0.2603	0.1624	**0.5782**	0.0646
Hf	0.1812	0.1102	0.0075	0.2223	0.3436	0.1817	0.2413	0.278	0.1292
Cr	0.1718	0.124	0.2232	0.0315	0.0965	0.2639	0.0809	0.1805	0.0927
Rb	0.1365	0.0761	0.0462	0.2204	0.182	0.0856	0.1518	0.1315	0.1369
Ba	0.1303	0.2278	**0.4727**	**0.4371**	0.2135	**0.5316**	0.0646	0.2158	0.1432
La	0.1243	0.3531	0.276	0.1532	0.0679	0.0005	0.3302	0.0721	0.0969
Ce	0.104	0.1654	0.3762	0.1921	0.0254	0.0398	0.0253	0.0112	0.0645
Na	0.0724	0.0245	0.035	0.0319	0.1601	0.0228	0.0222	0.0779	0.0002
Sm	0.0688	0.1625	**0.4237**	0.1953	0.0187	0.0706	0.0757	0	0.1008
Al	0.0548	0.0007	0.0084	0.0404	0.132	0.0348	0.0632	0.1248	0.0419
Cs	0.0187	**0.5881**	0.0221	**0.4122**	0.0286	0.0414	0.2837	0.0591	0.0474
U	0.0144	0.1631	**0.4228**	0.1915	0.044	0.1499	0.2475	0.074	0.1041

Table C-4. Mahalanobis Distance Calculation and Posterior Classification of Newly Analyzed Gorman Formation Chert-Source Samples and Previously Defined Compositional Groups in the Texas Cchert Database.

Probability calculations are based upon the first eight principal components derived from the entire Texas chert database, accounting for 89.66% of the total chemical variation in the dataset. Highest probabilities are indicated in bold. Group abbreviations are: HH_PC: Horse Hollow (Quigg 2006); GEO_PC: Leon Creek (Hudler 2001); WGT_PC: Wright Creek (Hudler 1998); SF_PC: Edwards/Segovia Formation (Turnbull 1994); GF_PC: Gorman Formation (Present study); EFC_PC: Edwards Formation (Quigg 2004); CFCD_PC: Edwards Formation (Frederick 1994); EFC6_PC: Fort Hood Gray (Frederick 1994); EFC5_PC: Heiner Lake Tan (Frederick 1994); EFC4_PC: Novaculite (Frederick 1994); EFC3_PC: Tan (Frederick 1994); EFC2_PC: Gray-Brown-Green (Frederick 1994); EFC1_PC: Owl Creek (Frederick 1994); LRG_PC: Edwards Formation-Llano River Gravel (Present Study).

ID. NO.	TRC369	TRC370	TRC371	TRC372	TRC373	TRC374	TRC375	TRC376	TRC377	TRC378
HH_PC	0	0	0.012	0.006	0.006	0.057	0.021	0.006	0.007	0.039
GEO_PC	0	0	0	0	0	0	0	0	0	0
WGT_PC	0.039	0.204	0.426	0.262	5.295	0.401	0.297	0.362	0.296	0.324
SF_PC	0.001	0.003	0.025	0.004	0.024	0.024	0.064	0.005	0.041	0.057
GF_PC	**76.832**	**97.289**	**52.792**	**12.828**	**42.923**	**80.082**	19.914	**29.635**	**67.187**	16.855
EFC_PC	0	0.011	0.052	0.118	8.179	0.692	1.08	1.725	0.058	0.473
CFCD_PC	0.091	1.478	5.575	1.415	38.902	19.739	28.07	12.207	9.959	**20.538**
EFC6_PC	0	0	0.001	0	0.003	0.001	0.007	0	0.001	0.003
EFC5_PC	0	0	0	0	0	0	0	0	0	0
EFC4_PC	0	0	0	0	0	0	0	0	0	0
EFC3_PC	0	0	0	0	0	0	0	0	0	0
EFC2_PC	0	0	0	0	0	0	0	0	0	0
EFC1_PC	0	0	0	0	0	0	0	0	0	0
LRG_PC	1.875	5.95	3.432	8.62	2.712	12.005	**29.864**	6.414	5.434	4.848
From:	5	5	5	5	5	5	5	5	5	5
Into:	5	5	5	5	5	5	14	5	5	7

Table C-5. **Mahalanobis Distance Calculation and Posterior Classification of Newly Analyzed Llano River Gravel Chert-Source Samples and Previously Defined Compositional Groups in the Texas Chert Database.**

Probability calculations are based upon the first eight principal components derived from the entire Texas chert database, accounting for 89.66% of the total chemical variation in the dataset. Highest probabilities are indicated in bold. Group abbreviations are: HH_PC: Horse Hollow (Quigg 2006); GEO_PC: Leon Creek (Hudler 2001); WGT_PC: Wright Creek (Hudler 1998); SF_PC: Edwards/Segovia Formation (Turnbull 1994); GF_PC: Gorman Formation (Present study); EFC_PC: Edwards Formation (Quigg 2004); CFCD_PC: Edwards Formation (Frederick 1994); EFC6_PC: Fort Hood Gray (Frederick 1994); EFC5_PC: Heiner Lake Tan (Frederick 1994); EFC4_PC: Novaculite (Frederick 1994); EFC3_PC: Tan (Frederick 1994); EFC2_PC: Gray-Brown-Green (Frederick 1994); EFC1_PC: Owl Creek (Frederick 1994); LRG_PC: Edwards Formation-Llano River Gravel (Present Study).

ID. NO.	TRC358	TRC359	TRC360	TRC361	TRC362	TRC363	TRC364	TRC365	TRC366	TRC367
HH_PC	32.93	4.453	0.591	0	0.52	0.012	5.315	0.223	0.209	13.57
GEO_PC	0	0	0.025	0	0	0	0	0	0.029	0
WGT_PC	46.259	**49.909**	62.102	42.924	6.347	5.772	80.867	28.746	**67.833**	**54.6**
SF_PC	0.066	0.188	0.382	0.002	1.472	0.618	0.02	0.015	0.04	1.332
GF_PC	15.444	11.93	14.19	8.579	39.326	15.82	9.826	6.246	21.606	11.857
EFC_PC	28.186	0.768	0.391	0	1.094	0.005	2.193	0.018	23.189	1.211
CFCD_PC	**66.309**	21.162	20.659	0.052	34.22	2.751	22.848	4.196	46.634	54.088
EFC6_PC	0.002	0.142	0.623	0.037	0.508	0.073	0.01	0.007	0.175	0.059
EFC5_PC	0	0	0	0	0	0	0	0	0	0.008
EFC4_PC	0.019	1.278	0.044	0.008	0.004	0.008	0.035	0.025	0.19	0.82
EFC3_PC	0	0	0	0	0.035	0.013	0	0	0	0
EFC2_PC	0	0	0	0	0.049	0.005	0	0	0	0
EFC1_PC	0	0	0	0	0.001	0	0	0	0	0
LRG_PC	25.402	27.731	**77.943**	**69.711**	**77.552**	**47.877**	**95.456**	**53.849**	5.809	48.453
From:	14	14	14	14	14	14	14	14	14	14
Into:	7	3	14	14	14	14	14	14	3	3

Table C-6. Mahalanobis Distance-Based Probabilities of Group Membership for the 39 Newly Analyzed Chert Artifacts from 41MS69.

Probability calculations are based upon the first eight principal components derived from the entire Texas chert database, accounting for 89.66% of the total chemical variation in the dataset. Highest probabilities are indicated in bold. Group abbreviations are: HH_PC: Horse Hollow (Quigg 2006); GEO_PC: Leon Creek (Hudler 2001); WGT_PC: Wright Creek (Hudler 1998); SF_PC: Edwards/Segovia Formation (Turnbull 1994); GF_PC: Gorman Formation (Present study); EFC_PC: Edwards Formation (Quigg 2004); CFCD_PC: Edwards Formation (Frederick 1994); EFC6_PC: Fort Hood Gray (Frederick 1994); EFC4_PC: Novaculite (Frederick 1994); LRG_PC: Edwards Formation-Llano River Gravel (Present Study). Note that probabilities of membership to all other compositional groups in the Texas chert database were less than 0.1. Probabilities of membership to these groups are removed here to conserve page space, but they can be provided upon request.

ID. NO.	HH_PC	GEO_PC	WGT_PC	SF_PC	GF_PC	EFC_PC	CFCD_PC	EFC6_PC	EFC4_PC	LRG_PC
TRC319	0.337	0.031	**70.843**	0.122	14.213	0.158	23.539	0.117	0.015	7.102
TRC320	1.328	0	**28.297**	0.047	9.253	1.672	24.246	0.002	0.016	8.292
TRC321	0.788	0	8.371	0.17	37.64	25.32	**58.439**	0.078	0.004	3.596
TRC322	33.38	0	59.341	0.436	12.024	2.312	**59.41**	0.019	0.085	9.116
TRC323	0.143	0	1.421	0.005	**78.115**	18.343	27.733	0	0	14.272
TRC324	0.684	0	7.037	0.162	7.176	0.001	3.58	0.064	0.312	**10.46**
TRC325	34.817	0.001	61.77	0.812	17.928	27.151	**83.941**	0.167	2.858	6.407
TRC326	0.086	0	29.184	0.349	**53.294**	4.171	7.902	0.027	0.001	1.799
TRC327	0.018	0.04	10.15	0.229	5.279	0.802	**15.25**	0.001	0	1.246
TRC328	0.603	0	11.024	1.107	26.237	1.352	**36.349**	0.215	0.005	4.949
TRC329	0.013	0.007	**42.189**	0.005	11.542	1.527	12.664	0.002	0	0.456
TRC330	0.114	0	**56.223**	0.003	7.226	0.003	1.176	0	0	0.387
TRC331	2.368	0	1.282	0.003	**17.408**	7.084	7.916	0	0	1.685
TRC332	2.59	0.015	**78.485**	0.137	16.807	2.111	43.282	0.009	0.005	0.526
TRC333	0.006	0	0.071	0.001	**20.785**	3.168	9.306	0	0	2.446
TRC334	23.243	0	12.659	0.286	6.307	1.185	**51.782**	0.001	0.549	6.809
TRC335	5.733	0	17.059	0.724	36.596	5.715	**61.463**	0.279	0.009	3.651
TRC336	0.968	0.001	11.6	0.27	22.121	51.601	**59.401**	0.213	0.008	2.578
TRC337	15.555	0	65.368	0.124	15.381	32.095	**71.853**	0.009	0.016	49.775
TRC338	3.566	0	6.185	1.851	16.868	45.339	**75.83**	0.598	0.008	5.861
TRC339	1.107	0.032	**65.355**	0.21	22.811	4.902	57.988	0.101	0.107	1.182
TRC340	29.126	0.001	59.993	0.81	19.08	34.205	**86.82**	0.159	4.779	3.23
TRC341	0.021	0	0.494	0.014	27.233	4.482	**40.408**	0.002	0	2.035
TRC342	0.237	0.572	**73.978**	0.139	18.518	2.599	46.205	0.049	0.025	0.751
TRC343	0	0	0.262	0.009	**7.661**	0	0.013	0.001	0	1.337

Table C-6. Mahalanobis Distance-Based Probabilities of Group Membership for the 39 Newly Analyzed Chert Artifacts from 41MS69 (continued).

ID. NO.	HH_PC	GEO_PC	WGT_PC	SF_PC	GF_PC	EFC_PC	CFCD_PC	EFC6_PC	EFC4_PC	LRG_PC
TRC344	4.996	0	**44.141**	0.071	12.275	1.867	40.668	0.002	0.001	0.815
TRC345	0.021	0.002	3.137	0.006	15.475	9.057	**33.317**	0.001	0.001	0.543
TRC346	0.044	0.006	**47.769**	0.019	21.674	21.749	44.876	0.027	0.001	2.191
TRC347	0.042	0	0.489	0.245	21.472	5.751	36.922	0.039	0	**39.262**
TRC348	0.023	0	1.131	0.13	**24.126**	0.094	10.952	0.022	0	3.686
TRC349	2.99	0.002	**82.125**	0.101	14.119	12.156	68.944	0.018	0.017	6.311
TRC350	39.643	0	20.01	0.478	9.705	10.565	**91.229**	0.003	2.303	41.705
TRC351	25.114	0	59.087	10.549	19.516	9.186	**95.151**	0.075	0.161	14.968
TRC352	0.046	0.008	0.033	0.449	**7.885**	0.001	0.354	0.001	0	2.782
TRC353	0.045	0	8.239	0.017	**24.471**	0.091	2.689	0	0	2.741
TRC354	13.437	0	**77.371**	0.035	10.141	3.87	41.084	0.01	0.104	15.334
TRC355	0.014	0.33	16.788	0.058	13.056	12.017	32.304	0.05	0.007	**91.868**
TRC356	0.375	0	2.983	0.234	4.363	0.023	**23.081**	0	0.005	7.031
TRC357	0.318	0.011	14.5	2.419	14.851	4.104	**65.488**	0.326	0.239	13.63

Table C-7. Summary of Mahalanobis Distance-based Probabilities for 39 Artifacts from 41MS69. See Table C-6 of this report for specific probabilities of group membership.

Group:	0.01	0.1	1	5	10	20	100
HH_PC	2	13	23	30	31	33	39
GEO_PC	32	37	39	39	39	39	39
WGT_PC	0	2	5	10	14	21	39
SF_PC	7	14	35	38	38	39	39
GF_PC	0	0	0	1	9	26	39
EFC_PC	4	7	9	23	28	32	39
CFCD_PC	0	1	2	5	8	11	39
EFC6_PC	18	30	39	39	39	39	39
EFC5_PC	38	39	39	39	39	39	39
EFC4_PC	24	30	36	39	39	39	39
EFC3_PC	34	38	39	39	39	39	39
EFC2_PC	39	39	39	39	39	39	39
EFC1_PC	39	39	39	39	39	39	39
LRG_PC	0	0	6	22	30	35	39

Table C-8. Summary of Best-fit Assignments of the 39 Artifacts from 41MS69.

Group abbreviations are: HH_PC: Horse Hollow (Quigg 2006); GEO_PC: Leon Creek (Hudler 2001); WGT_PC: Wright Creek (Hudler 1998); SF_PC: Edwards/Segovia Formation (Turnbull 1994); GF_PC: Gorman Formation (Present study); EFC_PC: Edwards Formation (Quigg 2004); CFCD_PC: Edwards Formation (Frederick 1994); EFC6_PC: Fort Hood Gray (Frederick 1994); EFC5_PC: Heiner Lake Tan (Frederick 1994); EFC4_PC: Novaculite (Frederick 1994); EFC3_PC: Tan (Frederick 1994); EFC2_PC: Gray-Brown-Green (Frederick 1994); EFC1_PC: Owl Creek (Frederick 1994); LRG_PC: Edwards Formation-Llano River Gravel (Present Study).

	Artifacts
HH_PC	0
GEO_PC	0
WGT_PC	11
SF_PC	0
GF_PC	8
EFC_PC	0
CFCD_PC	17
EFC6_PC	0
EFC5_PC	0
EFC4_PC	0
EFC3_PC	0
EFC2_PC	0
EFC1_PC	0
LRG_PC	3
Total	*39*

APPENDIX D
PRESENCE/ABSENCE ANALYSIS OF POLLEN AT 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Steven Bozarth, Ph.D.
University of Kansas Palynology Laboratory
Lawrence, Kansas

This page intentionally left blank.

PRESENCE/ABSENCE ANALYSIS OF POLLEN AT 41MS69

Steven Bozarth, Ph.D.

D.1 INTRODUCTION

Six sediment samples from 41MS69 were analyzed for presence/absence of pollen. These include 107-4-1c, 108-4-1c, 109-4-1c, 505-4-1a, 507-4-1a, and 511-4-1a (Table D-1).

D.2 METHODS

A number of pollen extraction procedures exist, but heavy-liquid flotation and centrifugation was selected because of the vulnerability of pollen from the study area to degradation by chemical digestion techniques. The heavy-liquid flotation and centrifugation procedure has been refined in the University of Kansas Palynology Laboratory and has proven to be highly effective in the isolation of pollen from a variety of sediment matrices.

Pollen was extracted from 7-20 gm sediment samples. This procedure consists of six steps; 1) introduction of "spike" spores; 2) removal of carbonates with dilute hydrochloric acid; 3) removal of colloidal organics, clays, and very fine silts by deflocculation with sodium pyrophosphate, centrifugation, and decantation through a 7-µm filter; 4) heavy-liquid flotation of phytoliths from the heavier clastic mineral fraction using zinc bromide concentrated to a specific gravity of 2.0; 5) washing and dehydration of isolate with butanol; and 6) storage in a 1-dram glass vial with several times as much silicone fluid (500-centistoke viscosity) as isolate. After thorough mixing, an aliquot of the mixture from each isolate was mounted on a microscope slide under a 22x40 mm cover glass and sealed with paraffin.

D.3 POLLEN CONCENTRATIONS

Pollen concentration studies can be useful for determining the amount of pollen that may have been destroyed during the post-depositional period of a deposit. Post-depositional processes, such as pedogenesis, mechanical destruction, chemical oxidation, rapid changes in atmospheric-moisture levels, high pH levels, and microbial activity, may greatly reduce the amount of pollen in a deposit. The pollen recovered from archaeological site sediments represent the sum total of the originally deposited pollen minus the pollen lost to the various processes of deterioration. Pollen concentrations from open air sites which do not contain at least 1,000 pollen grains per gram have undergone severe pollen loss through post depositional alteration and may not provide reliable information. Low numbers of identified plant taxa and high percentages of indeterminate grains also suggest that the pollen data may be suspect because of poor preservation.

As mentioned above, "spike" tablets containing an average of 18,583 Lycopodium spores per tablet were introduced into the soil/sediment sample prior to the flotation in order to verify pollen extractions and for quantitative evaluation of microfossil concentrations. Lycopodium was selected for the following reasons: (1) it is very rare to the study area; (2) its spores are distinctive and easy to identify; (3) it is commonly used to calculate pollen concentrations; and (4) it is readily available. To calculate the pollen concentrations per gram, the following equation was used:

$$\text{Conc} = \frac{E_t X_n}{E_n} \div \text{sample weight}$$

where E_t is the total number of exotics introduced into the sample, X_n is the number of fossil pollen grains counted in the scan, and En is the number of exotics counted.

After the slides were made, each pollen isolate was analyzed with a petrographic Zeiss microscope. Two transects were scanned at a magnification of 625X.

D.4 ANALYSIS OF POLLEN ISOLATES

No pollen was found. Due to the lack of pollen preservation, I do not recommend additional pollen analysis at 41MS69.

Table D-1. Provenience Information on Samples Analyzed.

Catalogue No.	Column	Unit	Depth (cmbs)	Feature No.	Material
107-4-1c	1	Zone 8	224-228		Sediment
108-4-1c	1	Zone 9	292-296		Sediment
109-4-1c	1	Zone 11	395-397		Sediment
505-4-1a	1	5 Ext	151-154	1	Sediment
507-4-1a	1	6	134	1	Sediment
511-4-1a	1	5	177	2	Sediment

APPENDIX E
PRESENCE/ABSENCE ANALYSIS OF PHYTOLITHS AT 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Steven Bozarth, Ph.D.
University of Kansas Palynology Laboratory
Lawrence, Kansas

This page intentionally left blank.

PRESENCE/ABSENCE ANALYSIS OF PHYTOLITHS AT 41MS69

Steven Bozarth, Ph.D.

E.1 INTRODUCTION

Six sediment samples (107-4-1b, 108-4-1b, 109-4-1b, 505-4-1b, 507-4-1b and 511-4-1b) were processed for presence/absence of phytoliths from 41MS69 (Table E-1).

E.2 METHODS

Phytoliths were isolated from 5-gram samples using a procedure based on heavy-liquid (zinc bromide) flotation and centrifugation. This procedure consists of five basic steps: 1) removal of carbonates with dilute hydrochloric acid; 2) removal of colloidal organics, clays, and very fine silts by deflocculation with sodium pyrophosphate, centrifugation, and decantation through a 7-µ filter; 3) oxidation of sample to remove organics; 4) heavy-liquid flotation of phytoliths from the heavier clastic mineral fraction using zinc bromide concentrated to a specific gravity of 2.3; 5) washing and dehydration of phytoliths with butanol; and 6) dry storage in 1-dram vials.

A representative portion of each phytolith isolate was mounted on a microscope slide in immersion oil under a 22 x 40 mm cover glass and sealed with clear nail lacquer

E.3 RESULTS

Phytoliths were not adequately preserved for analysis in three samples (107-4-1b, 108-4-1b, and 109-4-1b). However, phytoliths were well-preserved in the other three samples (505-4-1b, 507-4-1b, and 511-4-1b). C3 and C4 grass phytoliths were common, whereas arboreal phytoliths were present but rare, in these three samples. It is important to note that these sediment samples were much darker than the first three. Therefore, phytolith analysis of samples with similar color, i.e., organic content, from 41MS69 should provide interpretable archaeological data.

Table E-1. Provenience of Samples Analyzed.

Catalogue No.	Column	Unit	Depth (cmbs)	Feature No.	Material
107-4-1b	1	Zone 8	224-228		Sediment
108-4-1b	1	Zone 9	292-296		Sediment
109-4-1b	1	Zone 11	395-397		Sediment
505-4-1b	1	5 Ext	151-154	1	Sediment
507-4-1b	1	6	134	1	Sediment
511-4-1b	1	5	177	2	Sediment

This page intentionally left blank.

APPENDIX F
PLANT REMAINS FROM 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Phil Dering, Ph.D.
Shumla Archeobotanical Services
P.O. Box
110 Alpine
Comstock, TX 78837

This page intentionally left blank.

PLANT REMAINS FROM 41MS69

Phil Dering, Ph.D.

F.1 INTRODUCTION

Michael Quigg of TRC Environmental Corporation (TRC) in Austin submitted three soil samples totaling 8.9 liters. Shumla Archeobotanical Services processed the soil samples using standard flotation methods and identified the recovered macrobotanical remains. The samples were collected from burned rock Features 1 and 2. Sediment from Feature 2 measured 8 liters, and the other two soil samples were less than 1 liter each. The Shumla Archeobotanical flotation effort averaged just under 3 liters per sample. Additionally, picked specimens from two other flotation samples (#511-4 and #512-4) were submitted for identification, along with 19 macrobotanical samples.

F.2 LABORATORY METHODS

F.3 FLOTATION

Flotation is the process by which organic remains, primarily charred plant fragments, are recovered from archeological sediments using water as the separating agent. The soil samples were processed at Shumla Archeobotanical Services using a simple screen and swirl technique by pouring the sample into a 5-gallon bucket filled with water. The sample is stirred gently with a narrow metal rod and rocked back and forth. The heavy material, which may consist of large clasts, some bone, and denser wood charcoal, falls to the bottom of the bucket, and the lighter material, including most of the plant material, both carbonized and uncarbonized, floats to the surface. The floating light fraction is directed onto a 0.350 mm screen, a mesh that will catch the smallest seeds. The sinking heavy fraction is passed through a 1 mm stainless steel screen. Both fractions are tagged and slowly dried before they are examined in the laboratory. The archeological soils in the current study were fairly uniform, consisting of a sandy/silty loam with little or no structure, and mixed with water rapidly. Flotation recovery was tested in two samples using 50 poppy seeds, and 84 percent of the poppy seeds were recovered.

F.3.1 Analysis

The analysis follows standard archeobotanical laboratory procedures. The light fraction of each flotation sample is passed through a nested set of screens of 4 mm, 2 mm, 1 mm, and 0.350 mm mesh and examined for charred material that is separated for identification. The heavy fraction is also scanned for charcoal, which is set aside for identification. The results are combined with identifications from each corresponding light fraction. Only charred plant material is included in the analysis, because uncarbonized material is consumed by insects, fungi and bacteria and does not survive more than a few years in open deposits. Carbonized plant material is sorted into two categories –woody fragments and seed/fruit fragments including maize or agave parts when present.

Carbonized wood from the 4 mm and 2 mm screens (smaller pieces are seldom identifiable) is separated in a 25 piece grab sample and identified. Care is taken to select representative materials from both levels (cf. Diehl 2003:213; Huckell 2002:645; Miksicek 1994:243). When a sample contains more than 25 wood fragments, the additional material is scanned and sorted into wood charcoal types. For each type with more than 25 fragments, the volume of each type is measured in milliliters and reported along with its weight.

Charred material caught on all of the sieve levels, including the bottom pan, is scanned for floral parts, fruits, seeds, and other potentially edible plant parts such as agave or maize fragments, and these plant parts are counted and examined for identification.

F.3.2 Disturbance Indicators

Sample content may be affected by various biological disturbance factors, including insect or small mammal activity, and plant root growth. In an effort to assess this impact, the amounts of insect parts, termite pellets, rodent/rabbit pellets, gastropods, and modern uncharred seeds are estimated for each flotation sample. These amounts are reported on a scale of 1 to 25 (+), 25 to 50 (++), and over 50 (+++). In the current study, roots, insect parts, and gastropod remains were noted in the light fractions. There was no material other than a few small, unsorted gravels in the heavy fractions.

F.3.3 Identification

Identification of carbonized wood is accomplished by using the snap technique, and examining the transverse, radial, and tangential surfaces at 7.5 to 75 power with a binocular dissecting microscope, and comparing the material to reference specimens in the Shumla Archeobotanical Services reference collection. Seeds, fruit fragments, and *Agavaceae* - type (agave, sotol, yucca, etc.) are identified using seed manuals and reference specimens. When I could distinguish vessels imbedded in fibers and parenchyma, I classified the wood as a hardwood (not a conifer). If the wood sample contained sufficient diagnostic features, I assigned it to a more restrictive category, such as woody-legume type or live-oak type. I did not observe wood consisting primarily of tracheids (eg. conifer wood/juniper) in this assemblage.

The wood of mesquite, acacia, and other members of the legume family (*Fabaceae*), is difficult to separate beyond the family level (*Fabaceae*). Mesquite can be separated from other woody members of that family, but in cases where the charcoal fragments are too small or the gross anatomy does not include diagnostic features, the material is assigned to the *Fabaceae*-type (woody legume-type).

F.4 RESULTS

The flotation sample summary and the identification of plant materials recovered from the site are presented Tables F-1 through F-3. The sample summary includes provenience information, soil sample volume, disturbance indicators, and sample richness indicators. The light fraction of each sample was small, and

Table F-1. Flotation Sample Summary.

Catalog No.	Feature	Provenience, Level (CMBS)	Sample Volume (L)	Light Fraction Vol (ml) and Wt (g)	Insect Parts (ip), roots (r), rodent pellets (rp), termite pellets (tp)	Uncharred (modern) seeds	Number of charred seed taxa	Total charred seeds or root fragments	Density seeds/liter	Total charcoal (grams)
513-004	2	U-5 Ext, Level 19	8.0	70; 27.4	r+++, ip+++, g+	0	0	0	0	0.8
508-004	1	TU-6, Level 15	0.6	10; 0.4	r+++, ip+, g+	0	0	0	0	<0.1
509-004-1	1	TU-6, Level 16	0.3	6; 0.3	r+++, ip+, g+	0	0	0	0	0.0

dominated by roots. Small gastropods and insect parts were a common indication of disturbance. The soil was sandy/silty, and charred plant material, where present, was in fairly good condition. The total weight of charcoal from the three flotation samples was about 0.8 g. However, one of the samples from Feature 1 contained only very small, unidentifiable charcoal flecks.

Table F-2 presents the identifications from the flotation samples. Oak and hackberry wood, recovered were the wood types identified in the samples from Feature 2, Hackberry nutlets also were noted from Feature 2. The antiquity of hackberry nutlets is difficult to determine because they are composed mostly of calcium carbonate and are very resistant to deterioration. They are roughly spherical and tend to roll into burrows, cracks, and open excavation units. There was abundant evidence of insect disturbance in the Feature 2 samples, so it is possible that the hackberry seeds were introduced into the deposits recently.

One sample from Feature 3 contained carbonized oak wood (Table F-3). Other samples in the assemblage from 41MS69 contain wood charcoal of woody legume and Texas persimmon. Overall, however, the botanical assemblage from 41MS69 was poorly preserved and difficult to manipulate and identify.

F.5 DISCUSSION AND CONCLUSIONS

As previously noted, I processed three flotation samples, and TRC submitted selected specimens from two other flotation samples, for a total of five samples. The five flotation samples indicate that plant preservation is poor at 41MS69. Wood charcoal content includes woody legume, Texas persimmon, oak, and hackberry types. Other than the hackberry nutlets, no seeds were identified in the samples.

It is difficult to predict when and where archaeologists will encounter botanical remains, due primarily to the stochastic nature of botanical preservation. Recovery from open site deposits depends on carbonization of the plant fragments, and carbonization is usually a byproduct of plant processing or food preparation accidents, waste disposal, burning of structures after abandonment, or in the best case scenario, catastrophic burning of an occupied structure. In the case of temporary encampments of foragers, one can expect low recovery rates, especially from shallowly buried and briefly occupied archeological sites located on stable landforms. If the samples in the current analysis are an accurate indication, 41MS69 does not have good potential to yield botanical information.

Table F-2. Plant Materials Identified in the Flotation Samples.

Catalog Number	Feature	Provenience	Taxon	Common	Part	Count	Vol (ml)
508-004	1	TU-6, Level 15	Indeterminate	NA	Wood	5	--
509-004-1	1	TU-6, Level 16	Charcoal flecks	NA	NA	--	--
511-4-1h	2	TU-5, 177 cm	*Celtis* sp.	Hackberry	Wood	3	--
511-4-1h	2	TU-5, 177 cm	Indeterminate	NA	Wood	15	0.2
512-4-a	2	TU-5, Ext. 170-174 cm	Indeterminate	NA	Wood	22	<.1
513-004	2	TU-5 Ext, Level 19	*Quercus* sp.	Oak	Wood	25+	.8
513-004	2	TU-5 Ext, Level 19	*Celtis* sp.	Hackberry	Nutlet (seed)	4	--

Table F-3. Macrobotanical Sample Identification.

Catalog No.	Feature	Provenience, Level (cmbs)	Taxon	Common	Part	Count	Wt (g)
515-7-1a	2	TU-6, 170-173	Indeterminate	NA	Wood	2	<.1
512-7-a	2	TU-5.5 170-174	Indeterminate	NA	Wood	3	<.1
514-007-4	2	NA	Indeterminate hardwood	NA	Wood	9	+
516-007-1	3	NA	*Quercus* sp.	Oak	Wood	9	0.2
100-007	--	NA	*Quercus* sp.	Oak	Burl-wood	5	0.5
110-007	--	NA	Indeterminate hardwood	NA	Wood	2	+
18-007	--	NA	*Quercus* sp.	Oak	Wood	8	1.1
3-007	--	NA	Fabaceae	Woody legume-type	Wood	3	0.1
36-007-1	--	NA	*Quercus* sp.	Oak	Wood	9	0.6
36-007-2	--	NA	*Diospyros texana*	Texas persimmon	Wood	3	+
36-007-3	--	NA	Fabaceae	Woody legume-type	Wood	7	0.1
36-007-6	--	NA	*Quercus* sp.	Oak	Wood	9	0.1
37-007-1	--	NA	*Quercus* sp.	Oak	Wood	5	+
37-007-3	--	NA	*Diospyros texana*	Texas persimmon	Wood	32	1
37-007-4	--	NA	Indeterminate hardwood	NA	Wood	20	0.1
41-007	--	NA	*Quercus* sp.	Oak	Wood	2	0.1
45-007	--	NA	*Quercus* sp.	Oak	Wood	10	0.1
511-007-1	--	NA	Indeterminate hardwood	NA	Wood	8	+
514-007-2	--	NA	*Quercus* sp.	Oak	Wood	11	0.1

F.6 REFERENCES

Diehl, M.
2003 Prehistoric Subsistence Strategies and the Macrobotanical Assemblage. In *Hohokam Farming on the Salt River Floodplain,* edited by T. Kathleen Henderson, pp. 211-230. Anthropological Papers No. 42, Center for Desert Archaeology, Tucson. Anthropological Papers No. 9. Pueblo Grande Museum. Phoenix.

Huckell, L.
2002 Paleoethnobotany. In *Tonto Creek Archaeological Project Artifact and Environmental Analyses. Volume 2: Stone Tool and Subsistence Studies,* edited by Jeffery J. Clark, pp. 643-709. Anthropological Papers No. 23. Center for Desert Archaeology. Tucson.

Miksicek, C.
1994 Deceptive Barrenness: Archaeobotanical Material From the Schuk Toak Project Area. In *Archaeological Studies of the Avra Valley, Arizona: Excavations in the Schuk Toak District. Vol 2. Scientific Studies and Interpretations,* edited by Allen Dart, pp. 243-266. Anthropological Papers No. 16. Center for Desert Archaeology. Tucson.

This page intentionally left blank.

APPENDIX G
RESIDUE AND USE-WEAR ANALYSIS OF STONE ARTIFACTS FROM SITE 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Bruce L. Hardy, Ph.D.
Department of Anthropology
Kenyon, Collage
Gambier, OH 43022

This page intentionally left blank.

RESIDUE AND USE-WEAR ANALYSIS OF STONE ARTIFACTS FROM SITE 41MS69

Bruce L. Hardy, Ph.D.

G.1 INTRODUCTION

A sample of 14 artifacts from 41MS69 was subjected to use-wear and residue analysis in order to investigate tool function. These artifacts are from a short-term Middle Archaic site with cooking features that dates between 4700 and 5400 B.P.

G.2 METHODS

Artifacts were examined under bright-field incident light using an Olympus BH30 microscope (magnification 50-500x). Images were recorded using a Motic 5 digital camera and Motic Images Plus 2.0 software. All residues observed were photographed and their location noted on a line drawing of each artifact. Identification of residues was based on comparison with a large modern reference collection and with published sources (Anderson-Gerfaud 1990; Beyries 1988; Brunner and Coman 1974; Catling and Grayson 1982; Crowther 2009; Hoadley 1990; Fullagar 1991; Teerink 1991; Hather 1993; Hardy 1994; Brom 1986; Kardulias and Yerkes 1996; Williamson 1996; Hardy and Garufi 1998; Pearsall 2000; Haslam 2004; Dove et al. 2005; Fullagar 2006; Genten et al. 2009; Warren 2009; Huffman et al. 2008). Identifiable residue categories include wood, bark, plant fibers, starch grains, calcium oxalate crystals, plant tissue, resin, hair, feathers, fish scales, skin, and bone (Hardy and Moncel 2011). Starch grains can potentially be mistaken for fungal spores or other materials and identification under reflected light is therefore considered preliminary (Haslam 2006; Loy 2006). For all identifications, a suite or related residues (e.g. hair fragments, collagen, bone or plant cells, starch grains, plant fibers) strengthened the confidence of the identification (Lombard and Wadley 2007). Calcium oxalate crystals (raphides) can be mistaken for rod-shaped calcite crystals (Crowther 2009). Treatment of putative raphides with acetic acid is necessary to confirm their identification.

Use-wear analysis to identify the relative hardness of the use-material and the use-action included the identification of striations, edge rounding and microflake scars (Odell and Odell- Vereecken 1980; Mansur-Franchomme 1986). Due to the potential overlap of polishes from different worked materials, polishes were identified as either “soft” (animal skin, muscle or soft plants) or “hard/high silica” (bone, antler, wood, or plants with high silica content) (Fullagar 1991; Hardy et al. 2001; Hardy 2004; Hardy et al. 2008). Högberg et al. (2009) have described one other category of polish characterized by linear streaks of dull, greasy polish with bright spots that develops during fish processing. Striations and polish on the proximal 1/3 to ½ of an artifact are sometimes indicative of hafting (Lombard and Wadley 2007). Residue distribution and co-occurrence of wear patterns were used to help determine if residues were use-related.

G.3 RESULTS

Ten of fourteen artifacts showed either use-wear patterns or residues that suggested they were used in the past. Residues are relatively rare on these artifacts, possibly because a number of the artifacts were washed. In some cases, therefore, it is only possible to determine which part of a tool was used and the broad category of material worked. See Figure G-1 for a visual summary of results and Table G-1 for assemblage summary.

G.3.1 Bifaces and Points

The sample includes 3 bifaces (or biface fragments) and one partial point. The partial point (#33-10) shows no signs of use and may have broken during manufacture. A distal biface fragment (#31-10) has hard/high silica polish over most of its surface indicating cutting of a hard or high silica material. A large, rough biface (#38-10) shows soft polish, hair fragments, and collagen concentrated in the same area. This may indicate use on hide or during butchery activities. Finally, a trapezoidal biface fragment (#511-10) shows hard/high silica polish along with bark and wood fragments suggesting use in wood working (Figure G-2).

G.3.2 Edge-modified Flakes

The remaining 10 artifacts are edge-modified flakes. Three of these show no signs of use. Of the remaining, two have hard high silica polish and plant remains. The plant remains are not diagnostic and cannot be identified more specifically. Three lack residues and can only be classified as used on hard or soft material. The two remaining flakes have soft polish associated with hair and/or collagen fragments and are thus interpreted as hide working or butchery tools (Figure G-3).

G.4 DISCUSSION AND CONCLUSIONS

Despite the fact that many of these artifacts have been washed, some functional evidence was preserved. Traces indicating woodworking, non-specific plant processing, and hide working or butchery tasks were observed. Several pieces were used but specific materials could not be identified.

G.5 REFERENCES CITED

Anderson-Gerfaud, P.
1990 Aspects of behavior in the Middle Paleolithic: Functional analysis of stone tools from southwest France. In: *The Emergence of Modern Humans: An Archaeological Perspective*, edited by P. Mellars, pp. 389-418. Cornell University Press, Ithaca.

Beyries, S.
1988 *Industries Lithiques: Traçeologie et Technologie*. British Archaeological Reports International Series, London.

Brom, T.
1986 Microscopic identification of feathers and feather fragments of palearctic birds. *Bijdragen Tot De Dierkunde* 56:181-204.

Brunner, H. and B. J. Coman
1974 The Identification of Mammalian Hair. Inkata Press, Melbourne.

Catling, D. and J. Grayson
1982 *Identification of Vegetable Fibres*. Chapman and Hall, New York.

Chandler, A. C.
1916 A study of feathers, with reference to their taxonomic significance. University of California, *Publication Zoology* 13:243-446.

Crowther, A.
2009 Morphometric analysis of calcium oxalate raphides and assessment of their taxonomic value for archaeological microfossil studies. *Archaeological Science under a Microscope [Electronic Resource]: Studies in Residue and Ancient DNA Analysis* in Honour of Thomas H. Loy, edited by Michael Haslam [et al.]. Terra Australis 30:102-128.

Dickson, W. C.
2000 *Integrative Plant Anatomy.* San Diego: Harcourt.

Dove, C. J., P. G. Hare and M. Heacker
2005 Identification of ancient feather fragments found in melting alpine ice patches in southern Yukon. *Arctic* 58:38-43.

Fullagar, R.
1991 The role of silica in polish formation. *Journal of Archaeological Science* 18:1-24.

2006 Starch on Artifacts. In *Ancient Starch Research*, edited by R. Torrence and H. Barton, pp. 177-204. Walnut Creek: Left Coast Press.

Genten, F., E. Terwinghe and A. Danguy
2009 *Atlas of Fish Histology*. Enfield, New Hampshire: Science Publishers.

Hardy, B. L.
1994 Investigations of stone tool function through use-wear, residue and DNA analyses at the Middle Paleolithic site of La Quina, France. Unpublished Ph.D. dissertation, Indiana University.

2004 Neanderthal behaviour and stone tool function at the Middle Paleolithic site of La Quina, France. *Antiquity* 78:547-565.

Hardy, B. L. and G. T. Garufi
1998 Identification of woodworking on stone tools through residue and use-wear analyses: Experimental results. *Journal of Archaeological Science* 25:177-184.

Hardy, B. L., M. Kay, A. E. Marks, and K. Monigal
2001 Stone tool function at the Paleolithic sites of Starosele and Buran Kaya III, Crimea: Behavioral implications. Proceedings of the National Academy of Sciences, U.S.A. 98:10972-10977.

Hardy, B. L. and M. H. Moncel
2011 Neanderthal use of fish, mammals, birds, starchy plants and wood 125-250,000 Years Ago. *PloS One*, 6(8), e23768.

Hardy, B. L., M. Bolus, and N. J. Conard
2008 Hammer or crescent wrench? Stone-tool form and function in the Aurignacian of southwest Germany. *Journal of Human Evolution* 54: 648-662.

Haslam, M.
2004 The decomposition of starch grains in soils: Implications for archaeological residue analyses. *Journal of Archaeological Science* 31:1715-1734.

2006 Potential misidentification of in situ archaeological tool-residues: starch and conidia. *Journal of Archaeological Science* 33:114-121.

Hather, J.
1993 *An Archaeobotanical Guide to Root and Tuber Identification*, Vol. I: Europe and South West Asia. Oxbow Books, Oxford.

Hoadley, R.
1990 Identifying Wood: Accurate Results with Simple Tools. Taunton Press, Newtown.

Huffman, D., L. Tiffany, G. Knaphus, and R. Healy
2008 Mushrooms and Other Fungi of Midcontinental United States. Iowa City: University of Iowa.

Kardulias, N. and R. Yerkes
1996 Microwear and metric analysis of threshing sledge flints from Greece and Cyprus. *Journal of Archaeological Science* 23:657-666.

Lombard, M.
2007 The gripping nature of ochre: the association of ochre with Howiesons Poort adhesives and Later Stone Age mastics from South Africa. *Journal of Human Evolution* 53(4):406-419.

Lombard, M. and L. Wadley

2007 The morphological identification of micro-residues on stone tools using light microscopy: progress and difficulties based on blind tests. *Journal of Archaeological Science* 34:155-165.

Loy, T.

2006 Optical properties of potential look-alikes. In *Ancient Starch Research*, edited by R. Torrence, and H. Barton, p. 123. Walnut Creek, California, Left Coast Press.

Mansur-Franchomme, M. E.

1986 Microscopie du Matériel Lithique Préhistorique: Traces d'Utilisation, Altération Naturelles, Accidentelles, et Technologiques. National Centre for Scientific Research, Paris.

Odell, G. and F. Odell-Vereecken

1980 Verifying the reliability of lithic usewear assessments by ''blind tests'': The low-power approach. *Journal of Archaeological Science* 7:87-120.

Pearsall, D.

2000 *Paleoethnobotany: A Handbook of Procedures*. Second edition, Academic Press, New York.

Schultz, J. M.

1992 The use-wear generated by processing bison hides. *The Plains Anthropologist* 37(141):333-351.

Teerink, B. J.

1991 Hair of West European Mammals: Atlas and Identification Key. Cambridge University Press, Cambridge.

Williamson, B. S.

1996 Preliminary stone tool residue analysis from Rose Cottage Cave. South Africa. *Journal of Field Archaeology* 5:36-44.

Warren, R.

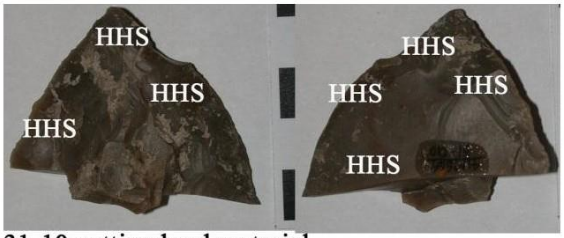
2009 The potential role of fish in the diet of Neanderthals. Unpublished senior honors thesis. Kenyon College, Gambier, Ohio.

Table G-1. Results of Use-wear and Residue Analysis.

Cat. No.	Type	Residue	Use-wear	Function
31-10	Biface	-----	Hard/high silica polish	Cutting hard material
33-10	Point	-----	-----	Unknown/unused
36-10	Edge-modified Flake	-----	Hard/high silica polish	Cutting hard material
37-10	Edge-modified Flake	Plant tissue	Edge damage, striae, hard/high silica polish	Whittling hard plant
38-10	Biface	Hair, collagen	Soft polish	Cutting hide/butchery
38-11	Edge-modified Flake	-----	-----	Unknown/unused
41-10	Edge-modified Flake	-----	Edge damage, soft polish	Cutting soft material
41-11	Edge-modified Flake	-----	-----	Unknown/unused
42-11	Edge-modified Flake	Hair, collagen	Striated polish	Cutting hide/butchery
42-12	Edge-modified Flake	Hair, collagen	Soft polish, edge damage	Cutting hide/butchery
47-10	Edge-modified Flake	-----	Soft polish	Cutting soft material
47-11	Edge-modified Flake	-----	-----	Unknown/unused
47-12	Edge-modified Flake	Plant tissue	Hard/high silica polish	Cutting hard/high silica plant
511-10	Biface	Wood, bark	Hard/high silica polish	Cutting wood

Table G-2. Key for Visual Summary Figures.

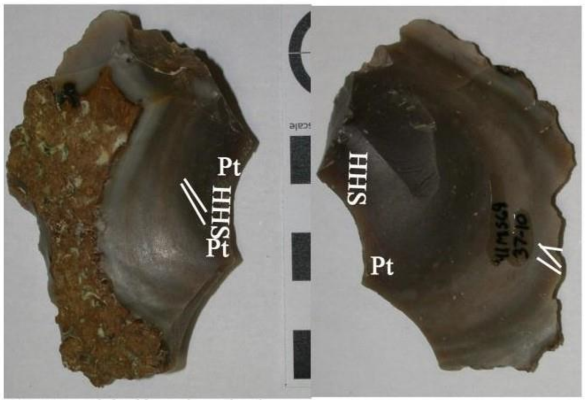
HHS	Hard/high silica polish
Sf	Soft polish
Parallel lines	Striae (oriented as on artifact)
Co	Collagen
Bk	Bark
Hr	Hair
Pt	Plant tissue
Wd	Wood



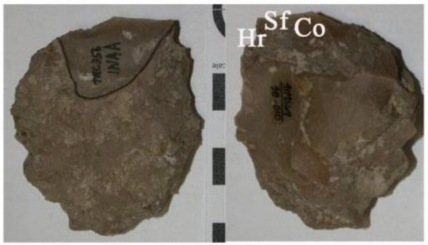
31-10 cutting hard material

33-10 unknown/unused

36-10 cutting hard material



37-10 whittling hard plant



38-10 cutting hide/butchery

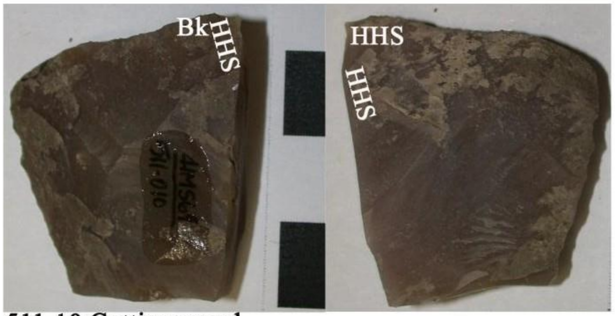
38-11 unknown/unused

41-10 cutting soft

41-11 unknown/unused

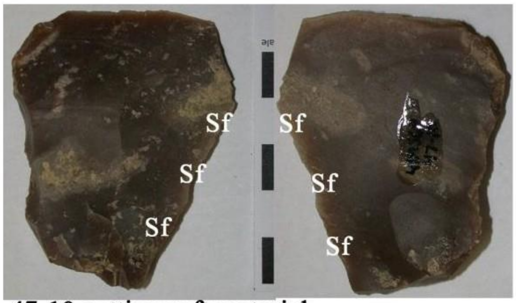
Figure G - 1. Visual summary of results.

42-12 cutting hide/butchery



511-10 Cutting wood

47-11 unknown/unused



47-10 cutting soft material

47-12 cutting hard plant

Figure G-1. Visual summary of results (continued).

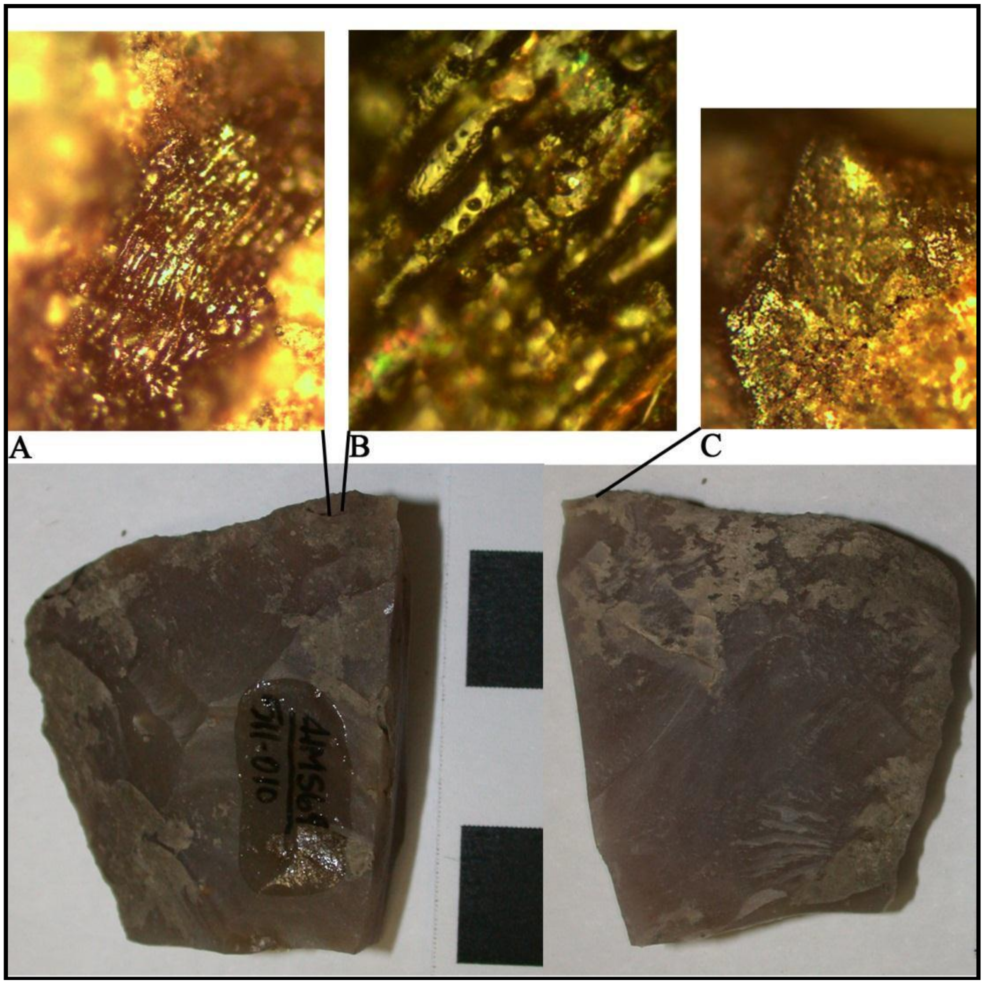


Figure G-2. 511-10, biface fragment, A) fragment of bark (original magnification 100x); B) close-up of bark cells (orig. mag. 500x); C) hard/high silica polish (orig. mag. 100x).

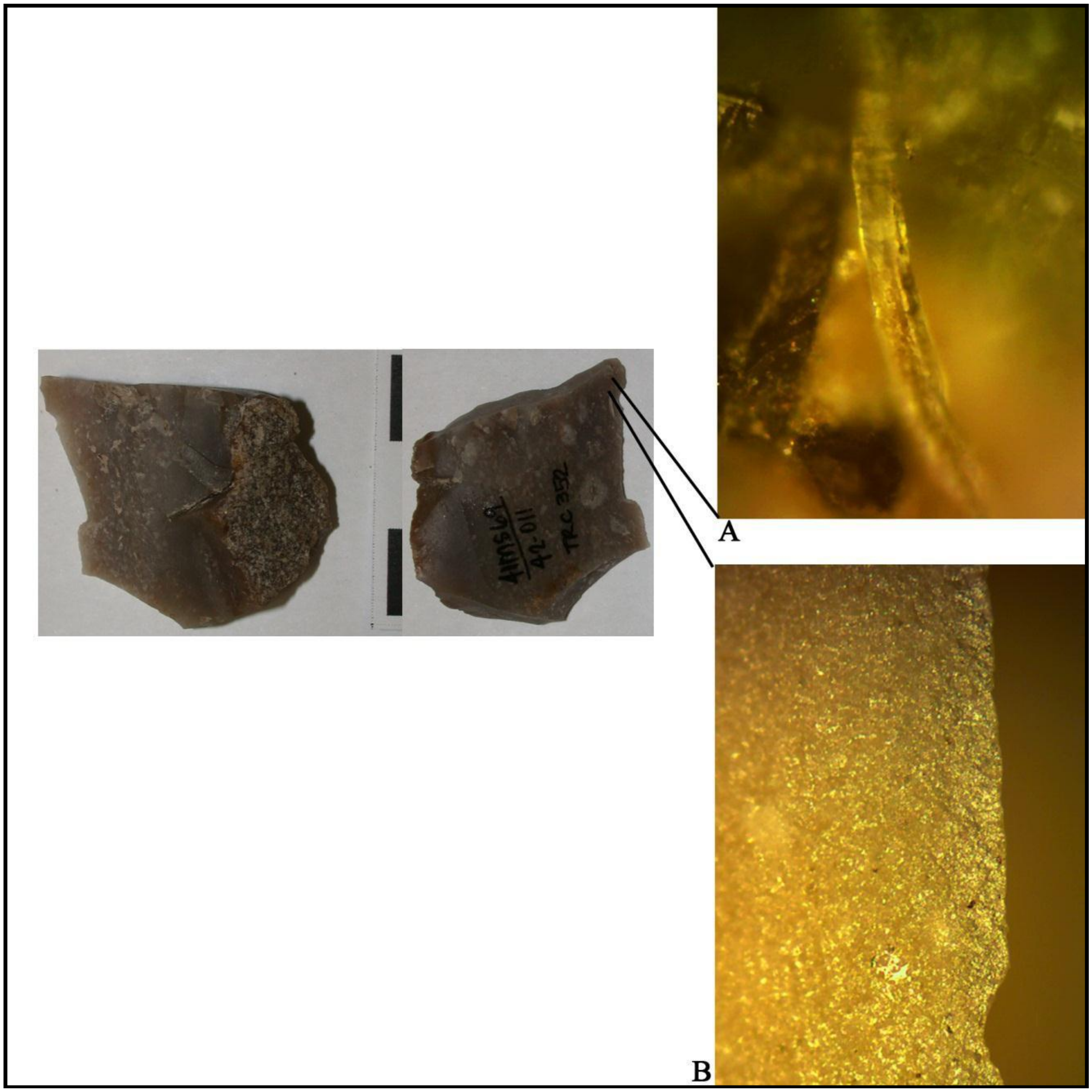


Figure G-3. 42-12. A) hair with medulla; B) soft polish and edge damage.

This page intentionally left blank.

APPENDIX H
ANALYSIS OF THE FATTY ACID COMPOSITIONS OF ARCHAEOLOGICAL BURNED ROCK RESIDUES FROM SITE 41MS69, MASON COUNTY, CENTRAL TEXAS

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

M. E. Malainey, Ph.D. and Timothy Figol
Department of Anthropology
Brandon University
Brandon, MB
Canada R7A 6A9

This page intentionally left blank.

ANALYSIS OF THE FATTY ACID COMPOSITIONS OF ARCHEOLOGICAL BURNED ROCK RESIDUES FROM SITE 41MS69, MASON COUNTY, CENTRAL TEXAS

Marry E. Malainey, Ph.D. and Timothy Figol

H.1 INTRODUCTION

A total of 17 fragments of burned rock were submitted for analysis; where necessary, subsamples were taken. Exterior surfaces were ground off to remove any contaminants and samples were crushed. Absorbed lipid residues were extracted with organic solvents. Fatty acid components of the lipid extracts were analyzed using gas chromatography. Residues were identified using criteria developed from the decomposition patterns of experimental residues. The first section of this report outlines the development of the identification criteria. Following this, analytical procedures and results are presented.

H.2 FATTY ACIDS AND DEVELOPMENT OF THE IDENTIFICATION CRITERIA

H.2.1 Introduction and Previous Research

Fatty acids are the major constituents of fats and oils (lipids) and occur in nature as triglycerides, consisting of three fatty acids attached to a glycerol molecule by ester-linkages. The shorthand convention for designating fatty acids, Cx:yz, contains three components. The "Cx" refers to a fatty acid with a carbon chain length of x number of atoms. The "y" represents the number of double bonds or points of unsaturation, and the "z" indicates the location of the most distal double bond on the carbon chain, i.e. closest to the methyl end. Thus, the fatty acid expressed as C18:19, refers to a mono-unsaturated isomer with a chain length of 18 carbon atoms with a single double bond located nine carbons from the methyl end of the chain. Similarly, the shorthand designation, C16:0, refers to a saturated fatty acid with a chain length of 16 carbons.

Their insolubility in water and relative abundance compared to other classes of lipids, such as sterols and waxes, make fatty acids suitable for residue analysis. Since employed by Condamin et al. (1976), gas chromatography has been used extensively to analyze the fatty acid component of absorbed archaeological residues. The composition of uncooked plants and animals provides important baseline information, but it is not possible to directly compare modern uncooked plants and animals with highly degraded archaeological residues. Unsaturated fatty acids, which are found widely in fish and plants, decompose more readily than saturated fatty acids, sterols or waxes. In the course of decomposition, simple addition reactions might occur at points of unsaturation (Solomons 1980) or peroxidation might lead to the formation of a variety of volatile and non-volatile products which continue to degrade (Frankel 1991). Peroxidation occurs most readily in fatty acids with more than one point of unsaturation.

Attempts have been made to identify archaeological residues using criteria that discriminate uncooked foods (Marchbanks 1989; Skibo 1992; Loy 1994). Marchbanks' (1989) percent of saturated fatty acids (%S) criteria has been applied to residues from a variety of materials including pottery, stone tools and burned rocks (Marchbanks 1989; Marchbanks and Quigg 1990; Collins et al. 1990). Skibo (1992:89) could not apply the %S technique and instead used two ratios of fatty acids, C18:0/C16:0 and C18:1/C16:0. He (1992) reported that it was possible to link the uncooked foods with residues extracted from modern cooking pots actively used to prepare one type of food; however, the ratios could not identify food mixtures. The utility of these ratios did not extend to residues extracted from archaeological potsherds because the ratios of the major fatty acids in the residue changed with decomposition (Skibo 1992:97). Loy (1994) proposed the use of a Saturation Index (SI), determined by the ratio: SI = 1-[(C18:1+C18:2)/C12:0+C14:0+C16:0+C18:0)]. He (1994) admitted, however, that poorly understood decompositional changes to the original suite of fatty acids make it difficult to develop criteria for distinguishing animal and plant fatty acid profiles in archaeological residues.

The major drawback of the distinguishing ratios proposed by Marchbanks (1989), Skibo (1992) and Loy (1994) is they have never been empirically tested. The proposed ratios are based on criteria that discriminate food classes on the basis of their original fatty acid composition. The resistance of these criteria to the effects of decompositional changes has not been demonstrated. Rather, Skibo (1992) found his fatty acid ratio criteria could not be used to identify highly decomposed archaeological samples.

In order to identify a fatty acid ratio unaffected by degradation processes, Patrick et al. (1985) simulated the long-term decomposition of one sample and monitored the resulting changes. An experimental cooking residue of seal was prepared and degraded in order to identify a stable fatty acid ratio. Patrick et al. (1985) found that the ratio of two C18:1 isomers, oleic and vaccenic, did not change with decomposition; this fatty acid ratio was then used to identify an archaeological vessel residue as seal. While the fatty acid composition of uncooked foods must be known, Patrick et al. (1985) showed that the effects of cooking and decomposition over long periods of time on the fatty acids must also be understood.

H.2.2 Development of the Identification Criteria

As the first stage in developing the identification criteria used herein, the fatty acid compositions of more than 130 uncooked Native food plants and animals from Western Canada were determined using gas chromatography (Malainey 1997; Malainey et al. 1999a). When the fatty acid compositions of modern food plants and animals were subject to cluster and principal component analyses, the resultant groupings generally corresponded to divisions that exist in nature (Table H-1). Clear differences in the fatty acid composition of large mammal fat, large herbivore meat, fish, plant roots, greens and berries/seeds/nuts were detected, but the fatty acid composition of meat from medium-sized mammals resembles berries/seeds/nuts.

Samples in cluster A, the large mammal and fish cluster had elevated levels of C16:0 and C18:1 (Table H-1). Divisions within this cluster stemmed from the very high level of C18:1 isomers in fat, high levels of C18:0 in bison and deer meat and high levels of very long chain unsaturated fatty acids (VLCU) in fish. Differences in the fatty acid composition of plant roots, greens and berries/seeds/nuts reflect the amounts of C18:2 and C18:33 present. The berry, seed, nut and small mammal meat samples appearing in cluster B have very high levels of C18:2, ranging from 35% to 64% (Table H-1). Samples in subclusters V, VI and VII have levels of C18:1 isomers from 29% to 51%, as well. Plant roots, plant greens and some berries appear in cluster C. All cluster C samples have moderately high levels of C18:2; except for the berries in subcluster XII, levels of C16:0 are also elevated. Higher levels of C18:33 and/or very long chain saturated fatty acids (VLCS) are also common except in the roots which form subcluster XV.

Secondly, the effects of cooking and degradation over time on fatty acid compositions were examined. Originally, 19 modern residues of plants and animals from the plains, parkland and forests of Western Canada were prepared by cooking samples of meats, fish and plants, alone or combined, in replica vessels over an open fire (Malainey 1997; Malainey et al. 1999b). After four days at room temperature, the vessels were broken and a set of sherds analysed to determine changes after a short term of decomposition. A second set of sherds remained at room temperature for 80 days, then placed in an oven at 75C for a period of 30 days in order to simulate the processes of long term decomposition. The relative percentages were calculated on the basis of the ten fatty acids (C12:0, C14:0, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1w9, C18:1w11, C18:2) that regularly appeared in Precontact Period vessel residues from Western Canada. Observed changes in fatty acid composition of the experimental cooking residues enabled the development of a method for identifying the archaeological residues (Table H-2).

It was determined that levels of medium chain fatty acids (C12:0, C14:0 and C15:0), C18:0 and C18:1 isomers in the sample could be used to distinguish degraded experimental cooking residues (Malainey 1997; Malainey et al. 1999b). These fatty acids are suitable for the identification criteria because saturated fatty acids are stable and the mono-unsaturated fatty acid degrades very slowly, as compared to polyunsaturated fatty acids (deMan 1992). Higher levels of medium chain fatty acids, combined with low levels of C18:0 and C18:1 isomers, were detected in the decomposed experimental residues of plants, such as roots, greens and most berries. High levels of C18:0 indicated the presence of large herbivores. Moderate levels of C18:1 isomers, with low levels of C18:0, indicated the presence of either fish or foods similar in composition to corn. High levels of C18:1 isomers with low levels of C18:0, were found in residues of beaver or foods of similar fatty acid composition. The criteria for identifying six types of residues were established experimentally; the seventh type, plant with large herbivore, was inferred (Table H-2). These criteria were applied to residues extracted from more than 200 pottery cooking vessels from 18 Western Canadian sites (Malainey 1997; Malainey et al. 1999c; 2001b). The identifications were found to be consistent with the evidence from faunal and tool assemblages for each site.

Work has continued to understand the decomposition patterns of various foods and food combinations (Malainey et al. 2000a, 2000b, 2000c, 2001a; Quigg et al. 2001). The collection of modern foods has expanded to include plants from the Southern Plains. The fatty acid compositions of mesquite beans (*Prosopis glandulosa*), Texas ebony seeds (*Pithecellobium ebano Berlandier*), tasajillo berry (*Opuntia leptocaulis*), prickly pear fruit and pads (*Opuntia engelmannii*), Spanish dagger pods (*Yucca treculeana*), cooked sotol (*Dasylirion wheeler*), agave (*Agave lechuguilla*), cholla (*Opuntia imbricata*), piñon (*Pinus edulis*) and Texas mountain laurel (or mescal) seed (*Sophora secundiflora*) have been determined. Experimental residues of many of these plants, alone or in combination with deer meat, have been prepared by boiling foods in clay cylinders or using sandstone for either stone boiling (Quigg et al. 2000) or as a griddle. In order to accelerate the processes of oxidative degradation that naturally occur at a slow rate with the passage of time, the rock or clay tile containing the experimental residue was placed in an oven at 75C. After either 30 or 68 days, residues were extracted and analysed using gas chromatography.

The results of these decomposition studies enabled refinement of the identification criteria.

H.3 METHODOLOGY

Descriptions of the samples are presented in Table H-3. Possible contaminants were removed by grinding off the exterior surfaces with a Dremel® tool fitted with a silicon carbide bit. Immediately thereafter, the sample was crushed with a hammer mortar and pestle and the powder transferred to an Erlenmeyer flask. Lipids were extracted using a variation of the method developed by Folch et al. (1957). The powdered sample was mixed with a 2:1 mixture, by volume, of chloroform and methanol (2 X 25 mL) using ultrasonication (2 X 10 min). Solids were removed by filtering the solvent mixture into a separatory funnel. The lipid/solvent filtrate was washed with 13.3 mL of ultrapure water. Once separation into two phases was complete, the lower chloroform-lipid phase was transferred to a round-bottomed flask and the chloroform removed by rotary evaporation. Any remaining water was removed by evaporation with benzene (1.5 mL); 1.5 mL of chloroform-methanol (2:1, v/v) was used to transfer the dry total lipid extract to a screw-top glass vial with a Teflon®-lined cap. The sample was flushed with nitrogen and stored in a -20C freezer.

A 400 L aliquot of the total lipid extract solution was placed in a screw-top test tube and dried in a heating block under nitrogen. Fatty acid methyl esters (FAMES) were prepared by treating the dry lipid with 5 mL of 0.5 N anhydrous hydrochloric acid in methanol (68°C; 60 min). Fatty acids that occur in the sample as di- or triglycerides are detached from the glycerol molecule and converted to methyl esters. After cooling to room temperature, 3.4 mL of ultrapure water was added. FAMES were recovered with petroleum ether (2.5 mL) and transferred to a vial. The solvent was removed by heat under a gentle stream of nitrogen; the FAMES were dissolved in 75 µL of *iso*-octane then transferred to a GC vial with a conical glass insert.

Solvents and chemicals were checked for purity by running a sample blank. The entire lipid extraction and methyl esterification process was performed and FAMES were dissolved in 75 L of *iso*-octane. Traces of contamination were subtracted from sample chromatograms. The relative percentage composition was calculated by dividing the integrated peak area of each fatty acid by the total area of fatty acids present in the sample.

The step in the extraction procedure where the chloroform, methanol and lipid mixture is washed with water is standard procedure for the extraction of lipids from modern samples. Following Evershed et al. (1990), who reported that this step was unnecessary for the analysis of archaeological residues, previously the solvent-lipid mixture was not washed. This step was recently adopted to remove impurities so that clearer chromatograms could be obtained in the region where very long chain fatty acids (C20:0, C20:1, C22:0 and C24:0) occur. It was anticipated that the detection and accurate assessment of these fatty acids could be instrumental in separating residues of animal origin from those of plant (Malainey *et al.* 2000a, 2000b, 2000c, 2001a).

In order to identify the residue, the relative percentage composition was determined first with respect to all fatty acids present in the sample (including very long chain fatty acids) (see Table H-4) and secondly with respect to the ten fatty acids utilized in the development of the identification criteria (C12:0, C14:0, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1w9, C18:1w11 and C18:2) (not shown). The second step is necessary for the application of the identification criteria presented in Table H-2.

It must be understood that the identifications given do not necessarily mean that those particular foods were actually prepared because different foods of similar fatty acid composition and lipid content would produce similar residues. It is possible only to say that the material of origin for the residue was similar in composition to the food(s) indicated.

H.3.1 Gas Chromatography Analysis Parameters

The GC analysis was performed on a Varian 3800 gas chromatograph fitted with a flame ionization detector connected to a personal computer. Samples were separated using a DB-23 fused silica capillary column (30 m X 0.25 mm I.D.; J&W Scientific; Folsom, CA). An autosampler injected a 3 L sample using a split/splitless injection system. Hydrogen was used as the carrier gas with a column flow of 1.0 mL/min. Column temperature was held at 80ºC for 1 minute then increased to 140ºC at a rate of 20 ºC per minute. It was then programmed from 140 to 230ºC at 4ºC per minute. The upper temperature was held for 17 minutes. Chromatogram peaks were integrated using Varian MS Workstation® software and identified through comparisons with external qualitative standards (NuCheck Prep; Elysian, MN).

H.4 RESULTS OF ARCHAEOLOGICAL DATA ANALYSIS

The fatty acid compositions of residues extracted from 12 samples are presented in Table H-4. The term, Area, represents the area under the chromatographic peak of a given fatty acid, as calculated by the Varian MS Workstation ® software minus the solvent blank. The term, Rel%, represents the relative percentage of the fatty acid with respect to the total fatty acids in the sample. Hydroxide or peroxide degradation products can interfere with the integration of the C22:0 and C22:1 peaks; these fatty acids were excluded from the analysis. Insufficient fatty acids were recovered from five residues to attempt identification: residues 7MQ 35 (#4-003-2a), 7MQ 36 (#505-003-1a), 7MQ 37 (#505-003-2a), 7MQ41 (#508-003-2a) and 7MQ 44 (#514-003-1a).

Levels of C18:1 isomers in three residues, 7MQ 34 (#4-003-1a), 7MQ 42 (#508-003-3a) and 7MQ 43 (#510-003-2a), are very high, ranging from 51.85% to 57.54%. The levels of C18:1 isomers in two other residues, 7MQ 39 (#505-003-4a) and 7MQ 46 (#514-003-4a) are slightly lower, 49.01% and 50.29%; these two fall on the border between high and very high fat content. These levels are observed in the decomposed residues of foods of very high fat content seeds or nuts, such as piñon. Rendered fats of certain mammals (other than large herbivores) exhibit similarly very high levels of C18:1 isomers, but only when fresh. These residues also have elevated or slightly elevated levels of medium chain fatty acids and C18:2, suggesting they represent residues of plants. Residues 7MQ 34 and 7MQ 46 are unusual in that their levels of C16:0 are very low for decomposed food residues; one would expect the levels of C16:0 to be much closer to 20%. For this reason, the hypothesis that these residues are of cultural origin should be tested using an independent line of evidence, such as radiocarbon dating.

Levels of C18:1 isomers in four residues, 7MQ 38 (#505-003-3a), 7MQ 40 (#508-003-1a), 7MQ 45 (#514-003-3a) and 7MQ 48 (#514-003-6a), are high, ranging from 43.57% to 46.78%. These levels are observed in the decomposed residues of high fat content seeds or nuts. Rendered fats of certain mammals (other than large herbivores) exhibit high levels of C18:1 isomers. Residues 7MQ 40 and 7MQ 45 are probably of plant origin because their medium chain fatty acid levels are above 10%. At almost 10%, the level of C18:0 in residue 7MQ 48 is significantly higher than the other three high fat content residues, which may indicate traces of animal products. The origin of residue 7MQ 38 is ambiguous.

One residue, 7MQ 50 (#515-003-4a), has a moderately-high level of C18:1 isomers, 32.89%. Foods known to produce similar residues include Texas ebony seeds and the fatty meat of medium-sized mammals, such as beaver. The level of C18:1 isomers in two other residues, 7MQ 47 (#514-003-5a) and 7MQ 49 (#515-003-1a), fall on the border between moderately-high and high fat content. The level of C18:0 in residue 7MQ 47 is similar to that observed in residue 7MQ 48, about 10%. The levels in residues 7MQ 49 and 7MQ 50 are both about 20%. Residues 7MQ 49 and 7MQ 50 may be of animal origin or represent plant and animal combinations; traces of animal products may also be present in residue 7MQ 47.

The fatty acid, C17:1, appears at levels between about 2.5 and 4.7% in most residues; but it approaches 7% in residue 7MQ 46. It most likely represents an environmental contaminant; its presence or absence does not affect the residue characterizations given.

H.5 REFERENCES CITED

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 Archaeology 6. Texas Archaeological Research Laboratory, The University of Texas at Austin.

Condamin, J., F. Formenti, M. O. Metais, M. Michel, and P. Blond
1976 The Application of Gas Chromatography to the Tracing of Oil in Ancient Amphorae. *Archaeometry* 18(2):195-201.

deMan, J. M.
1992 Chemical and Physical Properties of Fatty Acids. In *Fatty Acids in Foods and their Health Implications*, edited by C. K. Chow, pp. 17-39. Marcel Dekker, New York.

Evershed, R. P., C. Heron and L. J. Goad
1990 Analysis of Organic Residues of Archaeological Origin by High Temperature Gas Chromatography and Gas Chromatography-Mass Spectroscopy. *Analyst* 115:1339-1342.

Folch, J., M. Lees and G. H. Sloane-Stanley
1957 A simple method for the isolation and purification of lipid extracts from brain tissue. *Journal of Biological Chemistry* 191:833.

Frankel, E. N.
1991 Recent Advances in Lipid Oxidation. *Journal of the Science of Food and Agriculture* 54:465-511.

Loy, T.
1994 Residue Analysis of Artifacts and Burned Rock from the Mustang Branch and Barton Sites (41HY209 and 41HY202). In: *Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas. Volume 2: Topical Studies*, by R. A. Ricklis and M. B. Collins, pp. 607- 627. Studies in Archeology 19, Texas Archaeological Research Laboratory, The University of Texas at Austin.

Malainey, M. E.
1997 The Reconstruction and Testing of Subsistence and Settlement Strategies for the Plains, Parkland and Southern boreal forest. Unpublished Ph.D. thesis, University of Manitoba.

Malainey, M. E., K. L. Malisza, R. Przybylski and G. Monks
2001a The Key to Identifying Archaeological Fatty Acid Residues. Paper presented at the 34th *Annual Meeting of the Canadian Archaeological Association*, Banff, Alberta, May 2001.

Malainey, M. E., R. Przybylski and B. L. Sherriff
1999a The Fatty Acid Composition of Native Food Plants and Animals of Western Canada. *Journal of Archaeological Science* 26:83-94.

Malainey, M. E., R. Przybylski and B. L. Sherriff

1999b The Effects of Thermal and Oxidative Decomposition on the Fatty Acid Composition of Food Plants and Animals of Western Canada: Implications for the Identification of archaeological vessel residues. *Journal of Archaeological Science* 26:95-103.

1999c Identifying the former contents of Late Precontact Period pottery vessels from Western Canada using gas chromatography. *Journal of Archaeological Science* 26(4):425-438.

2001b One Person's Food: How and Why Fish Avoidance May Affect the Settlement and Subsistence Patterns of Hunter-Gatherers. *American Antiquity* 66(1):141-161.

Malainey, M. E., R. Przybylski and G. Monks

2000a The identification of archaeological residues using gas chromatography and applications to archaeological problems in Canada, United States and Africa. Paper presented at *The 11th Annual Workshops in Archaeometry*, State University of New York at Buffalo, February 2000.

2000b Refining and testing the criteria for identifying archaeological lipid residues using gas chromatography. Paper presented at the *33rd Annual Meeting of the Canadian Archaeological Association*, Ottawa, May 2000.

2000c Developing a General Method for Identifying Archaeological Lipid Residues on the Basis of Fatty Acid Composition. Paper presented at the *Joint Midwest Archaeological & Plains Anthropological Conference*, Minneapolis, Minnesota, November 2000.

Marchbanks, M. L.

1989 Lipid Analysis in Archaeology: An Initial Study of Ceramics and Subsistence at the George C. Davis Site. Unpublished M.A. thesis, The University of Texas at Austin.

Marchbanks, M. L. and J. M. Quigg

1990 Appendix G: Organic Residue and Phytolith Analysis. In: *Phase II Investigations at Prehistoric and Rock Art Sites, Justiceburg Reservoir, Garza and Kent Counties, Texas, Volume II*, by D. K. Boyd, J. T. Abbott, W. A. Bryan, C. M. Garvey, S. A. Tomka and R. C. Fields. pp. 496-519. Reports of Investigations No. 71. Prewitt and Associates, Inc, Austin.

Patrick, M., A. J. de Konig and A. B. Smith

1985 Gas Liquid Chromatographic Analysis of Fatty Acids in Food Residues from Ceramics Found in the Southwestern Cape, South Africa. *Archaeometry* 27(2):231-236.

Quigg, J. M., C. Lintz, S. Smith and S. Wilcox

2000 *The Lino Site: A Stratified Late Archaic Campsite in a Terrace of the San Idelfonzo Creek, Webb County, Southern Texas*. Technical Report No. 23765, TRC Mariah Associates Inc., Austin. Texas Department of Transportation, Environmental Affairs Division, Archaeological Studies Program Report 20, Austin.

Quigg, J. M., M. E. Malainey, R. Przybylski and G. Monks

2001 No bones about it: using lipid analysis of burned rock and groundstone residues to examine Late Archaic subsistence practices in South Texas. *Plains Anthropologist* 46(177):283-303.

Skibo, J. M.

1992 Pottery Function: A Use-Alteration

Perspective. Plenum Press, New York.

Solomons, T. W. G.

1980 *Organic Chemistry*. John Wiley & Sons, Toronto.

Table H-1. **Summary of Average Fatty Acid Compositions of Modern Food Groups Generated by Hierarchical Cluster Analysis.**

Cluster	**A**				**B**							**C**			
Subcluster	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**XIII**	**XIV**	**XV**
Type	Mammal Fat and Marrow	Large Herbivore Meat	Fish	Fish	Berries and Nuts	Mixed	Seeds and Berries	Roots	Seeds	Mixed	Greens	Berries	Roots	Greens	Roots
C16:0	19.90	19.39	16.07	14.10	3.75	12.06	7.48	19.98	7.52	10.33	18.71	3.47	22.68	24.19	18.71
C18:0	7.06	20.35	3.87	2.78	1.47	2.36	2.58	2.59	3.55	2.43	2.48	1.34	3.15	3.66	5.94
C18:1	56.77	35.79	18.28	31.96	51.14	35.29	29.12	6.55	10.02	15.62	5.03	14.95	12.12	4.05	3.34
C18:2	7.01	8.93	2.91	4.04	41.44	35.83	54.69	48.74	64.14	39.24	18.82	29.08	26.24	16.15	15.61
C18:3	0.68	2.61	4.39	3.83	1.05	3.66	1.51	7.24	5.49	19.77	35.08	39.75	9.64	17.88	3.42
VLCS	0.16	0.32	0.23	0.15	0.76	4.46	2.98	8.50	5.19	3.73	6.77	9.10	15.32	18.68	43.36
VLCU	0.77	4.29	39.92	24.11	0.25	2.70	1.00	2.23	0.99	2.65	1.13	0.95	2.06	0.72	1.10

VLCS - Very Long Chain (C20, C22 and C24) Saturated Fatty Acids
VLCU - Very Long Chain (C20, C22 and C24) Unsaturated Fatty Acids

Table H-2. Criteria for the Identification of Archeological Residues Based on the Decomposition Patterns of Experimental Cooking Residues Prepared in Pottery Vessels.

Identification	Medium Chain	C18:0	C18:1 isomers
Large herbivore	15%	27.5%	15%
Large herbivore with plant OR Bone marrow	low	25%	15% *X* 25%
Plant with large herbivore	15%	25%	no data
Beaver	low	Low	25%
Fish or Corn	low	25%	15% *X* 27.5%
Fish or Corn with Plant	15%	25%	15% *X* 27.5%
Plant (except corn)	10%	27.5%	15%

Table H-3. Known Food Sources for Different Types of Decomposed Residues.

Decomposed Residue Identification	Plant Foods Known to Produce Similar Residues	Animal Foods Known To Produce Similar Residues
Large herbivore	Tropical seed oils, including sotol seeds	Bison, deer, moose, fall-early winter fatty elk meat, Javelina meat
Large herbivore with plant or Bone marrow		
Low Fat Content Plant (Plant greens, roots, berries)	Jicama tuber, buffalo gourd, yopan leaves, biscuit root, millet	Cooked Camel's milk
Medium-Low Fat Content Plant	Prickly pear, Spanish dagger	None
Medium Fat Content (Fish or Corn)	Corn, mesquite beans, cholla	Freshwater fish, *Rabdotus* snail, terrapin, late winter fat-depleted elk
Moderate-High Fat Content (Beaver)	Texas ebony	Beaver and probably raccoon or any other fat medium-sized mammals
High Fat Content	High fat nuts and seeds, including acorn and pecan	Rendered animal fat (other than large herbivore), including bear fat
Very High Fat Content	Very high fat nuts and seeds, including pine nuts	Freshly rendered animal fat (other than large herbivore)

Table H-4. List of 41MS69 Burned Rock Samples Analyzed in 2007.

Lab No.	Catalogue Number	Feature	Provenience; Level (cmbs)	Sample Size (g)
7MQ 34*	4-003-1a		TU 1; 35	31.932
7MQ 35*	4-003-2a	-	TU 1; 37	34.359
7MQ 36	505-003-1a	1	TU 5 Extension; 152	37.914
7MQ 37	505-003-2a	1	TU 5 Extension; 150-160	39.790
7MQ 38	505-003-3a	1	TU 5 Extension; 150-160	28.310
7MQ 39	505-003-4a	1	TU 5 Extension; 150-160	34.982
7MQ 40	508-003-1a	1	TU 6; 140-150	35.210
7MQ 41	508-003-2a	1	TU 6; 140-150	28.956
7MQ 42	508-003-3a	1	TU 6; 140-150	36.437
7MQ 43	510-003-2a	2	TU 5; 163-170	33.598
7MQ 44	514-003-1a	2	TU 6; 167	37.161
7MQ 45	514-003-3a	2	TU 6; 168	39.742
7MQ 46	514-003-4a	2	TU 6; 165	31.504
7MQ 47	514-003-5a	2	TU 6; 163-170	38.274
7MQ 48	514-003-6a	2	TU 6; 172	25.350
7MQ 49	515-003-1a	2	TU 6; 174	35.674
7MQ 50	515-003-4a	2	TU 6; 177	27.291

* Residues not subject to additional analyses in 2014

Table H-5. List of 41MS69 Burned Rock Samples Analyzed in 2014.

Lab No.	PNUM/CAT/EXT	Column	Feature	Sample Size (g)
14MQ 19	0501-003-1a	1	1	32.934
14MQ 20	0507-003-1e	1	1	27.553
14MQ 21	0508-003-4a	1	1	35.636
14MQ 22	0508-003-5a	1	1	39.262
14MQ 23	0512-003-4a	1	2	30.558
14MQ 24	0512-003-5	1	2	30.428
14MQ 25	0512-003-6	1	2	31.026
14MQ 26	0515-003-2a	1	2	26.083

Table H-6. Lipid Compositions and Identifications of Residues from Site 41MS69.

Fatty acid	**7MQ 38, 505-003-3a**		**7MQ 39, 505-003-4a,**		**7MQ 40, 508-003-1a**		**7MQ 42, 508-003-3a**	
	Area	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**
C12:0	0	0.00	3411	0.86	3856	1.02	4308	1.18
C14:0	19125	4.81	27721	7.00	20676	5.48	20186	5.54
C14:1	0	0.00	0	0.00	0	0.00	0	0.00
C15:0	12413	3.12	22796	5.76	16118	4.28	12793	3.51
C16:0	97042	24.39	81558	20.60	109895	29.15	64806	17.80
C16:1	6048	1.52	4466	1.13	0	0.00	3519	0.97
C17:0	1749	0.44	2037	0.51	1534	0.41	1823	0.50
C17:0	15258	3.84	15047	3.80	11295	3.00	11964	3.29
C18:0	25227	6.34	0	0.00	14827	3.93	3005	0.83
C18:1s	186100	46.78	194082	49.01	168174	44.61	209507	57.54
C18:2	25829	6.49	23637	5.97	23409	6.21	26336	7.23
C18:3w3	0	0.00	9954	2.51	0	0.00	0	0.00
C20:0	3640	0.91	0	0.00	1947	0.52	940	0.26
C20:1	3738	0.94	9156	2.31	5228	1.39	4899	1.35
C24:0	1681	0.42	2122	0.54	0	0.00	0	0.00
Total	397850	100.00	395987	100.00	376959	100.00	364086	100.00
Biomarkers	β-sitosterol; possibly Cholesterol; possibly Dehydroabietic acid		Cholesterol; β-sitosterol; possibly Stigmasterol; probably Dehydroabietic acid		Probably β-sitosterol; Probably Cholesterol; probably Dehydroabietic acid		***Probably Cholesterol; Possibly β-sitosterol***	
Triacylglycerols	C48 TAG and traces of others; Plant products dominant		C48 TAG & progressively smaller C50 and C52 TAGs; Plant products dominant		C48 TAG, smaller C50 TAG & traces of others; Plant products dominant		***C48 TAG, smaller C50 TAG and traces of others; Plant products dominant***	
Identification	**High fat content; Plant products dominant, some animal products; Conifer products may occur**		**Borderline High-Very high fat content and Low Fat Content Plant; Plant & animal combination, dominated by plant; Conifer products probably occur**		*High fat content and Low Fat Content Plant; Probable plant and animal combination, dominated by plant; Conifer products probably occur*		**Very high fat content and Low Fat Content Plant; Probable plant and animal combination**	
Catalogue No.	505-003-3a		***505-003-4a***		***508-003-1a***		508-003-3a	

Table H-6. Lipid Compositions and Identifications of Residues from Site 41MS69 (continued).

Fatty acid	**7MQ 43, 510-003-2a**		**7MQ 45, 514-003-3a**		**7MQ 46, 514-003-4a**		**7MQ 47, 514-003-5a**		**7MQ 48,** 514-003-6a	
	Area	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**
C12:0	3492	0.65	17788	2.88	16193	1.13	17796	3.67	0	0.00
C14:0	24493	4.57	44996	7.28	93430	6.51	27713	5.72	16754	5.30
C14:1	0	0.00	0	0.00	0	0.00	3253	0.67	2163	0.68
C15:0	17018	3.17	48712	7.88	105007	7.32	11727	2.42	4090	1.29
C16:0	103784	19.36	132812	21.48	150617	10.50	93271	19.24	64814	20.52
C16:1	2922	0.54	0	0.00	0	0.00	3615	0.75	2242	0.71
C17:0	1076	0.20	9919	1.60	64804	4.52	1730	0.36	1702	0.54
C17:1	13316	2.48	18786	3.04	98722	6.88	22826	4.71	13581	4.30
C18:0	15487	2.89	17488	2.83	46174	3.22	51947	10.71	31090	9.84
C18:1s	303682	56.64	274513	44.40	721654	50.29	188910	38.96	137653	43.57
C18:2	33237	6.20	34395	5.56	100966	7.04	17753	3.66	12247	3.88
C18:3w3	4283	0.80	2718	0.44	0	0.00	0	0.00	2871	0.91
C20:0	2733	0.51	3082	0.50	10140	0.71	11122	2.29	8374	2.65
C20:1	10626	1.98	9402	1.52	5984	0.42	13705	2.83	6201	1.96
C24:0	0	0.00	3634	0.59	21380	1.49	19533	4.03	12132	3.84
Total	536149	100.00	618245	100.00	1435071	100.00	484901	100.00	315914	100.00
Biomarkers	***Probably Cholesterol; Possibly β-sitosterol***		Probably β-sitosterol; possibly Cholesterol; possibly Stigmasterol		Possibly Cholesterol; possibly β-sitosterol		Possibly Cholesterol; possibly β-sitosterol; probably Dehydroabietic acid		***Possibly Cholesterol; possibly β-sitosterol; probably Dehydroabietic acid***	
Triacylglcerols	***C48 TAG & traces of others;*** ***Plant products dominant***		C48 & progressively smaller C50 and C52 TAGs; Plant products dominant		1.2: 1.1: 1.7: 1.0 Plant and Animal combination		Possible C48 TAG Plant products		C48 and C50 TAGs; ***Plant and animal combination***	
Identification	**Very high fat content; plant and animal combination**		**High fat content and Low Fat Content Plant; plant and animal combination dominated by plant**		*Borderline High-Very high fat content and Low Fat Content Plant; plant and animal combination*		**Borderline Moderate high-High fat content and Low Fat Content Plant; plant and animal combination, dominated by plant; conifer products probably present**		**High fat content; plant and animal combination; conifer products probably present**	
Catalogue No.	510-003-2a		***514-003-3a***		***514-003-4a***		514-003-5a		514-003-6a	

Table H-6. Lipid Compositions and Identifications of Residues from Site 41MS69 (continued).

Fatty acid	7MQ 49		7MQ 50		14MQ 19		14MQ 20		14MQ 21	
	Area	Rel%	Area	Rel%	Area	Rel%	Area	Rel%	Area	Rel%
C12:0	3003	0.26	0	0.00	2990	1.37	0	0.00	4341	2.62
C14:0	54963	4.80	22643	4.74	16578	7.62	4425	2.16	9079	5.47
C14:1	7786	0.68	2747	0.57	0	0.00	0	0.00	1850	1.11
C15:0	18513	1.62	6375	1.33	4951	2.27	2265	1.11	3921	2.36
C16:0	239104	20.90	123184	25.77	95872	44.05	76523	37.35	60617	36.53
C16:1	0	0.00	0	0.00	3357	1.54	0	0.00	0	0.00
C17:0	41776	3.65	3551	0.74	6086	2.80	4786	2.34	4757	2.87
C17:1	35812	3.13	17819	3.73	0	0.00	0	0.00	0	0.00
C18:0	234319	20.48	97501	20.39	34653	15.92	68480	33.43	24303	14.65
C18:1s	426605	37.28	157257	32.89	42387	19.47	39296	19.18	50146	30.22
C18:2	45121	3.94	18136	3.79	6057	2.78	4383	2.14	1196	0.72
C18:3w3	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C20:0	11526	1.01	8849	1.85	4734	2.17	4697	2.29	2466	1.49
C20:1	10759	0.94	8823	1.85	0	0.00	0	0.00	3248	1.96
C24:0	15018	1.31	11197	2.34	0	0.00	0	0.00	0	0.00
Total	1144305	100.00	478082	100.00	217665	100.00	204855	100.00	165924	100.00
Biomarkers	***Probably Cholesterol; possibly β-sitosterol; probably Dehydroabietic acid***		Cholesterol; probably β-sitosterol; possibly Stigmasterol; Dehydroabietic acid		Probably Cholesterol; probably Dehydroabietic acid		Possibly Cholesterol; probably Dehydroabietic acid		***Probably Cholesterol; possibly Dehydroabietic acid***	
Triacylglcerols	3.3: 1.6: 1.8: 1.0 Plant and Animal combination, dominated by plant		C48 TAG & progressively smaller C50 & C52 TAGs Plant products dominant		Slight traces of C48:0, C50, C52 and C54 TAGs		C50 TAG & slight traces of others Animal products dominant		Possibly C48 & C54 TAGs Possible Plant and Animal combination	
Identification	**Borderline Moderate high-High fat content** **Plant and animal combination dominated by plant; conifer products probably present**		*Moderate-high fat content* **Plant and animal combination dominated by plant; conifer products present**		**Medium fat content and Low fat content plant; plant and animal combination; conifer products present**		**High C18:0 – Large Herbivore; conifer products probably present**		*Moderate-high fat content and Low fat content plant; plant and animal combination; conifer products may be present*	
Catalogue No.	***515-003-1a***		***515-003-4a***		0501-003-1a		0507-003-1e		***0508-003-4a***	

Table H-6. Lipid Compositions and Identifications of Residues from Site 41MS69 (continued).

Fatty acid	14MQ 22, 508-003-5a		14MQ 23, 512-003-4a		14MQ 24, 512-003-5		14MQ 25, 512-003-6		14MQ 26, 515-003-2a	
	Area	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**	**Area**	**Rel%**
C12:0	3085	1.90	1560	0.56	1028	0.80	2164	1.33	1509	1.44
C14:0	3496	2.15	3850	1.39	4781	3.73	5987	3.69	4473	4.25
C14:1	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C15:0	2919	1.80	3090	1.12	3354	2.62	3150	1.94	2882	2.74
C16:0	72106	44.41	77481	28.03	53496	41.74	67719	41.72	50150	47.69
C16:1	1123	0.69	1309	0.47	0	0.00	2194	1.35	0	0.00
C17:0	4027	2.48	4073	1.47	4352	3.40	4816	2.97	3577	3.40
C17:1	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C18:0	28333	17.45	145318	52.58	20979	16.37	25722	15.85	19693	18.73
C18:1s	44402	27.35	32952	11.92	33416	26.08	42035	25.90	19879	18.90
C18:2	0	0.00	1518	0.55	1391	1.09	1895	1.17	0	0.00
C18:3w3	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
C20:0	1673	1.03	3686	1.33	4115	3.21	4503	2.77	2990	2.84
C20:1	1188	0.73	1542	0.56	1238	0.97	2122	1.31	0	0.00
C24:0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	162352	100.00	276378	100.00	128149	100.00	162307	100.00	105153	100.00
Biomarkers	***Probably Cholesterol; possibly Dehydroabietic acid***		Probably Cholesterol; Dehydroabietic acid		Possibly Cholesterol; possibly Dehydroabietic acid		Possibly Cholesterol; possibly Dehydroabietic acid		***Probably Cholesterol; Dehydroabietic acid***	
Triacylglcerols	Possibly C48 TAG & possibly C50 TAGs Possible Plant and Animal combination		Possibly C48 TAG & possibly C50 TAGs Possible Plant and Animal combination		Possibly C48 TAG & possibly C50 TAGs Possible Plant and Animal combination		Possibly C48 TAG & possibly C50 TAGs Possible Plant and Animal combination		Possibly C48 TAG & probaly C50 TAG Probable Animal and Plant combination, dominated by animal	
Identification	*Borderline Medium and Moderate-high fat content; possible plant and animal combination, dominated by animal; conifer products may be present*		**High C18:0- Large Herbivore; Animal products dominant; conifer products present**		**Medium fat content; possible plant and animal combination; conifer products may be present**		**Medium fat content; possible plant and animal combination, conifer products may be present**		*Medium fat content; animal and plant combination dominated by animal; conifer products present*	
Catalogue No.	0508-003-5a		0512-003-4a		0512-003-5		0512-003-6		***0515-003-2a***	

Table H-7. Biomarker and TAG Distributions of Lipid Residues with Insufficient Fatty Acids.

Lab No./ Cat. No.	Biomarkers Detected	Occurrence of Triacylglycerols (TAGs)	Identification
7MQ 36 **505-003-1a**	Probably Cholesterol; possibly β-sitosterol	C48 TAG & possible traces of others; Plant material dominates	**Plant and animal combination, plant dominant**
7MQ 37 **505-003-2a**	Possibly Cholesterol; Possibly β-sitosterol	C48 TAG & possible traces of others; Plant material dominates	**Plant and Animal material, plant dominant**
7MQ 41 **508-003-2a**	Probably Cholesterol; possibly β-sitosterol; probably Dehydroabietic acid	C48 & possible traces of others; Plant material dominates	**Plant and Animal combination, plant dominant; conifer products probably present**
7MQ 44 **514-003-1a**	Possibly Cholesterol; Dehydroabietic acid	Probably C50 TAG, possibly C48 TAG, & possible traces of others Animal and Plant combination, animal material dominates	**Animal and Plant material, animal dominant; conifer products present**

APPENDIX I
STARCH GRAIN ANALYSIS OF 32 SAMPLES FROM 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

Linda Perry, Ph.D.
Executive Director
The Foundation for Archeobotanical Research in Microfossils
P.O. Box 37
Fairfax, VA 22038

This page intentionally blank.

STARCH GRAIN ANALYSIS OF 32 SAMPLES FROM 41MS69

Linda Perry, Ph.D.

I.1 INTRODUCTION TO STARCH GRAIN ANALYSIS

Archaeobotanical investigators are constantly seeking new methods by which previously unobtainable data can be recovered. Among archaeologists who work in regions characterized by the poor preservation of organic remains, the analyses of starch granules have proven particularly useful in accessing the residues of starchy root and tuber crops that have previously been invisible in the archaeological record (Bryant 2003; Coil et al. 2003; Fullagar et al. 1998; Hall et al. 1989; Iriarté et al. 2004; Loy et al. 1992; Pearsall et al. 2004; Perry 2001, 2002, 2004, 2005, 2007; Perry and Quigg 2011a, 2011b; Perry et al. 2006, 2007, 2010; Piperno and Holst 1998; Piperno et al. 2000). These residues have proven to be tenacious survivors in harsh climates, and their preservation on the surfaces of lithic tools that were used in the processing of starch-bearing plants occurs consistently in archaeobotanical investigations (Iriarté et al. 2004; Pearsall et al. 2004; Perry 2001, 2002, 2004, 2005, 2007, 2010; Perry and Quigg 2011a, 2011b; Perry et al. 2006, 2007; Piperno and Holst 1998; Piperno et al. 2000).

Investigations of the starchy remains of plant foods on the surfaces of archaeological lithic tools began with simple analyses using chemical reagents that identified the residues in question as plant-derived storage starch (Bruier 1976) rather than animal tissue. Within the last fifteen years, however, archaeologists have been successfully employing morphological criteria to identify plant taxa. The methods are almost identical to those used in the analysis of phytolith microfossils.

Just as different plants produce characteristically shaped leaves, flowers, and seeds, different genera and species make starch grains that are distinctive to and diagnostic for each taxon. The anatomical features that distinguish the starch of one species of plant from another have been noted by botanists (e.g., Denniston 1904; MacMasters 1964; Reichert 1913), and their methods have been expanded by archaeobotanists who are now able even to distinguish wild from domesticated species in some plant families (Iriarté et al. 2004; Pearsall et al. 2004; Perry 2001, 2002, 2004; Piperno et al. 2000). Basic physical features that are comparable between modern reference specimens and archaeological samples can be viewed using a light microscope and include gross morphological features such as shape and faceting, the location of and appearance of the hilum, and presence and patterning of lamellae (Iriarté et al. 2004; Loy 1994; Pearsall 2004; Perry 2004; Piperno and Holst 1998; Piperno et al. 2000). Fissuring and other internal patterning have also proven to be useful criteria for identification. The successful identification of starch granules relies upon the viewing of each granule in three dimensions to gain an accurate assessment of its morphological features.

Because starch granules differ morphologically between plants, their distinctive characteristics can often allow identification to the level of genus or species in archaeological samples (e.g., Iriarté et al. 2004; Pearsall et al. 2004; Perry 2001, 2002, 2004, 2005, 2007; Perry et al. 2006, 2007; Piperno and Holst 1998; Piperno et al. 2000). The method has proven particularly useful in identifying the remains of plant tissues that would not usually be preserved as macroremains, such as the remnants of root and tuber crops (Bryant 2003; Coil et al. 2003; Fullagar et al. 1998; Hall et al. 1989; Iriarté et al. 2004; Loy et al. 1992; Pearsall et al. 2004; Perry 2001, 2002, 2004, 2005; Piperno and Holst 1998; Piperno et al. 2000). This role of starch analysis as a tool for revealing the significance of plant foods in the archaeobotanical record also adds to our understanding of the pre-contact significance of starchy seed crops like maize (*Zea mays*).

In a citation of preliminary results from an ongoing study, the archaeological remains of maize starch have been extracted from 2000 year-old obsidian artifacts from the Honduran site of Copán (Haslam 2003, 2004). The starchy residues of maize were also successfully recovered and identified from a migmatite milling stone from Cueva de los Corrales 1 in Argentina (Babot and Apella 2003). In this case, the grinding stone was found to have multiple purposes, including the grinding of burnt bone, presumable for a non-food purpose. Starch analyses of ground stone artifacts from Real Alto have supported previously published phytolith studies that indicate the great antiquity of maize in Ecuador, and its role in subsistence during the Formative period (Pearsall et al. 2004). Seventeen examined artifacts from Real Alto yielded concentrations of maize starch granules ranging from one to more than ten granules per sampled tool. Other Neotropical studies have resulted in the recovery of more complex assemblages of starches.

Archaeologists have recovered starch granules from maize, beans (*Phaseolus* sp.), and *Canna* from the Los Ajos mound complex in Uruguay (Iriarté et al. 2004). Maize starch granules were reported from three ground stone tools including one mano and two milling stone bases. Concentrations of maize starches ranged from two to eleven granules on tools from contexts dating from 3600 years before present to about 500 years before present (Iriarté et al. 2004: supplementary information). The starch data were combined with phytolith evidence and, together, these results introduce compelling evidence for the early development of a mixed subsistence economy in this region of South America. In other regions of the Neotropics, starch analysis has been an essential tool in defining similar subsistence patterns that included the exploitation of root and tuberous food plants.

Starch granules of maize, manioc (*Manihot esculenta*), both wild type and domesticated yams (*Dioscorea* spp.), and arrowroot (*Maranta arundinacea*) have been recovered from edge ground cobbles and grinding stone bases collected from the Aguadulce rock shelter as well as the sites of Monagrillo, La Mula, and Cerro Juan Diaz in Panama (Piperno and Holst 1998; Piperno et al. 2000). Edge ground cobbles are characterized by faceting that is hypothesized to have resulted from the processing of root crops against larger grinding stone bases (Ranere 1975), and the analyses of the residual remains of plant tissues supports this hypothesis. However, the use of the milling stones does appear to have been more complex than previously believed. Maize remains were recovered from all twelve artifacts that bore starch (Piperno et al. 2000). The numbers of starch granules of maize per artifact ranged from one to twenty-five per artifact. Two starch granules of arrowroot occurred on a single artifact, manioc starch granules were recovered from three artifacts (one, five, and eight granules), and yam starch granules were found on the surfaces of three of the artifacts (two, three, and sixteen granules) (Piperno et al. 2000). These investigations resulted in the recovery of the oldest evidence for root and tuber crop cultivation in the Neotropics, with radiocarbon dates spanning from 5,000 to 7,000 years before present.

Starch granules of maize, yams, and arrowroot have also been recovered from twelve flake and three ground stone tools collected from Pozo Azul Norte 1 and Los Mangos del Parguaza in Venezuela (Perry 2001, 2002, 2004, 2005). These sites date from the middle first century AD to contact. As in the above-cited set of studies, maize remains were recovered from every examined artifact and ranged in number from two to fifty-one per artifact. Additionally, four granules of yam starch were recovered from two flake tools, four flake tools yielded four granules of guapo (*Myrosma* sp.) starch, and seven starch granules from arrowroot were collected from five tools, one of which was a ground stone artifact. These findings were significant in that five of the examined artifacts were chosen for study due to their hypothetical function as microlithic grater flakes from a manioc specific grater board. The evidence indicated a more complex function of these tools that did not include the processing of manioc.

More recent investigations have led to the recovery of direct evidence for contact between the highland Peruvian Andes and the lowland tropical forest to the east (Perry et al. 2006). This contact and interaction had been a significant component of Andean theory for decades, but direct evidence had been elusive until starch microfossils of arrowroot were collected from both sediment samples and lithic tools at the mid-elevation site of Waynuna (Perry et al. 2006). Further, the discovery and cataloging of a microfossil will allow for the recovery and understanding of the origins and subsequent dispersals of chili peppers (Perry et al. 2007), plants whose histories are poorly understood due to the lack of preservation of macroremains in the archaeobotanical record. Remains of these plants have been successfully recovered throughout the Americas from ceramic sherds, lithic tools, and sediment samples dating from 6250 BP to European contact.

I.2 UNDERSTANDING THE RELATIONSHIP BETWEEN RESIDUES AND ARTIFACTS

Early work on starch remains from Panamanian sites used stepwise analysis to support the direct association between starchy residues on tools and the tools' use (Piperno et al. 2000). These studies demonstrated that starch grains were not present in sediments adhering to stone tools or on unused parts of the lithics, but they did occur in the cracks and crevices of the tools on used surfaces, thus indicating that the residues were the result of the tools' use and not environmental contamination. Similar experiments have been undertaken independently by other researchers, and the results were equivalent.

In a study of obsidian artifacts recovered from an open air site in Papua New Guinea, the frequency of starch granules recovered from stone artifacts was compared to that present in the soil matrix immediate to the tool (Barton et al. 1998). The frequency of starch granules was found to be much higher on used artifacts than in the surrounding soil. Thus, the conclusion was drawn that the tools were not contaminated by environmental starch sources. Further, use-wear analyses were used in combination with the soil and starch analyses to assess the degree of association of starchy residues with the used surfaces of tools (Barton et al. 1998). The researchers found that, indeed, the occurrence of starch granules was highly correlated with obsidian tools that bore use-wear and was not correlated with unused tools.

In a study of starch residues occurring on stone pounding tools from the Jimmium site in north central Australia, the starch forms in soil samples were compared to those extracted from the artifacts (Atchison and Fullagar 1998). It was found that, although starch granules did occur in the soil matrices surrounding the tools, they were of different size and shape than those present on the pounding stones, and, therefore, are probably not from the same plant source. This result was interpreted as evidence that the tools had not been contaminated by soil-borne starches.

Another method for assessing whether or not starch residues are culturally deposited involves the analysis of control samples from non-cultural contexts surrounding a site. If different types of starches, or different concentrations of starches, or no plant residue whatsoever are recovered from the control samples than are recovered from the artifacts undergoing testing, then one can be more secure that the residues are the remains of prehistoric food processing (Brieur 1976).

In addition to the study of association of microfossils with tool use, experimentation with processing methods has also been undertaken. In

Argentina, a researcher replicated ancient Andean methods of food processing and found that each different process resulted in diagnostic damage to starch granules in plant tissues including potato tubers (*Solanum tuberosum*) and quinoa seeds (*Chenopodium* spp.) (Babot 2003). Modern plant materials were subjected to freeze-drying, dehydration, roasting, charring, desaponification (a process particular to the preparation of quinoa), and grinding. It was found that fragments of starches that would probably otherwise be identified as unknowns or non-starches are actually damaged starches. Further, with careful analysis, researchers can link damage patterns with processing techniques (Babot 2003). Experimentation with various cooking techniques have resulted in similar conclusions: cooked starches are identifiable as such, and different cooking techniques yield different patterns of damage (Henry et al. 2009).

Recent work at the Pipeline, Pavilion, and Corral sites in Texas have demonstrated the utility of starch grain analysis in understanding the function of burned rocks in archaeological contexts (Perry 2010). Here, the analysis of burned rocks yielded starch grains that bore clear damage from boiling and secured the function of many burned rocks as oiling stones used for the cooking of wildrye. The analysis of other artifacts from the sites yielded wildrye starches bearing damage from grinding, thus indicating that the grain was probably milled into flour prior to cooking (Perry 2010).

Archaeobotanists have focused their energies upon honing their methods toward the effective recovery of and identification of residual starch granules to understand plant use and processing. Studies have resulted in an impressive assemblage of various suites of starchy food plants, both wild and domesticated, raw and cooked. At this juncture in time, more studies are being undertaken and starch remains are being successfully recovered. What we now lack are baseline data as to how and why different plant materials may or may not adhere to stone tools. Thus, we are not yet able to understand issues such as intensity of use based upon numbers of recovered grains, or the history of a tool based upon the numbers of species of plants recovered from its surface. Linda Perry has obtained funding and will be performing experiments over the next year in the hopes of gaining an understanding of these issues.

I.3 METHODS

Thirty-two samples from the site were selected for analysis. These samples included one groundstone artifact, 26 burned rocks, and five sediment samples. All artifacts were collected and bagged separately without washing. Washing is a traditional step in the collection and curation of artifacts, but it will remove some of the residues that are of interest to archaeologists.

The methods used in the extraction of starch remains have been developed over a period of more than fifteen years of study by the author, and are typical of those used throughout the field. Detailed methods are available at www.fossilfarm.org.

All artifacts were placed in clean, metal beakers and were covered with filtered water. The beakers were then set aside for ten minutes to soak in the hope that this step would loosen the microfossils and allow for a better extraction. At this point, the beakers were placed in a sonic bath for fifteen minutes to shake the microfossils loose from the artifacts. The artifacts were removed from the beakers and the surfaces were rinsed with filtered water that was collected in the same effluent vessel.

The effluent from the cleaning was allowed to settle overnight, then the settled material was centrifuged for ten minutes at 1000 RPM to pellet out the solids. The solid materials were then subject to a heavy liquid flotation using cesium chloride (CsCl) at a density of 1.8 g/cm^3 to separate the starch grains from the sediment matrix.

Sediment samples were deflocculated with a combination of baking soda and deionized water for a period of three days. The samples were then centrifuged and the baking soda/water was discarded. The sediments were then subjected to a heavy liquid flotation, after which the steps are identical to those used in artifact processing.

The material collected from the flotation was rinsed and centrifuged three times with filtered water to ensure that the CsCl was completely removed from the solution. At this point, the pellet from the final centrifugation was placed on a clean glass slide with a small amount of water/glycerin solution.

Slides were scanned with a Zeiss Universal compound microscope for polarized light at 200, and identifications were made at 400 using standard methods. Digital images were captured at 800 magnification using a Micropublisher 3.3 camera and software.

I.4 RESULTS

Fourteen of the twenty-six burned rocks yielded starch remains. Eight of these samples were from Feature 1, and six were from Feature 2. A total of seventeen intact starch grains were recovered from the burned rock samples, sixteen of which were identifiable to some level (Table I-1). Five lenticular starch grains typical of those derived from grasses in the Triticeae, the group that includes wildrye and little barley, were recovered (Figure I-1). Ten starch grains of an as yet unidentified legume were recovered. A single grain of starch from a grass that is not in the Triticeae was recovered, as was a single unidentified grain.

Damaged starches were observed in ten of the burned rock samples. The types of damage include gelatinization, or heating in the presence of liquid water, and parching, indicative of a dry heating process. Unidentifiable damage was also noted (Table I-1).

No starch remains were recovered from the ground stone artifact or the sediment samples.

I.4.1 Feature 1

BR 4-3-1c: This rock yielded a single, lenticular starch grain.

BR 4-3-2c: This rock contained gelatinized starch.

BR 505-3-2b: This rock yielded a single, lenticular starch grain, and also contained starch that was damaged by an unidentified process.

BR 507-3-1d: A single starch grain from an unidentified legume was recovered from this rock, as was damaged starch.

BR 508-3-3b: Three starch grains from the same, unidentified legume mentioned above were recovered from this burned rock.

BR 508-3-3d: Gelatinized starch was recovered from this rock.

BR 508-3-4b: Gelatinized starch was recovered from this rock.

BR 508-3-5b: This burned rock yielded a single, lenticular starch grain and gelatinized starch.

I.4.2 Feature 2

BR 510-3-2b: This burned rock yielded six starch grains from the unidentified legume as well as a single, unidentified grain.

BR 512-3-3: This rock contained damaged starches, some of which were gelatinized.

BR 514-3-3b: This rock yielded one lenticular starch grain that showed damage due to parching.

BR 514-3-6b: A single, lenticular grain was recovered from this rock.

BR 515-3-1b: A starch grain from a grass that is not in the Triticeae was recovered from this rock along with gelatinized starch remains.

BR 515-3-3d: Gelatinized starch was recovered from this rock.

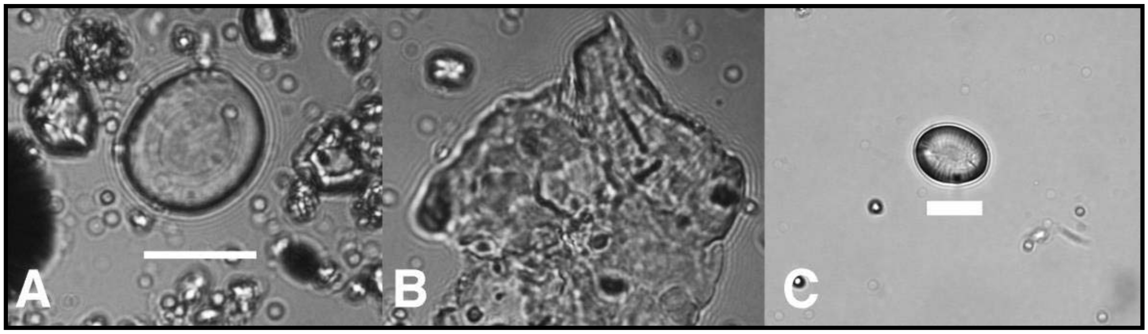


Figure I-1. Starch remains recovered from artifacts from Site 41MS69. The scale bar represents 20 microns, and images A and B are at equivalent magnification. A = a lenticular starch grain typical of those recovered at the site, from burned rock #505-3-2b. B = a gelatinized mass of starch from burned rock #508-3-4b. C = a leguminous starch grain from burned rock #508-3-3b.

I.4.3 The Unidentified Legume

At this point in time, the only legumes that can be ruled out in the identification of the remains from this site are tepary bean and scarlet runner bean. Phaseolus, or common bean, cannot be ruled out at this time, though it cannot yet be confirmed either. Work is currently underway to secure identification.

I.5 DISCUSSION AND CONCLUSIONS

The archaeobotanical remains from the site include grasses from the Triticeae, probably wildrye, an unknown legume, and a single occurrence of another grass. The wildrye-type starches and the legume occur in both feature contexts and on multiple rocks, indicating they were probably being used as food. Thus, at least two types of food resources, grass seeds and "beans" of some sort were being exploited. Identification of the legume should assist in our understanding of what types of foods were being prepared.

The damaged starches indicate at least two types of processes were occurring in the preparation of the food. The parched lenticular grain indicates that the grass seed was heated without water, possibly as a precursor to grinding. The presence of gelatinized starch remains on seven separate burned rocks in both features indicates stone boiling occurred at this site.

I.6 REFERENCES CITED

Atchison, J. and R. Fullagar
1998 Starch residues on pounding implements from Jinmium rock-shelter. In *A Closer Look: Recent Studies of Australian Stone Tools*, edited by R. Fullagar, pp. 109-126. Sydney University Archaeological Methods Series 6, Archaeological Computing Laboratory, School of Archaeology, University of Sydney, Sydney.

Babot, M. del Pilar
2003 Starch grain damage as an indicator of food processing. In Phytolith and Starch Research in the Australian-Pacific-Asian Regions: The State of the Art. Papers from a conference held at the ANU, August 2001, Canberra, Australia, edited by D. M. Hart, and L. A. Wallis, pp. 69-8. Pandanus Books.

Babot, M. del Pilar and M. C. Apella
2003 Maize and bone: residues of grinding in northwestern Argentina. *Archaeometry* 45:121–132.

Barton, H., R. Torrence and R. Fullagar
1998 Clues to Stone Tool Function Re-examined: Comparing Starch Grain Frequencies on Used and Unused Obsidian Artefacts. *Journal of Archaeological Science* 25:1231-1238.

Briuer, F. L.
1976 New Clues to Stone Tool Function: Plant and Animal Residues. *American Antiquity* 41(4):478-484.

Bryant, V. M.
2003 Invisible clues to new world plant domestication. *Science* 299:1029-1030.

Coil, J., M. A. Korstanje, S. Archer, and C. A. Hastorf
2003 Laboratory goals and considerations for multiple microfossil extraction in archaeology. *Journal of Archaeological Science* 30:991–1008.

Crawford, G. W. and D. G. Smith
2003 Paleoethnobotany in the Northeast. In *People and Plants in Ancient Eastern North America*, edited by P. E. Minnis, pp. 172-257. Smithsonian Books, Washington D.C.

Denniston, R. H.
1904 The Growth and Organization of the Starch Grain. Unpublished Ph.D. dissertation. University of Wisconsin, Madison, Wisconsin.

Fullagar, R., T. Loy, and S. Cox
1998 Starch grains, sediments and stone tool function: evidence from Bitokara, Papua New Guinea. In *A Closer Look: Recent Australian Studies of Stone Tools*, edited by R. Fullagar, pp. 49-58. Archaeological Computing Laboratory, University of Sydney.

Green W. and C. Tolmie
2004 Analysis of Plant Remains from Blood Run. *Plains Anthropologist* 49(192):525-542.

Hall, J., S. Higgins, and R. Fullagar
1989 Plant Residues on Stone Tools. *Tempus* 1:136-155.

Haslam, M.
2003 Evidence for maize processing on 2000 year old obsidian artefacts from Copán, Honduras. In Phytolith and Starch Research in the Australian-Pacific-Asian Regions: The State of the Art. Papers from a conference held at the ANU, August 2001, Canberra, Australia, edited by D. M. Hart and L. A. Wallis, pp. 153-161. Pandanus Books.

2004 The decomposition of starch grains in soils: implications for archaeological residue analyses. *Journal of Archaeological Science* 31:1715-1734.

Henry A. G., H. F. Hudson, and D. R. Piperno
2009 Changes in starch grain morphologies from cooking. *Journal of Archaeological Science* 36:915-922.

Iriarté, J., I. Holst, O. Marozzi, C. Listopad, E. Alonso, A. Rinderknecht, and J. Montaña
2004 Evidence for cultivar adoption and emerging complexity during the mid-Holocene in the La Plata basin. *Nature* 432:614-617.

Loendorf, L. L.
1985 A Possible Explanation for the Association between Wild Rye Grass (*Elymus* spp.) and Formerly Occupied Cave Sites in the Pryor Mountains, Montana. *Plains Anthropologist* 30(108):137-144.

Loy, T. H.
1994 Methods in the Analysis of Starch Residues on Prehistoric Stone Tools. In *Tropical Archaeobotany: Applications and New Developments*, edited by J. G. Hather, pp. 86-113. Routledge.

Loy, T. H., M. Spriggs, and S. Wickler
1992 Direct evidence for human use of plants 28,000 years ago: starch residues on stone artifacts from the northern Solomon Islands. *Antiquity* 66:898-912.

MacMasters, M. M.
1964 Microscopic Techniques for Determining Starch Granule Properties. In *Methods in Carbohydrate Chemistry*, edited by R. L. Whistler, pp. 233-240. Academic Press.

Pearsall, D. M., K. Chandler-Ezell, and J. A. Zeidler
2004 Maize in ancient Ecuador: results of residue analysis of stone tools from the Real Alto site. *Journal of Archaeological Science* 31:423–442.

Perry, L.
2001 Prehispanic subsistence in the middle Orinoco basin: starch analyses yield new evidence. Unpublished Ph.D. dissertation, Southern Illinois University Carbondale, Illinois.

2002 Starch analyses indicate multiple functions of quartz "manioc" grater flakes from the Orinoco basin, Venezuela. *Interciencia* 27(11):635-639.

2004 Starch analyses reveal the relationship between tool type and function: an example from the Orinoco valley of Venezuela. *Journal of Archaeological Science* 31(8):1069-1081.

2005 Reassessing the traditional interpretation of “manioc” artifacts in the Orinoco valley of Venezuela. *Latin American Antiquity*.

2007 Starch grains, preservation biases, and plant histories. In *Rethinking Agriculture: Archaeological and Ethnographic Perspectives*, edited by T. Denham, L. Vrydaghs and J. Iriarté. One World Archaeology, Left Coast Press.

2010 Starch Analyses from the BLM Landis Property. In *Landis Property: Data Recovery at Three Prehistoric Sites (41PT185, 41PT186, and 41PT245) in Potter County, Texas*, edited by J. Michael Quigg, Charles D. Frederick, Paul M. Matchen, and Kendra G. DeBois, pp. 767-785. TRC Technical Report 150832, TRC Environmental Corporation, Austin.

Perry L. and J. M. Quigg
2011a Starch remains and stone boiling in the Texas panhandle part 1: The Pipeline, Corral, and Pavilion sites. *Plains Anthropologist* 56:95-108.

Perry L. and J. M. Quigg
2011b Starch remains and stone boiling in the Texas panhandle part 2: Identifying wildrye (*Elymus* spp.). *Plains Anthropologist* 56:109-120.

Perry, L., D. Sandweiss, D. Piperno, K. Rademaker, M. Malpass, A. Umire, and P. de la Vera.
Early Maize Agriculture and Interzonal Interaction in Southern Peru. *Nature* 440:76-79.

Perry, L. R. Dickau, S. Zarrillo, I. Holst, D. Pearsall, D. Piperno, M. Berman, R. Cooke, K. Rademaker, A. Ranere, J. Raymond, D. Sandweiss, F. Scaramelli, K. Tarble, and J. Zeidler.
2007 Starch fossils and the domestication and dispersal of chili peppers (*Capsicum* spp. L.) in the Americas. *Science* 315:986-988. With accompanying Perspective by S. Knapp. Some Like it Hot. *Science* 315: 946-947.

Piperno, D. R. and I. Holst
1998 The presence of starch grains on prehistoric stone tools from the humid Neotropics: indications of early tuber use and agriculture in Panama. *Journal of Archaeological Science* 25:765–776.

Piperno, D. R., A. J. Ranere, I. Holst, and P. Hansell
2000 Starch grains reveal early root crop horticulture in the Panamanian tropical forest. *Nature* 407: 894-897.

Ranere, A. J.
1975 Tool making and tool use among the preceramic peoples of Panama. In *Lithic Technology*, edited by E. H. Swanson, pp. 173-210. Mouton.

Reichert, E. T.
1913 The Differentiation and Specificity of Starches in Relation to Genera, Species, Etc. In two parts. Carnegie Institution of Washington.

.

Table I-1. Starch Remains from 41MS69.

Provenience (Column, Unit, Level No.)	Feature No.	PNUM/Cat/ Ext	Artifact Type	Lenticular	Legume	Grass	Unidentified	Damaged	Total
Bank	2	104-10	Ground Stone						0
C1, 1, 4		4-3-1c	Burned Rock	1					1
C1, 1, 4		4-3-2c	Burned Rock					GL	X
C1, 5.5, 16	1	505-3-1b	Burned Rock						0
C1, 5.5, 16	1	505-3-2b	Burned Rock	1				X	1X
C1, 5.5, 16	1	505-3-3b	Burned Rock						0
C1, 5.5, 16	1	505-3-4c	Burned Rock						0
C1, 6, 14	1	507-3-1d	Burned Rock		1			X	1X
C1, 6, 15	1	508-3-1b	Burned Rock						0
C1, 6, 15	1	508-3-2b	Burned Rock						0
C1, 6, 15	1	508-3-3b	Burned Rock		3				3
C1, 6, 15	1	508-3-3d	Burned Rock					GL	X
C1, 6, 15	1	508-3-4b	Burned Rock					GL	X
C1, 6, 15	1	508-3-5b	Burned Rock	1				GL	1X
C1, 5, 17	2	510-3-1	Burned Rock						0
C1, 5, 17	2	510-3-2b	Burned Rock		6		1		7
C1, 5, 18	2	511-3-1g	Burned Rock						0
C1, 5, 18	2	511-3-2g	Burned Rock						0
C1, 5.5, 18	2	512-3-1	Burned Rock						0
C1, 5.5, 18	2	512-3-2	Burned Rock						0
C1, 5.5, 18	2	512-3-3	Burned Rock					GLX	X

Table I-1. Starch Remains from 41MS69 (continued).

Provenience (Column, Unit, Level No.)	Feature No.	PNUM/Cat/ Ext	Artifact Type	Lenticular	Legume	Grass	Unidentified	Damaged	Total
C1, 6, 18	2	514-3-3b	Burned Rock	1				P	1X
C1, 6, 18	2	514-3-6b	Burned Rock	1					1
C1, 6, 18	2	515-3-1b	Burned Rock			1		GL	1X
C1, 6, 18	2	515-3-2b	Burned Rock						0
C1, 6,, 18	2	515-3-3d	Burned Rock					GL	X
C1, 6 18	2	515-3-4b	Burned Rock						0
C1,		107-4-e	Sediment						0
C1, 5.5, 16	1	505-4-1g	Sediment						0
C1, 5, 18	2	511-4-1d	Sediment						0
C1, 6, 14	1	507-4-1d	Sediment						0
C1, 6, 16		43-4-2a	Sediment						0
Total			**32**	**5**	**10**	**1**	**1**	**10**	**17**

Note: "GL" indicates gelatinized starch. "P" indicates parched starch. "X" is used to designate those starches that have damage from an unidentified process.

APPENDIX J
BIOGENIC SILICA ASSESSMENT OF SEDIMENT SAMPLES FROM 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

J. Byron Sudbury, Ph.D.
J. S. Enterprises, Inc.
Ponca City, Oklahoma

This page intentionally left blank.

BIOGENIC SILICA ASSESSMENT OF SEDIMENT SAMPLES FROM 41MS69

J. Byron Sudbury, Ph.D.

J.1 SUMMARY

Five sediment samples, two old geomorphic samples and three from cultural Features 1 and 2, were processed for biogenic silica recovery and analysis. Overall biogenic silica preservation was very poor due to the basic pH environment of the cambic Oakalla silty clay loam matrix. Zero biogenic silica was recoverable from the two geomorphic samples, and partial degradation was evident in the biogenic silica component of the feature samples. Poaceae short cell phytoliths, some specimens of which showed evidence of weathering, were present in variable levels suggesting that possible selective particle dissolution had occurred. Bulliform cells and other larger phytoliths did survive, but generally showed varying degrees of surface weathering or dissolution. One cucurbit phytolith was noted from Feature 1. Charcoal was abundant in some samples, and biogenic silica specimens showed evidence of fire. Sponge spicules were recovered in good condition and a few small statospores were present in three samples, but no diatoms were observed. The sand fractions contained chunks of carbonate encrusted sand grains as well as carbonate fragments containing root impressions, emphasizing the carbonate content of the soil. The basic pH soil preserved snails, which were photographed and recovered. A variety of micro-flake debitage was also noted.

J.2 PHYTOLITHS AND BIOGENIC SILICA

Biogenic silica is formed in plants (phytoliths), freshwater sponges (spicules), resting phase cysts of certain algae ("statospores", or Chrysophycean cysts), and diatoms (frustules). Each material is chemically the same, but is form by varied mechanisms. In all cases, the amorphous (i.e., non-crystalline) biogenic silica remains after the death of the plant or organism that produced it, and in a terrestrial environment is incorporated into the soil mineral fraction (Piperno 2006:5). The target of this study--phytoliths--are generally incorporated in the silt fraction of the soil (2-50 micron particle size) as are most specimens of diatoms and statospores. Complete sponge spicules are frequently larger than 50 microns so technically are a component of the sand fraction. However, laboratory sample extraction techniques have been developed which enable all four biogenic components to be recovered together in the isolated silt fraction[1]. This separation and recovery is possible because biogenic silica ($SiO_2 \bullet nH_2O$) has a lower particle density than the quartz-based soil matrix; thus, the effective separation is based on a combination of particle size, particle shape, and particle density.

Phytoliths are a signature or proxy of the plants which grew on location at the time the soil was developing. Leaves of certain Poaceae subfamilies have distinct phytolith morphologies (Twiss et al. 1969); as those plant categories thrive best under different climatic conditions, the phytolith signature is a proxy for the extant climate when the soil was forming. Sponge spicules reflect conditions of the water where the sponges grew; the siliceous spicule condition may provide clues as to whether the spicules are local or were introduced via mechanical transport (such as wind or water, which can result in surface abrasion). Diatoms

---

[1] Several spicule sections in the 145-150 micron size range were recovered (Figure J-18:I and P). Other large biogenic silica fragments were also recovered in the 2-50 micron silt fraction (Figure J-13K = 111 microns; 14P = 108 microns).

provide a great amount of detail about water chemistry and environmental conditions; aerial diatom species also occur. Statospores--a resting or cyst phase--form as a protective mechanism when the parent algae is exposed to desiccation.

J.3 LABORATORY SAMPLE PROCESSING

The five soil samples (Table J-1) were transferred to 250 milliliter preweighed glass sample jars, and oven dried at 105ºC for 24 hours. The samples were then cooled in a desiccator, and reweighed to obtain the starting dry sediment weights.

Two hundred milliliters of Calgon solution was added to each soil sample (Piperno 2005:90). The samples were tightly capped, and then vigorously shaken for 24 hours on an Eberbach shaker in order to deflocculate the clays in the soil. The sample solution mixtures were then allowed to settle and return to room temperature. Then, using times calculated via Stoke's Law (>50 microns, assuming sphericity, and the quartz density value of 2.65 g/cm^3), the sand fraction was allowed to settle, at which time the upper ~80% of the clay and silt fraction that remained suspended was decanted into another container for future processing. These steps-- resuspending, timed settling, decanting, and pooling the sample decants--were repeated until the aqueous phase above the sand fraction was clear. At this point initial fraction separation was complete; the sand fractions were dried in a 105ºC oven, cooled in a desiccator, and weighed to determine the amount of sand present in the parent samples. The clean sand fractions are shown in Figure J-1; considerable variation in charcoal, shell, and lithic content is clearly visible. The sand fractions were then transferred to glass Petri dishes for microscopic examination at 25x.

The pooled silt/clay fractions for each sample were processed in the same manner to separate the silt and clay fractions. The initial settling of the pooled sand decants was allowed to continue for three days (30 cm deep water column for the settling distance). After the first clay decant was removed, the remaining silt and silt/clay mixture was transferred to the 250 ml bottles which previously contained the sand fractions. The particle fractionation steps were repeated (10 cm water column) removing the suspended clay until the liquid above the silt fraction was clear at the time for the next decant. At this time, water above the silt layer was removed, and the pooled clay sample decants were set aside and allowed to settle at which point they were dried and saved. The silt fractions were oven dried at 105ºC, cooled in a desiccator, and weighed to determine the amount of silt present in each sample. Based on the weight percent of sand and silt present in the samples, sample soil textures were determined (Table J-2, Figure J-2).

Table J-1. Sediment Samples from Column 1 (41MS69).

JSE Lab No.	Sample No.	Unit	Level	Other Prov.	Depth (cmbs)	Feat No.	PNUM	Cat No.	Ext. No.	Comment
MQ14-1	1	Zone 8		top	224-228		0107	004	g	
MQ14-2	2	Zone 11			395-398		0109	004	d	clay
MQ14-3	3	5.5	16	ext	151-154	1	0505	004	1e	N5 E5 plotted
MQ14-4	4	6	14		134	1	0507	004	1e	S-1 under BR
MQ14-5	5	5	18		177	2	0511	004	1c	S1; plotted

Figure J-1. Isolated sand fractions (41MS69). Sample numbers as indicated (#1-5) [image 4' shows intact soil Sample 4 prior to deflocculation and sand isolation; the large snail is visible]. (Internal diameter of the 250 ml glass sample jars is 2.2 inches. Sample key in Table J-1.)

Table J-2. Soil Texture and Soil Phytolith Concentrations (41MS69).

JSE Lab Sample No.	Depth (cmbs)	Feature No.	Sample wt (g)	Sand wt %	Silt wt %	Phytolith Fraction (wt % of soil)	
						with CO present	with CO removed
MQ14-1	224-228		27.09	21.8	41.4	0.09	0.04
MQ14-2	395-398		33.85	27.5	40.4	0.09	0.03
MQ14-3	151-154	1	31.53	45.6	29.5	0.11	0.04
MQ14-4	134	1	26.82	53.4	26.9	0.21	0.05
MQ14-5	177	2	30.45	46.2	32.9	0.18	0.04

Note: Upon further examination, fractions of Samples 1 and 2 contained no phytoliths or biogenic silica--only soil minerals.

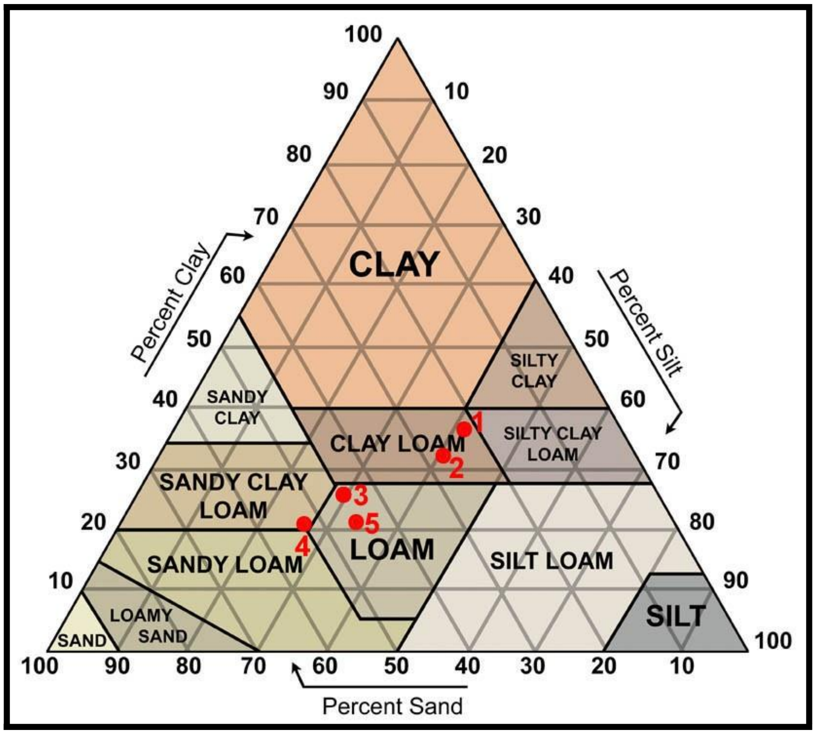


Figure J-2. Soil textures (41MS69). (Sample key is in Table J-1.)

[Note that this Stoke's Law based gravimetric soil texture determination is not the more commonly reported soil texture analyses determination by soil hydrometer or mechanical sieving.]

The dry silt fractions were transferred to porcelain crucibles, and the silt fractions ashed at 530ºC to remove any organic material in the samples. After cooling, the cleaned silt fractions were transferred to 50 ml centrifuge tubes. Then, heavy liquid--aqueous 2.35 g/cm^3 solution of zinc bromide--at was added to each sample. The quartz silica matrix (density 2.65 g/cm^3) remains submerged in the solution while lighter soil minerals (including phytoliths and other biogenic silica components) float to the top. In reality, this separation is not immediate due to both the very viscous near-pasty soil matrix, and the fact that sample drying during organic removal via ashing seems to cause particles to bind together, which must then again be disaggregated. A Vortex Genie mixer is used to frequently stir the sample/heavy liquid mixture vigorously, and with time (often a month or more) floating particles begin to become visible at the surface. The tubes are then centrifuged, and the upper liquid portion containing the floating particulate is transferred to another tube, and flotation of the original silt sample repeated. The decants are pooled and checked for purity (i.e., heavier debris carryover). Once no more material floats from the parent sample and the decants are clean and contain only <2.35 g/cm^3 material, water is added to the isolate lowering the solution density causing the biogenic silica to settle. Use of a centrifuge accelerates this step, and the biogenic pellet is repeatedly rinsed with distilled water until the heavy liquid residue has been removed.

Next, the cleaned isolates were quantitatively transferred to 4 dram vials, dried, and weighed. As carbonates in the sample and never removed--carbonates were removed after this initial biogenic isolate weighing. Carbonate neutralization was accomplished by adding 10% hydrochloric acid at a slow rate allowing effervescence to occur. When the vial was full, it was centrifuged, the spent acid removed via Pasteur pipet, and fresh acid added. Once no more effervescence was observed, the cleaned isolate was rinsed and centrifuged repeatedly until all residual acid had been removed. The samples were then oven dried and reweighed. The original carbonated-contaminated phytolith isolate ranged from 0.09-0.21 weight percent the dry soil sample weight. However, after acid treatment (Figure J-3), the actual solids recovery was much lower: 0.03-0.05 weight percentage (Table J-2).

This is an extremely low soil phytolith content. [As it turned out--much of the remaining isolate weight was due to low density mineral contamination; no (zero) phytoliths or other biogenic silica was recovered from Samples 1 or 2.]

Slides of recovered particulate were mounted in Canada balsam as described elsewhere (Sudbury 2011a:50-52), and then allowed to cure in an incubator set at 35ºC. Once the balsam at the slide edges sets up, the slides were scanned via polarized light microscopy (PLM) at 500x during particle counting and photo-documentation. After completion of scanning at 500x for particle counts, each slide was completely rescanned at 100x to search for any significant particles that may have been initially overlooked. Images of particles were collected as they were observed during scans. Imaging was via an Olympus DP-12 digital camera system with a 2x convertor, using an Olympus BX51 petrographic microscope with x-y stage. [Images of particles in the sand fractions were photographed using an Olympus SZ12 Stereo Zoom microscope with an Olympus DP-12 digital camera and a 2x convertor. Most sand-related images were taken at 25x magnification.]

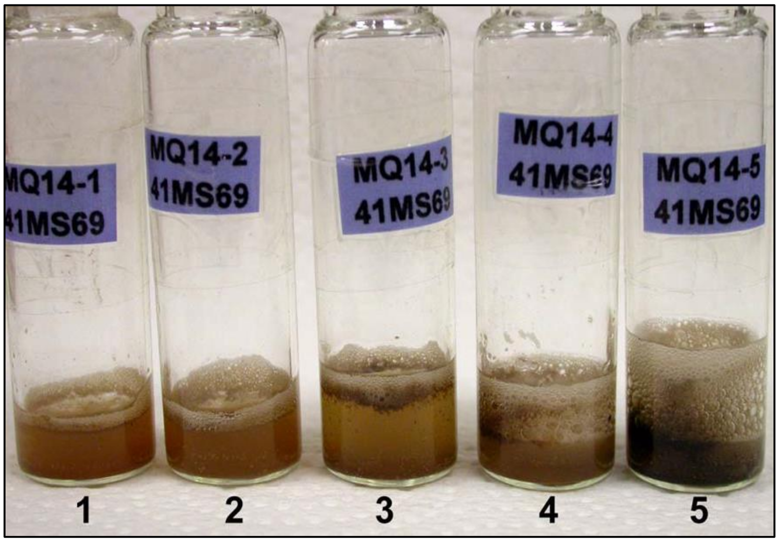


Figure J-3. Isolated phytolith fractions during neutralization of contaminating carbonate with 10% hydrochloric acid (41MS69). (The sample key is in Table J-1).

J.4 DATA—SAND FRACTIONS

The sand fractions contained a considerable amount of visible carbonate (Figure J-3). This included carbonate that formed around roots as a product of a combination of root decay and microbial respiration (Figure J-4:A-C, E, F), as well as carbonate chunks which contain quartz sand grains (Figure J-4:C, left 1/4; Figure J-4:D; lower left quadrant). The arrow in Figure J-4:F denotes a microflake on edge in the carbonate which formed around a root and also encompassed the flake. What appears to be a quartz flake is in Figure J-4:E, as well several quartz crystals (6 o'clock position; one facet of the upper crystal reflects light).

Examination of the sand fraction yielded a variety of snail specimens (Figures J-5 and J-6). The very large snails in Figure J-1:3, 4, 4', and 5 may be specimens of the same species (Figures J-5:G-G"; 4:J-H', and Figure J-6:A-A"). A variety of other snail species were also recovered, but species identification has not been determined.

A variety of micro lithic debris was noted in the sand fractions; specimens were observed in all five samples (Figure J-7). A number of pieces of clear quartz were also noted (Figure J-8) including several that appeared to exhibit a bulb of percussion. Careful examination of the photographs in Figure J-8 reveal what appears to be conchoidal fractures evident on some specimens (Figure J-8: S, U, X, and i).

Several hackberry seed fragments were only found in the 41MS69 feature Samples 3-5, a few of which are illustrated (Figure J-9). Both fragments recovered in Sample 3 were burned, the only specimen found in Sample 4 was not burned, and three of the eight fragments in Sample 5 were burned.

A variety of other distinctive but unidentified particles were observed in the sample sand fractions (Figure J-10). The specimens in Figure J-10:A-D, F, and J appear to be fossils; Figure J-10:F and J are sections of marine sponge spicules made of calcium carbonate, and the specimen in B may be a section of crinoid. With the exception of the specimen in Figure J-10L, the other specimens are unidentified. The specimen in Figure J-10L is a fragment from an oogonia of a Charophyte--the sole specimen observed in these samples (for examples of complete oogonia of Charophytes, see Sudbury 2013b: Figure 15; 2014a: Figures 7 and 8).

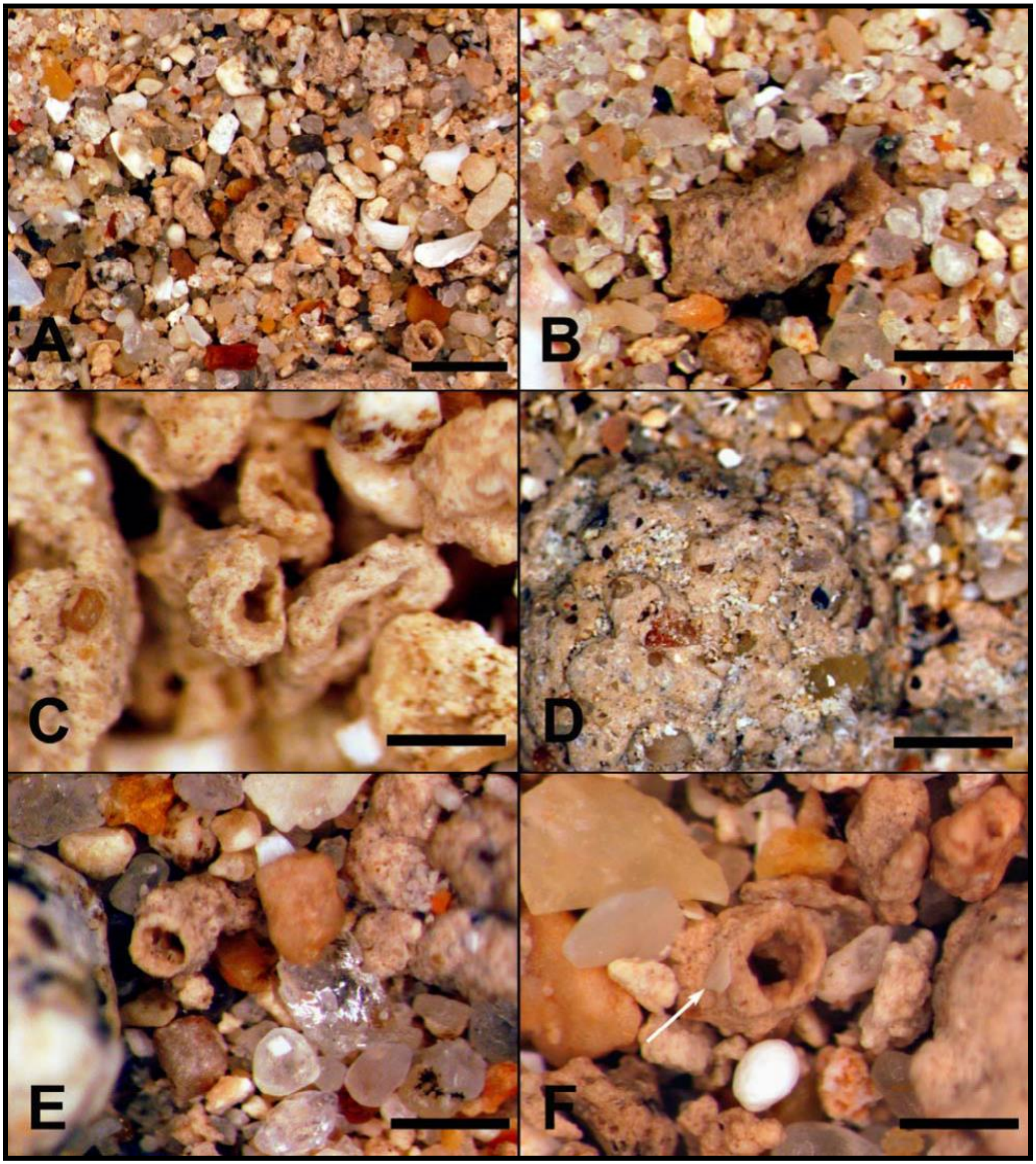


Figure J-4. Carbonates observed in 41MS69 sand fractions. Carbonate chunks (C, D), fragments, and root casts are readily visible in the sand samples. The arrow in F indicates a micro flake. Sample 2: images A-E; and Sample 1: image F. (Bar scales are 1 mm. Sample identities are in Table J-1).

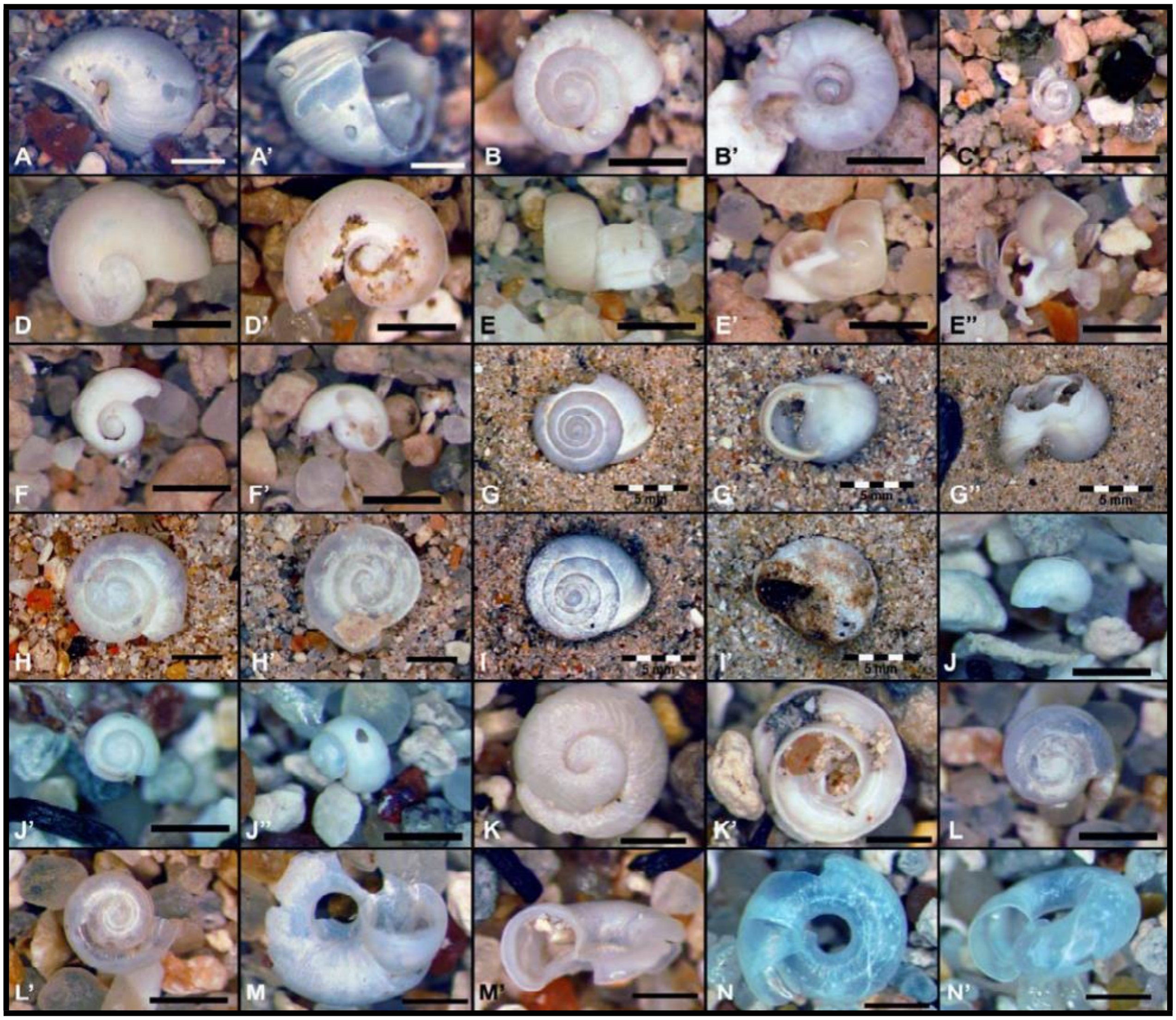


Figure J- 5. Snails from Samples 1-4 (41MS69). Sample 1: Specimens A-C; Sample 2: Specimens D-F; Sample 3: Specimen G; and Sample 4: Specimens J-N. Sample identities are in Table J-1. (All bar scales are 1 mm (except in G-G" and I-I' which are 5 mm).

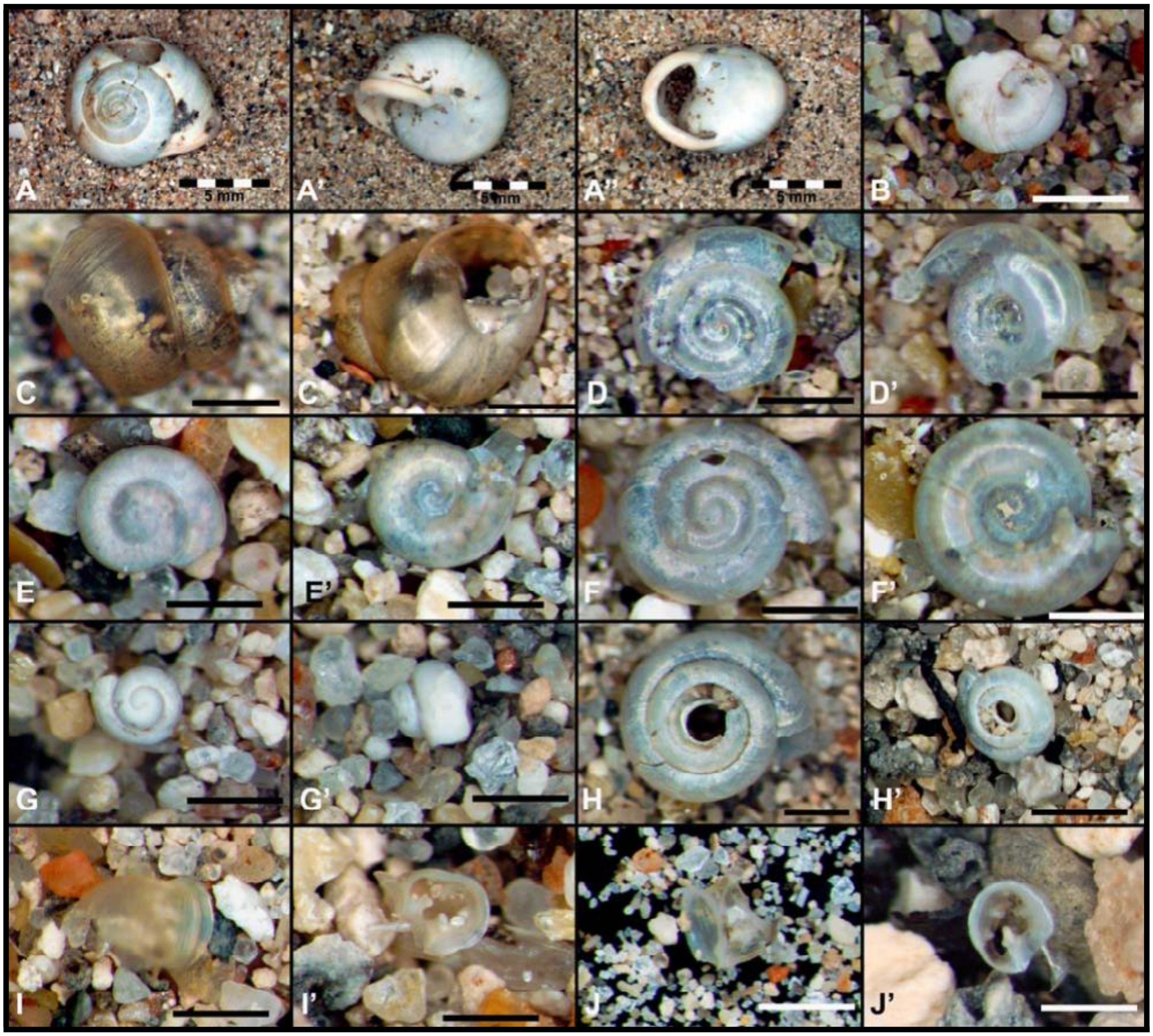


Figure J-6. **Snails from Sample 5 (41MS69). Sample 5: Specimens A-J. Sample identities are in Table J-1. (All bar scales are 1 mm except in A-A" which are 5 mm).**

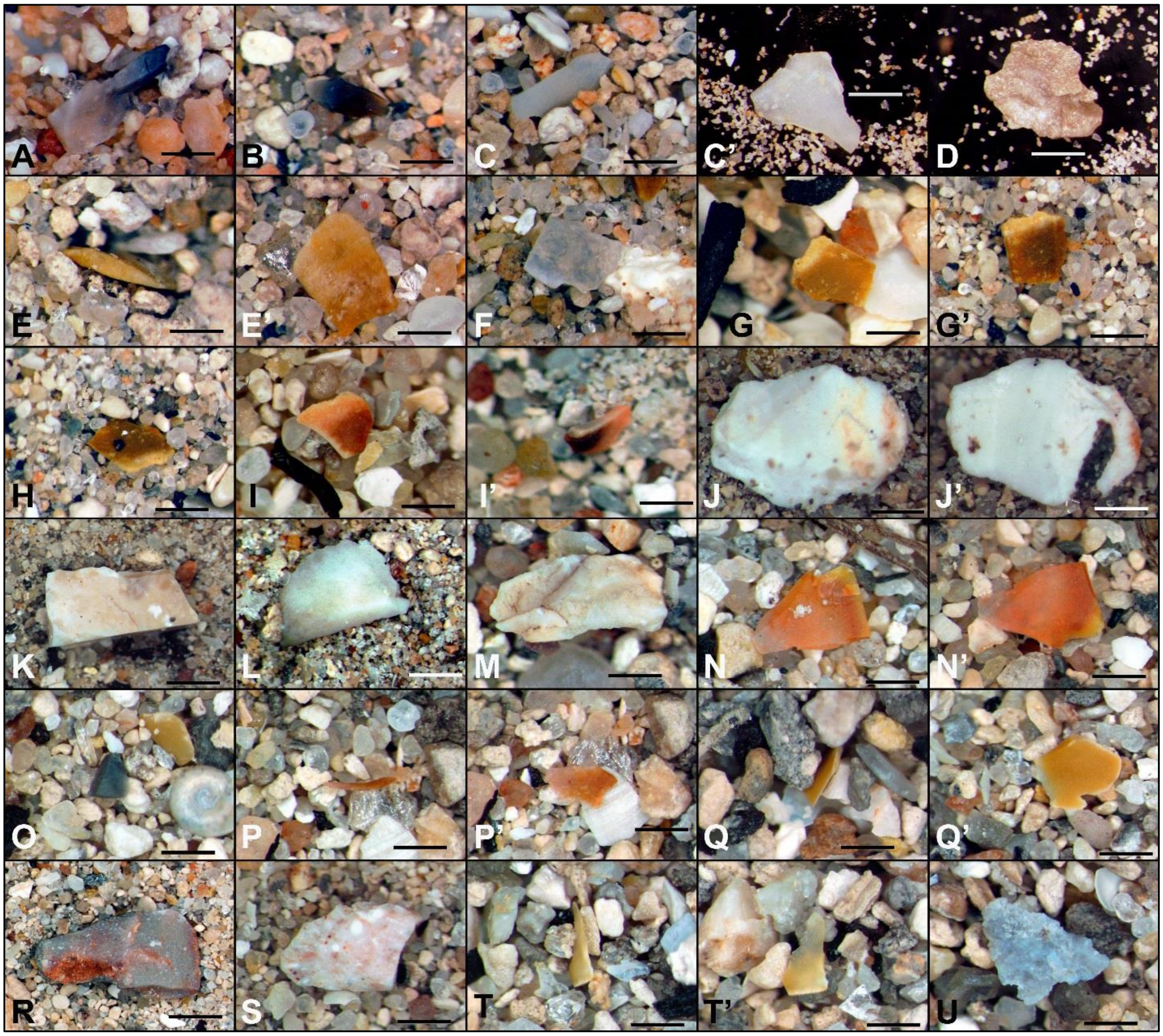


Figure J-7. **Lithic flake debris from Samples 1-5 sand fractions (41MS69). Sample 1: A-D; Sample 2: E-F; Sample 3: G-H; Sample 4: I; and Sample 5: J-U. (Sample key is in Table J-1. B ar scales are 1 mm.)**

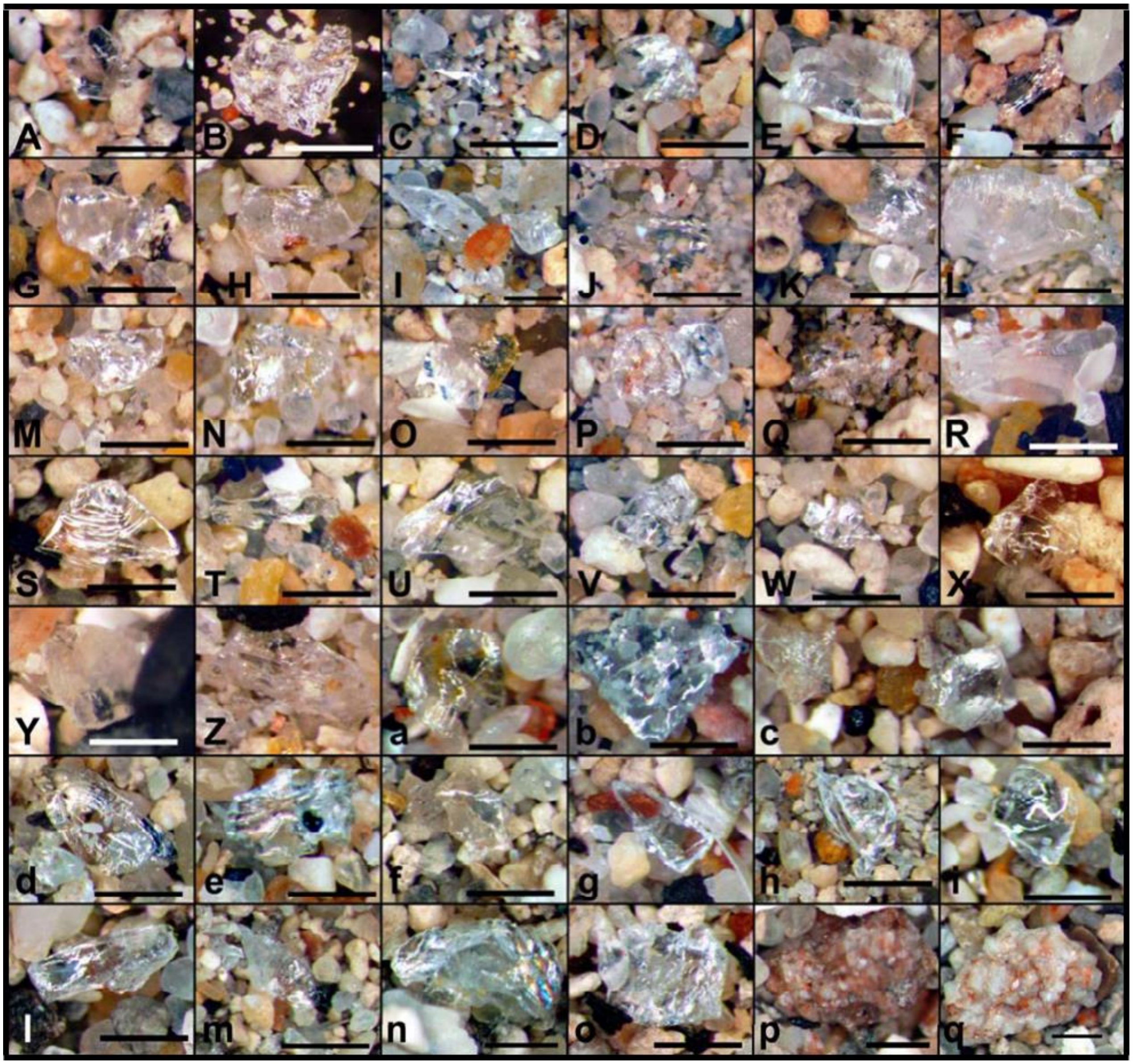


Figure J-8. Quartz debris including some apparent micro flakes in sand fractions of Samples 1-5 41MS69). Sample 1: A-F; Sample 2: G-P; Sample 3: Q-Z; Sample 4: a-e; and Sample 5: f-q. (P and q are small clusters of relatively opaque quartz crystals) (Sample key is in Table J-1. Scales are all 1 mm).

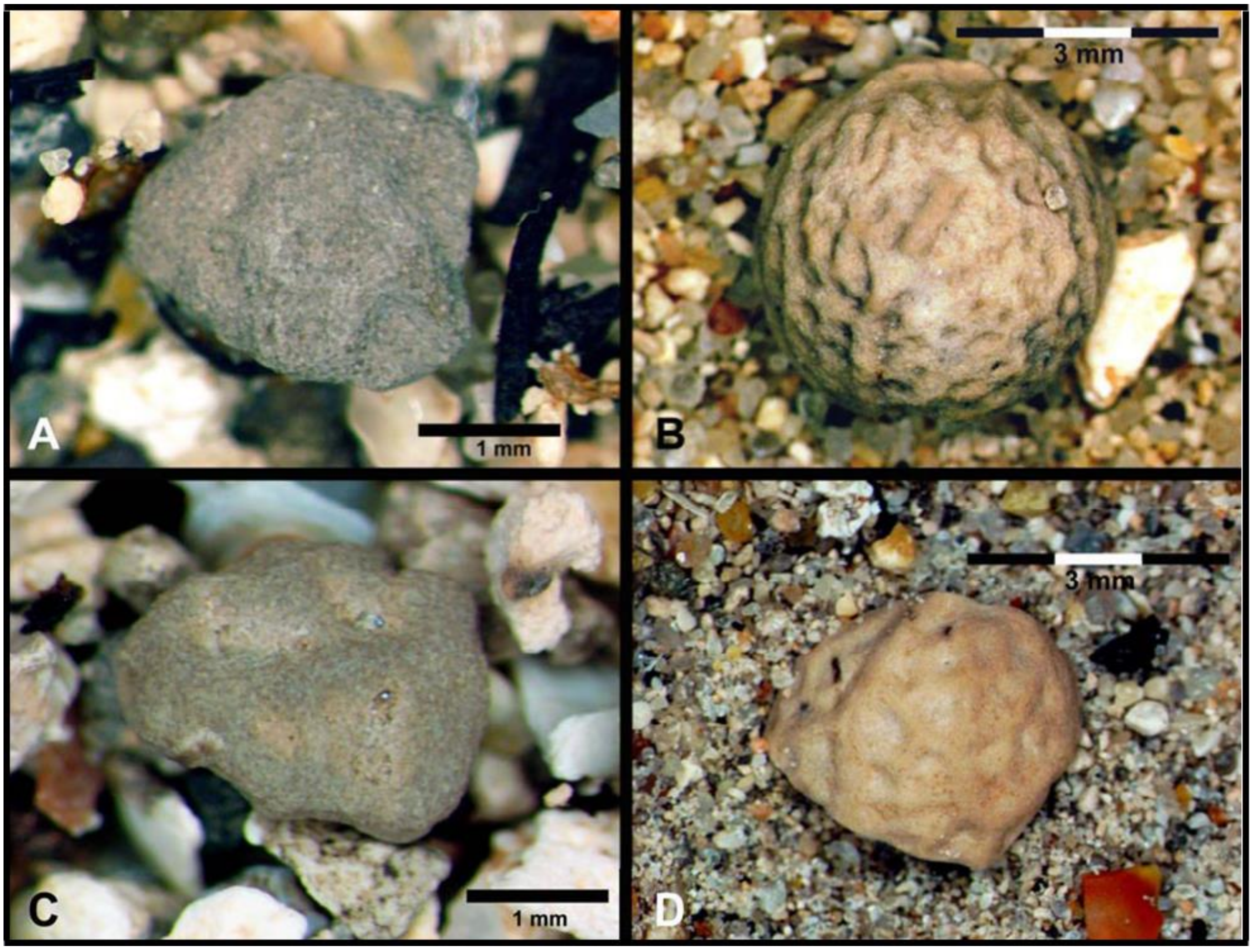


Figure J-9. Hackberry seed fragments from 41MS69 sample sand fractions. Sample 3: A; Sample 4: B; and Sample 5: C-D. The specimens in A and C are burned. (Sample key is in Table J-1. Scales as indicated).

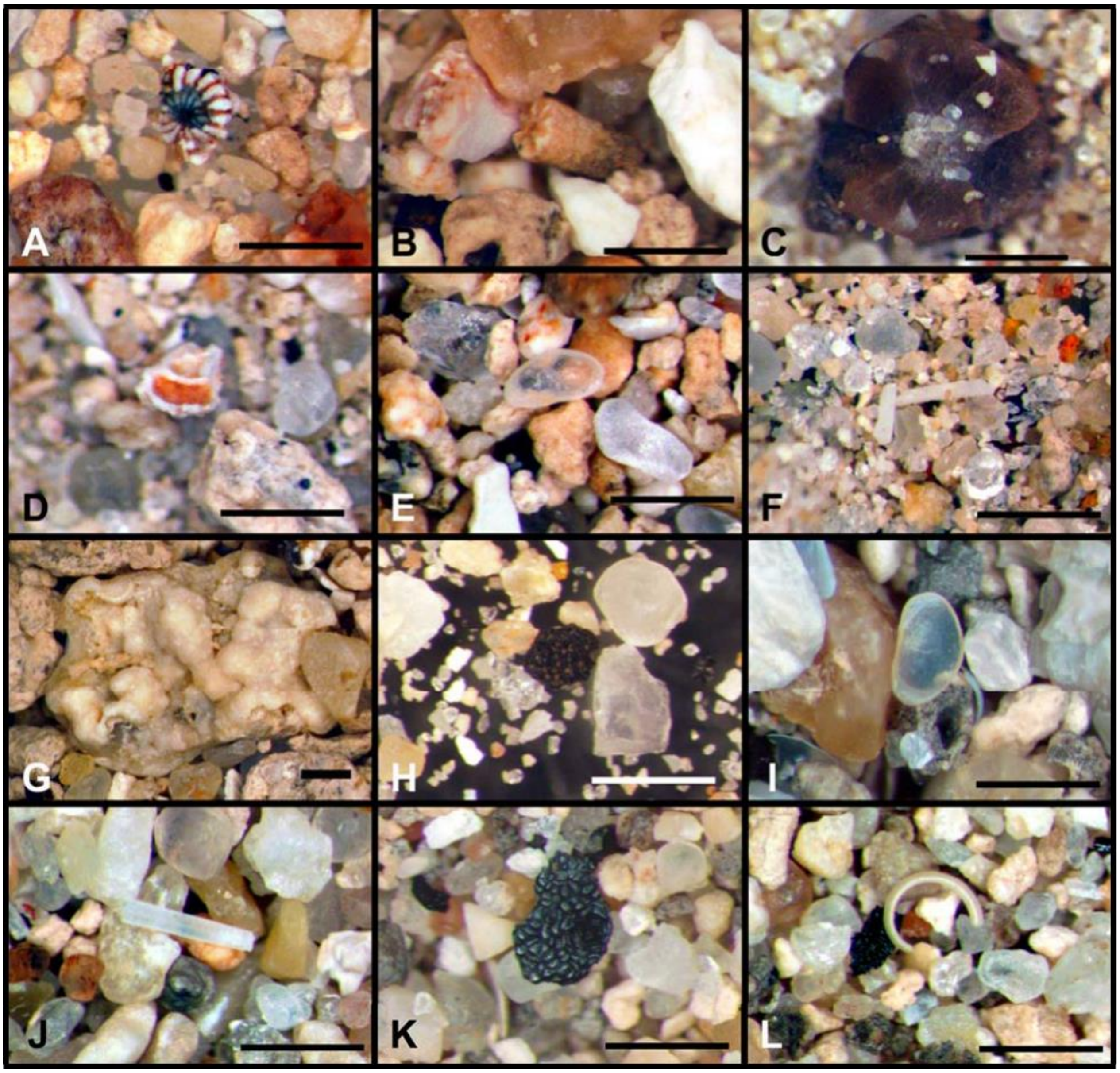


Figure J-10. Fossils and miscellaneous particles in 41MS69 sand fractions. Sample 1: A-E; Sample 2: F-G; Sample 3: H; Sample 4: I-J; and Sample 5: K-L. The specimens in A-D, F-G, and J are fossils. Specimen in L is a fragment of a Charophyte Oogonia. The other four illustrated specimens are unidentified. (Sample key is in Table J-1. The bar scales are 1 mm).

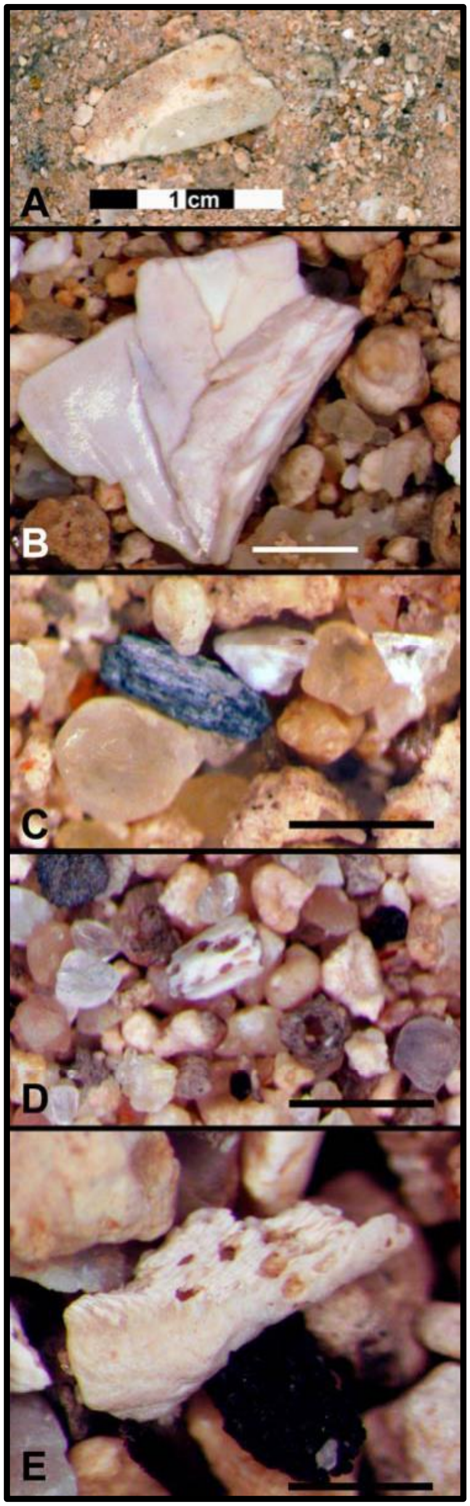


Figure J-11. Shell and burned bone fragments observed in 41MS69 sand fractions. Sample 1: A-B; Sample 2: C; and Sample 5: D-E. (Sample key is in Table J-1. Scales 1 mm (except A).

The sand fractions also contained several larger shell fragments that do not appear to have originated from snails (Figure J-11: A and B). A few burned bone fragments were also noted (Figure J-11: C-E [identification of C is uncertain]).

J.5 DATA—BIOGENIC SILICA FRACTION

Portions of each isolated low density fraction isolate from the silt matrices were mounted on microscope slides and scanned. No biogenic silica in any form was present in the slides for Samples 1 and 2. Their fraction weight in Table J-2 is due to mineral contaminants (presumably carbonate-related, but not yet identified).

Biogenic silica particles recovered from soil Samples 3-5 were present on the isolate microscope slides. Spicules were relatively well-preserved as were the few very small statospores that were observed. However, the quality of phytolith preservation was variable between samples. For the three feature samples from which phytoliths were recovered (Samples 3-5) there were not enough short cell phytoliths present to tabulate in order to provide a significant environmental interpretation based on published statistical guidelines (Strömberg 2009). Diatoms were completely absent from all five sample isolates (zero specimens).

Representative short cell phytoliths recovered from Samples 3-5 are shown in Figure J-12. Most forms were present although the individual particle counts were very low. The predominant short cell category recovered were Chloridoids (i.e., "saddle" morphologic form representing hot dry season grasses). This is in contrast to a similar age site where similar basic pH soil preservation issues were encountered where the crenate form was by far the most abundant (Sudbury 2014a). Visually from the specimens present, individual particle preservation ranged from good to poor (Figure J-12).

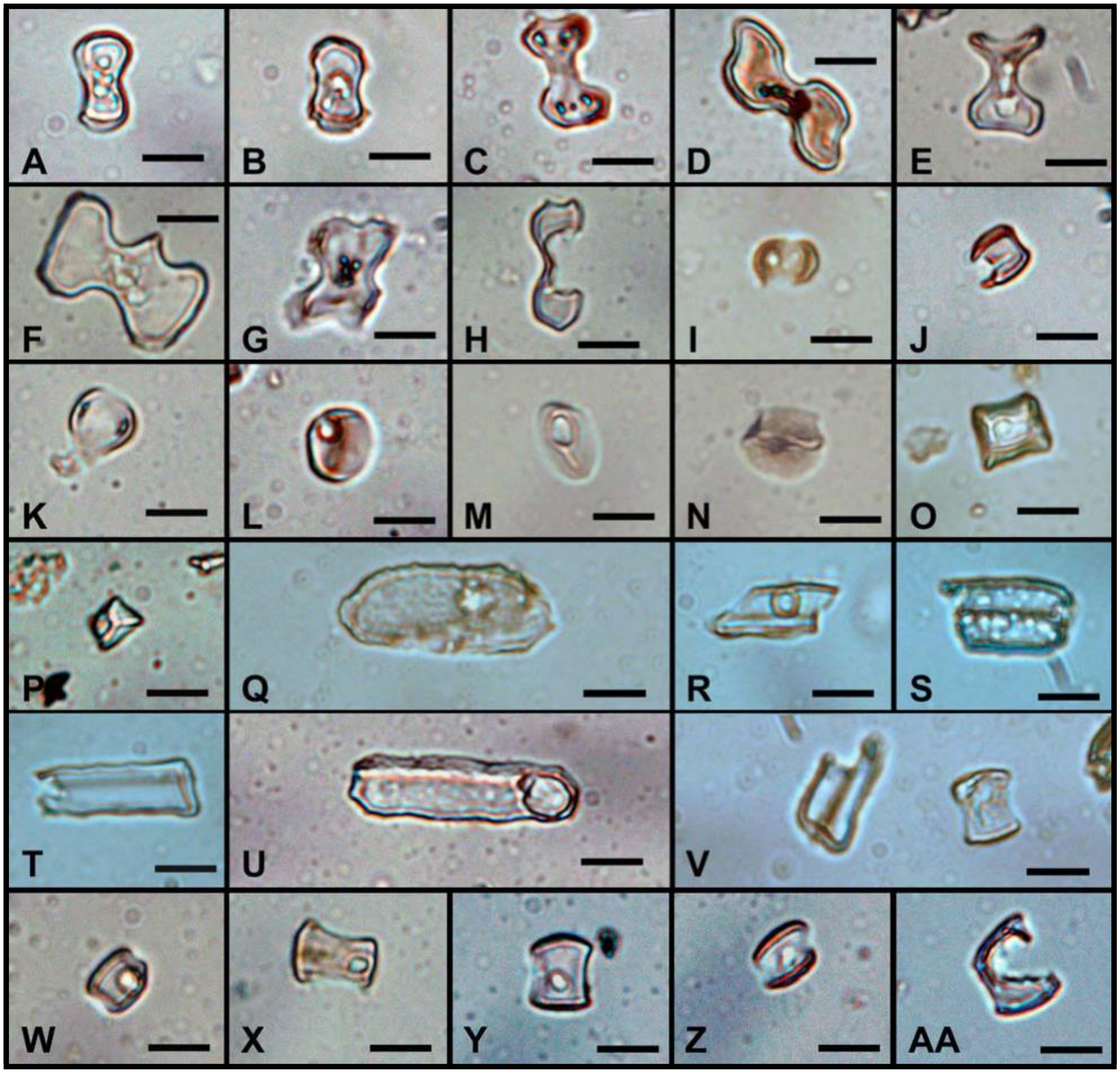


Figure J-12. Example Poaceae short cell phytoliths (41MS69). Sample 3: A, C, J, Q, R, and V. Sample 4: D-H, K-M, S-U, and W-X. Sample 5: B, I, O-P, and Y-AA. A-K: Panicoids; L-V (left): Pooids; and V (right)-AA: Chloridoids. A-B (simple lobate); C-E and J-K (Panicoid lobate); F (Panicoid polylobate); and G (Panicoid cross). L-N (keeled); O-P (pyramidal); and Q-V (left) (crenate). V (right), X, Y, and AA (Chloridoid, tall); and W and Z (Chloridoid, squat). (Bar scales are 10 microns. The sample key is in Table J-1).

Table J-3. Biogenic Silica Fraction Summary (41MS69).

Sample	**41MS694**					**Figure**
	1	**2**	**3**	**4**	**5**	
Biogenic Silica						
Phytoliths	-	-	+	+	+	
- Pooids	-	-	tr	tr	tr	12
- Panicoid	-	-	tr	tr	tr	12
--Panicoid Lobate (% burned)	-	-	33.3	29.2	0	
-Chloridoids	-	-	+	+	+	12
--Chloridoids (tall:squat)	-	-	3.6	4.9	2.9	
--Chloridoids, tall (% burned)	-	-	5.1	7.7	2.1	
--Chloridoids, squat (% burned)	-	-	9.1	37.5	0	
- bulliform cells	-	-	+++	+++	+	13
- spiny spheroids	-	-	+	+	+	14
- tracheids	-	-	+	+	+	14
- tracheids with bordered pits	-	-	-	-	+	14
- angular particles ("blocky polyhedrons"?)	-	-	+	+	+	14
- amorphous sheets	-	-	+	+	+	15
Sponge Spicules	-	-	+	+	+	17
Statospores	-	-	+	-	+	17
Diatoms	-	-	-	-	-	
Other Materials						
Charcoal	tr	+++c	+	tr	+++f	
Crystalline Mineral(s)	+++	+++	+	+	+	

Note: Abbreviations used in Table J-3: "-" absence; "tr" trace amount; "+" presence; "+++" very abundant; "c" coarse or larger particles; "f" fine particles; number values are in percent except in the tall:squat chloridoid ratio. The total number of chloridoid phytoliths observed were 50 in Sample 3, 47 in Sample 4, and 66 in Sample 5; chloridoids were by far the most abundant short cell category observed (each sample's total short cell count was <100). The descriptors "tracheids with bordered pits" and "blocky polyhedrons" is adopted from Bozarth (1993:99).

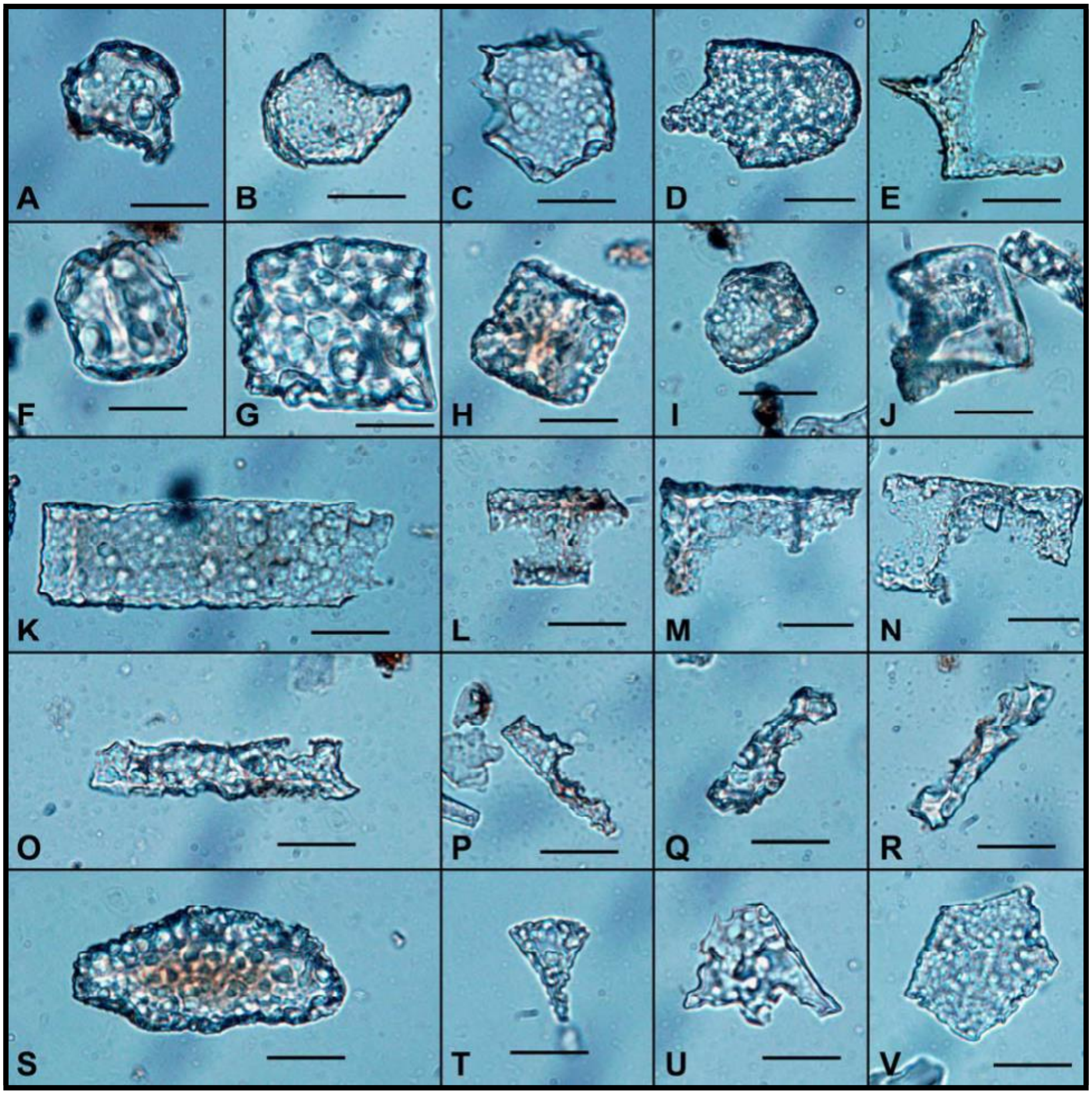


Figure J-13. Bulliform cells and other large phytoliths exhibiting evidence varying degrees of chemical weathering/dissolution (41MS69). Sample 3: specimens in B, H, K, L, Q, S, T, and V. Sample 4: specimens in A, C-E, G, M-P, R, and U. Sample 5: specimens in F, I, and J. (Bar scales are 25 microns. Sample key is in Table J-1).

The basic observations made when scanning and counting a particles on the specimens slides are summarized in Table J-3. The tall to squat saddle ratio is given, as well as the percent of burned short cell types when such were recovered. Although preservation of short cells was poor thus possibly making sample comparisons questionable, there were striking differences in the percent of burned short cell phytoliths recovered. Whether this is evidence of intentional vegetative sampling by the site occupants for use, an indication of some chronologic or seasonal variation, or a simple sampling fluke is unknown.

In addition to short cells, other phytolith forms were also present. The abundant bulliform cells-- the predominant phytolith category recovered in the Samples 3-5--generally showed varying degrees of surface pitting and dissolution (Figure J-12) which is attributed to burial in a harsh soil environment (i.e., basic pH possibly exacerbated by the presence of charcoal). Some specimens were relatively unscathed (Figure J-12: A and F); whereas others showed severe damage to the point of near total dissolution (Figure J-12: E, M, and N), with intermediate degrees of particle damage to other specimens readily apparent. The specimen in Figure J-12:B is interesting in that it looks as if there was an exterior crust on the particle [left end] that has nearly all disappeared leaving the core.

Phytolith forms attributable to trees were also present; although much less abundant than bulliform cells, they were generally better preserved. Specimens of four general particle types were observed (Figure J-14). The only particle morphology with any claims to specificity appears to be the bordered pit cells (Figure J-14: W and X) which are attributed to gymnosperms (Bozarth 1993:99[2]; Hodson et al. 1997:130). Bozarth isolated specimens from Jack Pine needles (*Pinus banksiana*) and white spruce (*Picea glauca*) (1993:98). Hodson (et al. 1997:130) illustrated a specimen isolated from white pine (*Pinus strobus*). Specimens which likely originated from several different species were represented in the 19 tracheid with bordered pits specimens recovered from an ashy stain on a pithouse floor at 41RB112 in the panhandle of Texas (Sudbury 2013a:732). Preparation of several reference gymnosperms revealed bordered pit type phytoliths in Rocky Mountain Juniper (*Juniperus scopulorum*) (ibid. 2013a:742) although they did not match the morphology of the specimens recovered from the archeological site (ibid). Interestingly, bordered pit phytoliths were only observed in Feature 2 (Sample 5) at 41MS69.

Bozarth also illustrates various example "blocky smooth polyhedrons" [Figure J-14: O-T from 41MS69 could be so classified; if correct and if gymnosperm specific, gymnosperms would also be represented in Sample 4], "blocky polyhedrons with grainy surfaces", "elongate polyhedrons", and a "thin long plate with smooth parallel sides and pointed end" from reference gymnosperms (Bozarth 1993:99-100). Only single "ideal" phytolith specimen illustrations were provided rather than showing the morphologic range encountered in different species. More work is needed to clarify the species specificity of these forms and to identify the significant variations in form within a given species.

---

[2] The single specimen illustrated by Bozarth was from Jack Pine, and he stated that "silicified tracheids are formed in only jack pine and white spruce" and are much more common in Jack Pine (Bozarth 1993:98). He examined five conifer reference specimens. The very long well-formed phytoliths with bordered pits reported from the Long View Site (Sudbury 2103:732) and the smaller specimens from 41MS69 are totally dissimilar from those reported by Bozarth (upon inquiry, Bozarth did state that the Long View site specimens did appear to be bordered pit phytoliths (Bozarth personal communication, 2011)). Phytoliths somewhat morphologically similar to the general rectangular bordered pit form were reported in Rocky Mountain Juniper specimens (Sudbury 2013a: 742) but are more reminiscent of the phytoliths in Figure J-14:Y-c). Work processing additional reference botanical specimens-- especially junipers and other conifers--is ongoing. The botanical source of the specimens in Figure J - 14:W-c remains unknown.

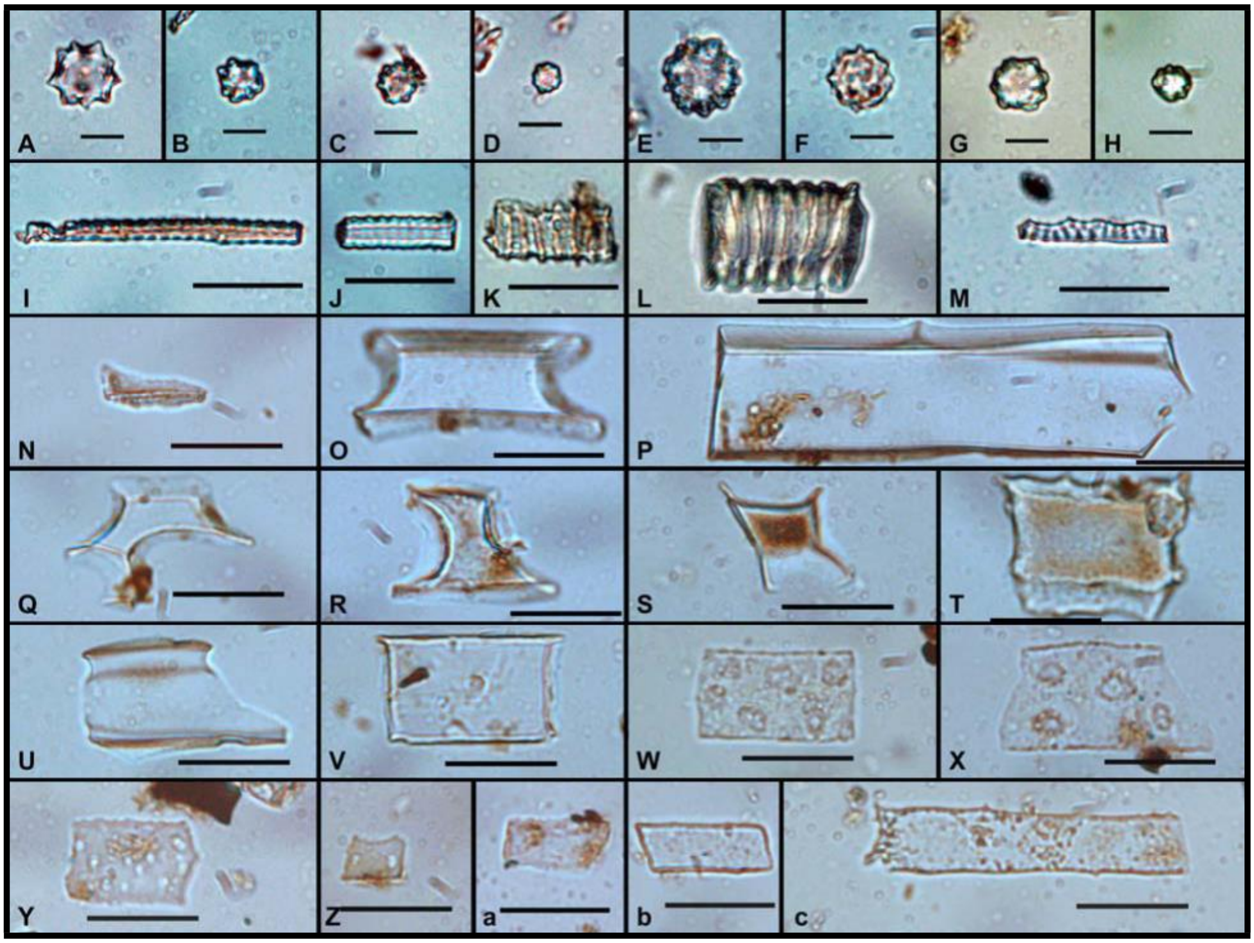


Figure J-14. Tree-related phytoliths (41MS69). A-H: Spiny Spheroids; I-M: tracheid elements [L is bnormally large, but morphologically appears similar to vascular tracheid elements]; N-V: angular particles ("blocky polyhedrons" after Bozarth 1993:99); W-X: tracheids with bordered pits; and Y-c: unidentified biogenic particles of reminiscent in overall morphology to bordered pit phytoliths. Sample 3: A-D, I-J, and N; Sample 4: E-G, K-L, and O-U; and Sample 5: H, M, and V-c. (Bar scales: samples A-H (10 microns) and I-c (25 microns. Sample key is in Table J-1).

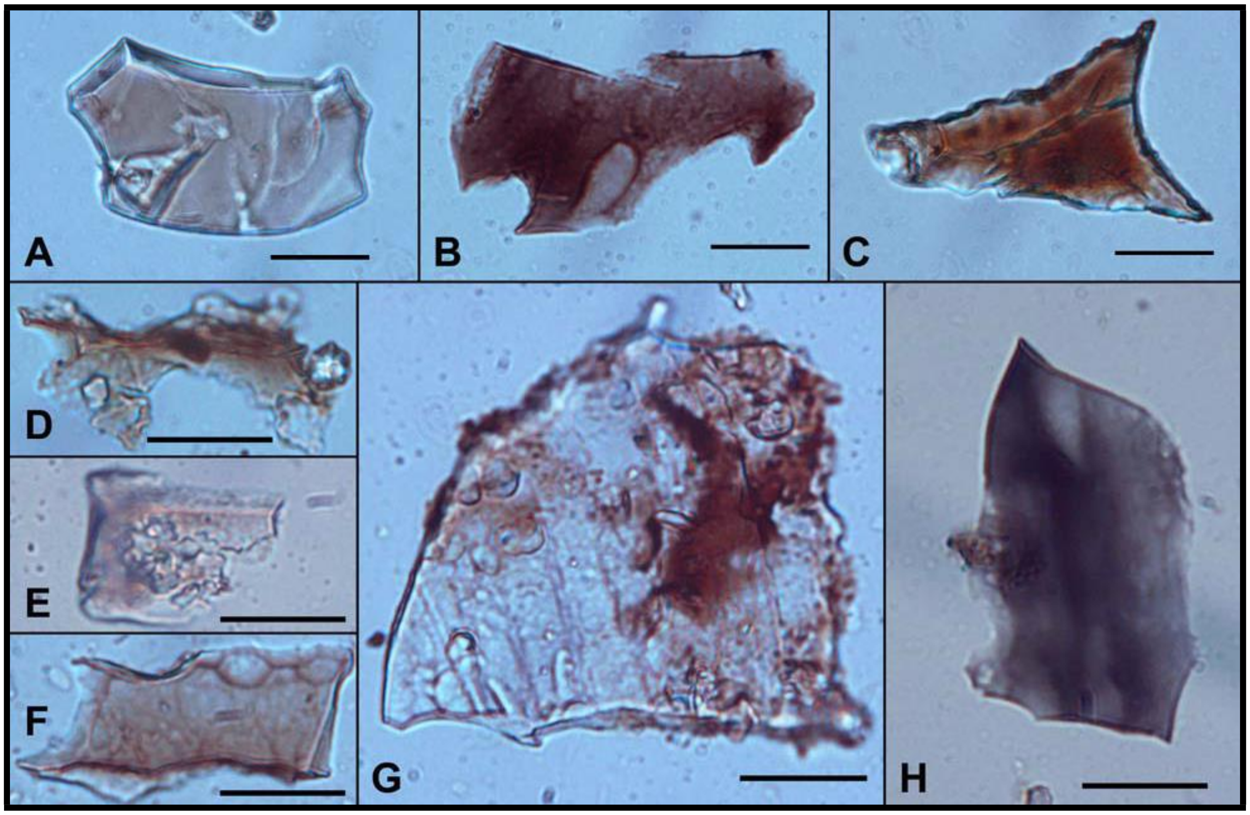


Figure J-15. Burned amorphous masses of silica (41MS69). Sample 3: A-D; Sample 4: E, G, and H: and Sample 5:F. [Specimens A, E, and F may be misshapen "angular" tree-related phytoliths or burned polyhedral cells rather than amorphous masses.] (Bar scales are 25 microns. Sample key is in Table J-1).

Figure J-16. Cucurbit phytolith from 41MS69 Sample 4. (Sample key in Table J-1).

Figure J-17. Unidentified phytoliths of potential interest (41MS69). Sample 3: D-F, H, I, O, T, and U. Sample 4: B, C, G, J-N, Q, and R. Sample 5: A [twin crystalline material at in the lower left corner], P, S, and V. (Bar scales are 10 microns. Sample key is in Table J-1).

Some amorphous silica deposits that appear to be molten sheets or "globs" were also observed in all three feature samples (Figure J-14). The dark coloration suggests that they were heated to a very high temperature in the presence of organic matter. The linear striations in Figure J-14G may be traces of residual cell outlines.

One small spherical phytolith from a wild gourd was found in these samples; it was found in Feature 1 (Sample 4) (Figure J-16).

A variety of unknown phytolith forms were also encountered; some are illustrated in Figure J-17. The specimen in Figure J-17:D--fused phytolith cells--appears to have partially melted enough to stick together, but was not heated long and/or hot enough to become a nondescript amorphous sheet such as those in Figure J-15[3]. The unknown specimen in Figure J-17:B shares some of the properties of both the angular and bordered pit phytoliths illustrated in Figure J-14; it remains unidentified. The twinned crystal in Figure J-17:A (lower left corner) is present in low concentration in several samples. It is not known if this is a real sample inclusion or a processing artifact caused by soluble ions released from the carbonate-laden silt fraction during flotation which then recrystallized when the samples were dried. Research on this crystalline material is ongoing. Other odd phytolith forms encountered during this study are also illustrated.

---

[3] This particle type has not been frequently reported from soil samples in the past. Many laboratories follow old protocols that call for initially sieving the disaggregated soil to remove the sand fraction (> 50 microns) leaving the silt and clay fractions together for further processing and phytolith recovery. Thus, large > 50 micron particles such as those in Figures J-12-16 would be left in the sand fraction and overlooked when following established standard laboratory protocols. Although Bozarth illustrated larger reference phytoliths, many laboratories sample processing methods continue to preclude their recovery when present.

J.6 DATA—SPONGE SPICULES

Sponges live in freshwater streams and bodies of water across North America. When recovered from a soil environment, sponges are identifiable to species [and thus are especially useful in environmental interpretation since difference species thrive in different aqueous habitats] based on their reproductive spicules. No reproductive spicules--which are called gemmoscleres--were observed in the 41MS69 samples. The recovered sponge spicule specimens are shown in Figure J-18.

However, sections of the larger linear structural spicules which form the physical support network for sponges were recovered (Figure J-18:A-U). The two spicule types that make up the structural network of sponges are known as meglascleres and microscleres based on their relative size. The two types overlap dimensionally between different sponge species, so it is uncertain to which category the recovered spicules belong. No spiny spicules were observed; all of the recovered specimens were smooth.

There are a number of ways spicules could be incorporated in site sediment samples. These include aeolian transport, overbank flood deposits, intentional water usage at the site, and being introduced via offal or excrement. The specimen in Figure J-18:C shows considerable surface abrasion, which could be the result of aeolian or alluvial deposition. The surfaces of the other specimens do not show evidence of heavy abrasion or wear on broken ends; thus they may be specimens which originated locally. Several specimens show some evidence of likely chemical (soil pJ- induced) weathering; the left ends of the specimens in Figures J-18:E and J-18:L show evidence of dissolution. None of the other specimens show evidence of extreme chemical weathering.

Spicules were most abundant in Sample 4 (14 specimens) followed by Sample 3 (6 specimens) and Sample 5 (1 small specimen) (Figure J-18). The most spicules and the longest spicule sections were observed in Sample 4. The ends of the spicules in Sample 4 generally demonstrate fresh breaks which suggests minimal transport and abrasion. Of these three samples, based on both number and preservation, the spicule data from Sample 4 is most indicative of intentional water usage on site.

The best detailed ecological overview of sponges remains that by Harrison (1974) while the best recent illustrated freshwater sponge spicule summary overview is that by Reiswig et al. (2010). A recent illustrated sample provided from a paleoenvironmental point of view is also available (Sudbury 2011c).

J.7 DATA—STATOSPORES

When desiccated, Chrysophycean algae form protective siliceous cysts and go dormant while waiting for improved moisture conditions. These Chrysophycean cysts are commonly referred to as statospores in the archeological literature. On an archeological site, statospores may indicate a formerly wet area which has dried with the parent algae present. Alternatively, statospores may have been transported to the site as cysts. Specimens were found in Samples 3 and 5 at 41MS69 (representative examples in Figure J-19).

All of the 41MS69 statospores are very small and rather uniform in appearance. When identified to species, specimens do convey information about their specific water environment. However, identification is normally performed based on detailed Scanning Electron Micrograph images--a technique which is not available at JSE Laboratories. The two available particle atlases are the best statospore summary literature available (Duff, Zeeb, and Smol 1995; Wilkinson, Zeeb, and Smol 2001).

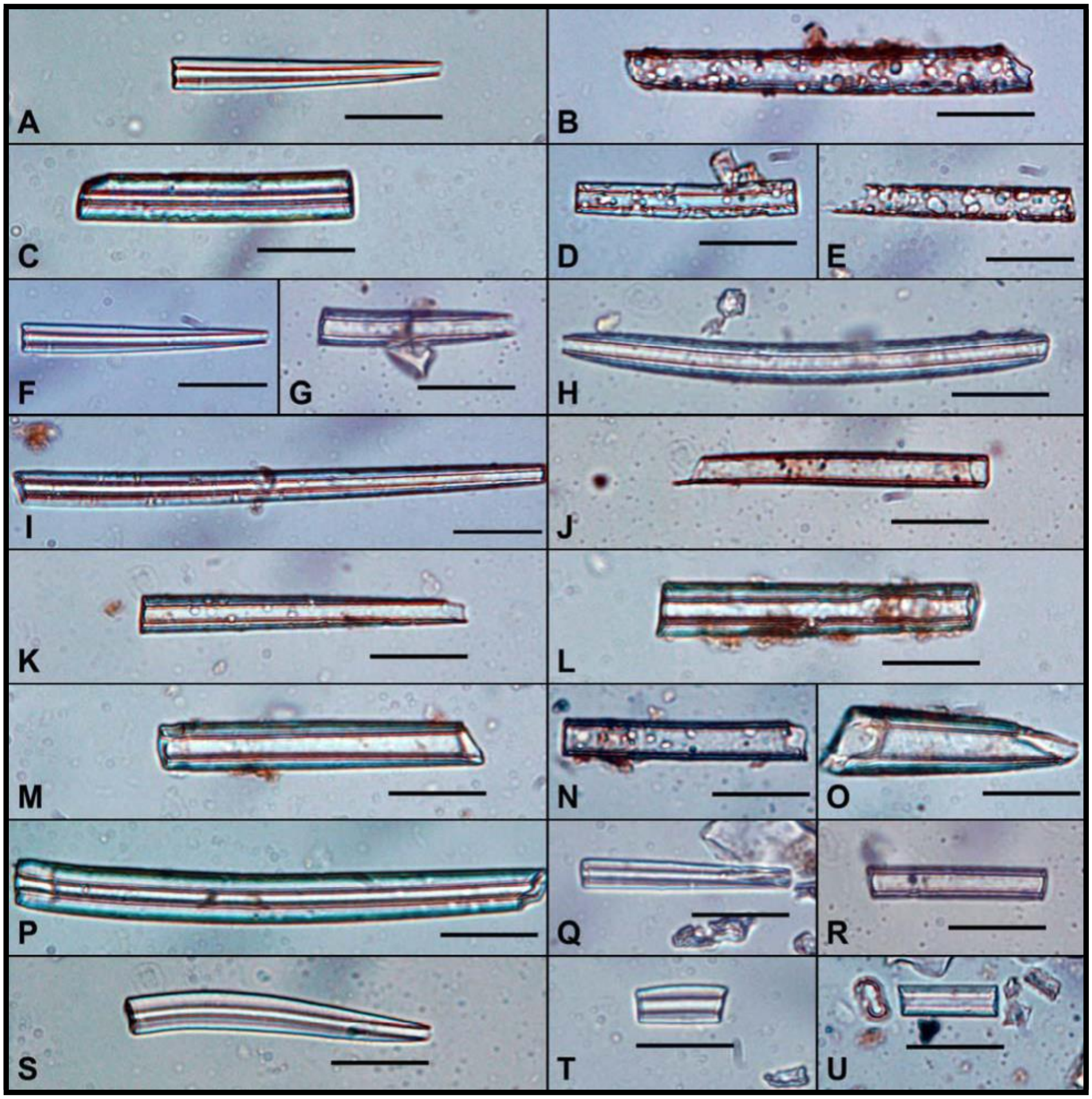


Figure J-18. Sponge spicules recovered from 41MS69 sediment samples. Sample 3: A-F; Sample 4: G-T; and Sample 5:U. (Bar scales are 25 microns. The sample key is in Table J-1).

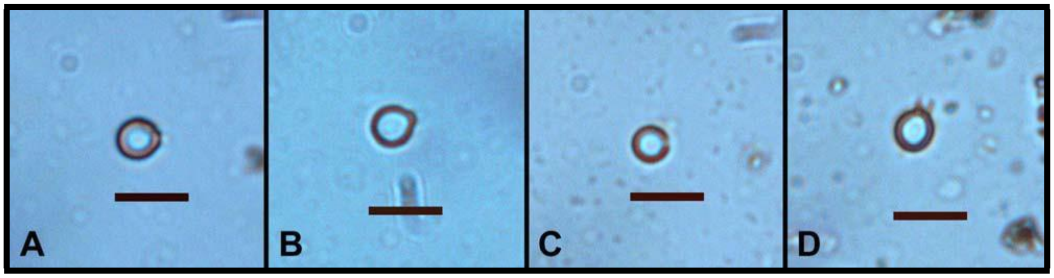


Figure J-19. Statospores recovered from 41MS69 sediment samples. Sample 3: A-B; and Sample 5: C-D. (10 micron bar scales. The sample key is in Table J-1).

J.8 DISCUSSION—SOIL ENVIRONMENT

Overall, biogenic silica preservation at 41MS69 was poor. This is attributed to chemical dissolution due to basic soil pH and the presence of high carbonate concentration in the soil. Information regarding the physical and chemical causative factors leading to biogenic silica dissolution have been recently summarized (Sudbury 2014a) and were previously addressed by Piperno (2006:21-22) and others. Several major contributors to poor phytolith preservation include a basic soil pH, the loss of protective ions from the silica surface, particle size, and relative particle density. Other likely contributors appear to be the presence of charcoal, and periodic soil wetting which dilutes the soil pore water's silicon concentration encouraging additional biogenic dissolution (i.e., shifts the chemical equilibrium).

Phytolith preservation issues have been encountered at three central and south central Texas sites; the soil information for those sites taken from the soil web survey is summarized in Table J-4. All three sites have high carbonate content soil, with 41MS69 having the highest concentration and also exhibiting the poorest phytolith preservation. All three of the sites in Table J-1 are on active stream banks or, in the case of 41TV2161, on a visible paleochannel (Sudbury 2014a, 2014c).

Table J-4. Site Soil Types and Carbonate Content (via USDA OSDs).

Site Number	41MS69	41BL278	41TV2161
Soil Name (typical texture)	Oakalla (silty clay loam)	Venus (loam)	Lewisville (silty clay)
Soil Classification (Taxonomic Class)	Fine-loamy, carbonatic, Thermic Cumulic Haplustolls	Fine-loamy, mixed, superactive, thermic Udic Calciustolls	Fine-silty, mixed, active, thermic Udic Calciustolls
Average CO3 Equivalent	40-60%	15-40%	20-40% [at 10-40"]
Calcic Horizon (>15% CO3)	-	14-60" (Bk or K)	16-62" (Bk)
Cambic Horizon	Ap, Ak1 (33%; 0-6"); Ak2-Bk1 (41%-~50%; 16-53")	-	-
Parent Material/ Base Residuum	Formed in loamy calcareous alluvium derived from limestone of Cretaceous age	Formed in loamy calcareous alluvial sediments of Pleistocene age	Formed in ancient loamy and calcareous sediments
Flood Plain	Flood plains of perennial streams in river valleys	Stream terraces and foot slopes of valleys	Upland, along major streams
Comment	PZ has 33% calcium carbonate equivalent	PZ also contains some CO_3	PZ also contains some CO_3
Soil Type Location Average Rainfall/Mean Temperature	24-34", 64-70ºF	28-40"; 62 69ºF	28-38"; 66ºF
Thornthwaite P-E index	36-46	44-64	44-66

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Electronic document, https://soilseries.sc.egov.usda.gov/, accessed August 3, 2014 and August 11, 2014.

The USDA Official Soil Description includes the following comments about Oakalla soil:

1. The "Diagnostic horizons and features recognized in this [Oakalla] pedon are: Mollic epipedon: 0 to 58 cm (0 to 23 in.) (A and Ak horizons) Cambic horizon: 58 to 203 cm (23 to 80 in.) (Bk horizons)"
2. "Other features: Some pedons have Ab horizons below 76 cm (30 in.)."
3. "The soil floods at 1 to 10 year intervals" (Oakalla OSD [see footnote 6])

By definition, a cambic horizon is "a non-sandy, mineral soil horizon that has soil structure rather than rock structure, contains some weatherable minerals and is characterized by the alteration or removal of mineral material...." (Schaetzl and Anderson 2005:747). A calcic horizon, such as that encountered at 41BL278 and 41TV2161, is "a mineral soil horizon of secondary carbonate enrichment that is >15 cm thick, has a $CaCO_3$ equivalent of >150 g kg^{-1}, and has at least 50 g kg^{-1} more calcium carbonate equivalent than the underlying C horizon." (ibid. 2005:746)

As noted in Table J-2, weight percent phytolith recovery was very low at 41MS69. For comparison, the phytolith soil content of the three carbonate-containing Texas sites in Table J-4 is compared to that of two non-calcic/non-cambic Oklahoma site soil profiles--one of which contains low levels of calcium carbonate--and both of which include a similar age ca. 5100 B.P. cultural deposit in their profile with excellent phytolith recovery (Table J-5). Site 41MS69 is the only one of these sites that had some samples which contained no biogenic silica.

Winsborough (2014) recently reported that diatoms were concentrated in carbonate deposits at 41TV2161, whereas the regular soil matrix was relatively void of diatoms. She indicated that the diatoms were apparently feeding on organic matter associated with the plant roots. The metabolism of bacteria in this microenvironment is what releases the CO_2 via respiration which reacts with the soil calcium to form calcium carbonate deposits around the roots (Bouchardt 2002:715). These deposits visibly formed around in the rhizosphere (see 41MS69 root casts illustrated in Figure J-4), and engulfed the feeding diatoms. As diatoms were not preserved in the basic soil matrix, Winsborough wisely tested the carbonate fraction and found an entombed sample of the target horizon's diatom assemblage.

The carbonate component of the sand fractions isolated during phytolith extraction has not been tested for phytolith content. It is likely that phytoliths deposited in the soil that became the root zone are preserved isolation. Thus, the carbonate-containing sand fractions in the carbonate.

Table J-5. Relative Phytolith Isolate Concentrations at Five Recent Study Sites.

Site Number	Phytoliths, Avg. Wt. % in Soil	Phytolith, Wt. % in Soil	N =	Soil Carbonate Content	Fraction from which CO_3 was removed
41MS69	0.04 %	0.03 - 0.05 %	5	Cambic	Phytolith isolate
41BL278	0.05 %	0.03 - 0.07 %	4	Calcic	Phytolith isolate
41TV2161	0.10 %	0.04 - 0.16 %	24	Calcic	Silt fraction
41TV2161	< 0.18 %	<0.07 - 0.53 %	12	Calcic	not neutralized
34WO69	2.58 %	0.80 - 4.11 %	24	Trace Carbonate	not neutralized
34NW132	1.62 %	0.46 - 4.60 %	25	nil	NA

However, phytoliths may not be as concentrated as the diatoms since the phytoliths were inanimate rather than actively feeding as were the diatoms. The 41MS69 carbonate residues are potentially useable for diatom analysis or δ^{13} analysis, as well as for carbon dating or phytolith are being retained pending determination of their best utilization if it is determined that additional work is needed on these samples.

Samples 1 and 2 depths (Table J-2) explain their soil textural characteristics relative to that of Samples 3-5 (Table J-2, Figure J-2). Texturally, deeper origin Samples 1 and 2 were lower in sand content, and higher in both silt and clay fraction components than the other three samples, and did not contain any biogenic silica particles. Their higher silt and clay content may be due to higher concentrations of fine carbonate-related particles in the silt and clay size. This particle size difference in turn supports the observed absence of biogenic silica in those two samples as their pH was likely more basic (and/or the soil had more basic buffering capacity), which led to complete biogenic silica dissolution. The other three samples contained two times as much sand (or more) and thus contained less of the finer (higher surface area) silt and clay size particles. As the shallower Samples 3-5 produced low levels of biogenic silica particles (Table J-2), this textural/presumed compositional difference in a cambic soil apparently may be able to affect biogenic silica preservation. Even with high carbonate soil, there does appear to be a threshold effect as some horizons permitted partial biogenic particle survival. However, the visible particle weathering (Figures J-12-13), differential degrees of weathering, and overall low short cell phytolith recoveries imply that the phytolith assemblage from 41MS69 is likely incomplete.

In particular, particle counts of the very important Poaceae short cell phytoliths were too low to use in making a statistical assessment of the climatic signature in any of the samples from 41MS69. The weathering apparent in the sample phytoliths is likely chemical-based (i.e., partial [c.f., Figure J-12:J-K, Q-V, and AA] to complete dissolution), raising the possibility that differential particle dissolution may have occurred. Potential causes of this phenomenon in basic pH soils based on laboratory investigations of biogenic silica in simplified aqueous solutions was presented in detail by Iler (1979) as recently partially summarized by Sudbury (2014a). Thus, the short cell count data, and an environmental interpretation are not being made as the data set is deemed to likely be incomplete. The larger bulliform cells with a much smaller surface to volume ratio than the short cells tended to survive better although they too showed significant evidence of chemical degradation on their surfaces (Figure J-13). Several of the large tree origin phytoliths appear to show slight evidence of surface weathering (c.f., Figure J-14:O, R, and T). In contrast, the sponge spicules generally did not show significant evidence of chemical degradation (Figure J-18) while the statospores were too small to clearly evaluate surface preservation (Figure J-19). Diatom frustules, with their very large surface area to total silicon content were totally absent in all five samples, implying complete dissolution. In the previously mentioned 41TV2161 diatom study, diatoms were essentially absent in the calcic soil matrix, but were abundant in tested carbonate root casts which had encased diatoms protecting them from dissolution processes (Winsborough 2014). The carbonates are likely very old, having formed at the time the site vegetation was dying.

J.9 DISCUSSION—SAMPLE DATA COMPILATIONS

Sample 1 (224-228 cmbs). Clay loam (Figure J-2), no phytoliths or other biogenic silica observed. Significant carbonate load visible in the sand fraction (Figure 4:F). Some snails present (Figure J-5:A-C). Lithic flake debris (Figure J-7:A-D) and quartz shatter (Figure J-8:A-F) present. No hackberry seeds observed. Some fossils including marine spicules [carbonate] observed in the sand fractions (Figure J-10:A-D), as well as shell fragments (Figure J-11:A-B). A trace amount of charcoal noted (Table J-3). The primary component of the "phytolith" isolate-- which partially reacted with 10% HCL--was mineral particles (Table J-3).

Sample 2 (395-398 cmbs). Clay loam (Figure J-2), no phytoliths or other biogenic silica observed. Significant carbonate load visible in the sand fraction (Figure J-4:A-E). Some snails present (Figure J-5:D-F). Lithic flake debris (Figure J-7:E-F) and quartz shatter (Figure J-8:G-P) present. No hackberry seeds observed. Some fossils including marine spicules [carbonate] observed in the sand fractions (Figure J-10:F-G), and a possible piece of burned bone (Figure J-11:C). Abundant charcoal particles were noted (Table J-3). The primary component of the "phytolith" isolate-- which partially reacted with 10% HCL--was mineral particles (Table J-3).

Sample 3 (151-153 cmbs; Feature 1). Loam (Figure J-2), biogenic silica recovered (phytoliths, sponge spicules, and statospores; no diatoms (Table J-3). Only one snail observed (Figure J-5:G). Some lithic flake debris (Figure J-7:G-H) and quartz shatter (Figure J-8:Q-Z) present with several specimens exhibiting conchoidal fracture (Figure J-8:S, U, and X). Two burned hackberry seed fragments noted (Figure J-9:A). Unidentified black granular-appearing particle observed (Figure J-10:H). No bone fragments noted.

Short cell phytoliths present from all three grass subfamilies in low quantities with chloridoids predominant (Figure J-12; Table J-3). One-third of the Panicoid lobate phytoliths recovered were burned (Table J-3 [very low particle count]). Relative incidence of burned squat to tall chloridoid phytoliths was about 2:1 (Table J-3).

Tree phytolith evidence present (spiny spheroids, tracheids, and angular [blocky polygon] phytoliths (Table J-3; Figure J-14:A-D, I-J, and N). No tracheids with bordered pits were observed (Table J-3). Large burned amorphous masses of biogenic silica present (Figure J-15:A-C) suggestive of a hot fire. No cucurbit phytoliths noted. Unusual unidentified phytolith forms also noted (some examples shown in Figure J-17:D-F, H, I, O, T, and U). Six sponge spicule sections noted (Figure J-18:A-F), one with physical abrasion suggestive of transport/movement (Figure J-18:C) and at least one showing some evidence of chemical dissolution (Figure J-18:E, left end). A few statospores were noted (examples shown in Figure J-19:A-B).

Sample 4 (134 cmbs; Feature 1). Loam (Figure J-2), biogenic silica recovered (phytoliths and sponge spicules; no statospores or diatoms (Table J-3). Large snail assemblage (Figure J-5:J-N). One lithic flake noted (Figure J-7:I) and quartz shatter (Figure J-8:A-E) present. One half unburned hackberry seed fragment noted (Figure J-9:B). One marine spicule fragment and half of a small bivalve (?) noted (Figure J-10:I-J). No bone fragments observed.

Short cell phytoliths present from all 3 grass subfamilies in low quantities with chloridoids predominant (Figure J-12; Table J-3). Twenty-nine percent of the Panicoid lobate phytoliths recovered were burned (Table J- 3 [very low particle count]). Relative incidence of burned squat to tall chloridoid phytoliths was about 5:1 (Table J-3) which is the opposite of the total tall:short ratio of 4.9:1 possibly suggestive of selective fall botanical processing.

Tree phytolith evidence noted (spiny spheroids, tracheids, and angular phytoliths (Table J-3; Figure J-14:E-G, K-L, and O-U). No tracheids with bordered pits observed (Table J-3). Large burned amorphous masses of biogenic silica present (Figure J-15:D, E, and G), suggestive of a hot fire. A single cucurbit phytolith noted (Figure J-16). Unusual unidentified phytolith forms also noted (some examples shown in Figure J-17:B, C, G, J-N, Q, and R). Fourteen sponge spicule sections noted (Figure J-18:G-T), exhibiting minimal physical abrasion suggestive of minimal transport; only one specimen shows some evidence of chemical dissolution (Figure J-18:J, left end). One complete or nearly complete spicule (Figure J-18:H), several very long spicule sections (Figure J-18:I and P), and the high spicule abundance are possibly indicative of water use at the site. No statospores observed.

As statospores form when algae dries out, their absence and the abundance of spicules in this sample suggests the strongest water signature at the site of these five samples.

Sample 5 (177 cmbs; Feature 2). Sandy clay loam [very nearly loam] (Figure J-2), biogenic silica recovered (phytoliths, sponge spicules, and statospores; no diatoms (Table J-3). Large snail assemblage (Figure J-6:A-J). Relatively abundant lithic flake debris (Figure J-7:J-U) with quartz shatter also present (Figure J-8:A-F)--including one specimen exhibiting conchoidal fracture (Figure J-8:i). Eight hackberry seed fragments were noted, of which three were burned (Figure J-9:C-D). Unidentified black granular particle observed (Figure J-10:K) as well as one fragment of the oogonia of a Charophyte (Figure J-10:L). Two bone fragments noted (Figure J-11:D-E).

No burned panicoid lobates present (Table J-3 [low count]) and only a trace (2%) of burned tall chloridoids were noted with no burned squat chloridoids (Table J-3). Extremely low burned phytolith incidence. The Sample 5 acid treated phytolith isolate was loaded with charcoal fragments (Figure J-20); 1,238 charcoal fragments were observed during the count scans that recorded 73 short cell phytoliths. The high charcoal content likely implies high wood ash concentration which would further negatively impact soil matrix pH issues at that level as well as down profile.

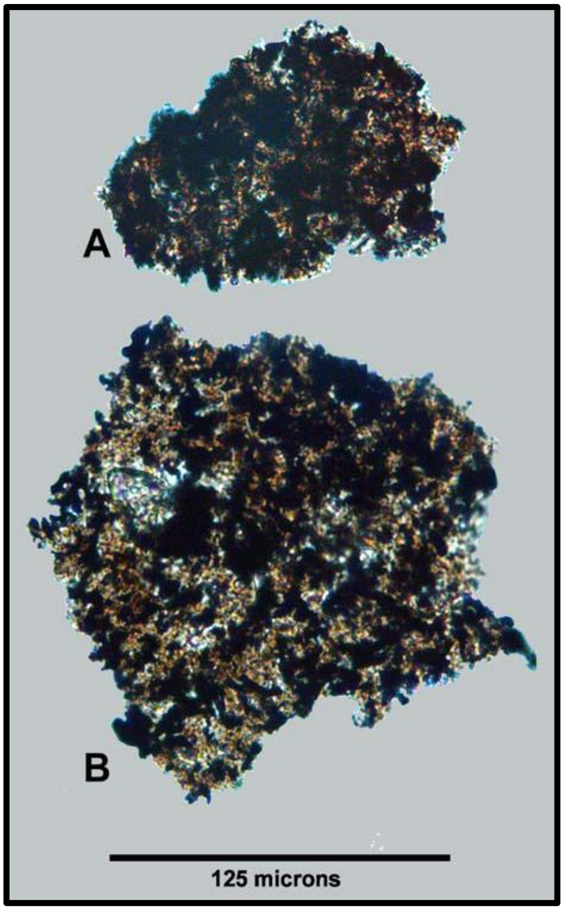


Figure J-20. Phytolith isolate from Sample 5 (41MS69). Several particle conglomerates from the phytolith isolate that survived gentle crushing and mixing prior to slide mounting, which illustrate the very high charcoal load in this sample. Abundant charcoal was also observed in the sand fraction (Figure J-1:5).

Tree phytolith evidence noted (spiny spheroids, tracheids, and angular phytoliths (Table J-3; Figure J-14:H, M, and V). Bordered pits phytoliths observed indicative of gymnosperms; these were only noted in Sample 5 (Table J-3; Figure J-14:W-X). Possible molten mass of biogenic silica present (Figure J-15:F) suggestive of a hot fire. No cucurbit phytoliths noted. Unusual unidentified phytolith forms also noted (some examples shown in Figure J-17:A, P, S, and V). Only one very small sponge spicule section was noted (Figure J-18:U). A few statospores noted (examples shown in Figure J-19:C-D).

J.10 DISCUSSION OF SAMPLE DATA

Based on recoveries at 41MS69, biogenic silica preservation in a cambic horizon soil is very poor. In the two deepest samples (224-228 and 395-398 cmbs) preservation was zero--no biogenic silica survived. Preservation in the other three samples studied (134 cmbs, 151-154 cmbs, and 177 cmbs) was poor but some biogenic silica particles did survive. The best preserved specimens were freshwater sponge spicules which were most abundant in Sample 4 (134 cmbs). Diatoms were totally absent in all five sample preparations. Statospores--which form during drying episodes--were present in very low levels in Samples 3 and 5.

Phytoliths were present in all three of the most recent (Samples 3-5), with variable degrees of preservation which tended to at least in part to correlate with relative particle size. The large bulliform cells tended to be well-represented at least in Samples 3 and 4; they were somewhat less abundant in the deepest productive Sample 5 (177 cmbs); they were partially degraded via chemical weathering in all samples. On the other hand, the generally much smaller Poaceae short cell phytoliths appear to likely be under-represented with the hot dry weather chloridoid form being the most abundant form remaining of the three major grass subfamilies (Table J-3). Chloridoid phytolith content can be very high in an upland prairie setting (up to 80+% of the total short cell count [Figure J-20]) but in a riparian setting the abundant environmental water generally significantly lowers the overall sample saddle phytolith content relative to other particles from species concentrated around the waterway. It is for that reason--and the apparent overall poor phytolith preservation--that it is felt that the short cell phytolith data sets from 41MS69 are incomplete/skewed due to differential particle dissolution. [Representative phytolith short cell distributions are covered in some detail elsewhere (Sudbury 2011a).]

Burned short cell phytoliths were observed in very low total numbers at 41MS69. Burned panicoids were absent in Sample 5 (177 cmbs), but comprised about 30% of the panicoid specimens in the other two feature samples (3, 151-154 cmbs and 4, 134 cmbs [Table J-3]). The two primary cultural activities that would result in burned short cells are use as tinder or fuel for a fire, or from processing grasses for utilitarian use (food and/or other applications). Panicoid plants have the largest biomass of the three grass subfamilies with significant short cell phytolith assemblages, and would represent available dry fuel throughout the fall and winter. Alternatively, Panicoid processing for food would likely occur in the late summer or fall as the plants mature. Other possible sources of burned phytoliths are aeolian contribution via an upwind fire, and alluvial redeposition from a burned landscape.

Chloridoid species which produce the saddle-shaped phytoliths (Figure J-12:V [right]-AA) are low biomass hot dry weather plants. Thus, gathering for food and fuel would also occur as for the Panicoids--in late summer and fall, with biomass gathering through the winter months. The opposite direction difference in saddle morphology ratios between burned and non-burned saddles in Sample 4 suggests that plants with squat (short) saddles were intentionally being concentrated. This trend was only noted in Sample 4 where the burned squat saddle percentage concentration was very high (Table J-3). This data could be interpreted as indication of fall gathering activities.

Overall, tall chloridoid phytoliths outnumbered squat chloridoids by ~ 3:1 to 5:1 (Samples 3-5 in Table J-3). In the Opossum Creek soil profile, the horizontal [x-axis] variability defined by this ratio correlated with some vegetation variation in the riparian setting over time. The actual upland chloridoid prairie site sample (red square in Figure J-21) was predominantly squat saddles, and the overall phytolith sample was comprised

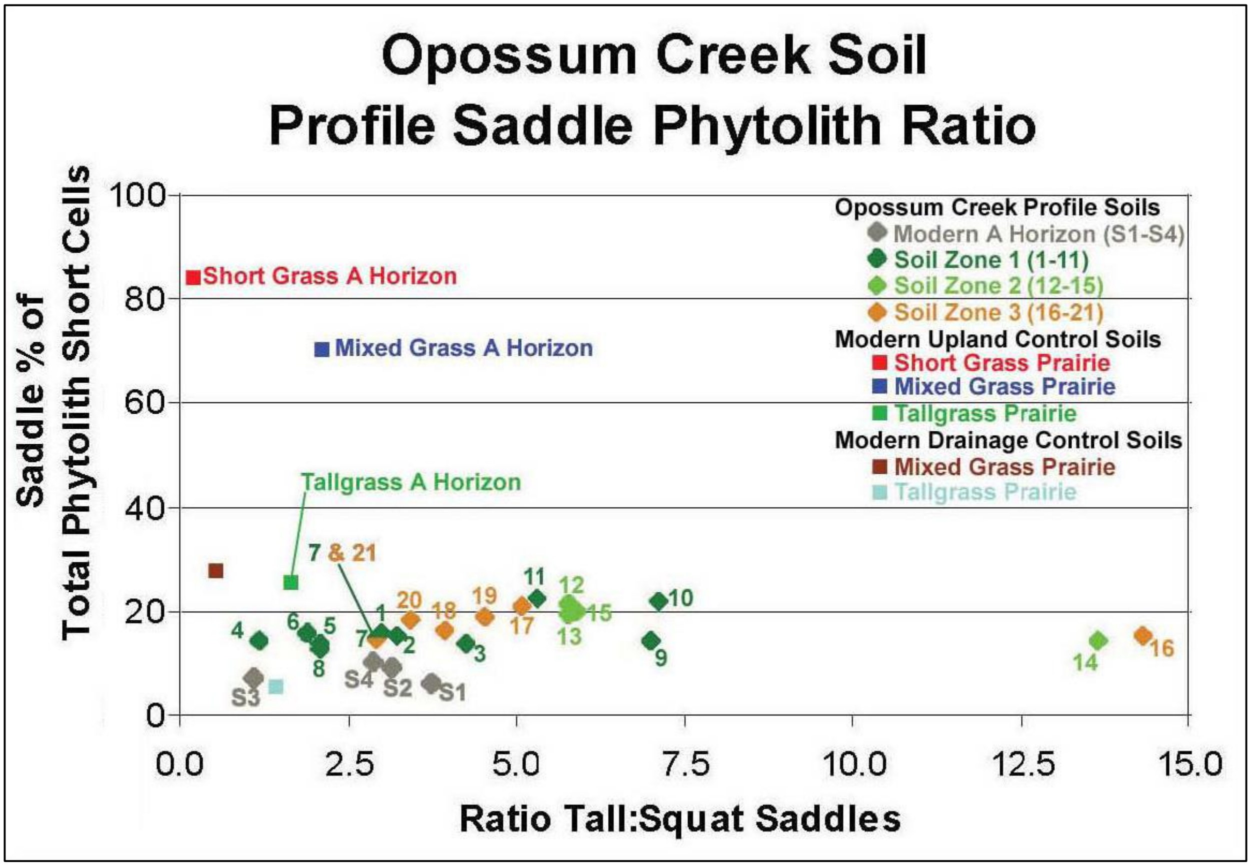


Figure J-21. Saddle phytolith plot of soil profile samples from riparian setting on Opossum Creek-a minor tributary of major stream in northeastern Oklahoma (reproduced from Sudbury 2011b:20 Figure 16 with permission). The three upland control prairie sites and two drainage control soils are in Oklahoma. The mixed grass drainage soil is situated in a small steep gradient drainage, whereas the tallgrass drainage area is much larger and the stream is lower gradient.

predominantly of saddles (82%). However, the buried A horizons in the soil profile at the upland control prairie site--Bull Creek (34BV176)--exhibited considerable variation in their saddle ratio signatures (Figure J-22). Whereas the riparian setting plot was restricted primarily to movement along the x-axis (presumably due to the regular increased available moisture in the riparian setting [Figure J-21]), the drier upland site showed significant movement in both x and y directions during the Holocene. Concurrent analysis of the pollen signature from the same Bull Creek buried soil samples revealed that the plant assemblage at the site varied during development of this stacked series of buried soils as different species slowly became more or less prominently represented on the local landscape over time (Bement et al. 2007)--almost certainly due to changing climatic conditions. Thus, the variations in the saddle plot based on percent of total short cell composition (y-axis) and the tall:squat ratio (x-axis) are due to actual vegetative changes on the landscape--which is a response to changes in climate (i.e., temperature and moisture). Note that the Bull Creek samples were from a soil profile sampling the native landscape over time, whereas the 41MS69 samples are from different age cultural features whose contents may have been selectively modified during resource gathering.

As the total short cell assemblage at 41MS69 is suspected to be incomplete due to soil pH dissolution issues, only the x-axis ratios (i.e., saddle morphology ratio ["tall:squat"]) are felt to be discernable from the 41MS69 data. For this reason, the tall:squat ratios are provided (Table J-3), but the saddle plot was not prepared as the presumed incomplete 41MS69 data set does not provide reliable y-axis information. The x-axis values imply at least some climatic fluctuation between samples--or a cultural change in gathering activities since the samples were all feature-related--resulting in some vegetative differences [the samples plotted in Figures J-21 and J-22 were collected from soil profiles].

The normal x-axis range of variation at any given time has not been determined, but the tallgrass prairie replicate surface control data set presented elsewhere indicates that local variation along the x-axis can occur within a 50 meter circular area (Sudbury 2011a:178); even in the upland tallgrass prairie setting, that species variation was subsequently noted to be due to differences in localized water availability (Sudbury personal observation). Thus, different environmental niches even on an upland area landscape may produce a different plant community composition and thus different x-axis values at the same time. In that tallgrass prairie example, even though the morphologic saddle ratio changed for a few samples (x-axis, tall:squat ratio), the y-axis values remained relatively constant for the entire sample set (modern A-horizon of a virgin tallgrass prairie).

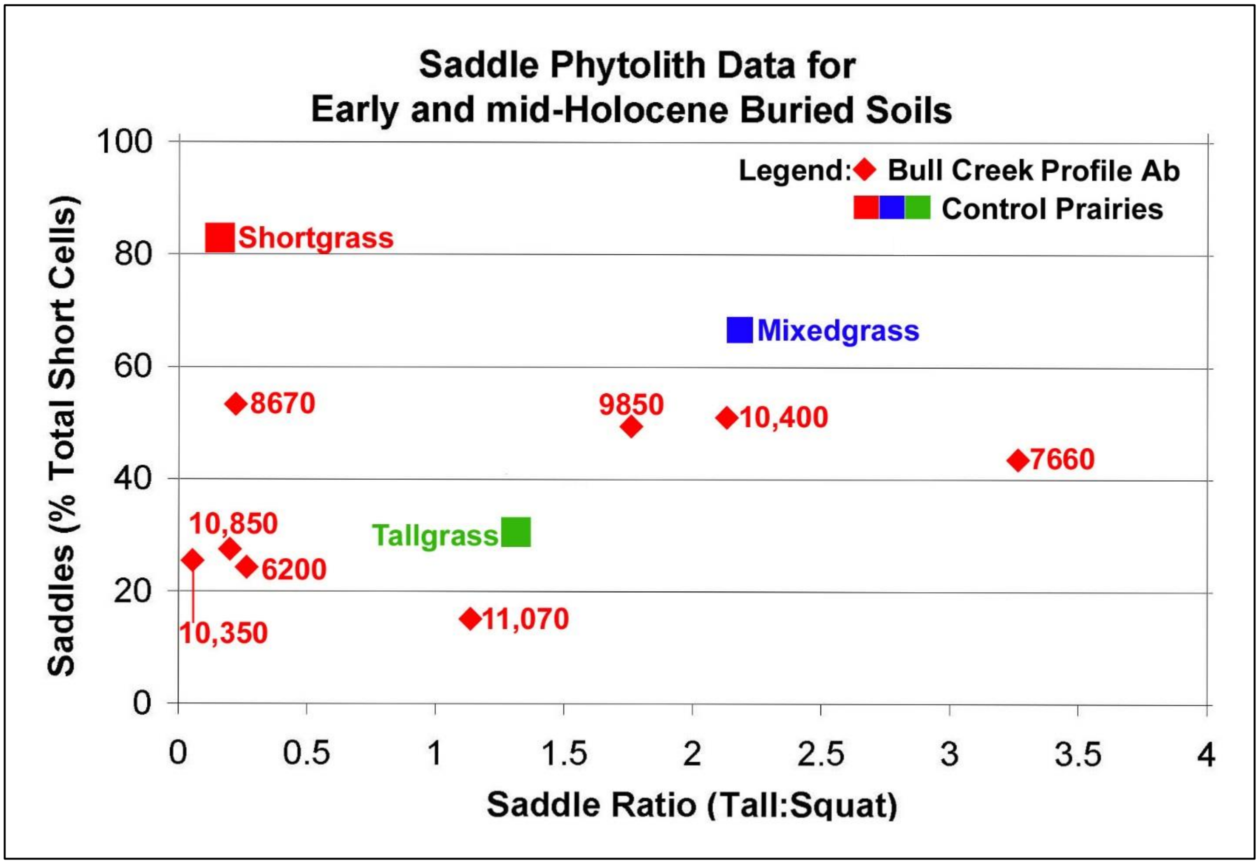


Figure J-22. Saddle ratio variability in a current upland prairie setting soil profile during the Holocene. Data based on a study of a stacked series of buried soils dated from 10,850 B.P. to 6200 B.P. at the Bull Creek Site (Bement et al. 2007). The shortgrass control prairie soil [red square] is the modern surface at this study site (34BV176). (Reproduced from Sudbury 2014b).

J.11 SUMMARY

The two deepest samples, from geomorphic Zone 8 and Zone 11 (395-398 and 224-228 cmbs) were completely devoid of any biogenic silica particles. Biogenic silica particles were present in the other three soil samples which were associated with Features 1 and 2 dated to ca. 5100 B.P. The cambic character of the Oakalla soil (i.e., high carbonate content and basic pH) was suggested as the main causative factor of the poor biogenic silica preservation at the site. The relatively sandier texture of the three more recent samples may in part be due to additional fine carbonate-related particles having been translocated to and/or formed in the two deeper sample strata.

Biogenic silica was recovered from the three feature samples, but the phytolith assemblage appears to be incomplete--likely due to partial dissolution caused by the basic pH soil environment. No diatoms were recovered from any samples--they were presumably lost to dissolution. Sponge spicules were well-preserved in all three feature samples, and a few statospores were observed in two of the samples. Sample 4 (134 cmbs) contained the most spicule fragments and the most large spicule fragments, which may be indicative of water use at the site. Statospores were absent from Sample 4.

Phytolith preservation was variable, but overall poor; the recovered assemblage is tilted toward larger particles with a lower surface area to volume ratio which is conjectured to result in a slower rate of particle dissolution. Many of the large phytoliths, such as bulliform cells, showed surface weathering and pitting suggestive of partial dissolution. The smaller short cell phytoliths were present in fairly low numbers; some showed evidence of chemical weathering, and their type distribution appeared to be spotty and likely incomplete. The one upside of the basic soil environment is that the snail assemblage was in a very good state of preservation.

The sand fractions yielded snails, and flake debris (chert, and likely quartz), and several bone and shell fragments. Hackberry seed fragments were noted in all three features samples, with 45% of the 11 fragments observed being burned. Other than marine spicule fragments, most of the few fossils observed were in Sample 3 (Feature 1, 151-154 cmbs); among the possible explanations for this observation, the fossils could be a result of rock fragmentation or due to more water flow from flood events during that occupation.

The predominant phytolith form in the sample was bulliform cells. The predominant short cell form recovered was chloridoid phytoliths (from plants preferring a hot dry climate). The chloridoid morphologic ratio difference between the three samples is suggestive of some species variation between the three features; this could be due to changes in climate or differences in cultural resource gathering activities. The burned chloridoid frequency varied considerably as well--with 0% in Sample 5, 9% in Sample 3, and 37% in Sample 4 for the short ("squat") saddle form. The burned tall saddle frequency showed less variation, being lowest in Sample 5. The burned panicoid frequency was zero in Sample 5, but around 30% in the other two feature samples.

The opposite direction difference in saddle morphology ratios between burned and non-burned saddles in sample 4 suggests that plants with squat (short) saddles were intentionally concentrated. This trend was only noted in Sample 4 where the burned squat saddle percentage concentration was very high compared to the other two samples (Table J-3; [37.5:7.7 = 4.87 squat:tall ratio, which is the of the total tall:squat ratio of 4.9 (or 0.20 recalculated as squat:tall). This is nearly a 24 fold concentration gradient difference]). This data could be interpreted as indication of fall gathering activity for plant processing.

One small spherical cucurbit phytolith was recovered from Feature 1 (Sample 4).

Tree-related phytoliths were found in all three feature samples; a few tabular amorphous silica particles showed evidence of burning. Only Sample 5 is certain to have contained gymnosperm phytoliths based on the presence of tracheids with bordered pits. If grass was being used as tinder in feature Samples 3 and 4, perhaps the tinder was not needed as much sample five due to the flammable properties of gymnosperms. Another evidence of fire is the abundant charcoal noted in some of the sand fractions and phytolith isolates. Evidence of hot fires is the several burned bone fragments noted and the molten biogenic silica sheets recovered from all three feature samples.

J.12 ACKNOWLEDGEMENTS

I gratefully acknowledge the contributions of Leslie Bush and Thom Hopen in the completion of this report.

J.13 REFERENCES

Bement, L. C., B. J. Carter, R. A. Varney, L. S. Cummings and J. B. Sudbury
2007 Paleoenvironmental reconstruction and bio-stratigraphy, Oklahoma Panhandle, USA. Q*uaternary International* 169-170:39-50.

Borchardt, G.
2002 Mineralogy and Soil Tectonics. In *Soil Mineralogy with Environmental Applications*, edited by J. B. Dixon and D. G. Schulze, pages 711-736. Number 7 in the Soil Science Society of America Book Series. Soil Science Society of America, Inc., Madison, Wisconsin.

Bozarth, S.
1993 Biosilicate Assemblages of Boreal Forests and Aspen Parklands. In *Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology*, edited by D. M. Pearsall, and D. R. Piperno, pp. 95-105. MASCA Research Papers in Science and Archaeology, Vol. 10. The University Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.

Duff, K. E., B. A. Zeeb, and J. P. Smol
1995 *Atlas of Chrysophycean Cysts*. Kluwer Academic Publishers, Dordrecht. 189 p.

Harrison, F. W.
1974 Sponges (Porifera:Spongillidae). In *Pollution Ecology of Freshwater Invertebrates*, edited by C.W.Hart, Jr. and S. L. H. Fuller, pp. 29-66. Academic Press, New York.

Hodson, M. J., S. E. Williams, and A. G. Sangster
1997 Silica deposition in the needles of the gymnosperms. I. Chemical analysis and light microscopy. In *The State-of-the-Art of Phytoliths in Soils and Plants*, edited by A. Pinilla, J. Juan-Tresserras, and M. J. Machado, pp. 123-133. Monografías del Centro de Ciencias Medioambientales, Consejo Superior de Investigaciones Cientificas, Madrid.

Iler, R. K.
1979 *The Chemistry of Silica*. John Wiley & Sons: New York. 866 p.

Piperno, D. R.
2006 Phytoliths A Comprehensive Guide for Archaeologists and Paleoecologists. AltaMira Press, New York. 237 p.

Reiswig, H. M., T. M. Frost, and A. Ricciardi
2010 Porifera. In *Ecology and Classification of North American Freshwater Invertebrates*, edited by J. H.Thorp, and A. P. Covich, pp. 91-123). Academic Press, New York.

Schaetzl, R. and S. Anderson
2005 *Soils Genesis and Geomorphology.* Cambridge University Press, Cambridge. 817 p.

Strömberg, C. A. E.
2009 Methodological concerns for analysis of phytolith assemblages: Does count size matter? *Perspectives on Phytolith Research: 6th International Meeting on Phytolith Research. Quaternary International* 193:124-140.

Sudbury, J. B.
2014a Biogenic Silica Assessment of Sediment Samples from the Soil Profile and Select Cultural Features at 41TV2161. (In press, ms submitted to TRC [6-10-14]).

2014b "Phytolith Insights into the mid-Holocene Calf Creek Paleoenvironment." Presentation at the SAA Annual Meeting, Austin (April 26).

2014c Phytolith and Biogenic Silica Assessment of Select Sediment Samples from of Mid-Holocene 41BL278. (In press, ms submitted to TRC [8-8-14]).

2013a Appendix B 41RB112 Sediment Sample Phytolith Aanalysis. In *Long View (41RB112): Data Recovery of Two Plains Village Period Components in Roberts County, Texas Volume II*, by J. M. Quigg, P. M. Matchen, C. D. Frederick, and R. A. Ricklis, pp. 707-766. TRC Technical Report No. 174542. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Archeological Studies Program Report No. 147. Austin, Texas.

2013b Environmental Biosilica Data from 41LM50 and 41LM51, Early Archaic through Late Prehistoric Periods. (In press, ms submitted to TRC [8-30-13]).

2011a Quantitative Phytolith Analysis—A Working Example from Modern Prairie Soils and Buried Holocene A Horizons. Phytolith Press, Ponca City, Oklahoma. 288 p.

2011b *Biogenic Silica from an Opossum Creek Soil.* Phytolith Press, Ponca City, Oklahoma. 107 p.

2011c Sponge Spicules in the Opossum Creek Soil Profile, Nowata County, Northeastern Oklahoma. In *Biogenic Silica from an Opossum Creek Soil Profile, Nowata County, Oklahoma, USA*, pp. 75-101. Sudbury, J.B. Phytolith Press, Ponca City, Oklahoma.

Twiss, P. C., E. Suess, and R. M. Smith
1969 Morphological Classification of Grass Phytoliths. *Soil Science Society of America Proceedings* 33:109-115.

Wilkinson, A. N., B. A. Zeeb, and J. P. Smol
2001 *Atlas of Chrysophycean Cysts II*. Kluwer Academic Publishers, Dordrecht. 169 p.

Winsborough, B. M.
2014 Diatom Paleoenvironmental Analysis of Sediments from Archeological Site 41TV2161, Travis County, Texas. (In Press, submitted May 2014).

APPENDIX K
LITHIC DEBITAGE ANALYSIS OF MATERIALS ASSOCIATED WITH BURNED ROCK FEATURES 1 AND 2 AT 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

This page intentionally left blank.

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
31	1	Flake	Cortical	3/4 inch	fragment	26-50%	No	waterworn	N/A	Chert	Edwards	yellow Edwards	1	12.3
31	2	Flake	Crushed	3/4 inch	fragment	1-25%	No	waterworn	N/A	Chert	Edwards	yellow Edwards	1	1.8
31	3	Shatter	Missing	3/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	7.0
31	4	Shatter	Missing	3/4 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	burned orange Edwards	1	1.1
31	5	Shatter	Missing	3/4 inch	fragment	0%	No	N/A	N/A	Chert	Alibates	dark mauve	1	2.6
31	6	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	1.0
31	7	Flake	Flat	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.7
31	8	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.2
31	9	Flake	Multifaceted	1/4 inch	fragment	0%	Yes	N/A	crazed	Chert	Edwards	orangey Edwards	1	0.2
31	10	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	5	4.2
31	11	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	2	1.2
31	12	Shatter	Missing	1/4 inch	fragment	76-100%	No	rough	N/A	Chert	Unknown	dark mauve	1	0.9
31	13	Shatter	Missing	1/4 inch	fragment	0%	Yes	N/A	potlids	Chert	Edwards	orangish Edwards	1	0.5

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
31	14	Shatter	Missing	1/4 inch	fragment	0%	Yes	N/A	potlids	Chert	Unknown	mottled unknown	1	1.5
31	15	Shatter	Missing	1/4 inch	fragment	0%	Yes	N/A	potlids	Chert	Unknown	dark mauve	2	3.1
31	16	Flake	Multifaceted	<1/4 inch	debris	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1
31	17	Flake	Multifaceted	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1
31	18	Shatter	Missing	<1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Edwards	burned orange Edwards	1	0.3
31	19	Shatter	Missing	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mauve	2	0.2
31	1							waterworn	N/A	Chert	Edwards	yellow Edwards		
32	1	Flake	Flat	3/4 inch	complete	0%	yes	N/A	potlids	Chert	Unknown	burned orange Edwards	1	4.4
32	2	Flake	Cortical	1/2 inch	complete	1-25%	No	rough	N/A	Ortho-Quartzite	Unknown	dark mauve	1	1.6
32	3	Flake	Cortical	1/2 inch	complete	51-75%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	3.2
32	4	Flake	Crushed	1/2 inch	complete	26-50%	No	unknown	N/A	Chert	Edwards	yellow Edwards	1	3.4
32	5	Shatter	Missing	1/2 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	yellow Edwards	1	1.5

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
32	6	Shatter	Missing	1/2 inch	fragment	1-25%	No	rough	N/A	Chert	Edwards	dark orange Edwards	1	3.1
32	7	Shatter	Missing	1/2 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	dark orange Edwards	1	1.5
32	8	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.7
32	9	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A		Chert	Edwards	yellow Edwards	1	0.4
32	10	Flake	Dihedral-Faceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.5
32	11	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	3	1.5
32	12	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	dark orange Edwards	1	0.4
32	13	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	dark orange Edwards	1	0.2
32	14	Shatter	Missing	1/2 inch	broken	0%	yes	N/A	crazed & potlids	Chert	Edwards	dark orange Edwards	2	1.2
32	15	Shatter	Missing	<1/4 inch	broken	0%	yes	N/A	both crazed and potlids	Chert	Edwards	dark orange Edwards	1	0.1
32	16	Shatter	Missing	<1/4 inch	broken	0%	No	N/A	N/A	Chert	Edwards	dark orange Edwards	1	0.1

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
33	1	Flake	Multifaceted	3/4 inch	broken	1-25%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	16.1
33	2	Shatter	Missing	1/2 inch	broken	1-25%	No	unknown	N/A	Chert	Unknown	dark mauve	1	2.0
33	3	Flake	Crushed	1/2 inch	broken	76-100%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	6.5
33	4	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange yellowish Edwards	1	0.5
33	5	Flake	Crushed	1/4 inch	complete	0%	yes	N/A	both lightly crazed and potlids	Chert	Unknown	mauve	1	0.2
33	6	Flake	Crushed	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
33	7	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
33	8	Flake	Crushed	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
33	9	Shatter	Missing	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange yellowish Edwards	1	0.2
34	1	Flake	Dihedral-Faceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.3
34	2	Shatter	Missing	3/4 inch	fragment	1-25%	yes	smooth	heat treatment	Chert	Edwards	yellow Edwards	1	3.4

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
34	3	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.2
34	4	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Chert	Unknown	mauve	1	0.5
34	5	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	burned orange Edwards	1	0.4
34	6	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.3
34	7	Flake	Flat	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.3
34	8	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.9
34	9	Flake	Flat	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
34	10	Shatter	Missing	<1/4 inch	fragment	0%	yes	N/A	potlids	Ortho-Quartzite	Unknown	dark mauve	1	0.2
35	1	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Edwards	burned yellow Edwards	1	0.3
36	1	Flake	Flat	3/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	10.4
36	2	Shatter	Missing	1/2 inch	fragment	26-50%	yes	rough	crazed & potlids	Chert	Edwards	orange Edwards	1	6.7
36	3	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.4

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
36	4	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	2.4
36	5	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chalcedony-Chert	Unknown	dark mauve	1	0.7
36	6	Flake	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.5
36	7	Flake	Multifaceted	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.1
37	1	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.7
37	2	Shatter	Missing	1/4 inch	fragment	1-25%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.1
37	3	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	1.3
37	4	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	N/A	Chert	Edwards	orange Edwards	1	0.4
37	5	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chalcedony-Chert	Unknown	dark mauve	1	0.7
38	1	Shatter	Missing	1/2 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	3.5
38	2	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	potlids	Chert	Unknown	dark mauve	1	0.7
38	3	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.2

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
38	4	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	2	0.6
39	1	Flake	Cortical	1/2 inch	complete	76-100%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	2.3
40	1	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.9
40	2	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.1
40	3	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.1
40	4	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	2	0.9
40	5	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.6
40	6	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.3
40	7	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.5
40	8	Flake	Multifaceted	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.2
40	9	Shatter	Missing	<1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	1	0.1
40	10	Flake	Multifaceted	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.2
40	11	Shatter	Missing	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
40	1	Flake	Flat	1 inch	complete	26-50%	yes	smooth	heat treatment	Chert	Edwards	orange Edwards	1	48.0
41	1	Flake	Flat	3/4 inch	complete	26-50%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	6.2
41	2	Shatter	Missing	1/2 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	3.3
41	3	Flake	Dihedral-Faceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.6
41	4	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.4
41	5	Flake	Flat	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.4
41	6	Flake	Multifaceted	1/4 inch	fragment	1-25%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	0.6
41	7	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	2	1.8
41	8	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.8
41	9	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	1.0
41	10	Flake	Multifaceted	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.1
41	11	Flake	Multifaceted	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.2
41	12	Flake	Flat	<1/4 inch	complete	0%	No	N/A	N/A	Ortho-Quartzite	Unknown	dark mauve	1	0.2

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
42	1	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.2
42	1	Flake	Multifaceted	1/2 inch	complete	76-100%	No	unknown	N/A	Chert	Edwards	yellow Edwards	1	11.4
43	1	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.0
45	1	Flake	Cortical	1 inch	complete	1-25%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	24.9
45	2	Flake	Flat	3/4 inch	complete	1-25%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	19.6
45	3	Shatter	Missing	3/4 inch	fragment	1-25%	No	rough	N/A	Chert	Edwards	orange Edwards	1	3.3
45	4	Flake	Indeterminate	1/4 inch	fragment	51-75%	No	N/A	N/A	other	Unknown	mottled unknown	1	2.0
45	5	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chalcedony-Chert	Unknown	dark mauve	1	1.6
45	6	Shatter	Missing	1/4 inch	fragment	0%	Yes	N/A	crazed & potlids	Chert	Unknown	dark mauve	1	1.5
46	1	Flake	Multifaceted	3/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	4.4
46	2	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	2.5
46	3	Shatter	Missing	1/2 inch	fragment	51-75%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	1.4
46	4	Shatter	Missing	1/2 inch	fragment	0%	Yes	N/A	crazed & potlids	Chert	Unknown	dark mauve	1	2.1

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
46	5	Flake	Multifaceted	1/2 inch	fragment	0%	Yes	N/A	crazed & potlids	Chert	Unknown	mottled unknown	1	6.2
46	6	Shatter	Missing	1/4 inch	fragment	1-25%	Yes	unknown	heat treatment	Chert	Unknown	orange Edwards	1	0.4
46	7	Flake	Multifaceted	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
47	1	Flake	Multifaceted	3/4 inch	fragment	1-25%	No	rough	N/A	Chert	Unknown	mauve	1	4.9
47	2	Shatter	Crushed	3/4 inch	fragment	1-25%	yes	rough	crazed & potlids	Chert	Edwards	orange Edwards	1	13.4
47	3	Flake	Multifaceted	1/2 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	2.6
47	4	Flake	Flat	1/2 inch	complete	26-50%	yes	smooth	heat treatment	Chert	Edwards	yellow Edwards	1	3.4
47	5	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	2.1
47	6	Flake	Flat	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	6.3
47	7	Flake	Crushed	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	2.2
47	8	Shatter	Missing	1/2 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.0
47	9	Shatter	Missing	1/2 inch	fragment	51-75%	yes	smooth	heat treatment	Chert	Unknown	mottled unknown	1	3.3
47	10	Flake	Multifaceted	1/2 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	1	2.1

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
47	11	Shatter	Missing	1/2 inch	fragment	0%	No	N/A	crazed & potlids	Chert	Unknown	mottled unknown	1	4.1
47	12	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.6
47	13	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	crazed & potlids	Chert	Edwards	yellow Edwards	1	0.6
47	14	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.1
47	15	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.4
47	16	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1
47	17	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1
47	18	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	crazed & potlids	Chert	Edwards	orange Edwards	1	0.5
47	19	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	4	1.7
47	20	Flake	Dihedral-Faceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	dark mauve	1	0.3
47	21	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chalcedony-Chert	Unknown	mauve	1	0.5
47	22	Flake	Flat	1/4 inch	complete	1-25%	No	smooth	N/A	Chalcedony-Chert	Unknown	mauve	1	1.3

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
47	23	Flake	Flat	1/4 inch	fragment	1-25%	yes	smooth	crazed	Chert	Unknown	mauve	1	0.4
47	24	Shatter	Missing	1/4 inch	fragment	26-50%	yes	smooth	crazed	Chert	Unknown	mauve	1	1.0
47	25	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mauve	1	0.5
47	26	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	1.0
47	27	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	2	1.3
47	28	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.2
47	29	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.7
47	30	Shatter	Missing	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.1
47	31	Flake	Flat	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.4
47	32	Flake	Multifaceted	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.1
47	33	Shatter	Missing	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mauve	1	0.2
47	34	Flake	Crushed	<1/4 inch	complete	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.2
48	1	Flake	Flat	1 inch	complete	76-100%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	35.1

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
48	2	Flake	Flat	1 inch	complete	0%	No	N/A	N/A	Ortho-Quartzite	Unknown	da	1	20.4
48	3	Flake	Multifaceted	1/2 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	5.1
48	4	Flake	Multifaceted	1/2 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	1.1
48	5	Flake	Multifaceted	1/2 inch	complete	1-25%	No	rough	N/A	Chert	Edwards	orange Edwards	1	3.6
48	6	Flake	Flat	1/4 inch	complete	76-100%	No	rough	N/A	Chert	Edwards	yellow Edwards	1	0.7
48	7	Flake	Multifaceted	1/4 inch	fragment	0%	No	unknown	N/A	Chert	Edwards	yellow Edwards	1	0.5
48	8	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	3.1
48	9	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.4
48	10	Flake	Flat	1/4 inch	complete	76-100%	No	rough	N/A	Ortho-Quartzite	Unknown	dark mauve	1	0.3
48	11	Flake	Multifaceted	1/4 inch	fragment	26-50%	yes	rough	crazed	Chert	Unknown	mottled unknown	1	1.6
48	12	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Ortho-Quartzite	Unknown	mottled unknown	1	1.0
48	13	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.4
48	14	Shatter	Missing	1/4 inch	fragment	76-100%	yes	rough	crazed	Chert	Unknown	mottled unknown	1	1.4

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
48	15	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	1	0.6
48	16	Flake	Flat	<1/4 inch	fragment	0%	No	N/A	N/A	Chert	Unknown	mottled unknown	1	0.1
48	17	Shatter	Missing	<1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	1	0.2
48	18	Shatter	Missing	<1/4 inch	fragment	0%	yes	N/A	crazed	Chert	Unknown	mottled unknown	1	0.1
49	1	Flake	Flat	1 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	16.2
501	1	Flake	Flat	1 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	27.9
501	2	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Meta-Quartzite	Unknown	mauve	1	0.8
503	1	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	1.0
503	2	Flake	Multifaceted	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.7
503	3	Shatter	Missing	1/4 inch	fragment	0%	yes	N/A	potlids	Chert	Edwards	orange Edwards	1	0.3
503	4	Flake	Multifaceted	1/4 inch	fragment	1-25%	No	rough	N/A	Chert	Edwards	orange Edwards	1	0.3
511	1	Flake	Flat	1/4 inch	complete	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.4
511	2	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.2

PNUM No.	Artifact No.	Type	Platform Type	Size Grade	Completeness	Amount of Cortex	Thermal Alteration	Cortex Type	Type of Thermal Alteration	Lithology	Material Type	UV Response	Counts	Weights (g)
515	1	Flake	Multifaceted	3/4 inch	complete	1-25%	No	rough	N/A	Chert	Unknown	unknown green mottled	1	13.7
515	2	Flake	Multifaceted	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	yellow Edwards	1	0.2
515	3	Shatter	Missing	1/4 inch	fragment	0%	No	N/A	N/A	Chert	Edwards	orange Edwards	1	0.3

This page intentionally left blank.

APPENDIX L
PROJECTILE POINT ANALYSIS FOR 41MS69

Prepared for:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

Prepared by:

TRC Environmental Corporation
505 East Huntland Drive, Suite 250
Austin, Texas 78752

This page intentionally left blank.

PNUM	**4**	**4**	**9**	**12**	**14**	**23**
Catalog No.	**10**	**11**	**10**	**10**	**10**	**10**
Class	Biface	Biface	Biface	Biface	Biface	Biface
Subclass	Formal	Formal	Formal	Formal	Formal	Formal
Type	Dart	Dart	Dart	Dart	Dart	Dart
Identity	Montell	Indet	Indet	Indet	Indet	Marcos
Max Length (mm)	66.1	24.2	15.1	29.1	15.8	57.8
Max Width (mm)	48.6	25.7	26.5	24.6	27	36.5
Max Thickness (mm)	10	3.8	5.4	5.9	4.5	7.2
Weight	29.3	1.8	2.4	4.7	2.7	11
Edge Angle 1	57	53	59	53	49	63
Edge Angle 2	53	47	70	69	49	63
Stage	Finished Product	Indet	Indet	Indet	Indet	Finished Product
Portion	Proximal-medial	Distal-medial	Medial	Medial	Medial	Complete
Failure or Discard	Snap / end shock	Snap / end shock	Snap / end shock	Snap / end shock	Snap / end shock	Edge collapse
Alteration	NO	White patina	NO	Thermal	NO	Thermal
Edge Morphology Distal	n/a	n/a	n/a	n/a	n/a	Straight
Edge Morphology Proximal	Recurved	Point	n/a	n/a	n/a	Point
Edge Morphology Left Lateral	Convex	Straight	Indet	Indet	Indet	Straight

PNUM	**4**	**4**	**9**	**12**	**14**	**23**
Catalog No.	**10**	**11**	**10**	**10**	**10**	**10**
Edge Morphology Right Lateral	Straight	Straight	Indet	Indet	Indet	Straight
Flake Scar Pattern	Random	Random	Random	Random	Random	Random
Edge Construction 1	n/a	Bifacial-bilateral	n/a	n/a	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 2	n/a	Bifacial-bilateral	n/a	n/a	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 3	n/a	n/a	n/a	n/a	n/a	n/a
Edge Construction 4	n/a	n/a	n/a	n/a	n/a	n/a
Proximal Edge Grinding	NO	NO	NO	NO	NO	NO
Flaking Attribution 1	NP	NP	NP	NP	Bifacial-bilateral	Bifacial-bilateral
Flaking Attribution 2	NP	NP	NP	NP	Bifacial-bilateral	Bifacial-bilateral
Flaking Attribution 3	n/a	n/a	n/a	n/a	n/a	n/a
Flaking Attribution 4	n/a	n/a	n/a	n/a	n/a	n/a
Crushing 1	NP	NP	NP	NP	NP	NP
Crushing 2	NP	NP	NP	NP	NP	NP
Crushing 3	n/a	n/a	n/a	n/a	n/a	n/a
Crushing 4	n/a	n/a	n/a	n/a	n/a	n/a
Smoothing 1	NP	NP	NP	NP	NP	NP
Smoothing 2	NP	NP	NP	NP	NP	NP
Smoothing 3	n/a	n/a	n/a	n/a	n/a	n/a

PNUM	**4**	**4**	**9**	**12**	**14**	**23**
Catalog No.	**10**	**11**	**10**	**10**	**10**	**10**
Smoothing 4	n/a	n/a	n/a	n/a	n/a	n/a
Polish 1	NP	NP	NP	NP	NP	NP
Polish 2	NP	NP	NP	NP	NP	NP
Polish 3	n/a	n/a	n/a	n/a	n/a	n/a
Polish 4	n/a	n/a	n/a	n/a	n/a	n/a
Etching or Pitting 1	NP	NP	NP	NP	NP	NP
Etching or Pitting 2	NP	NP	NP	NP	NP	NP
Etching or Pitting 3	NP	NP	NP	NP	NP	NP
Etching or Pitting 4	NP	NP	NP	NP	NP	NP
Hafting Evidence	n/a	n/a	n/a	n/a	n/a	NO
Lithology	Chert	Chert	Chert	Chert	Chert	Chert
Fort Hood Chert Type	Edwards	Edwards	Edwards	Edwards	Unknown	Edwards
Point Class	Corner Notched	Indet	Indet	Indet	Indet	Corner Notched
Point Length	66.1	24.2	15.1	29.1	15.8	48.1
Point Width	48.6	25.7	26.5	24.6	27	35.4
Point Ratio						
Blade Length Left	46.16	27.94	14.5	29.23	15.8	53.66
Blade Length Right	58.64	24.05	12.74	22.16	27	48.84
Base or Stem Length	12.78	n/a	n/a	n/a	n/a	11.09

PNUM	**4**	**4**	**9**	**12**	**14**	**23**
Catalog No.	**10**	**11**	**10**	**10**	**10**	**10**
Base or Stem Width	24.17	n/a	n/a	n/a	n/a	22.23
Neck Thickness	6.64	n/a	n/a	n/a	n/a	6.5
Neck Width	23.07	n/a	n/a	n/a	n/a	17.11
Notch Depth Left	8.35	n/a	n/a	n/a	n/a	8.41
Notch Depth Right	7.66	n/a	n/a	n/a	n/a	5.85
Notch Ratio						
Base to Blade Ratio Length						
Base to Blade Ratio Width						
Base or Stem Length to Width Ratio						
Base or Stem Ratio Definition						
Base Form	Notched	Indet	Indet	Indet	Indet	Straight
Stem Form	Expanding	Indet	Indet	Indet	Indet	Expanding
Distal Base Form	Convex	Indet	Indet	Indet	Indet	Convex
Lateral Base Stem Form	Expanding	Indet	Indet	Indet	Indet	Expanding
Blade Curvature Left	Convex	Straight	Indet	Indet	Indet	Straight
Blade Curvature Right	Convex	Straight	Indet	Indet	Indet	Straight

PNUM	**4**	**4**	**9**	**12**	**14**	**23**
Catalog No.	**10**	**11**	**10**	**10**	**10**	**10**
Shoulder Angle Left	77	n/a	n/a	n/a	n/a	25
Shoulder Angle Right	78	n/a	n/a	n/a	n/a	n/a
Shoulder Junction	Curved	Indet	Indet	Indet	Indet	Curved
Base Angle Left	67	n/a	n/a	n/a	n/a	68
Base Angle Right	58	n/a	n/a	n/a	n/a	65
Symmetry	Symmetrical	Asymmetrical	Asymmetrical	Asymmetrical	Asymmetrical	Symmetrical
Technological Observations	broken distal tip	only the distal tip remains, patina covered			non Edwards	missing right barb, and a middle portion of left lateral edge.
UV color	orange	orange mottled	orange Edwards	orange mottled	burnt orange	orange
Analyzed						

PNUM	**26**	**33**	**63**	**66**	**67**	**71**
Catalog No.	**10**	**10**	**11**	**10**	**10**	**10**
Class	Biface	Biface	Biface	Biface	Biface	Biface
Subclass	Formal	Formal	Formal	Formal	Formal	Formal
Type	Dart	Dart	Dart	Dart	Dart	Dart
Identity	Indet	Andice	Indet	Indet	Indet	Travis
Max Length (mm)	14.4	48.5	17.2	19	47.4	62.6
Max Width (mm)	17.7	49.9	21.2	27.9	36.5	30.4
Max Thickness (mm)	5.8	7	5.2	7.6	9	8.7
Weight	1.7	14	1.6	3.7	11.6	15.1
Edge Angle 1	71	69	76	70	57	65
Edge Angle 2	79	69	67	64	62	70
Stage	Indet	Finished Product	Indet	Indet	Early Stage Forming	Finished Product
Portion	Proximal	Medial	Distal	Medial	Medial	Complete
Failure or Discard	Snap / end shock	Perverse	Snap / end shock	Snap / end shock	Snap / end shock	Indet
Alteration	NO	Thermal	NO	NO	Carbon/ate build-up	Carbon/ate build-up
Edge Morphology Distal	Concave	n/a	n/a	n/a	n/a	Straight
Edge Morphology Proximal	n/a	n/a	Point	n/a	n/a	Point
Edge Morphology Left Lateral	Recurved	Indet	Serrated	Straight	Serrated	Convex

PNUM	**26**	**33**	**63**	**66**	**67**	**71**
Catalog No.	**10**	**10**	**11**	**10**	**10**	**10**
Edge Morphology Right Lateral	Recurved	Indet	Serrated	Straight	Straight	Convex
Flake Scar Pattern	Random	Indet	Random	Random	Random	Random
Edge Construction 1	n/a	Bifacial-circumferential	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 2	n/a	n/a	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 3	n/a	n/a	n/a	n/a	n/a	n/a
Edge Construction 4	n/a	n/a	n/a	n/a	n/a	n/a
Proximal Edge Grinding	NO	NO	NO	NO	NO	NO
Flaking Attribution 1	NP	n/a	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Flaking Attribution 2	NP	n/a	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Flaking Attribution 3	n/a	n/a	n/a	n/a	n/a	n/a
Flaking Attribution 4	n/a	n/a	n/a	n/a	n/a	n/a
Crushing 1	NP	n/a	NP	NP	NP	NP
Crushing 2	NP	n/a	NP	NP	NP	NP
Crushing 3	n/a	n/a	n/a	n/a	n/a	n/a
Crushing 4	n/a	n/a	n/a	n/a	n/a	n/a
Smoothing 1	NP	n/a	NP	NP	NP	NP
Smoothing 2	NP	n/a	NP	NP	NP	NP
Smoothing 3	n/a	n/a	n/a	n/a	n/a	n/a

PNUM	26	33	63	66	67	71
Catalog No.	**10**	**10**	**11**	**10**	**10**	**10**
Smoothing 4	n/a	n/a	n/a	n/a	n/a	n/a
Polish 1	NP	Indet	NP	NP	NP	NP
Polish 2	NP	NP	NP	NP	NP	NP
Polish 3	n/a	NP	n/a	n/a	n/a	n/a
Polish 4	n/a	n/a	n/a	n/a	n/a	n/a
Etching or Pitting 1	NP	Indet	NP	NP	NP	NP
Etching or Pitting 2	NP	Indet	NP	NP	NP	NP
Etching or Pitting 3	NP	Indet	NP	NP	NP	NP
Etching or Pitting 4	NP	Indet	NP	NP	NP	NP
Hafting Evidence	NO	n/a	NO	n/a	n/a	NO
Lithology	Chert	Chert	Chert	Chert	Unknown	Unknown
Fort Hood Chert Type	Unknown	33 Indet dark gray	Edwards	Edwards	Unknown	Unknown
Point Class	Stemmed	Indet	Indet	Indet	Indet	Stemmed
Point Length	14.3	37.3	17.2	19	47.4	62.6
Point Width	17.7	47.8	21.2	27.9	36.5	30.4
Point Ratio						
Blade Length Left	n/a	37.65	15.32	18.19	35.38	48.99
Blade Length Right	n/a	26.19	19	17.9	44.34	47.43
Base or Stem Length	14.42	7.45	n/a	n/a	n/a	16.9

PNUM	**26**	**33**	**63**	**66**	**67**	**71**
Catalog No.	**10**	**10**	**11**	**10**	**10**	**10**
Base or Stem Width	17.64	18.88	n/a	n/a	n/a	18.57
Neck Thickness	5.77	19.66	n/a	n/a	n/a	7.07
Neck Width	15.05	6.6	n/a	n/a	n/a	16.44
Notch Depth Left	n/a	15.46	n/a	n/a	n/a	n/a
Notch Depth Right	n/a	n/a	n/a	n/a	n/a	n/a
Notch Ratio						
Base to Blade Ratio Length						
Base to Blade Ratio Width						
Base or Stem Length to Width Ratio						
Base or Stem Ratio Definition						
Base Form	Concave	Indet	Indet	Indet	Indet	Concave
Stem Form	Contracting	Indet	Indet	Indet	Indet	Expanding
Distal Base Form	Indet	Indet	Indet	Indet	Indet	Concave
Lateral Base Stem Form	Indet	Indet	Indet	Indet	Indet	Contracting
Blade Curvature Left	Indet	Indet	Straight	Indet	Straight	Convex
Blade Curvature Right	Indet	Indet	Straight	Indet	Straight	Convex

PNUM	**26**	**33**	**63**	**66**	**67**	**71**
Catalog No.	**10**	**10**	**11**	**10**	**10**	**10**
Shoulder Angle Left	n/a	n/a	n/a	n/a	55	60
Shoulder Angle Right	n/a	n/a	n/a	n/a	82	44
Shoulder Junction	Indet	Indet	Indet	Indet	Indet	Angular
Base Angle Left	n/a	n/a	n/a	n/a	n/a	67
Base Angle Right	90	n/a	n/a	n/a	n/a	58
Symmetry	Asymmetrical		Asymmetrical	Asymmetrical	Asymmetrical	Asymmetrical
Technological Observations	missing small portion of left stem base	This piece has calcium carbon/ate build up, use-wear			non Edwards	non Edwards, analyzed with use-wear but not sent for use-wear.
UV color	burnt orange	yellow	orange	orange	orange	mauve
Analyzed		TRC 354 INAA, Use-wear				

PNUM	**72**	**73**	**87**	**103**
Catalog No.	**10**	**10**	**10**	**10**
Class	Biface	Biface	Biface	Biface
Subclass	Formal	Formal	Formal	Formal
Type	Dart	Dart	Dart	Dart
Identity	Indet	Pedern/ales	Indet	Bulverde
Max Length (mm)	15.6	17	46.7	49.7
Max Width (mm)	17.3	22	30	36.4
Max Thickness (mm)	6.3	6.9	6.1	8.2
Weight	1.6	2.3	5.7	13.1
Edge Angle 1	66	n/a	49	74
Edge Angle 2	69	n/a	46	64
Stage	Early Stage Forming	Finished Product	Finished Product	Finished Product
Portion	Proximal	Proximal	Distal-medial	Distal-medial
Failure or Discard	Snap / end shock	Snap / end shock	Perverse	Snap / end shock
Alteration	NO	NO	NO	NO
Edge Morphology Distal	n/a	n/a	Point	Convex
Edge Morphology Proximal	Convex	Concave	n/a	n/a
Edge Morphology Left Lateral	Concave	n/a	Recurved	Straight

PNUM	**72**	**73**	**87**	**103**
Catalog No.	**10**	**10**	**10**	**10**
Edge Morphology Right Lateral	Straight	n/a	Recurved	Straight
Flake Scar Pattern	Random	Random	Random	Random
Edge Construction 1	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 2	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral
Edge Construction 3	n/a	n/a	n/a	n/a
Edge Construction 4	n/a	n/a	n/a	n/a
Proximal Edge Grinding	NO	NO	NO	NO
Flaking Attribution 1	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	NP
Flaking Attribution 2	Bifacial-bilateral	Bifacial-bilateral	Bifacial-bilateral	n/a
Flaking Attribution 3	n/a	n/a	n/a	n/a
Flaking Attribution 4	n/a	n/a	n/a	n/a
Crushing 1	NP	NP	NP	NP
Crushing 2	NP	NP	NP	NP
Crushing 3	n/a	n/a	n/a	NP
Crushing 4	n/a	n/a	n/a	n/a
Smoothing 1	NP	NP	NP	NP
Smoothing 2	NP	NP	NP	NP
Smoothing 3	n/a	n/a	n/a	NP

PNUM	**72**	**73**	**87**	**103**
Catalog No.	**10**	**10**	**10**	**10**
Smoothing 4	n/a	n/a	n/a	n/a
Polish 1	NP	NP	NP	NP
Polish 2	NP	NP	NP	NP
Polish 3	n/a	n/a	n/a	NP
Polish 4	n/a	n/a	n/a	n/a
Etching or Pitting 1	NP	NP	Indet	Indet
Etching or Pitting 2	NP	NP	Indet	Indet
Etching or Pitting 3	NP	NP	Indet	Indet
Etching or Pitting 4	NP	NP	Indet	Indet
Hafting Evidence	NO	NO	n/a	NO
Lithology	Chert	Chert	Chert	Chert
Fort Hood Chert Type	Edwards	Edwards	Unknown	Edwards
Point Class	Stemmed	Stemmed	Indet	Stemmed
Point Length	15.6	17	46.7	49.7
Point Width	17.3	22	30	36.4
Point Ratio				
Blade Length Left	15.62	17.02	34.41	30.69
Blade Length Right	17.25	15.06	48.15	34.26
Base or Stem Length	13.93	15.06	n/a	19.89

PNUM	**72**	**73**	**87**	**103**
Catalog No.	**10**	**10**	**10**	**10**
Base or Stem Width	17.16	18.5	n/a	19.09
Neck Thickness	5.45	6.59	n/a	7.31
Neck Width	15.68	17.46	n/a	19.18
Notch Depth Left	n/a	n/a	n/a	2.91
Notch Depth Right	n/a	n/a	n/a	6.23
Notch Ratio				
Base to Blade Ratio Length				
Base to Blade Ratio Width				
Base or Stem Length to Width Ratio				
Base or Stem Ratio Definition				
Base Form	Convex	Concave	Indet	Concave
Stem Form	Parallel	Parallel	Indet	Parallel
Distal Base Form	Convex	Straight	Indet	Convex
Lateral Base Stem Form	Expanding	Parallel	Indet	Parallel
Blade Curvature Left	Indet	Indet	Convex	Straight
Blade Curvature Right	Indet	Indet	Convex	Straight

PNUM	**72**	**73**	**87**	**103**
Catalog No.	**10**	**10**	**10**	**10**
Shoulder Angle Left	n/a	n/a	n/a	0
Shoulder Angle Right	n/a	n/a	n/a	49
Shoulder Junction	Indet	Indet	Indet	Curved
Base Angle Left	62	81	n/a	76
Base Angle Right	52	80	n/a	82
Symmetry	Asymmetrical	Asymmetrical	Symmetrical	Asymmetrical
Technological Observations			non Edwards	Edwards. pinkish hue with off white band at the base of the stem. Analyzed with use-wear but not sent for use-wear.
UV color	dark orange	orange	dark mauve	orange
Analyzed				TRC 355,

Abbreviation definitions:

Indet (Indeterminate)
NP (Not present)
NO (Not observed)
n/a (Not applicable)