CAMPFIRES IN CONTEXT: HUNTER-GATHERER FIRE TECHNOLOGY AND THE ARCHAEOLOGICAL RECORD OF THE SOUTHERN HIGH PLAINS, USA

PAUL NATHAN BACKHOUSE

A thesis submitted in partial fulfilment of the requirements of Bournemouth University for the degree of Doctor of Philosophy

January 2008

VOLUME 2 of 2

LIST OF CONTENTS

Volume 2

Title Page 251

Table of Contents 253

Illustrations

Chapter 1 255

Chapter 2 257

Chapter 3 267

Chapter 4 273

Chapter 5 282

Chapter 6 286

Chapter 7 293

Chapter 8 300

Chapter 9 323

Appendix 1 - Experiment 1 – Hot Rock Technology 1 A-1

Appendix 2 - Experiment 2 – Site Formation Processes A-33

Appendix 3 - Experiment 3 – Physical Outputs A-73

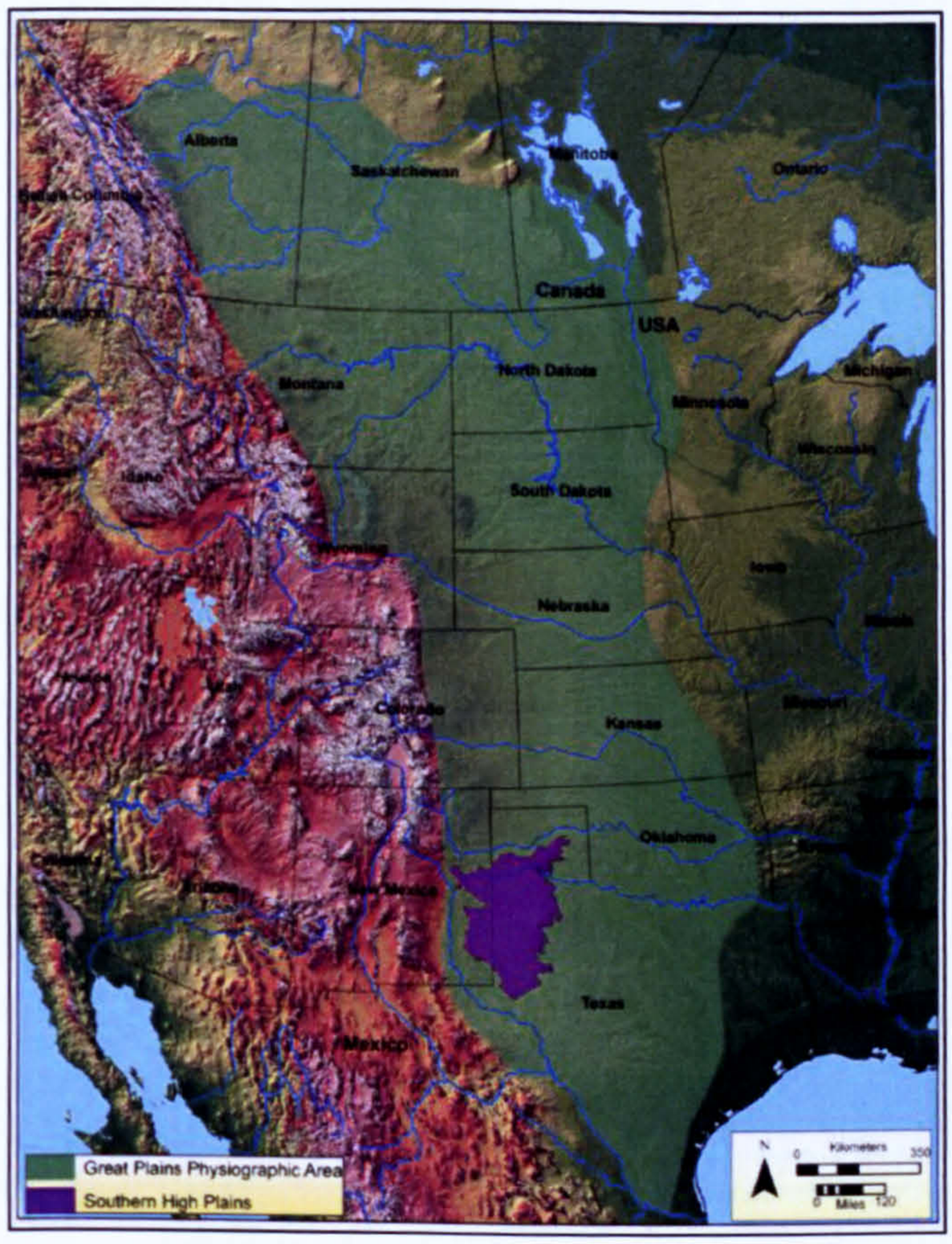
Appendix 4 - Experiment 4 – Hot Rock Technology 2 A-89

Appendix 5 - Informant Interview A-115

Appendix 6 - Southern High Plains Sites Database A-125

Chapter 1

a.



b.



Figure 1.1. Location of the Southern High Plains: a) in relation to the Great Plains physiographic province; b) regional overview (diagram b) modified from Holliday 1997, Fig. 1.2).

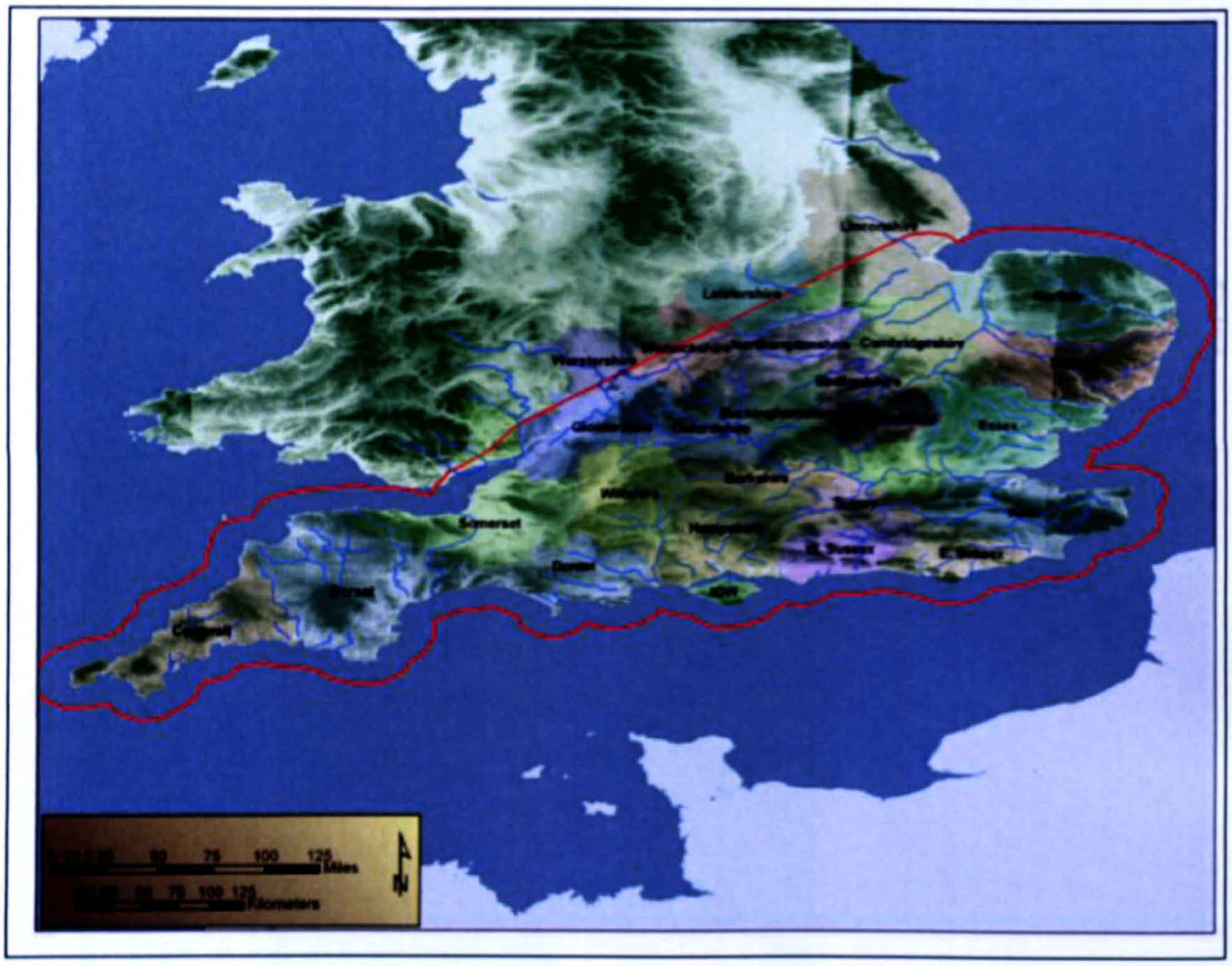


Figure 1.2. Regional overview of the southern British study area, with the locations of modern county boundaries and drainages indicated.

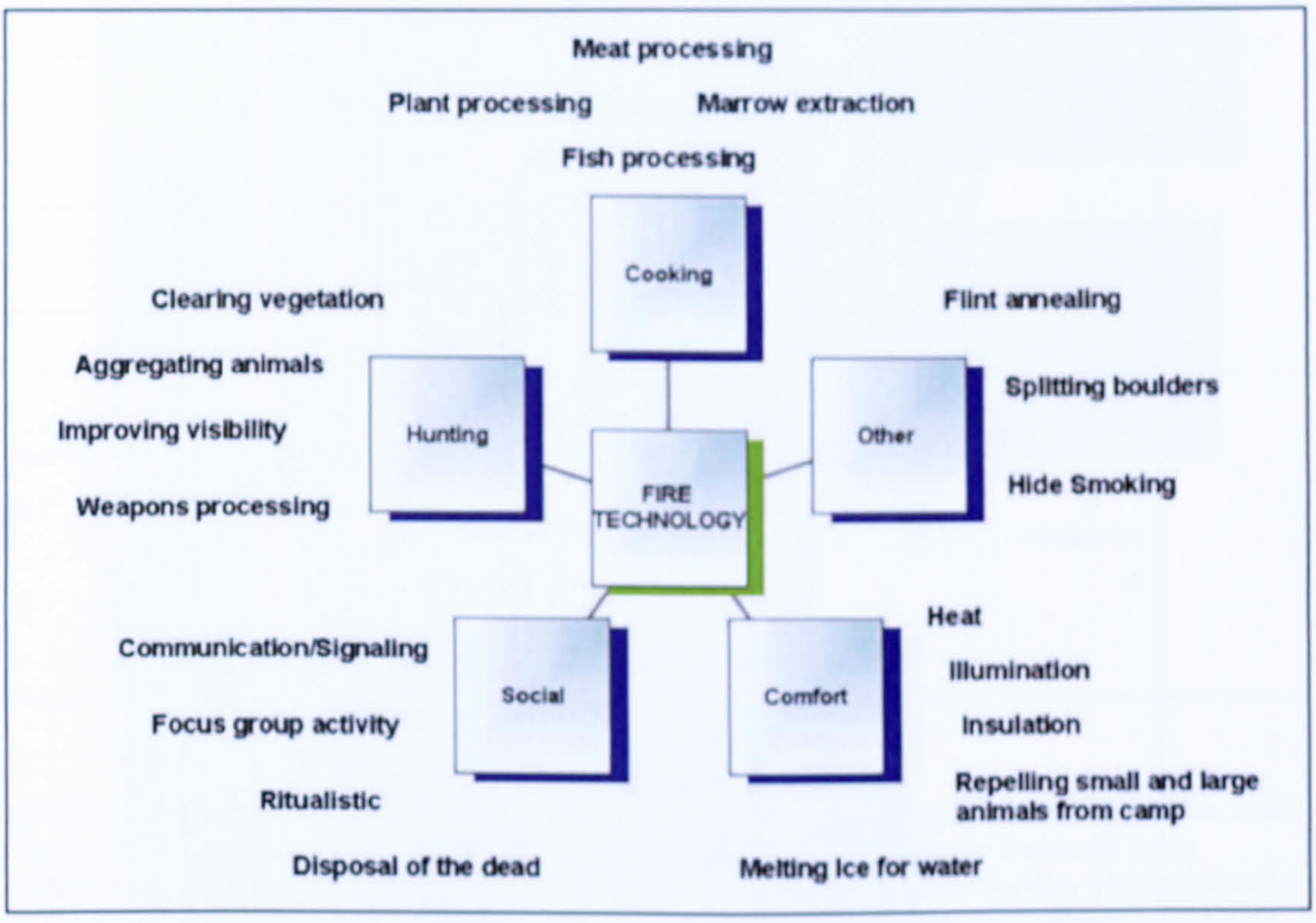


Figure 2.1. Overview of the range of hunter-gatherer fire technologies identified in the ethnographic and archaeological record (diagram after Rolland 2004:table I; Bellomo 1994, fig.2).

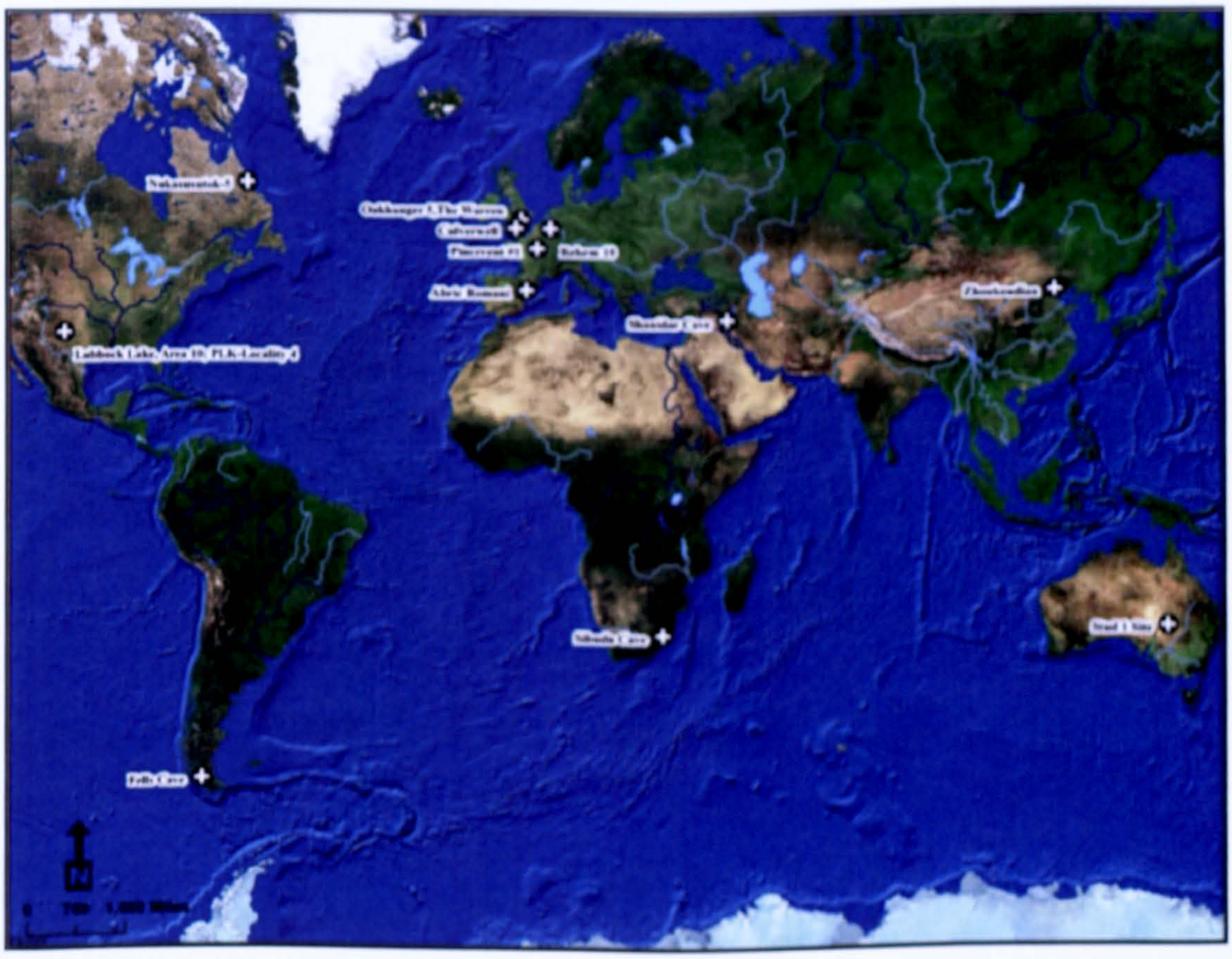
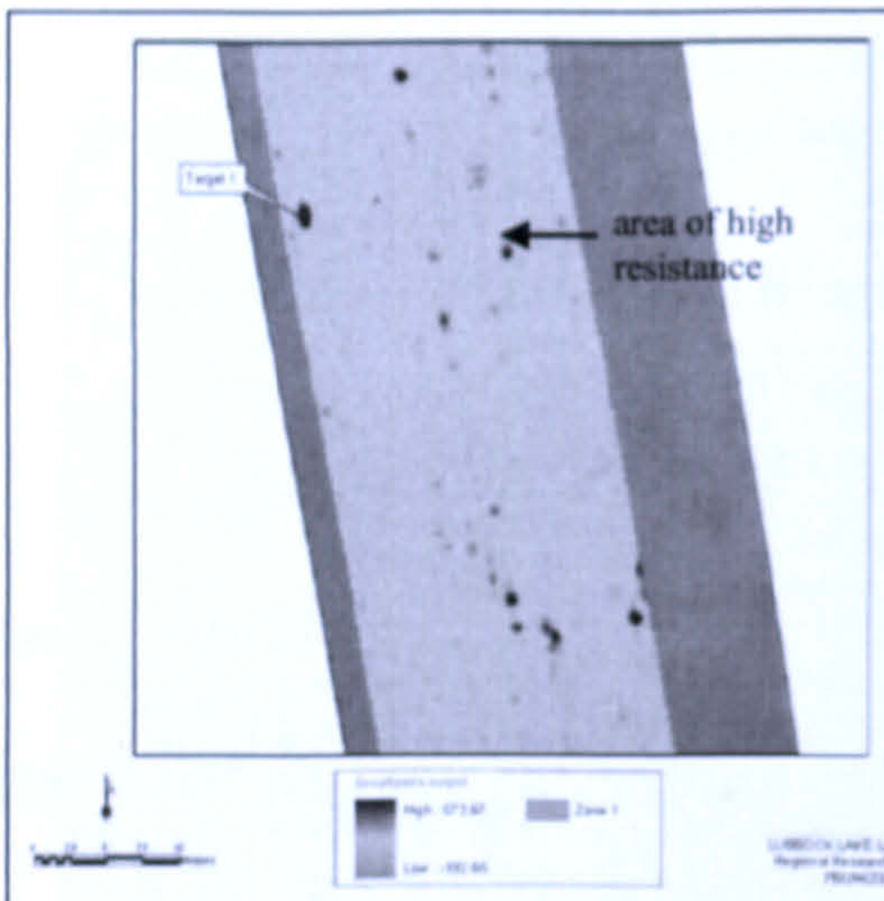
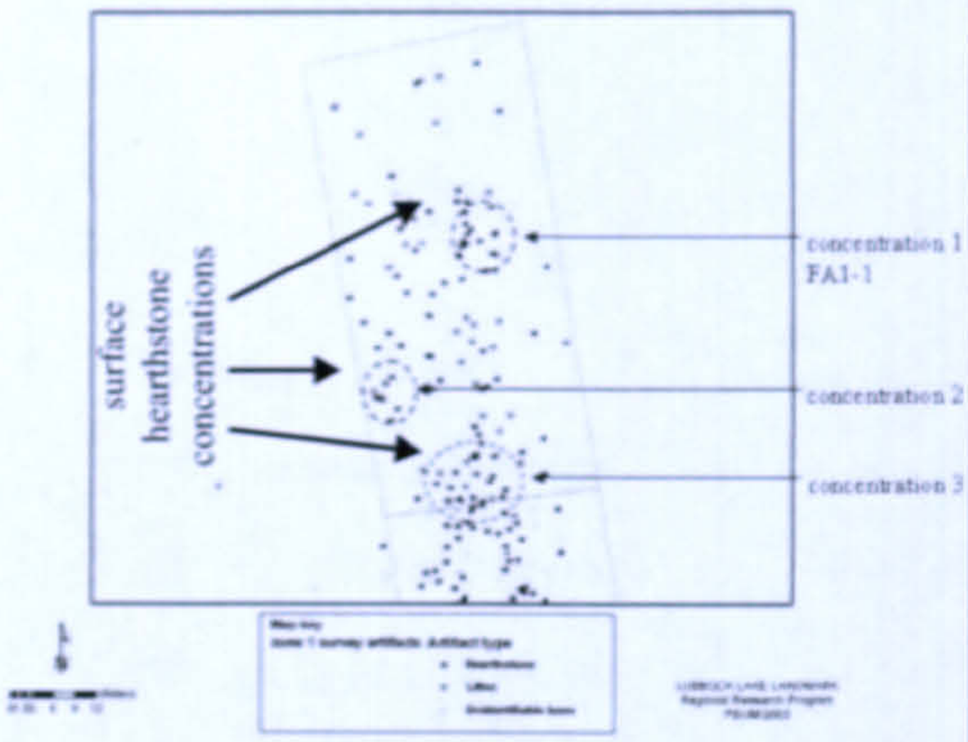


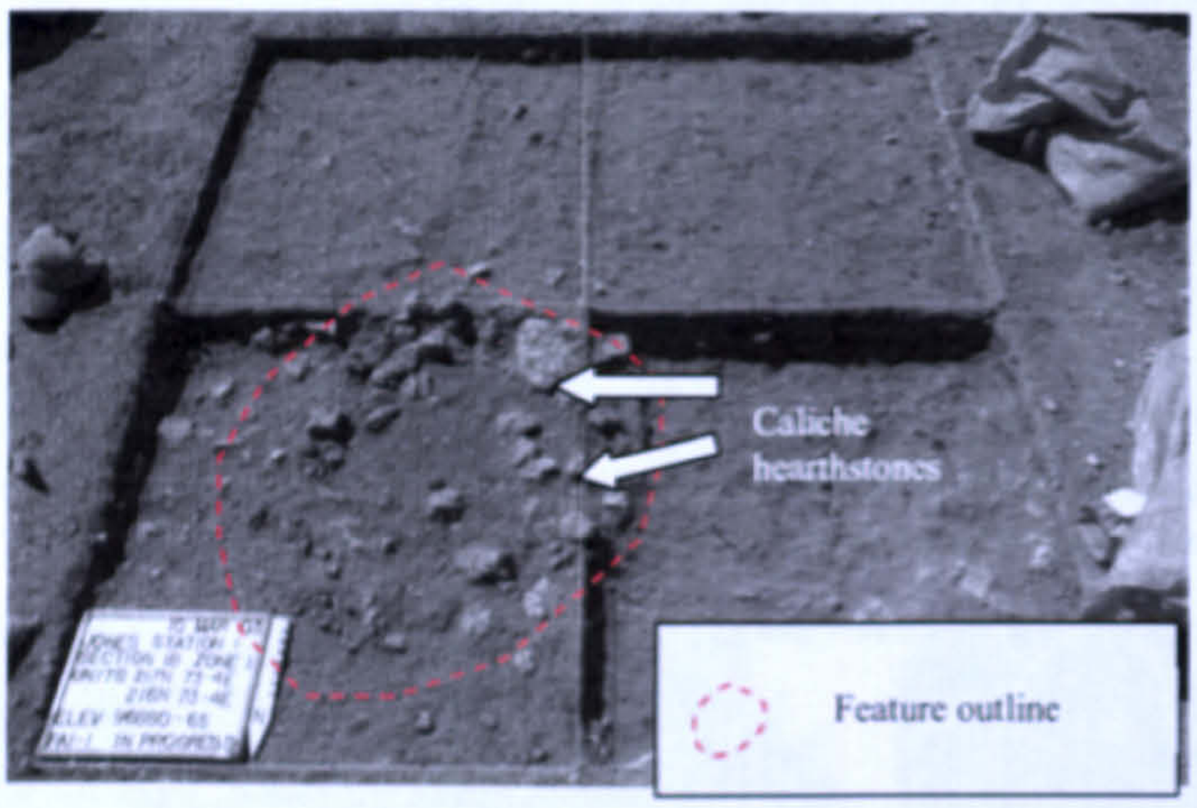
Figure 2.2. Location of hunter-gatherer sites with identified LTFs mentioned and discussed in Chapter 2.



a.



b.



c.

Figure 2.3. Example of a typical sequence of field methods for the identification of an LTF (FA-1) at 41LU129 on the Southern High Plains of North America: a) Output of an electromagnetic survey, note: in this instance the geophysical survey failed to identify any LTFs; b) density of cultural material recovered throughout the same area as the geophysical survey, note: concentration 1 indicates the positive identification of an LTF; c) hand excavation of 1m^2 test units facilitates the detailed excavation of the feature identified in the survey plot (figures modified from Backhouse et al 2005a, figs. 15.39, 15.26, 15.57).

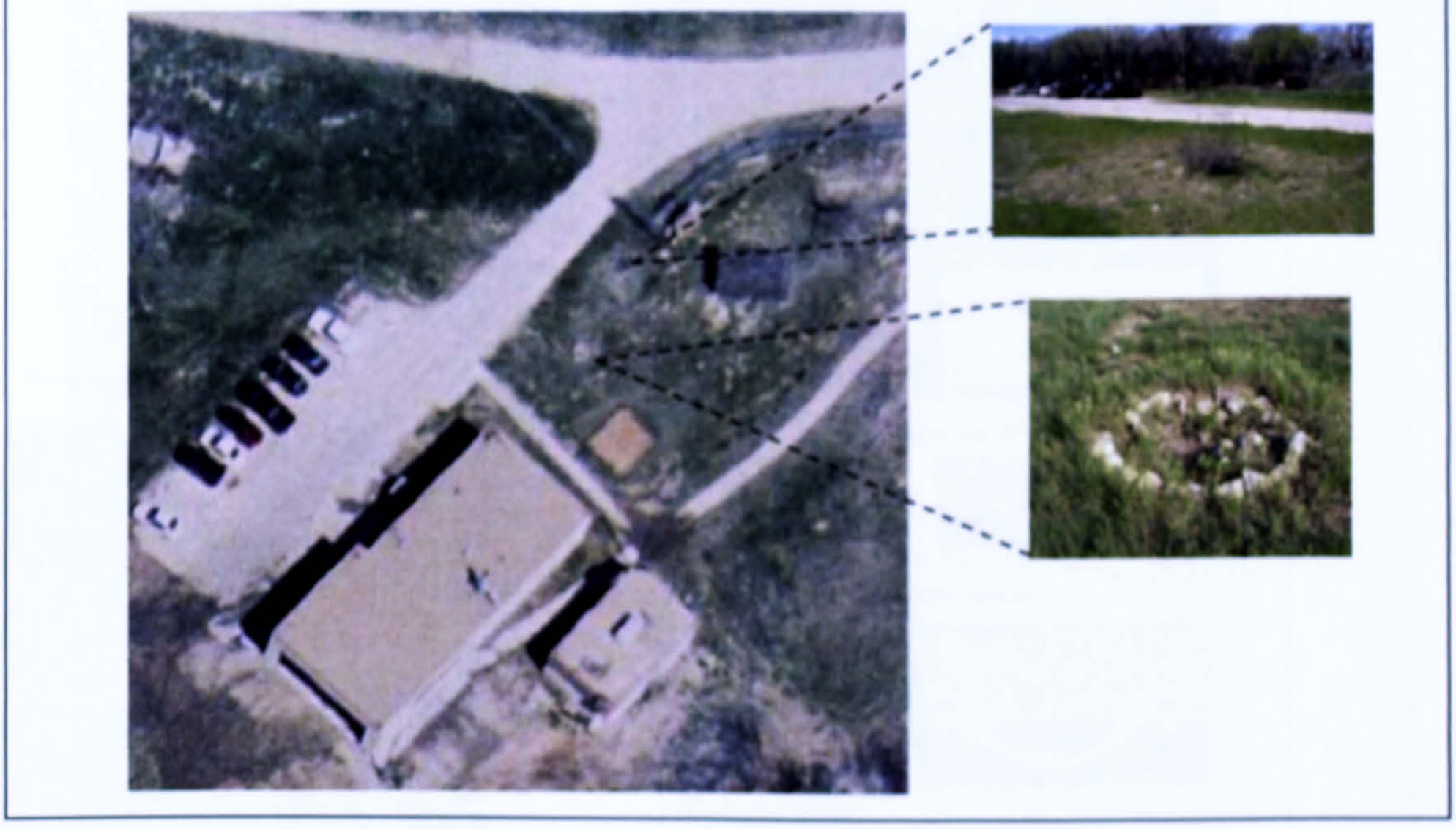
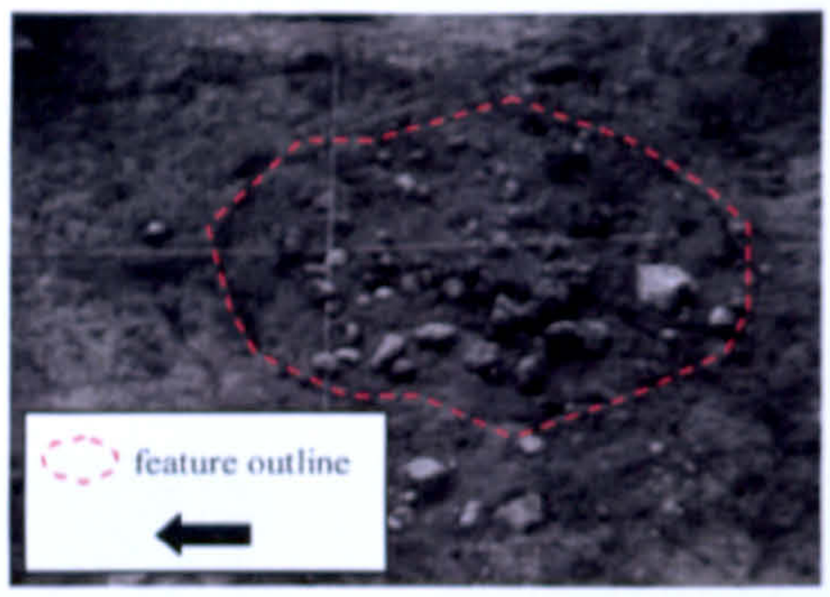
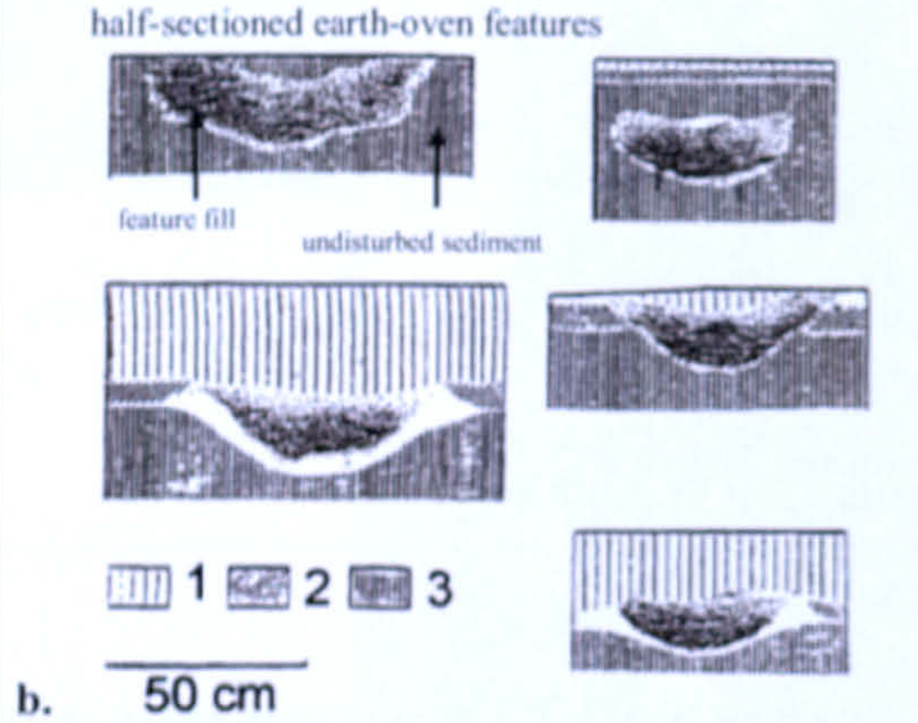


Figure 2.4. High resolution (6in/15.2cm pixel resolution) aerial photograph taken in March 2005 showing two thermal features within the experimental research area at the Lubbock Lake Landmark, Texas; top insert shows an oblique view of the corresponding feature which measures ca.0.5m in diameter and was also photographed in March 2005; bottom insert shows an oblique view of the corresponding feature, a large 1.5m diameter earth oven, photograph taken in June 2005 (aerial photograph available from: http://maps2005.ci.lubbock.tx.us).

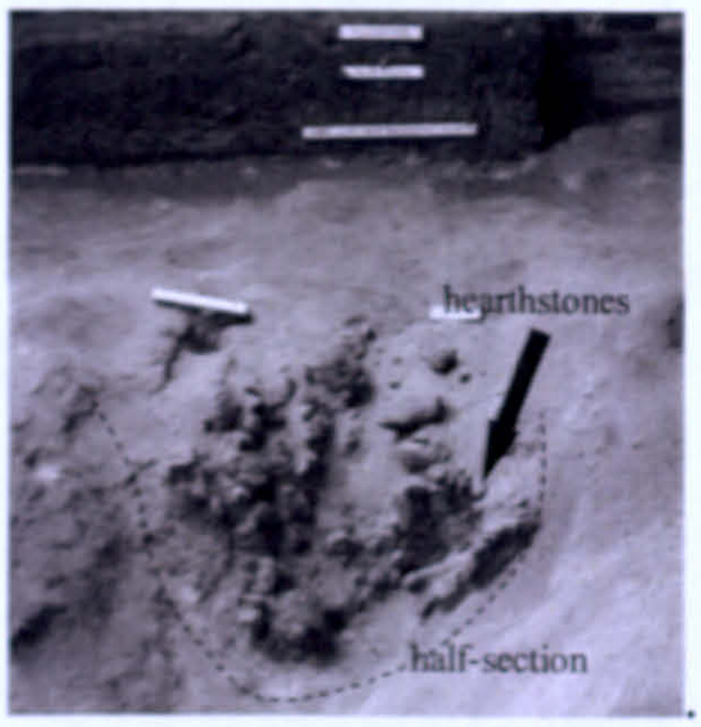


a.





b.



c.

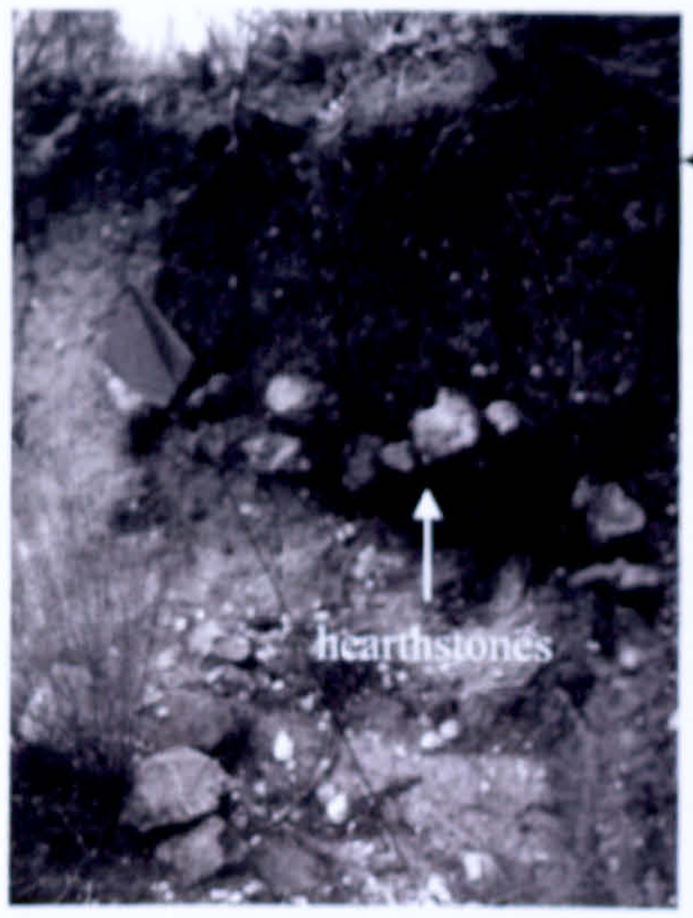


d.



e.

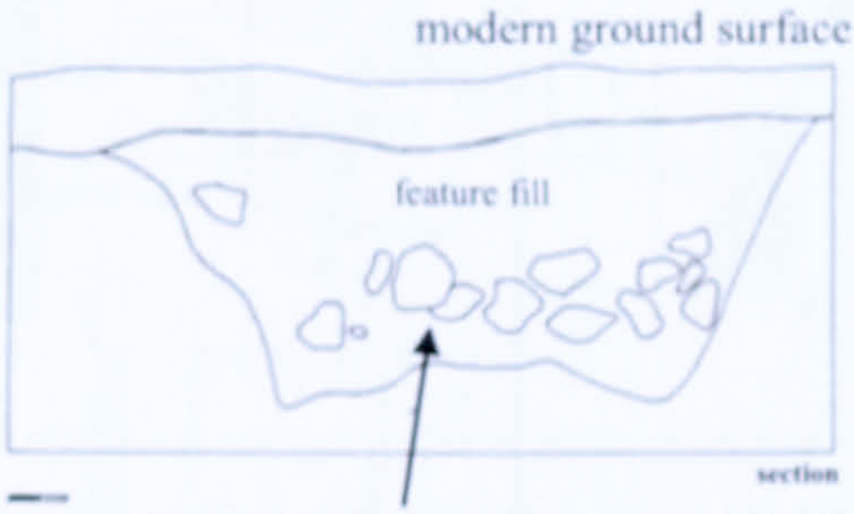
Figure 2.5. Example of some typical LTFs recorded during archaeological fieldwork: a) field photograph and plan drawing of a well-defined basin feature during excavation at 41LU118 in Texas, USA; b) section drawings of well-defined charcoal filled pit features from excavated Dutch Mesolithic localities; c) field photograph of a pit feature, during excavation of a Mesolithic camp at Abinger Manor, Sussex. Note burned charcoal lens at the base and burned rocks exposed in section; d) cluster of burned rocks exposed on the modern ground surface at 41LU35 in Texas, USA; e) discrete area of burning revealed on the modern ground surface after a blowout episode in a dune field, unnamed site, Southern High Plains, Texas (figures a) modified from Backhouse et al. 2001; b) after Perry 1997, fig. 4.4; c) after Leakey 1951, plate IV; d and e) courtesy of the Anthropology Division, Museum of Texas Tech University).



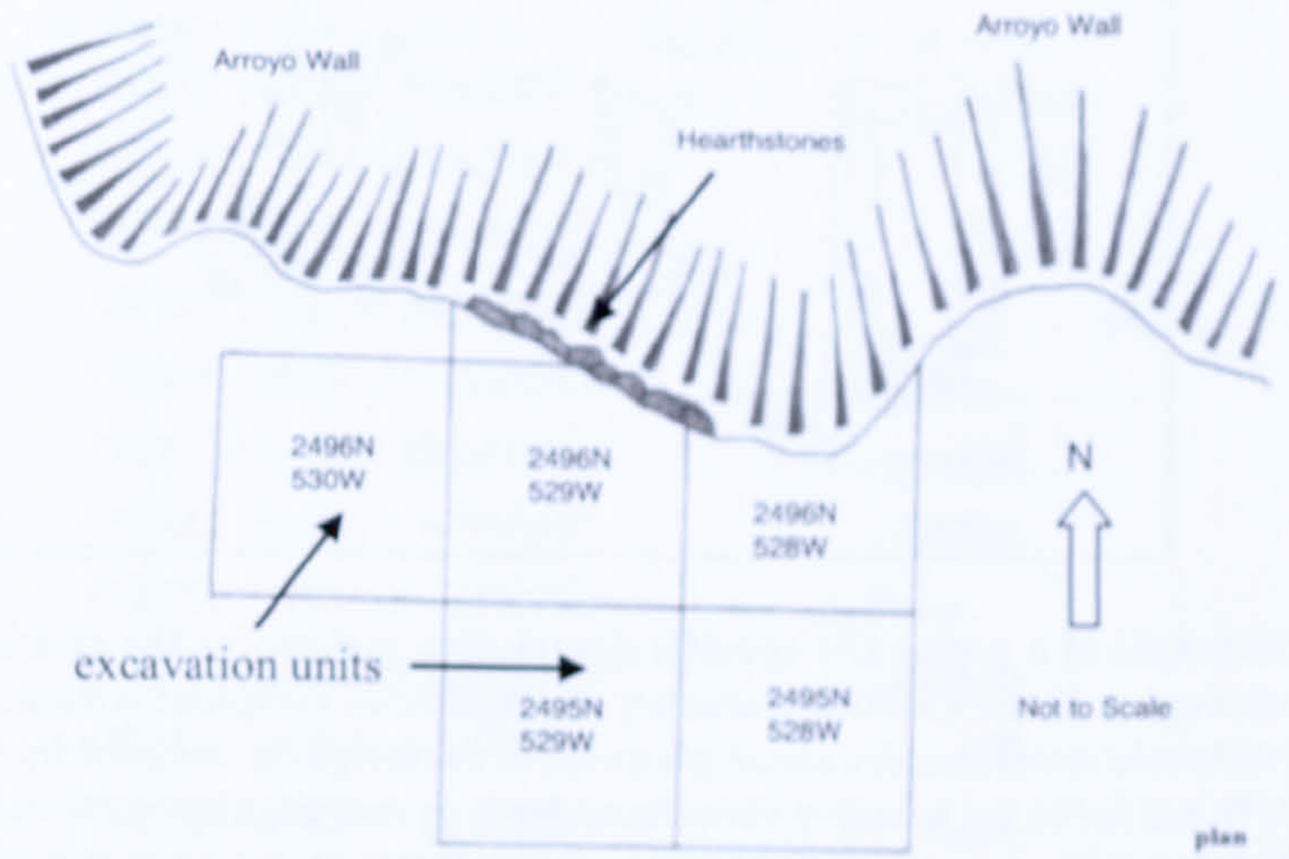
photograph

a.

high fractions of charcoal mixed with the feature fill



b.



c.

Figure 2.6. Excavation of thermal pit feature during the 2001 field season at Tahoka Lake (41LY52) Area 14: a) field photograph of the feature exposed in the arroyo wall; b) profile of feature with the locations of the hearthstones indicated within the feature fill; c) Plan view of the excavation area. Note the hearthstones exposed in the wall of unit 2496N529W (figures modified from Backhouse 2003, fig. 6.2, 6.4, 6.3).



Figure 2.7. Hearthstone cluster on the modern ground surface at PLK Locality 4 identified during pedestrian survey on a ranch in west Texas. Note the dark discoloration of the rocks.

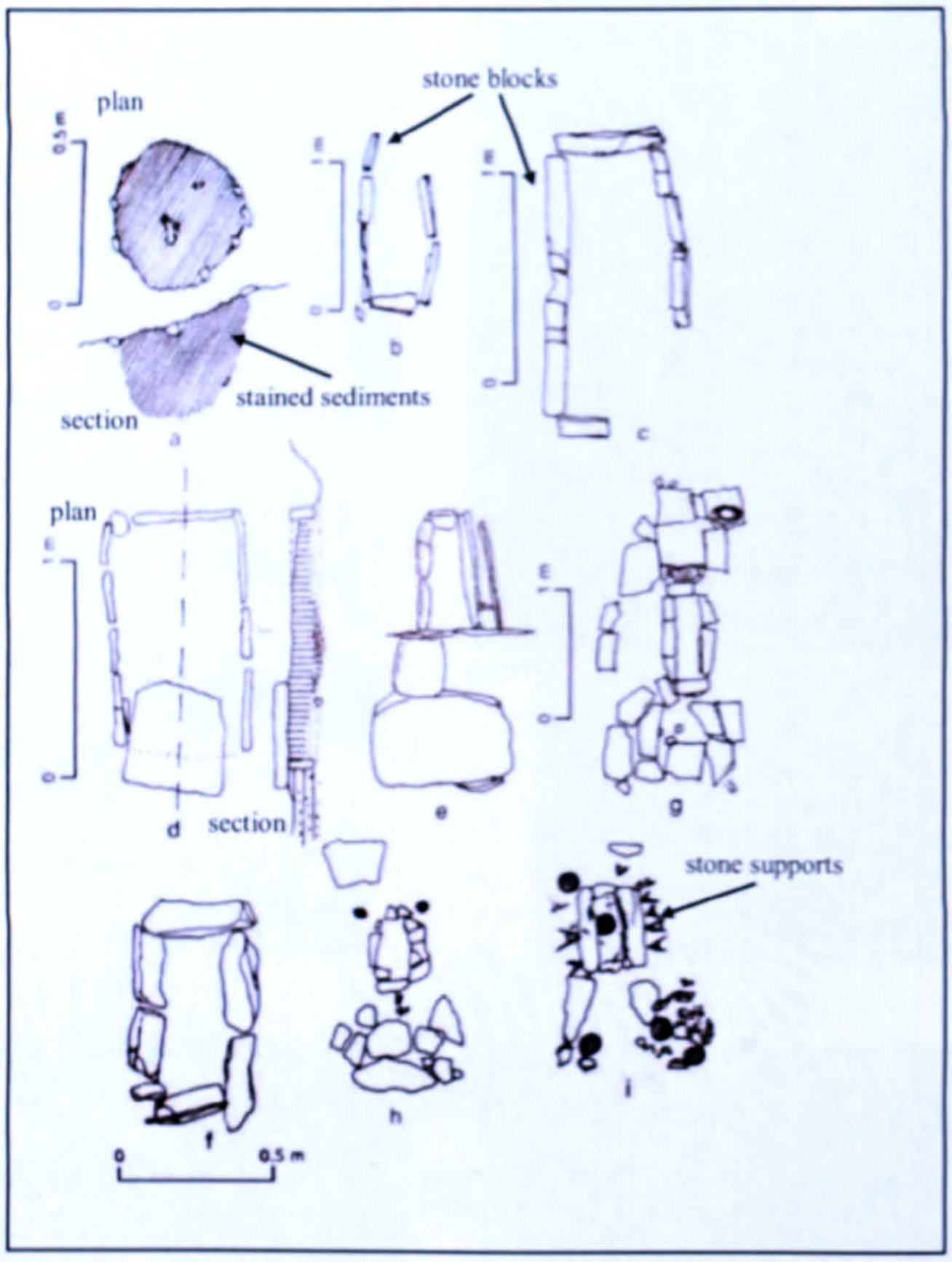


Figure 2.8. Example of a regionally specific descriptive system for the classification of LTFs from the Iron Gates region of the Central Balkans: a) ellipsoidal recipient with no other constructive elements; b) ellipsoid bordered by stone plaques; c) rectangular covered by stone plaque; e) with side channel; f) bordered by massive stone boulders; g) rectangular with an ash bordered by stone plaques; h) bordered by massive stone blocks; i) bordered by massive stone blocks and signs/supports (modified from Radovanović 1996, fig. 3.52).

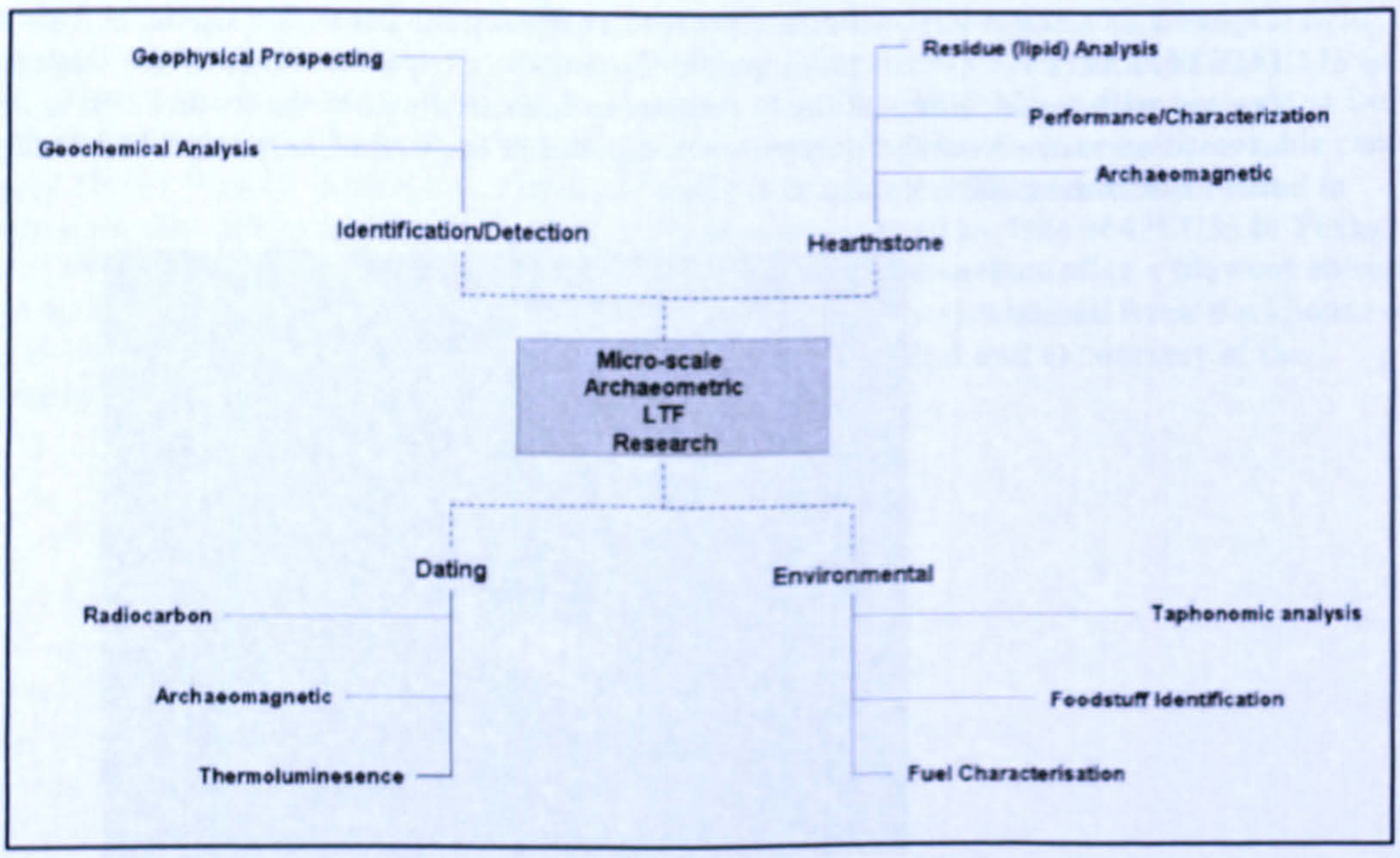


Figure 2.9. Overview of the range of archaeometric techniques applied to the investigation of LTFs encountered during archaeological fieldwork.

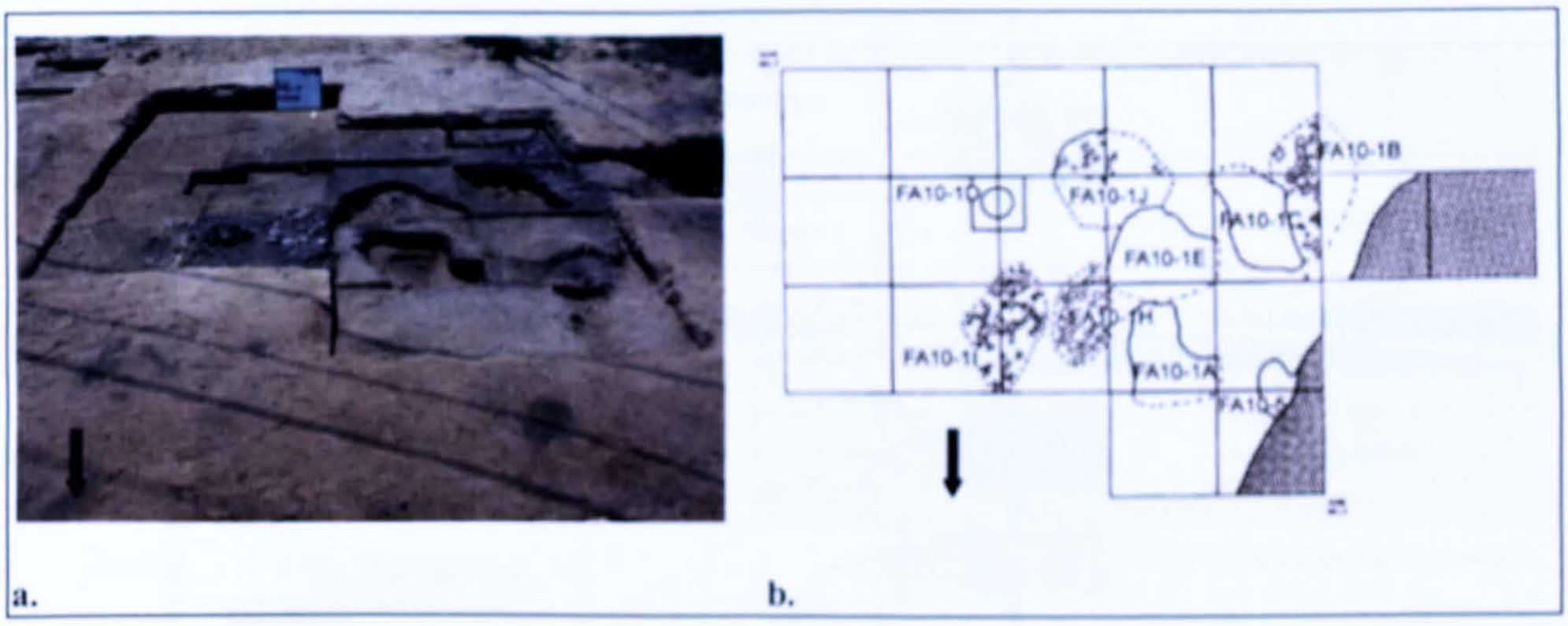


Figure 2.10. Intersecting LTFs excavated into the aeolian upland sediments at 41LU1, Area 10 in Lubbock County, Texas, USA: a) field photograph taken after the complete excavation of several of the features; b) feature map drawn during the 1999 field season (photograph a) courtesy of the Anthropology Division, Museum of Texas Tech University; diagram b) modified from Selwood and Holliday 2002, fig. 9.2).

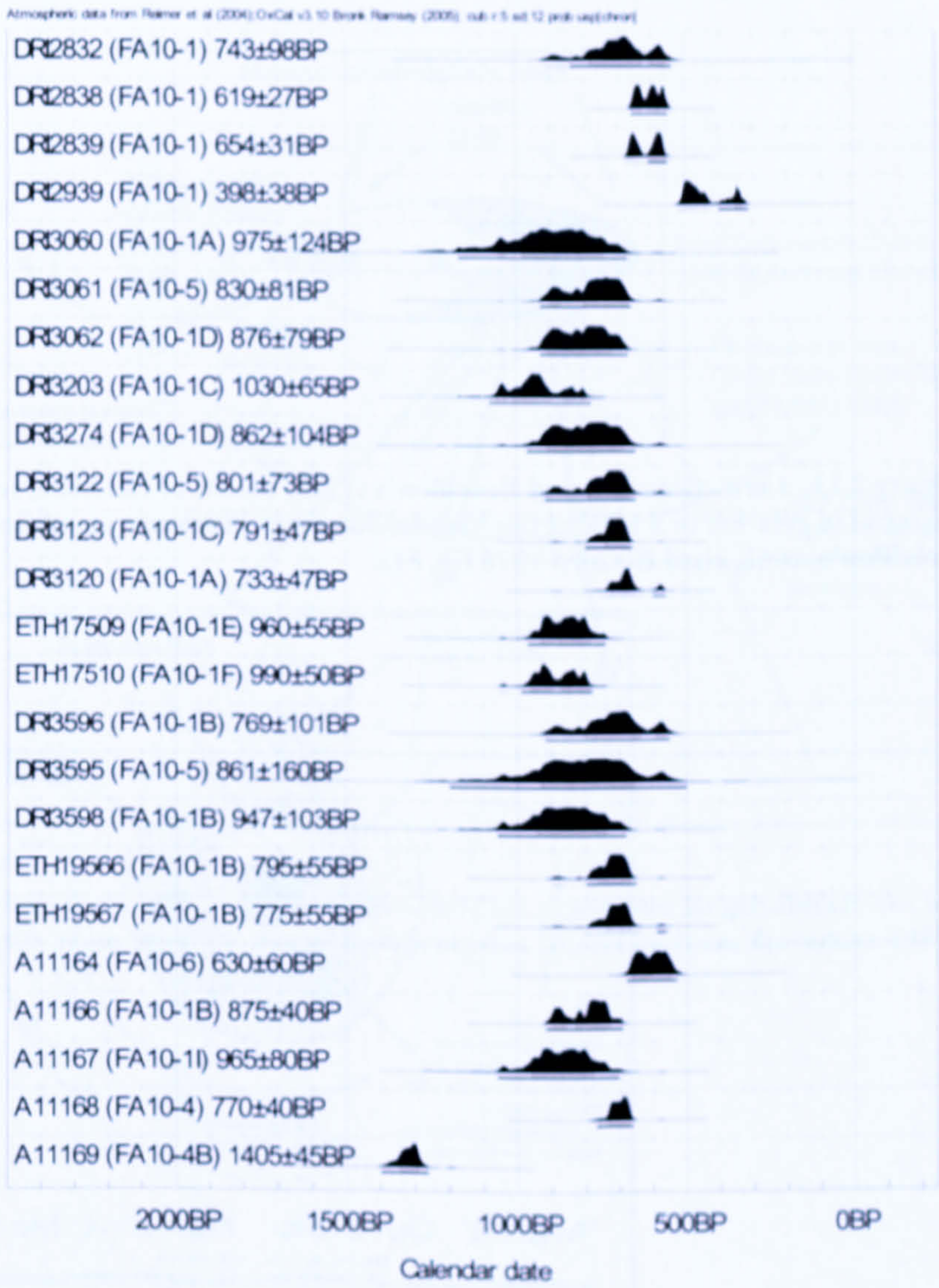


Figure 2.11 Results of samples sent for radiocarbon dating from 41LU1 Area 10 plotted using OxCal Viewer Version 3.9 (data from Buchanan 2002, table 7.1; Backhouse 2002, table 10.5).

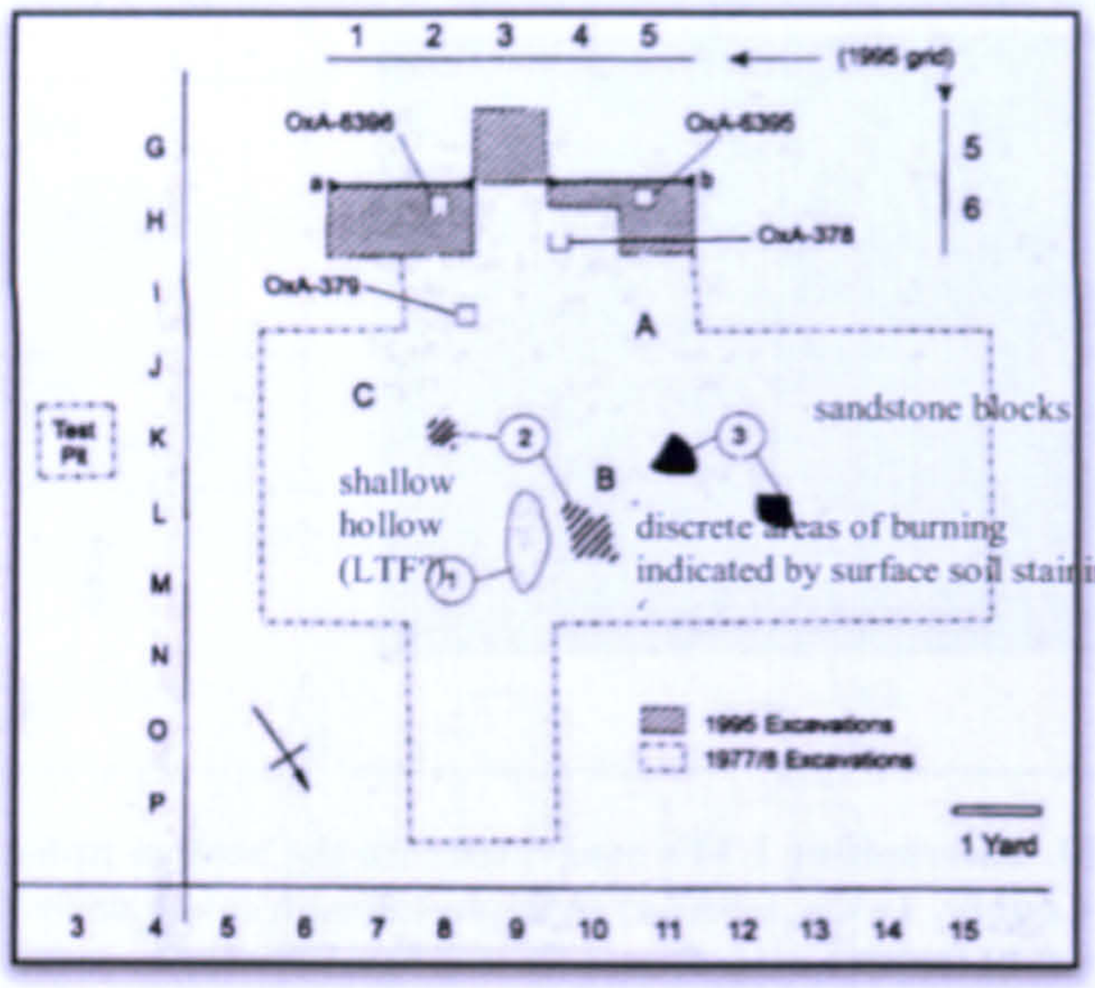


Figure 2.12. Example of recorded LTF structures as components in hunter-gatherer site structure at Kettlebury 103, Surrey (modified from Reyneir 2002, fig. 4).

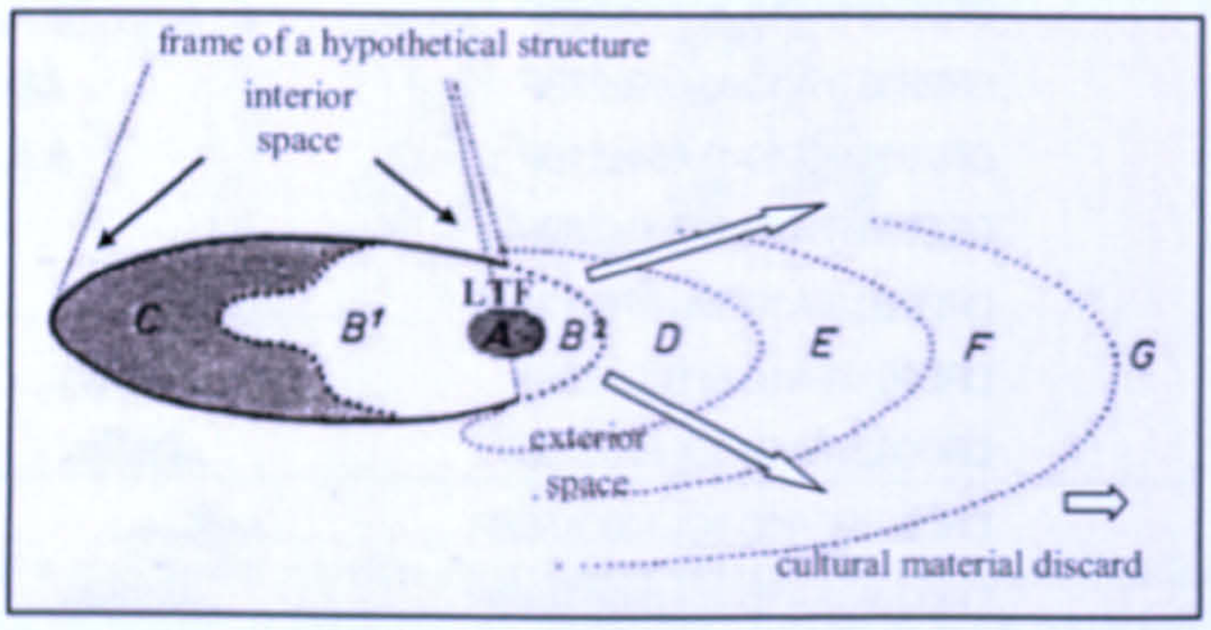


Figure 2.13. Leroi-Gourhan and Brézillon's (1962) model of radiating sectors of discarded cultural material in relation to a LTF at the Magdalenian site Pincevent (modified from Leroi-Gourhan and Brézillon's, 1962, cited Binford 1978 fig. 81).

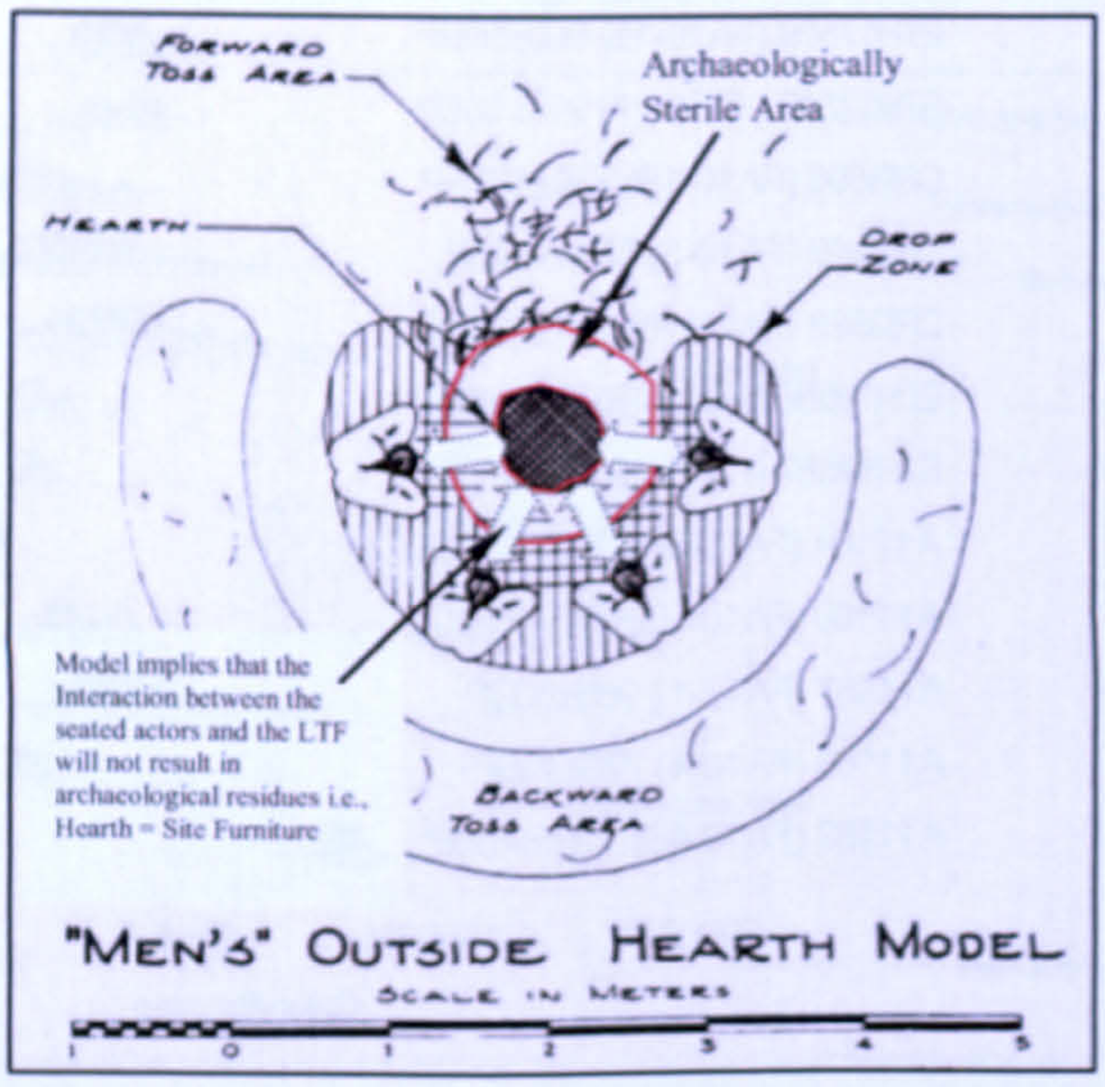


Figure 2.14. Binford's drop and toss zone model developed from his ethnographic observations of Nunamiut at the Mask site, Alaska (modified from Binford 1978, fig. 89).

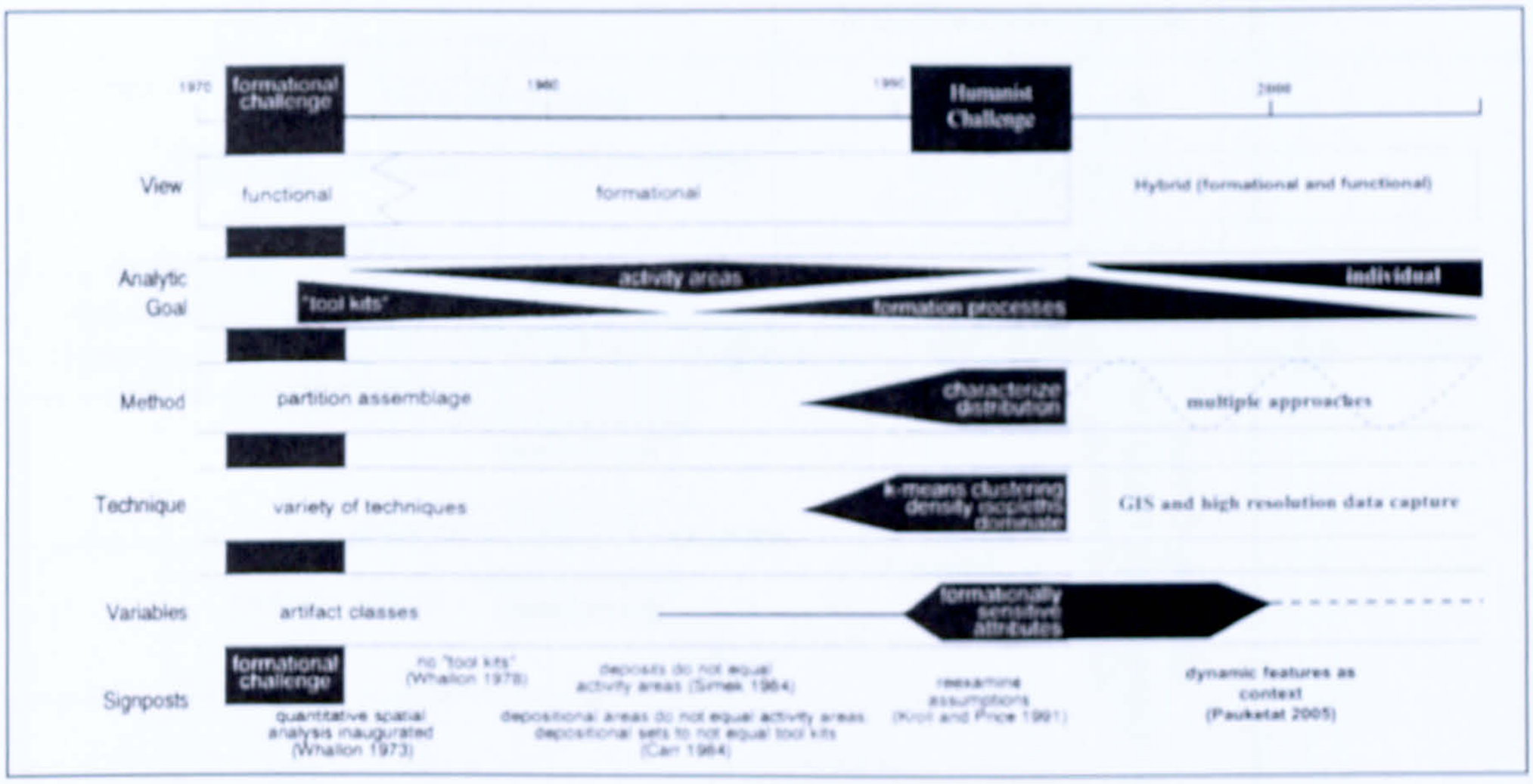


Figure 2.15. Theoretical development and trends in spatial analysis research (after Wandsnider 1996, fig. 1).

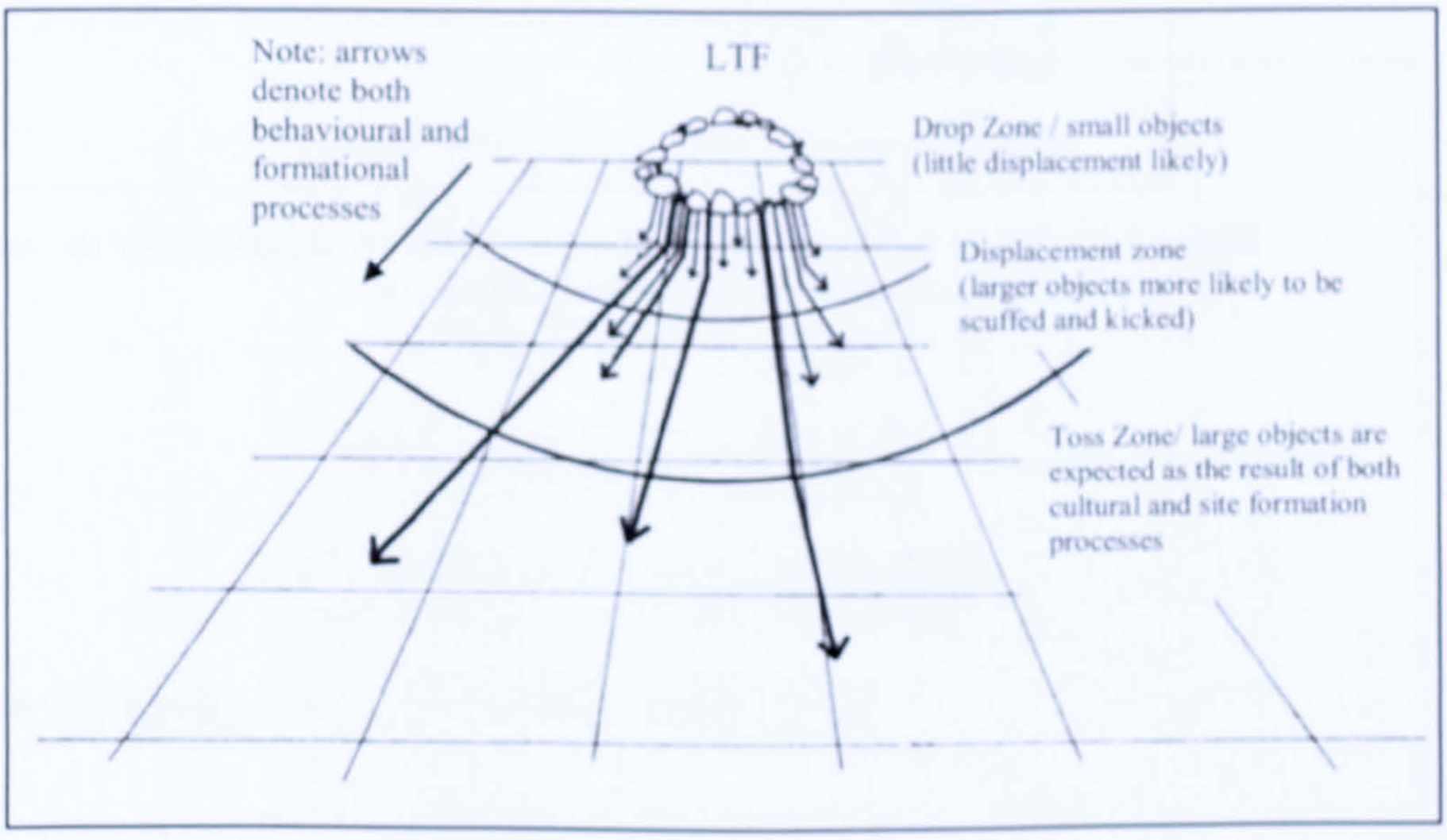


Figure 2.16. Marc Stevenson's size sorting model that predicates larger objects are more likely to be displaced away from the LTF by cultural processes (modified from Stevenson 1991, fig. 2).

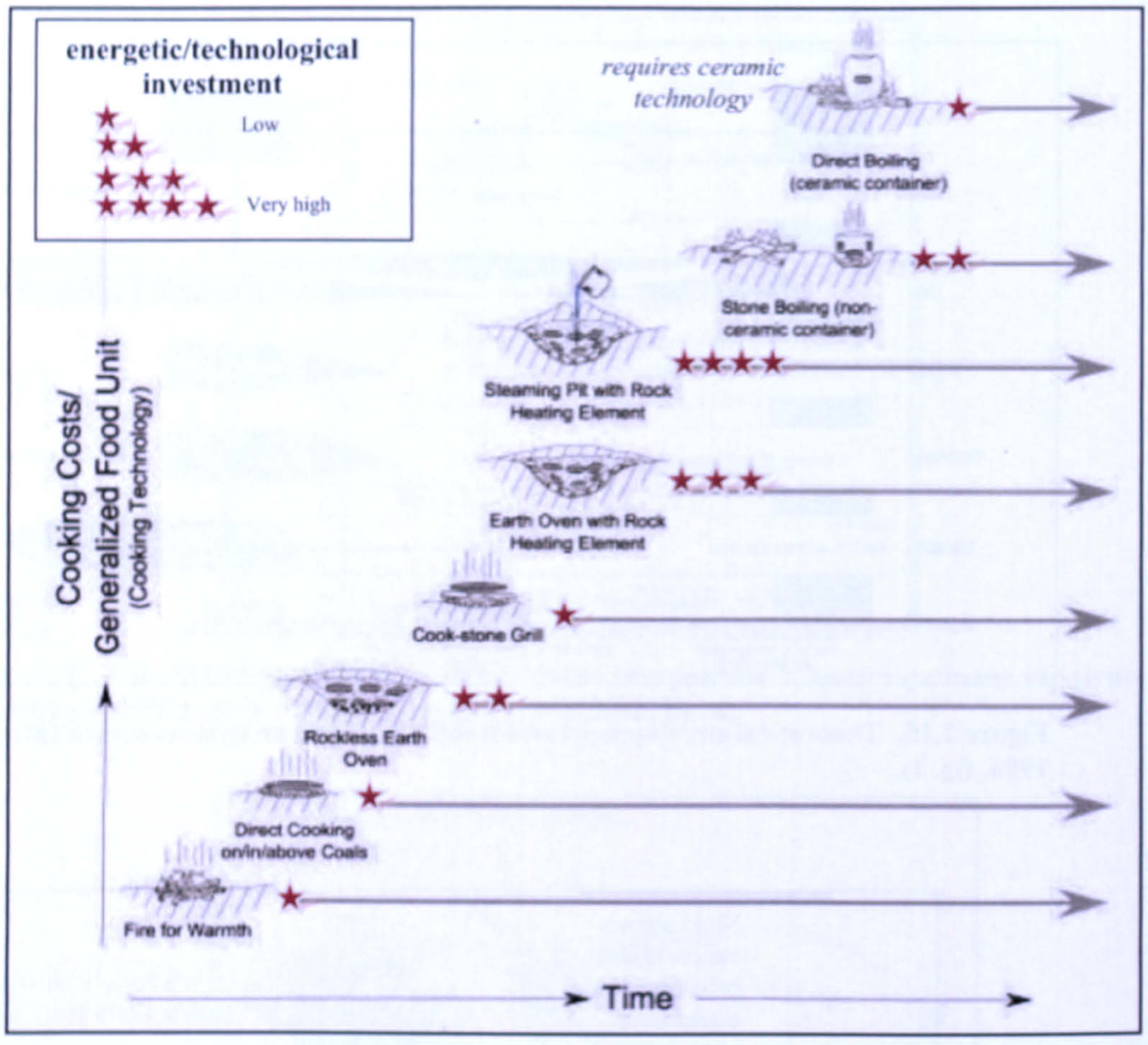


Figure 2.17. Model for the prediction of expected temporal patterns for the onset of different cooking techniques (modified from Thoms 2005, fig. 16).

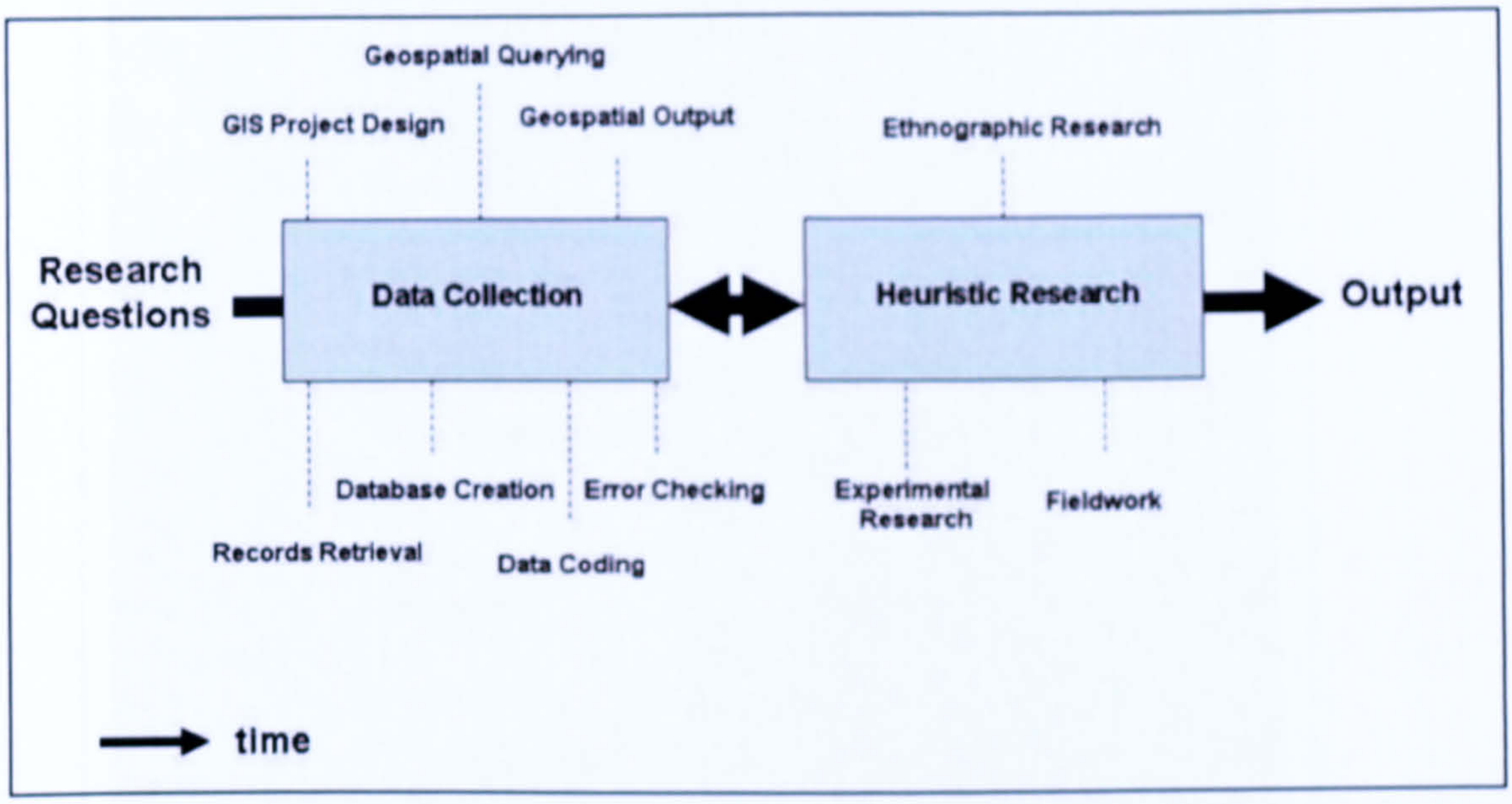


Figure 3.1. Conceptual timeline showing the main methodological components of the research project.

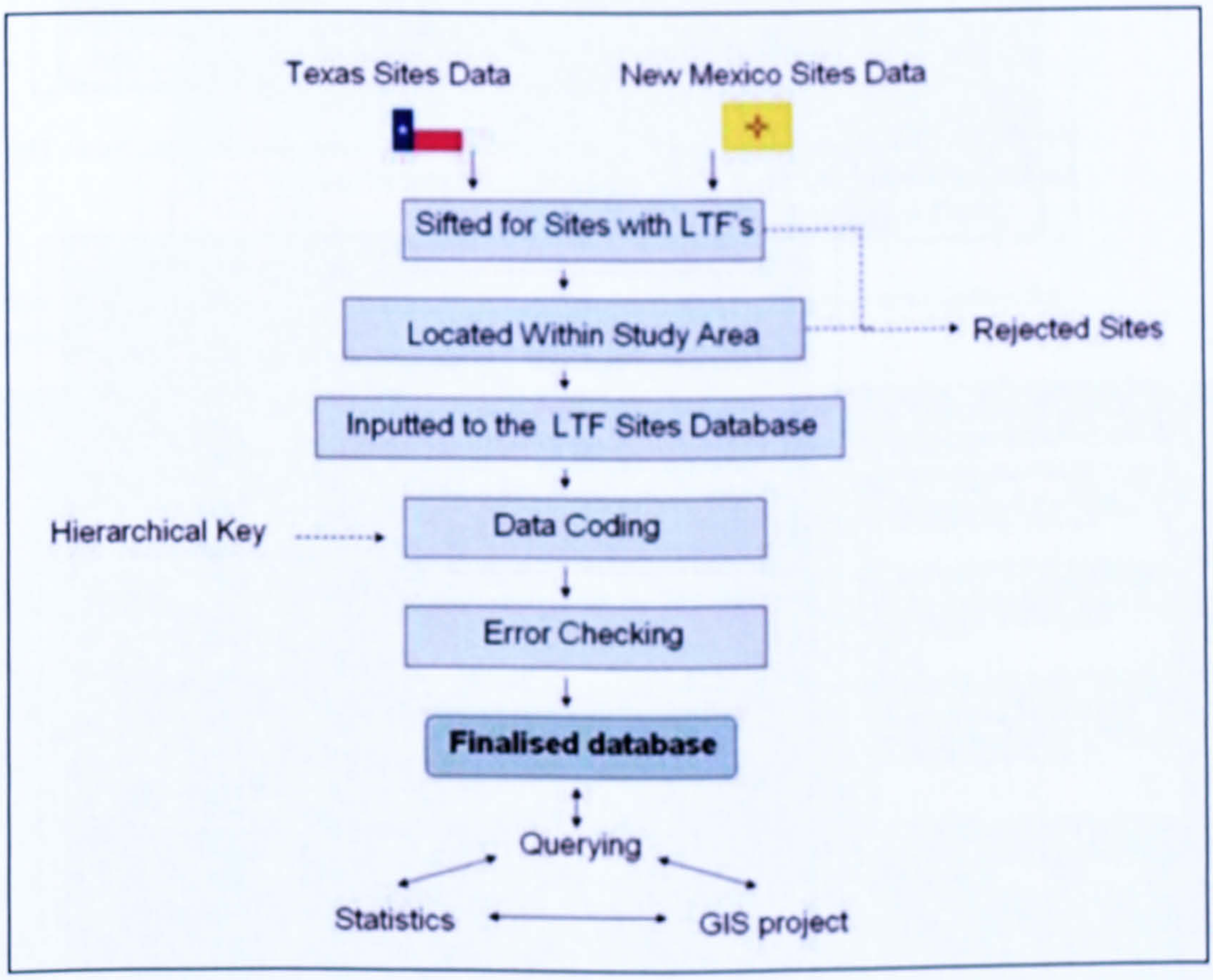


Figure 3.2. Simplified process chart showing the component steps of data capture.

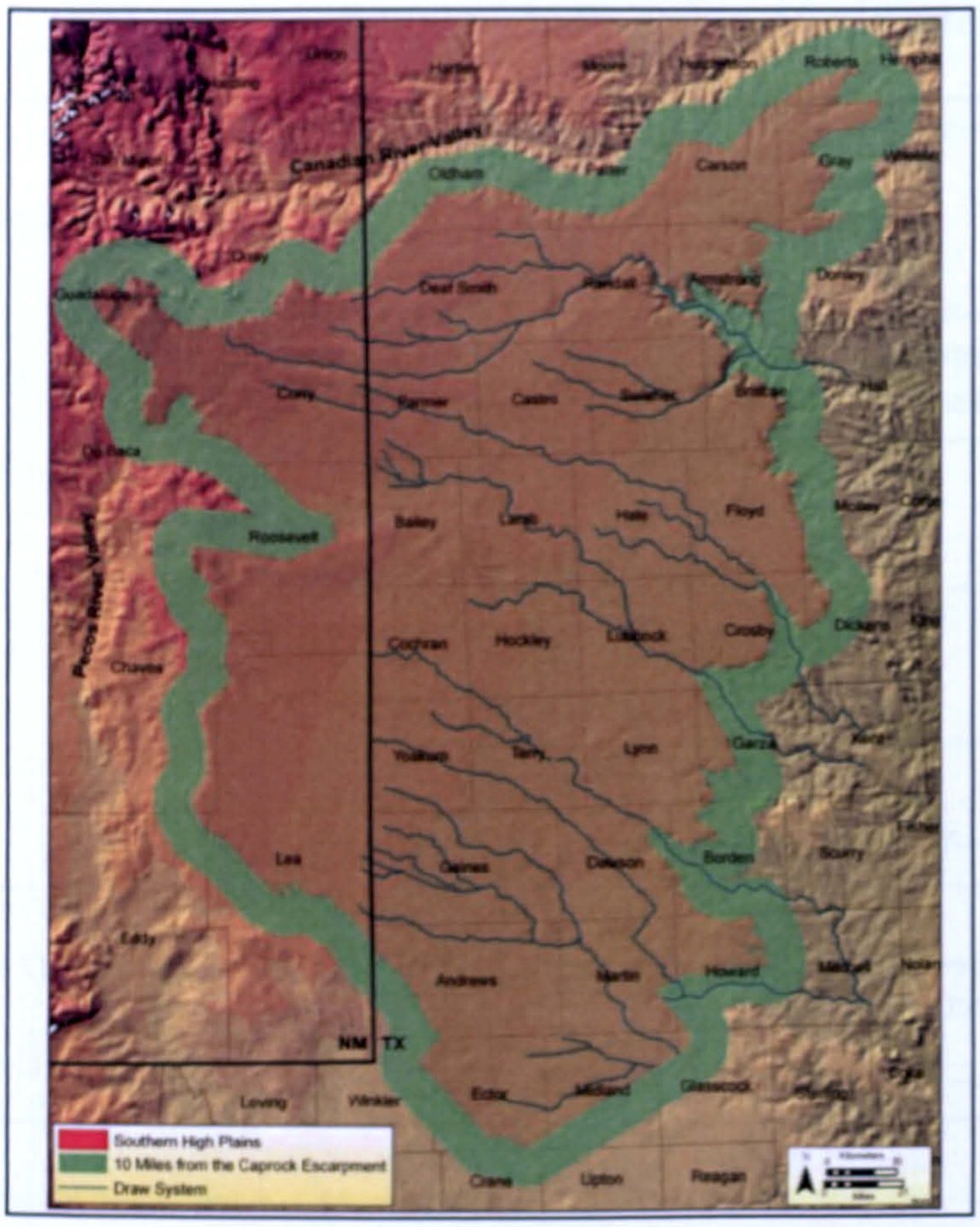


Figure 3.3. Southern High Plains region showing the County boundaries. Note: The ten-mile boundary around the physiographic region indicated in green.

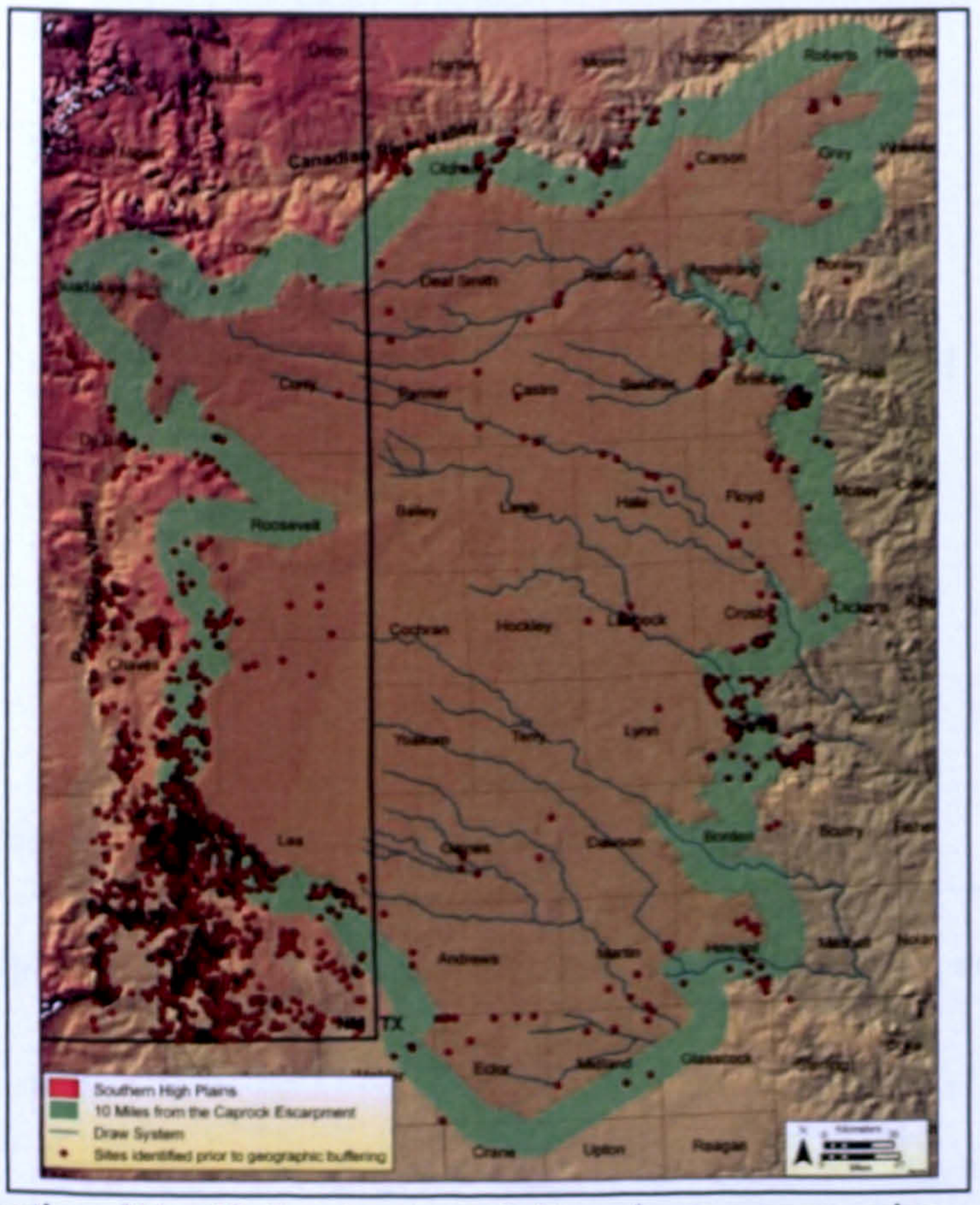


Figure 3.4. Distribution of identified archaeological sites prior to geoprocessing.

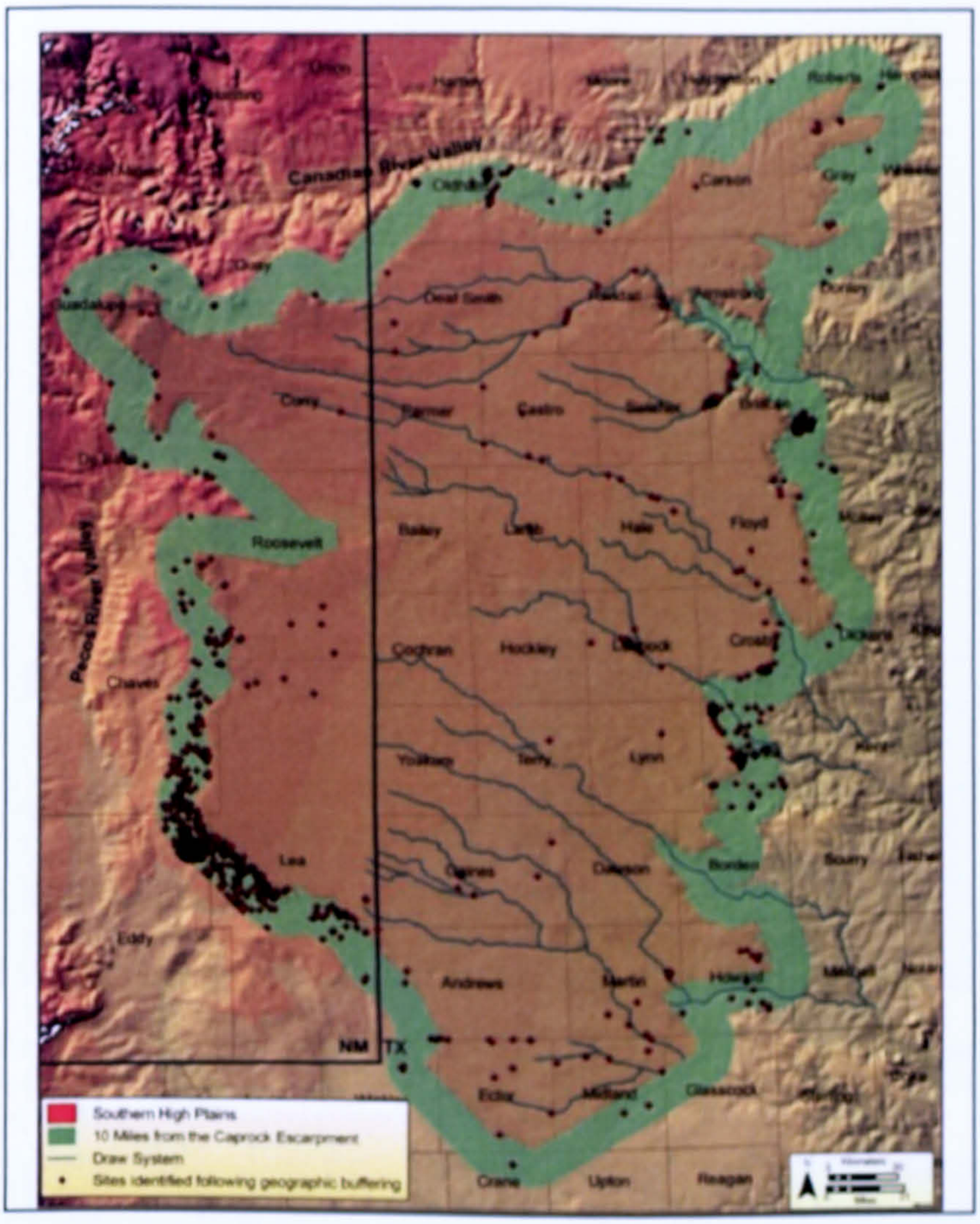


Figure 3.5. Distribution of archaeological sites within the investigation area following geoprocessing.

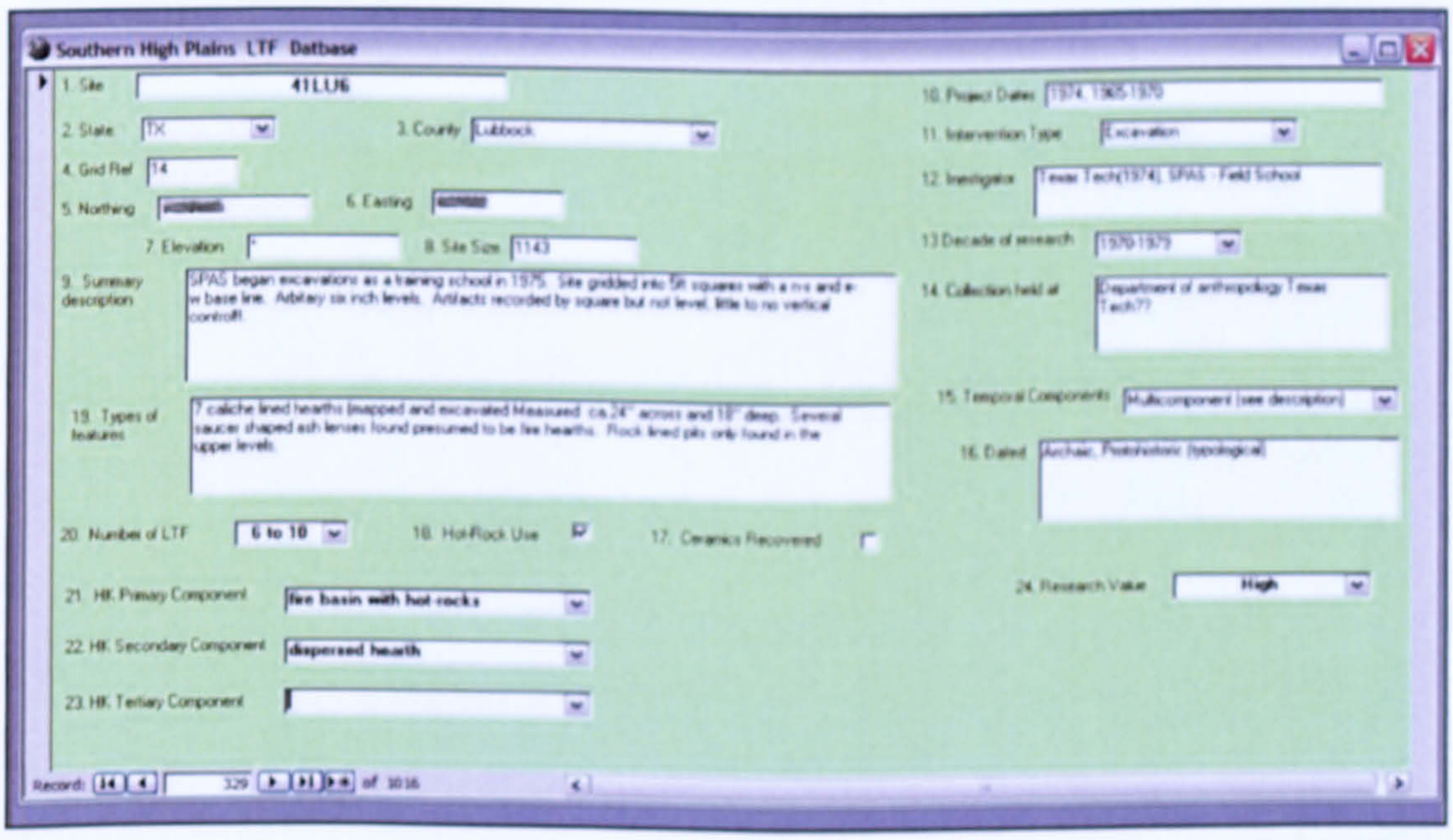


Figure 3.6. Example record output from the sites database. Note: the northing and easting are obscured in this example to protect the location of the archaeological site, site location data in Texas are confidential under state (§191.004 Texas Natural Resources Code (VTCA 1995)) and federal (Archeological Resources Protection Act of 1979, 16 USC §470aa et. seq.) laws.

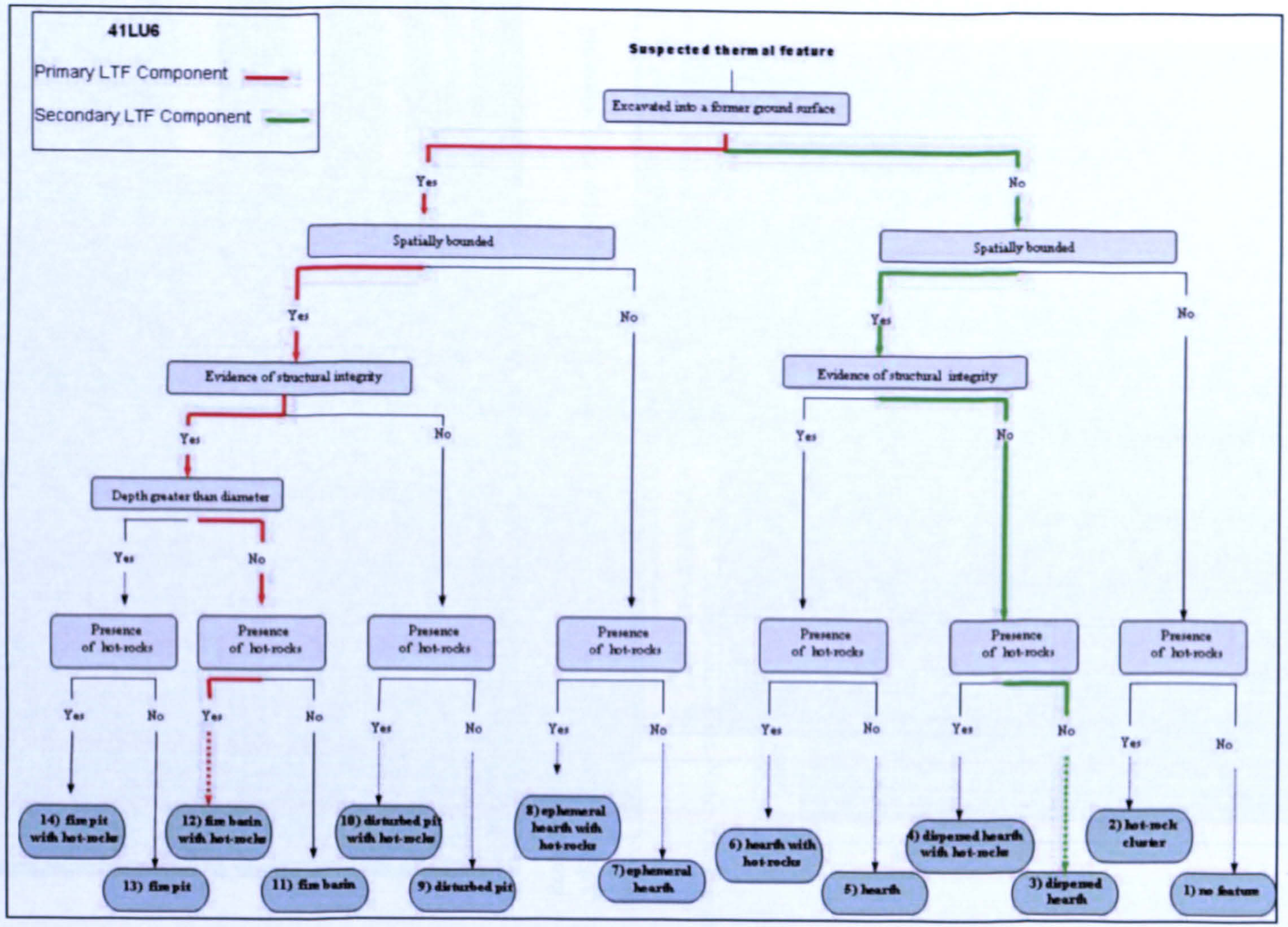


Figure 3.7. Example of the decision making process in the assignment of the primary and secondary LTF components at 41LU6 based on the descriptive data compiled from the site survey record.



Figure 3.8. Reconstruction drawing of hunter-gatherer residential activities in relation to a centrally placed LTF (figure Sidell *et al.* 2002:20, fig. 15, copyright Museum of London Archaeological Service).



Figure 3.9. Ray Olachia instructs local high school teachers, students, and professional archaeologists in the construction of an earth oven at the Lubbock Lake research area.



Figure 3.10. Excavation block at 41LU118 during full-scale excavation.

Chapter 4



Figure 4.1. Major cultural areas identified in North America, with the Plains physiographic province highlighted (modified from Fagan 1991).

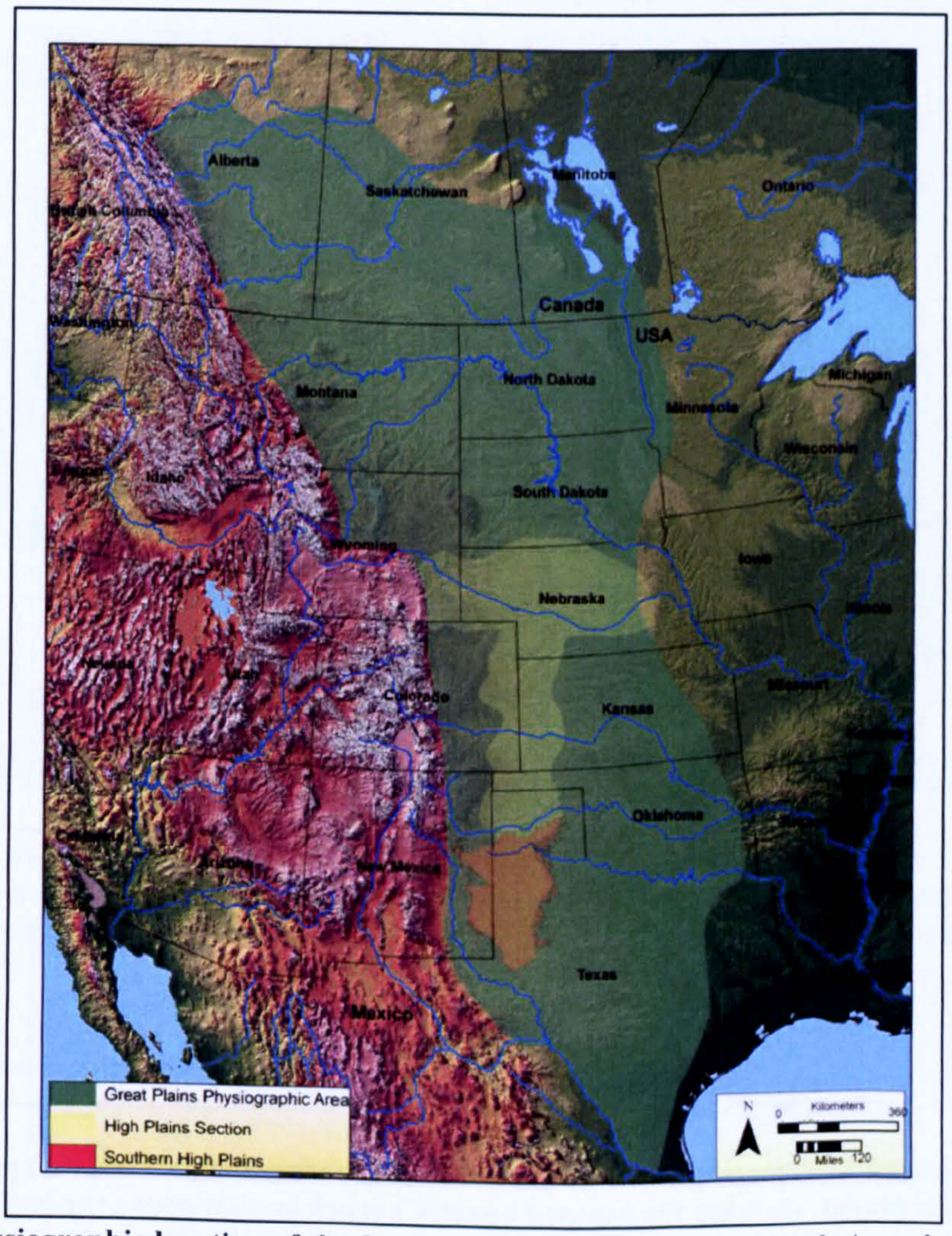


Figure 4.2. Physiographic location of the Southern High Plains on the North American Plains overlaid with the location of modern political boundaries.

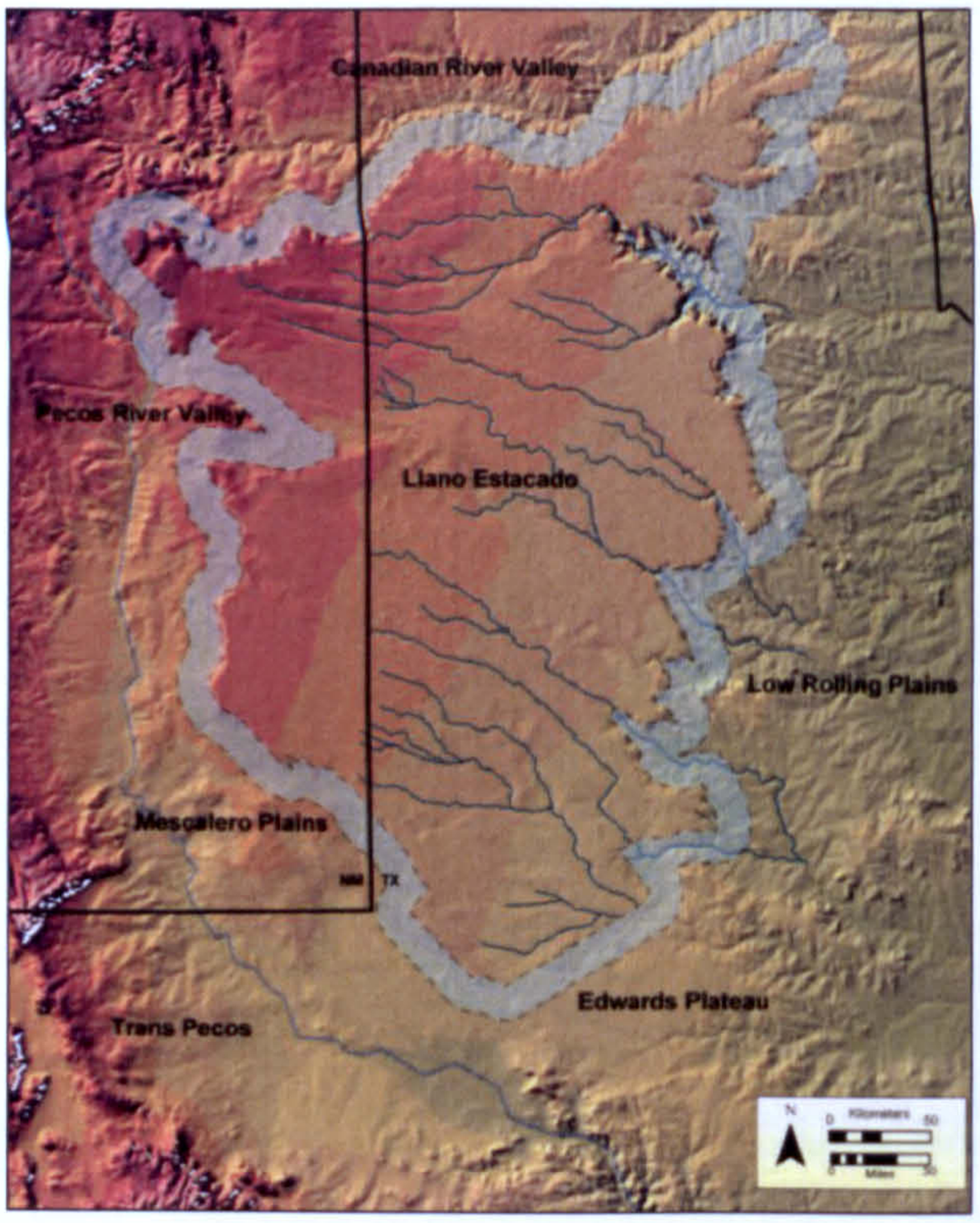


Figure 4.3. Physiographic setting of the Southern High Plains (Llano Estacado) with neighbouring geographic areas indicated.

a.



b.

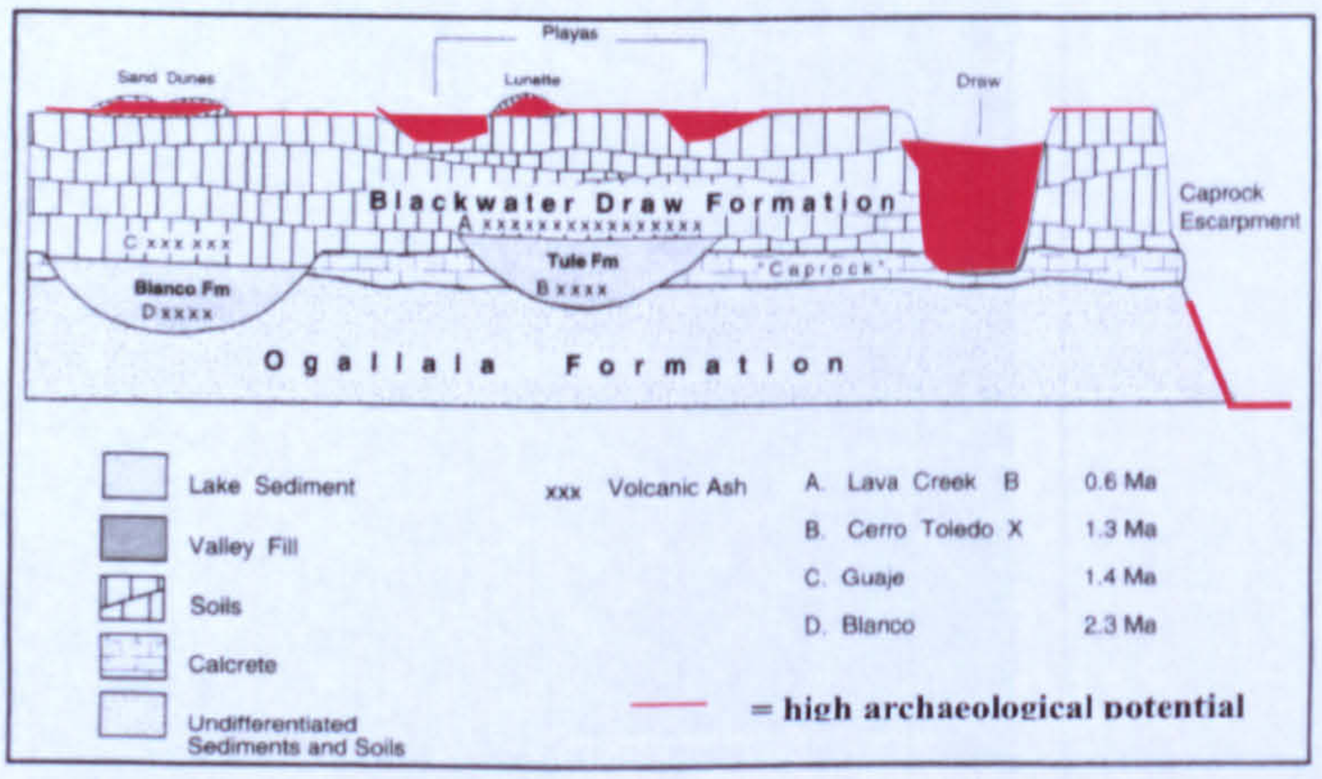


Figure 4.4. Geomorphic development of the Southern High Plains: a) photograph of the eastern escarpment, showing the exposed upper Caprock section above the low Rolling Plains; b) idealised geomorphologic cross section of the upper geologic units that comprise the Southern High Plains (diagram b) modified from Holliday 1997, fig. 1.4).

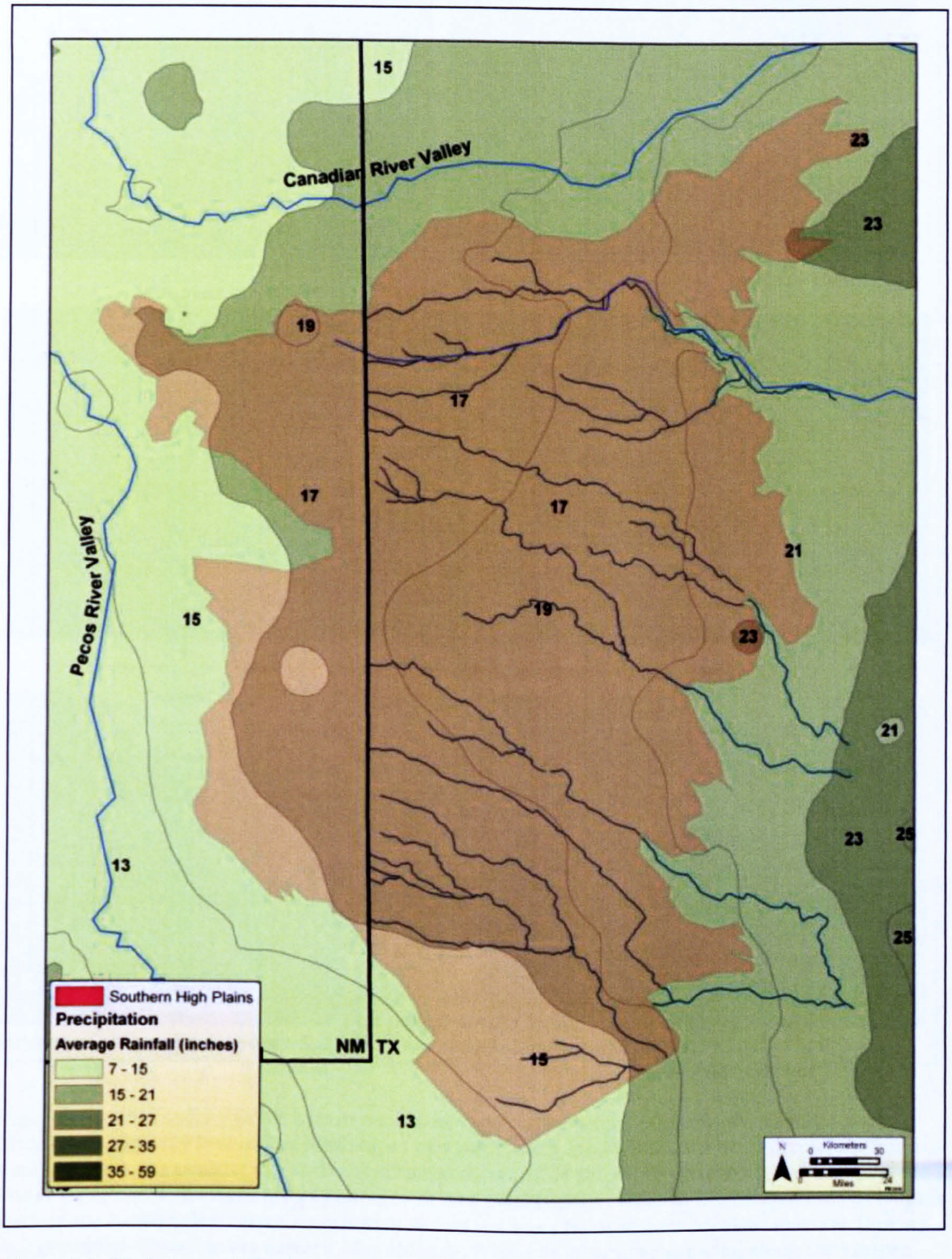


Figure 4.5. Modern precipitation pattern for the Southern High Plains Regions. Note that rainfall increases from southwest to northeast across the region (data National Oceanic Atmospheric Administration).

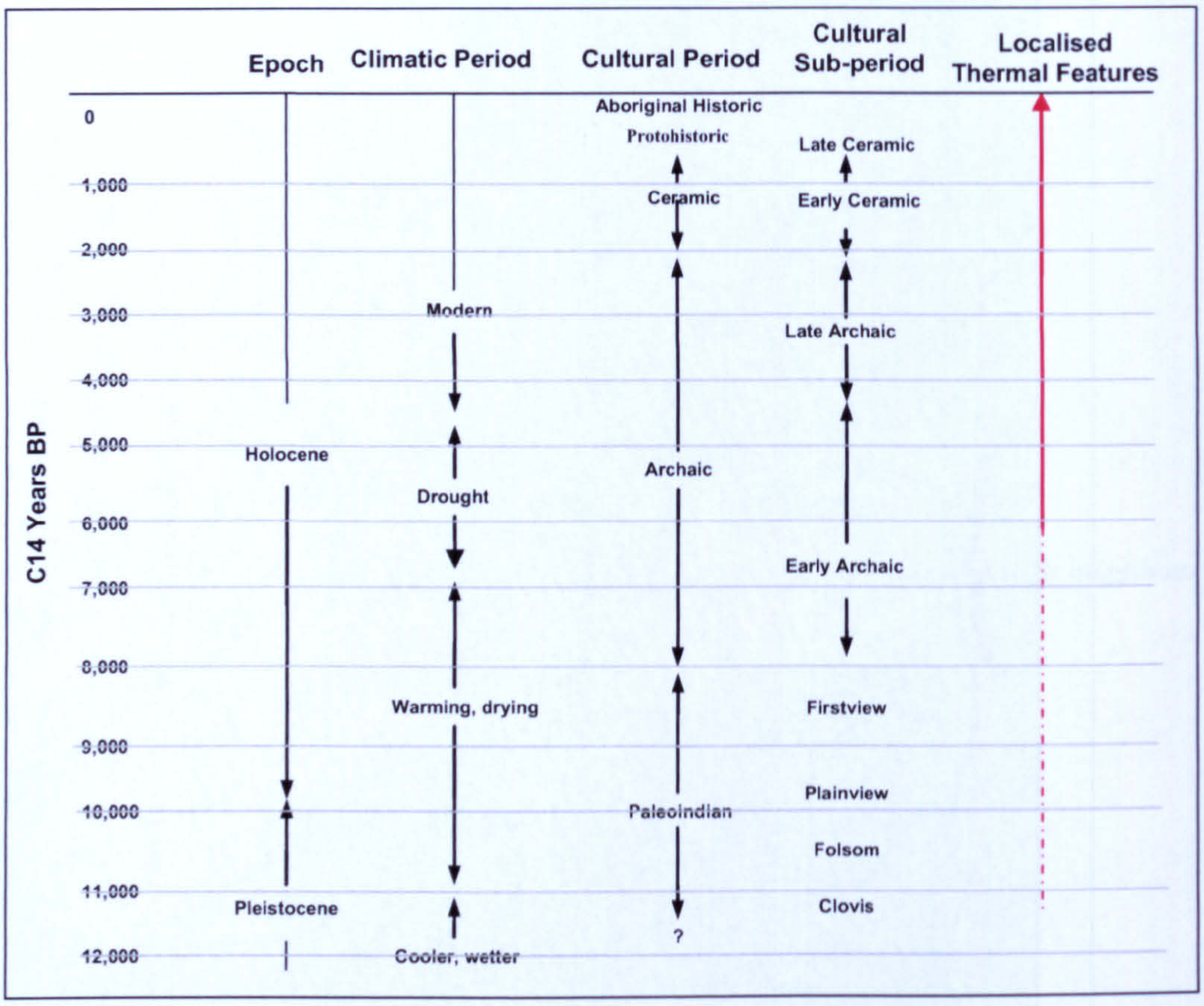


Figure 4.6. Generalised temporal framework for the Southern High Plains showing climatic and cultural periods, with the approximate appearance of localised thermal feature technology indicated in red (modified after Johnson 1987a, fig. 2.7; chronostratigraphic conventions follow Holliday 1997:16).



a.



b.



c.



d.



e.



f.

Figure 4.7. The modern environment on and around the Southern High Plains: a) short-grass prairie in a virtually featureless landscape; b) a prairie dog emerges from his subterranean burrow excavated into the prairie; c) the desert scrubland just off of the south eastern escarpment, note the honey mesquite to the right of the photograph and prickly pear cactus in the foreground; d) looking back at the western Mescalero escarpment across the dune fields of New Mexico; e) water flowing in a perennial stream in the eastern canyonlands; f) Stands of juniper growing along the eastern escarpment and rough canyonlands.

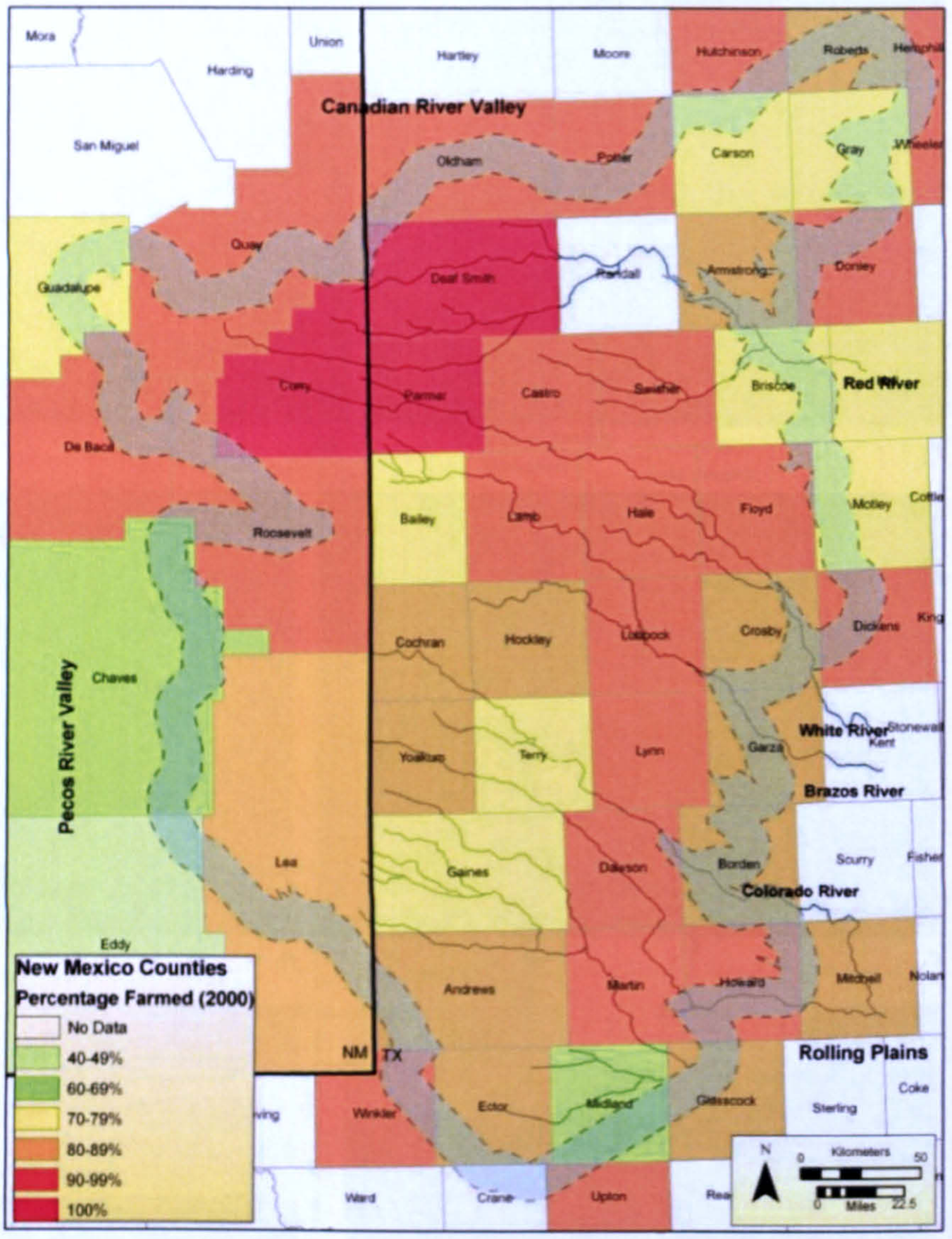


Figure 4.8. Modern farming intensity by county (data U.S. Census Bureau, Census 2000).

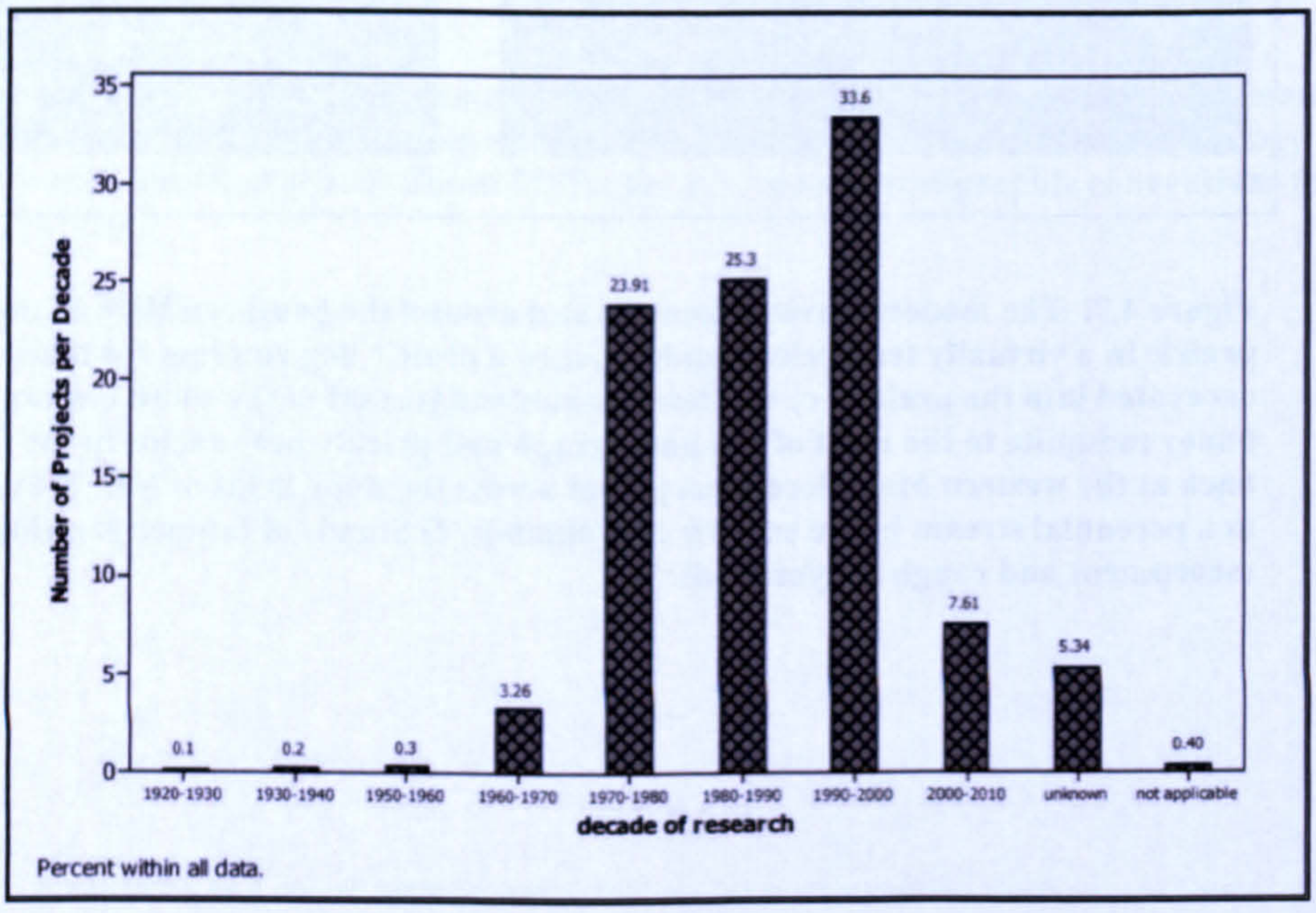


Figure 4.9. Intensity of archaeological research on the Southern High Plains presented by decade (data sampled from TARL and ARMS and accessed September 2005).

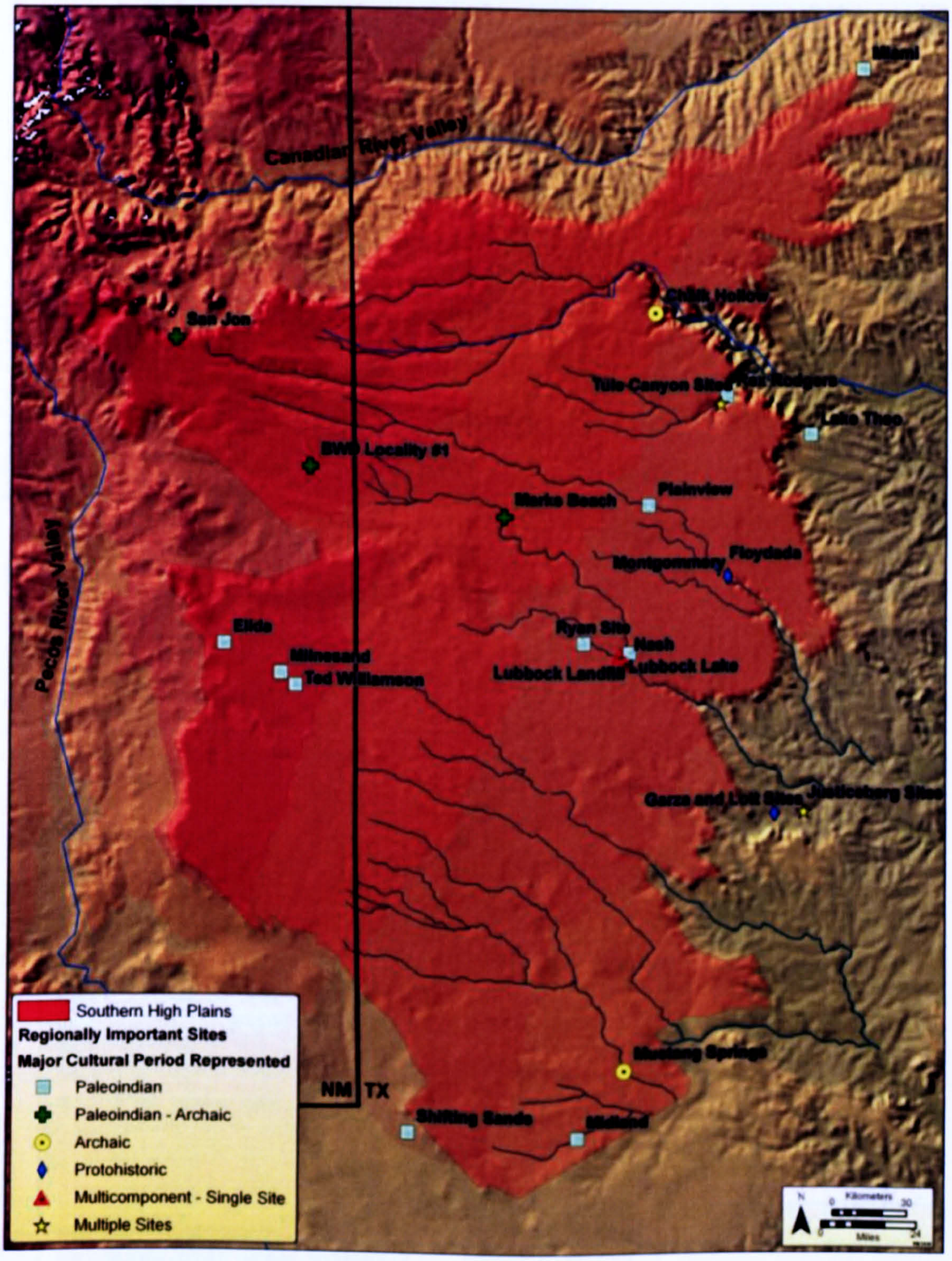


Figure 4.10. Key sites identified on and in proximity to the Southern High Plains.

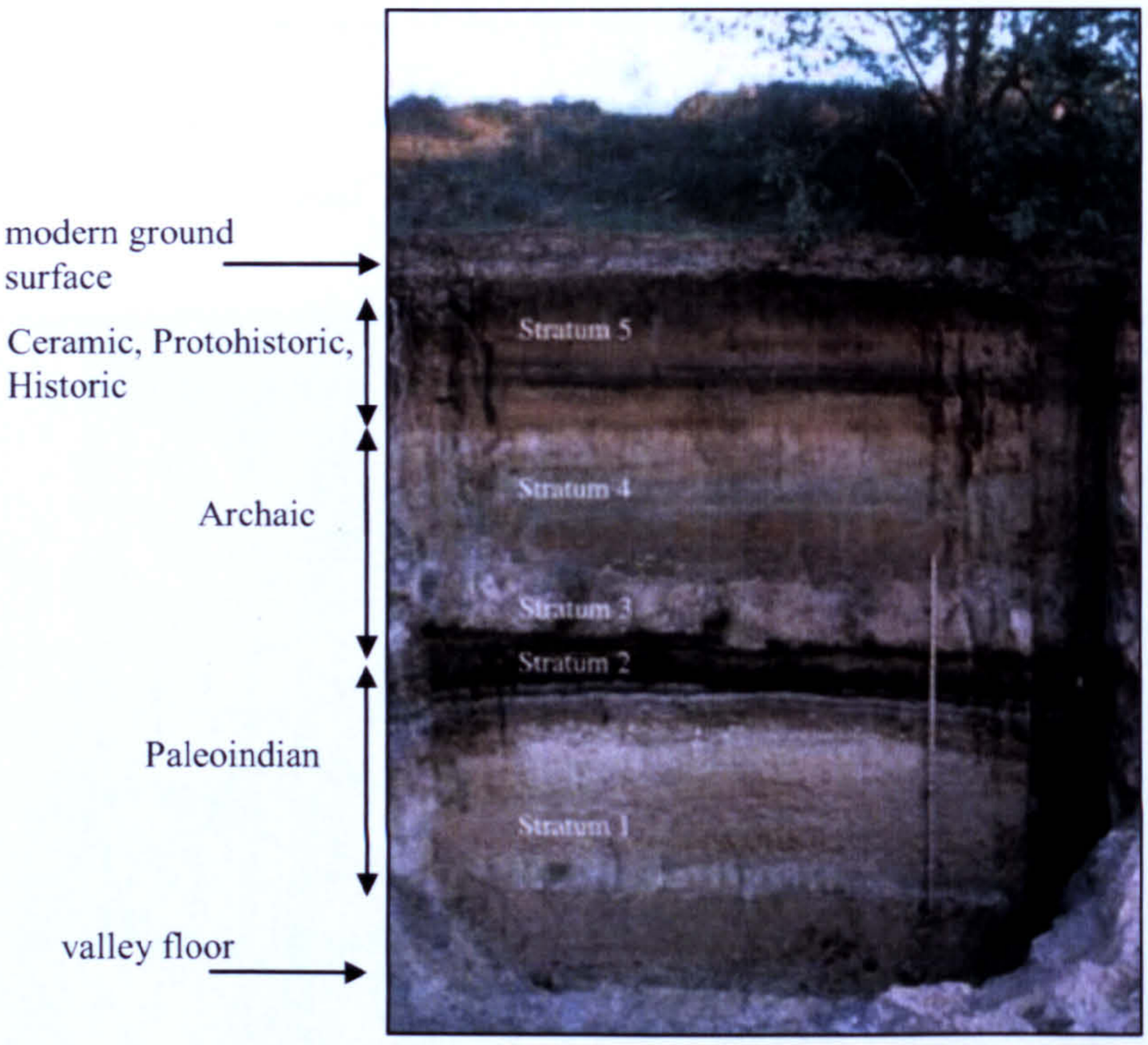


Figure 4.11. Late Quaternary valley fill exposed in the type section at Lubbock Lake (41LU1). Note the stratigraphic sequence spans the late Pleistocene through Holocene (photograph courtesy of the Anthropology Division, Museum of Texas Tech University).

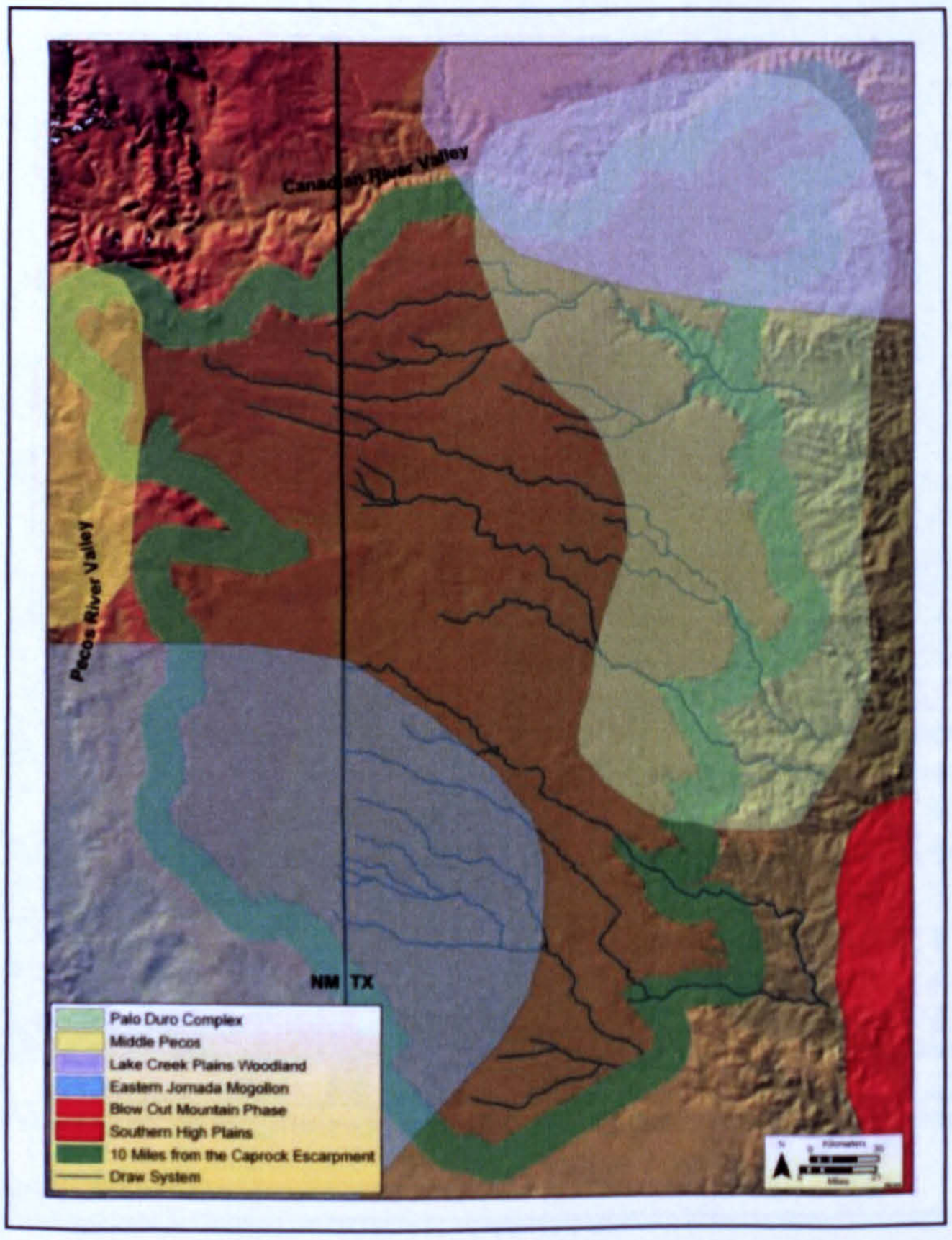


Figure 4.12. Boyd's Late Prehistoric (c. 750 – 1450 B.P.) culture complexes and phases for the Southern High Plains region (modified after Boyd 1995, fig. 3).

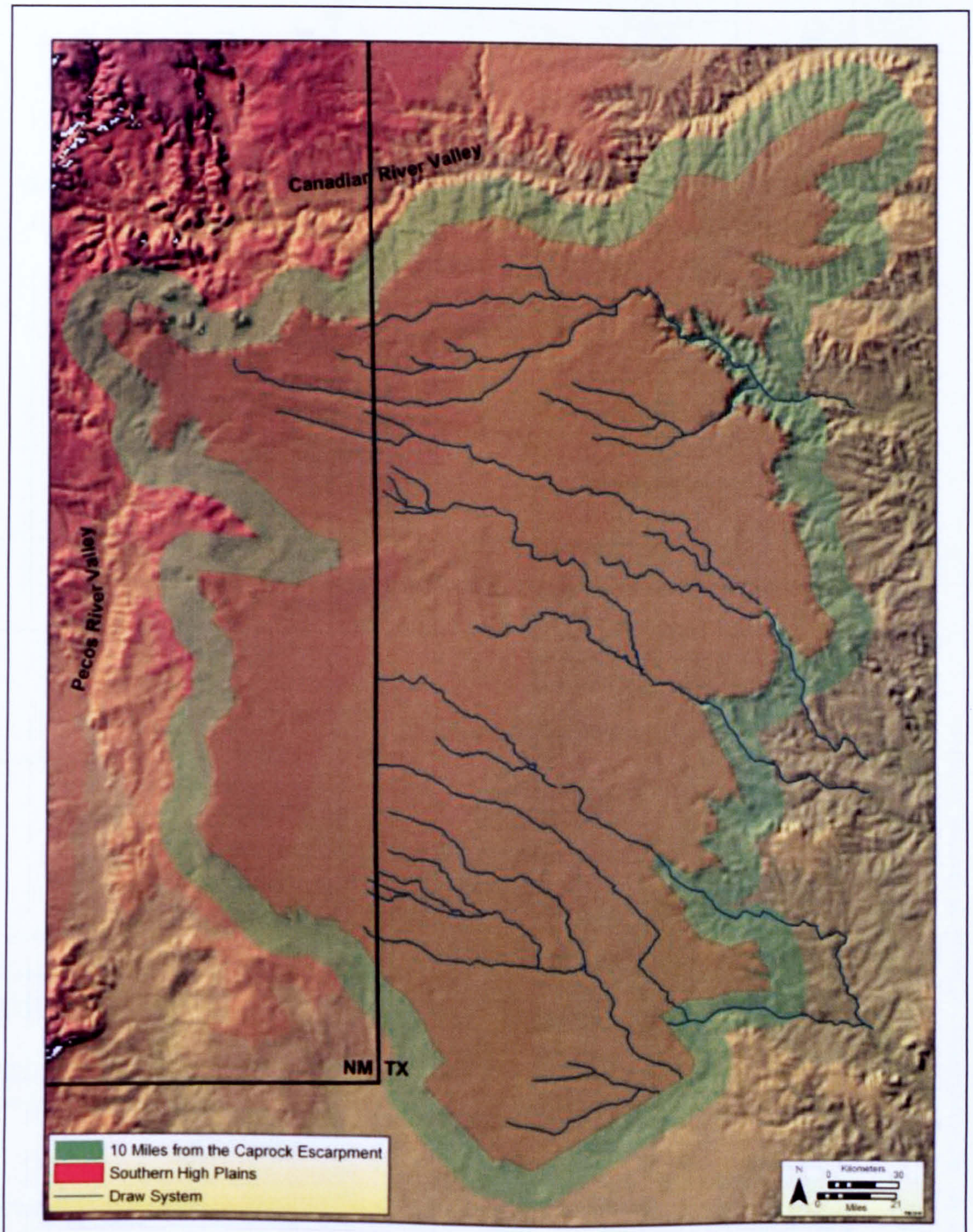


Figure 4.13. Southern High Plains region showing the arbitrary ten-mile extension used in the current program of research.

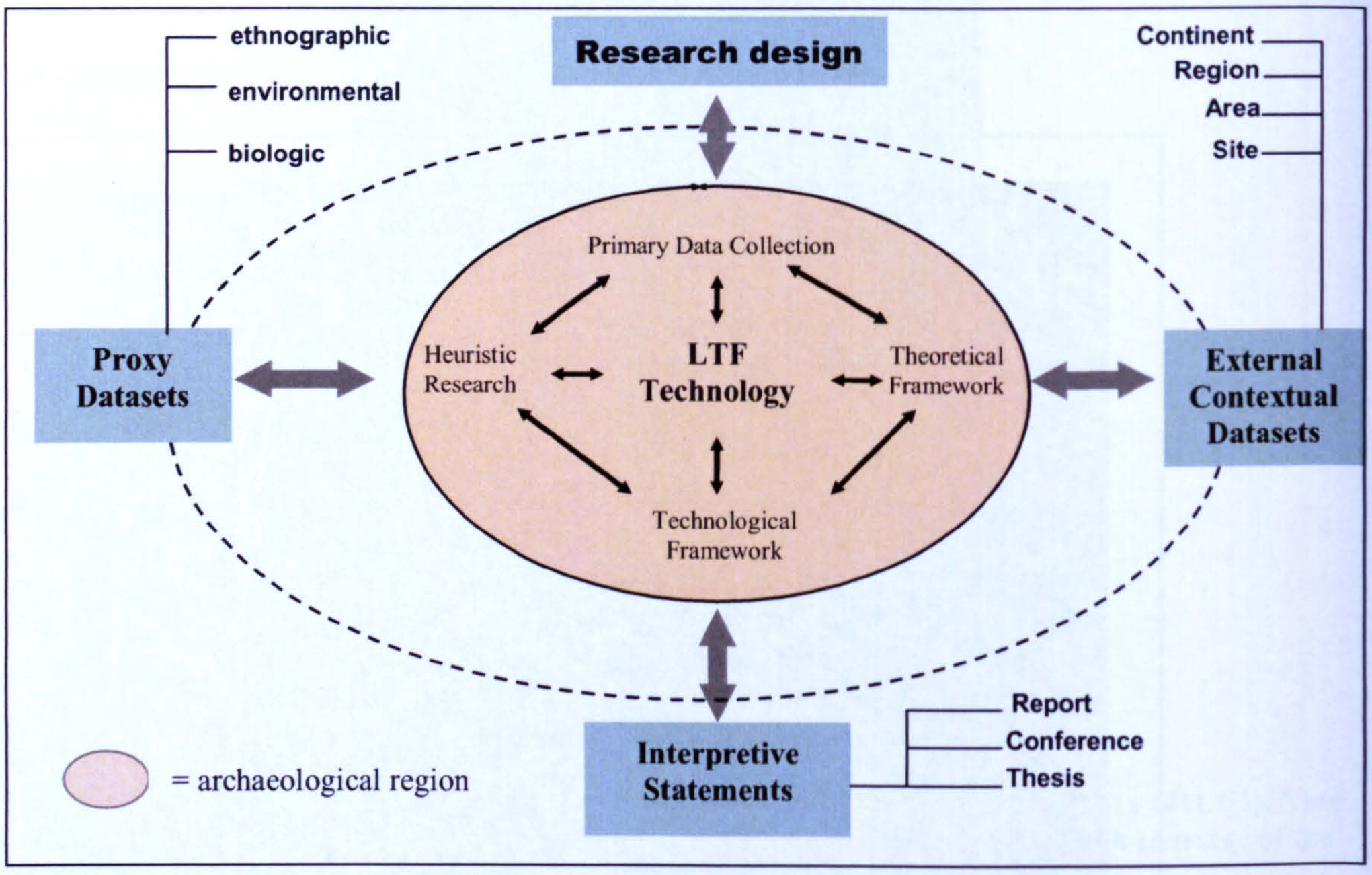


Figure 5.1. Research model for the investigation of localised thermal features.

STATE OF TEXAS
Archeological Data Site Form
Trinomial

GENERAL SITE INFORMATION

Site Name: A Hypothetical Site
Revisit: False
Form Date: 03/26/2006 **Site ID:** 2
Local ID: 2
Site Type: Prehistoric Campsite
Explanation of Type: Lithic scatter

PROJECT AND PERMIT

Project Name: Hypothetical survey #1
Project Number: 1234
Project Funding: Hypothetical Utilities Company
Permitting Source: Texas Historical Comission **Permit Number:** 1234

RECORDER INFORMATION

Recorder: Mr David Badger **Recorder Visited Site:** True
123 A Street
Delstin , TX 12345
Phone: (123) 123123 **Fax:** (123) 123123
Email: D.Badger@email.net
Recorder Affiliation: Hypothetical University

SOURCES OF INFORMATION

Owner: Mr and Mrs D. Weasel, The NotReal Ranch, Delstin, TX
Informant: Mr C. Squirrel, 1234 B Street, Delstin
Additional Source: Badger (2010) Interim Report of Investigations Undertaken at the NotReal Ranch. Hypothetical University Research Report #1. pp. 1-456.

WORK PERFORMED

ACTION DATES AND METHODS

Observe/Record Date: 12th June 2010
Surface Inspect/Collect Dates: 13th June 2010
Method: Pedestrian Survey walked in linear transects with 1m spacing.
Mapping Dates: 13th June 2010
Method: Total Station, Trimple GPS
Testing Dates: 20th June 2010
Method: Shovel-testing of 20 isolated units and 1/4in screen sieving of excavated sediments.
Excavation Dates: na
Method: na

RECORDS AND MATERIALS

Records: artifact sketches, computer disks, daily journal, feature record, lab inventory, shovel test records, slides
Materials Collected:
12 projectile points, 3 pieces of micaeous pottery, lithic debitage (286 pieces mainly flakes), hearthstones (23 grab sample)
Special Samples:
charcoal collected from the hearth feature for radiocarbon dating
Temporary Housing: Hypothetical University
Permanent Housing: Museum of Hypothetical University

LOCATIONAL & ENVIRONMENTAL INFORMATION

03/26/2006 Page 1

STATE OF TEXAS
Archeological Data Site Form
Trinomial

LOCATION

Primary County: Zaled **Site Location in County:** central
Other County:
USGS MAP Name & Quad #: NoName Creek (2201)
UTM Zone: 15 **Easting:** 12345 **Northing:** 12345 **UTM Range:** 12345NE-12345SW
Latitude: ° ' " **Longitude:** ° ' "
Elevation: 1234 **Elevation Range:** 1234-1235
Description of Location:
Site is located on a low bluff overlooking arable land on a large ranch.

ENVIRONMENT

Nearest Natural Water: Noname Creek 123m Southwest of site
Major Creek Drainage: North Fork Of the Noname River
Name of Drainage Basin: Rio Zapata
SCS Soil Series, Mapping Unit:
Podazi clay-loam (1-2% slopes) Zaval County mapping sheet 15
Soil Genetic Type: loam
Percentage Ground Surface Visible: 10-20%
Surface Texture: fine
Soil Derivation: In Situ: False **Marine:** False **Eolian:** True **Colluvial:** True **Alluvial:** False
Other Soils:
Environmental/Topographical Setting:
site sits on a low bluff and sediments appear to be fairly thin above the granite bedrock. Vegetation cover consists of patchy short grasses and some succulents.

CULTURAL MANIFESTATIONS

Time Period of Occupation:
Unknown
Basis for Time: no diagnostic material recovered
Single Component: False **Multiple Component:** False **Component Unknown:** True
Basis for Component: site appears to consist of at least one buried component and a scatter of material eroding down
Cultural Features:
a cluster of burned limestone slabs (FA-1) were recorded (diameter ca. 1m) during pedestrian survey. Subsequent shovel-testing of this feature revealed subsurface charcoal to a depth of ca. 30cm.
Approximate Site Size: 12345sqm
Basis for Determination: distribution of artifacts
Top of Deposit Below Surface: 0cm at ground surface
Basis for Determination: pedestrian survey
Thickness of Deposit: 30cm
Basis for Determination: shovel-test excavation
Artifactual Materials Present:
flaked lithic tools and debitage (12 projectile points, 286 debitage fragments), 3 pieces of micaeous pottery also recovered. The majority of the artifacts were recovered from the modern ground surface during pedestrian survey.
Discussion of Site:
Site appears to represent an ephemeral hunter-gatherer campsite. The presence of low frequencies of lithic material and the identification of a single feature suggests a single occupation episode. Radiocarbon analysis of a sample recovered from the single feature suggests an Archaic time period for the main occupation activity.

SITE CONDITIONS

Circumstances Affecting Observations:

03/26/2006 Page 2

Figure 5.2. Example of the types of information typically recorded for a hypothetical site in Texas, USA. and on file at the Texas Archaeological Research Laboratory and the Texas Historical Commission Sites Database.

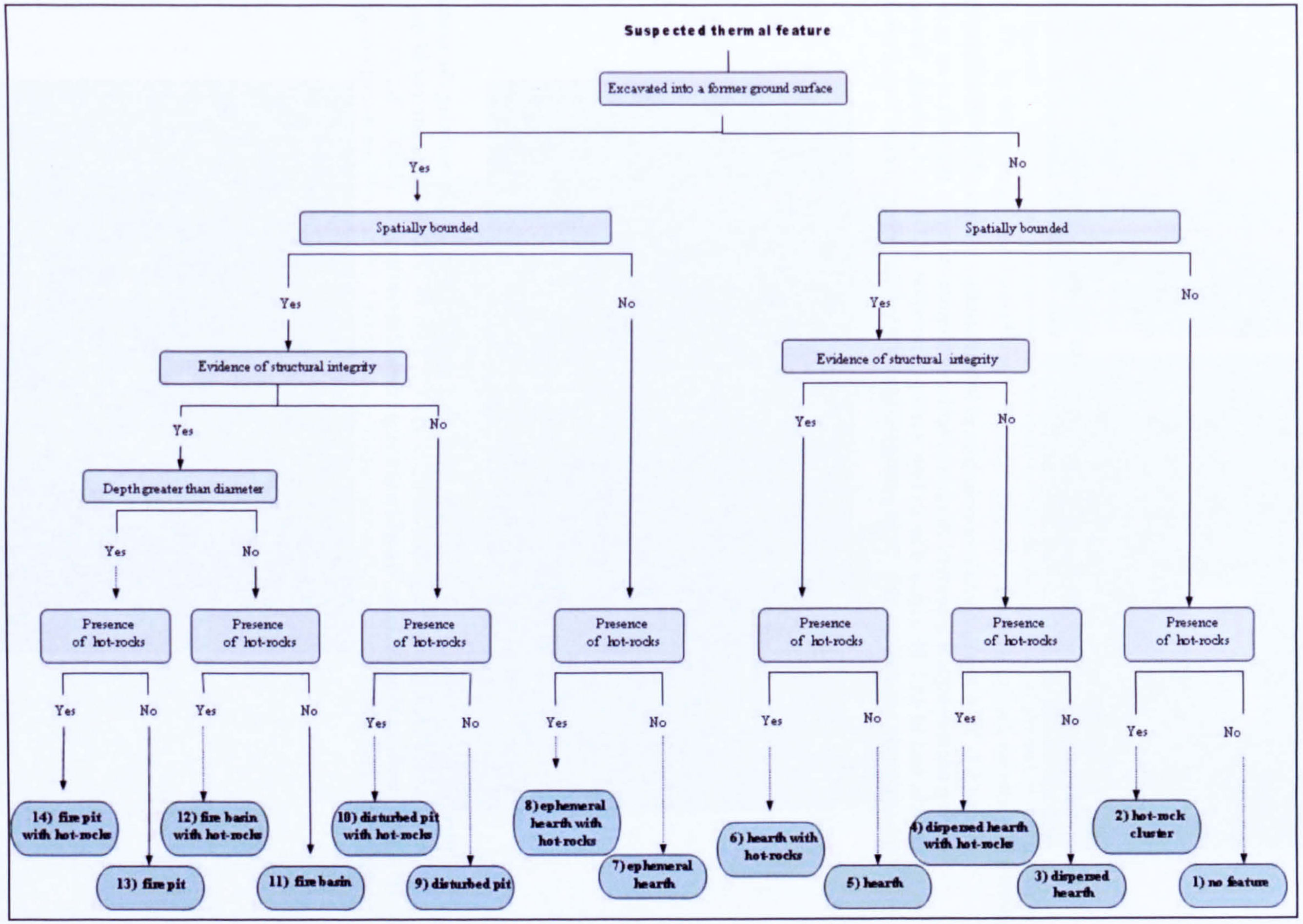


Figure 5.3. Hierarchical key for the classification of localised thermal features.



a. b.

Figure 5.4. Two North American examples of intentionally excavated LTF structures encountered during archaeological research: a) stained sediments encountered in the wall of an excavated trench; and b) an LTF exposed in section during excavation at 41LU1, Lubbock, Texas (photographs courtesy of the Anthropology Department, Museum of Texas Tech University).



Figure 5.5. North American example of a thermally altered soil stain defining the spatial boundary of a feature recorded during excavation at 41LU1, area 10 (Photograph courtesy of the Anthropology Department, Museum of Texas Tech University).



Figure 5.6. Example of a structurally intact feature; note the presence of fine ash around the exposed hearthstones and the obvious visual difference between the carbonized material within the feature and the surrounding sediments.

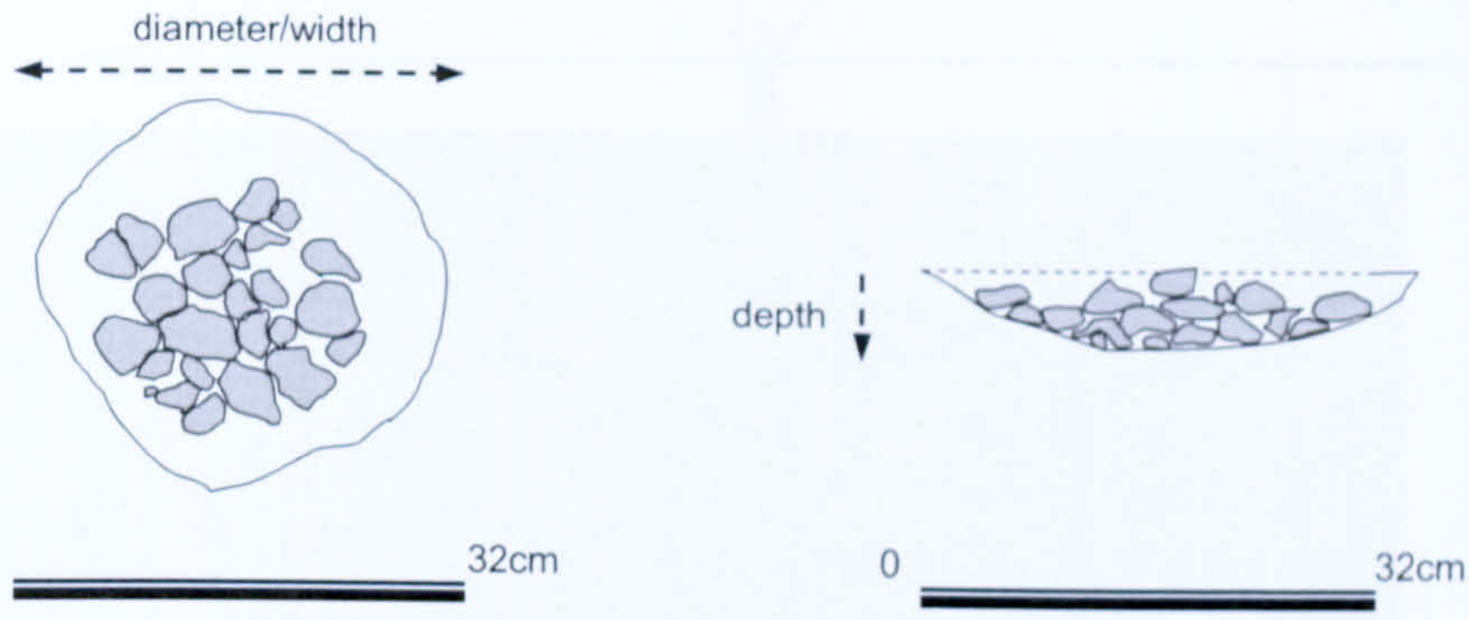


Figure 5.7. Example of the two measurements for the determination of diameter and depth of an LTF. In this example maximum width is greater than the maximum depth resulting in a basin-shaped structure.



Figure 5.8. Caliche hot-rocks within an experimental LTF at Lubbock Lake Landmark, Texas (photograph courtesy of the Anthropology Department, Museum of Texas Tech University).



Figure 6.1. Locations of the major Native American ethnic groups on the Great Plains by the early 19th Century (modified from Carlson 1998:3).

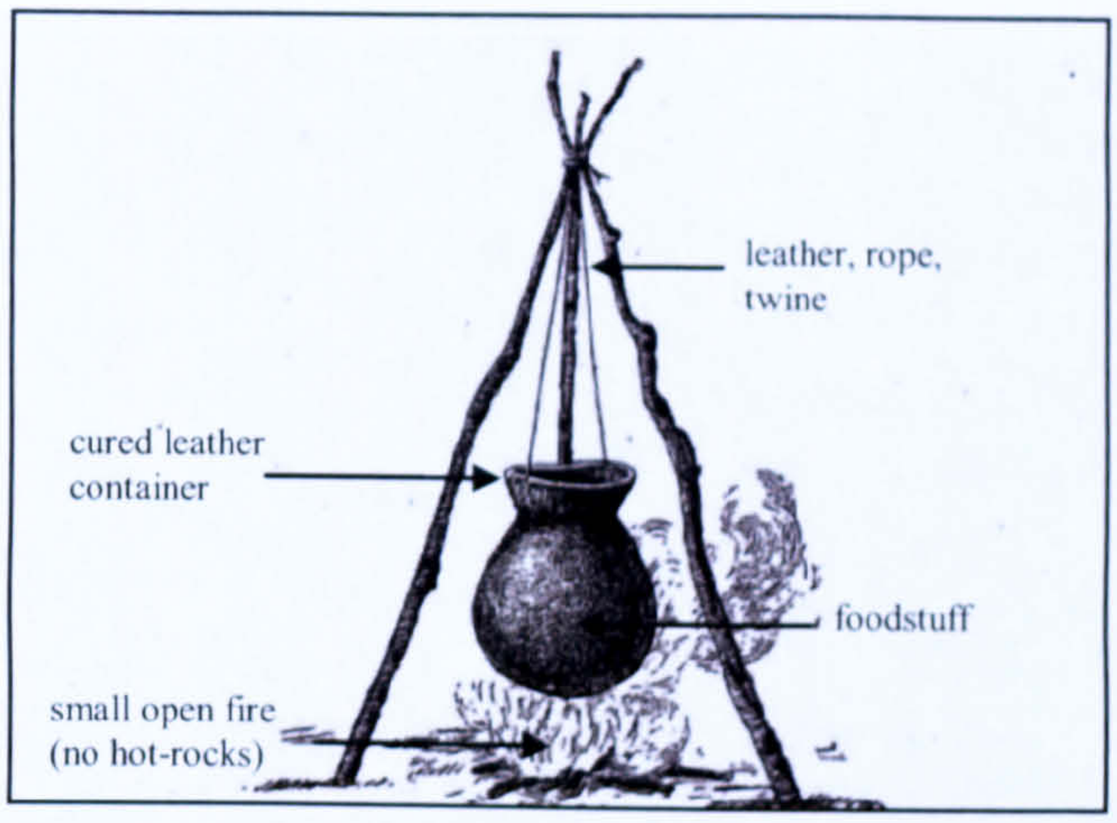


Figure 6.2. An early example of the suspension method of direct fire boiling sketched by Schoolcraft and appearing in the 1898-1899 Annual Report of the American Bureau of Ethnology (modified from Holmes 1903, fig. 2).



Figure 6.3. A Dakota tribe member using indirect hearthstone technology removing a hot-rock from a hearth and adding it to a suspended cow stomach for boiling of soup (modified from Smithsonian Institution National Anthropological Archives, In: Spencer *et al.* 1977).



Figure 6.4. Example of two Chippewa women directly boiling over an open fire. Note: much of the material culture used in the cooking process is temporary or organic and unlikely to be represented in any resulting archaeological record (Minnesota Historical Society, photograph collection 1910, available from *http://collections.mnhs.org/visualresources*).

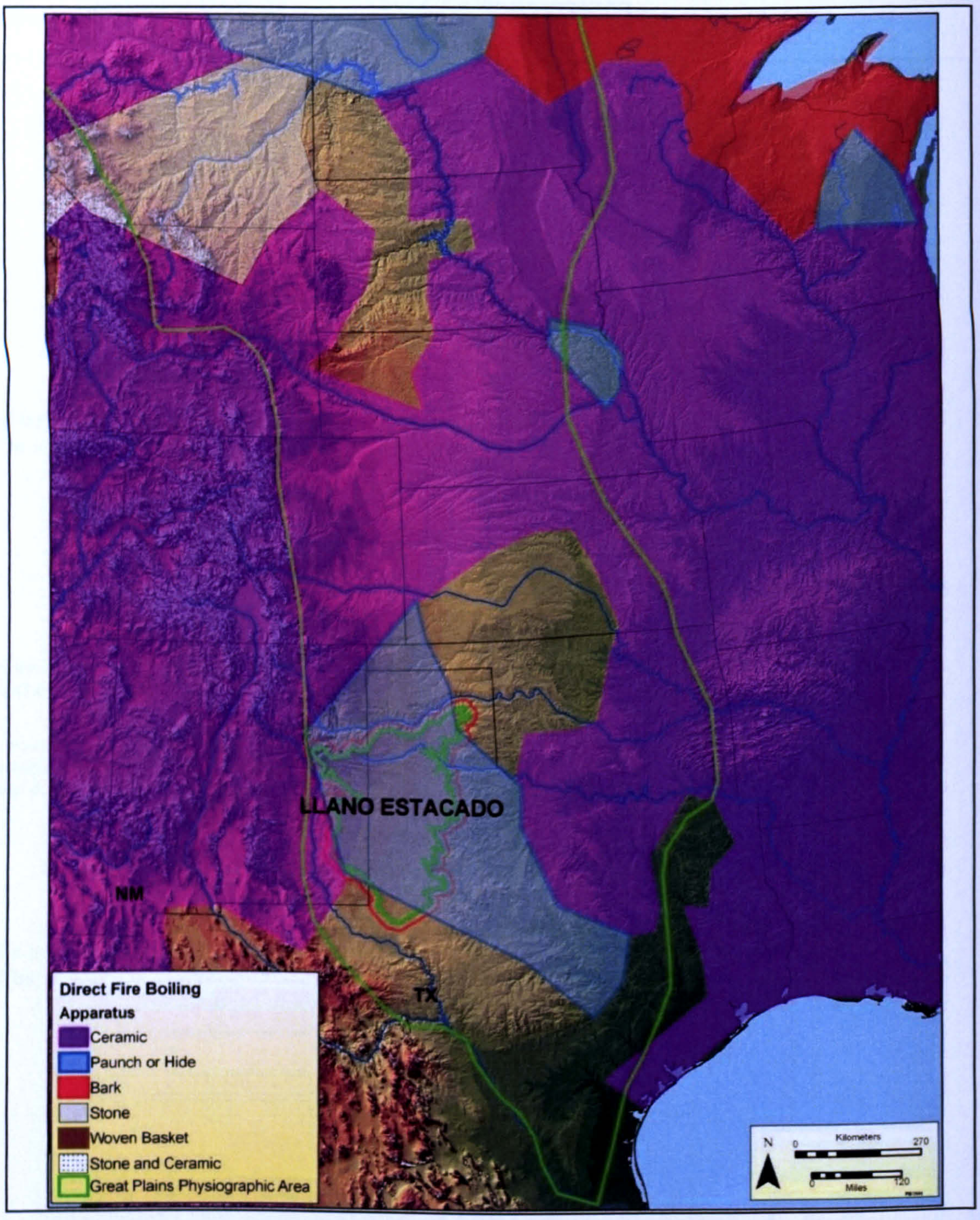


Figure 6.5. Ethnographic spatial distribution of direct fire boiling technology in relation to the Southern Plains and the Llano Estacado Research Area (data modified from Driver and Massey 1957, maps 41 and 42).

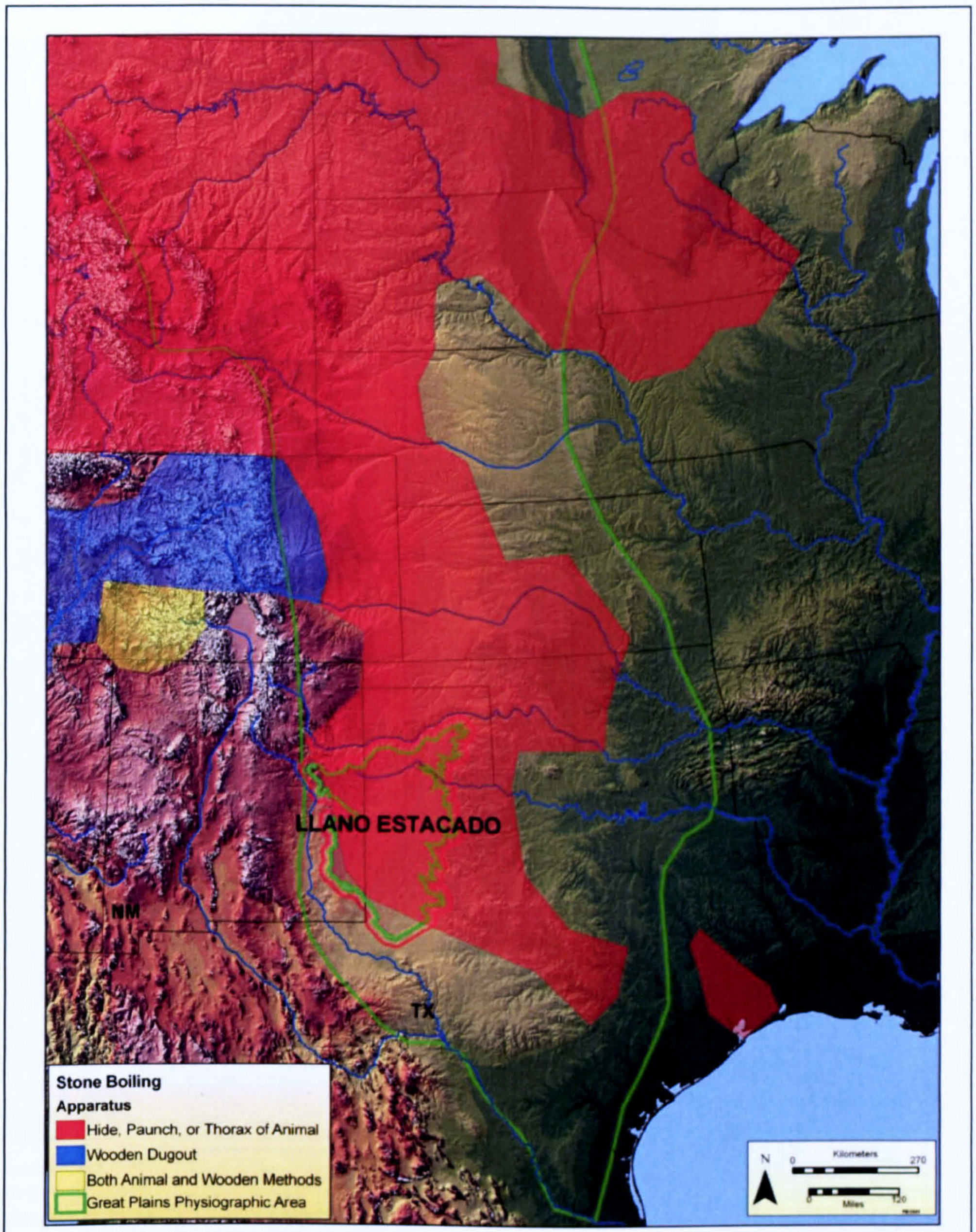


Figure 6.6. Ethnographic spatial distribution of indirect fire boiling technology in relation to the Southern Plains and the Llano Estacado Research Area (data modified from Driver and Massey 1957, maps 43 and 44).

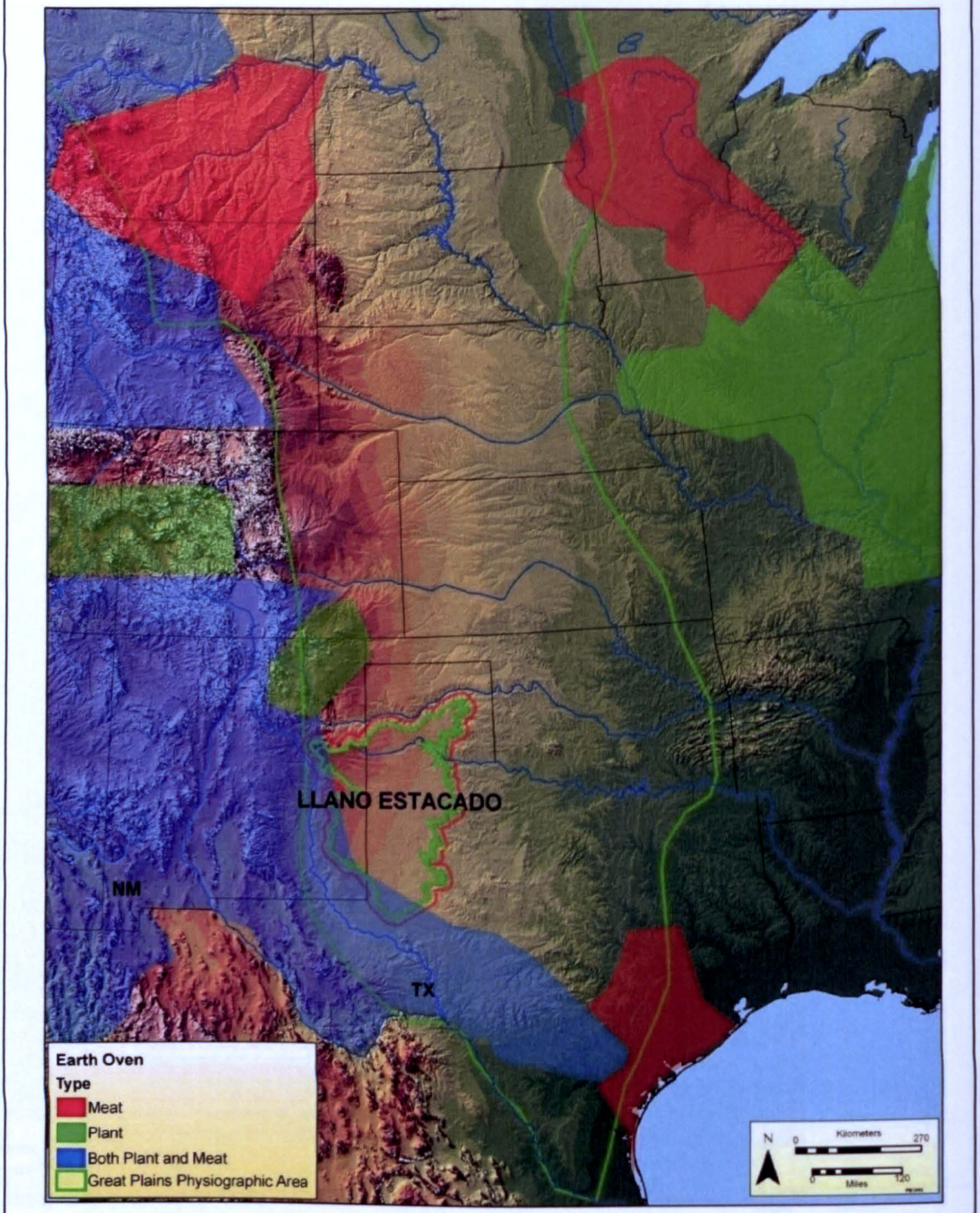


Figure 6.7. Ethnographic spatial distribution of earth oven technology in relation to the Southern Plains and the Llano Estacado Research Area (data modified from Driver and Massey 1957, map 45).



Figure 6.8. A Mescalero Apache woman photographed in 1906 harvesting Mescal, probably for processing by earth oven technology (Northwestern University Digital Library Collections, available from *http://curtis.library.northwestern.edu/curtis*).

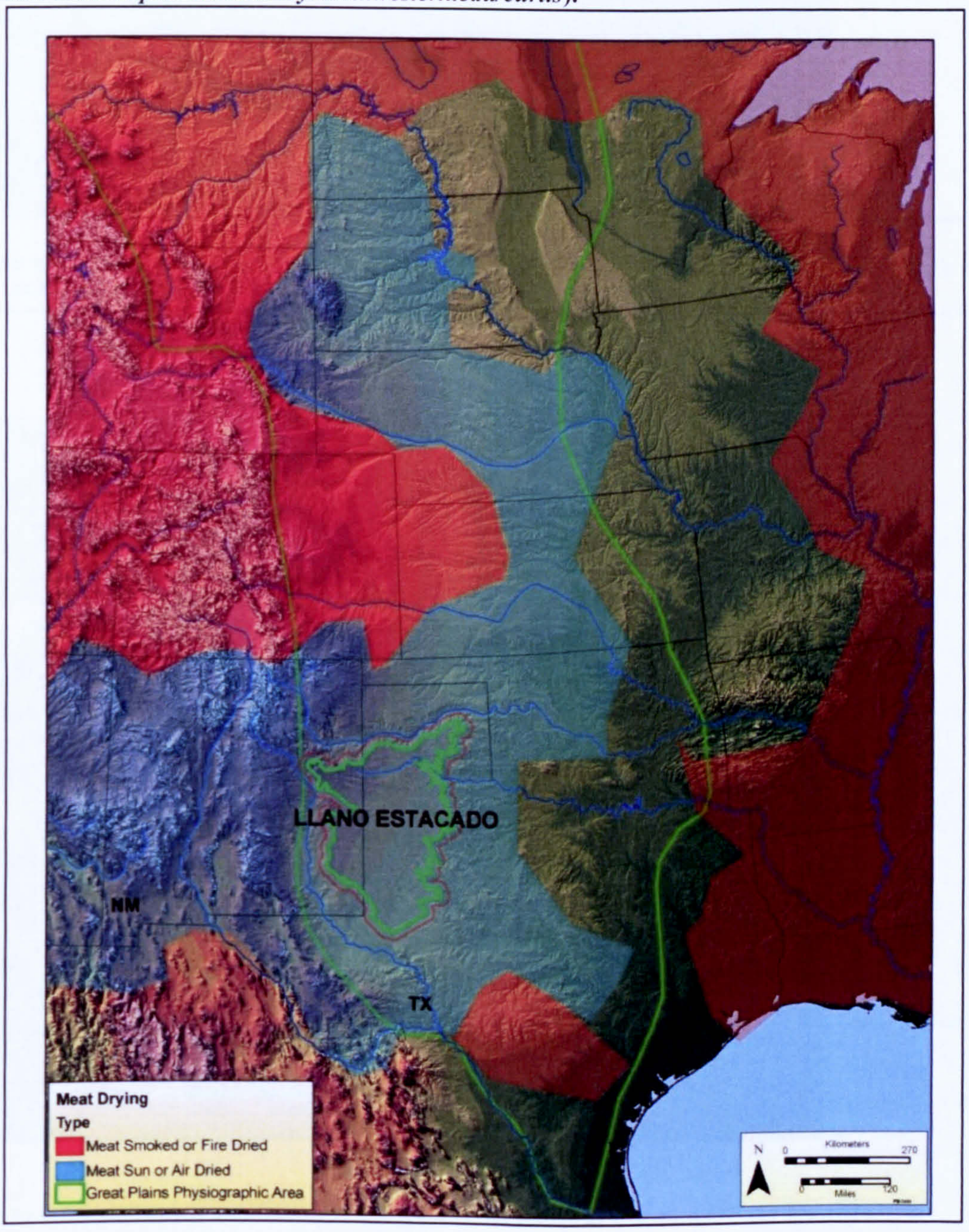


Figure 6.9. Ethnographic spatial distribution of meat drying technology in relation to the Southern Plains and the Llano Estacado Research Area (data from Driver and Massey 1957, map 53) .



Figure 6.10. Men of European American descent dominate the race to light an educational earth oven , an event in direct contrast to Ray Olachia's stated Mescalero Apache sexual task divisions (Note: the peripheral positions of European American females in this activity).



Figure 6.11. Women of European American descent dominate the preparation of food for placement in the earth oven (Note: the peripheral positions of the older European American men in this activity).

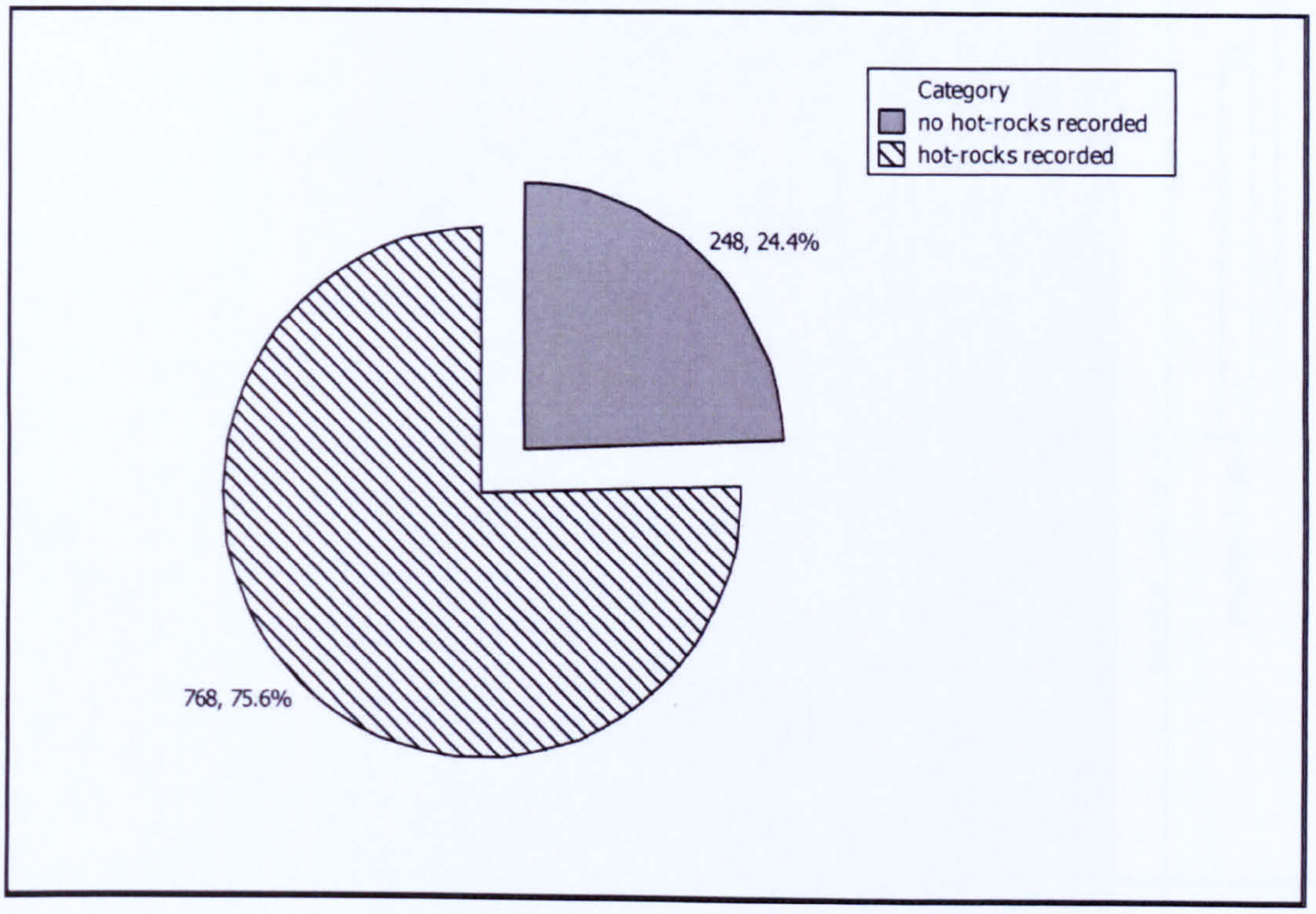


Figure 7.1. Frequency of prehistoric archaeological sites identified with evidence for hot-rock use.

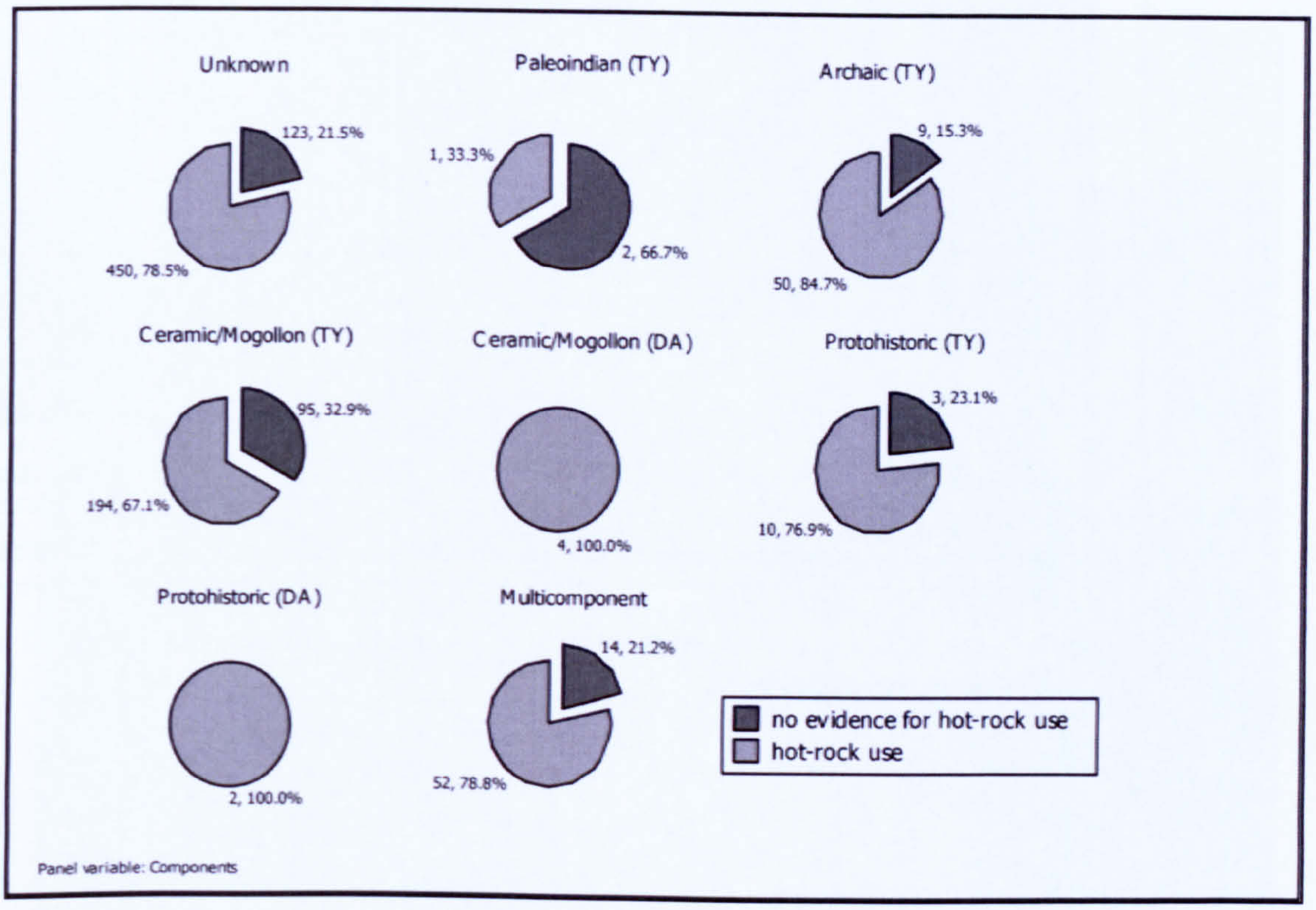


Figure 7.2. Temporal distribution of evidence for hot-rock use at prehistoric sites with LTF components within the study area. Note (TY) = age of site estimated from typological analysis of artefacts, (DA) = age of site secured from radiometric assay e.g., radiocarbon dated.

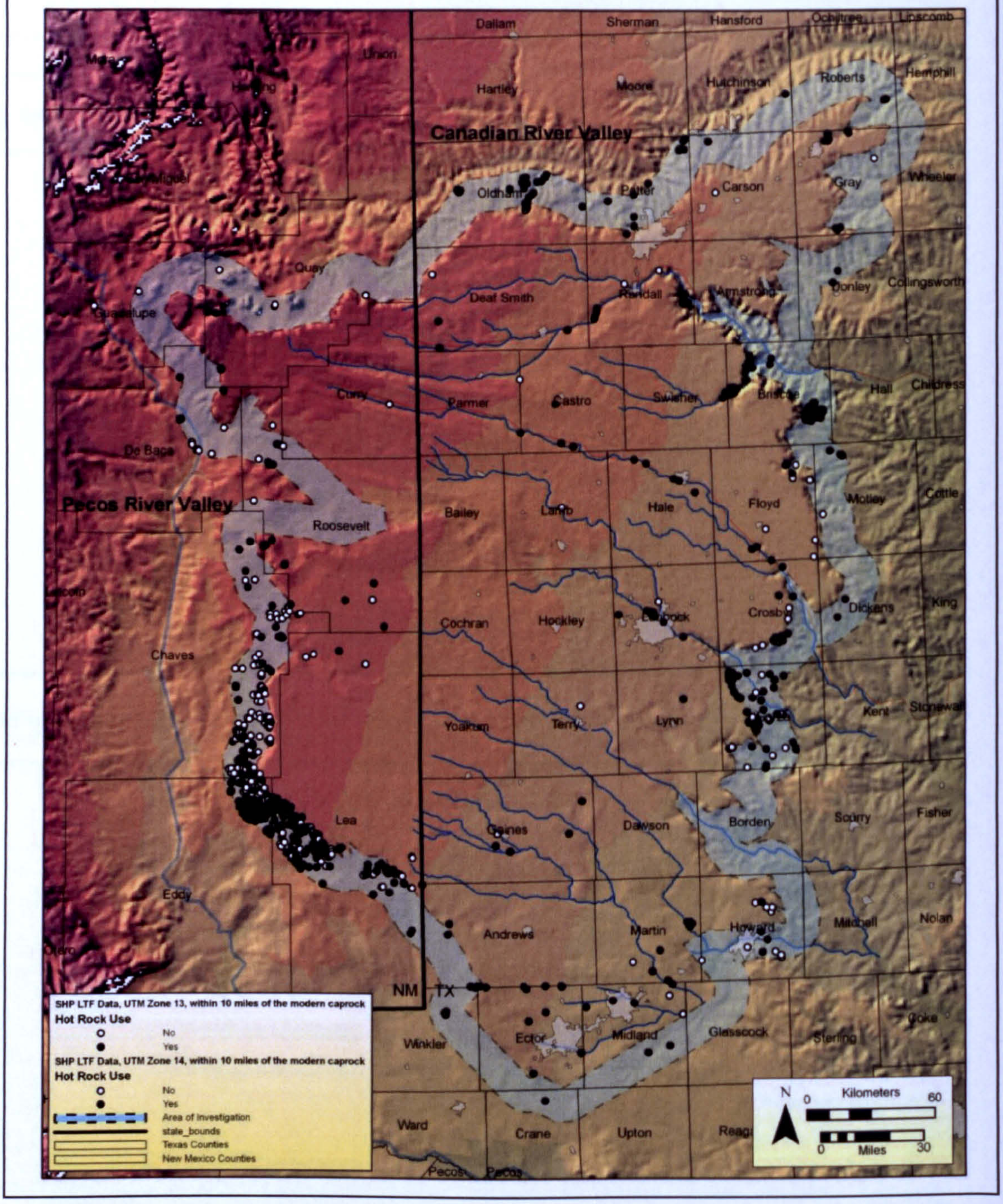


Figure 7.3. Geographic distribution of prehistoric archaeological sites within the LTF database with evidence for hot-rock use.

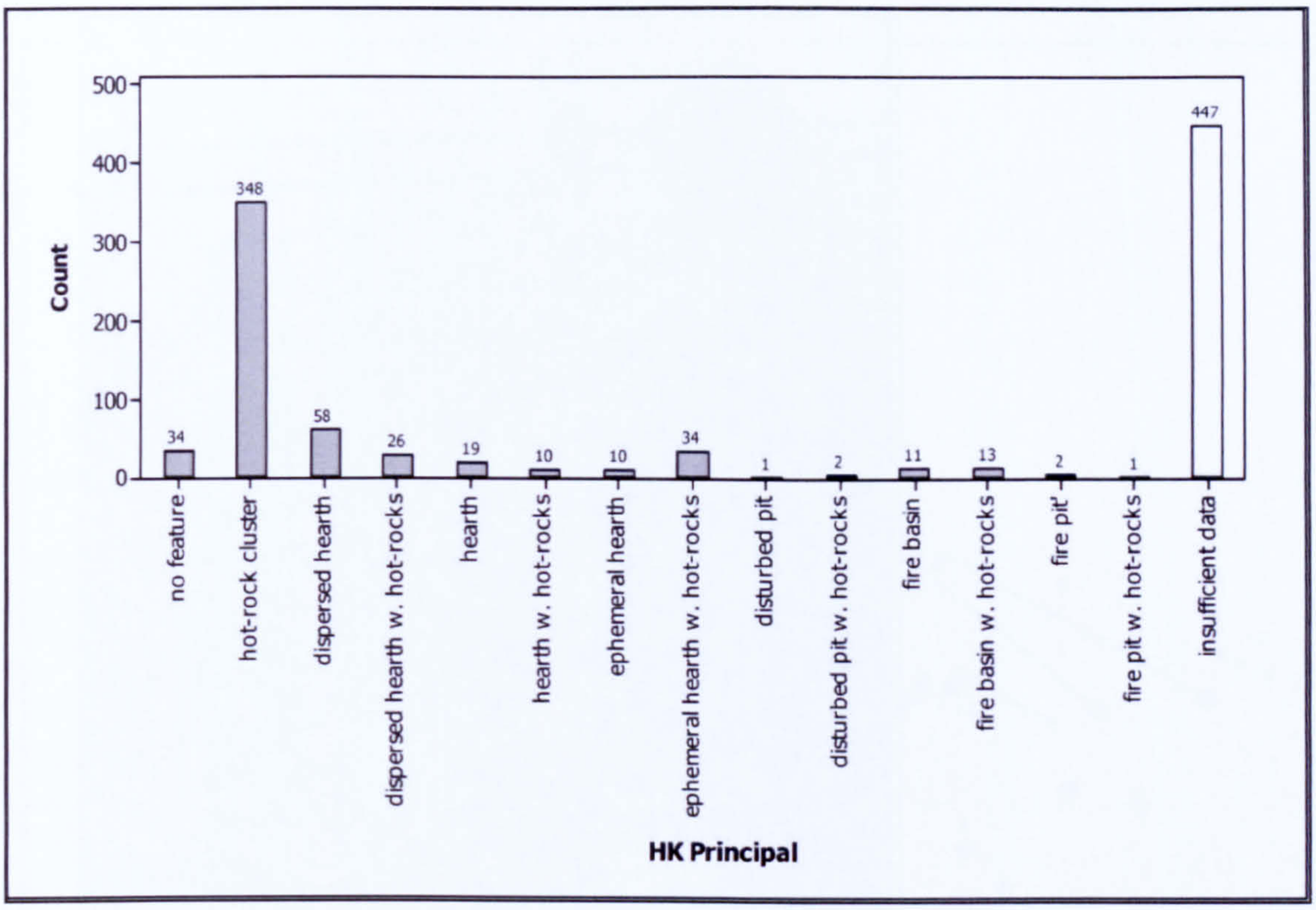


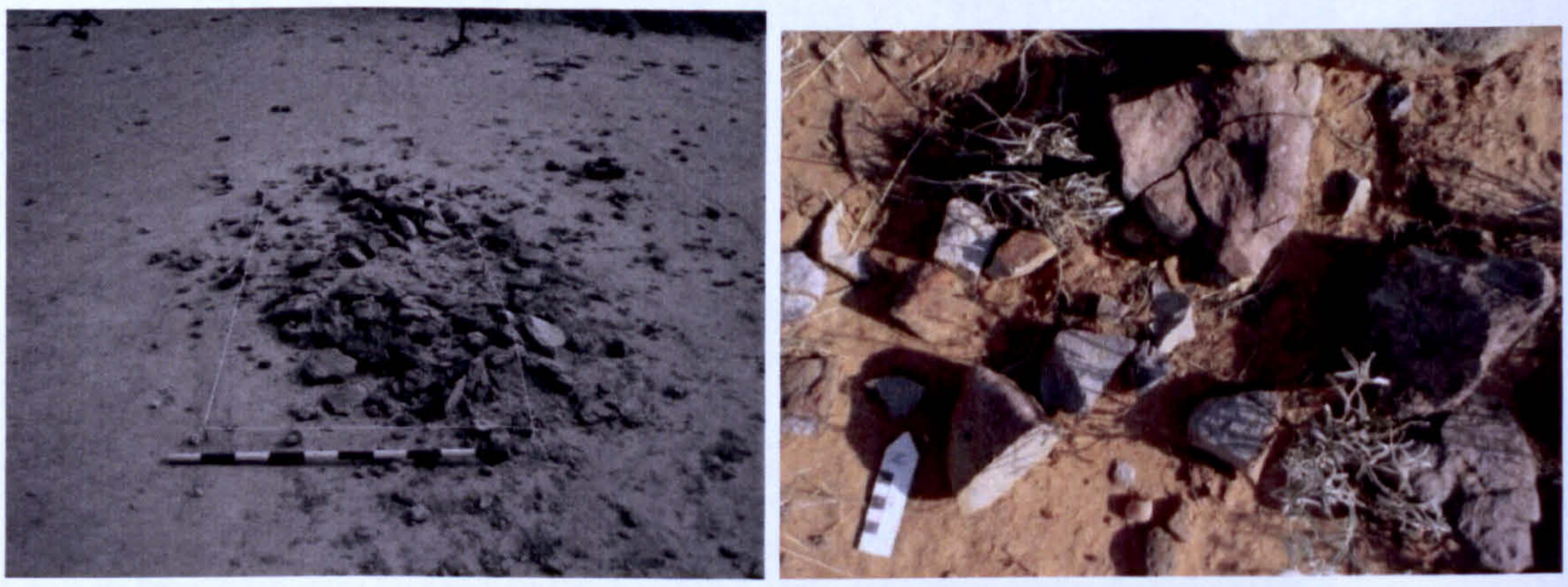
Figure 7.4. Classification of the primary LTF types at prehistoric archaeological sites within the study area.



Figure 7.5. Experimental research area at Lubbock Lake Landmark.



Figure 7.6. Alejandra Matarrese mapping the displacement of hearthstones during a bitterly cold winter's day on the Southern High Plains (photograph courtesy of the Anthropology Division, Museum of Texas Tech University).



a b

Figure 7.7. Experiment 4 facilitated the field identification of Ogallala Fm. gravels as indicators for hunter-gatherer domestic fire technologies; a) large structurally intact LTF with Potter member hearthstones identified during pedestrian survey at PLK-Locality 4; b) isolated Ogallala Formation hearthstone (indicated by black arrow) from an eroded hearth identified as 41GR146.

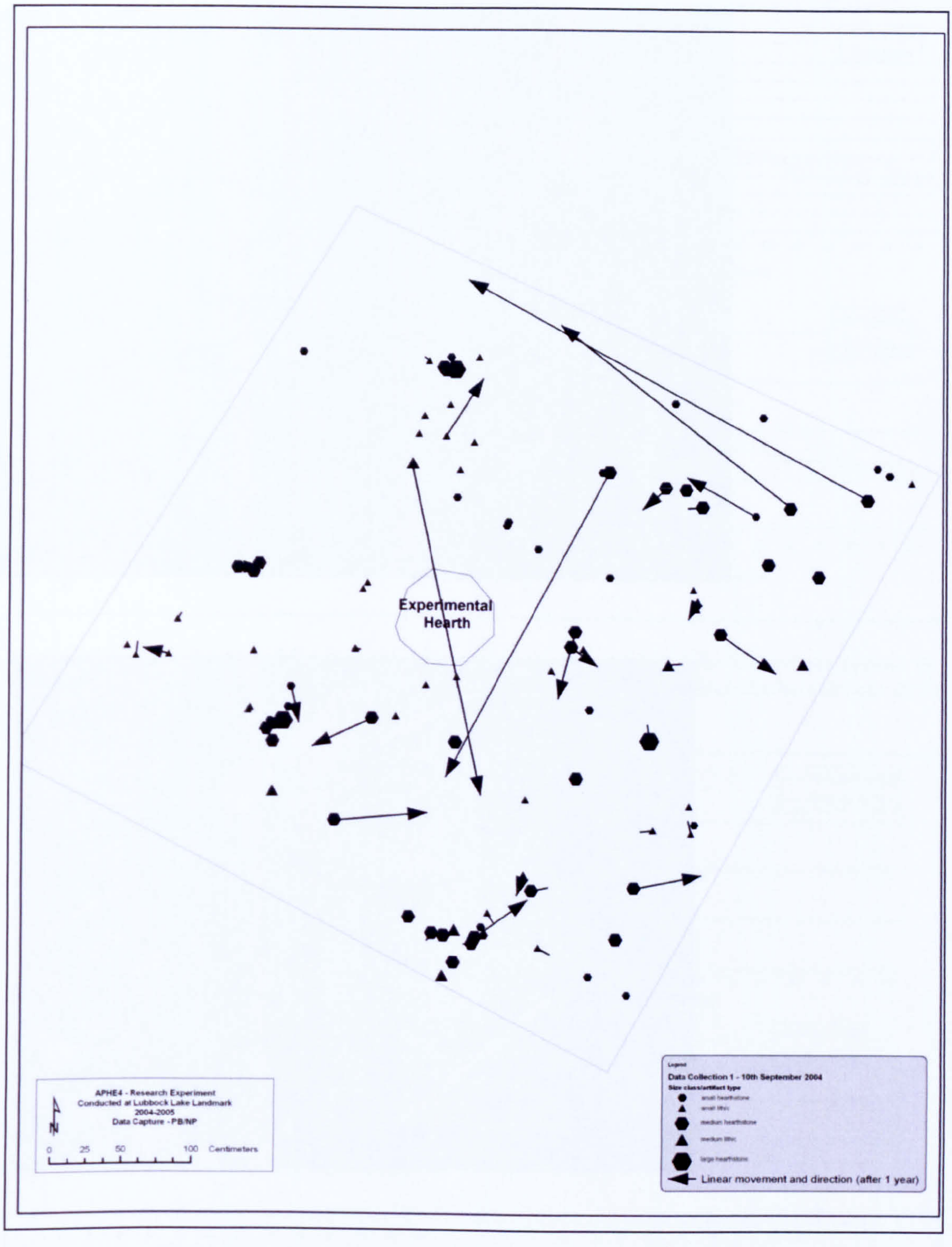


Figure 7.8. Spatial displacement of simulated cultural material around a hearth after one year; note the extreme horizontal displacement of specimens in the north of the experimental area along the route of the tour groups.



a.



b.

Figure 7.9. Basin hearth taphonomy experiment after two years of experimentation: a) overall view of the feature; b) close-up of an internal hearthstone that has fractured during the second year of experimentation.

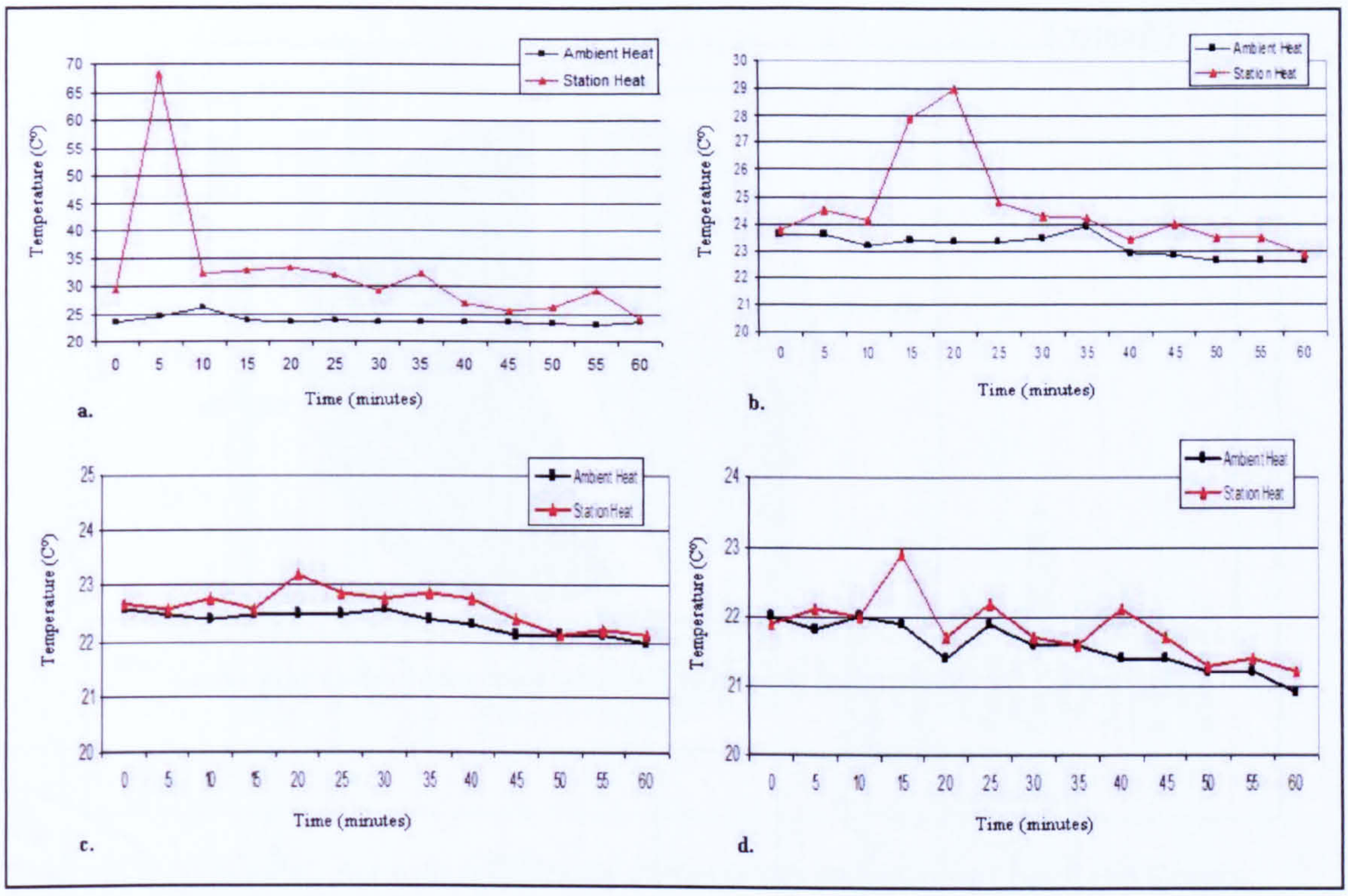


Figure 7.10. Heat dissipation from an experimental basin hearth plotted for a one-hour period: a) 0.5 meters from the hearth; b) 1.5 meters from the hearth; c) 2.5 meters from the hearth; and d) 3.5 meters from the hearth.

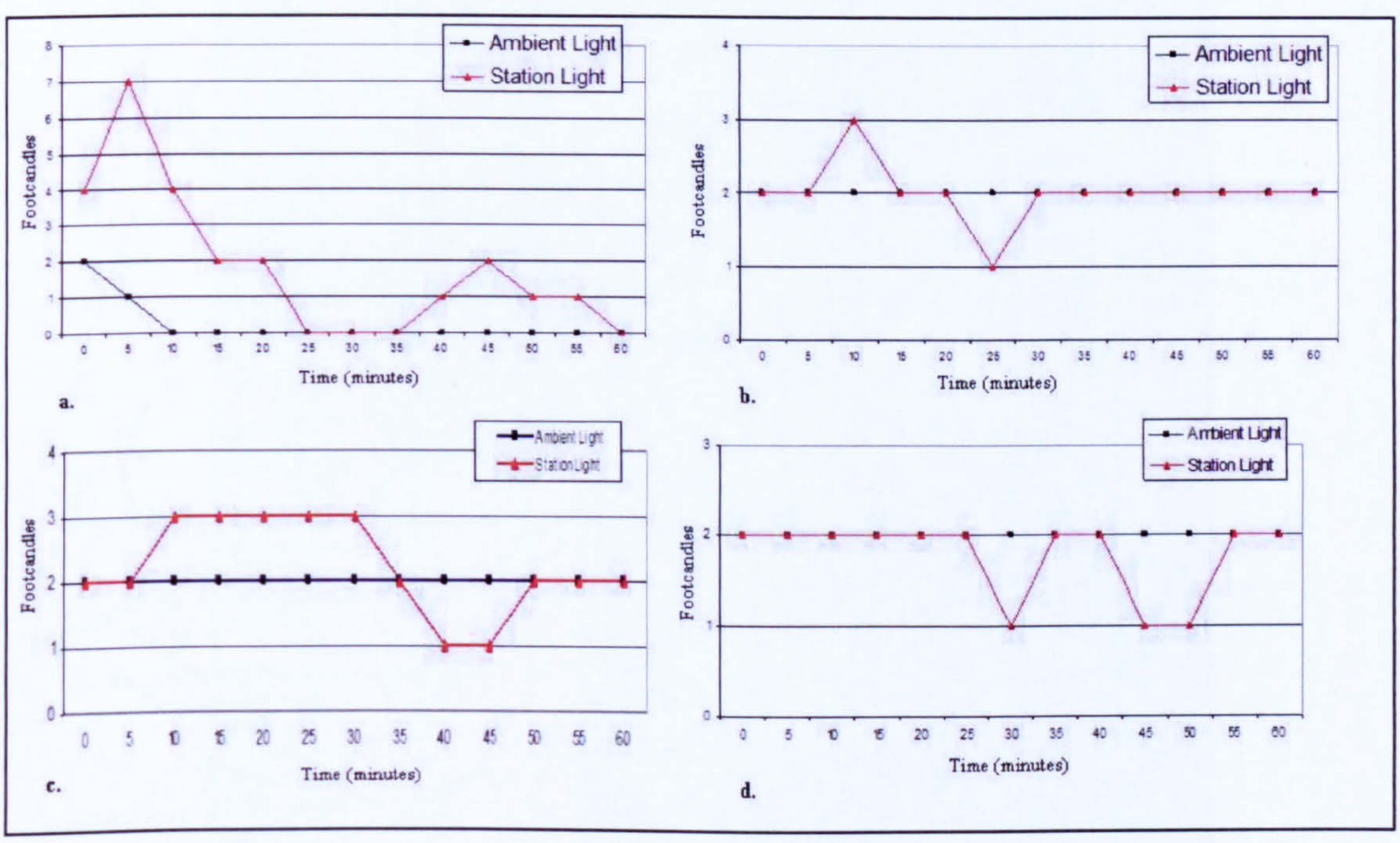


Figure 7.11. Light dissipation from an experimental basin hearth plotted for a one hour period: a) 0.5 meters from the hearth; b) 1.5 meters from the hearth; c) 2.5 meters from the hearth; and d) 3.5 meters from the hearth.

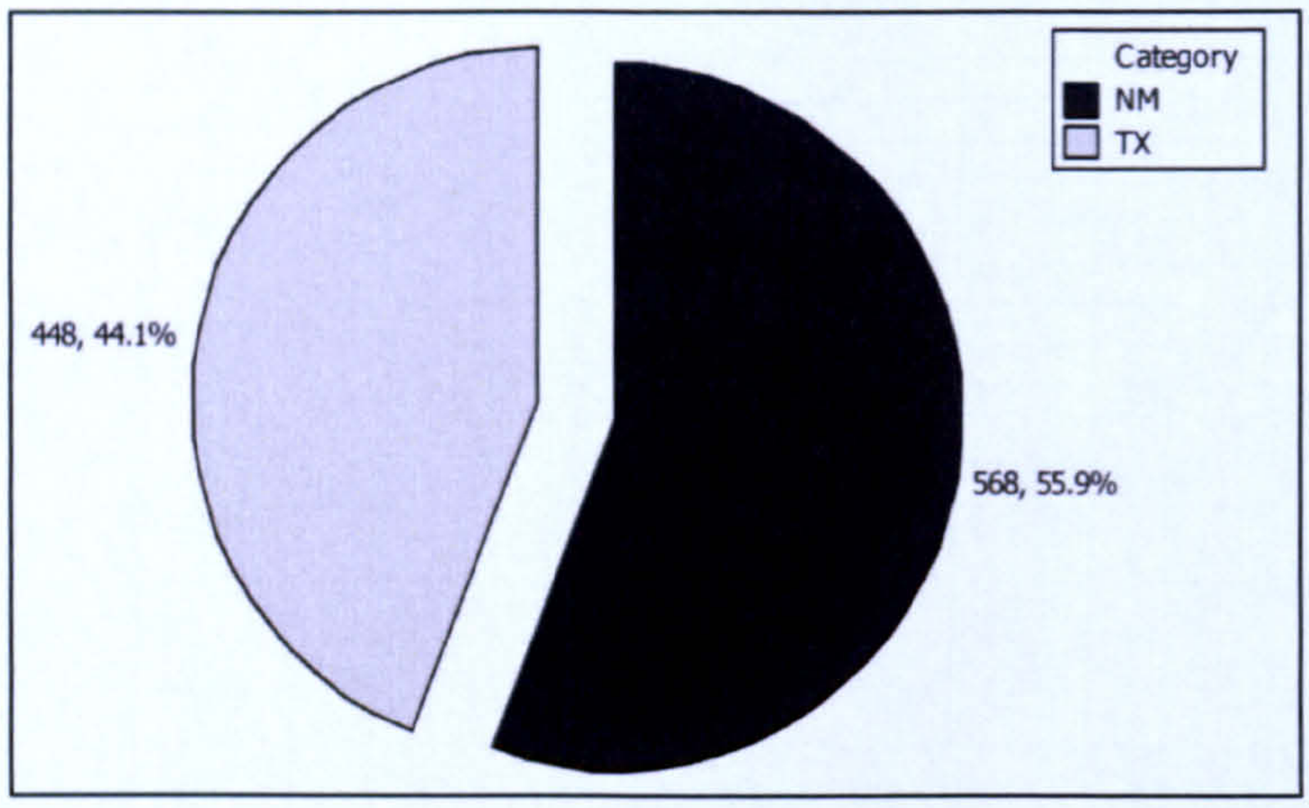


Figure 8.1. Archaeological sites with LTFs by state within the study area.

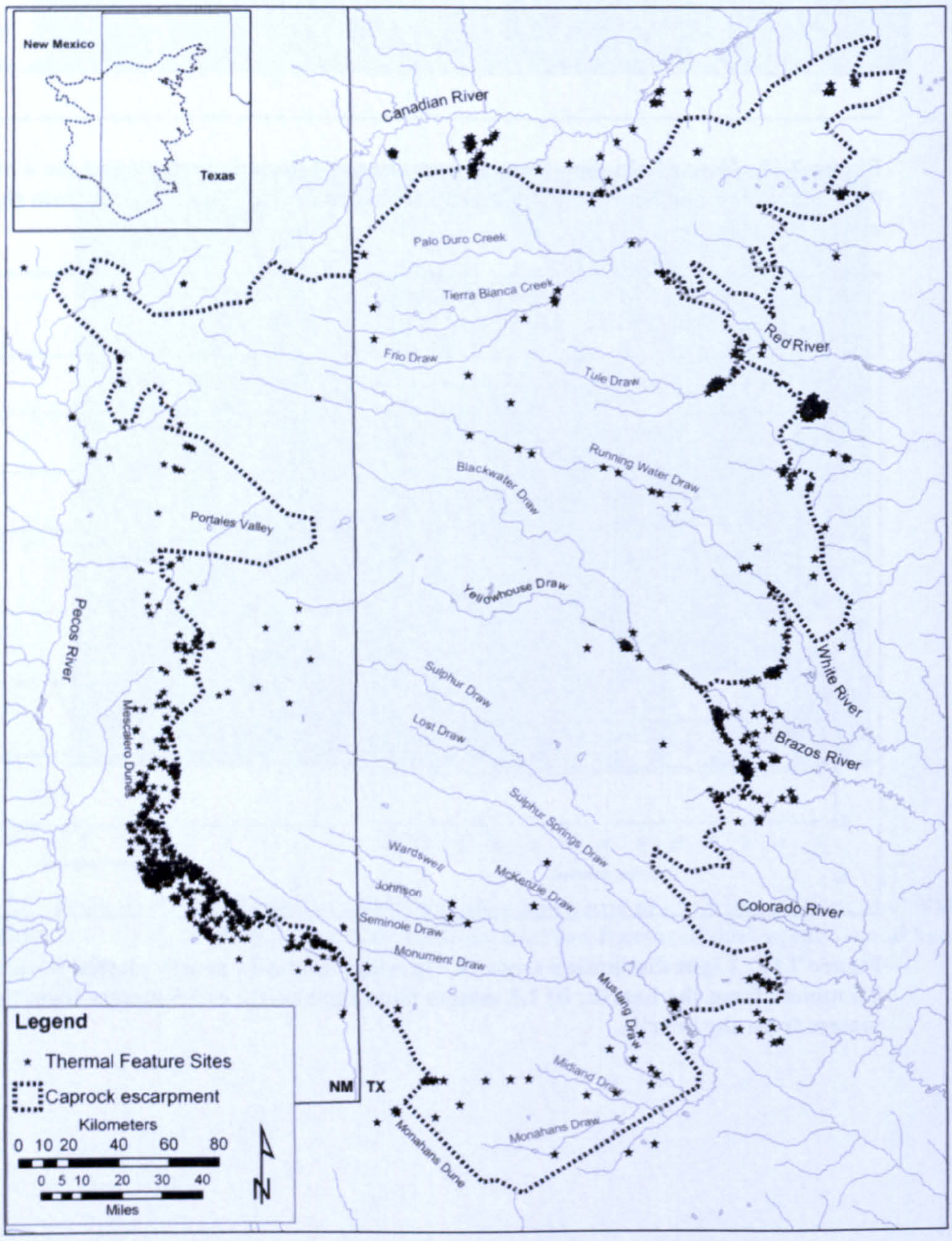


Figure 8.2. Spatial distribution of sites with LTFs identified in the research area.

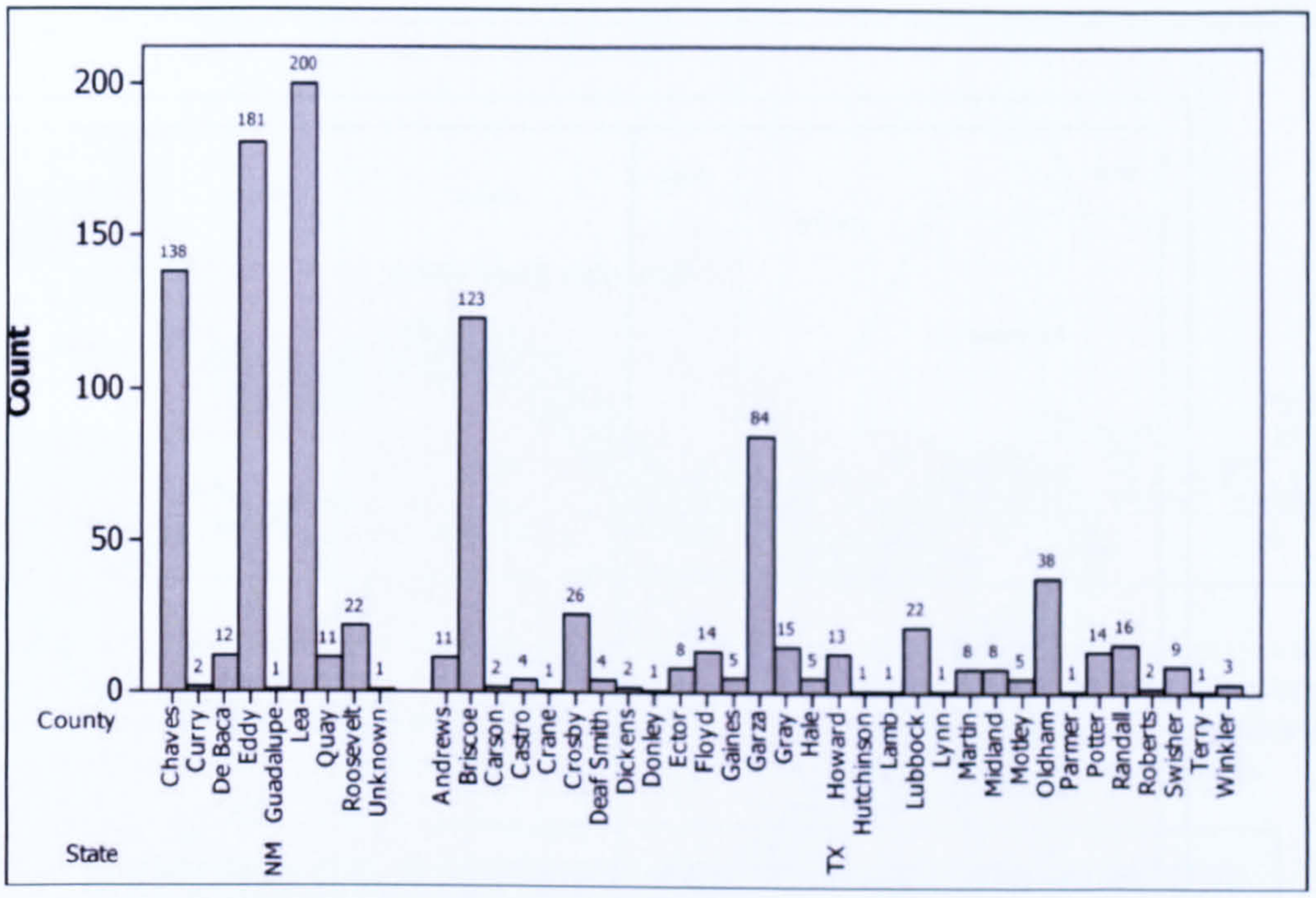


Figure 8.3. Number of sites with evidence for domestic fire technology by State and County.

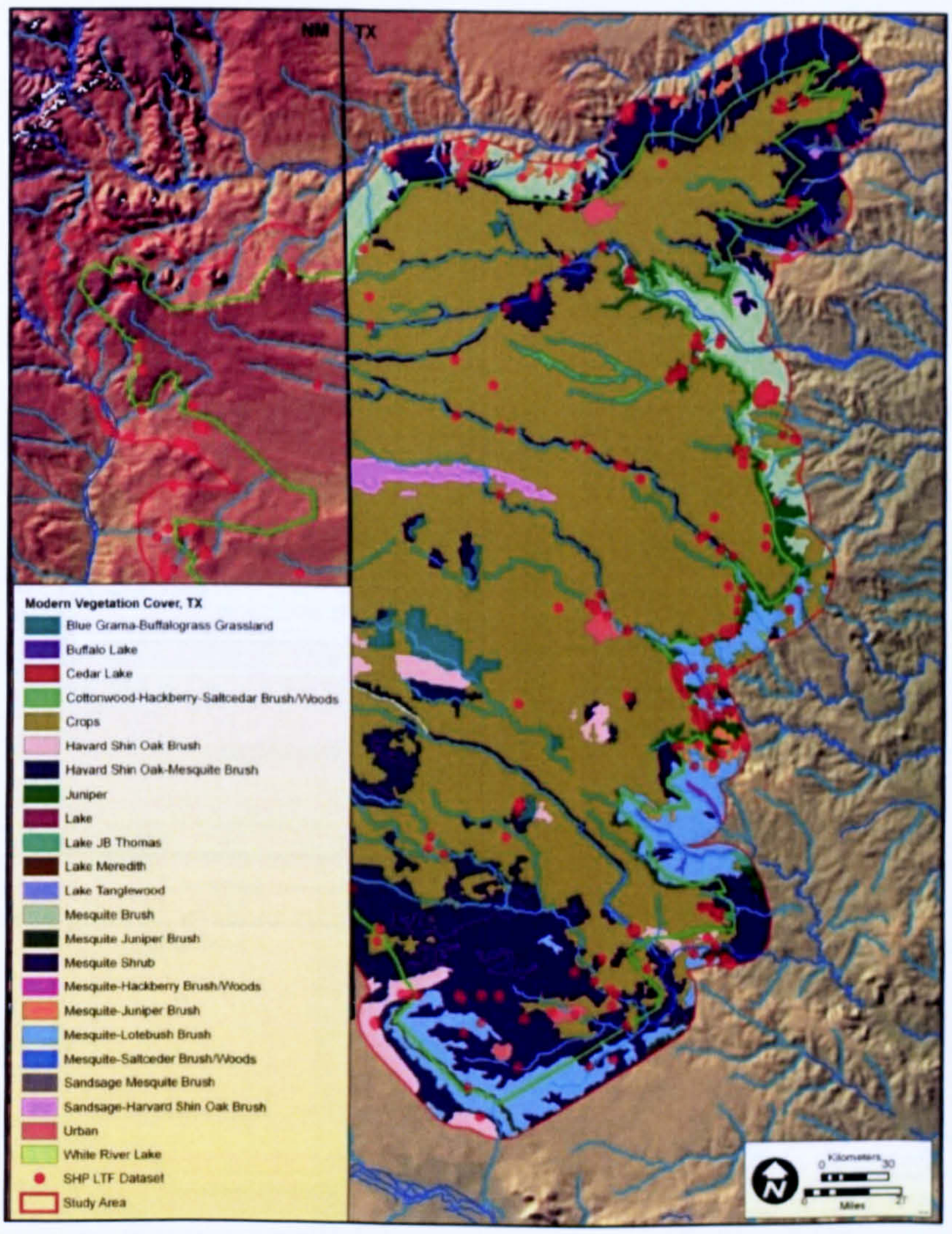


Figure 8.4. Spatial distribution of sites with LTFs identified within the research area overlaid on the modern vegetation communities along the Texas potion of the area (data: 1:100,000 scale vegetation community dataset, Texas Park and Wildlife).

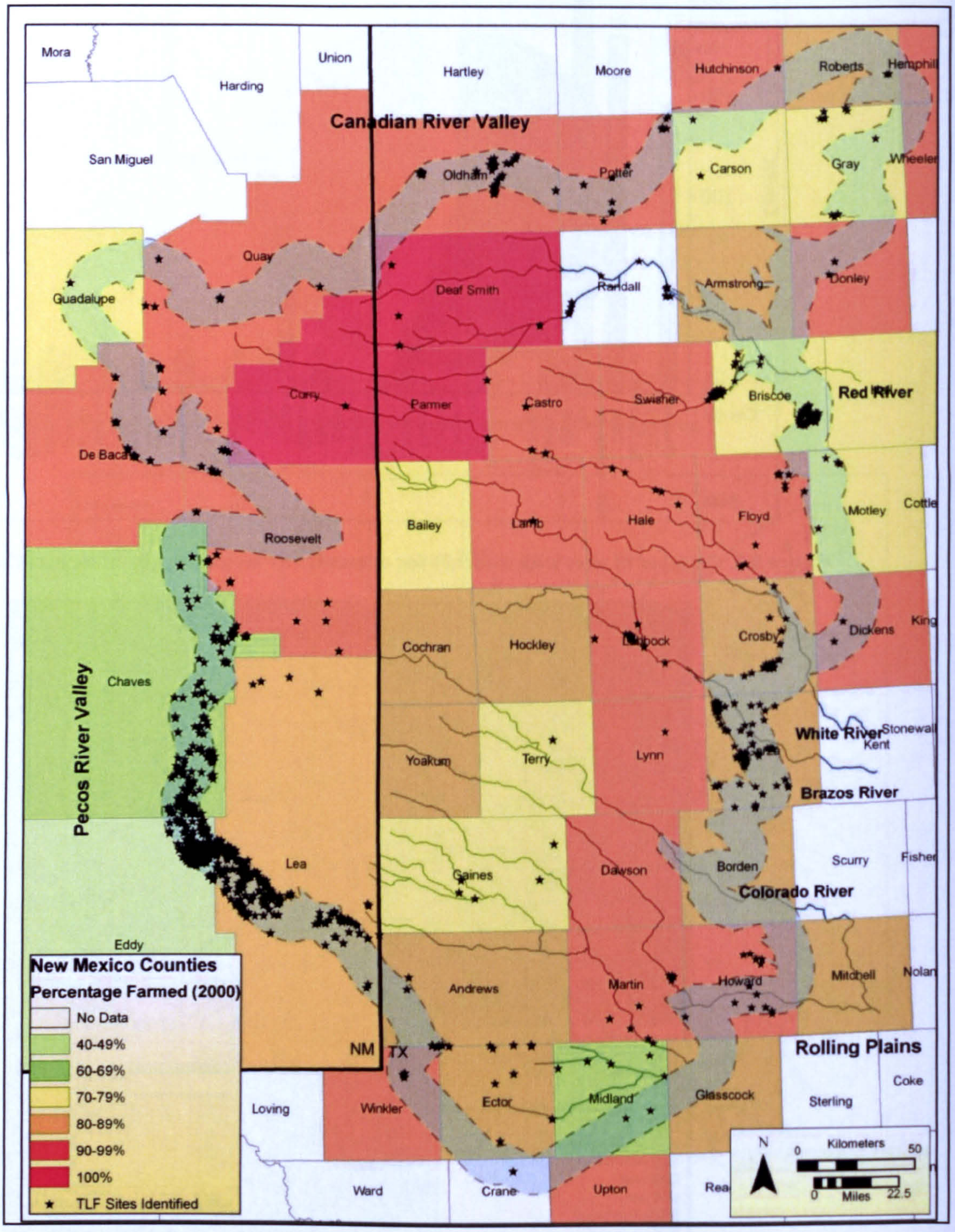


Figure 8.5. Spatial distribution of sites overlaid by modern farming intensity by county (data U.S. Census Bureau, Census 2000).

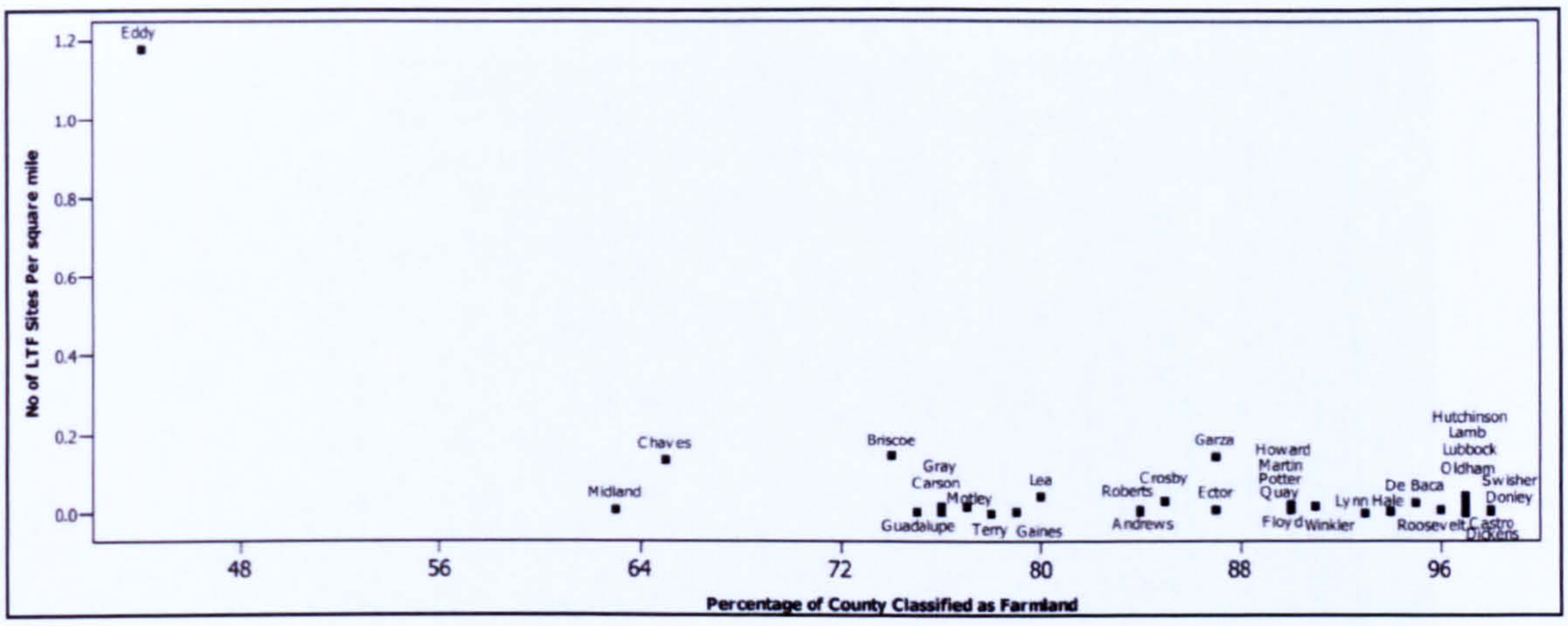


Figure 8.6. Bivariate scatterplot showing percentage of County classified as farmland versus the number of LTF sites identified per square mile, excluding Armstrong, Bailey, Borden, Chochran, Dawson, Glasscock, Hall, Hemphill, Hockley, Mitchell, Upton, Wheeler, and Yokam Counties due to the lack of identified sites (agricultural data from the U.S. Census Bureau, Census 2000).

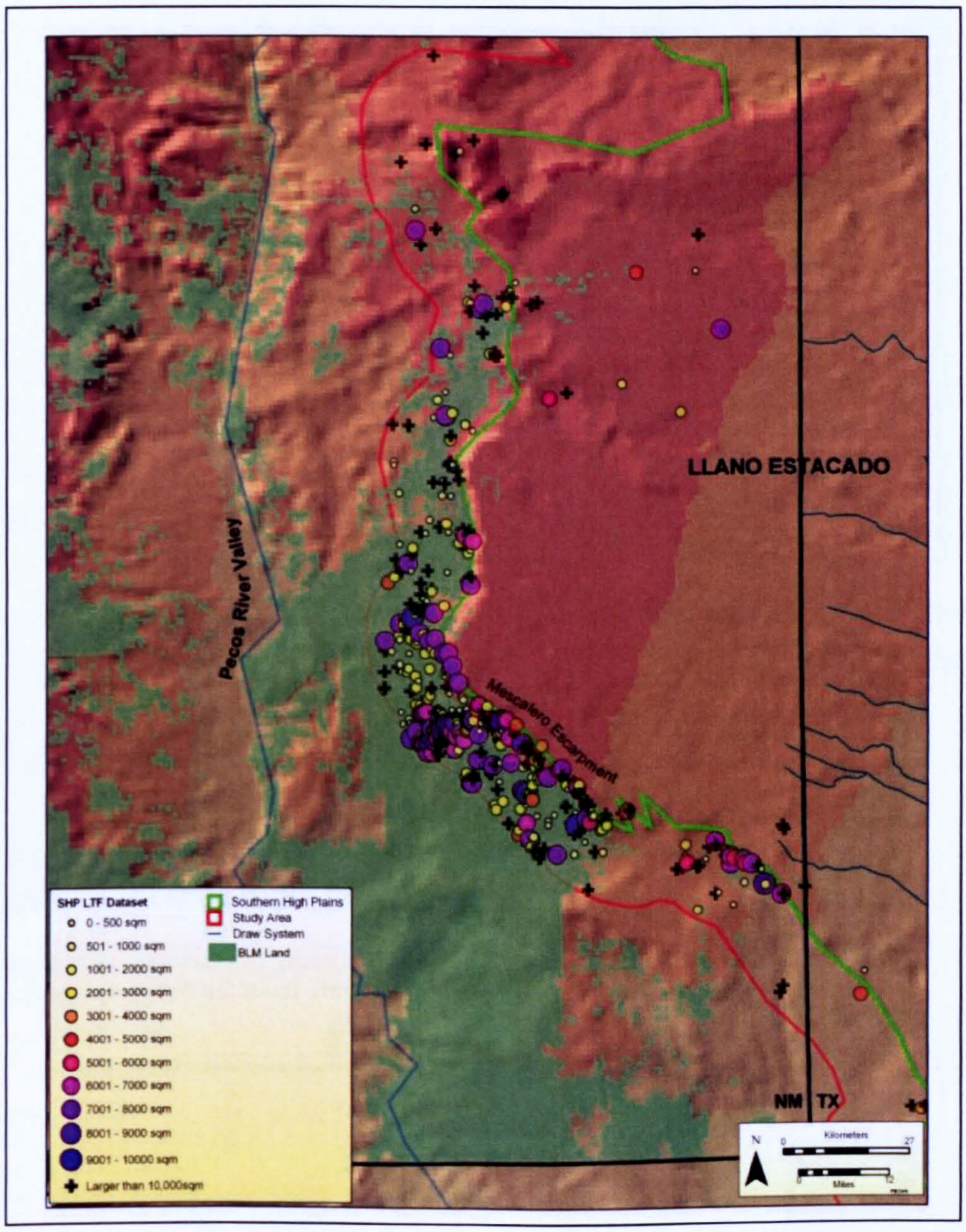


Figure 8.7. Distribution and size of sites identified along the Mescalero Escarpment and adjacent dunes relative to Bureau of Land Management (BLM) land.

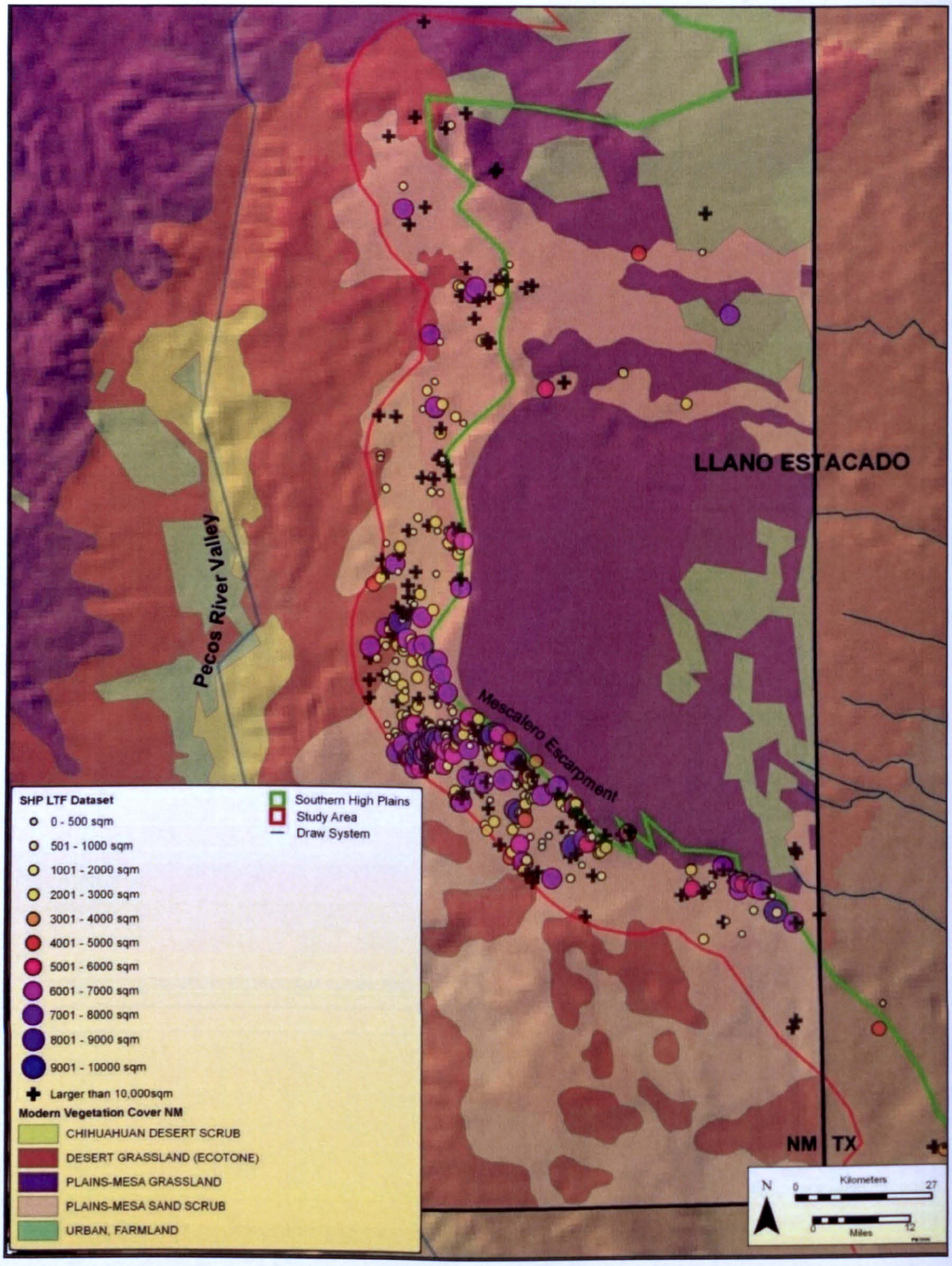


Figure 8.8. Distribution and size of sites identified along the Mescalero Escarpment and adjacent dunes relative to modern land cover (vegetation data from the Natural Resources Conservation Service, www.nrcs.usda.gov).

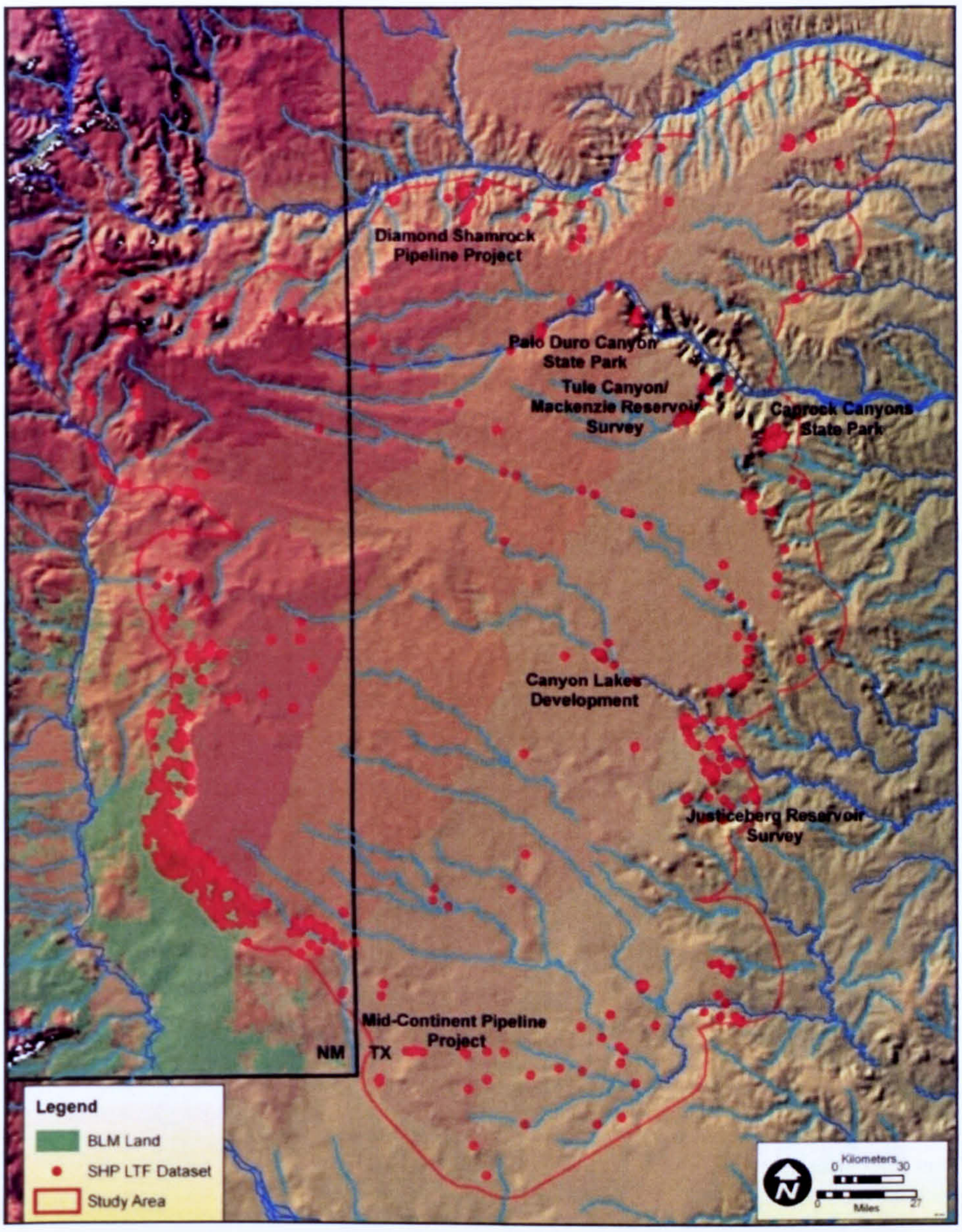


Figure 8.9. LTF sites identified as large-scale survey projects in the Texas portion of the study area.

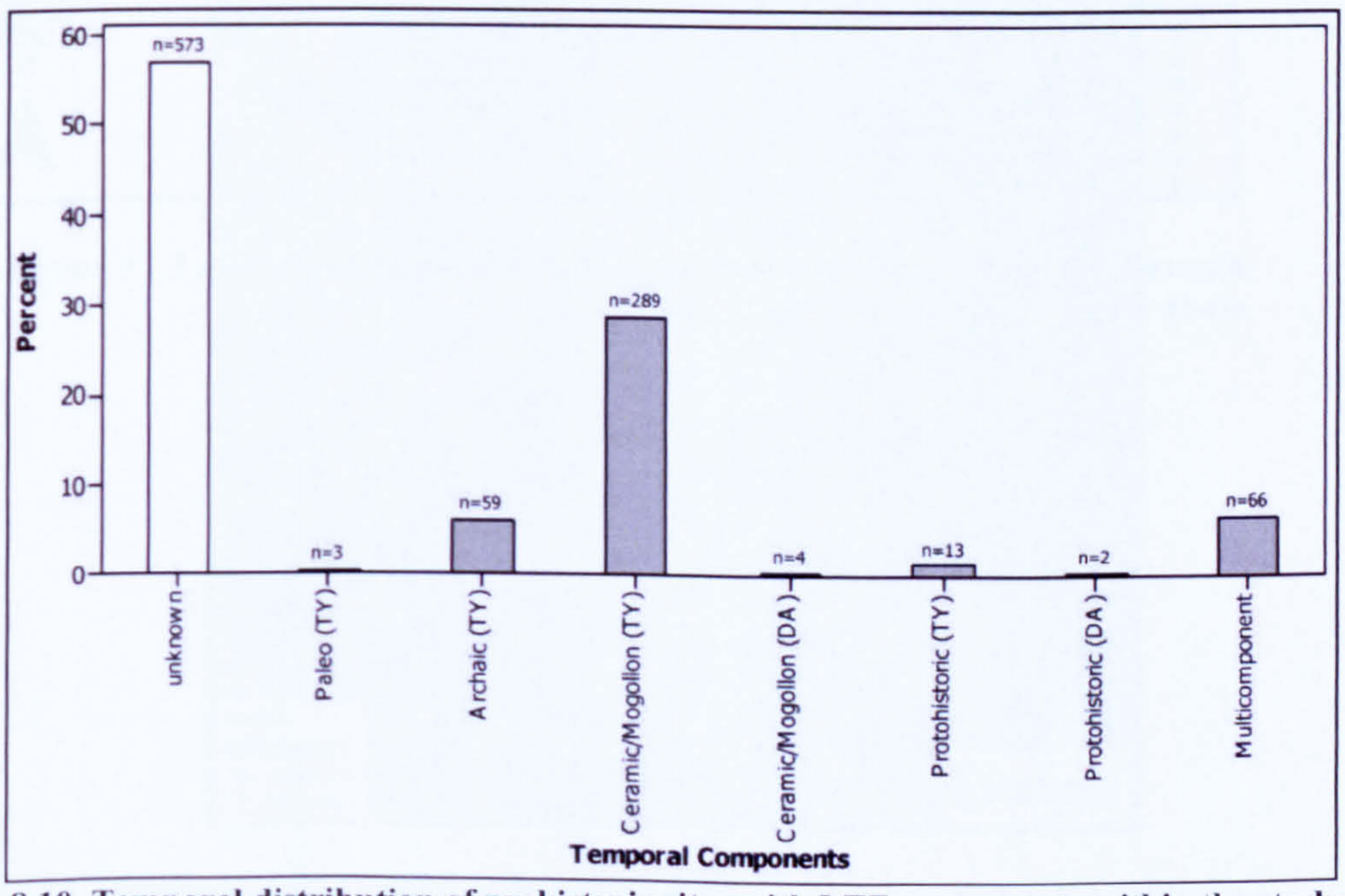


Figure 8.10. Temporal distribution of prehistoric sites with LTF components within the study area.

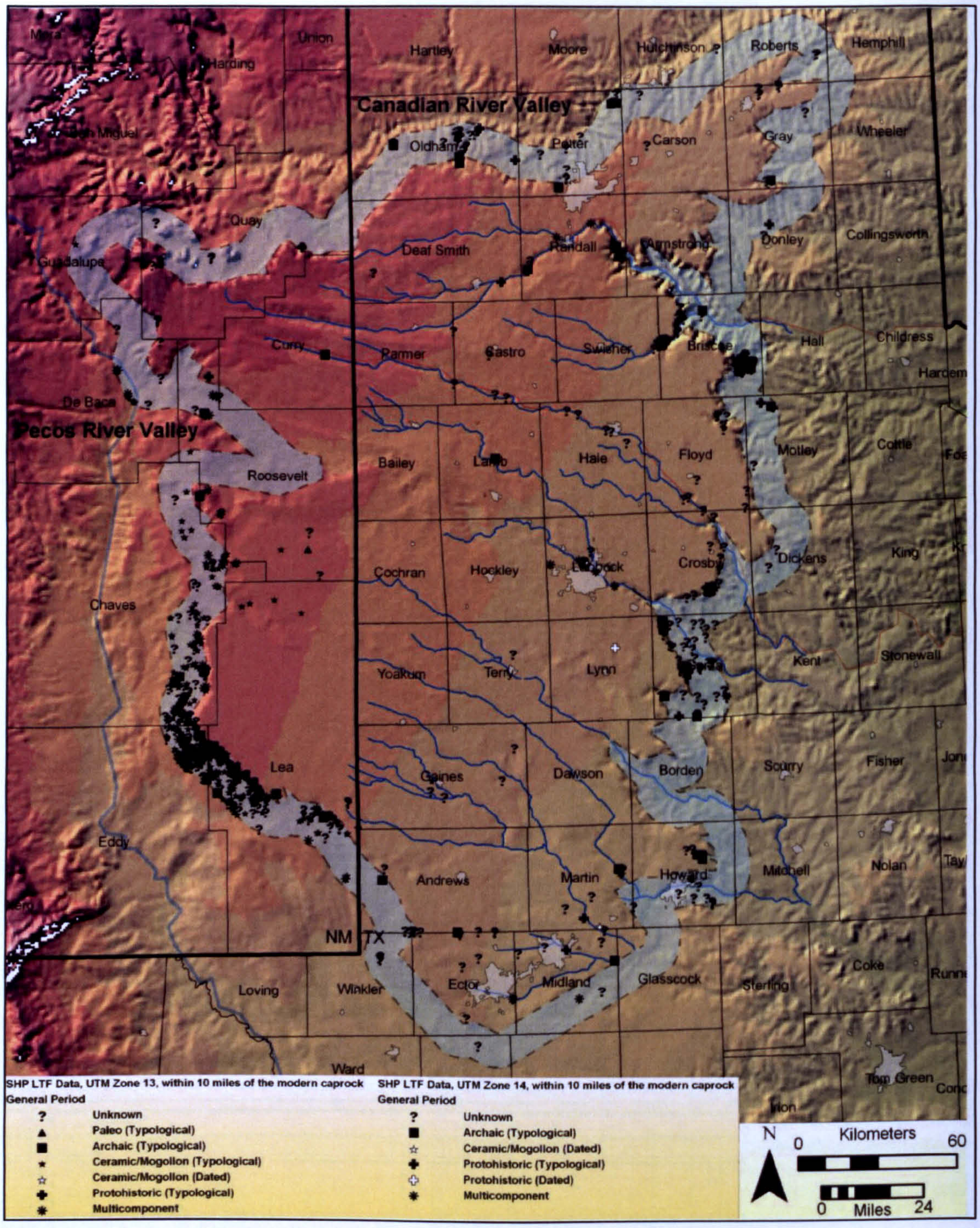


Figure 8.11. Spatiotemporal distribution of archaeological sites with LTF components within the study area.

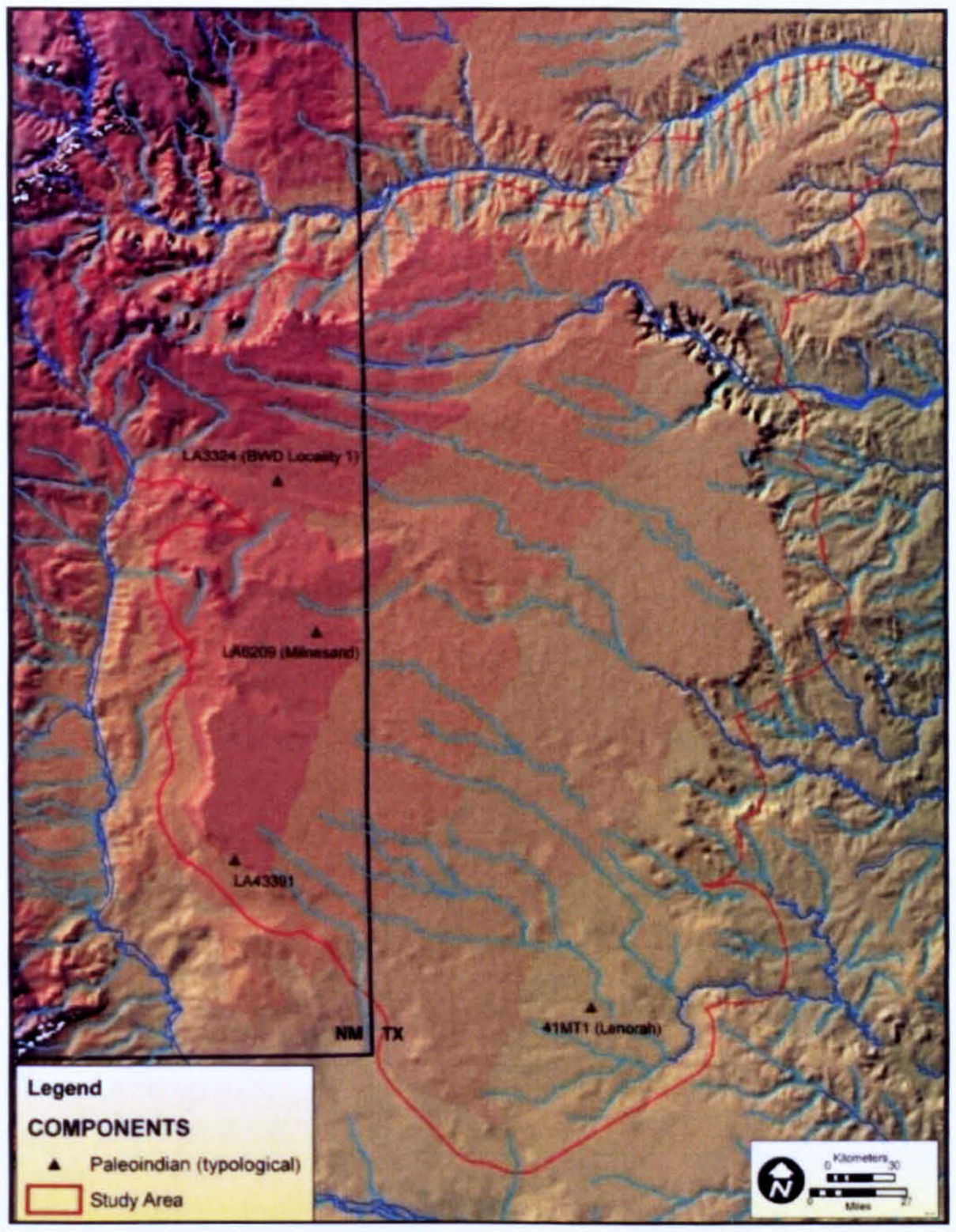


Figure 8.12. Distribution of Paleoindian archaeological sites with LTFs within the study area (BWD Locality 1 added).

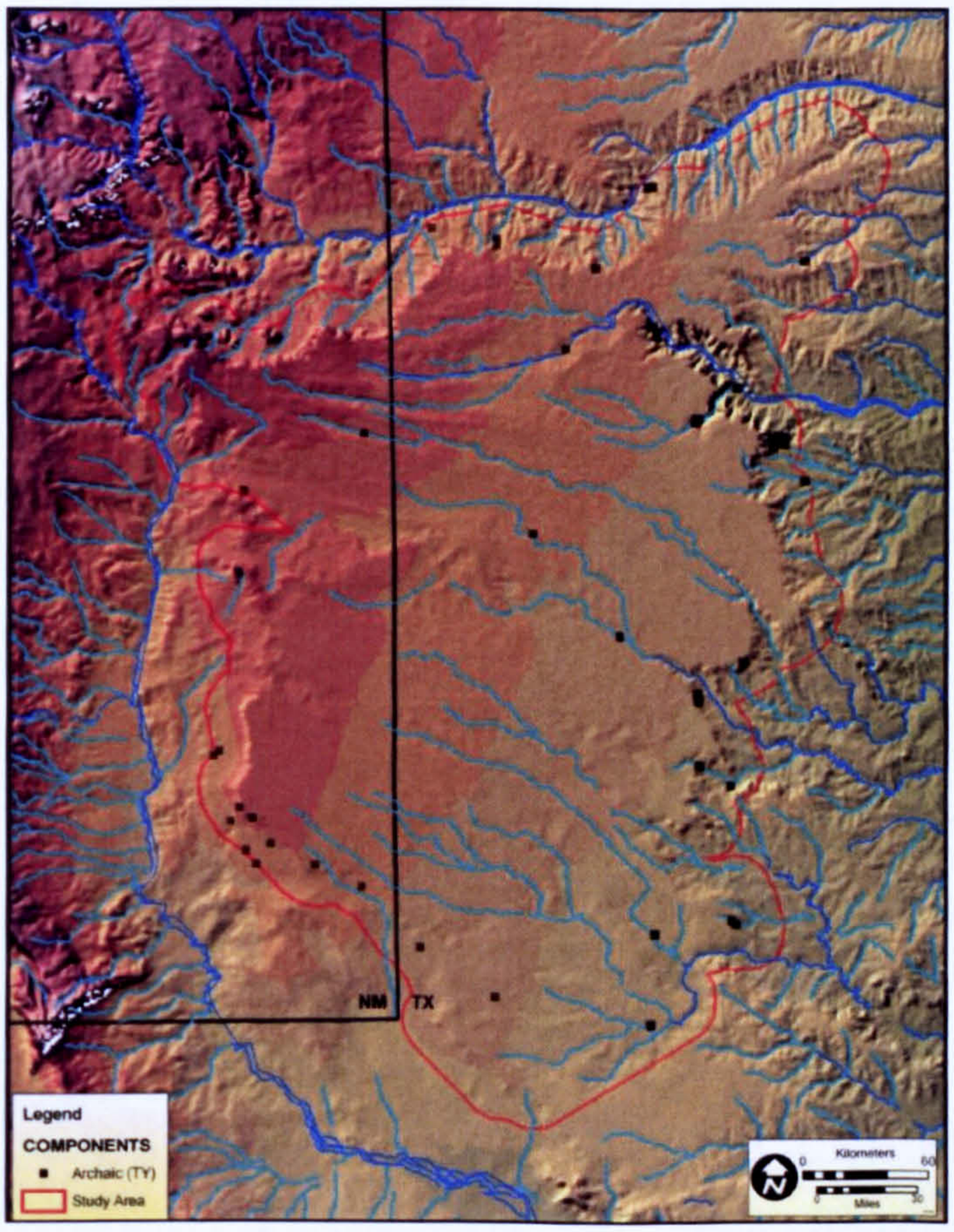


Figure 8.13. Distribution of Archaic archaeological sites with LTFs within the study area.

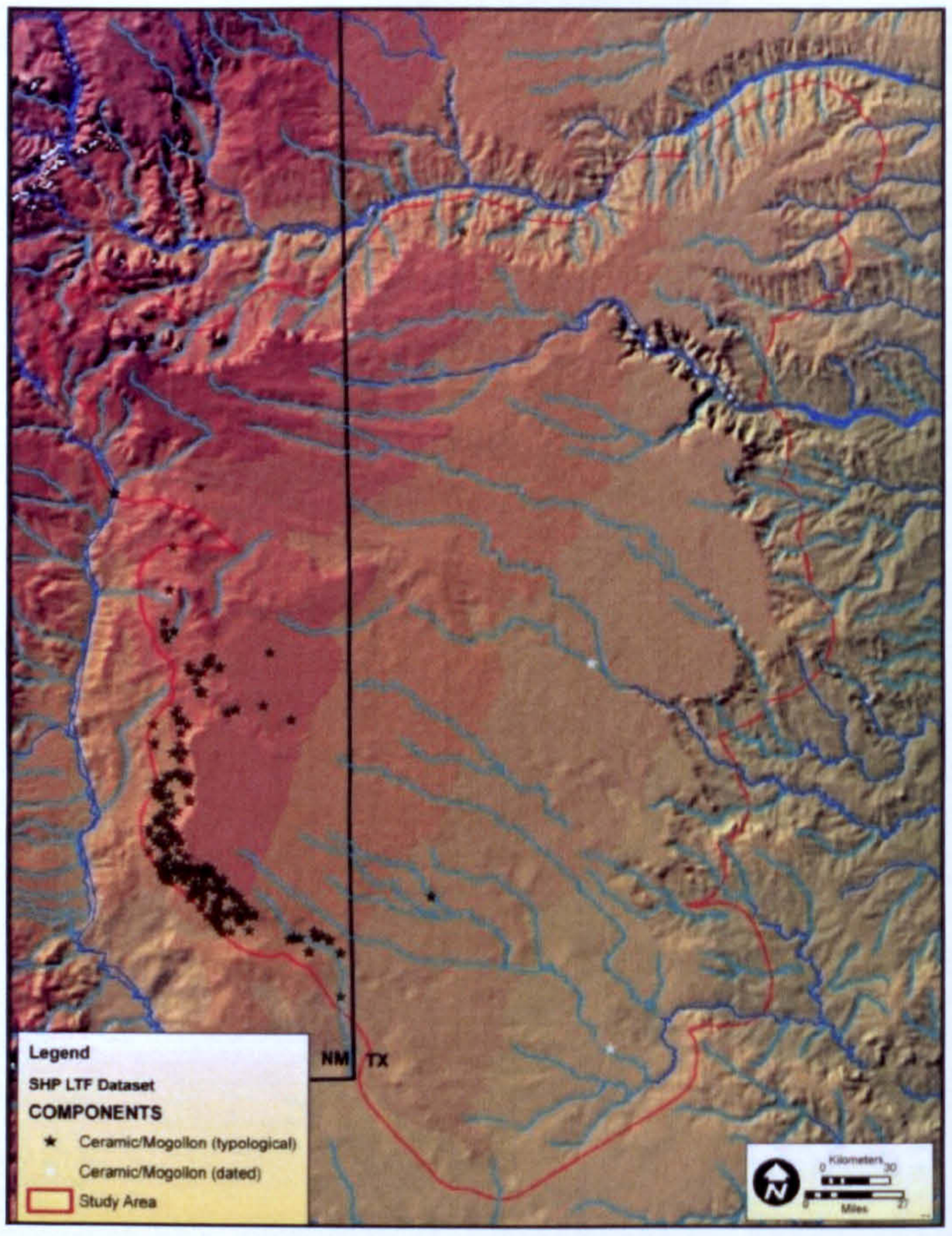


Figure 8.14. Distribution of Ceramic/Mogollon archaeological sites with LTF components within the study area.

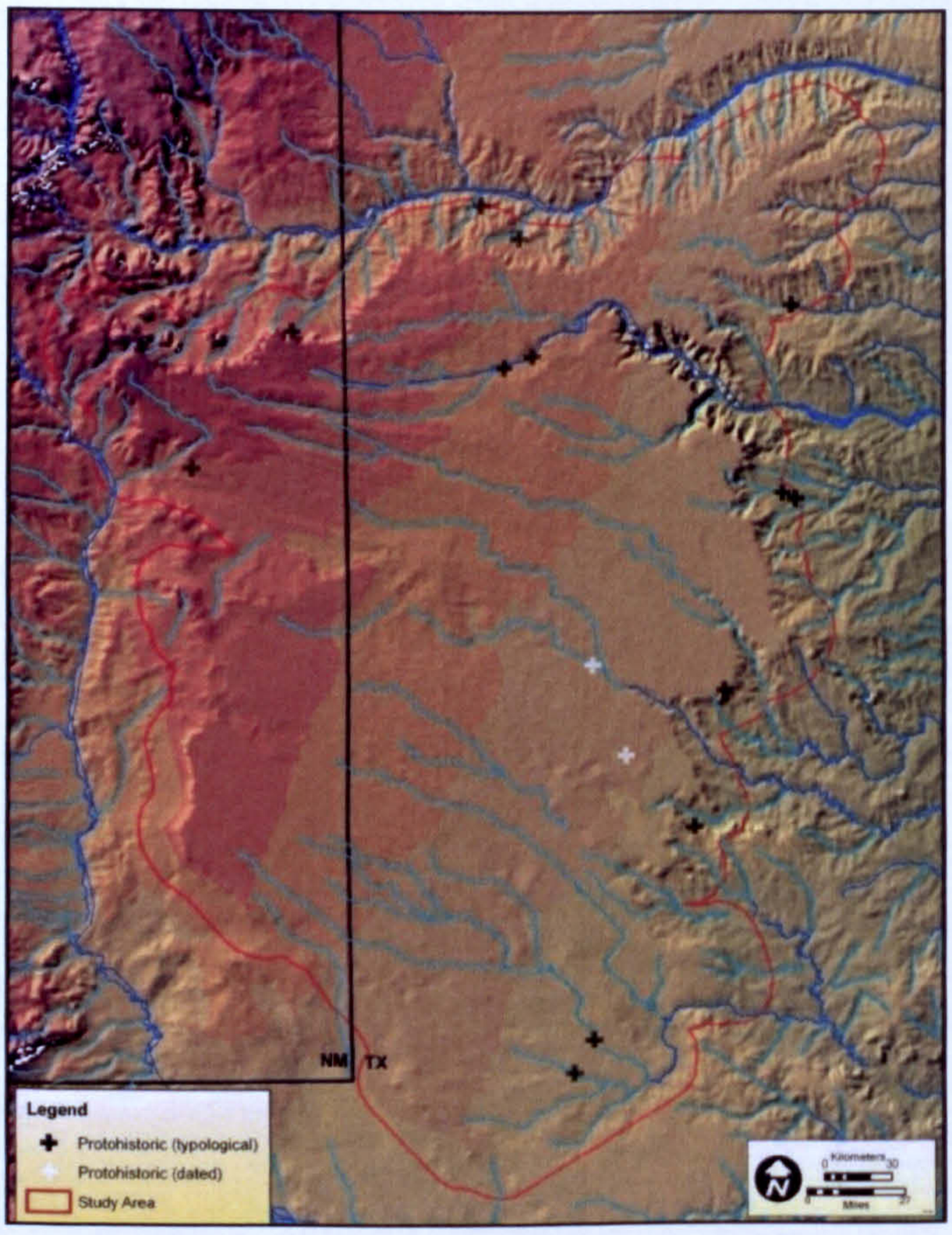


Figure 8.15. Distribution of Protohistoric archaeological sites with LTF components within the study area.

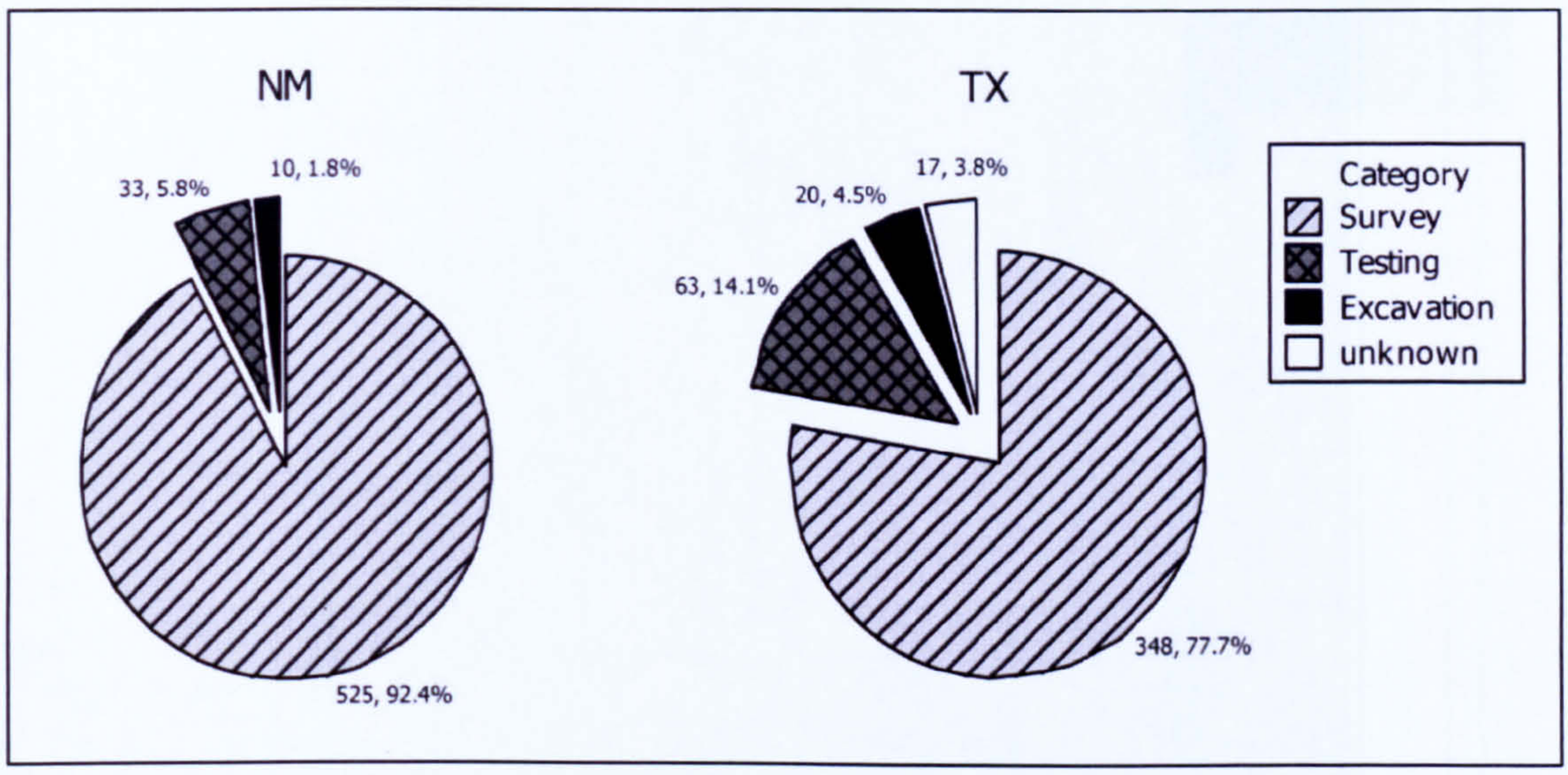


Figure 8.16. Mode of archaeological investigation undertaken at sites with LTFs by state. Note: where more than one mode of investigation occurs then the most intensive is selected regardless of date.

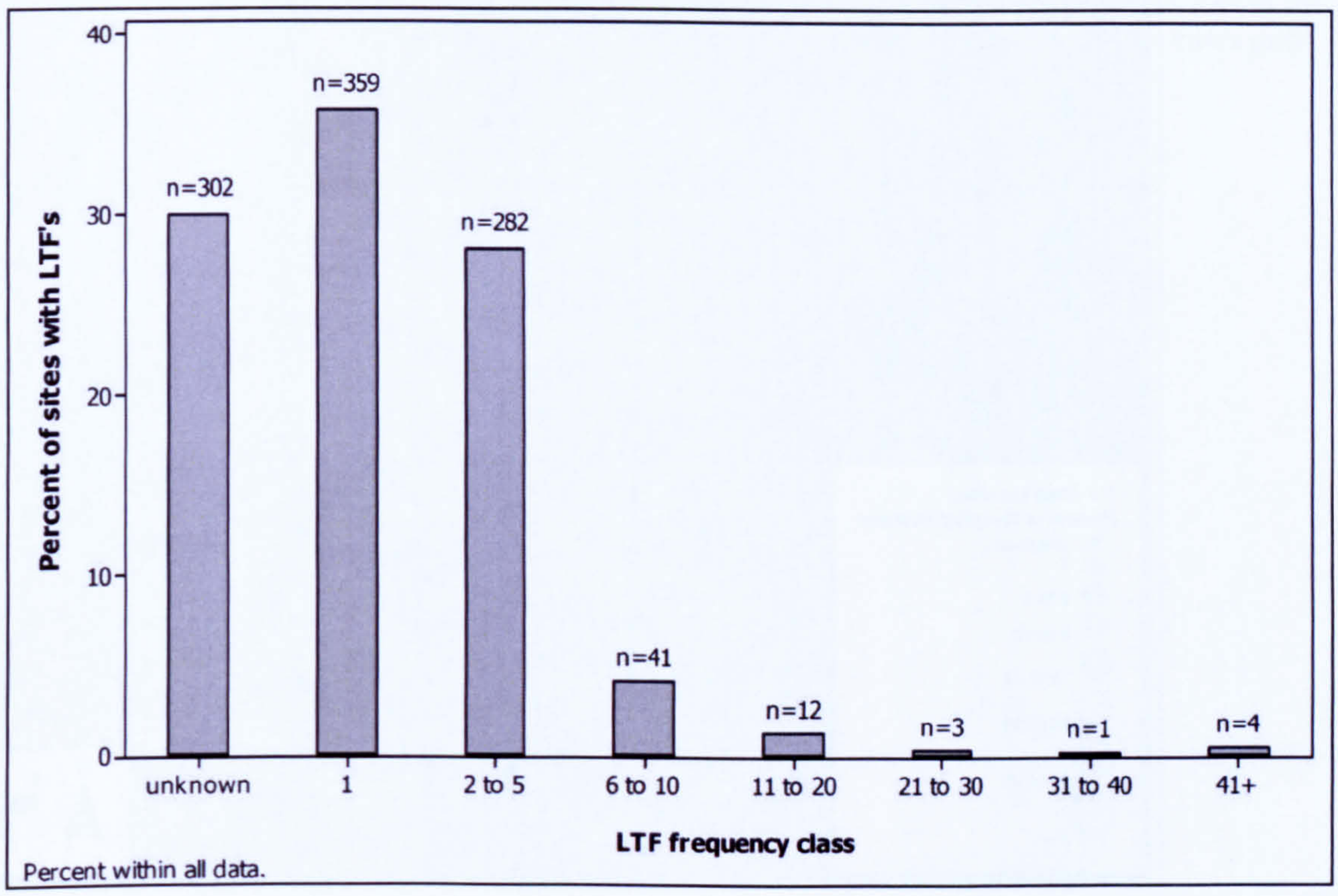


Figure 8.17. Frequency of LTFs at prehistoric archaeological sites within the study area.

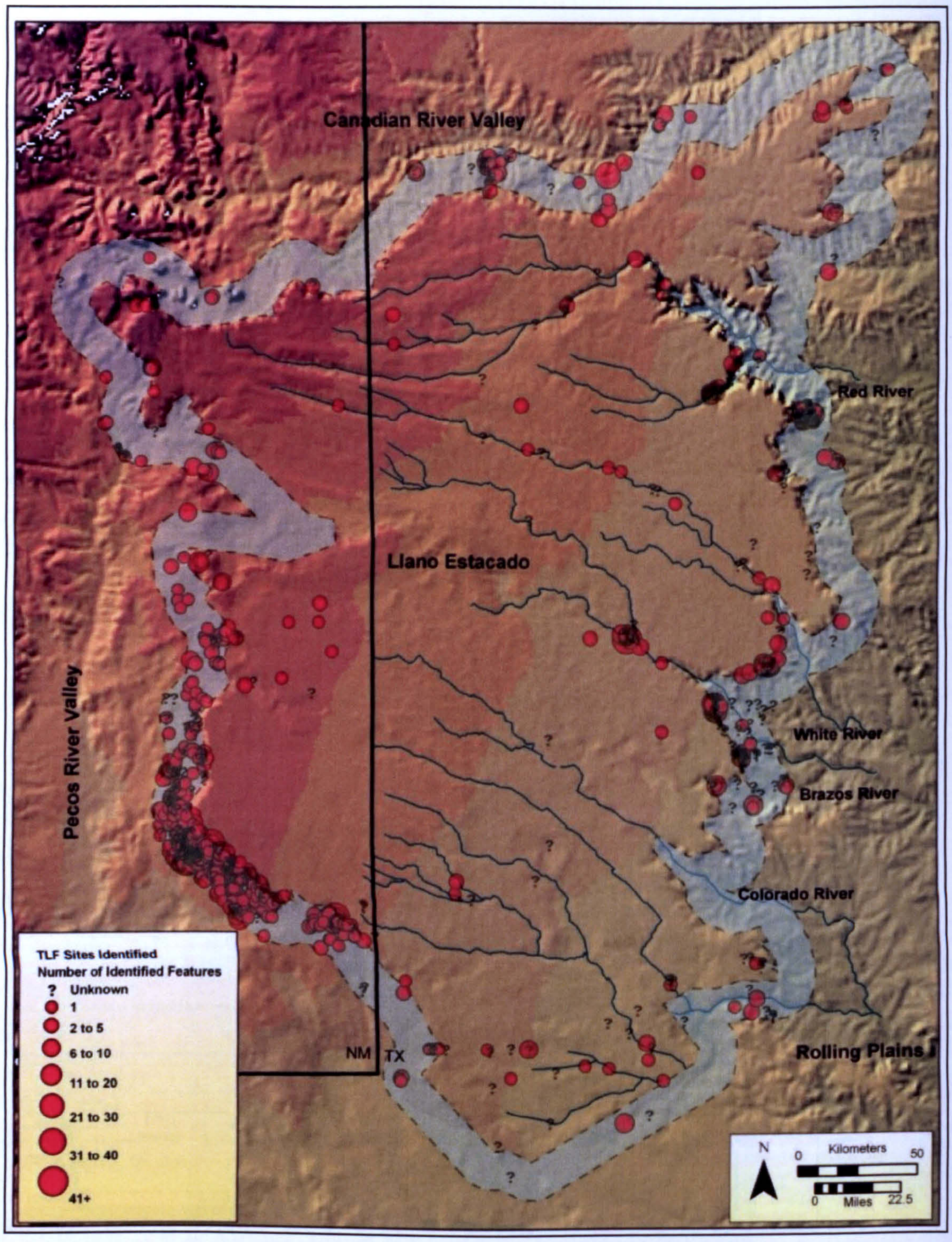


Figure 8.18. Frequency of LTFs by geographic location at prehistoric archaeological sites within the study area.

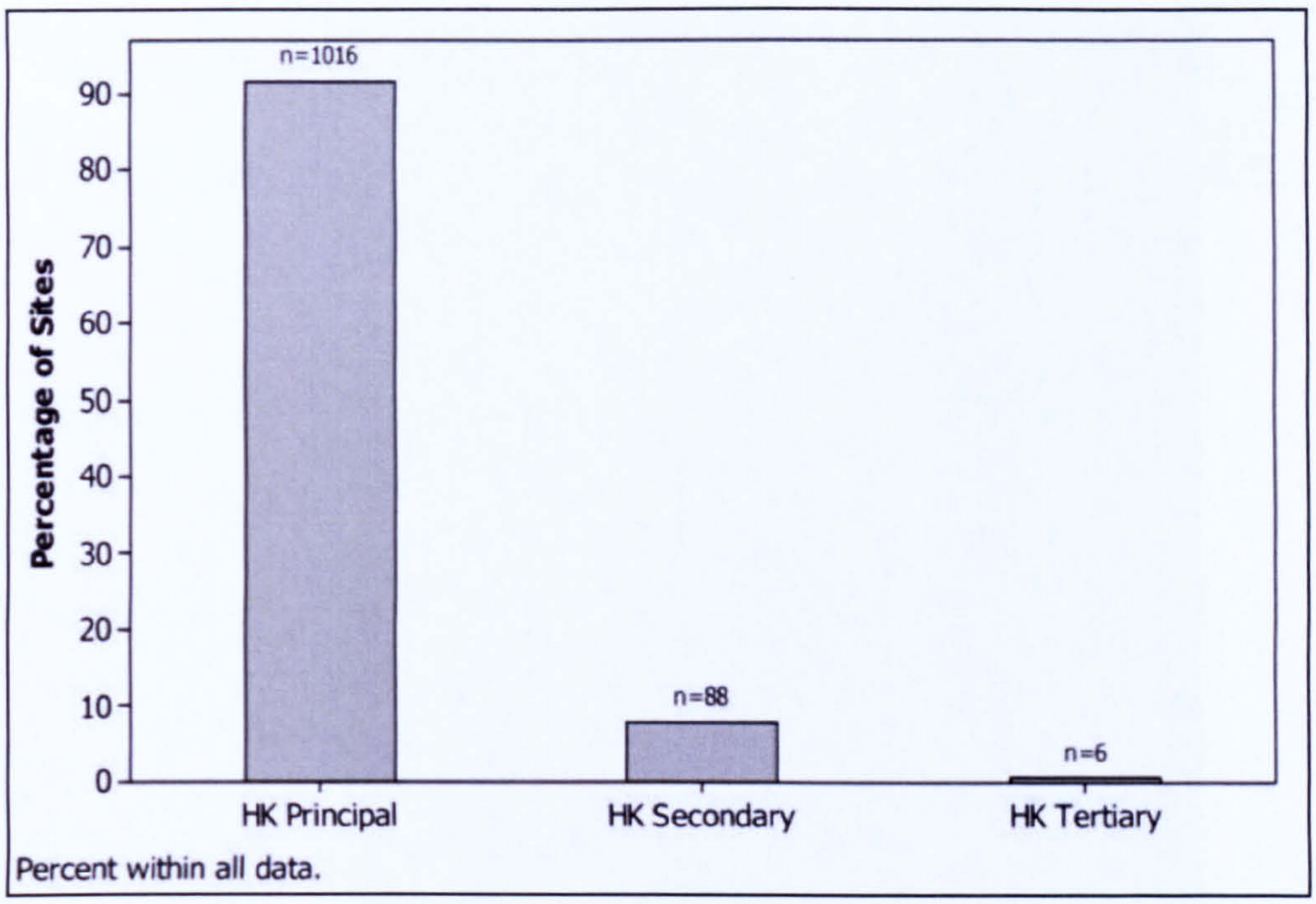


Figure 8.19. Frequency of different LTF components at prehistoric archaeological sites within the study area. Note: the lack of variation in identified components indicating that in most cases only one type of LTF was discernable when applying the hierarchical key.

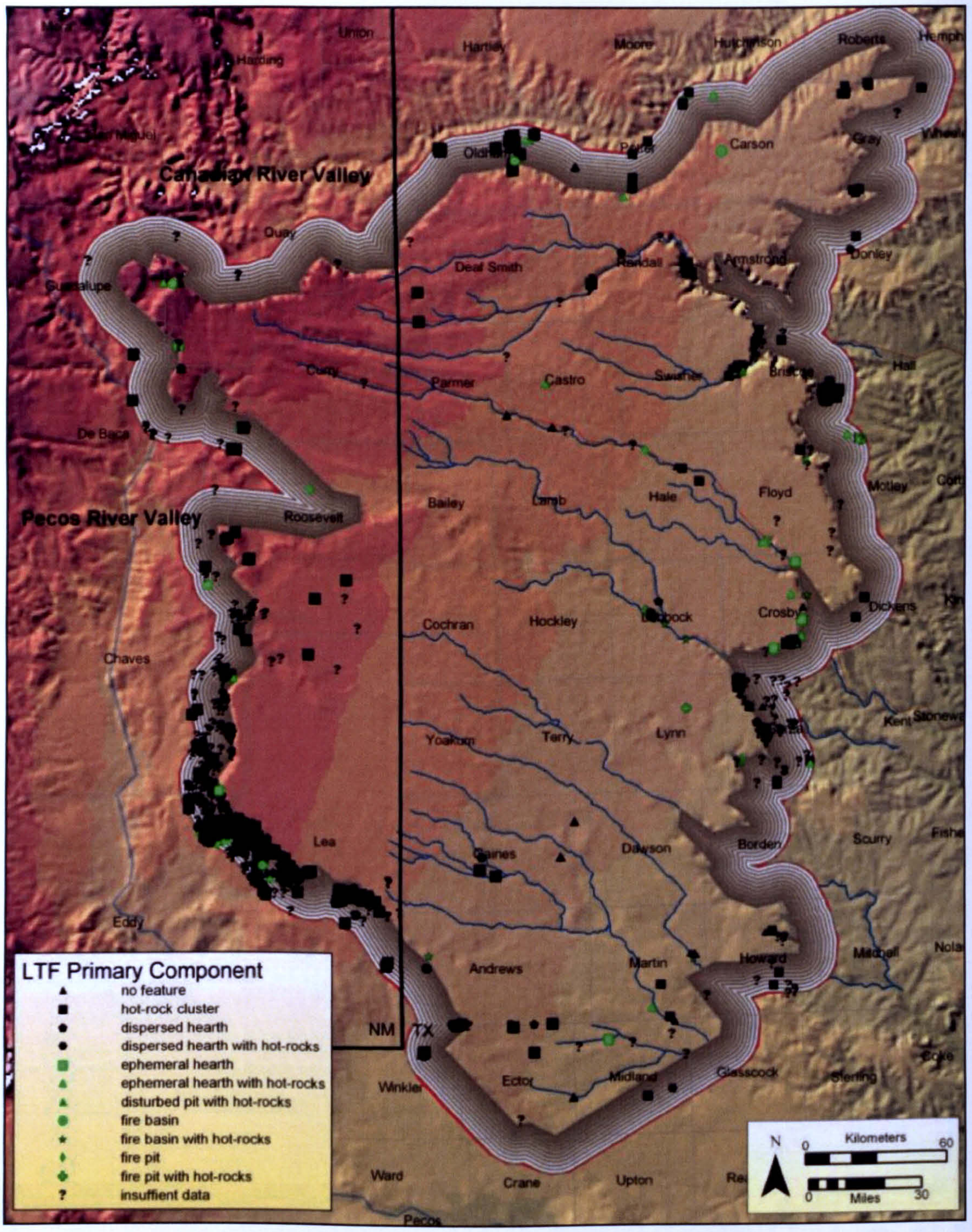


Figure 8.20. Classification of the primary LTF components at prehistoric archaeological sites within the study area.

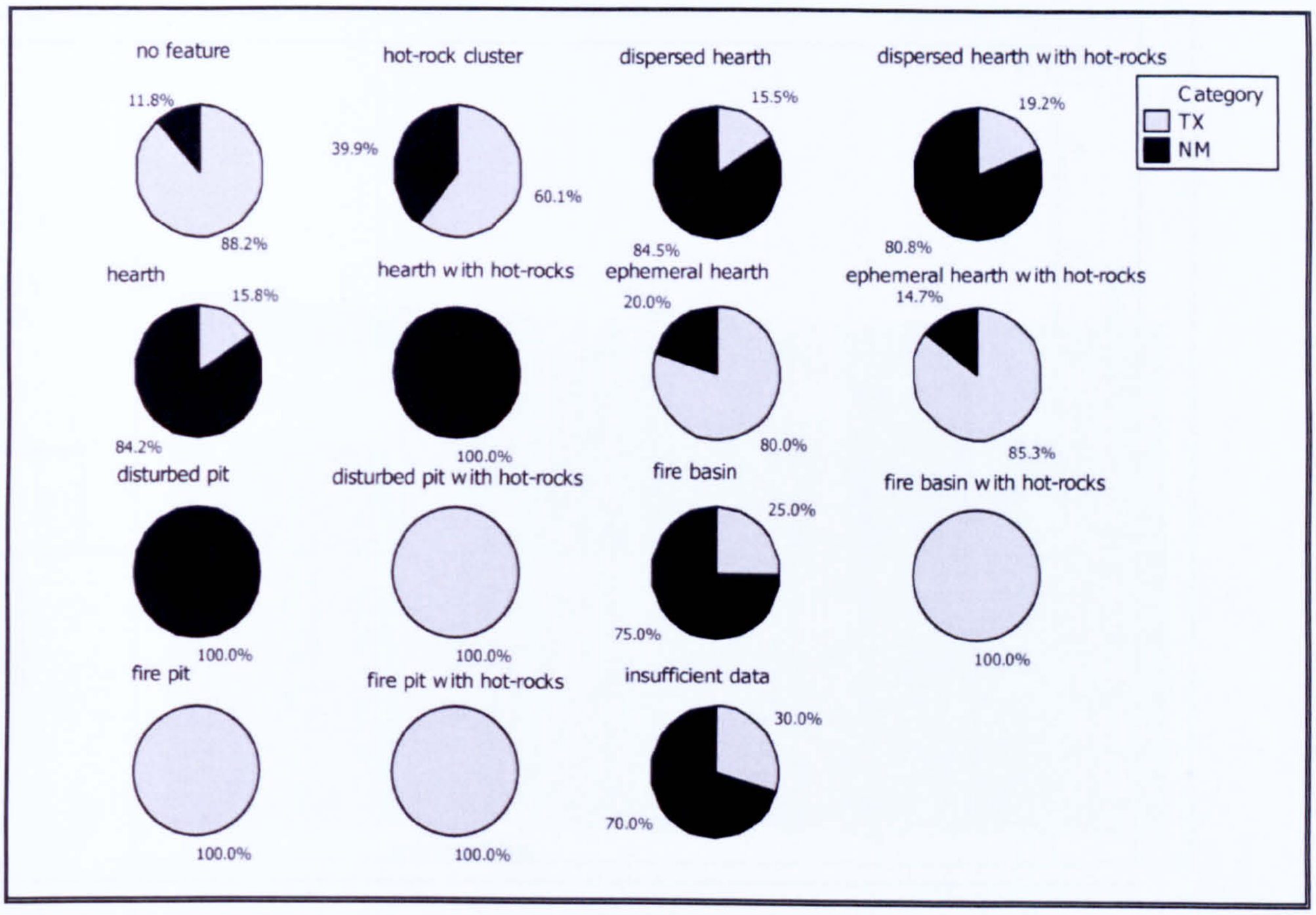


Figure 8.21. Distribution of the primary LTF components identified at sites and presented by State (note: including BWD, Locality 1).

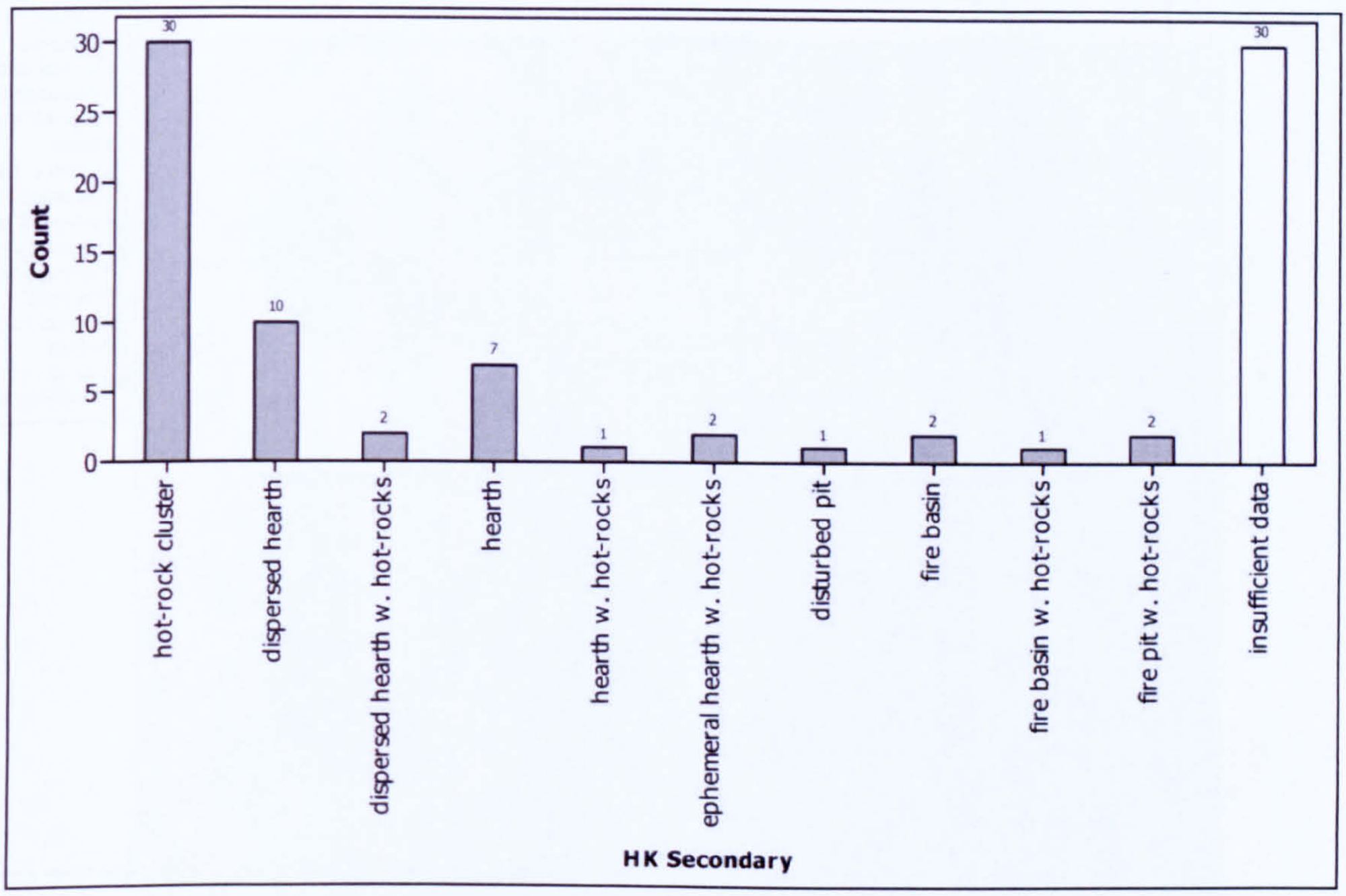


Figure 8.22. Classification of the secondary LTF components at prehistoric archaeological sites within the study area.

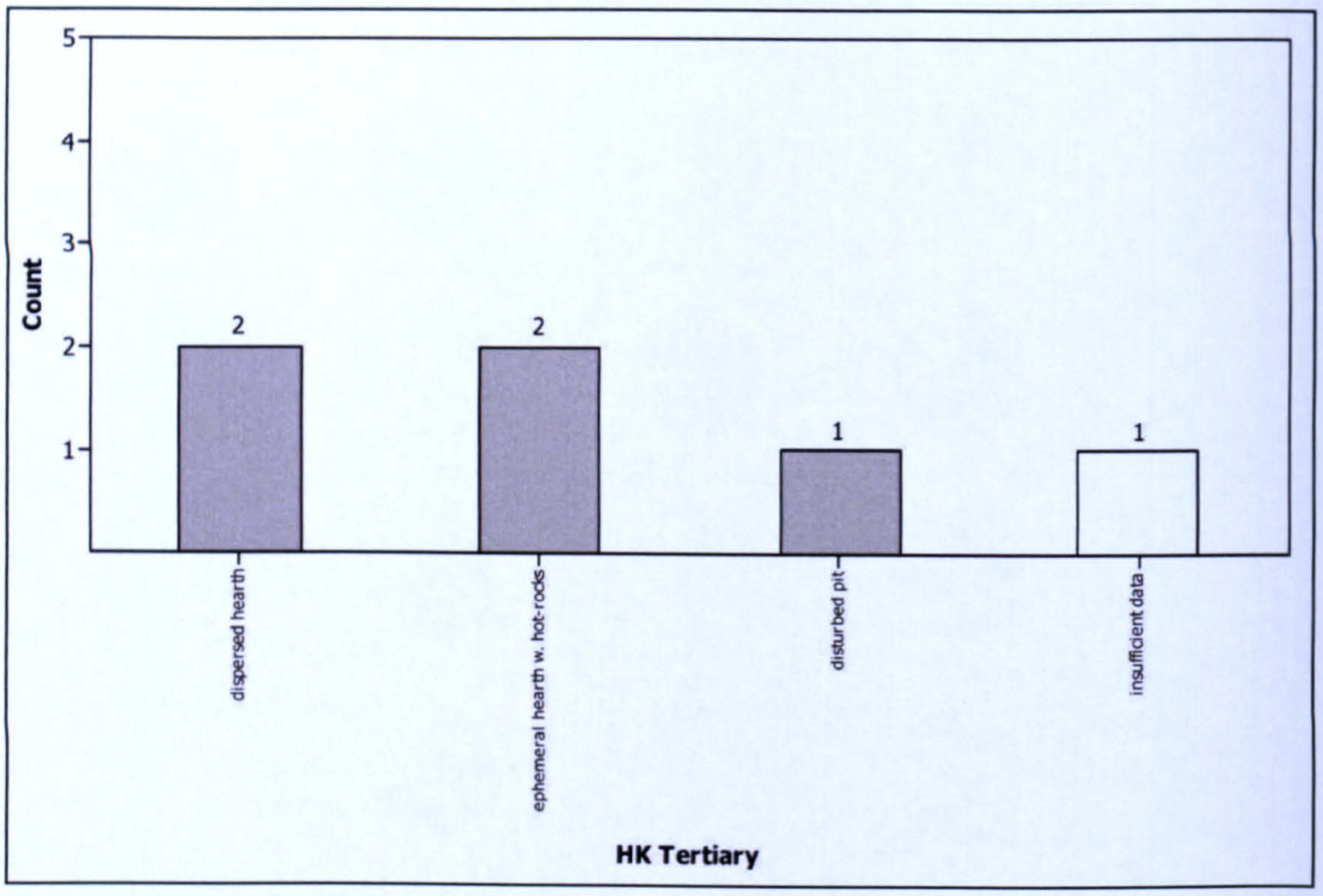


Figure 8.23. Classification of the tertiary LTF components at prehistoric archaeological sites within the study area.

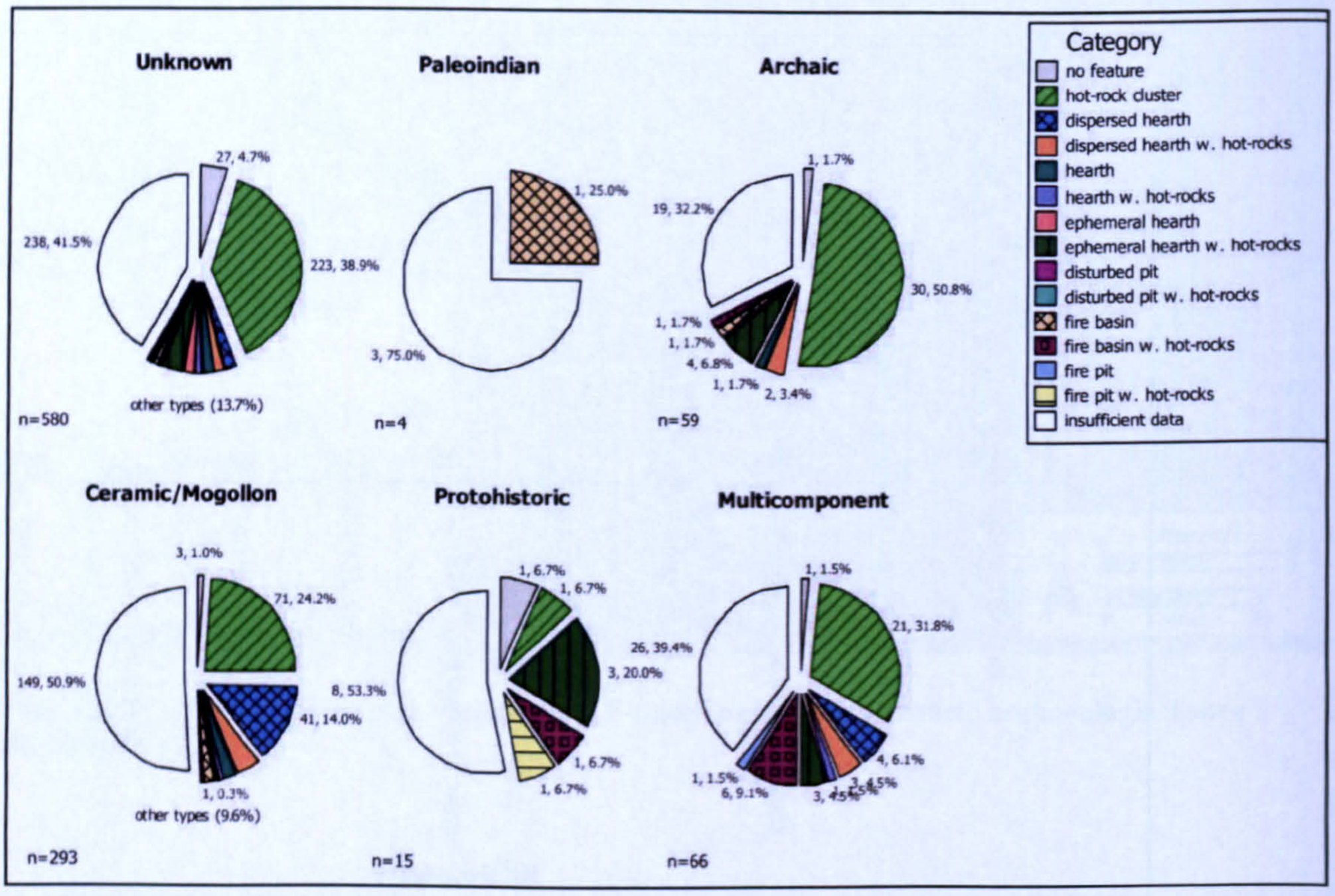


Figure 8.24. Temporal distribution of principal LTF components at prehistoric sites with LTF components within the study area (note: including BWD, Locality 1).

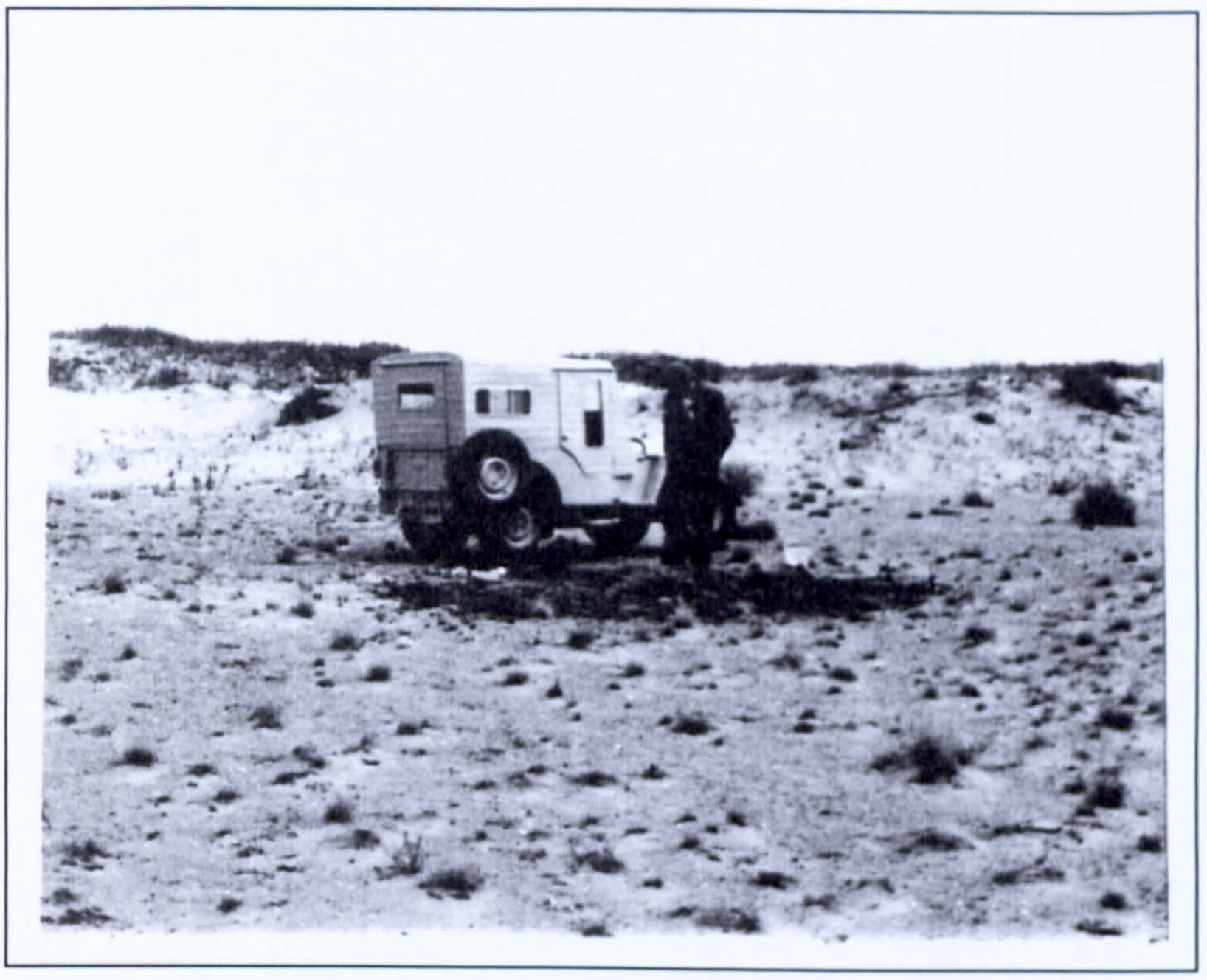


Figure 8.25. Photograph of the fire basin at the Milnesand site. Text caption hand written by James Warnica states 'Ted Williamson, Sr. Standing at hearth at the Milnesand site Feb. 21, 1965. Photo was Taken from Sellards 1954 Test Pit, Looking to the N.E.' (photograph: James Warnica, courtesy of the Anthropology Division Museum of Texas Tech University).

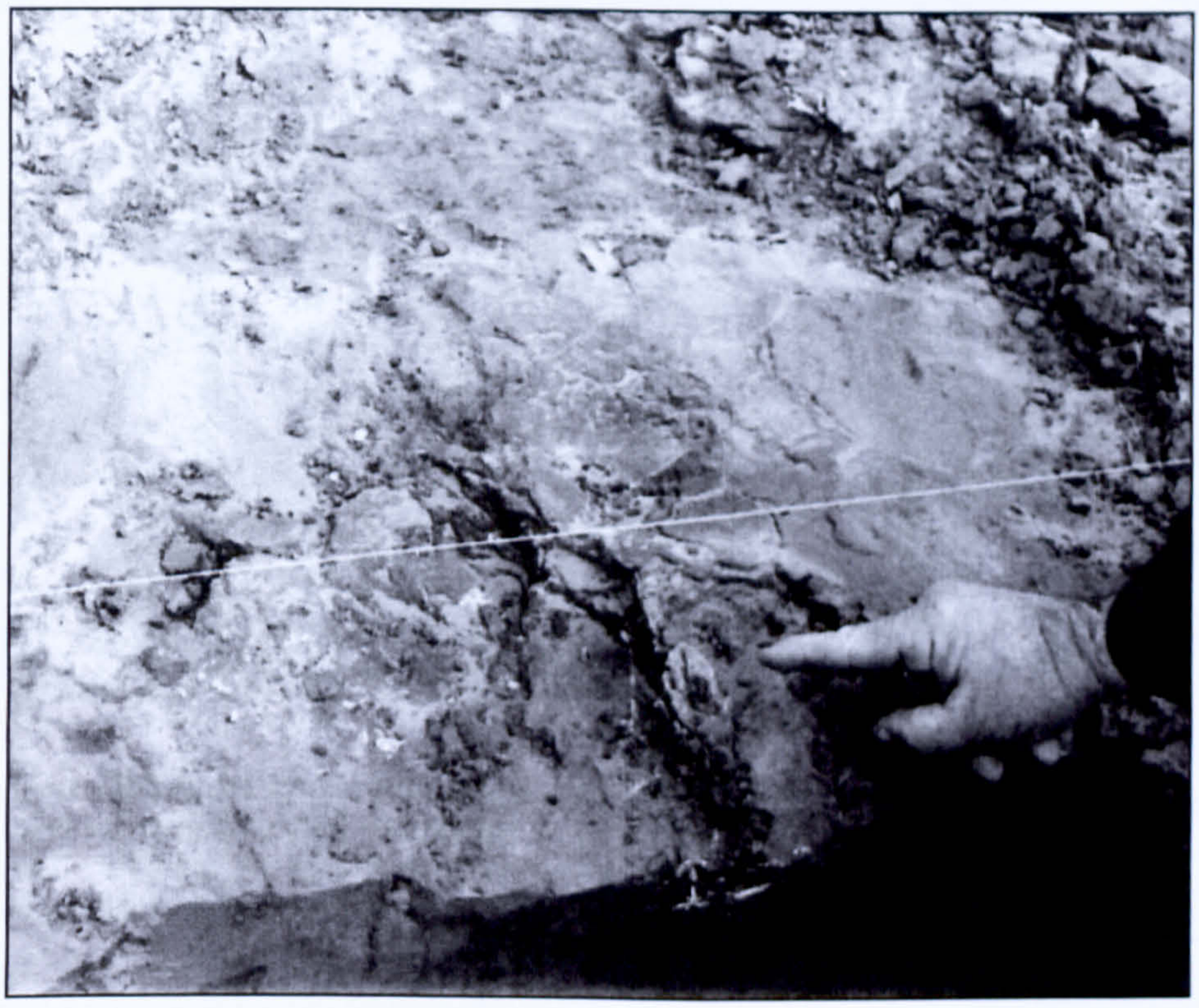


Figure 8.26. Photograph of the fire basin at the Milnesand site. Text caption hand written by James Warnica states 'Overhead view of hearth exposed at the Milnesand Site Feb. 21, 1965. Finger of Ted Williamson, Sr. points to charred bone' (photograph: James Warnica, courtesy of the Anthropology Division Museum of Texas Tech University).



Figure 8.27. Photograph of the fire basin at the Milnesand site. Text caption hand written by James Warnica states 'Bottom of hearth exposed at the Milnesand site. Finger of Ted Williamson, Sr. points to charred bone. Feb. 21, 1965' (Photograph: James Warnica, courtesy of the Anthropology Division Museum of Texas Tech University).

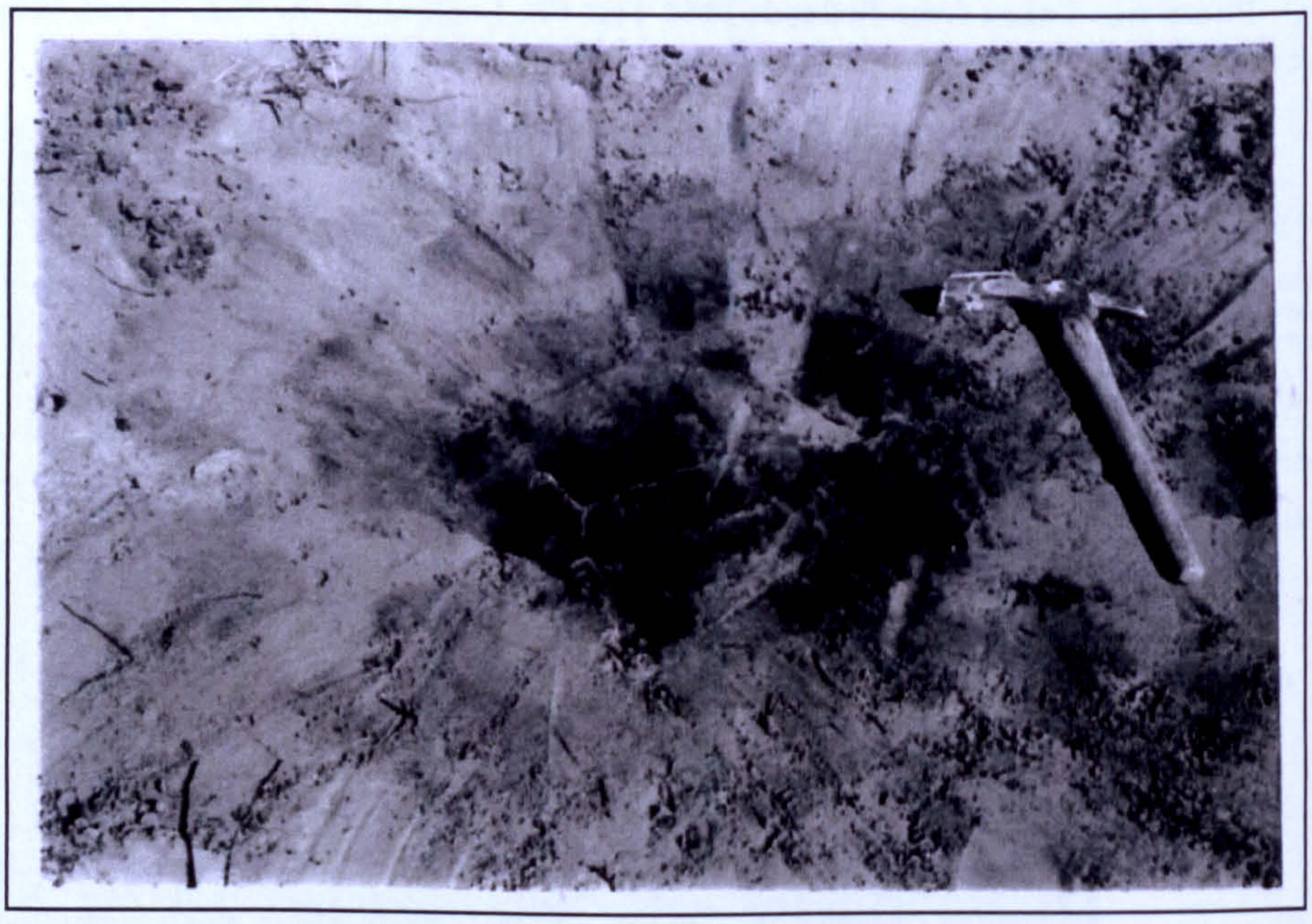


Figure 8.28. Photograph of the fire basin, most probably at the Williamson site. Text caption hand written by James Warnica states 'View of hearth at a Folsom site on the former game refuge S.E. of Milnesand Feb. 23, 1965. The sand was burned but it was not collected. There were no burned bones in the hearth' (Photograph: James Warnica, courtesy of the Anthropology Division Museum of Texas Tech University).

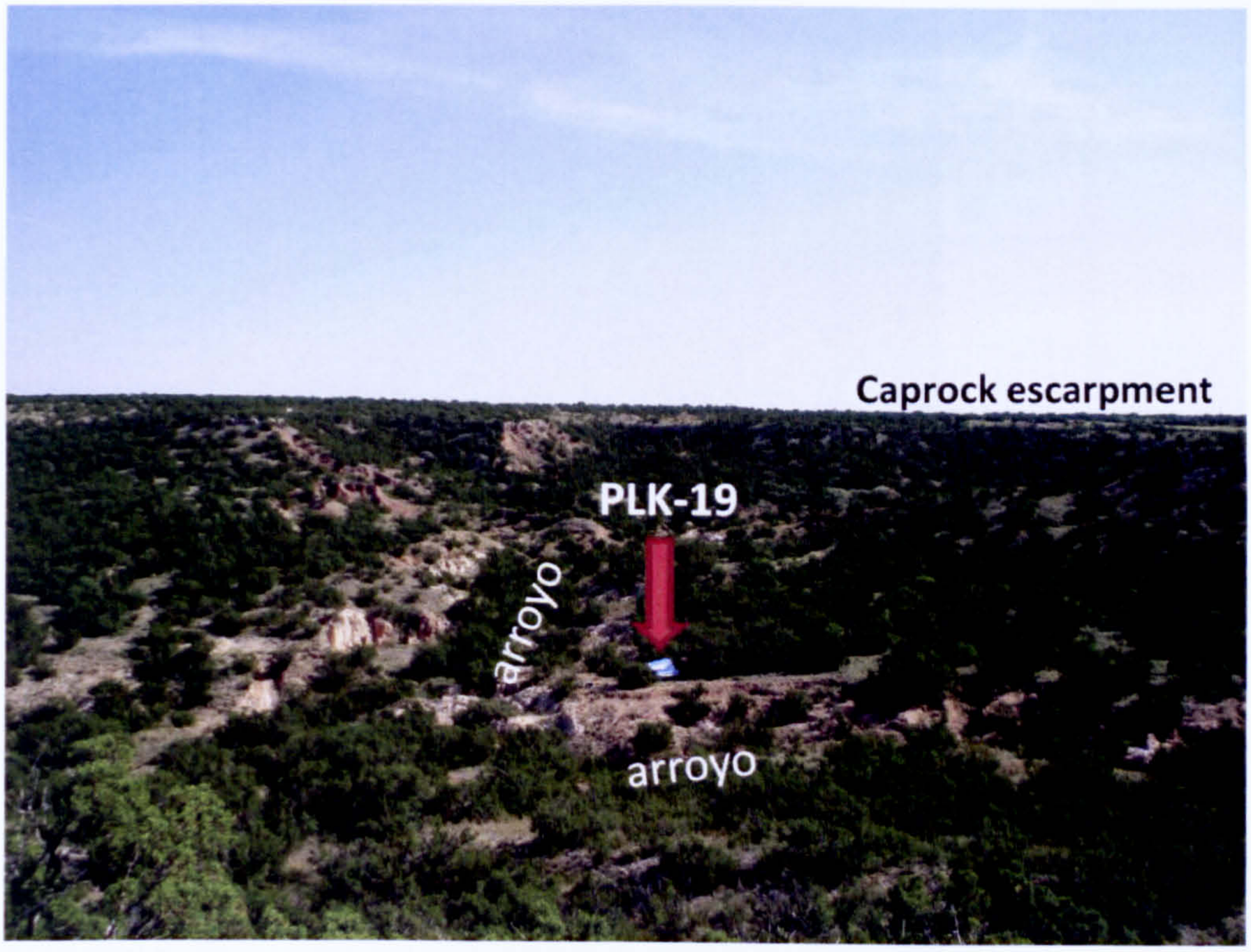
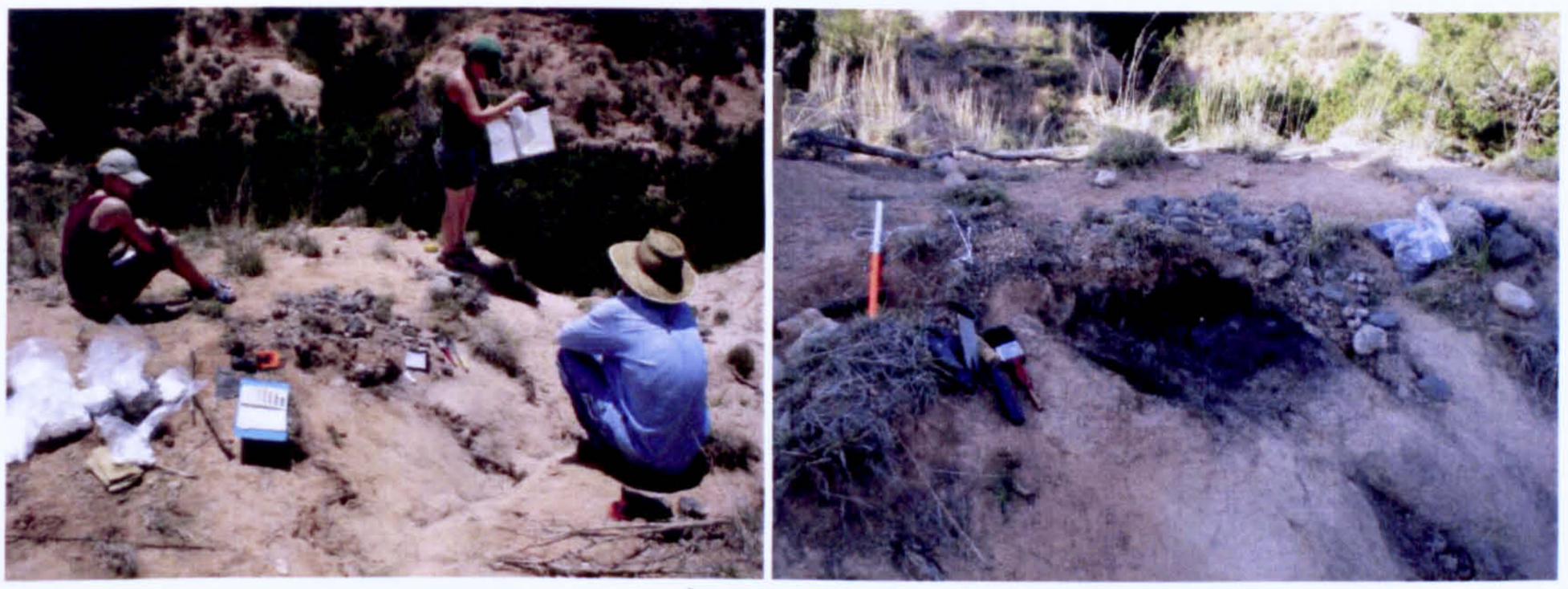


Figure 8.29. Location of PLK-Locality 19 amongst dense stands of Juniper found off the caprock along the eastern edge of the Llano Estacado.



a. **b.**

Figure 8.30. Excavation of a Late Archaic LTF (fire basin with hot-rocks) at PLK-Locality 19: a) field crew recording and mapping the LTF; b) half-section profile revealing the blackened sediments and largely intact structure at the base of the feature.



Figure 8.31. Early Ceramic LTF (hearth with hot-rocks) identified along an eroded intermittent drainage channel at PLK-Locality 4.

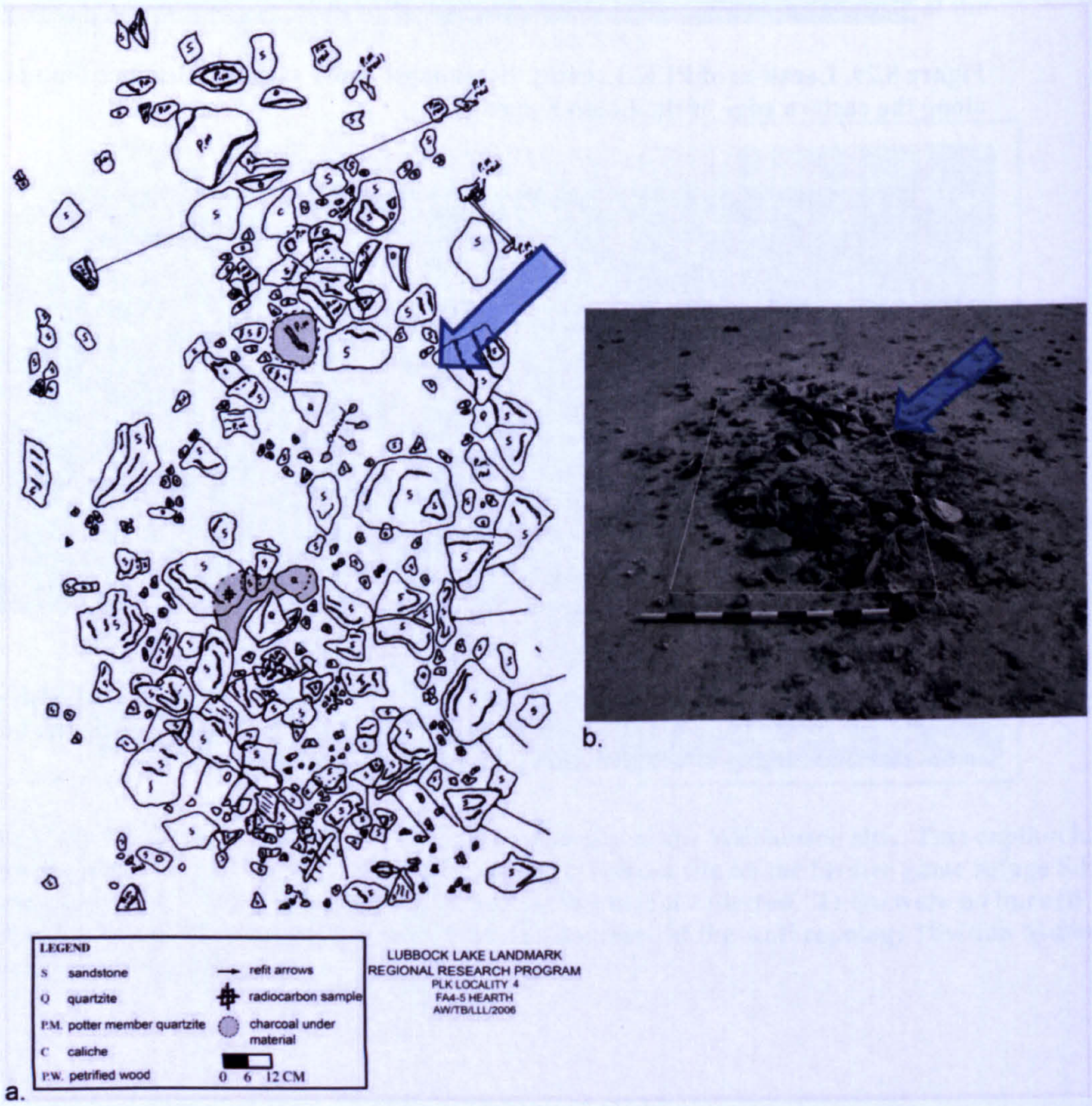


Figure 8.32. Close-up on an early Ceramic LTF (hearth with hot-rocks) deflated on to the modern ground surface at PLK-Locality 4: a) plan drawing; b) field photograph. Note: the blue arrows are positioned at the same location in each diagram and indicate the center of the feature, which contains no hearthstones or charcoal (after Backhouse and Johnson 2007b, fig. 9).

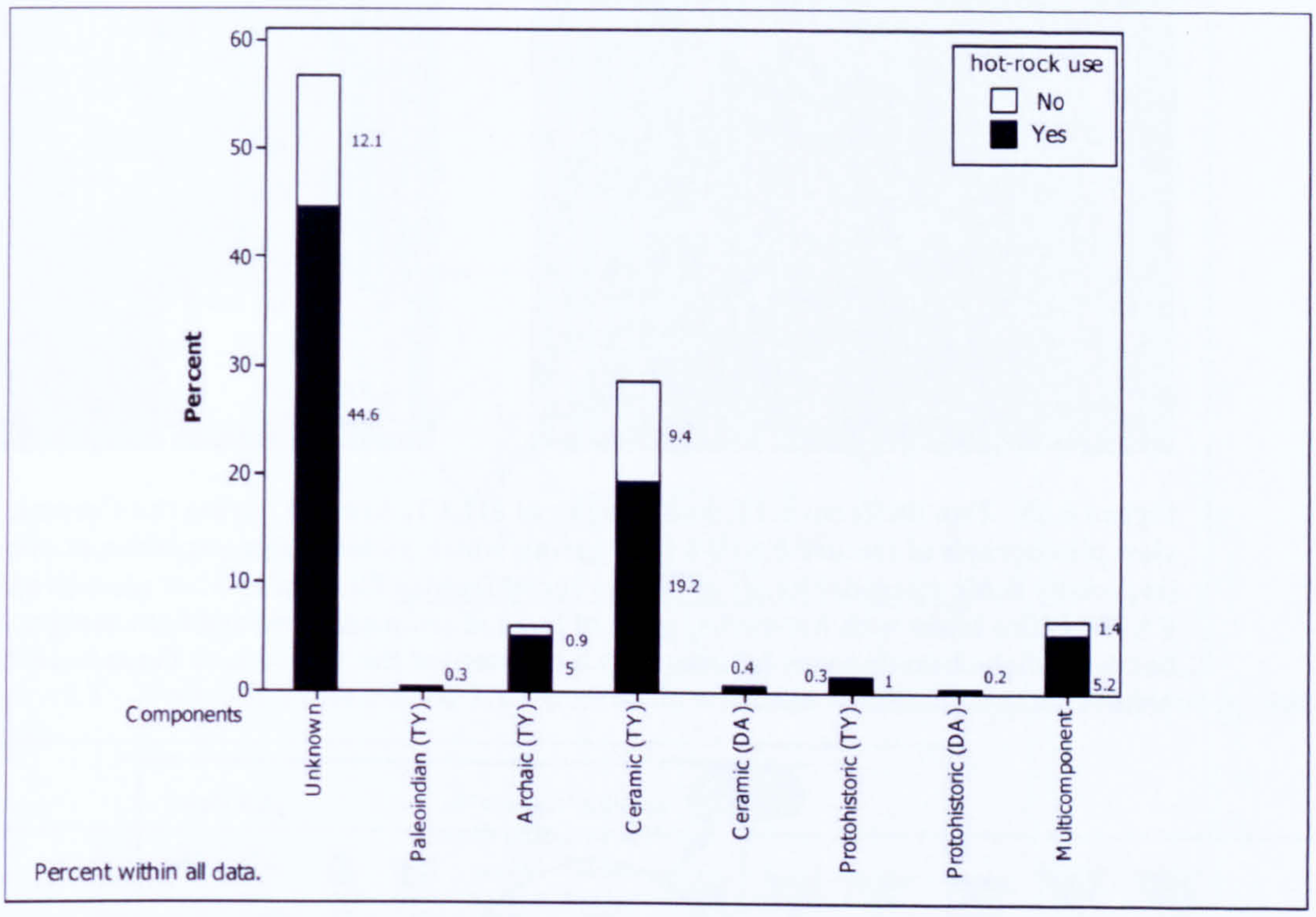


Figure 8.33. Frequency of sites exhibiting evidence for hot-rock technology by temporal component.

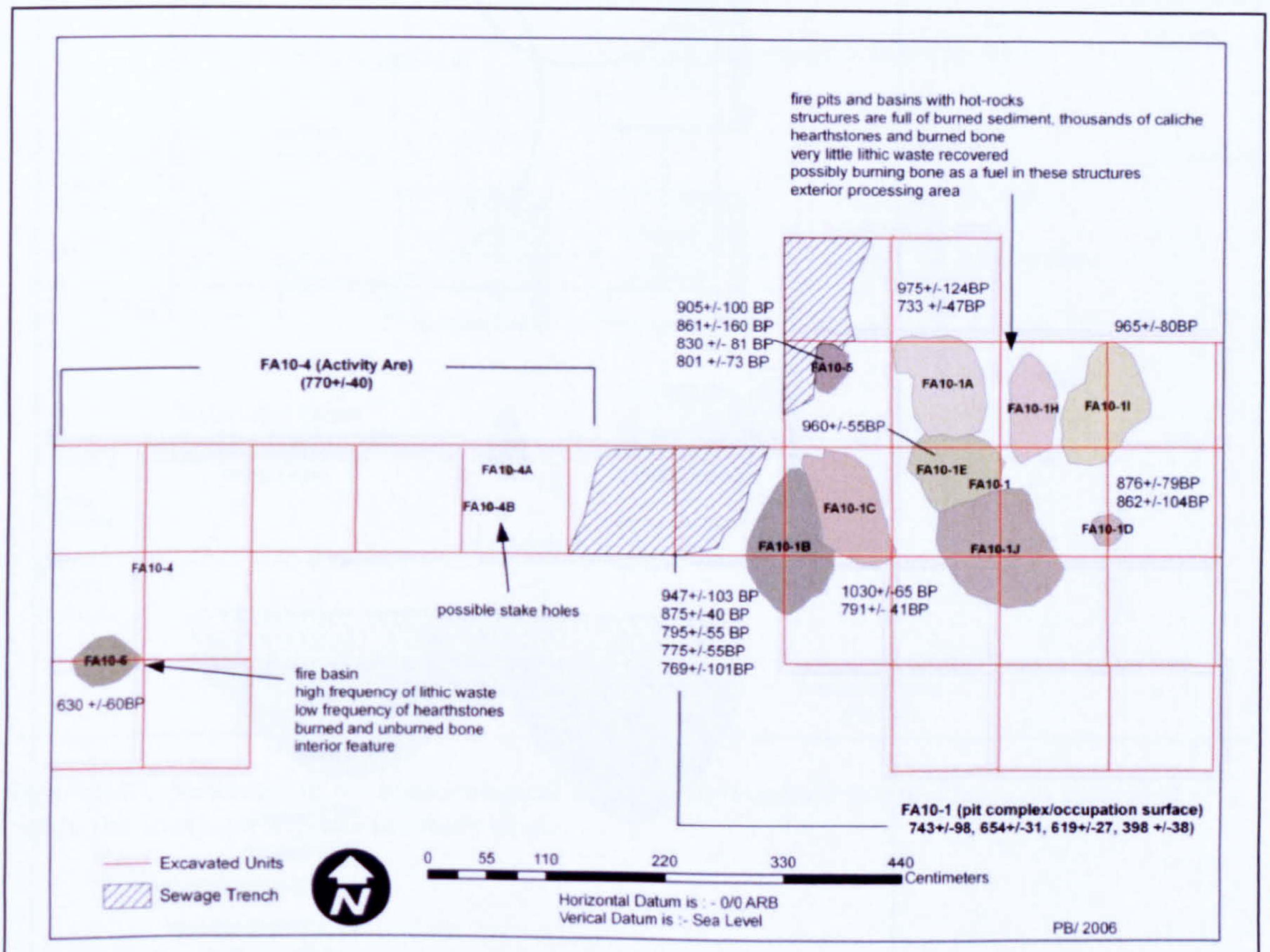


Figure 8.34. 41LU1, Area 10 plan drawing showing the relationship of the overlapping LTFS (fire basins with hot-rocks) to the east of the area and the more domestic focus to the west of the site; note radiocarbon assays are listed for individual features from oldest to youngest (data Backhouse 2002:table 10.5; Buchanan 2002:table 7.1).

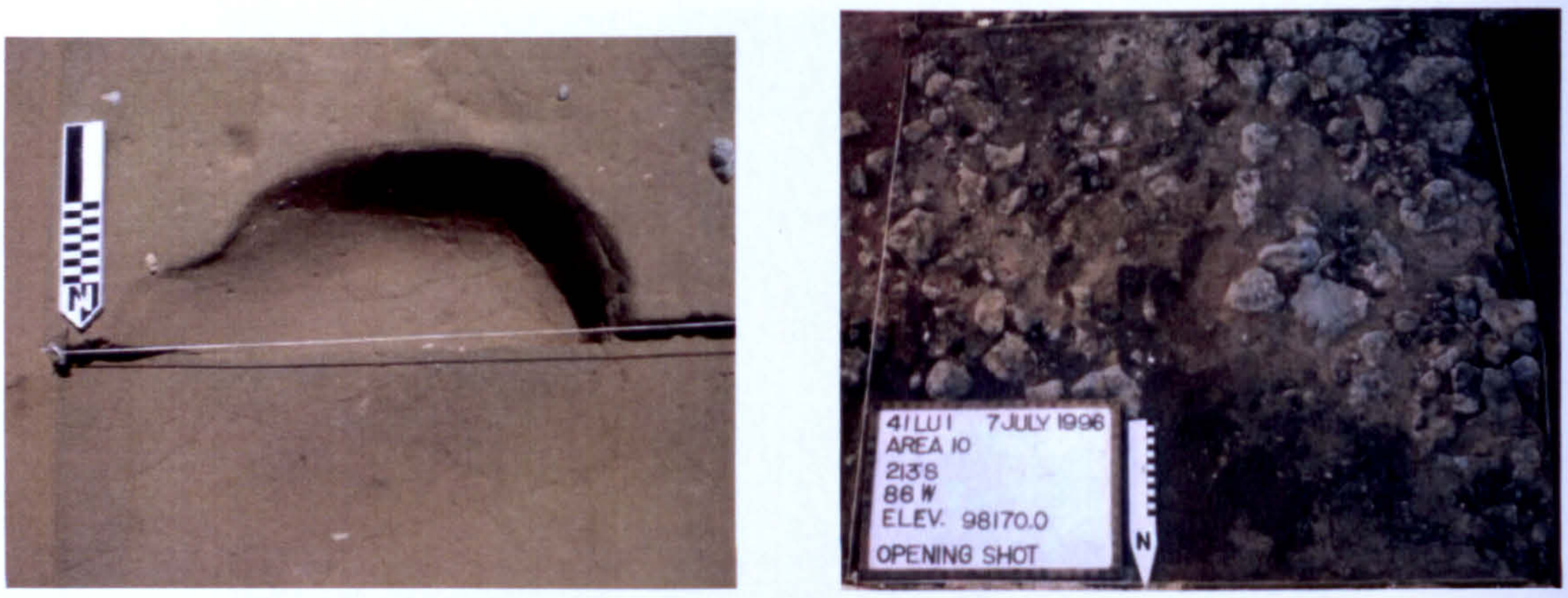


Figure 8.35. Two different LTF technologies at 41LU1, Area 10 during the Ceramic Period: a) plan view photograph of feature FA10-6 (fire basin), which yielded high quantities of domestic waste (especially lithic microdebitage) in the darkened feature fill; b) plan view photograph of feature FA10-1I (fire basin with hot-rocks) mass of burned sediments, burned bone scraps, charcoal, and burned caliche hearthstones (photograph b courtesy of the Museum of Texas Tech University, Anthropology Division).

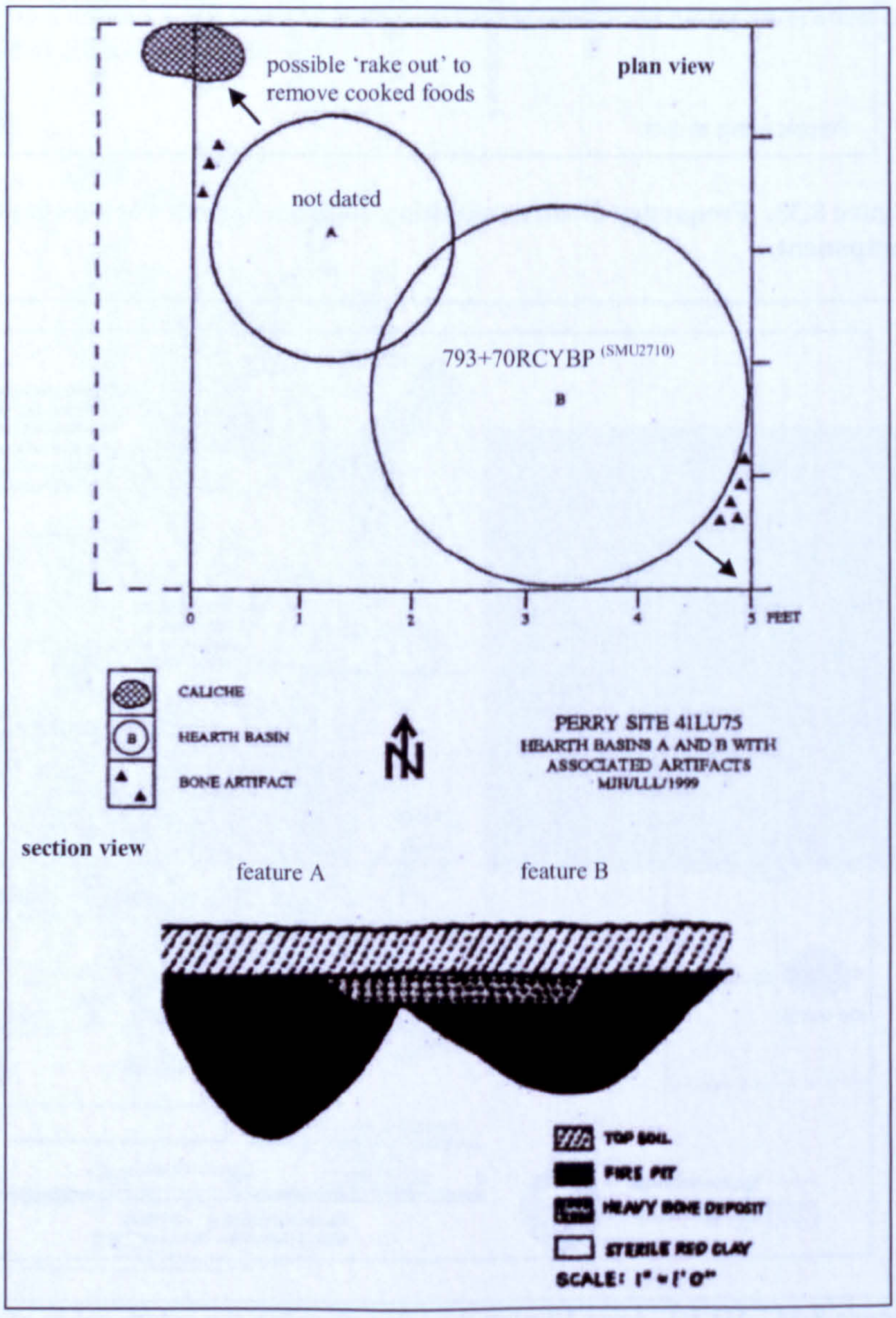


Figure 8.36. Intersecting LTF (fire pit with hot-rocks (Feature A) and a fire basin with hot-rocks (Feature B)) excavated at 41LU75 and dated to the late Ceramic period (modified from Brown, 1999, Fig. 1.27).

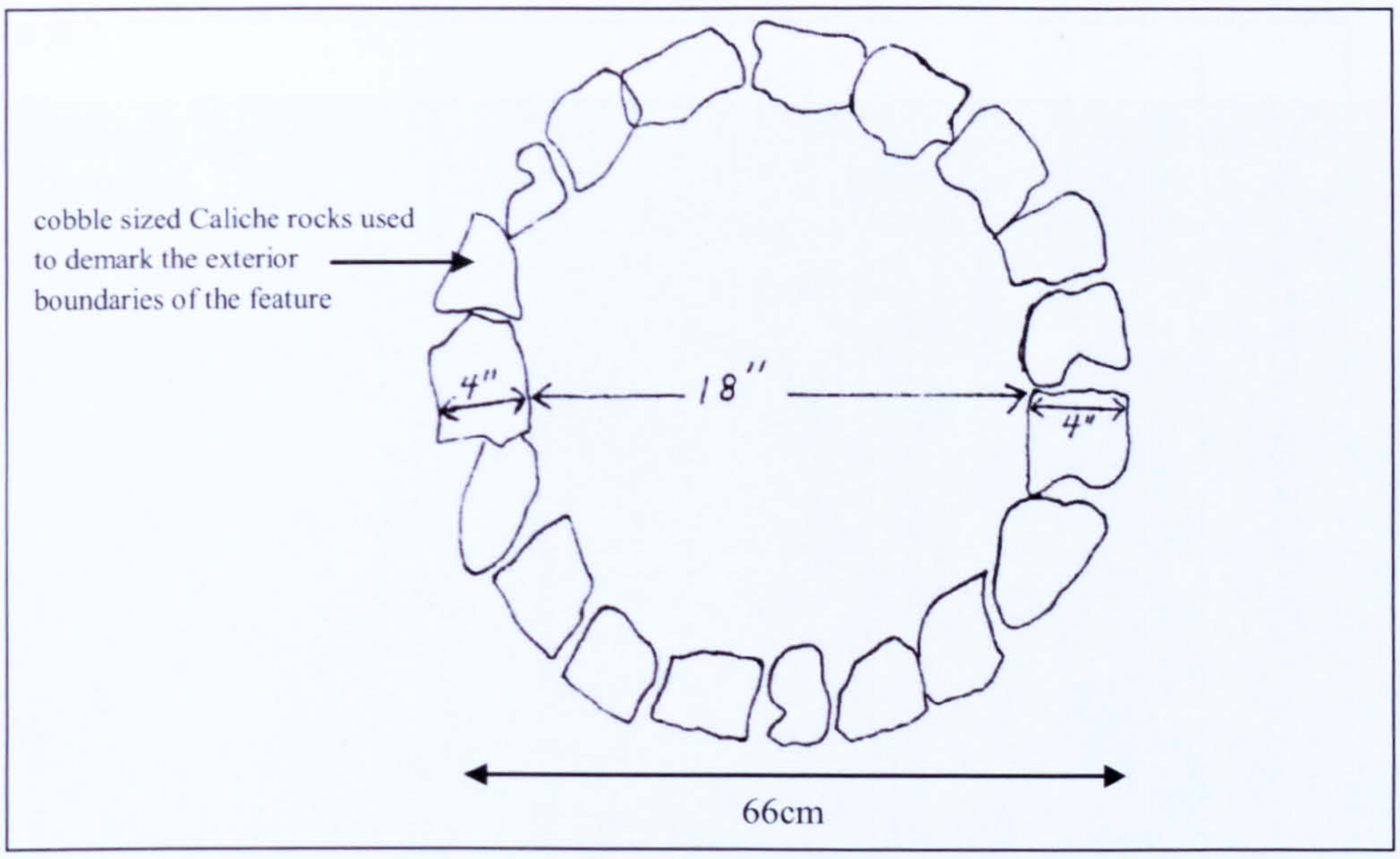


Figure 8.37. Probable Protohistoric LTF (fire basin with hot-rocks) at SPAS-LU-6 (Brown, 1986, Fig. 4).

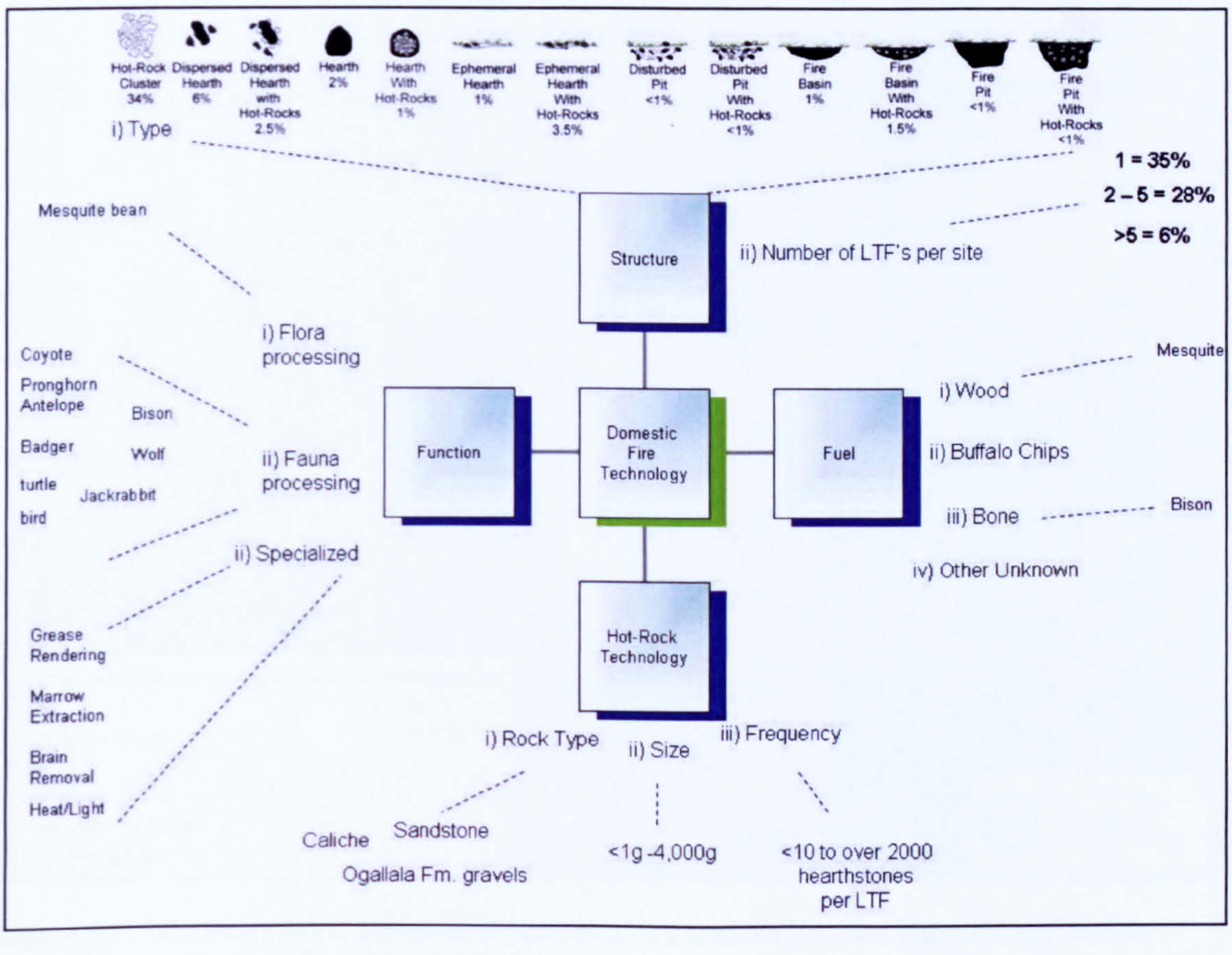


Figure 8.38. Summary of the archaeological evidence for localised thermal features identified within the Southern High Plains study area.

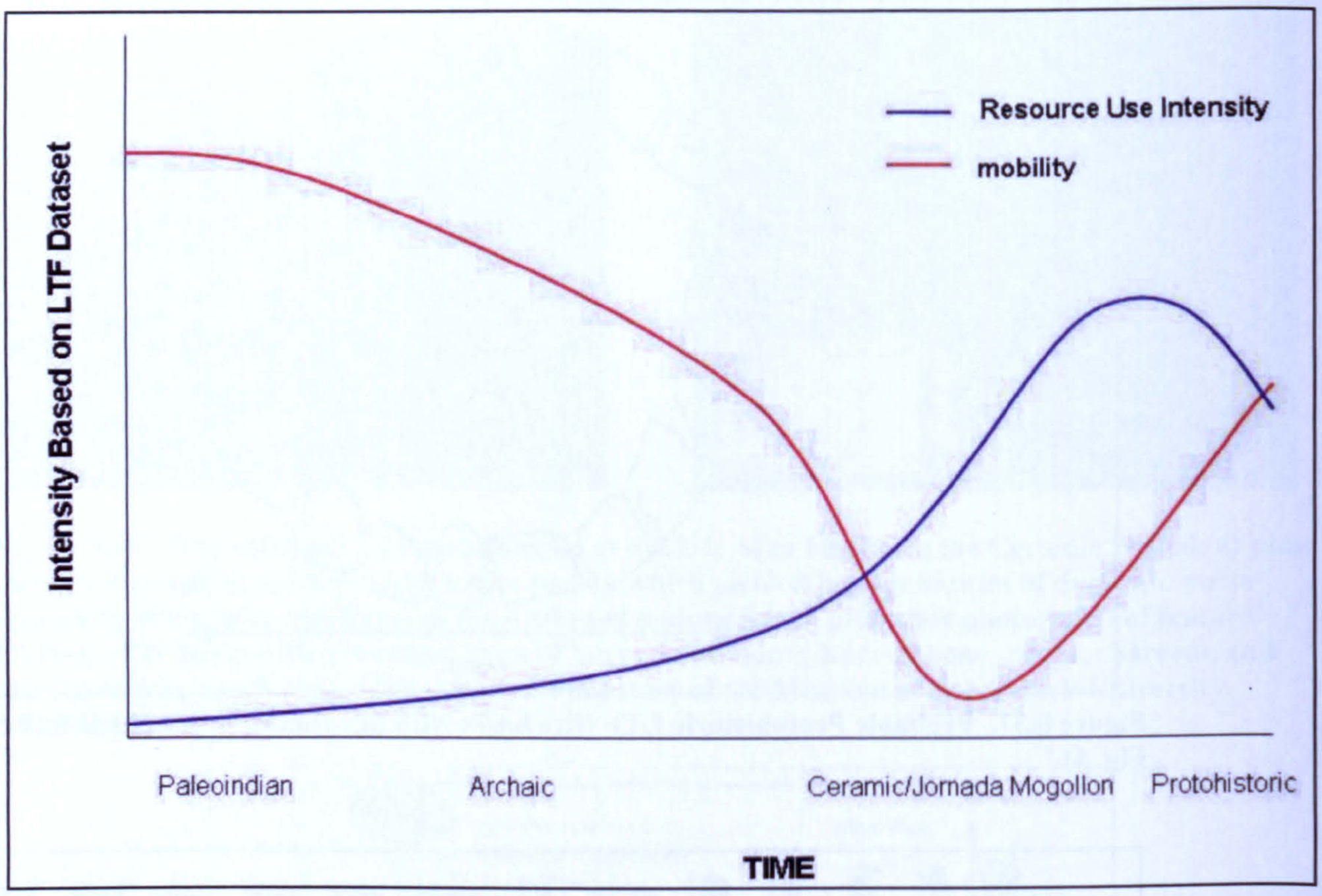


Figure 8.39. General population model based on the localised thermal feature dataset for the Southern High Plains study area.

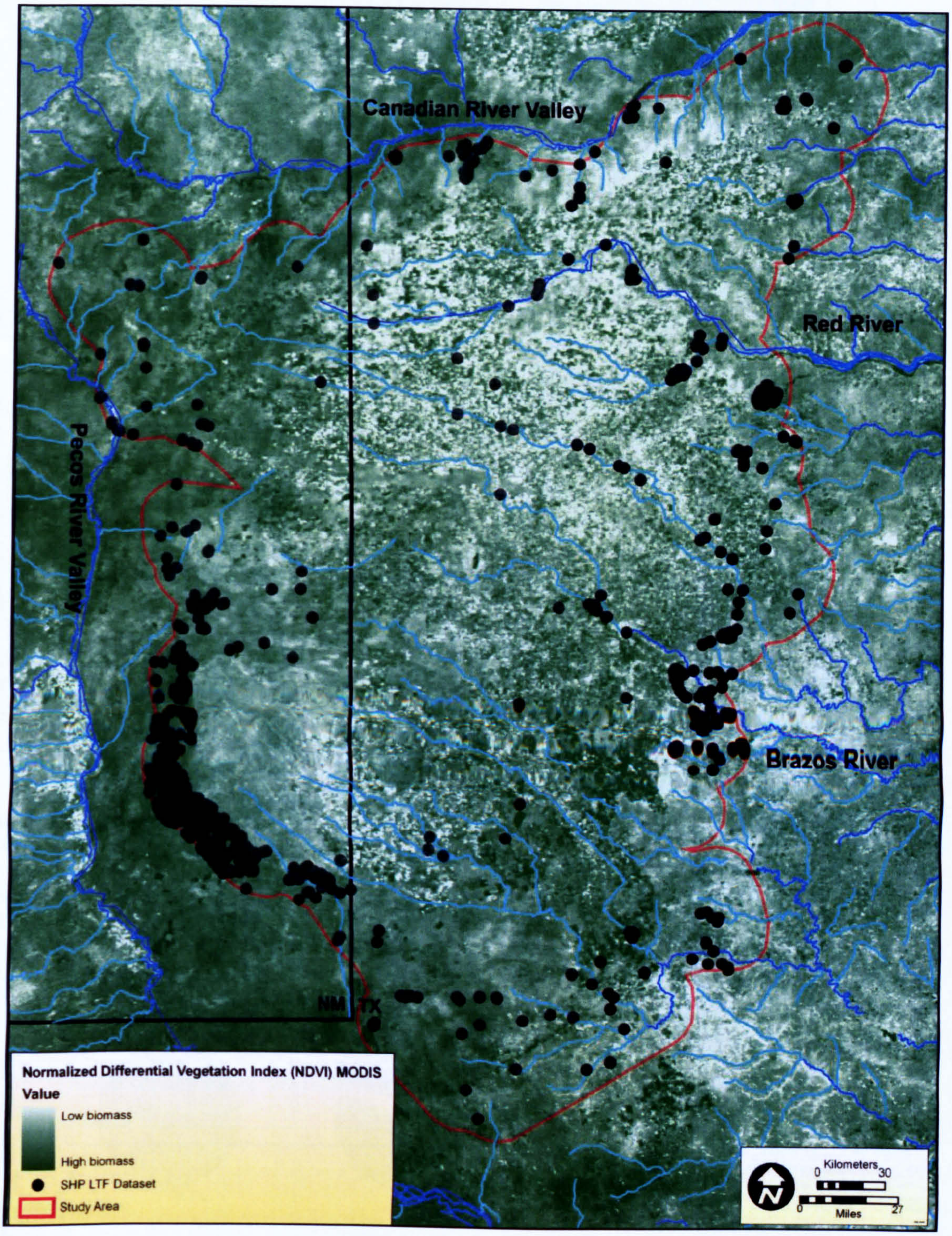


Figure 9.1. Hunter-gatherer campsite distribution and modern biomass index for the Southern High Plains Study area; Note that the darker shaded areas indicate areas of higher biomass(data: Normalized Differential Vegetation Index (NDVI) acquired from NASA's Moderate-resolution Imaging Spectroradiometer (MODIS), averaged data acquired between 1990 and 2005 and available from the USGS Seamless Data Server (www.seamless.usgs.gov)).

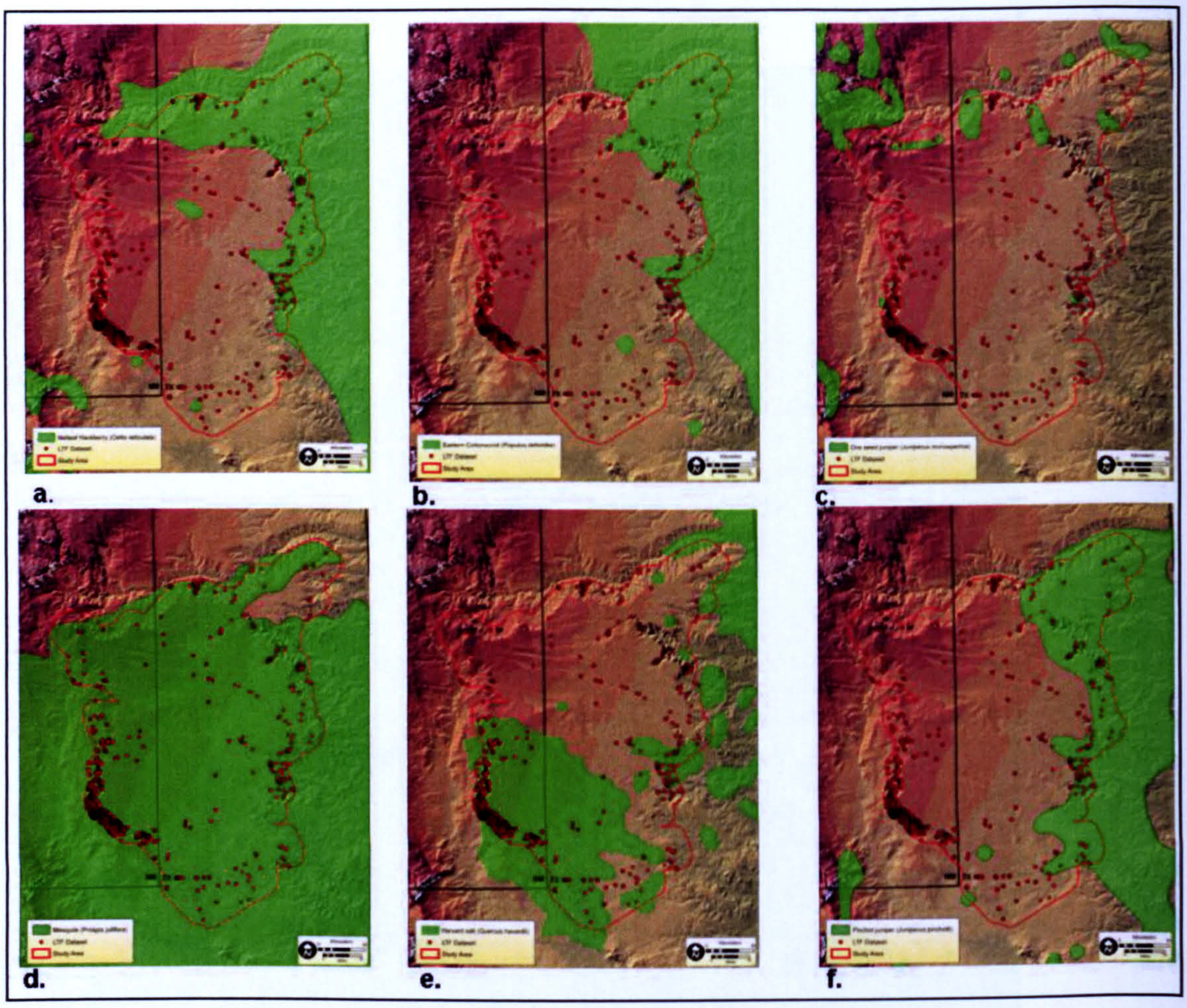


Figure 9.2. Hunter-gatherer campsite distribution and modern ranges of major tree species that may be suitable as fuel in domestic fire technologies: a) Netleaf Hackberry (*Celtis reticulata*); b) Eastern Cottonwood (*Populus deltoids*); c) One Seed Juniper (*Juniperus monosperma*); d) Mesquite (*Prospis prospubescens*); e) Harvard Oak (*Quercus havardii*); f) Pinchot Juniper (*Juniperus pinchotti*) (data: available from the United States Geologic Service and modified from Digital Representations of Tree Species Range Maps from "Atlas of United States Trees" by Elbert L. Little, Jr. (and other publications) and freely available from http://esp.cr.usgs.gov/data/atlas/little/).

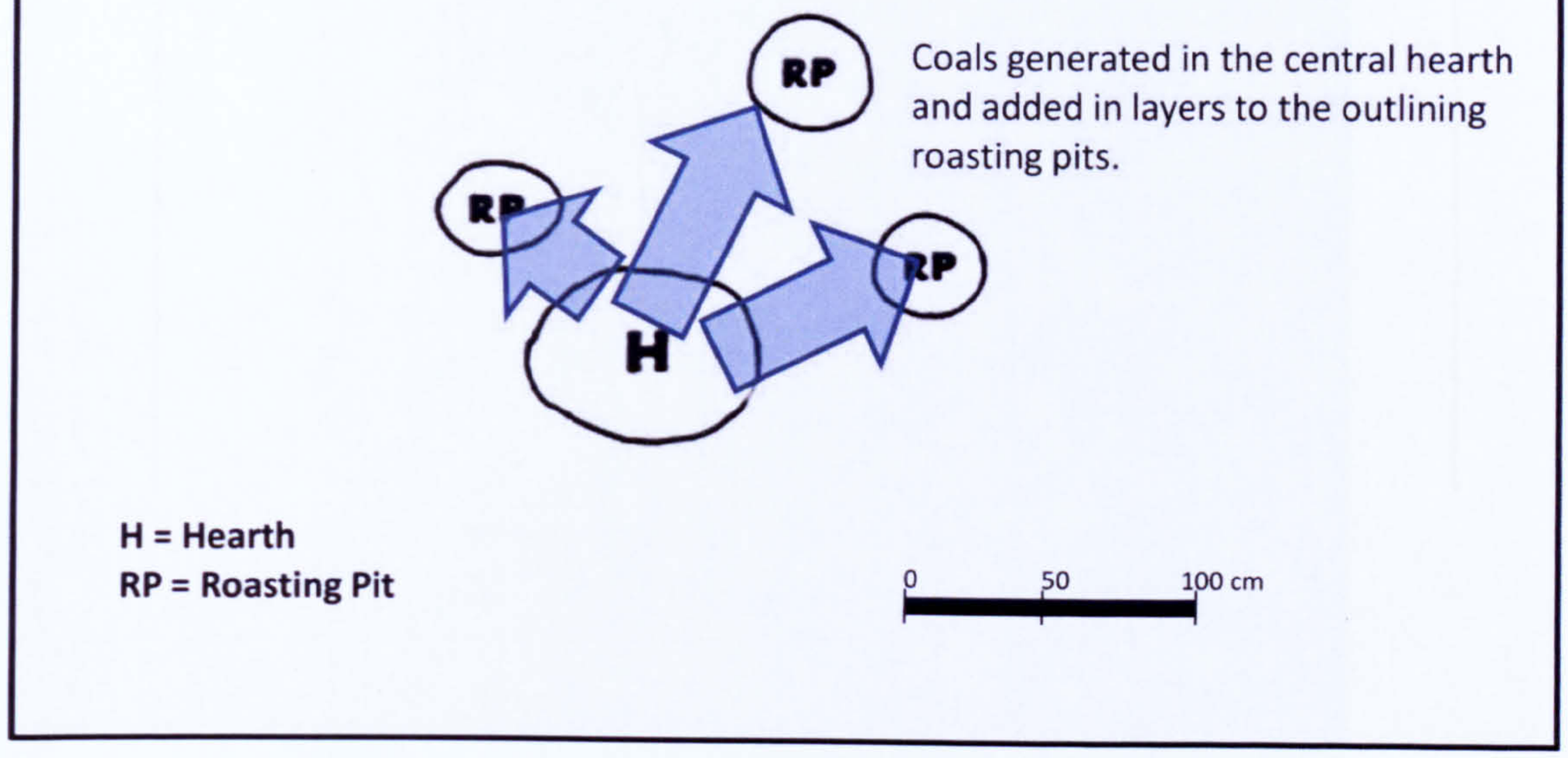


Figure 9.3. Interpretative model for Paleoindian LTF technology at the Barton Gulch Site, Montana (after Armstrong 1993, fig. 8).

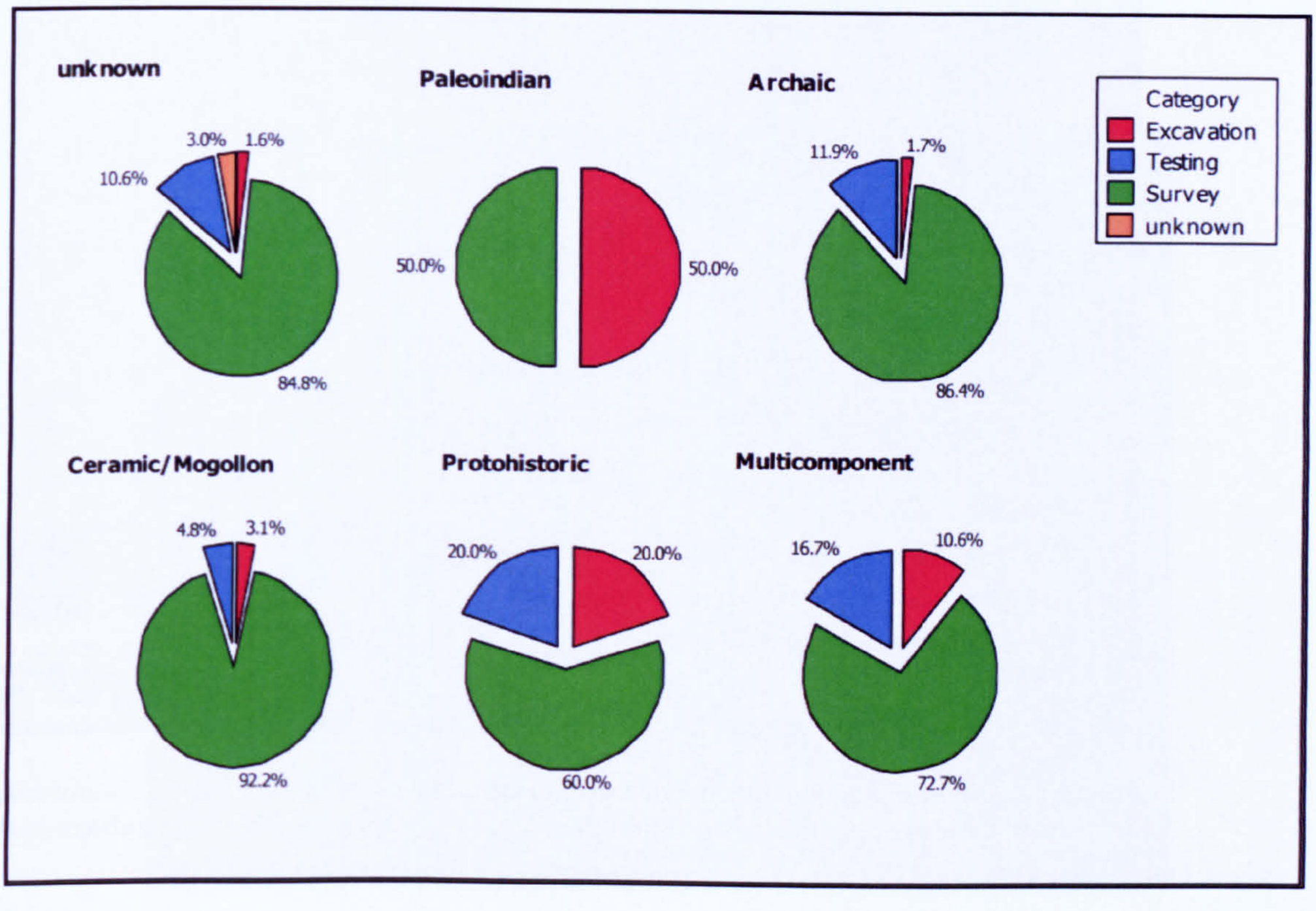


Figure 9.4. Modes of engaging the archaeological record on the Southern High Plains by major temporal period.

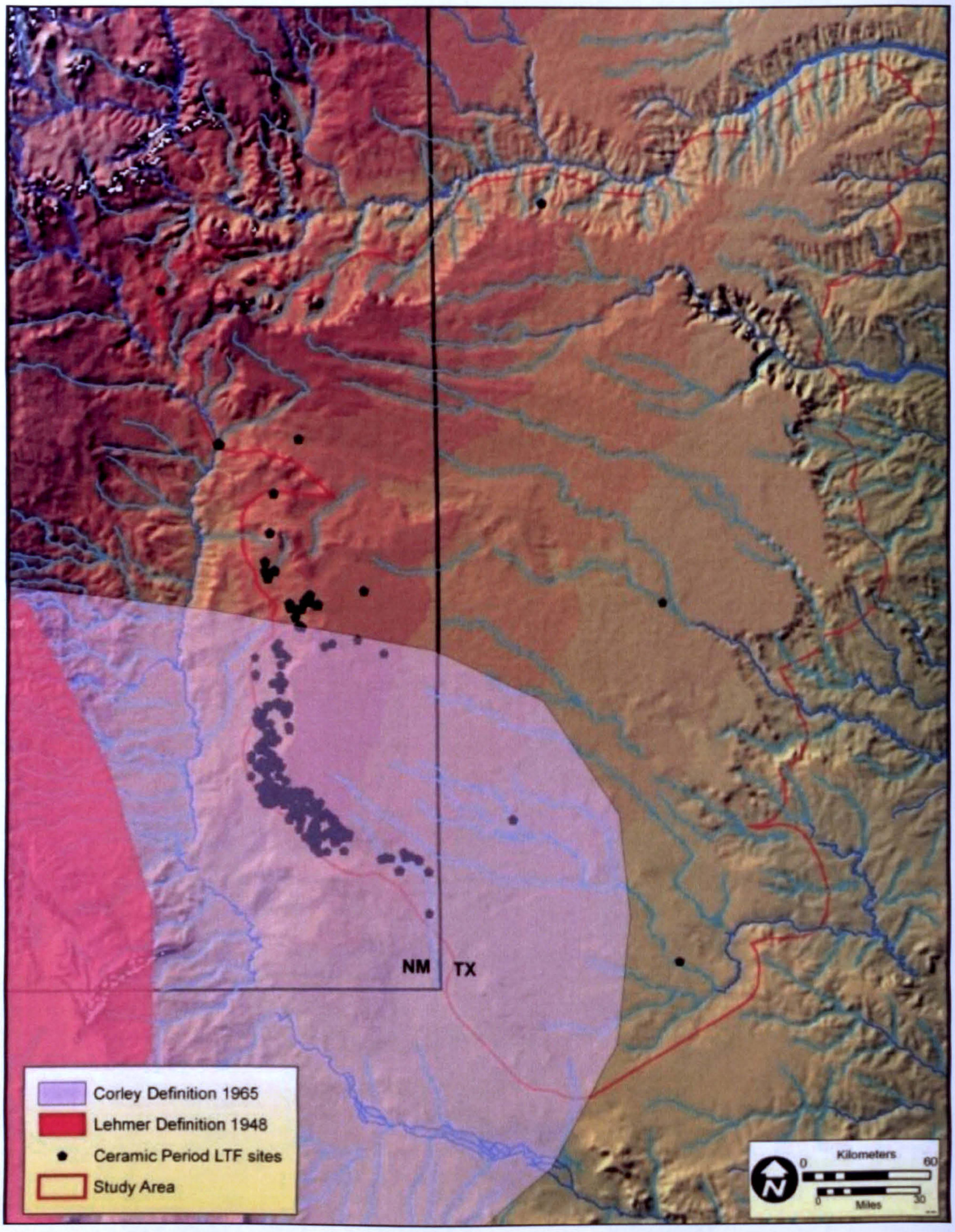
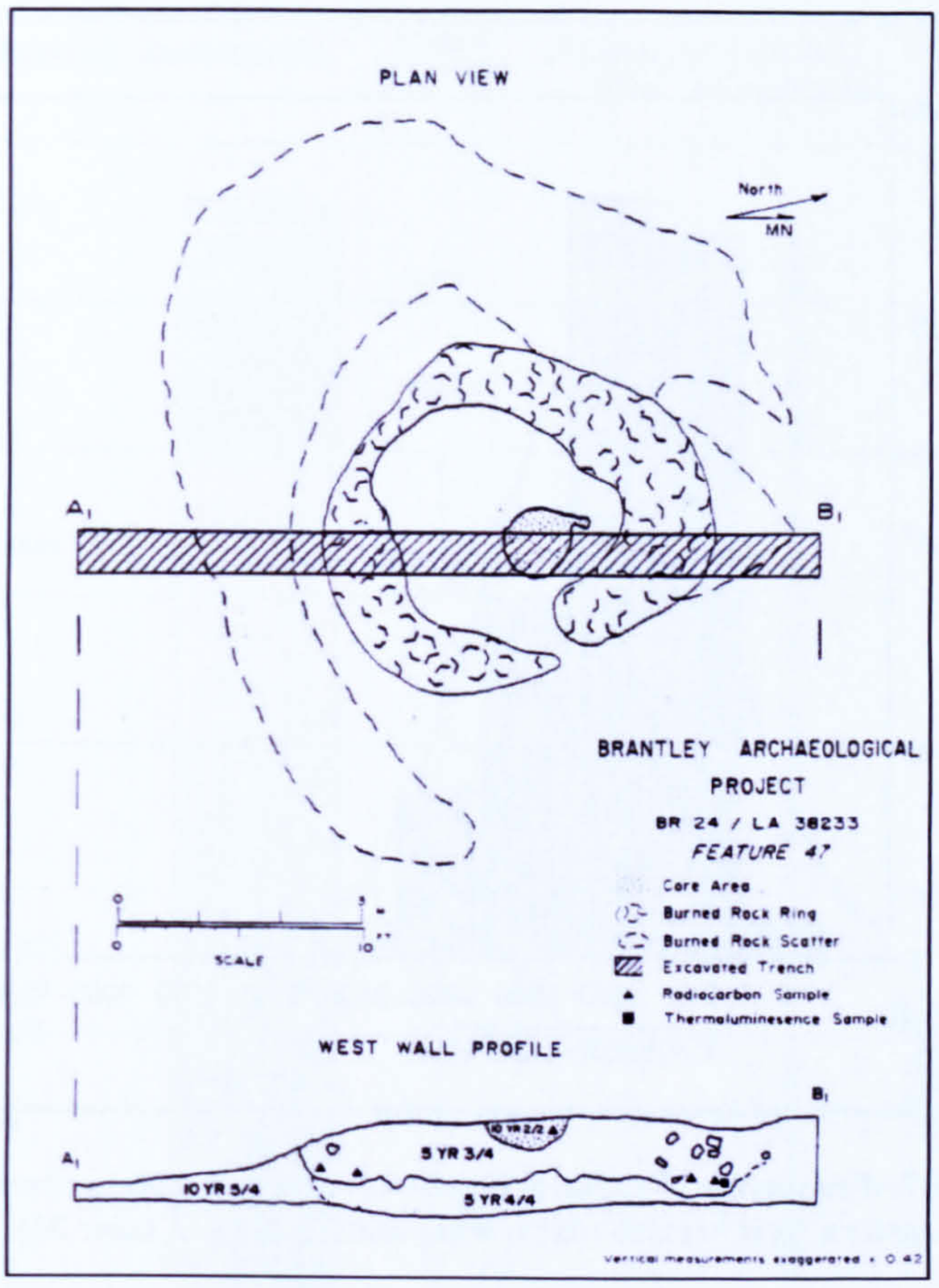


Figure 9.5. Spatial distribution of Ceramic period sites with evidence for LTFs and relationship to previously developed models for the spatial extent of the Jornada Mogollon culture (data Corley 1965).



a.



b.

Figure 9.6. Examples of 'Ring Midden' features: a) plan and section drawing of a feature recorded in the Brantley Reservoir, New Mexico; note the massive scale of the construction, which is more than 6 meters in diameter; b) photograph of a ring midden recorded along the western margin of the Pecos river. Note both features were located directly to the west of the present study area. (diagram a) Katz and Katz 1985:157 [courtesy P. Katz 2007]; and b) courtesy of the Bureau of Land Management, Carlsbad Office).

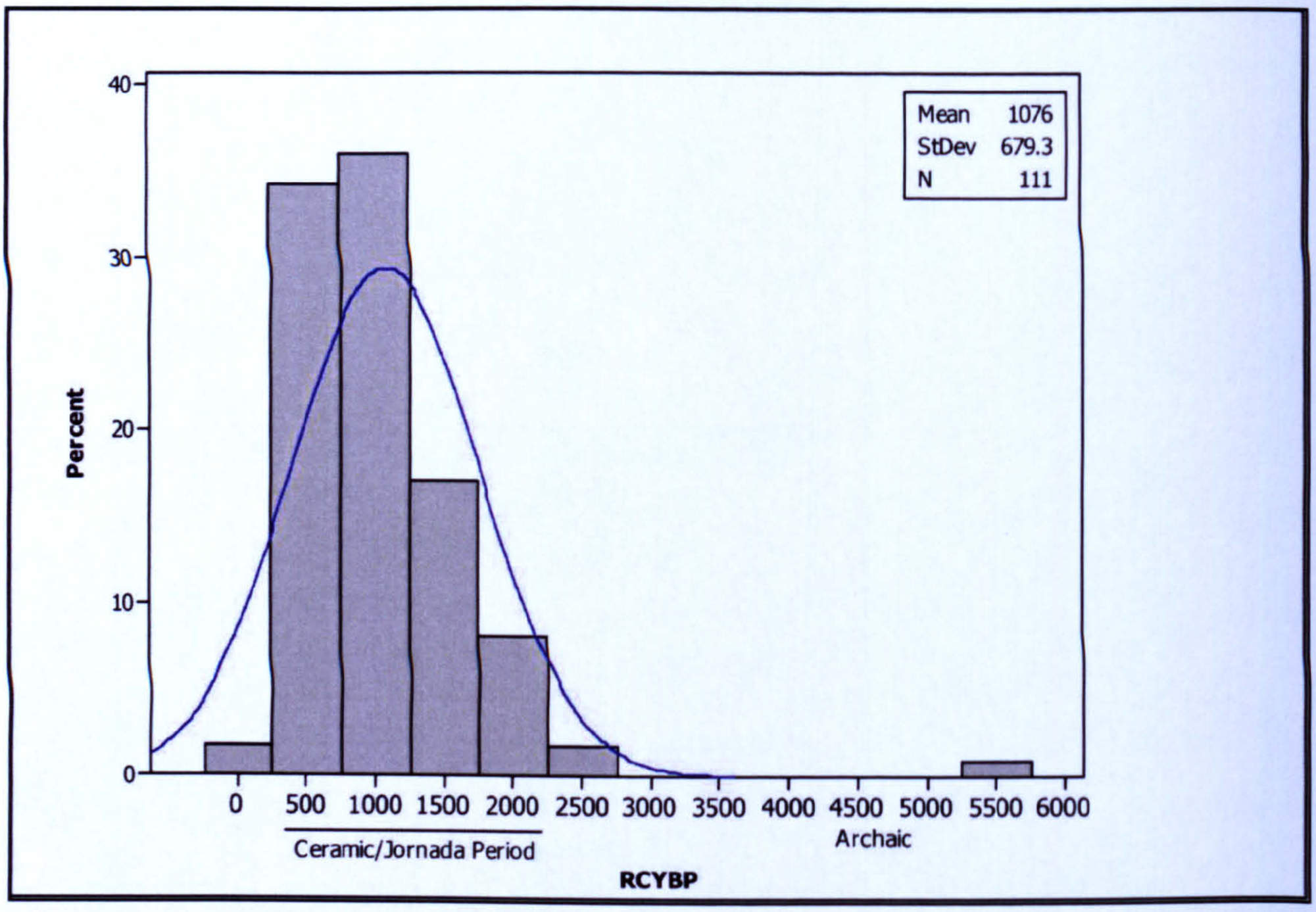


Figure 9.7. Frequency of radiocarbon determinations obtained on Ring Midden features identified in southeastern New Mexico (data: Katz and Katz 2000, table 35).

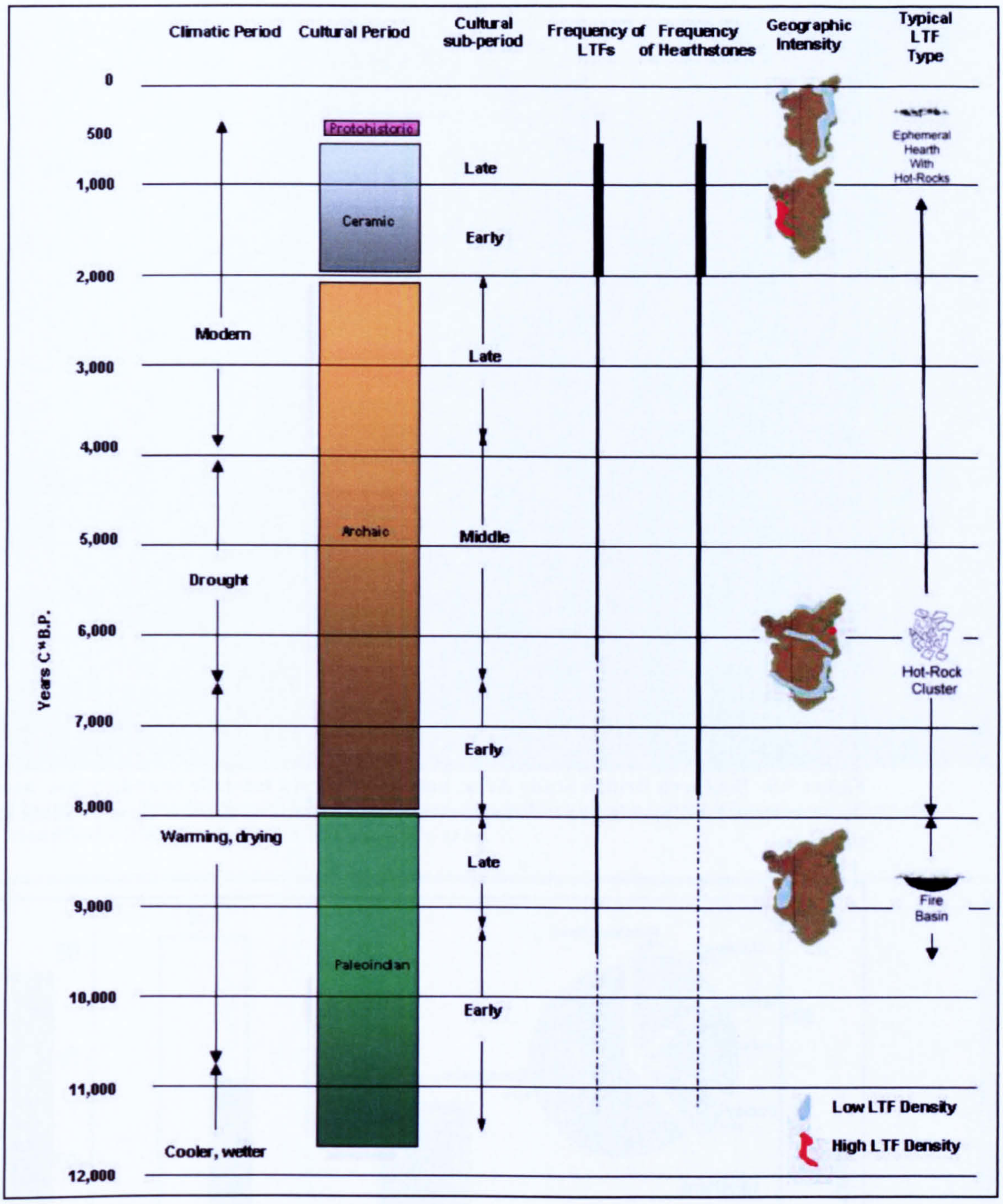


Figure 9.8. Summary of the regional record for hunter-gatherer fire technology on the Southern High Plains and surrounding area (climate and Cultural Periods after Johnson and Holliday 1995, 2004).

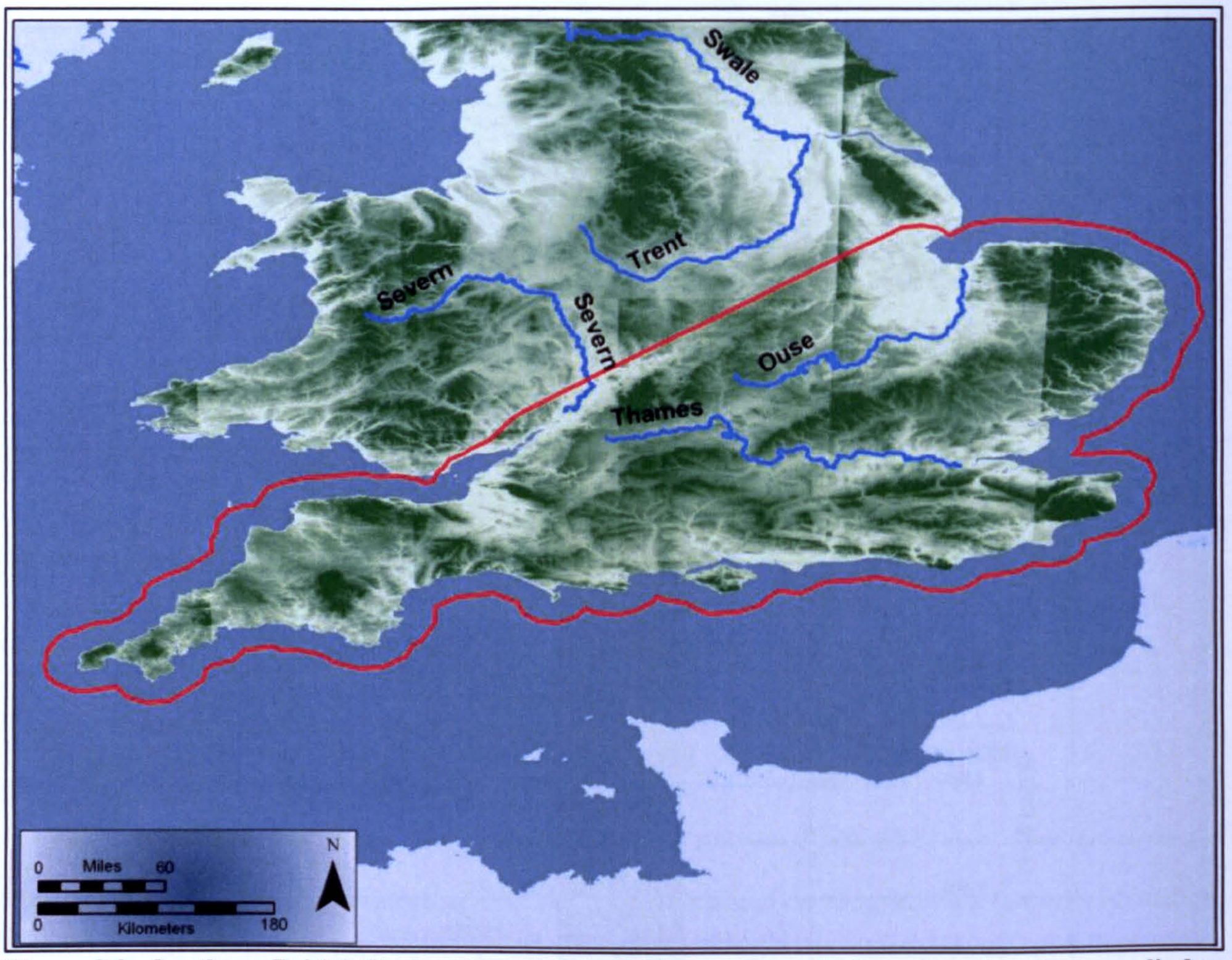


Figure 9.9. Southern British Study Area; note an arbitrary ten-mile boundary has been applied to the terrestrial landform in order to capture any sites located in shallow close-to-shore submerged contexts.

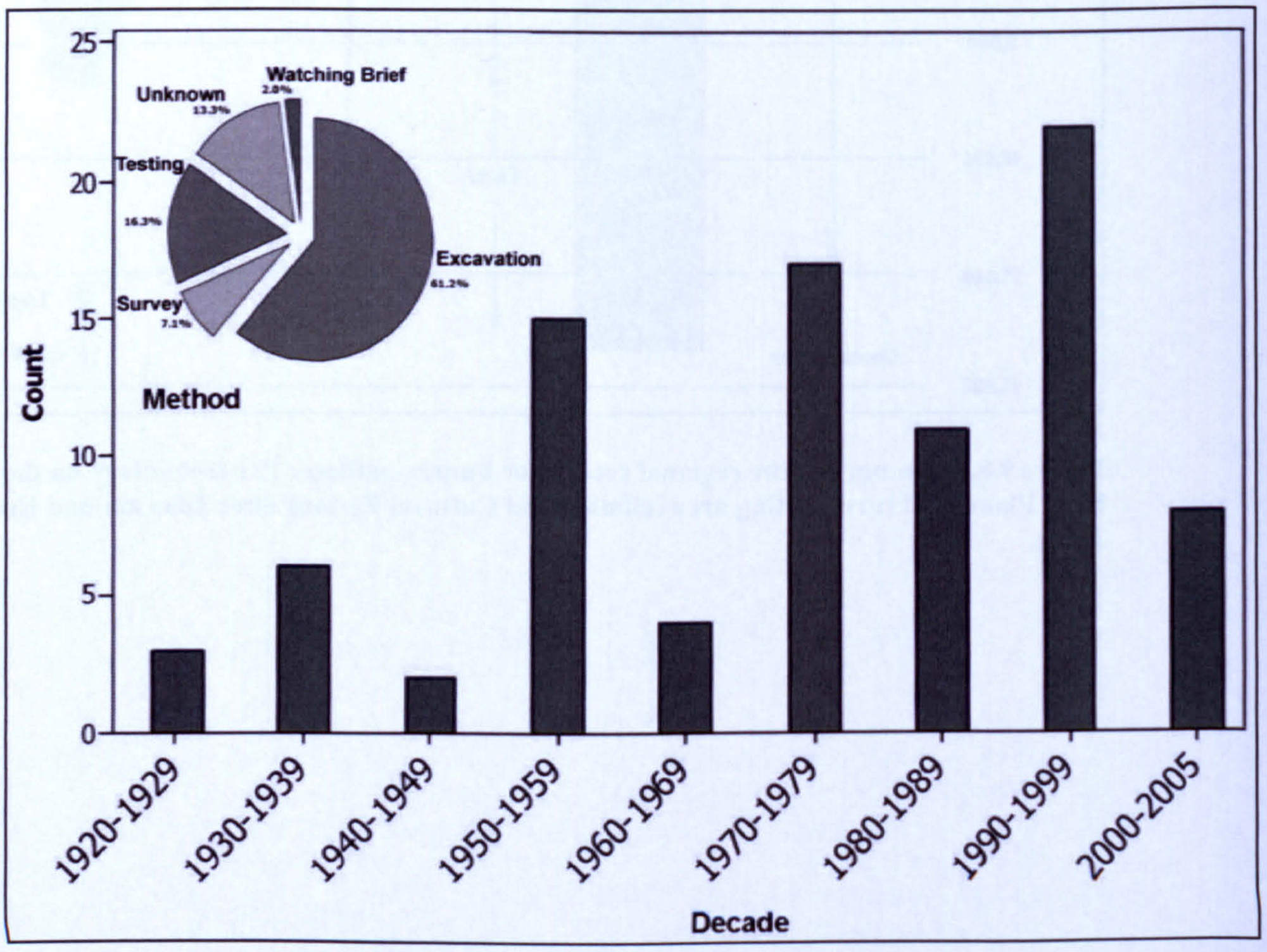


Figure 9.10. Historical frequency of hunter-gatherer research within the southern British study area; note pie chart insert illustrates the mode of investigation.

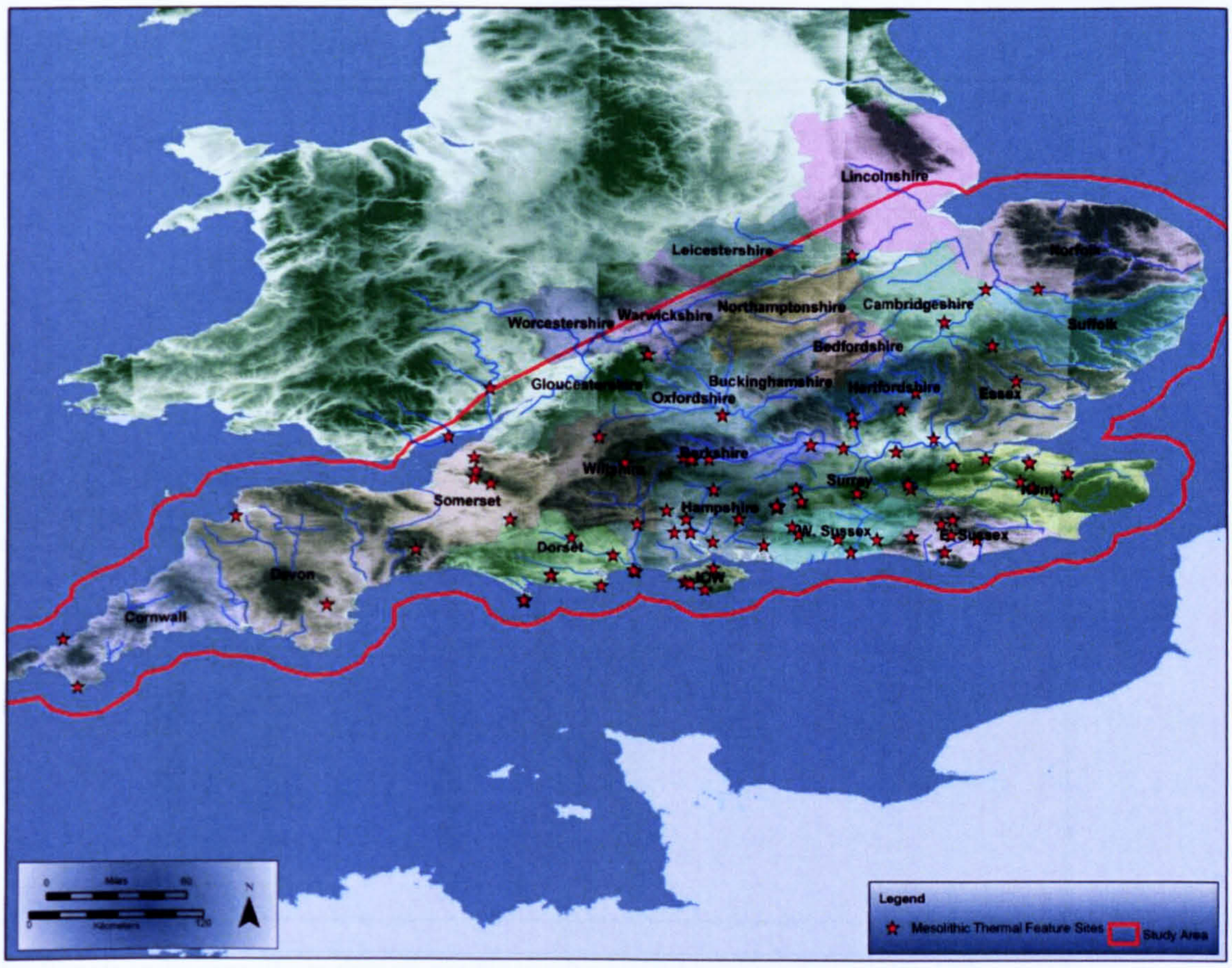


Figure 9.11. Distribution of hunter-gatherer sites with evidence for localised thermal features identified within the southern British study area.

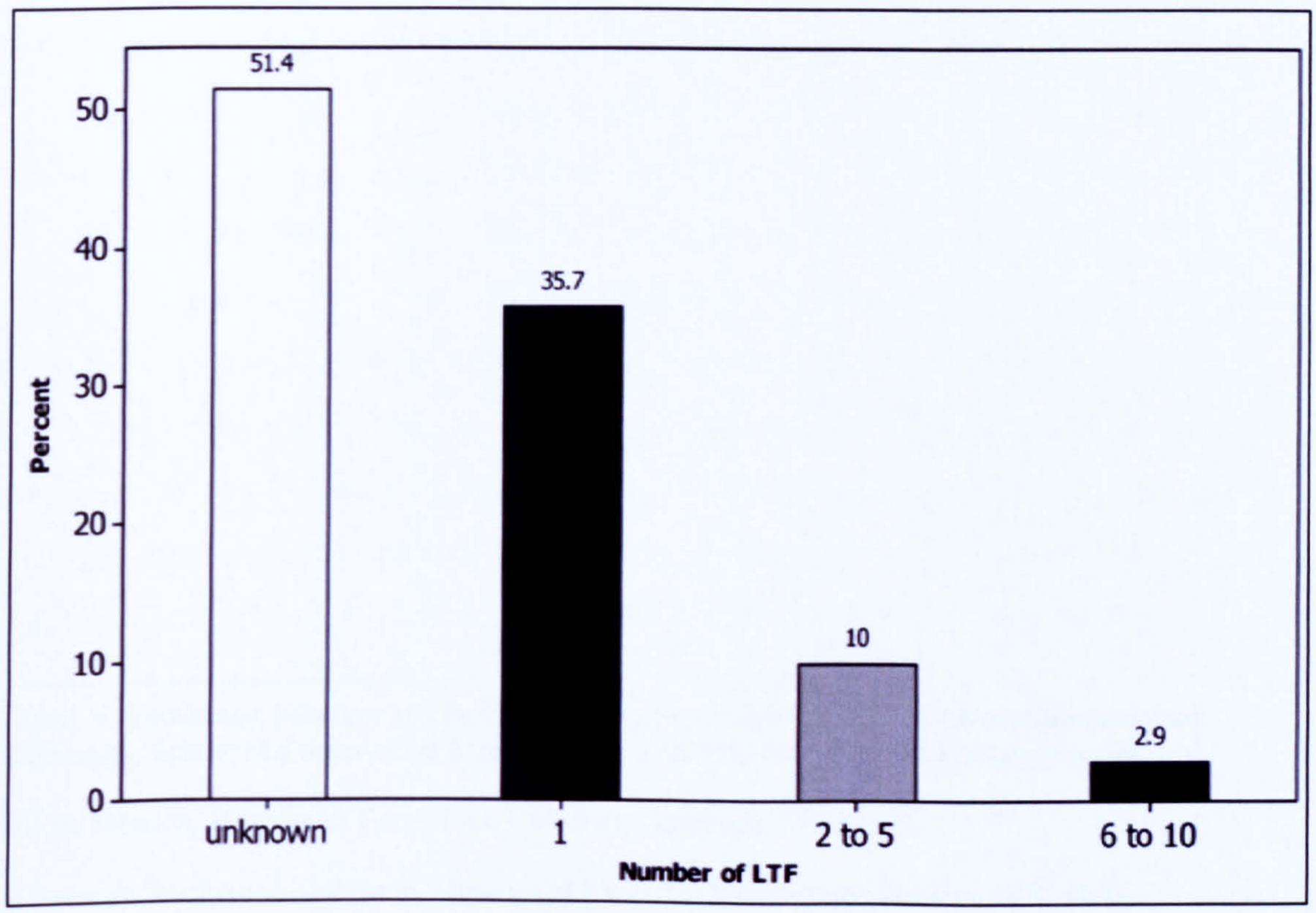


Figure 9.12. Number of LTFs identified at sites within the southern British study area.

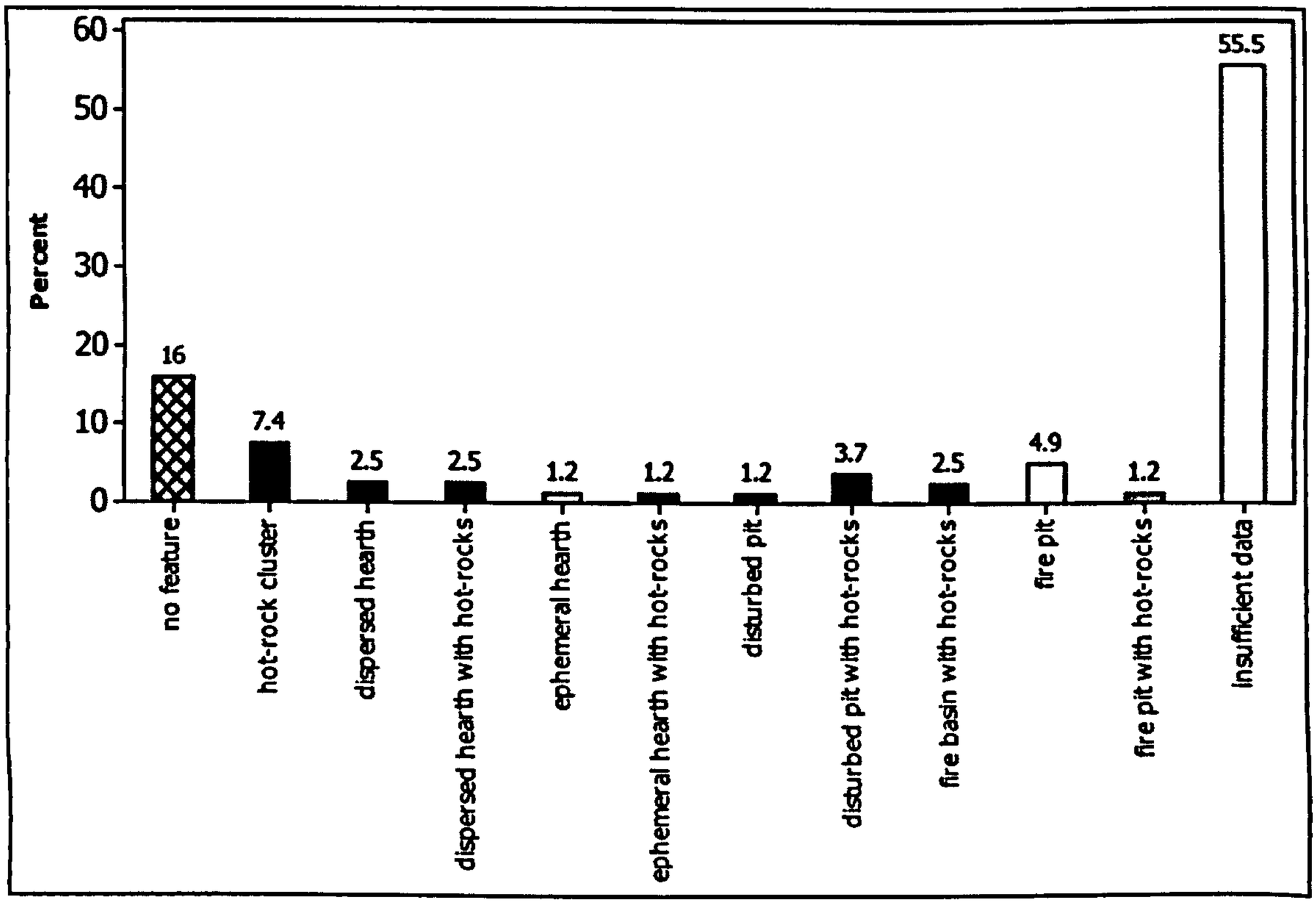


Figure 9.13. Range of types of LTF in the southern British study area after classification.

Appendix 1 – Hot Rock Technology 1

Experimental Hearths and the Thermal Alteration of Caliche on the Southern High Plains

Paul N. Backhouse, Eileen Johnson, Alexander Brackenreed-Johnston, and Briggs Buchanan *

Manuscript originally published in the Journal Geoarchaeology 2005, 20(7):795-716

* Paul N. Backhouse, Museum of Texas Tech University, Lubbock, TX, 79409 and Bournemouth University, School of Conservation Sciences, Bournemouth, UK, Paul.Backhouse@ttu.edu.

Eileen Johnson, Museum of Texas Tech University, Lubbock, TX, 79409.

Alexander Brackenreed-Johnston, Museum of Texas Tech University, Lubbock, TX. 79409.

Briggs Buchanan, Department of Anthropology, University of New Mexico, Albuquerque, NM, 87131-1086

ABSTRACT

Throughout the Holocene, caliche has been a ubiquitous technological resource for the people of the Southern High Plains. Archaeological sites on the Southern High Plains often contain thermal features that appear to utilize caliche nodules in various cultural processes. These processes usually involve some degree of thermal dynamic alteration to the caliche. This alteration is identified in the archaeological record as fire scorched or blackened nodules. Previous studies of the pyrodynamic properties of caliche have focused on quantification of color and fracture patterns within a laboratory setting without direct involvement with cultural process or problems associated with thermal features. Caliche thermal alteration variables are examined from an actualistic perspective utilizing previously excavated basin feature geometry and local caliche outcrops. Results indicate that the sustained intense heating of caliche (above 204°C) causes significant but variable structural transformations at the specimen level. The experimental use of shallow basin hearths demonstrate that the hearth structures were easily capable of achieving and sustaining temperatures that would result in the physical alteration of individual caliche nodules, defined here as hearthstones. The broader implication of this study suggest that the interpretation of archaeological hearthstone assemblages should reflect variability as observed during this experiment.

Keywords: caliche, hot-rocks, experimental hearth, Southern High Plains, thermal alteration.

INTRODUCTION

An experiment using shallow basins and the burning of locally obtained caliche nodules was designed to generate a greater understanding of the ubiquitous thermal basin features recorded in the archaeological record on the Southern High Plains. Previous experimental data have demonstrated that burned caliche nodules are hearthstones produced through activities related to cultural actions rather than the product of natural processes (Lintz, 1989; Ladkin, 1993). Based on these results, hypotheses concerning caliche nodule-lined basins are straight forward but untested with actualistic experimental data. They are: 1) high temperatures will discolor (carbonize) caliche as a function of time; 2) high temperatures will fracture caliche as a function of time; and 3) caliche will retain sufficient heat for cooking activities after the primary fuel (wood) has been expended. Observations and quantifiable results gleaned from the hearth basin experiments address these three hypotheses.

The analysis of thermal pit and basin features has received much attention (Frison, 1983; Groenendijk, 1987; Barfield, 1991; Collins and Ricklis, 1994; Black et al., 1997; Wandsnider, 1997; Lowell, 1999; Petraglia, 2002). The analysis of specific components of hearthstone or cookstone technology (Thoms, 1986, 2003) allows a broader understanding of prehistoric cooking strategies (e.g., Atkins, 1988; Jackson, 1998; Gose, 2000; Quigg et al., 2001; Brink and Dawe, 2003; Thoms, 2003). Although

the use of caliche hearthstone technology has been examined in several ecological settings (e.g., Tennis et. al., 1997), the analysis of caliche technology from the Southern High Plains is limited (Lintz, 1989; Ladkin, 1993). The use of caliche hearthstones constitutes a major component of Southern High Plains aboriginal prehistoric thermal technologies (Johnson and Holliday, 1986; Johnson, 1987; Lintz, 1989). This study is a first approximation at expanding the inferential potential of burned caliche through the implementation of experimental hearths.

The results of the actualistic experiment indicate that the empirical analysis of hearthstones can yield useful baseline data with which to assess the archaeological record. Evidence of burning on individual hearthstone specimens is the result of the interaction of a complex set of variables. Cultural processes that result in the discard of spent hearthstones, therefore, cannot be elucidated easily from the archaeological record. This result has wider implications to the archaeological investigation of hot-rock technology that extend beyond the regional dataset presented.

Environmental Setting

The Southern High Plains (Llano Estacado) is a flat, virtually featureless, plateau located in western Texas and eastern New Mexico (Figure 1). Bounded on three sides by an escarpment, the southern edge merges into the Edwards Plateau. The High Plains surface is blanketed by the aeolian sands of the Blackwater Draw Formation (Holliday, 1989). The local drainage system, cut through the bedrock, trends from northwest to southeast across the region and forms the headwaters for several major river systems in Texas.

Caliche nodules can be obtained from both the Blanco and Ogallala formations. The Blanco Formation, localized in certain areas of the Southern High Plains, often contains calcrete in its upper layers (Holliday and Welty, 1981). It is characterized as a lacustrine dolomite and clastic sediment deposited in large basins cut into the Ogallala Formation (Evans and Meade, 1945; Pierce, 1974; Harbour, 1975; Hawley et al., 1976; Holliday, 1988, 1997).

Throughout the Southern High Plains, caliche comprises the upper section of the Miocene-Pliocene age Ogallala Formation in the form of a strongly indurated calcretic layer (Holliday, 1997). This well-developed calcrete layer is known as the Caprock. The Ogallala Formation is the most ubiquitous rock unit of the High Plains, outcropping nearly continuously along the eastern, northern, and western escarpments of the Llano Estacado (Holliday, 1997:250). Entrenched draw systems that cut the largely flat High Plains topography provide one form of access to exposures of the underlying caliche.

Exposures most often are visible along valley walls where erosion processes break off caliche nodules that can be recovered from the surface.

The caliche nodules used in this experiment were obtained from an exposure of the Ogallala Formation located within Yellowhouse Canyon (Figures 1, 2). The chemical composition of caliche varies. Calcium carbonate ($CaCo_3$) is the cementing agent that binds unconsolidated sediment and geologic material. Calcium carbonate levels vary but it is always a major constituent (Sidwell, 1943; Evans, 1948; Bretz and Horberg, 1949; Gile et al., 1966; Reeves, 1976; Hennessy et al., 1983:723). The term caliche has been applied to calcareous caprocks, soil hardpans, and earthy or porous materials that occur at the surface or at shallow depths below the soil (Bretz and Horberg, 1949:491). Caliche is developed in the lower horizons of soils during pedogenesis (Gile, 1961; Gile et al., 1976; Reeves, 1976) and occurs in soils throughout the southwestern United States. Horizons on the Southern High Plains are among the most well developed caliche deposits found worldwide (Alomar-Camacho, 2001).

Archaeological Background

Burned caliche hearthstones have been identified in a large number of archaeological excavations on the Southern High Plains (e.g., Biesaart et al., 1985; Johnson, 1987; Baxevanis et al., 1997; Brown, 1999). Burned caliche scatters are ubiquitous in surface surveys (e.g., Hughes and Willey, 1978; Hughes and Speer, 1981; Litwinionek et al., 1997; Mitchell, 2001; Gill, 2002) and, therefore, are a useful indicator of prehistoric land use strategies. Excavations of discrete hearth basin features have revealed persistent use of caliche in thermal-producing activities over a long time span (e.g., Johnson, 1987; Backhouse, 2002; Buchanan, 2002). While caliche is not the only rock type associated with thermal rock features on the Southern High Plains, it is the most prevalent. At Lubbock Lake, it accounts for approximately 98% of all hearthstone material recovered (Johnson, 1987, 1989, 1993, 1995, 2002). Burned caliche, however, historically has been underutilized by researchers as an inferential analytical tool in understanding past lifeways on the Southern High Plains.

Analysis of thermal features highlights a plethora of subtle variation in hearthstone usage associated with different thermal processes and hearth morphologies (Ladkin, 1993; Backhouse et al., 2001; Backhouse, 2002; Buchanan, 2002). A clear standard typology for the characterization of thermal feature morphology has yet to be developed for the Southern High Plains. In the absence of such a system and based on the dynamic nature of the features themselves, the most convenient characterization of the type of feature addressed herein is a caliche rubble basin. These basin features

typically are filled with hearthstones and sediment with no clear internal structure. A basin is identified on the basis of a high diameter to depth ratio (Ellis, 1997:60).

Caliche rubble basins have been excavated at a number of sites on the Southern High Plains, and in particular at the Lubbock Lake Landmark (Johnson, 1993, 1995, 2002). The Lubbock Lake Landmark (41LU1) is located on the northern edge of the City of Lubbock (Figure 1). The Landmark covers more than 300 acres of the valley axis and margins of Yellowhouse Draw and adjacent upland rims and contains a well-dated stratigraphic record of valley fill and upland sediments (Holliday et al., 1983, 1985; Holliday, 1983, 1985, 1989, 1995; Holliday and Allen, 1987; Johnson, 2002) in which numerous archaeological activity areas date from 11,100 years ago to the Historic use of the area by Anglo settlers (Johnson, 1987).

At 41LU1 Area 10, located on the rim of the draw, an activity area has been occupied repeatedly over the last 1000 years or more and contains numerous hearth basins, some of which overlap and cross-cut one another (Backhouse, 2002; Buchanan, 2002). The basins are filled with burned caliche nodules that often are highly fragmented (Figure 3). The basins themselves generally are around 1m in diameter and fairly shallow (often less than 30 cm in depth). Caliche nodule counts for each basin are in excess of ca. 2000, although many pieces are fragmentary. Carbonized sediment and charcoal pieces occur throughout the matrix of these features, suggesting that fuel was loaded both above and below the hearthstones. The integrity of the internal structure of these basins suggests their use involved cooking on top of the hearthstones, not within the basin itself as inferred from pit ovens (e.g., Johnson and Holliday, 1986).

EXPERIMENTAL METHODOLOGY

Caliche nodules were collected from an exposed Ogallala Formation outcrop on the rim of Yellowhouse Canyon approximately four miles downstream from the Lubbock Lake Landmark (Figure 2). Nodules of varying sizes (20g-2447.5g) were collected for use in the experiment (Figure 3). Some caliche nodules had a significantly higher density than others of similar proportion; the cause of this variation was not identified. During the process of volume quantification using water displacement, very little slake (crumbles with treatment by water) was present when nodules were immersed in water, suggesting the vast majority of the nodules used in this experiment were hard caliche *(sensu* Gile, 1961).

The caliche nodules were assigned tag numbers for identification purposes. They were tagged prior to experimental burning by stamping their individual caliche

identity number on a steel tag and attaching the tag to the nodule with a thin band of steel wire.

A color designation using a standard 1994 U.S. Munsell color chart was determined for each nodule prior to the experiment (Table I). Munsell colors were assigned in the ranges Gley 1 through 2.5Y. The color value was recorded for the largest percentage of the visible exterior surface for each caliche nodule. Inter-observer variability tests were used as a check on the validity of the color results. Two of the authors (PB and BB) reanalyzed a random sample from all three experiments. The results revealed relatively minor variation in the colors recorded by the different observers.

Weight values were recorded in grams with a Triple Beam Balance 700. Fracture patterns were recorded by visual inspection. To aid in the quantification of the observed fracturing, only two categories were used: when significant fracture was present (i.e., pronounced angularity, a broken edge, or cracking), it was designated as fractured (F); if none of these characteristics were visible, it was designated as stable (S) (Table I).

The Experiment

Cultural and natural processes are active variables in the modification of rocks for use as hearthstones. The research objectives of the experiment explicitly anticipate a wide range of variability inherent in the processes that act to structure the archaeological record. Interpretations derived from this experiment, therefore, are not applicable precisely to the interpretation of individual site level structures. Rather, the objectives focus on generating broader interpretive statements with emphasis on the physical material transformation of hearthstones within a framework of hunter-gatherer thermal feature technology.

Four basins were hand-excavated in a culturally sterile area at the Lubbock Lake Landmark during the Spring of 2002 (Figure 5). The experimental basins were assigned control designations EXP-1, EXP-2, EXP-3, and EXP-4. Basins EXP-1 through EXP-3 were designed as three repetitions of the same experimental design. EXP-4 was used to test a number of external variables prior to and after the experimental burns in the other basins. Basin geometry was ca. 50cmx50cmx30cm, based on previously excavated basins at 41LU1 Area 10 (Backhouse, 2002; Buchanan, 2002).

Mesquite (*Prosopis glanulosa*) was chosen as the primary incendiary material based on several factors: 1) mesquite is a native plant (Thompson, 1987) and the results of tree identification based on charcoal from a number of Southern High Plains thermal

features have indicated the presence of mesquite (Backhouse et al., 2001; Johnson, 2003); 2) mesquite represents the most ubiquitous hard wood resource on the Southern High Plains (Anonymous, 1992); and 3) dead mesquite limbs can be harvested easily from the landscape with minimal expended effort. A variety of grasses were used as the initial kindling and tinder (pyrotechnic catalyst) followed by snapped mesquite limbs to fuel the fires. The wood used in each experimental burn weighed ca. 11,000g. The fuel was split into bundles consisting of limbs with a diameter larger than 50mm and bundles consisting of limbs with a diameter smaller than 50mm as kindling. Approximately half of the total fuel for each experiment was burned prior to the introduction of the caliche nodules and the remainder added above the coals and surrounding the newly added caliche layer.

A thermocouple (electronic temperature probe; Barant Type K) was used to take temperature readings at half hour intervals during the basin firing. In order to obtain a standardized temperature reading, the thermocouple was positioned in the center of the basin embers for two minutes before a temperature reading was recorded. The thermocouple was stored in the shade between readings and ambient environment temperature readings were noted prior to interior basin readings. The resultant temperature data were corrected by subtracting the ambient temperature from the hearth basin reading. Ambient environmental conditions for the local area were recorded from the Lubbock International Airport NEXRAD weather station (LBB/KLBB) situated ca. 2 miles north of the experiment location (Table II).

Each experiment was conducted for six hours with three days required for all experiments to be completed. The experimental pyrotechnic methodology attempted to standardize a series of set procedures in order to produce comparable data sets for analysis (Figure 5). On completion of an experiment, all caliche nodules were photographed and mapped with a total station before being removed systematically from a basin (Figure 6). Upon completion of all three experiments, the caliche nodules were brought to the laboratory for reanalysis. Reanalysis involved the quantification of the same set of variables that were recorded prior to burning (Munsell color, weight, and fracture; Table III).

RESULTS

The basin temperature data generally indicate that the highest temperatures were logged in the first three hours after burning (Table IV). Subsequent temperatures steadily decreased. EXP-2, on the other hand, remained at a steady burn temperature for the six hours (Figure 7). Variability in temperatures between the three experimental

basins is likely to be the result of several factors including the prevailing weather, source material variability, basin geometry, fuel variability, fuel load placement, caliche nodule placement, ignition material, and location of primary ignition.

Results showed a heat curve with a maximum acquired temperature of 673°C during the initial burn. Temperatures of between 275°C and 425°C were recorded after the initial fuel had been added and exhausted (Figure 7). However, a high degree of variability existed in the fall-off readings, with spikes of very hot temperatures up to six hours after the initial burn. Mesquite proved to be a high-energy primary pyrotechnic medium.

The ambient environmental data recorded from Lubbock LIA weather station show that on the day of the EXP-2 burning, higher winds and higher temperatures occurred throughout the day than for either EXP-1 or EXP-3 (Table II). The situation is likely a cause of the comparatively high sustained temperatures in EXP-2. EXP-3 has an average temperature of 279°C but the readings demonstrated high variability (Std. Dev.=49.65). That day is the coolest and least windy day of the three, and probably responsible for EXP-3 producing the least number of highly burned hearthstones. Of the three experimental basins, EXP-1 yielded the second highest number of highly burned hearthstones due most likely to the initial high temperatures in the first three hours of burning (Table II).

Gross comparison of Munsell color designations, obtained before and after experimentation, reveals significant color transformations have taken place on the outer surfaces of the caliche nodules (Table V). A general trend from color designations dominated by white, pink, and pale hues prior to burning is replaced by designations dominated by browns and grays after burning (Table V). A higher degree of variability is represented in the coloration of the post-burn assemblages as compared to the pre-burn assemblages. Nevertheless, the post-burn assemblage is dominated by high frequencies of gray and dark gray nodules.

The number of caliche nodules that were both stable and fractured before and after firing showed significant variation (Table VI). The collection of the fragmented hearthstones was as comprehensive as possible and involved hand sifting the ash remaining in the basins in order to recover the tiny hearthstone spalls. In each case, the quantity of extra-fragmented hearthstones was accounted for in the decrease in the quantity of stable caliche nodules post-burn (Table VI). EXP-1 produced the highest frequency of newly fractured hearthstones (12) and an additional 10 nodules that were characterized as stable prior to burning but now were fractured (Figure 8). EXP-2 had a

high burn temperature (Table IV) and caused 10 new fractures but only one less stable hearthstone (Table VII). EXP-3 yielded similar results to EXP-1 and yielded six newly fractured and four less stable caliche nodules. EXP-3 had a low burn rate throughout the six hours but its temperature oscillated continuously on average from 288°C to 232°C. The lower overall temperatures may have caused less fracturing to occur in comparison with EXP-1 and EXP-2 (Tables VI, VII). These data suggested the high initial temperatures followed by a rapid decrease can lead to a general fracturing over a greater number of hearthstones.

A loss of weight from pre-burn to post-burn in each experimental caliche assemblage was noted (Table VIII). This result suggested that either a loss of internal water occurred within individual nodules (Hennessey et al., 1983), combustion of carbonates had occurred within the hearthstone, a degree of micro-fracturing (small pieces of hearthstone not collected post-burn) existed, or some combination of these processes had taken place. With the proportion of weight loss recorded after burning, it may be possible to approximate the number of burning episodes that a caliche hearthstone assemblage are likely to cycle through before all the nodules are exhausted. A direct relationship likely existed between nodule size and heating efficiency. However, the results of these initial experiments did not attempt to quantify this relationship directly and would require a new experimental setup and sufficient repetition.

DISCUSSION

The data generated from these preliminary experiments highlights the utility of conducting actualistic research into the physical properties of burned caliche nodules. By testing basic assumptions concerning the way caliche may have been used, reused, and the transformations individual nodules undergo when heated, a comparative database can be generated with which to assess burned caliche hearthstones recovered from the archaeological record.

Variability within the data sets for all criteria makes quantification a complex task and is best viewed at a feature scale, i.e., by quantifying the characteristics for each of the features. In general, at least three physical alterations are observable once a caliche nodule is burned. Coloration becomes distinctly darker; total weight of individual nodules is reduced; and fracturing occurs. Two of the implicit assumptions associated with the thermal alteration characteristics of caliche proved to be confirmed: high temperatures will discolor caliche; and fracture is a function of intense heat.

The coloration data provide an adequate inferential tool for analyzing burned caliche. The current data set indicates a correlation between acquired basin temperature and subsequent caliche nodule coloration, as demonstrated in laboratory experiments (Lintz, 1989). Coloration (burning of the nodule surface) is achieved in the actualistic experiments at hearth basin temperatures of 204 to 371°C while coloration occurred above 300°C in the laboratory experiment (Lintz, 1989:328). Data from natural range fires indicate that temperatures of 84°C to 388°C are reached, with up to 682°C under optimal conditions (Stinson and Wright, 1969:9). However, given the characteristics of range fires, such temperatures would be maintained for only a short period of time (Stinson and Wright, 1969; Seabloom et al., 1991).

Caliche nodules subjected to prescription burning (quick burning, hot fire) are scorched superficially but not burned nor burned throughout (Thoms and Proctor, 1977; Ladkin, 1993:203). Generally, then, range fires do not burn hot enough long enough to cause the type of coloration recorded with the experimental nodules or the archaeological assemblages. These data indicate that hearth temperatures need to be a sustained minimum of 204°C to produce true coloration and, therefore, cultural burning. It may be possible in future experiments to ascertain color ranges for different firing temperatures, thus providing important data on potential basin function and technological process.

Insufficient data have been generated to test the internal temperatures of individual nodules or the dissipation of heat retained in individual nodules as a function of time. However, the coloration and temperature data sets indicate a sustained minimum overall hearth temperature of 204°C. In general, such a maintained temperature would be adequate to grill foodstuffs. How long nodules retain sufficient heat to bake foodstuffs still needs to be explored along with minimum temperature and minimum length of time needed when baking various foods.

Spatial variability in coloration throughout the burned nodules has been observed from within all three basins. This variability appears related to several factors, namely fuel load placement, wind direction, nodule positioning, and subtle differences in the internal structure of nodules. The simple assumption that the caliche at the center of the basin would be most burned did not hold true as a high degree of variability existed even within the internal structure of the basin. Basin features observed during fieldwork often contain seemingly unburned or scorched nodules within a concentration of highly burned specimens. Data suggest that interpretation of these specimens as in-situ, rather than as post-depositional inclusions, requires serious consideration. Future

work will need to contend with post-depositional taphonomic factors such as freeze/thaw cycles and trampling.

Fracture analysis (Tables VI, VII) has yielded unexpected results. The low degree of fracture during firing may relate to the hearth basin temperature, type of caliche used, or water content of caliche nodules during firing. Observations during the experimental work suggest that fracture was more likely to occur due to physical impact or thermal shock when the caliche nodule was placed in the basin. A number of tiny hearthstone spalls (less than 5g) have been produced by each of the experiments (Table VII). It appears these spalls came off the outer surface of individual nodules due to thermal shock.

The location of spalled pieces within the basin matrix reveal a distinct concentration of small angular spalls at the bottom of the basin (Figure 9). This result has the potential to determine hearth basin contextual integrity in archaeological settings with higher concentrations of small hearthstone pieces expected from the lower levels of intact thermal basin features. These angular spalled pieces are different from the rounded hearthstone bits frequently recovered. This difference indicates that spalls and bits may be produced through different mechanisms in the hearth process. Fracture often has been linked with utilization process in the archaeological literature (e.g., Black et al., 1997; Brink and Dawe, 2003). The dynamics of water boiling activities and nodule re-use remain to be investigated and integrated in with these preliminary results in order to assess the relationship between technological activity and caliche nodule structure.

All the experimental caliche nodule assemblages have undergone a loss in weight between their pre-burn and post-burn states (Table VIII). The interpretative inference is that intense heating of caliche nodules is a reducing process. The effective mass of individual nodules are being transformed as a function of heating. A similar reduction is noted by Lintz (1989:328) in which he calculated a loss of approximately 0.76 gram per 100°C at temperatures below 700°C. Because the assemblages examined here were subjected to only one heating event, it is uncertain how subsequent heating events will further affect the weights of the hearthstones.

Importantly, the reducing process of weight loss and fracturing characterizes burned caliche nodules as an expendable resource type. Discard of spent hearthstones usually is associated with activities that are secondary to the hearth basin itself such as water boiling (Ellis, 1997). The results of this experimental program suggest that hearthstone reduction is significant after one heating event and need not be a product of

secondary activities. Another interpretation, then, of discarded hearthstones recovered around a hearth basin is that they had been removed from the basin itself once they had been deemed too small to be useful as heat retention reservoirs. Economically, the availability of hearthstones in the surrounding landscape also will factor as a function of the longevity of a hearthstone's use life. The physical use-life of caliche nodules may provide a baseline for assessing gross economic yield based on the estimated redundancy of individual nodules.

Hearth basin temperatures achieved a maximum burn temperature of 673°C. This temperature was only sustained for a short period of time. Once ember beds developed, temperature ranges between 204°C and 371°C were sustained for at least six hours. Under laboratory conditions, significant alteration of caliche nodules occurred at temperatures above 700°C (Lintz, 1989:328). The results of this program of experimentation suggest that it is unlikely the mesquite-fueled basins could attain and sustain the temperature range at which Lintz (1989) observed physical signs of disintegration.

Inferences from the hearth basin temperatures should be regarded with caution. A recent study (Canti and Linford, 2000) suggests the use of a single thermocouple has limited potential for ascertaining useful data on the internal dynamics of fire pits during use. Variables such as thermocouple position, weather, wind down draft, and burning embers can lead to false readings that can be in excess or vastly under-representative of the overall temperature of the hearth. Therefore, without additional data, it is not possible to assess the relationship between the hearth basin geometry and dynamics of fuel expenditure as hypothesized by Groenendijk (1987).

The high variability associated with the results of this experiment largely stems from the actualistic research design of the experiment. These results, although not clear-cut, provide a more realistic baseline for interpreting burned caliche assemblages. Future experimental work is necessary and current research needs to integrate a suite of analytical tools that include spatial, volumetric, statistical, paleomagnetic, environmental, fuel source, and disturbance studies in order to facilitate a high level of interpretation of prehistoric hearthstone technologies.

CONCLUSION

Completion of this phase of actualistic research has generated a number of significant results that are pertinent to understanding the cultural use of caliche as a component of hunter-gatherer thermal feature technology on the Southern High Plains and more generally within a growing corpus of thermally-altered stone research (e.g.,

Atkins, 1988; Lintz, 1989; Ellis, 1997; Jackson, 1998; Thoms, 2003; Brink and Dawe, 2003).

The main results of this experiment indicate that:

1. when exposed to sustained high temperatures (above 204°C), caliche hearthstones generally become darker and more variable in color, undergo weight loss, and fracture;
2. shallow basin hearth structures fueled by mesquite are capable of achieving and sustaining temperatures that result in the physical alteration of individual caliche nodules;
3. burned caliche hearthstones generated by actualistic research are visually similar to those encountered in the archaeological record of the Southern High Plains;
4. evidence for burning on individual hearthstones is the result of the interaction of a complex set of variables, and therefore, cultural processes that result in the discard of spent hearthstones cannot be elucidated in a straightforward manner from the archaeological record;
5. a potentially predictable relationship appears to exist between firing temperature, coloration, fracture, and weight loss at an assemblage scale;
6. small fractured hearthstones in the archaeological record are not necessarily related directly to secondary cultural processes (such as water boiling) but are instead a secondary result of the burning process; and
7. hot-rock technology is essentially reductive and hearthstones are a non-renewable component that may be profitably analyzed in terms of economic benefit, redundancy, and re-cycling.

The analysis of hearthstones recovered from the archaeological record has significant potential for exploring prehistoric hunter-gatherer subsistence strategies. The broader implication of this investigation is the realization that the interpretation of hearthstones, as recovered during archaeological investigation, is rarely a straightforward matter. Further experiments using a wider range of hot-rock resources and simulated structures may help to explain the relationship between the physical properties and constraints indicated by this study. Future research designs need to prioritize fine-grained data recovery, structural analysis, and actualistic study of hunter-gatherer thermal feature technologies in order to build datasets capable of assessing the wide range of cultural variation inherent in the archaeological record. Expansion of the analytical focus to include the life-history of hearthstones and thermal features would engender the possibility of morphological variation following discard and abandonment.

Actualistic experimentation indicates the potential benefits of detailed analysis and interpretation of hearthstone assemblages currently is underutilized.

ACKNOWLEDGEMENTS

This manuscript is an expanded version of a paper presented at the 2002 annual meeting of the Plains Anthropological Conference, Oklahoma City. Photography was provided by Tara Backhouse (Museum of Texas Tech University). The authors would like to thank Drs. Alston V. Thoms (Texas A&M University) and Vance T. Holliday (University of Arizona) for comments on earlier drafts; and Dr. Michael Petraglia (University of Cambridge) and an anonymous reviewer for their useful suggestions. Any errors or omissions, however, are the responsibility of the authors. This research was funded by the Museum of Texas Tech University and the City of Lubbock. The manuscript represents part of the ongoing Lubbock Lake Landmark regional research into grasslands hunter-gatherers and adaptation to ecological change.

REFERENCES CITED

Alomar-Camacho, B.S. (2001). Stable Isotope Geochemistry of Caliche in the Blackwater Draw Formation, Southern High Plains, Texas. Master's Thesis, Lubbock: Texas Tech University.

Anonymous (1992). Wildflowers of the Western Plains. Austin: The University of Texas Press.

Atkins, N. (1988). Fire-cracked rock. In M.P. Marshall (Ed.), The excavation of the Cortez CO2 pipeline project sites 1982-1983 (pp. 173-178). Albuquerque: Contract Archaeology, University of New Mexico.

Backhouse, P.N. (2002). Excavations at 41LU1, Area 10 The 2000 Season. In E. Johnson (Ed.), Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work (pp. 183-194). Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 11.

Backhouse, P.N. (2003). Conceptualizing the Social Use of Space Around a Prehistoric Hearth Pit. 41st Annual Meeting, Plains Anthropological Society, Fayetteville, AK.

Backhouse, Paul N., Johnson, E., Hewat, C., Brackenreed-Johnson, A., & Holliday V.T. (2001). Archaic Times in Yellowhouse Canyon. 39th Annual Meeting, Plains Anthropological Society, Lincoln, NB.

Barfield, L.H. (1991). French research on prehistoric hearths: a review of conference proceedings. In M.A. Hodder & L.H. Barfield (Eds.), Burnt Mounds Hot Stone Technology (pp. 109-111). Sandwell: Sandwell Metropolitan Borough Council.

Baxevanis, S.E., Johnson E., Buchanan B., & Shannon, W. (1997). Test Excavations Within the Plow Zone at the Hogue Site (41TY2), a Playa Site on the Southern High Plains of Texas. Bulletin of the Texas Archaeological Society, 67, 337-386.

Biesaart, L.A., Roberson, W.R., & Spotts, L.C. (1985). Prehistoric Archaeological Sites in Texas, A Statistical Overview. Office of the State Archaeologist Special Report 28. Austin: Texas Historical Commission.

Black, S.L., Ellis, L.W., Creel, D.G., & Goode, G.T., Eds. (1997). Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas. Texas Archaeological Research Laboratory, Studies in Archaeology, No 22. Austin: The University of Texas at Austin.

Bretz, J.H., & Horberg, L. (1949). Caliche in Southeastern New Mexico. Journal of Geology, 57, 491-511.

Brink, J.W., & Dawe, B. (2003). Hot Rocks as Scarce Resources: The Use, Re-Use and Abandonment of Heating Stones at Head-Smashed-In Buffalo Jump. Plains Anthropologist, 48(186), 85-104.

Brown, C. (1999). Perry (41LU75)-A Lubbock County Playa Site. Bulletin of the South Plains Archaeological Society, 5, 1-56.

Buchanan, B. (1995). Archaeological Background of Lubbock County. In E. Johnson (Ed.), Playa Archaeology – Archaeological Investigations at Reese Air Force Base and Terry County Auxiliary Airfield, Lubbock and Terry Counties (pp. 39-80). Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 11.

Buchanan, B. (2002). Excavations at 41LU1, Area 10, The 1994-1996 Seasons. In E. Johnson (Ed.), Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work (pp. 139-160). Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 11.

Canti, M.G., & Linford N. (2000). The Effects of Fire on Archaeological Soils and Sediments: Temperature and Colour Relationships. Proceedings of the Prehistoric Society, 66, 385-395.

Collins, M.B., & Ricklis, R.R. (1994). Cultural Background. In R.A. Ricklis & M.B. Collins (Eds.), Archaic and Late Human Ecology in the Middle Onion Creek Valley, Hays County (pp.11-26). Texas Studies in Archaeology 19. Austin: The University of Texas at Austin.

Ellis, L.W. (1997). Hot Rock Technology. In S. Black, L.W. Ellis, D.G. Creel, & G.T. Goode, (Eds.), Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas (pp. 43-76). Texas Archaeological Research Laboratory, Studies in Archaeology, No 22, The University of Texas at Austin.

Evans, G.L. (1948). Geology of the Blanco Beds of West Texas. Geologic Society of America Bulletin, 59, 617-619.

Evans, G.L., & Meade, G.E. (1945). Quaternary of the Texas High Plains. University of Texas Publication, 4401, 485-507.

Frison, G.C. (1983). Stone Circles, Stone-Filled Fire Pits, Grinding Stones and High Plains Archaeology. Plains Anthropologist Memoir, 19, 81-91.

Gile, L.H. (1961). A classification of ca horizons in soils of a desert region, Dona Ana County, New Mexico. Soil Science Society American Proceedings, 25, 52-61.

Gile, L.H., Peterson, F.F., & Grossman, R.B. (1966). Morphological and genetic sequences of carbonate accumulation in desert soils. Soil Science, 101, 347-360.

Gill, M. (2002). Spatial Analysis of Surface Collected Materials at the Lubbock Lake Landmark Utilizing Geographic Information Systems. Master's Thesis, Lubbock: Texas Tech University.

Gose, W. (2000). Paleomagnetic Studies of Burned Rocks. Journal of Archaeological Science, 27, 409-421.

Groenendijk, H.A. (1987). Mesolithic Hearth-Pits in the Veenkolonien (Prov. Groningen, The Netherlands), Defining a Specific Use of Fire in the Mesolithic. Palaeohistoria, 29, 85-102.

Harbour, J. (1975). General Stratigraphy. In F. Wendorf & J.J. Hester (Eds.), Late Pleistocene Environments of the Southern High Plains (pp. 35-55). Taos, New Mexico: Publication of the Fort Burgwin Research Center, no. 9.

Hawley, J.W., Bachman, G.O., & Manley, K. (1976). Quaternary stratigraphy in the Basin and Range and Great Basin Provinces, New Mexico and western Texas. In W.C. Mahaney (Ed.), Quaternary Stratigraphy of North America (pp. 235-274). Stroudsburg: Hutchinson and Ross, Inc.

Hennessey, J.T., Gibbens, J.M., & Cardenas, M. (1983). Water Properties of Caliche. Journal of Range Management, 36(6), 723-726.

Holliday, V.T. (1983). Stratigraphy and Soils of the Lubbock Lake Landmark Area. In V.T. Holliday (Ed.), Guidebook to the Central Llano Estacado (pp. 25-80). Lubbock: ICASALS and the Museum of Texas Tech University.

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

Holliday, V.T. (1988). Mt. Blanco revisited: Soil-geomorphic implications for the ages of the upper Cenzoic Blanco and Blackwater Draw Formations. Geology, 16, 505-508.

Holliday, V.T. (1989). Geoarchaeological Investigations at the Lubbock Lake Landmark, 1987 Season. In E. Johnson (Ed.), 1987 Fenceline Corridor Survey and Testing Program (pp. 69-81). Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 1.

Holliday, V.T. (1995). Geoarchaeological Investigations at the Lubbock Lake Landmark, 1989 and 1990 Seasons. In E. Johnson (Ed.), Late Holocene Investigations at the Lubbock Lake Landmark. Volume 2. The 1989 and 1990 Work (pp. 33-53). Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 8.

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

Holliday, V.T., & Allen, B.L. (1987). Geology and Soils. In E. Johnson (Ed.), Lubbock Lake. Late Quaternary Studies on the Southern High Plains (pp. 14-21). College Station: Texas A&M Press.

Holliday, V.T., & Welty, C. (1981). Lithic Tool Resources of the Eastern Llano Estacado. Bulletin of the Texas Archeological Society, 52, 201-214.

Holliday, V.T., Johnson, E., Haas, H., & Stuckenrath, R. (1983). Radiocarbon Ages from the Lubbock Lake Site, 1981-1984. Plains Anthropologist, 30(110:1), 227-291.

Hughes, J.T., & Speer, R.D. (1981). An Archaeological Survey of the Pantex Plant, Carson County, Texas. Unpublished report submitted to Mason & Hanger – Silas Mason Co., Inc:1-115.

Hughes J.T., & Willey, P.S. (1978). Archaeology at Mackenzie Reservoir. Texas Historical Commission, Office of State Archaeologist, Archaeological Survey Report, 24.

Jackson, M.A. (1998). The Nature of Fire-Cracked Rock: New Insights from Ethnological and Laboratory Experiments. Master's Thesis, College Station: Texas A&M University.

Johnson, E., Eds. (1987). Lubbock Lake. Late Quaternary Studies on the Southern High Plains. College Station: Texas A&M University Press.

Johnson, E., Eds. (1989). Fenceline Corridor Survey and Testing Program. Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 1, 1-293.

Johnson, E., Eds. (1993). Late Holocene Investigations at the Lubbock Lake Landmark. Volume 1. The 1988 Work. Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series 5, 1-243.

Johnson, E., Eds. (1995). Late Holocene Investigations at the Lubbock Lake Landmark. Volume 2. The 1989 and 1990 Work. Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 8, 1-477.

Johnson, E., Eds. (2002). Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work. Museum of Texas Tech University, Lubbock Lake Landmark Quaternary Research Center Series, 11, 1-324.

Johnson, E., Eds. (2003). Explorations at Tahoka Lake, a Salina on the Llano Estacado. Lubbock: Museum of Texas Tech University.

Johnson, E., & Holliday, V.T. (1986). The Archaic Record at Lubbock Lake. In T.G. Baugh (Ed.), Current Trends in Southern Plains Archaeology (pp. 7-54). Plains Anthropologist Memoir, 22.

Ladkin, N. (1993). Burned Caliche from the 1988 Excavations. In E. Johnson (Ed.), Late Holocene Investigations at the Lubbock Lake Landmark. Volume 1 The 1988 Work (pp. 177-205). Museum of Texas Tech University, Lubbock, Lubbock Lake Quaternary Research Center Series, 5.

Lintz, C. (1989). Experimental Thermal Discoloration and Heat Conductivity Studies of Caliche from Eastern New Mexico. Geoarchaeology, 4(4), 319-346.

Litwinionek, L., Johnson, E., & Davis, M. (1987). Survey at the Southeastern Edge of the Llano Estacado. Bulletin of the Texas Archeological Society, 68, 301-335.

Lowell, J.C. (1999). The Fires of Grasshopper: Enlightening Transformations in Subsistence Practices through Fire-Features Analysis. Journal of Anthropological Archaeology, 18, 441-470.

Mitchell, J.R. (2001). Understanding Lithic Scatters on the Southern High Plains: Lithic Technology Strategies and Mobility at the Colston Playa. Master's Thesis, Lubbock: Texas Tech University.

Petraglia, M.D. (2002). The Heated and the Broken: Thermally Altered Stone, Human Behaviour, and Archaeological Site Formation. North American Archaeologist, 23(3), 241-269.

Pierce, H.G. (1974). The Blanco Beds. In G.E. Meade, G.L. Evans, & J.P. Brand (Eds.), Guidebook to the Mesozoic and Cenozoic Geology of the Southern Llano Estacado (pp.9-16). Lubbock, Texas: Lubbock Geological Society.

Quigg, M.J., Malainey, M.E., Przybylski, R., & Monks, G.
(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.

Reeves, C.C., Jr. (1976). Caliche: Origin, Classification, Morphology and Uses. Lubbock: Estacado Books.

Seabloom, R.W., Sayler, R.D., & Ahler, S.A. (1991). Effects of Prarie Fire on Archaeological Artifacts. National Park Service, Park Science, 11(1):1, 3.

Sidwell, R. (1943). Caliche deposits on the Southern High Plains, Texas. American Journal of Science, 241, 257-261.

Stinson, K.J., & Wright, H.A. (1969). Temperatures of Head Fires in the Southern Mixed Prairie of Texas. Journal of Range Management, 22, 169-174.

Tennis C.L., Hunziker, J.M., & Leach, J.D. (1997). Fire-cracked Rock Use and Reuse in The Hueco Bolson, Fort Bliss, Texas. Archaeological Technical Reports, No.12, Anthropology Research Center, The University of Texas at El Paso.

Thompson, J. (1987). Modern, Historic, and Fossil Flora. In E. Johnson (Ed.), Lubbock Lake. Late Quaternary Studies on the Southern High Plains (pp. 26-35). College Station: Texas A&M University Press.

Thoms, A.V. (1986). Hot Rocks The Short-term Storage of Energy in the Calispell Valley. In A.V. Thoms & G.C. Butchard (Eds.), Calispell Valley Archaeological Project, Interim Report for 1984 and 1985 Field Seasons. Center for Northwest Anthropology, Washington State University, Pullman.

Thoms, Alston V. (2003). Cook-Stone Technology in North-America: Evolutionary Changes in Domestic Fire Structures During the Holocene. In Marie-Chantal Frère-Sautot (Ed.), Le Feu Domestique et Ses Structures au Néothlique et Âges des Métaux (pp. 87-96). Âctes du Colloque de Bourg-en-Bresse et Breune, Monique Mergoil, Montagnac, France, Prèhistories, 9.

Thoms, A.V., & Proctor, D. (1977). Archaeological Reconnaissance Survey of Portions of the Flood Control Improvement Area, Plainview, Texas, Hale County. Submitted to Espey, Huston, and Associates, Inc. Austin, Texas by the Department of Anthropology Texas Tech University.

Wandsnider, L. (1997). The Roasted and the Boiled: Food Consumption and Heat Treatment with Special Emphasis on Pit-Hearth Cooking. Journal of Anthropological Archaeology, 16, 1-48.

Table I. Quantification summary of caliche nodule variables for all experimental basin hearths prior to burning.

Experiment No.	Total No. of Caliches	No. of Caliches Stable	No. of Caliches Fractured	Most Frequent Color Value	Volume Range (ml)	Weight Range (g)
1	50	34	16	10YR8/2	10-700	60-1674.6
2	40	28	12	7.5YR8/2	10-900	22.6-2068.5
3	49	27	22	10YR8/2	20-1000	55.7-2447.5

* Complete data on archive at the Museum of Texas Tech University

Table II. Ambient environmental conditions recorded from Lubbock LIA (LBB/KLBB) weather station.

Experiment/ Time	Temp. (C°)	Humidity	Pressure	Wind direction/ Speed (mph)	Dew Point	Description
EXP-1 8am	16.11	19%	29.96	SW 7	58	Partly cloudy
EXP-1 11:30am	24.44	51%	29.99	W 13	57	Cloudy
EXP-1 2pm	28.33	25%	29.97	W 9	44	Cloudy
EXP-2 8am	13.89	66%	29.98	W 6	46	Mostly Sunny
EXP-2 11:30am	27.22	24%	30.4	NW 12	41	Partly Sunny
EXP-2 2pm	30.56	25%	30.07	N 21	48	Clear
EXP-3 8am	12.78	71%	30.04	W 6	46	Cloudy
EXP-3 11:30am	18.89	43%	30.04	W 7	43	Cloudy
EXP-3 2pm	26.67	21%	30.04	W 9	37	Cloudy

Table III. Quantification summary of burned caliche nodules for all experimental basin hearths post-burn.

Experiment No.	Total No. of Caliches	No. of Caliches Stable	No. of Caliches Fractured	Most Frequent Color Value	Weight Range (g)
1	52	24	28	Gley1 5/N	5.7-1649.2
2	49	27	22	Gley1 4/N	2.5-1987
3	48	22	26	10YR4/1	19.9-2405.4

* complete data on archive at the Museum of Texas Tech University

Table IV. Temperatures of all experimental basin hearths taken at half hour intervals over six hours and compensated for ambient temperature.

Time (minutes)	Compensated Hearth Temp. EXP-1 (C°)	Compensated Hearth Temp. EXP-2 (C°)	Compensated Hearth Temp. EXP-3 (C°)
30	499.22	673.22	340.61
60	481.78	237.94	98.22
90	621.33	295.33	370.11
120	407.22	378.83	414.67
150	274.50	425.44	326.44
180	346.61	349.94	284.17
210	255.94	346.00	233.33
240	254.39	321.44	273.17
270	219.11	353.61	252.00
300	248.28	349.61	262.78
330	251.44	356.50	232.89
360	195.89	340.94	260.83

Mean temperature	337.98	369.07	279.10
Standard deviation	134.65	105.81	80.36
Range	195.89-621.33	237.94-673.22	98.22-414.67

Table V. Quantification of color variables before and after experimental burning for all experimental hearth basins, based on Munsell color descriptions.

Munsell Color	Color Description	EXP-1 Pre-burn	EXP-1 Post-burn	EXP-2 Pre-burn	EXP-2 Post-burn	EXP-3 Pre-burn	EXP-3 Post-burn	Total Pre-burn	Total Post-burn
7.5YR8/4	pink	2	0	4	0	3	0	**9**	**0**
10YR8/4	very pale brown	2	0	1	0	2	0	**5**	**0**
7.5YR8/3	pink	9	0	7	0	5	0	**21**	**0**
10YR8/3	very pale brown	8	0	4	0	9	0	**21**	**0**
7.5YR8/2	pinkish white	9	0	7	0	6	0	**22**	**0**
10YR8/2	very pale brown	8	0	6	0	10	0	**24**	**0**
2.5Y 8/2	pale yellow	1	0	1	0	0	0	**2**	**0**
7.5YR 8/1	white	1	0	1	0	3	0	**5**	**0**
10YR 8/1	white	5	0	7	0	6	0	**19**	**0**
7.5YR7/4	pink	1	0	0	0	0	0	**1**	**0**
10YR7/4	very pale brown	1	0	0	0	0	4	**1**	**4**
7.5YR7/3	pink	1	0	1	0	0	0	**2**	**0**
10YR7/3	very pale brown	1	0	0	0	1	0	**2**	**0**
10YR7/2	light gray	0	0	0	0	1	0	**1**	**0**
10YR7/1	light gray	0	0	0	0	0	1	**0**	**1**
7.5YR7/2	pinkish gray	1	0	1	0	0	0	**2**	**0**
10YR6/6	brownish yellow	0	0	0	1	0	5	**0**	**6**
10YR6/4	light yellowish brown	0	0	0	1	0	0	**0**	**1**
10YR6/3	pale brown	0	2	0	1	0	3	**0**	**6**
10YR6/2	light brownish gray	0	1	0	0	0	7	**0**	**8**
10YR 6/1	gray	0	4	0	1	0	2	**0**	**7**

Munsell Color	Color Description	EXP-1 Pre-burn	EXP-1 Post-burn	EXP-2 Pre-burn	EXP-2 Post-burn	EXP-3 Pre-burn	EXP-3 Post-burn	Total Pre-burn	Total Post-burn
2.5Y6/1	gray	0	2	0	2	0	7	0	14
10YR5/3	brown	0	0	0	1	0	0	0	1
10YR5/2	grayish brown	0	0	0	3	0	3	0	6
10YR5/1	gray	0	6	0	6	0	7	0	19
2.5Y5/1	gray	0	2	0	2	0	0	0	4
10YR4/2	dark grayish brown	0	1	0	0	0	0	0	1
10YR4/1	dark gray	0	12	0	9	0	8	0	29
2.5Y4/1	dark gray	0	2	0	0	0	1	0	3
10YR3/1	very dark gray	0	1	0	0	0	0	0	1
Gley1 7/N	light gray	0	1	0	1	0	0	0	2
Gley1 6/N	gray	0	1	0	0	0	0	0	1
Gley1 5/N	gray	0	14	0	11	0	6	0	31
Gley1 4/N	dark gray	0	1	0	10	0	1	0	12

Table VI. Number of burned caliche nodules recorded as either fractured or stable before and after burning.

	EXP-1 Prior to Burn	EXP-1 Post Burn	EXP-2 Prior to Burn	EXP-2 Post Burn	EXP-3 Prior to Burn	EXP-3 Post Burn
Fractured	16	28	12	22	20	26
Stable	34	24	28	27	26	22

Table VII. Number of fractured and stable burned caliche nodules with and without newly fractured nodules.

	EXP-1 Prior to Burn		EXP-1 Post Burn		EXP-2 Prior to Burn		EXP-2 Post Burn		EXP-3 Prior to Burn		EXP-3 Post Burn	
Fractured (F) Stable (S)	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	**S**
Including newly fractured caliche Nodules	16	34	28	24	12	28	22	19	20	26	26	22
Excluding newly fractured caliche Nodules			27	23			21	19			26	20

Table VIII. Average nodule and total assemblage weight loss, including the newly fractured nodules and excluding the newly fractured nodules, for each experiment.

	Average Nodule Weight* (g)	Total Assemblage Weight* (g)	Total Assemblage Weight Loss* %	Average Nodule Weight** (g)	Total Assemblage Weight** (g)	Total Assemblage Weight Loss** %
EXP-1 Pre Burn	505.72	25286.1		505.72	25286.1	
EXP-1 Post Burn	479.25	24921.1	1.44	497.96	24898.3	1.53
EXP-2 Pre Burn	442.26	17690.6		442.26	17690.6	
EXP-2 Post Burn	358.59	26394.1	0.68	436.34	17453.7	13.39
EXP-3 Pre Burn	573.78	26394.1		573.78	26394.1	
EXP-3 Post Burn	549.18	26360.7	0.13	572.08	26315.9	0.30

* Including analysis data from the newly fractured caliche nodules

** excluding analysis data from the newly fractured caliche nodules

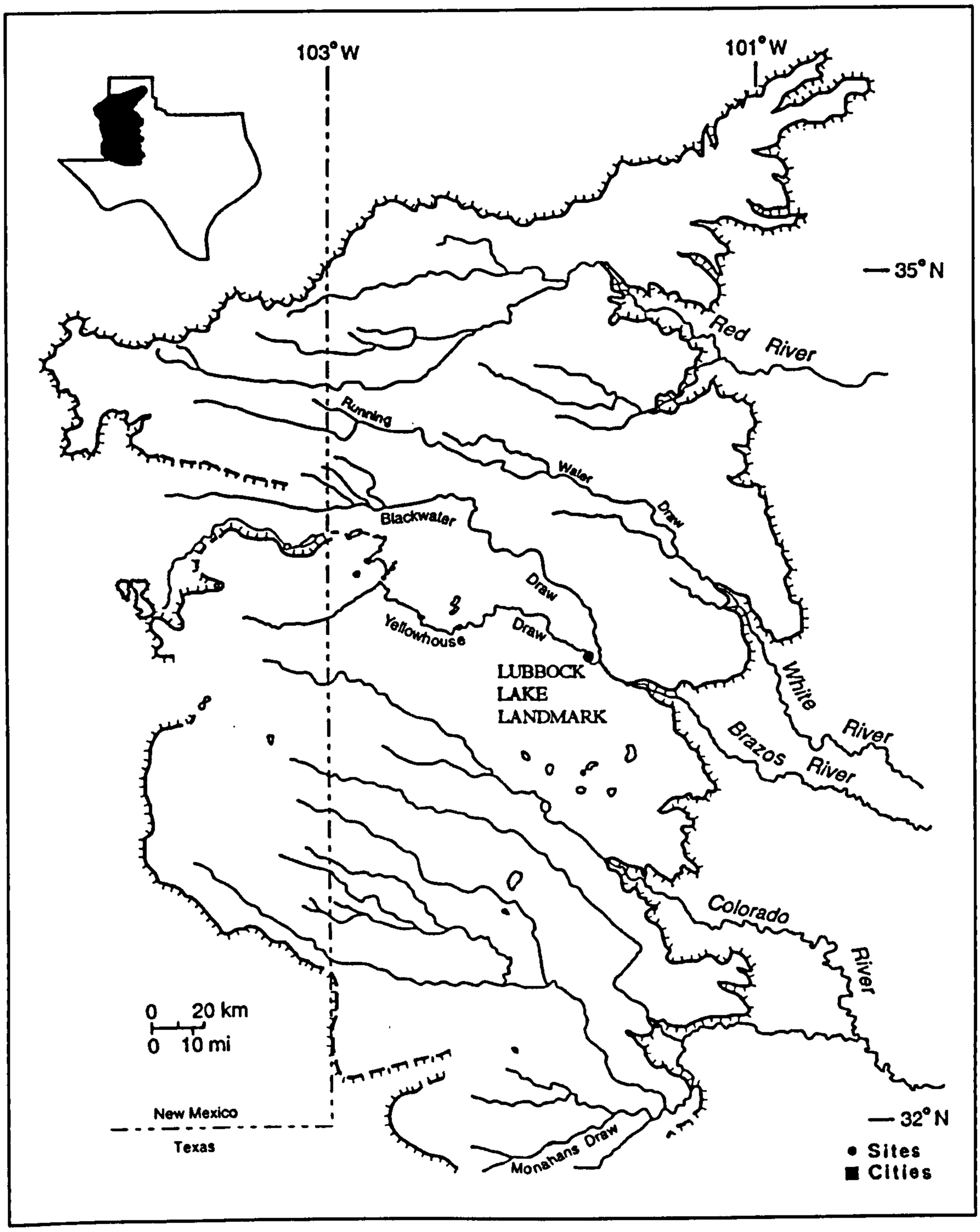


Figure 1. Southern High Plains physiographic province.

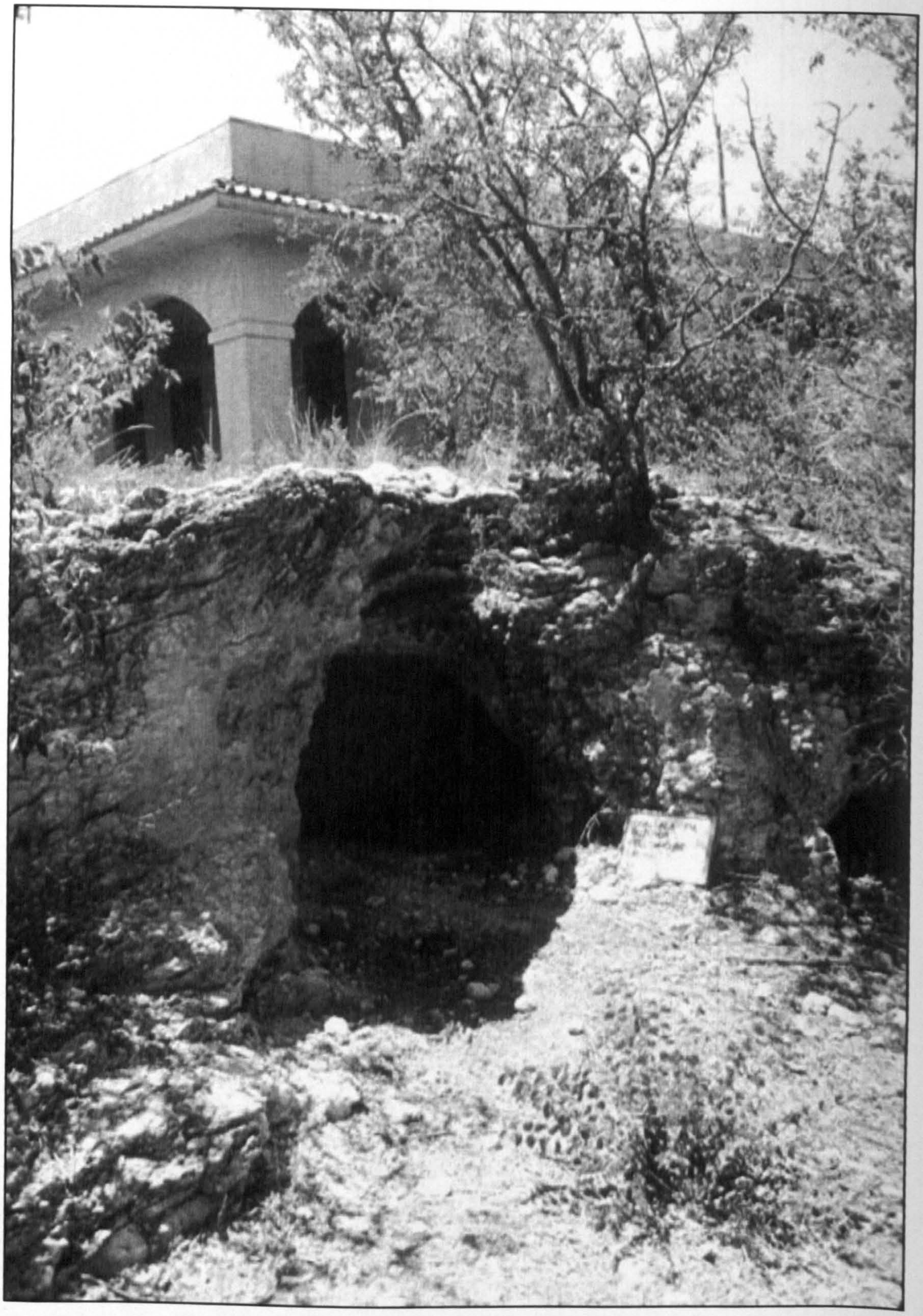


Figure 2. Ogallala Formation outcropping along the valley rim of Yellowhouse Canyon and collection area for the hearthstones used in the experiment.

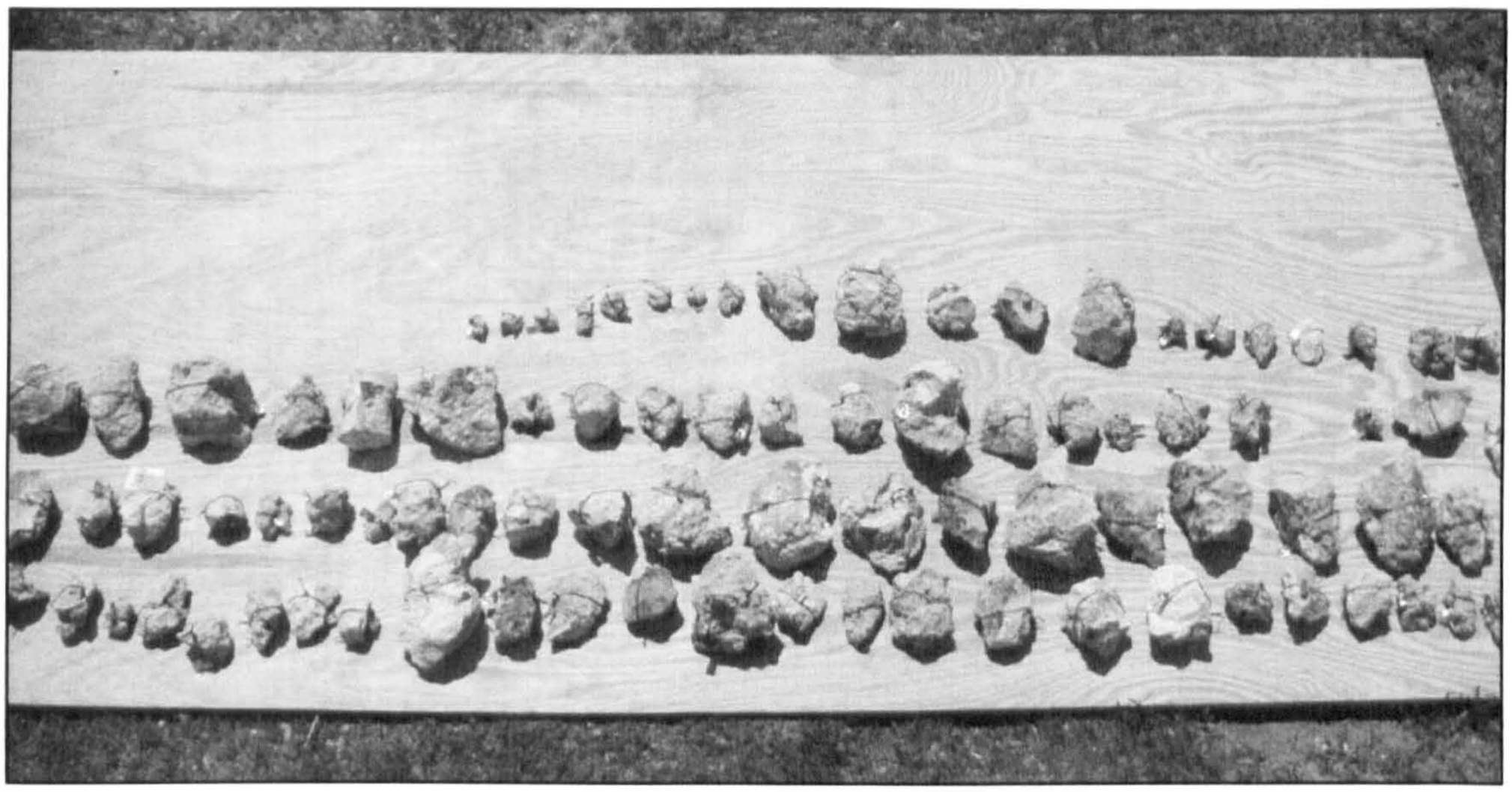


Figure 3. EXP-1 experimental caliche nodule assemblage prior to burn.

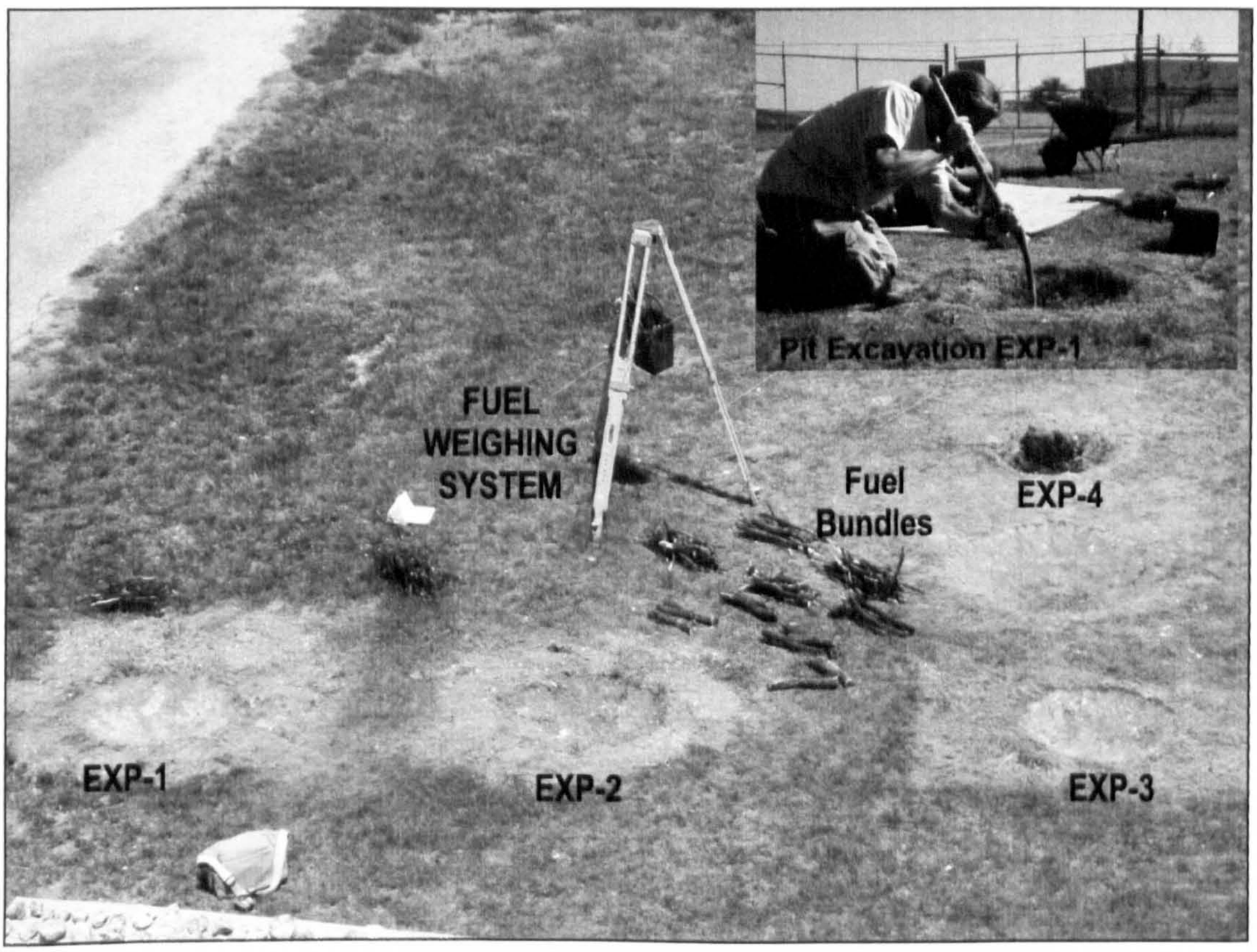


Figure 4. Experimental area at Lubbock Lake Landmark.



a.



b.



c.



d.

Figure 5. Generalized stages of hearth burning: a) initial wood burn and thermocouple use; b) initial burn dies to embers; caliche nodules added; c) caliche nodules mounded until completely covering the initial fire embers; d) grasses arranged above caliche nodule layer prior to adding additional fuel and burning on top of the caliche layer.



Figure 6. EXP-1 post-burn: a) post-burn; b) first caliche nodule removal; c) second caliche nodule removal; d) third caliche nodule removal; e) fourth caliche nodule removal; f) fifth caliche nodule removal.

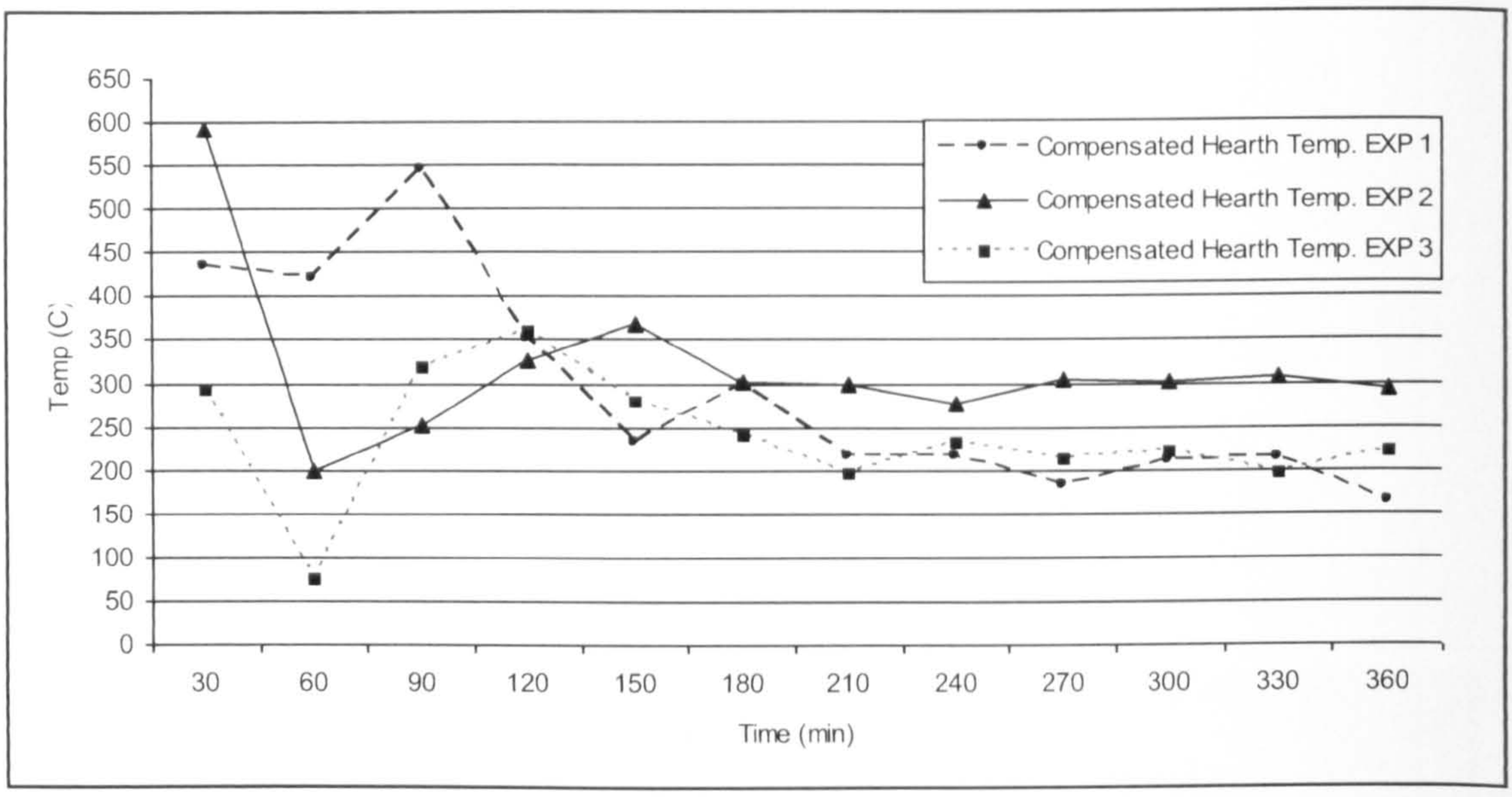


Figure 7. Hearth temperature taken by thermocouple probe.

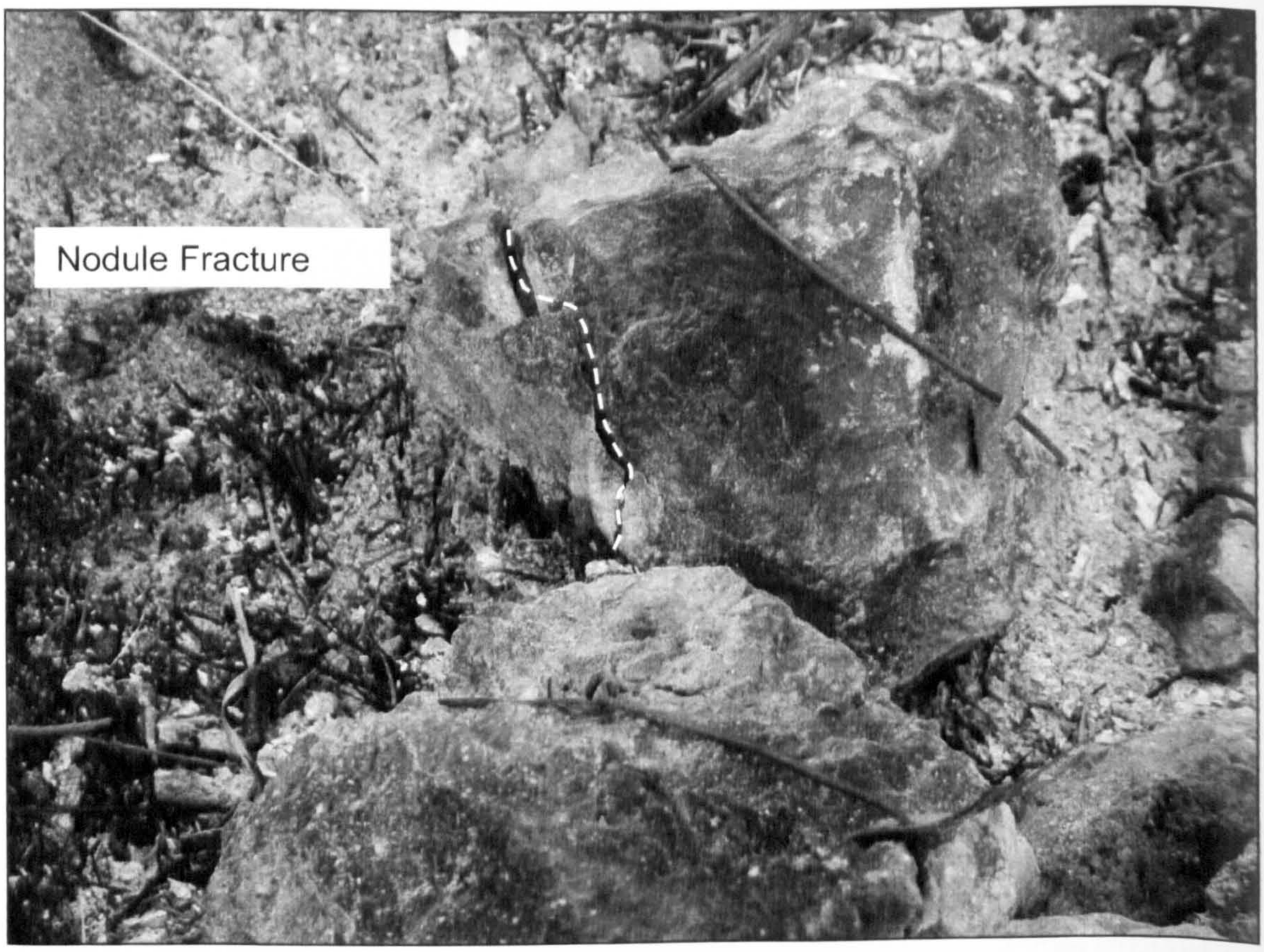


Figure 8. Example of a caliche nodule fracture after burning.



Figure 9. Caliche spalls recovered from the base of EXP-2.

Hearth Life: An Experimental Examination of Site-Formation Processes Acting on Upland Hunter-Gatherer Camp Site Assemblages on the Southern High Plains

Paul N. Backhouse and Eileen Johnson

Manuscript originally published in the journal Plains Anthropologist, 2007
52(202):253-[illegible]

Paul N. Backhouse, Museum of Texas Tech University, Lubbock, TX, 79409 and School of Conservation Sciences, Bournemouth University, Bournemouth, UK, paul.backhouse@ttu.edu.

Eileen Johnson, Museum of Texas Tech University, Lubbock, TX, 79409, eileen.johnson@ttu.edu.

Abstract

Survey and testing results on the Southern High Plains suggest that the material traces of prehistoric camp activity most likely are encountered in upland contexts. These sites are often either exposed on the modern ground surface or are only shallowly buried. Localized thermal features (such as hearths), often represented by hearthstone scatters, are the most commonly encountered prehistoric structural components recorded at such sites. A series of replicative experiments has been conducted in order to understand further the site formation processes acting on these site assemblages. The results of this limited program record a significant relationship between size, potential for loss, and horizontal displacement from the discard location for both flaked lithic and hearthstone specimens. Displacement is primarily the result of cultural processes operating on the assemblage during data collection. Morphologically, hearthstones undergo significant post-depositional structural transformation, while an experimental hearth itself remained largely structurally intact. The results highlight the complexity of interpreting cultural and natural signatures in this highly dynamic and often fragile depositional environment. The program has been successful in the development of a simple straightforward procedure that appears useful for understanding site formation processes for upland sites on the Southern High Plains and may be useful for semi-arid to arid settings.

Keywords: site formation processes, hearth, caliche, Southern High Plains, campsite

Hunter-gatherer campsites (sites with thermal features) on the Southern High Plains are found on the uplands in shallowly buried deposits and on the valley margins in deeply buried contexts. Archaeological investigations have highlighted what appears to be a preference for locating campsites at topographic high points in the upland landscape (Figure 1). The cultural material and features at such sites are often exposed at the modern ground surface and are therefore susceptible to a common range of disturbance processes. A series of experiments has been executed in order to test various assumptions about the archaeological expression of prehistoric campsites. Sites 41LU129 (Jones Station #1) and 41LU1 Area 10 are discussed, as they fit well within this general regional framework for upland site location preferences.

Site 41LU129 is a large multi-component site at which a single hearth feature has been recorded (Figure 2a). The site is situated on the southern rim of Yellowhouse Canyon and affords an excellent vantage point into the canyon at a point where flowing springs (Buffalo Springs) were documented historically within the valley axis (Brune 1981). Site 41LU1 Area 10, located on the rim of Yellowhouse Draw, is a spatially confined area that has been occupied repeatedly over the last 1000 years or more. The site contains numerous hearth basins (Figure 2b), some of which overlap and cross-cut one another (Backhouse 2002; Buchanan 2002).

In comparison to valley, dune, or playa settings, sites located in upland contexts along the rims of draw systems have an increased archaeological visibility. Morphologically, upland sites (including other non-rim settings such as playa sites) are for the most part geographically unconstrained. This type of site frequently is encountered by pedestrian surveys (e.g., Buchanan 1995a; Katz and Katz 1976; Lewis et al. 2002) and is also the most likely to be disturbed by modern activities such as farming.

Investigation of the spatial relationship of features and artifacts in upland rim contexts, therefore, is crucial to an understanding of the complex site formation processes acting on these assemblages and, by extension, the potential to interpret prehistoric behavior patterns from the material record (Sullivan 1998). Site formation processes, including the disturbance of discarded artifacts, continue to be active until an artifact is destroyed or recovered (e.g., Schiffer 1983, 1987). The examination of site formation processes presented here focuses on both the cultural and natural processes that structure the archaeological record.

The life-history of thermal features such as the one excavated at 41LU129 (Figure 2a) provides useful data on site formation processes and a spatial context for the analysis of surrounding artifact scatters. Thermal features comprise any discrete structure with contemporaneous evidence for burning and human activity. A lack of standardization in archaeological terminology has resulted in a vast array of morphological classificatory types becoming established for thermal features that include basin hearths, pit hearths, ovens, burned rock clusters, and wood hearths (Black et al. 1997). Regardless of the terminology used to describe thermal features, their occurrence in archaeological surveys on the Southern High Plains is well-documented (e.g., Backhouse 2002, 2003; Buchanan 1995a, 1995b; Johnson 1994; Katz and Katz 1976; Nickels 2002; Riggs 1986).

On the Southern High Plains, many thermal features appear to have been eroded severely, eventually resulting in amorphous hearthstone scatters with little or no structural integrity (e.g., Buchanan 1995a, 1995b). Upland thermal features with at least some structural integrity, therefore, are comparatively rare in the regional record (e.g., Backhouse 2003; Buchanan 2002). The critical contextual relationship between thermal features and surrounding artifact scatters, in locations of low or no deposition, has received scant attention regionally until recently (Backhouse 2004). A series of experiments was designed in a preliminary effort to understand some of the site

formation processes acting on the upland campsite assemblages of the Southern High Plains.

RESEARCH DESIGN

Experiments were geared toward an increased understanding of prehistoric thermal feature technology and its relationship to structuring prehistoric human behavior at a site level. Specific research objectives sought to address three distinct lines of enquiry through practical experimentation:

1) the extent to which spatial patterning of archaeological materials is altered by cultural and natural processes while exposed on an active ground surface;

2) the transformative effect of exposure to the elements on the morphology of typically recovered artifact classes; and

3) the structural transformation of an abandoned thermal feature over a limited period of time.

ENVIRONMENTAL SETTING

The Southern High Plains (Llano Estacado) is a flat, virtually featureless, plateau located in western Texas and eastern New Mexico (Figure 1). Bounded on three sides by an escarpment, the southern edge merges into the Edwards Plateau. The High Plains surface is blanketed by the aeolian sands of the Blackwater Draw Formation (Holliday 1997). The local drainage system, cut through the bedrock, trends from northwest to southeast across the region and forms the headwaters for several major river systems in Texas.

Despite the aquifers present in the structural geology of the Southern Plains, the Great Plains Province is today water deficient, with annual evapotranspiration exceeding annual precipitation (Osterkamp et al. 1987:182). The Southern High Plains has a continental climate classified as dry semiarid (steppe) (Holliday 1997:9). Precipitation generally increases from west to east and temperature increases from northwest to southeast. Cyclic periods of drought are common events in this landscape and often are linked with range fires that control the spread of trees onto the grasslands (Johnson 2006; Stewart 2002). Rainfall occurs mainly in the spring and fall, although violent summer storms also are common (Johnson 2006). Strong winds are a perennial feature of the Southern High Plains and for much of the year, the wind direction is from the southwest. The development of weather systems with life-threateningly cold winds is common during the winter months (Bomar 1995; Haragan 1983). Examination of local climate data recorded for Lubbock, Texas (an average annual temperature of 15.39°C [59.7°F] and an average annual precipitation of 44.96 cm/yr [17.7 in]) indicates

that only slight mechanical weathering is expected to occur in this environment (Waters 1992:19).

Geoarchaeological work on the Southern High Plains historically has focused on the examination and classification of deeply buried and well-stratified late Quaternary valley fill contained within the incised draw systems (Holliday 1995, 1997; Holliday and Allen 1987; Stafford 1981). In contrast, despite their relative abundance, sites located along the rims of draw systems just now are beginning to receive intensive investigation (Buchanan 2002; Johnson 1995; Lewis et al. 2002). Rim sites typically are shallowly buried or exposed at the modern ground surface because their topographic location prevents mass accumulation of sediment. These sites receive aeolian and slopewash sediments, that then are subject to aeolian deflation and further slopewash. This dynamic interchange has been occurring for at least the last 8,000 to 5,000 years (Stafford 1981:581). Aeolian sediments accumulate on top of either the aeolian deposits of the Blackwater Draw Formation (Quaternary) or the calcrete and aeolian and alluvial deposits of the Ogallala Formation (Miocene-Pliocene), and locally on lacustrine sediments of the Blanco Formation (late Pliocene) (Holliday 1990:491). Culturally relevant deposition along the rims of the draw systems rarely exceeds 50 cm in thickness and often is only between 10 to 15 cm thick.

SITE FORMATION PROCESSES AND UPLAND ASSEMBLAGES

Efforts to record the provenience of artifacts and features at a site level have long been a concern of archaeological field methods (Kroll and Price 1991). The more recent recognition that complex site formation processes act to structure the spatial relationships of these deposits has generated a diverse literature of theoretical as well as methodological propositions (e.g., Binford 1978, 1983; Carr 1991; Gifford-Gonzalez et al. 1985; Hilton 2003; Murray 1980; O'Connell 1987; Schiffer 1976, 1983, 1987; Wandsnider 1996; Yellen 1977). Recent research has sought to integrate elements of earlier ethnographic, quantative, and taphonomic models with an increasing awareness as to the importance of the human - feature relationship as a focus for performance and social life (Gamble 1999; Karkanas et al. 2004:513; Metcalfe and Heath 1990).

Interpretation of human discard behavior should be framed within a wider formational understanding of the processes operating on artifacts and features once they are abandoned or discarded (e.g., Hilton 2003; Stiner et al. 1995). The terminology used follows that previously established by Wandsnider (1996:23; Binford 1983) whereby *structure* pertains to the relationship between individual artifacts and assemblages as a

component of larger site formation processes operating across all spatial and temporal scales.

Preservation issues dictate that artifacts made on lithic materials dominate the archaeological record (Kroll and Price 1991:4). This pattern certainly is the case on the Southern High Plains where surface survey assemblages almost always contain high ratios of lithic artifacts to other artifact types (e.g., Buchanan 1995a, 1995b; Johnson 1994). Two material classes, flaked stone and hearthstones, therefore, have been selected for preliminary experimentation.

Relatively few published estimates are available as to the potential post-depositional dislocation of individual surface artifacts within an upland semi-arid landscape. Kvamme's (1998:130) survey of a portion of the Colorado Plateau used a 4m survey grid with which to assess flaked stone distributional patterns. This example illustrates that the scale of the research area (and by extension, research design) largely dictates the precision required from spatial analysis (Stapert and Street 1997; Wandsnider 1996). A clear need exists to build research questions directed toward a finer-grained empirical awareness of the manner and degree surface sites have been structured by human and non-human actions. Additionally, little examination has occurred of the consequences of non-collection survey (whereby artifacts are spatially plotted without being recovered) on the spatial integrity of assemblages.

Visually advantageous topographic locations with easy access to caliche (an important hearthstone resource) may have been favored as prehistoric campsite locations (Wandsnider 1998). Caliche outcrops along the edges of the incised drainage systems and at the edge of the region as the distinctive caprock. The duration and intensity of occupation at these upland localities is variable over both time and space. Following Stevenson's (1991:276) definition, a site ceases to be short-term when systematic refuse disposal becomes the dominant waste management strategy and secondary refuse deposits overwhelm other types of refuse deposits in area, volume, and number of elements present. Generally, the interpretative assumption is that the material and structures recorded represent short-term camping episodes.

Burned caliche hearthstones comprise the most abundant cultural marker for prehistoric human activities on the Southern High Plains (Backhouse et al. 2002, 2005). The long-term taphonomic processes operating on this ubiquitous artifact type, however, are understood poorly. Specific processes such as bioturbation, freeze/thaw cycles, and mechanical weathering require serious consideration when examining assemblages that have been exposed in low deposition contexts for considerable periods

of time (e.g., Hilton 2003). In an effort to improve this situation, caliche hearthstones have been analyzed prior to and following long-term exposure on a ground surface.

Basin hearth structures constitute a commonly encountered thermal feature class on the Southern High Plains (Johnson 1993, 1995, 2002). This feature morphology, therefore, has been selected as the basis for the structural transformation monitoring portion of the experiment. A basin is identified on the basis of a high diameter to depth ratio (Ellis 1997:60). At 41LU1 Area 10, the basins are filled with hearthstones that often are highly fragmented. The basins themselves are generally between 50 cm and 1 m in diameter and are fairly shallow, ca. 30 cm in depth. Hearthstone counts for each basin are in excess of ca. 2000, although many pieces are fragmentary. Carbonized sediment and charcoal pieces occur throughout the matrix of these features, suggesting that fuel was loaded both above and below the hearthstones.

Deflation processes often are recorded on site survey forms and used to qualify statements regarding remaining site structure (e.g., Briscoe 1989; Drake 1992; Nickels 2001). Regionally, the taphonomic processes acting on thermal features in general and basin hearths in particular remain largely assumed rather than actively investigated. In a preliminary effort toward understanding these processes, a basin hearth structure was constructed at Lubbock Lake Landmark.

THE EXPERIMENT

The methodology adopted attempted to approach the research objectives from a cohesive experimental perspective. All three research objectives were investigated simultaneously in the same experimental area on a single assemblage of replicated prehistoric cultural debris. The first research method sought to track the displacement (if any) of simulated artifacts (hearthstone and flaked lithic) left exposed on the ground surface. These specimens were subjected to both cultural and natural displacement processes throughout the course of the experiment. The second research method examined the morphological variation in the structure of hearthstones after prolonged exposure on the ground surface. The third method examined the visible taphonomic transformations following the abandonment of a basin hearth structure. Experimentation was conducted for a period of one year between July 2003 and July 2004.

Weather conditions for the period of experimentation indicate that the monthly rainfall and temperature readings were fairly typical for the region. Monthly climatological data recorded at the National Oceanic and Atmospheric Administration (NOAA), Lubbock station (LAT 33 39N, LON 101 49W), indicates that, on average, the region received 0.6 cm less rain than is typical (based on 30-year averages).

Temperature data indicate that the period was on average 1.31°C warmer than the 30-year average (data from NOAA, Preliminary Climatological Data (F-6), Lubbock Texas).

Experimental Setup: A 5 m by 5 m area was marked out and cordoned off within the larger established experimental research area at the Lubbock Lake Landmark (Figure 3). The area sloped very gently to the southeast. Existing vegetation comprised patchy native short grasses and intrusive weedy growth. Underlying sediments consisted of a sandy loam fill, brought in over the last decade, over bedrock. The fill was similar to late Holocene aeolian upland sediments encountered during fieldwork along the rims of the draw systems. The ground surface was prepared with modern equipment in order to simulate more accurately the lack of vegetation observed at 41LU129 (Figure 2a).

An artificial assemblage of 119 specimens was selected with which to seed the experimental area and examine any spatial variation over the one-year period. The specimens consisted of 51 flaked stone items and 68 hearthstones. The flaked stone assemblage was used only to test spatial displacement (research method 1), whereas the hearthstone assemblage was used both to test spatial displacement (research method 1) and morphological variation (research method 2). Individual hearthstone and flaked stone specimens were distributed across the modern ground surface within the experimental research area. The specimens were placed away from an experimental hearth located at the center of the area.

The flaked stone assemblage was derived from previous experimental work and was composed primarily of debitage (Table 1). Multiple material sources were utilized, although the majority of the assemblage was made on Edwards Formation chert (84%). Morphological variables were recorded for individual flaked stone specimens at points of maximum dimension (e.g., Andrefsky 1998). Regardless of artifact type, all flaked stone specimens subsequently were grouped into arbitrary size classes based on their recorded maximum measurements (Table 2).

The morphological characteristics of the overall experimental assemblage were dominated by small specimens with maximum dimensions less than 5 cm (Table 3). Some medium-sized flaked stone tools and medium to large hearthstones were included in an effort to simulate the general range of dimensional characteristics that usually are recorded during fieldwork.

The use of caliche in hearthstone technology constitutes a major component of Southern High Plains aboriginal prehistoric thermal technologies (Backhouse et al. 2002, 2005; Johnson 1987; Johnson and Holliday 1986; Lintz 1989). The experimental

hearthstone assemblage, therefore, consisted entirely of caliche nodules gathered locally from an exposure of the Ogallala Fm. within Yellowhouse Canyon. The selected nodules previously had been subjected to one heating episode with proximity temperatures ranging between ca. 70°C and 600°C over a period of six hours as part of a prior experiment (Backhouse et al. 2002, 2005).

Following heating in the experimental hearth, the caliche hearthstones were left in situ for 24 hours to cool. The hearth subsequently was dismantled and individual hearthstones removed for analysis. All hearthstones were cleaned and labeled, as per hearthstones recovered during fieldwork. In an effort to compensate for inter-observer variation, one person recorded the entire assemblage. The three principal variables selected for analysis were size, color and weight. Size was recorded in the same classes as defined for the flaked stone assemblage (Table 3).

Quantification of color followed the previously established methodology (Backhouse et al. 2002, 2005) of employing a standard 1994 US Munsell color chart to record the color for the largest burned surface of each specimen. A high degree of variability was recorded in the observed color values at the individual specimen level. Grouping of individual specimen values using established Munsell color nomenclature resulted in the identification of seven general color groups (Table 4). Dry weight was recorded for each hearthstone specimen with a digital scale (Explorer Ohaus E1H110). Recorded nodule weights ranged from 0.1 to 876.8 g with a mean nodule weight of 104.85 g.

Following quantification, the hearthstones were distributed across the modern ground surface within the experimental research area. Hearthstones remained exposed to the prevailing weather conditions over the course of the spatial experiment. Upon completion, the original person again recorded color and weight for each hearthstone at the end of the experiment.

An EDM (Pentax, PTS-V5, total station) was used to record the spatial locations of the specimens within the experimental area. Survey accuracy was achieved by back-sighting to a known datum (with an acceptable error range of less than 25 mm) prior to mapping. All specimens were mapped on a biweekly basis in order to track any displacement over the course of the experiment. A total of 25 mapping events took place between July 2003 and July 2004. Data capture (mapping) resulted in the intensive utilization of the area by one person for a total of ca. 52 hours over the year. The experimental area remained cordoned off, although various animal species were

observed often within the area. Vegetation control was not maintained during the course of the experiment.

For the structural transformation portion of the experiment (research method 3), a shallow basin was excavated (Figure 3) and the morphology designed to replicate archaeological field examples from Area 10 at 41LU1 (Backhouse et al. 2002, 2005). A diameter of ca. 65 cm and a maximum depth of ca. 30 cm were selected for the feature. A layer of caliche nodules previously unused and unburned was added at the base of the basin. Grasses and larger mesquite limbs were burned directly on top of the caliche layer until the basin could hold no more fuel. The fire was allowed to die down forming an ember bed above the lower caliche layer. At this point, more unburned caliche nodules and mesquite fuel were added until the entire hearth structure was mounded well above the modern ground surface. The fire again was allowed to die down and the hearth subsequently abandoned to the elements.

No further human interference was made to the hearth. The hearth was secured by its location at the center of the area used for the spatial displacement experiment. A program of observation and photography was initiated to document transformations in the morphology of the hearth structure over the subsequent year. The photographer attempted to standardize both the framing and position of the hearth in anticipation of comparative visual analysis. Examination of the hearth occurred on a regular basis over the year as a component of the two other concurrent experimental research designs. On completion of this experiment, the hearth was not disturbed in an effort to continue to monitor longer-term taphonomic processes

RESULTS

Spatial Displacement of Specimens. A distribution plot of the spatial data (Figure 4) shows the initial placement and relationship of the specimens on day one of the experiment (July 2003). Field observations on the last day of the experiment recorded no significant sediment deposition across the study area. Some larger specimens, however, accumulated localized aeolian sediments along one or more of their edges. No obvious directional preference was noted.

Data collection conducted on the last day of the experiment confirms the loss of 20 specimens (16.8%). A distribution plot of the lost specimens reveals some discernable clustering (Figure 5). A greater loss of specimens occurs in an area to the north (a) and an area to the south (b) of the experimental hearth (Figure 5). The most obvious criterion for failing to record individual specimens is size. The smaller the specimen, the harder it is to see in the field during data collection and the more

vulnerable it becomes to post-depositional disturbance (e.g., Gifford-Gonzalez et al. 1985).

A distribution plot of the lost specimens by size class and artifact type (Figure 5) indicates that the majority of the missing specimens are small lithic debitage (n=10) and hearthstones (n=9). The corollary of this result suggests specimen size was a primary factor in explaining loss. Some of the taphonomic processes acting on the missing specimens most likely are: a) specimens concealed from view by burial; b) specimens displaced outside the boundaries of the experimental research area; c) specimens not recorded due to limitations in the researcher's ability to re-identify them; or d) combination of these factors acting on the experimental assemblage. Size appears to be directly related to loss. Displacement, however, can be examined further by a temporal comparison of the spatial data.

Comparison of the initial distribution with that recovered on the last day of the experiment shows variation in the spatial location of individual specimens (Figure 6). The observed variation is not uniform across the experimental assemblage, the displacement of some specimens being slight, whereas displacement of others is more dramatic. For example, hearthstone TTU-E93 has shifted over a meter to the east whereas lithic TTU-E23 (seeded less than 15 cm to the west of TTU-E93) has shifted less than 20 cm (Figure 6). Displacement direction appears to have been a random process, with specimens in close proximity to one another often being shifted in different directions (e.g., compare hearthstones TTU-E110 and TTU-E74).

To compensate for some of the bias inherent in comparing variation between only two sample populations (i.e., comparing only the datasets generated on the first and last days of experimentation), mean spatial values of individual specimen locations during the first two months and last two months of the experiment were plotted. These combined datasets reduced the potential of any isolated data collection or precision problems skewing the dataset. The resultant plot, therefore, was a useful tool to determine if an assemblage-level displacement trend could be identified (Figure 7).

The plot shows significant clustering of specimens close to 0, indicating an overall low rate of displacement for the majority of the specimens in either material type assemblage. Closer examination of the cluster indicates 50.5% of the specimens were displaced less than 20 cm over the course of the experiment. The remaining 49.5% of the specimens were displaced in apparently random directions from their original seeded locations (Figure 7). Differentiation of the spatial displacement of specimens by material type indicates that hearthstones are much more likely to be displaced

significantly as compared to the flaked stone assemblage. A total of 74.1% of the hearthstone assemblage is displaced more than 20 cm. In comparison, only 14.3% of the flaked stone assemblage is shifted beyond 20 cm from its original position (Figure 7).

Hearthstone Morphology. Recovery of the hearthstone assemblage after a period of one year yielded only 58 of the 68 seeded specimens. Field recording over the course of the year noted any obvious transformations at an individual specimen level. For example, specimen TTU-E59 fractured along a pre-existing crack, resulting in two separate hearthstone pieces (Figure 8).

Reanalysis of the recovered hearthstone assemblage reveals a similar distribution of color values as those recorded prior to exposure (Table 4). Comparison of the two datasets confirms only a subtle shift in hearthstone color at an assemblage level (Figure 9). Two tentative trends are apparent in the color data. First, a general shift from dark gray to dark bluish gray colors appears to have occurred. This shift may relate to a physical transformation within the hearthstone assemblage due to interaction with environmental factors, such as chemical weathering. Alternatively, it may be the result of subjective observation criteria, inherent and perhaps unavoidable within the current research design. The second trend appears to be a general homogenization within the color variables, toward color group values around the mid-range (Figure 9). These shifts may be part of the weathering process. While the significance of the color shifts is tentative, they present two potentially useful future avenues for research.

Tabulation of the variation in hearthstone weight prior to and post-experiment revealed an average weight loss of 0.71 g per specimen. Weight loss, however, was not uniform across the experimental assemblage (Figure 10). The vast majority (n=49) of the assemblage exhibited some weight loss, while one specimen showed an increase in weight. The single increase (TTU-E101) was anomalous and most likely the result of an error in weighing during analysis prior to the experiment.

Significant variation was present in the amount of weight loss recorded for the majority of the assemblage (Figure 10). The results ranged between 0.1 and 6.0 g, with the larger variation the result of major fracturing events during the experiment. This situation was confirmed by visual inspection of the hearthstone with the highest recorded weight loss. For example, specimen TTU-E59 was observed as fractured in the field during the experiment (Figure 8) and subsequently showed a decrease of 5.2 g (Figure 10). The source of the lower order variation within the remainder of the assemblage could not be identified.

Hearth Morphology. Over the course of the experiment, the hearth was subjected to a number of extreme weather events including a snowstorm on day 206. Subsequent to the photographs taken on day one, the hearth was photographed four more times: on day 110, day 171, day 237, and day 330 (Figure 11).

The most visually dramatic morphological transformations occurred early on in the experiment (compare Figures 3 and 11a). The fine powder ash and some larger charcoal chunks that covered the exposed surface of the hearth quickly were subject to windborne transport away from the hearth and dispersed outside of the experimental area itself. Intermittent light rain in late August and early September appeared to remove some of the adhering carbonization from the exposed surfaces of the visible hearthstones. Wind abrasion most likely hastened the progress of this process. The result appeared to be an increasing homogenization in the coloration of the exposed hearthstones within the hearth. Some large charcoal chunks were observed on the ground surface outside of the feature. At the same time, larger chunks may have been gradually displaced downward toward the base of the feature as a result of gravity.

More of the internal structure of the hearth was exposed after 110 days than on day 1. Observations taken during this early stage of the experiment indicated the potential of heavier rains to flush larger material out of the hearth and deposit it in nearby contexts. This phenomenon was observed directly following a violent storm that filled the hearth completely with rainwater (day 77). Numerous charcoal chunks were transported up to 30 cm from the hearth during this event. Close examination of the margins of the hearth structure (Figure 11a) showed that some limited deposition appeared to have occurred. Hearthstones at the base of the margin slope in the foreground of the picture were buried partially by sediment accumulation. Some carbon staining was still visible at the top of the slope. Two large charcoal chunks also were visible along the basin margin.

After 171 days of exposure, a general transformation in the outline of the visible portion of the hearth occurred (Figure 11b). Accumulation of aeolian sediment and small pieces of wind-transported vegetative material (leaves, small sticks, dead weeds) resulted in the increased burial of the lowermost hearthstones and a subtle shift to a more elliptical overall form. Little variation was evident in the spatial structure of the visible internal hearthstones.

By day 237, infilling of sediment had lessened the variation between the modern ground surface and margins of the hearth to a point whereby differentiation between the two was difficult (Figure 11c, note the lower portion of the photograph). The basic

outline of the hearth, however, was readily apparent and would be identified easily. The spatial arrangement of the internal hearthstones did not appear to have undergone any displacement.

Beginning in the spring and continuing throughout the remainder of the experiment, invasive vegetation began to grow within the hearth itself (Figure 11d). The basin acted as a trap for airborne seeds dispersed during the previous summer and fall. The seeds subsequently germinated and thrived in the well-drained sediments provided by the caliche-choked basin. Comparison of the vegetation density within the hearth with that contained in the experimental area appeared to confirm this situation.

DISCUSSION

The results of this integrated program of research highlight the dynamic nature of upland hunter-gatherer sites and further posits experimentation as a useful tool in understanding the complex site formation processes that act on such assemblages. The loss of 16.8% of the specimens seeded within the area is significant in that it appears to be a function of artifact size and to some extent artifact type (Figure 12). Artifact size has been recognized as a prime factor in studying the effects of formation processes (Schiffer 1983, 1987). The failure to recover some of the small specimens during the present experiment likely is the result of aeolian burial (Behrensmeyer and Boaz 1980), wind transport (Schiffer 1983), vertical displacement by people and animals (Gifford-Gonzalez et al. 1985), or a combination of these factors. Loss most likely resulted from people walking around the area with the prism pole during data collection efforts. This process would have pushed smaller specimens underfoot into the ground surface, excluding them from future data collection. The lost specimens most likely could be recovered by limited excavation and screening.

Results from the spatial patterning experiment indicated that the general visible spatial arrangement of specimens remained largely intact at an assemblage level (Figure 7). Spatial variation at a specimen level was more pronounced and appears to be related to artifact type (Figure 7). The dislocation and movement of hearthstones was found to be far more likely than that of flaked stone (Figure 7). A spatial distribution of displacement plotted by artifact size class indicated that artifact size as well as artifact type again are important variables (Figure 12). In general, hearthstones of the medium and large-size classes were the most susceptible to displacement. Where flaked stone material had been displaced, the larger specimens again were the most prone (medium-size class, e.g., TTU-E45, TTU-E49, TTU-E51).

Rainfall patterns may have been responsible for the displacement of some specimens. If rainfall were the prime variable in the displacement, then a predictable pattern should exist in the selective displacement of the smaller and more easily transported material. Furthermore, a general gravitational model of specimen displacement of similar-size classes might be expected. This type of displacement did not appear to have been significant in the experimental data. Larger-size class objects were much more likely to be displaced in fairly random directions (Figure 12). The dislocation effect of rainfall on specimens most likely was more subtle than the resolution of the present dataset. Long-term artifact exposure and violent rain events would require further experimentation to gauge their effect on artifact displacement. The shape of specimens was not a measured variable in this study but should be examined in relation to the likelihood for displacement by disturbance factors.

Human activity within the experimental area appears to be the primary responsible agent for the spatial dislocation of some specimens. If people caused this horizontal displacement, then accidental human action is very much an active factor in assessing displacement during the prehistoric human occupation of a site. Intermittent pedestrian traffic (including archaeological research) also should be expected after a camp has been abandoned. Recent ethnographic studies (Galanidou 2000) have emphasized the complexity and dynamism of human behaviors at a site level and the difficulty in identifying these behaviors from the archaeological record. The results of this initial spatial analysis appear to validate a general size sorting model that may be useful in understanding cultural site formation processes and the spatial patterning of artifacts at a site scale and are also a useful avenue of research for more refined experimental testing.

Based on the results of the hearthstone morphological analysis at an assemblage level, two general trends were identified. Hearthstones appeared to continue to lose weight and become increasingly standardized in coloration during periods of prolonged exposure. Variability was present, however, in the assemblage at a specimen level.

Weight loss was in the order of less than 1% of the individual hearthstone weight. Large-scale fracturing was observed on only a small number of the overall assemblage (n=3 specimens). Therefore, at least one other process was responsible for the weight reduction. Possible explanations included: mechanical weathering processes acting to gradually reduce the external surfaces; water loss from the internal structure (Hennessey et al. 1983); small-scale flaking of the outer surface (Backhouse et al. 2002, 2005); or a combination of these processes.

The basin hearth taphonomy experiment provided visual data with which to study how such structures, once abandoned, become part of the archaeological record. Results indicated that the majority of evidence for a fire, largely organic (stained sediment, charcoal chunks, ash), were removed quickly from the structure. A combination of wind and water action cleaned out the internal structure of the feature while simultaneously removing much of the adhering carbon staining from the surfaces of exposed hearthstones. With much of the internal matrix quickly removed, the main indicator for a hearth's presence quickly became the internal hearthstones. The structure of hearthstones remained constant throughout the experiment; and the basin structure remained largely intact. Therefore, archaeologically, those upland hearths that retain stained sediment, charcoal, and ash must have been buried fairly rapidly after abandonment.

During the fall and winter, the hearth acted as a trap for airborne sediments and general vegetation debris. Sediments began to build up around the perimeter of the base of the hearth basin and at the same time the edges began to erode, losing some of their structure and internal geometry. Vegetation appeared to thrive within the basin during the following spring and summer as a result. Although the long-term effects of this phenomenon are unknown, continued vegetation growth may intensify the displacement of hearthstones through increased bioturbation. If the phenomenon was maintained over time, the implication for archaeological survey would be to target rather than avoid dense weed concentrations.

The three lines of enquiry explored were selected for their research potential in understanding how site formation processes affect archaeological sites in upland contexts. The site formation processes explored were generally specific to most semi-arid to arid upland contexts, but not to the idiosyncrasies encountered at a site-specific level. The spatial displacement of artifacts would be dependant on a complex web of variables that cannot be differentiated easily between factors related to site occupation or post-abandonment formation processes.

The most obvious result from all three lines of enquiry is that both material assemblages (flaked stone and hearthstone) and the hearth basin were visible after an elapsed time period of one year. This situation is pertinent in terms of site location preferences at a regional scale. All things being equal, upland locations along the rims of draw systems would be unconstrained in terms of space allocation. Therefore, the reasons for serial occupation of specific rim locations, at which the discarded material culture of the previous occupations would be ubiquitous, require further investigation.

Although beyond the scope of this paper, research might include landscape-based studies (e.g., Dooley 2004; Schlanger 1992) in which persistent places are identified and related to nearby economic resources. Wide-scale recycling of non-organic materials also may have been a factor in campsite location on the Southern High Plains.

The spatial displacement experiment showed a covariance in results between the extent of dislocation observed with two different but commonly occurring artifact types. The size of a particular artifact appeared to control the degree to which it was displaced. The research design controlled for and excluded most major regional disturbance processes (e.g., plowing, construction). Yet, the degree to which some specimens were displaced over the course of the year was significant. Based on present data, even a minimal human presence might cause a substantial shift in the relative location of larger artifacts to one another as well as to structured features (such as hearths or post holes).

This process may have been most active where occupation was brief enough not to warrant systematic refuse disposal (Stevenson 1991) as people moved around and engaged in different activities. Reoccupation of a locality would compound these contextual problems particularly in terms of material feature relationships. Importantly, these results may help to explain some of the site formation processes active in the spread of debris across active occupation surfaces. Furthermore, they indicate that the detailed spatial recording of small artifact classes, such as lithic debitage, is extremely worthwhile as it is precisely these small artifact classes that appear less prone to horizontal spatial dislocation than do larger artifact classes (Dunnell and Stein 1989; Metcalfe and Heath 1990; Sherwood 2001).

The reductive transformative process identified during caliche hearthstone use (Backhouse et al. 2002, 2005; Lintz 1989) appears to continue and perhaps intensifies following discard. The processes that result in a loss of mass (through fracturing and other events) are initiated during heating. Subsequent breakup of some of the exposed hearthstone assemblage suggest that small hearthstones and hearthstone bits (less than 10 g) recovered in the archaeological record most likely are the indirect result of cultural utilization and the direct result of post-depositional processes.

Observations on the extant surfaces of the hearthstones suggest the initial variability in coloration recorded among hearthstones may trend toward more homogenous color ranges as a function of time and surface exposure (Figure 12). This situation would impinge on accurately inferring (from coloration characteristics) the degree to which a particular hearthstone had been burned during utilization (Backhouse et al. 2002, 2005; Lintz 1989). The relationship between hearthstones that have been

exposed for a long time and those that underwent rapid burial before recovery remains to be explored.

CONCLUSIONS

The three integrated experiments generated a wealth of data that are relevant to understanding the general site formation processes acting on upland prehistoric site assemblages. The results represent a preliminary investigation into site formation processes in an upland setting, forming a general basis for future research.

The experiments sought to examine some of the site formation processes acting on prehistoric hunter-gatherer site assemblages located in upland contexts on the Southern High Plains. Results represent a first approximation and require further quantification as well as expanded research design. All three experiments recorded and identified at least one major site formation process that acted to disrupt the structure and context of the experimental material culture.

Six main conclusions are drawn from this research. First, smaller artifacts are less likely to be recovered than larger specimens. Larger artifacts are prone to accidental horizontal displacement by cultural processes. Small artifacts are prone to accidental vertical displacement by cultural processes. Caliche hearthstones can undergo significant structural transformations following discard. Initial variation in caliche hearthstone coloration appears to trend toward homogeneity as a function of time or exposure. Lastly, the structure of an abandoned basin-hearth structure changes little during the first year of exposure. In terms of archaeological analysis, these results provide a more detailed knowledge of upland site formation processes and, therefore, a more solid basis with which to assess human behavior at site specific scales.

ACKNOWLEDGEMENTS

The authors would like to thank the field crew who recorded "the same bunch of artifacts" in diverse and challenging weather conditions with enthusiasm and patience (Alejandra Mataresse, Dan Rafuse, Blake Morris, Alexander Brackenreed-Johnston, and Agustina Massigoge); Dr. Briggs Buchanan (University of British Columbia) for comments on an early draft; and Dr. Alston Thoms (Texas A&M University) and an anonymous reviewer for their positive suggestions. Tara Backhouse provided all photography and Karina Houle conducted the analysis for the hearthstone taphonomy experiment. This research was funded by the Museum of Texas Tech University and the City of Lubbock. The manuscript represents part of the ongoing Lubbock Lake Landmark regional research into grasslands hunter-gatherers and adaptation to ecological change on the Southern Plains.

REFERENCES CITED

Andrefsky, William Jr.
1998 *Lithics: Macroscopic Approaches to Analysis*. Cambridge University Press, Cambridge.

Backhouse, Paul N.
2002 Excavation Program at 41LU1 Area 10 for the 2000 Field Season. In Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work, edited by Eileen Johnson, pp. 183-194. Museums of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 11.

2003 The 2001 Archaeological Investigations at Tahoka Lake (41LY52) Area 14. In *Explorations At Tahoka Lake, A Salina on the Llano Estacado: the 2000 and 2001 Field Seasons*, edited by Eileen Johnson, pp. 65-83. Museum of Texas Tech University, Lubbock.

2004 Conceptualizing the Social Use of Space Around a Prehistoric Hearth Pit. Paper presented at the 69th Annual Meeting of the Society for American Archaeology, Montreal, Canada.

Backhouse, Paul N., Briggs Buchanan, Alexander Brackenreed-Johnston, and Eileen Johnson.
2002 Experimental Burned Caliche – Analytical Issues. Paper presented at the 60th Plains Anthropological Society Conference, Oklahoma City, Oklahoma.

Backhouse, Paul N., Eileen Johnson, Alexander Brackenreed-Johnston, and Briggs Buchanan.
2005 Experimental Hearths and the Thermal Alteration of Caliche on the Southern High Plains. *Geoarchaeology*, 20(7):695-716.

Behrensmeyer, Anna K., and Dorothy E. Dechant Boaz
1980 The Recent Bones of Amboseli National Park, Kenya, in Relation to East African Paleoecology. In *Fossils in the Making: Vertebrate Taphonomy and Paleoecology*, edited by Anna K. Behrensmeyer and A.P. Hill, pp. 72-92. University of Chicago Press, Chicago.

Binford, Lewis R.
1978 Dimensional Analysis of Behavior and Site Structure: Learning from an Eskimo Hunting Stand. *American Antiquity* 43(3):330-361.

1983 *In Pursuit of the Past*. Thames and Hudson, New York.

Black, Stephen L., Linda W. Ellis, Darrell G. Creel, and Glen T. Goode
1997 *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas*. Texas Archaeological Research Laboratory, Studies in Archaeology, No 22, The University of Texas at Austin.

Bomar, George W.
1995 *Texas Weather*, 2nd ed. University of Texas Press, Austin.

Briscoe, James
1989 Site Survey Form for 41GY54. Manuscript on file, Texas Archaeological Research Laboratory, Austin.

Brune, Gunnar
1981 *Springs of Texas, Volume 1*. Branch Smith Inc., Fort Worth.

Buchanan, Briggs
1995a Archaeological Background for Lubbock County. In Playa Archaeology/Archaeological Investigations at Reese Air Force Base and Terry County Auxiliary Airfield, Lubbock and Terry Counties, edited by Eileen Johnson, pp. 39-80. Museum of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 9.

1995b Archaeological Background for Terry County. In Playa Archaeology/Archaeological Investigations at Reese Air Force Base and Terry County Auxiliary Airfield, Lubbock and Terry Counties, edited by Eileen Johnson, pp. 81-110. Museum of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 9.

2002 Excavation Program at 41LU1 Area 10 for the 1993 through 1997 Field Seasons. In Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work, edited by Eileen Johnson, pp. 139-160. Museums of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 11.

Carr, Christopher
1991 Left in the Dust: Contextual Information in Model-Focused Archaeology. In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll and T. Douglas Price, pp.221-256. Plenum Press, London.

Dooley, Mathew A.
2004 Long-Term Hunter-Gatherer Land Use in Central North-Dakota: An Environmental Analysis. *Plains Anthropologist* 49(190):105-128.

Drake, D.
1992 Site Survey Form for 41GA51. Manuscript on file, Texas Archaeological Research Laboratory, Austin.

Dunnell, Robert C. and Julie K. Stein
1989 Theoretical Issues in the Interpretation of Microartifacts. *Geoarchaeology,* 4: 31–42.

Ellis, Linda W.
1997 Hot Rock Technology. In *Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas*, edited by Stephen Black, Linda W. Ellis, Darrell G. Creel, and Glen T. Goode, pp. 43-76. Texas Archaeological Research Laboratory, Studies in Archaeology, No 22, The University of Texas at Austin.

Galanidou, Nena
2000 Patterns in Caves: Foragers, Horticulturists, and the Use of Space. *Journal of Anthropological Archaeology* 19:243-275.

Gamble, Clive
1999 *The Paleolithic Societies of Europe*. Cambridge University Press, Cambridge.

Gifford-Gonzalez, Diane P., David B. Damrosch, Debra R. Damrosch, John Pryor, and Robert L. Thunen
1985 The Third Dimension in Site Structure: An Experiment in Trampling and Vertical Dispersal. *American Antiquity* 50(4):803-818.

Haragan, Donald R.
1983 *Blue Northers to Sea Breezes: Texas Weather and Climate*. Hendrick-Long Publishing Co., Dallas.

Hennessey, J.T., J. M. Gibbens, and M. Cardenas
1983 Water Properties of Caliche. *Journal of Range Management* 36(6):723-726.

Hilton, Michael R.
2003 Quantifying Postdepositional Redistribution of the Archaeological Record Produced by Freeze–Thaw and Other Mechanisms: An Experimental Approach. *Journal of Archaeological Method and Theory* 10(3):165-201.

Holliday, Vance T.
1990 Soils and Landscape Evolution of Eolian Plains: The Southern High Plains of Texas and New Mexico. *Geomorphology* 3:489-515.

1995 Late Quaternary Stratigraphy of the Southern High Plains. In *Ancient Peoples and Landscapes*, edited by Eileen Johnson, pp. 289-313. Museum of Texas Tech University, Lubbock.

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

Holliday, Vance T., and B.L. Allen
1987 Geology and Soils. In *Lubbock Lake. Late Quaternary Studies on the Southern High Plains*, edited by Eileen Johnson, pp. 14-21. Texas A&M University Press, College Station.

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

1993 Late Holocene Investigations at the Lubbock Lake Landmark. Volume 1. The 1988 Work. Museum of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 5:1-243.

1994 Archaeological Survey Along the Mobil ESTE CO_2 Pipeline Corridor from Denver City to Clairemont, Texas. Museum of Texas Tech University, Museums of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 6:1-238.

1995 Excavation Program. In Late Holocene Investigations at the Lubbock Lake Landmark, Volume 2. The 1989 and 1990 Work, edited by Eileen Johnson, pp. 65-123. Museums of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 8.

2002 Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work. Museum of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 11:1-323.

2006 Grassland Ecosystems of the Llano Estacado. In Shrubland Dynamics: Fire & Water, edited by Ronald E. Sosebee and David Wester. USDA Forest Service. Report, in press.

Johnson, Eileen, and Vance T. Holliday
1986 The Archaic Record at Lubbock Lake. In *Current Trends in Southern Plains Archaeology*, edited by Timothy G. Baugh, pp.7-54. Memoir 31. Plains Anthropologist Memoir.

Karkanas, P., M. Koumouzelis, J.K. Kozlowski, V. Sitlivy, K. Sobczyk, F. Berna, and S. Weiner
2004 The Earliest Evidence for Clay Hearths: Aurignacian Features in Klisoura Cave 1, Southern Greece. *Antiquity* 78(301):513-525.

Katz, Paul and Susana Katz
1976 Archaeological Investigations in Lower Tule Canyon Briscoe County, Texas. Museum of Texas Tech University, *Archaeological Survey Report* 16:1-139.

Kroll, Ellen M., and T. Douglas Price
1991 Introduction. In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll and T. Douglas Price, pp.1-5. Plenum Press, London.

Kvamme, Kenneth L.
1998 Spatial Structure in Mass Debitage Scatters. In *Surface Archaeology*, edited by Alan P. Sullivan III, pp. 127-141. University of New Mexico Press, Albuquerque.

Lewis, Patrick, Mathew Gill, Briggs Buchanan, and Stuart M. Selwood
2002 Lubbock Lake Survey Program for the 1991 through 1997 Field Seasons. In Holocene Investigations at the Lubbock Lake Landmark. The 1991 through 2000 Work, edited by Eileen Johnson, pp. 19-48. Museums of Texas Tech University, *Lubbock Lake Landmark Quaternary Research Center Series* 11.

Lintz, Christopher
1989 Experimental Thermal Discoloration and Heat Conductivity Studies of Caliche from Eastern New Mexico. *Geoarchaeology* 4(4): 319-346.

Metcalfe, Duncan and Kathleen M. Heath
1990 Microrefuse and Site Structure: The Hearths and Floors of Heartbreak Hotel. *American Antiquity* 55(4):781-796.

Murray, Priscilla
1980 Discard Location: The Ethnographic Data. *American Antiquity* 45(3): 490-502.

Nickels, David L.
2001 Site Survey Form for 41CB147. Manuscript on file, Texas Archaeological Research Laboratory, Austin.

2002 A Cultural Resource Inventory of the L7 Ranch, Crosby County, Texas. Southwest Texas State University, Center for Archaeological Studies, *Archaeological Studies Report* 1:1-280.

O'Connell, James F.
1987 Alyawara Site Structure and Its Archaeological Implications. *American Antiquity* 52(1):74-108.

Osterkamp, Waite R., Mark M. Fenton, Thomas C. Gustavson, Richard F. Hadley, Vance T. Holliday, Roger B. Morison, and Terrence J. Toy
1987 Great Plains. In *Geomorphic Systems of North America*, edited by William L. Graf, Boulder, Colorado: Geologic Society of America, Centennial Special Volume 2, 163-210.

Riggs, Aaron D. Jr.
1986 Comments on a Hearth. In *Selected Articles from the South Plains Archaeological Society Newsletters*, edited by Frank Runkles, Aaron Riggs Jr., Frank Cox, and Beverly Brantley, pp. 50. South Plains Archaeological Society, Lubbock.

Schiffer, Michael
1976 *Behavioral Archaeology*. Academic Press, New York.

1983 Toward the Identification of Formation Processes. *American Antiquity* 48(4):675-706.

1987 *Formation Processes of the Archaeological Record.* University of Utah Press, Salt Lake City.

Schlanger, Sarah H.
1992 Recognizing Persistent Places in Anasazi Settlement Systems. In *Space, Time, and Archaeological Landscapes*, edited by Jacqueline Rossignol and Luann Wandsnider, pp. 91-112. Plenum Press, New York.

Sherwood, Sarah C.
2001 Microartifacts. In *Earth Sciences and Archaeology*, edited by Paul Goldberg, Vance T. Holliday, and C. Reid Ferring, pp. 327–351. Kluwer Academic/Plenum, New York.

Stafford, Thomas Jr.
1981 Alluvial Geology and Archaeological Potential of the Texas Southern High Plains. *American Antiquity* 46(3):548-585.

Stapert, Dick and Martin Street
1997 High Resolution or Optimum Resolution? Spatial Analyses of the Federmesser Site at Andernach, Germany. *World Archaeology* 29(2):172-194.

Stevenson, Marc G.

1991 Beyond the Formation of Hearth-Associated Artifact Assemblages. In *The Interpretation of Archaeological Spatial Patterning*, edited by Ellen M. Kroll and T. Douglas Price, pp.269-299. Plenum Press, London.

Stewart, Omer C.,
2002 *Forgotten Fires: Native Americans and the Transient Wilderness*. University of Oklahoma Press, Norman.

Stiner, Mary C., Steven L. Kuhn, Stephen Weiner, and Ofer Bar-Yosef
1995 Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone. *Journal of Archaeological Science* 22:223-237.

Sullivan III, Alan P.
1998 *Surface Archaeology*. University of New Mexico Press, Albuquerque.

Wandsnider, LuAnn
1996 Describing and Comparing Archaeological Spatial Structures. *Journal of Archaeological Method and Theory* 3(4):319-384.

1998 Landscape Element Configuration, Lifespace, and Occupation History: Ethnoarchaeological Observations and Archaeological Applications. In *Surface Archaeology*, edited by Alan P. Sullivan III, pp.21-39. University of New Mexico Press, Albuquerque.

Waters, Michael R.
1992 *Principles of Geoarchaeology: A North American Perspective*. University of Arizona Press, Tucson.

Yellen, John
1977 *Archaeological Approaches to the Present: Models for Reconstructing the Past*. Academic Press, New York.

Table List

Table 1. Flaked stone artifact types used in the spatial experiment.

Table 2. Size class grouping scheme for specimens used in the spatial experiment.

Table 3. Size classes for specimens used in the spatial experiment.

Table 4. Munsell color groups observed on hearthstones prior to and post experiment 2 (note: individual identification numbers presented in cells; for cells with no fill the color group was unchanged post experiment; for cells with dark fill the color group was darker post experiment; for cells with a light fill the color group was lighter post experiment).

Figure List

Figure 1. Southern High Plains (Llano Estacado) physiographic province with location of prehistoric sites with identified thermal features indicated (note: map includes campsites identified within a ten mile radius of the Southern High Plains).

Figure 2. Example of types of thermal features encountered in upland contexts on the Southern High Plains: a) FA1-1 at 41LU129; b) site plan showing intersecting features at 41LU1 Area 10.

Figure 3. Experimental research area during set up in July 2003 (note: the hearth still burning in the center of the area).

Figure 4. Spatial location of specimens by artifact type on day 1 of the experiment.

Figure 5. Original location of specimens not recovered at the end of the 1 year period by size class and artifact type.

Figure 6. Location of specimens on day 1 of the experiment and displacement arrows showing their final recovery locations.

Figure 7. Graphed artifact displacement from initial location by artifact type; total numbers of specimens in each quadrant by artifact type as indicated (note: artifact locations represent an average of the first four mapping episodes [July-September 2003] versus an average of the last four mapping episodes [June-July 2004]).

Figure 8. Fracture and reduction in the morphology of hearthstone TTU-E59: a) prior to the experiment; b) post-experiment.

Figure 9. Comparison of Munsell color group variation recorded for hearthstones prior to and directly following the experiment.

Figure 10. Variation in recorded dry weights for hearthstones prior to and directly following the experiment (note: position of TTU-E59).

Figure 11. Experimental hearth photographed over the course of the experiment: a) day 110; b) day 171; c) day 237; d) day 330 (note: for (c), the hearthstones at the periphery of the hearth area are part of the spatial displacement experiment).

Figure 12. Location of specimens, by size class and artifact type, on day 1 of the experiment and displacement arrows showing their final recovery positions.

Table 1. Flaked stone artifact types used in the spatial experiment.

Artifact Type	Quantity
Biface	5
Lithic flake	36
Lithic debris	8
Core	2
Total	51

Table 2. Size class grouping scheme for specimens used in the spatial experiment.

Size class	Description	Maximum dimension range (cm)
1	small	less than 5 cm
2	medium	between 5 and 15 cm
3	large	between 15 and 30 cm

Table 3. Size classes for specimens used in the spatial experiment.

Material Type	Small (1)	Medium (2)	Large (3)	Total
Flaked stone	45	6	0	51
Hearthstone	34	31	3	68
Total	79	37	3	119

Table 4. Munsell color groups observed on individual hearthstones prior to and post experiment 2 (note: individual identification numbers presented in cells; for cells with no fill the color group was unchanged post experiment; for cells with dark fill the color group was darker post experiment; for cells with a light fill the color group was lighter post experiment).

Original Color (Munsell Color Name Group)	Color following Experiment (Munsell Color Name Group)						
	white	bluish gray	dark gray	dark bluish gray	very dark gray	very dark bluish gray	black
white	TTU-E-87						
gray			TTU-E-79				
dark gray				TTU-E-52			
dark gray				TTU-E-53			
dark gray				TTU-E-54			
dark gray				TTU-E-56			
dark gray			TTU-E-67				
dark gray		TTU-E-69					
dark gray		TTU-E-73					
dark gray				TTU-E-76			
dark gray				TTU-E-85			
dark gray			TTU-E-90				
dark gray				TTU-E-97			
dark gray				TTU-E-100			
dark gray				TTU-E-102			
dark gray				TTU-E-103			
dark gray				TTU-E-105			
dark gray		TTU-E-109					
dark gray				TTU-E-113			
dark gray		TTU-E-115					
dark gray			TTU-E-116				
dark bluish gray				TTU-E-57			
dark bluish gray				TTU-E-61			
dark bluish gray				TTU-E-63			
dark bluish gray			TTU-E-65				
dark bluish gray			TTU-E-68				
dark bluish gray				TTU-E-75			
dark bluish gray				TTU-E-83			
dark bluish gray				TTU-E-107			

Original Color (Munsell Color Name Group)	Color following Experiment (Munsell Color Name Group)
very dark gray	TTU-E-58
very dark gray	TTU-E-59
very dark gray	TTU-E-64
very dark gray	TTU-E-66
very dark gray	TTU-E-70
very dark gray	TTU-E-71
very dark gray	TTU-E-72
very dark gray	TTU-E-86
very dark gray	TTU-E-89
very dark gray	TTU-E-106
very dark gray	TTU-E-111
very dark gray	TTU-E-112
very dark gray	TTU-E-114
very dark gray	TTU-E-117
very dark bluish gray	TTU-E-78
very dark bluish gray	TTU-E-55
very dark bluish gray	TTU-E-92
black	TTU-E-74
black	TTU-E-81
black	TTU-E-82
black	TTU-E-88
black	TTU-E-91
black	TTU-E-93
black	TTU-E-98
black	TTU-E-99
black	TTU-E-101
black	TTU-E-110

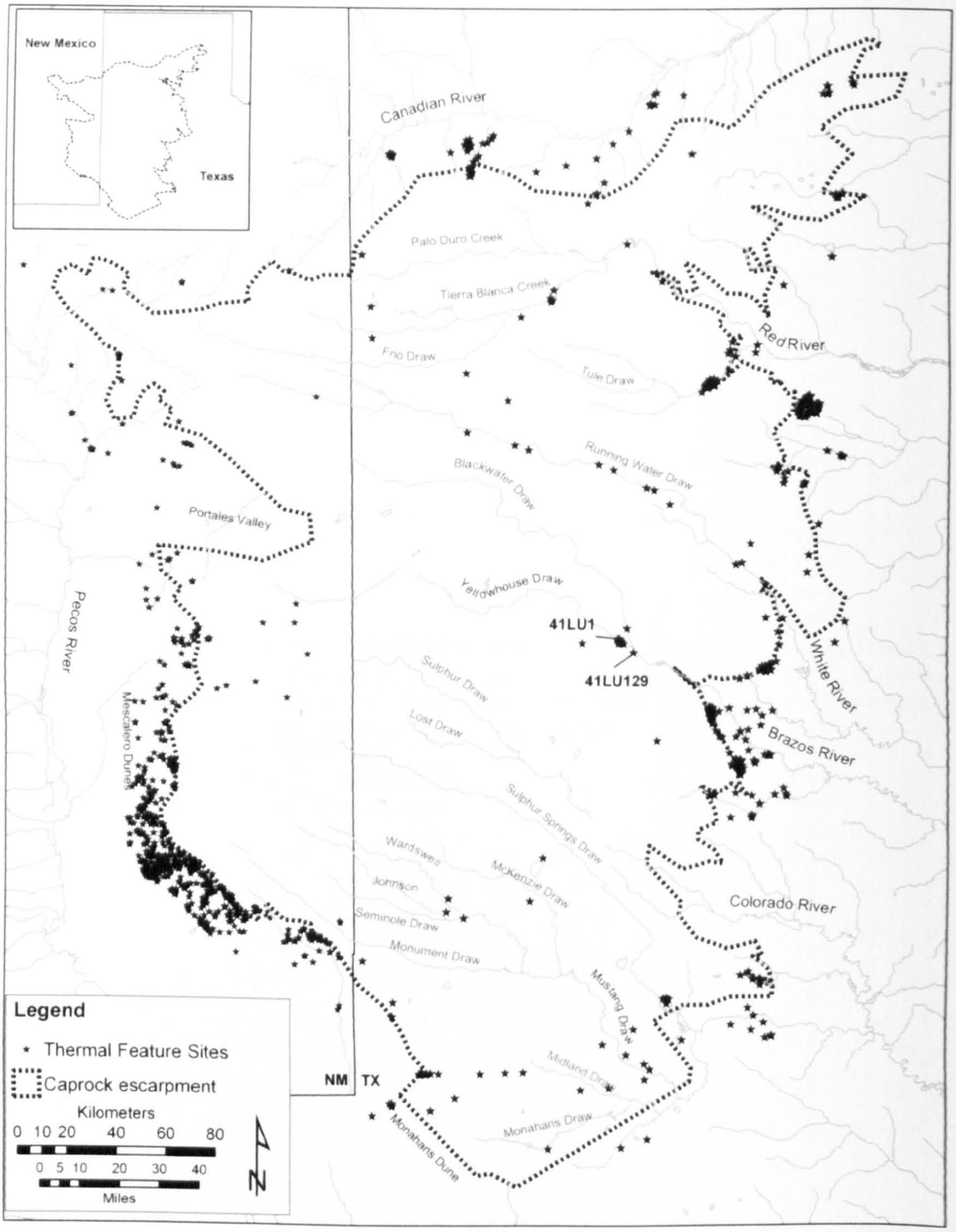
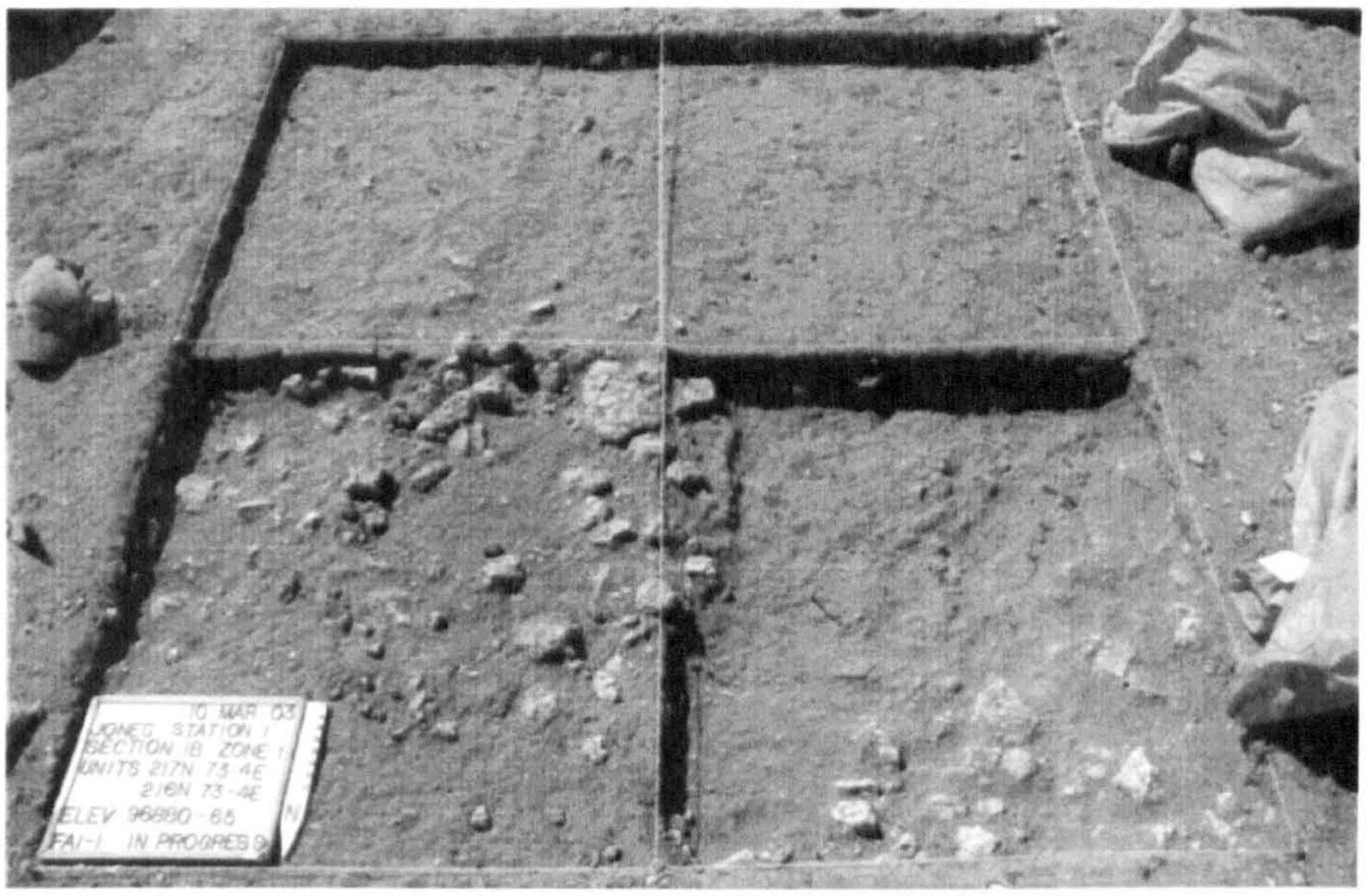
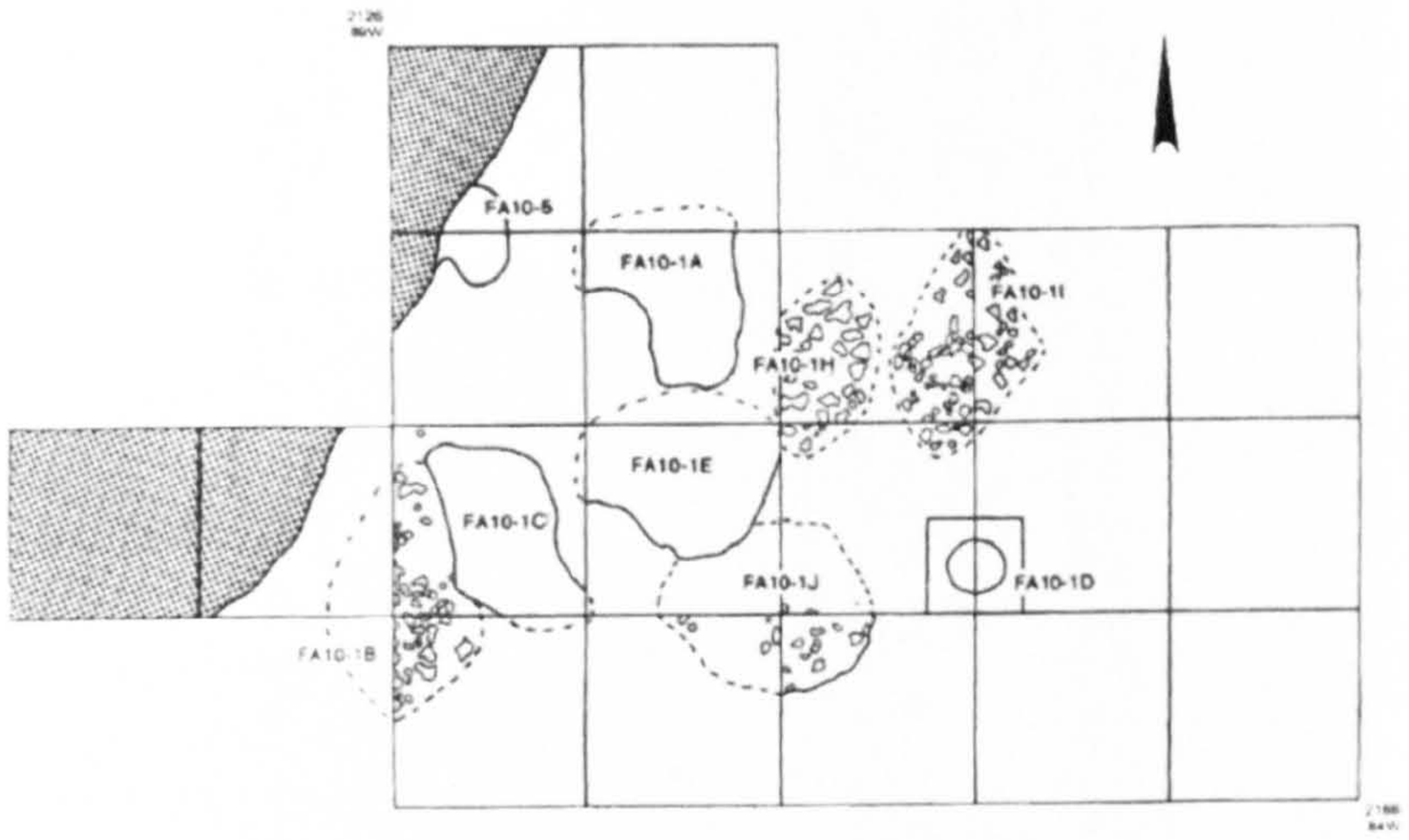

New Mexico
Texas
Canadian River
Palo Duro Creek
Tierra Blanca Creek
Frio Draw
Tule Draw
Red River
Blackwater Draw
Running Water Draw
Yellowhouse Draw
41LU1
41LU129
White River
Brazos River
Sulphur Draw
Lost Draw
Sulphur Springs Draw
Wardsweg
McKenzie Draw
Johnson
Seminole Draw
Monument Draw
Mustang Draw
Colorado River
Midland Draw
Monahans Draw
Monahans Dune
Portales Valley
Pecos River
Mescalero Dunes
NM
TX
Legend
Thermal Feature Sites
Caprock escarpment
Kilometers
0 10 20 40 60 80
0 5 10 20 30 40
Miles
N

Figure 1.


10 MAR 63
JONES STATION 1
SECTION 18 ZONE 1
UNITS 217N 73 4E
216N 73 4E
ELEV 96890 - 65
FAI-1 IN PROGRESS

a.


FA10-5
FA10-1A
FA10-1H
FA10-1I
FA10-1E
FA10-1C
FA10-1J
FA10-1D
FA10-1B
PIPE TRENCH
OUTLINE OF EXCAVATED PITS
BURNT CALICHE CONCENTRATIONS (UNEXCAVATED PITS)
PROJECTED OUTLINE OF PITS (FROM SOIL COLOR DESIGNAIONS)
LUBBOCK LAKE LANDMARK
41LU1 AREA 10 MAIN EXCAVATION BLOCK
DESIGNATED HEARTH PITS
MJH/SMS/LLL/1999

b.

Figure 2.

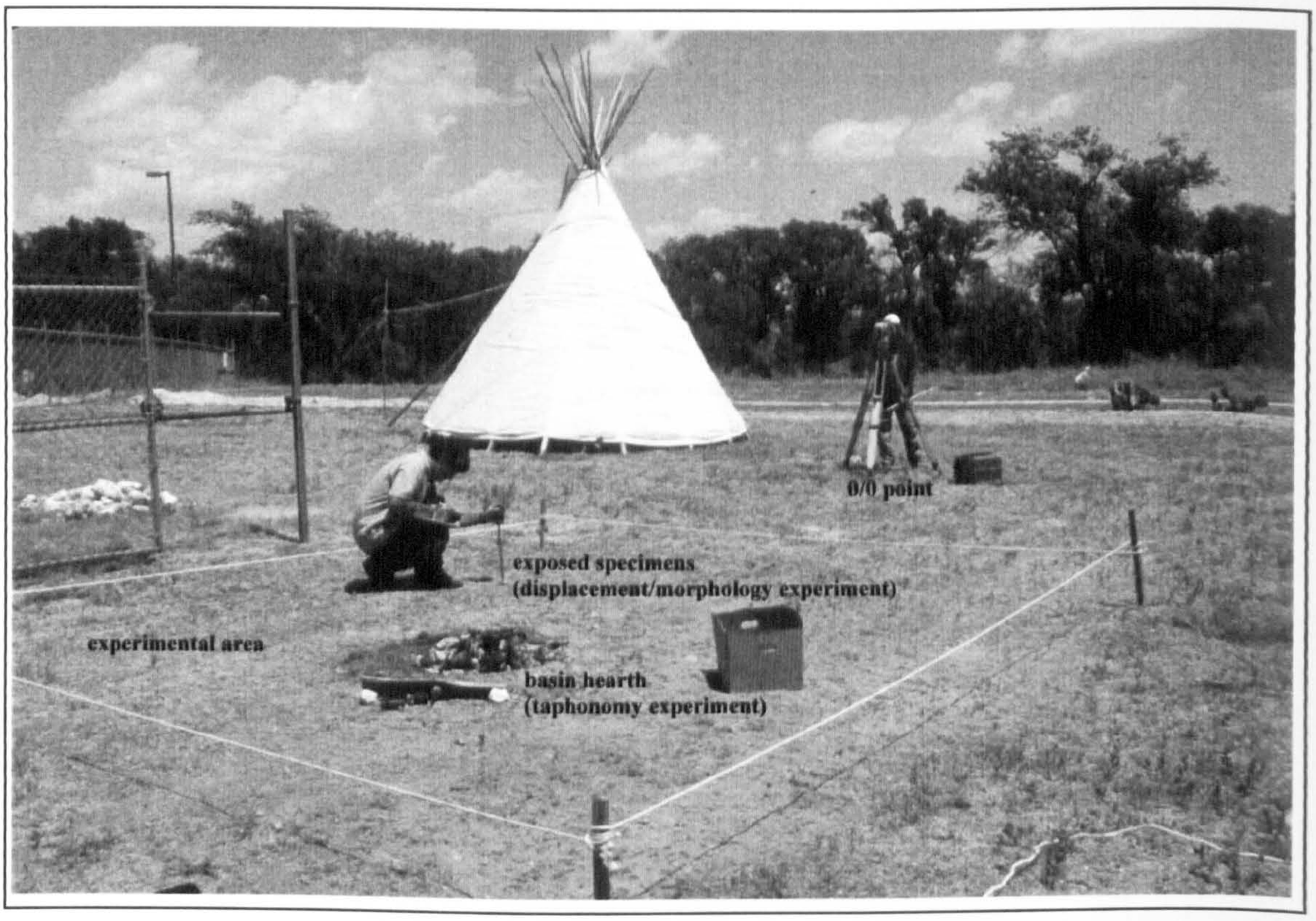

0/0 point
exposed specimens
(displacement/morphology experiment)
experimental area
basin hearth
(taphonomy experiment)

Figure 3.

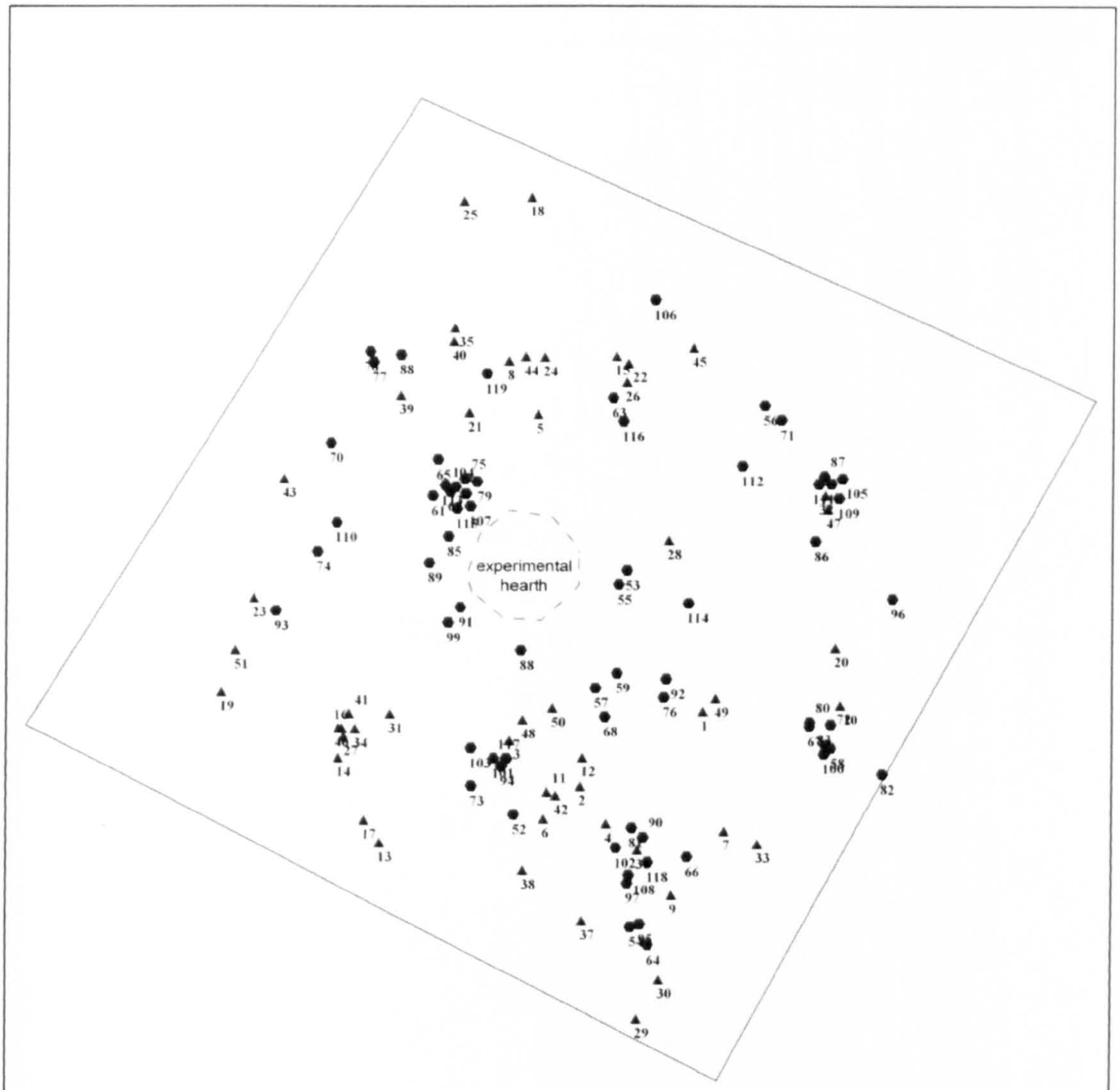

experimental
hearth
AHPE2 - Research Experiment
Conducted at Lubbock Lake Landmark
2003 - 2004
Data Capture - PB/ABJ/AM/AM/DR/BM
0 20 40 80 Centimeters
N
Legend
Data Capture 1 (26th July 2003)
artifact type
Hearthstone
Lithic

Figure 4.

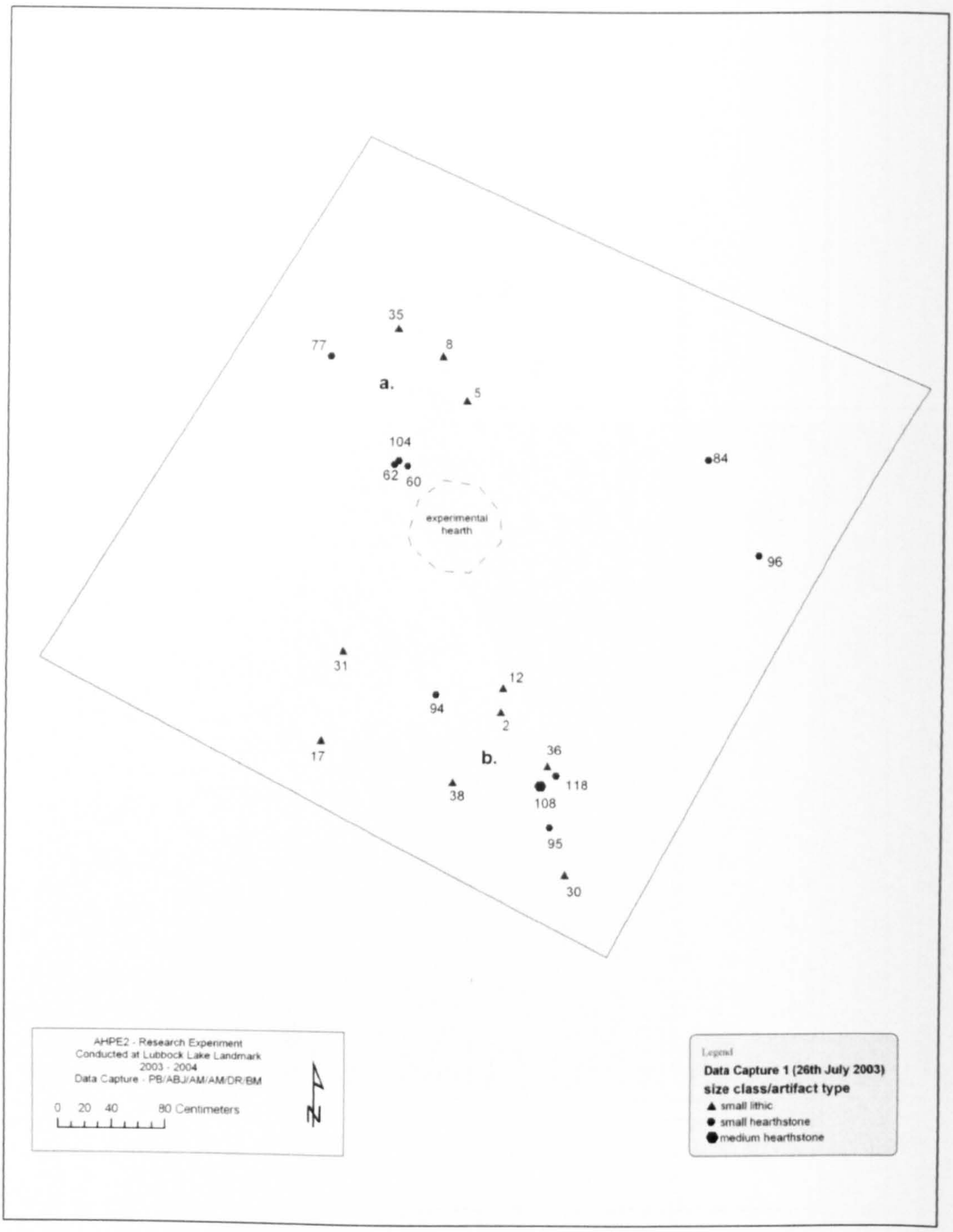

35
77
8
a.
5
104
62
60
84
experimental
hearth
96
31
12
94
2
17
b.
36
118
38
108
95
30
AHPE2 - Research Experiment
Conducted at Lubbock Lake Landmark
2003 - 2004
Data Capture - PB/ABJ/AM/AM/DR/BM
0 20 40 80 Centimeters
N
Legend
Data Capture 1 (26th July 2003)
size class/artifact type
small lithic
small hearthstone
medium hearthstone

Figure 5.

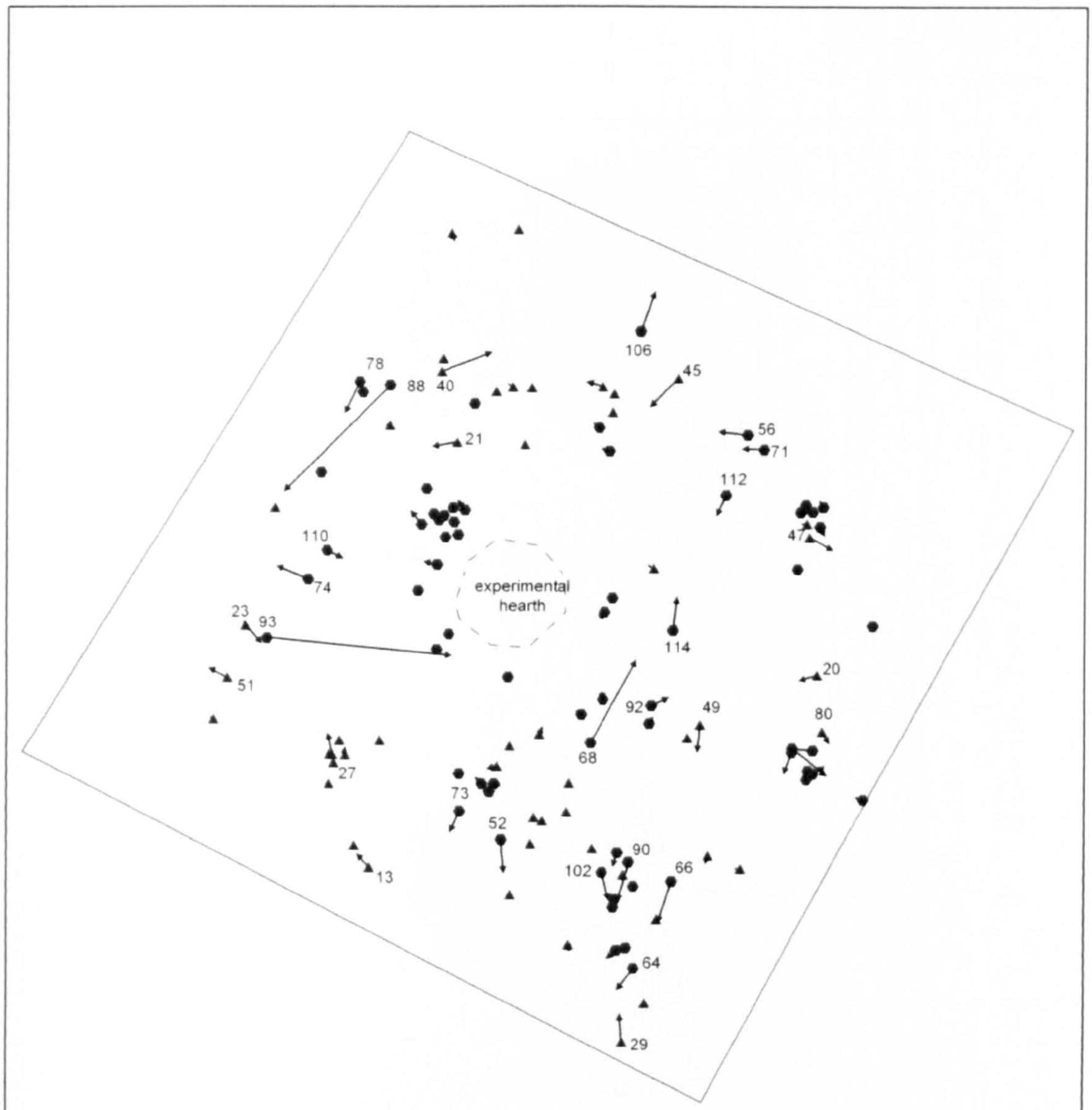
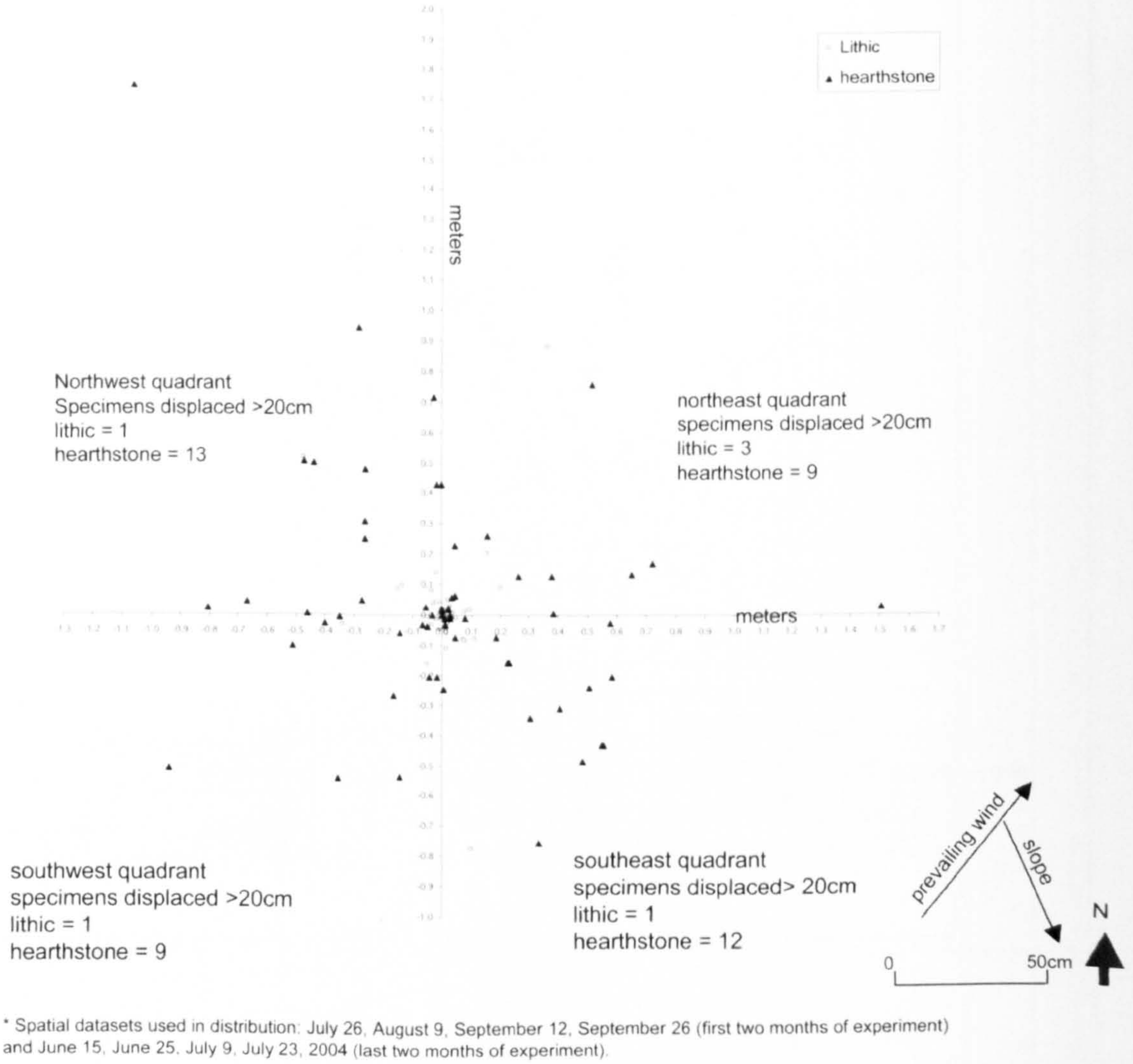

106
78
88
40
45
21
56
71
112
110
74
47
experimental
hearth
23
93
114
51
20
92
49
80
68
27
73
52
90
102
66
13
64
29
AHPE2 - Research Experiment
Conducted at Lubbock Lake Landmark
2003 - 2004
Data Capture - PB/ABJ/AM/AM/DR/BM
0 20 40 80 Centimeters
N
Legend
Data Capture 1 (26th July 2003)
artifact type
Hearthstone
Lithic
- Linear movement and direction (after 1 year)

Figure 6.



* Spatial datasets used in distribution: July 26, August 9, September 12, September 26 (first two months of experiment) and June 15, June 25, July 9, July 23, 2004 (last two months of experiment).

Figure 7.



a.

CM



b.

CM

Figure 8.

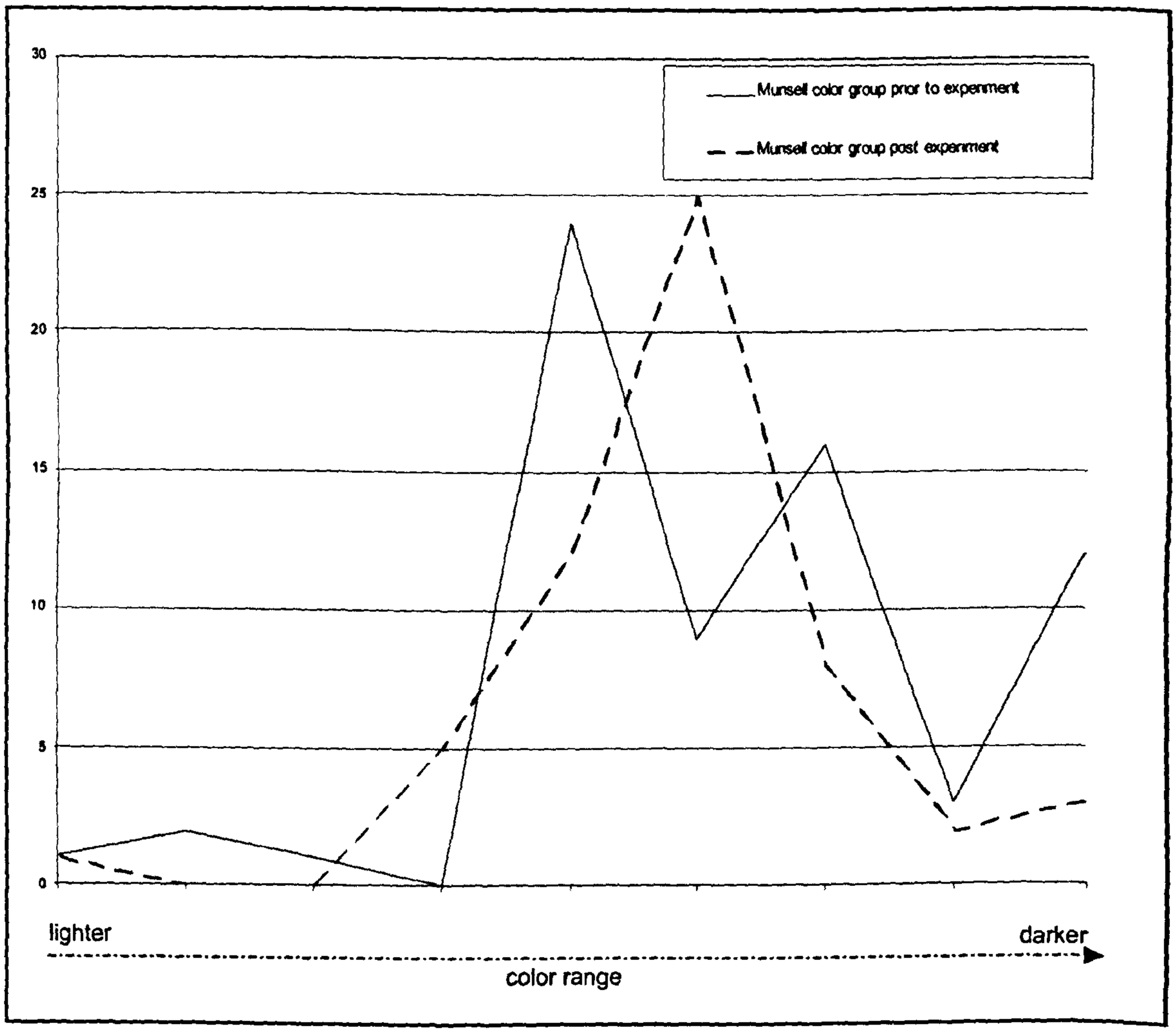

30
25
20
15
10
5
0
Munsell color group prior to experiment
Munsell color group post experiment
lighter
darker
color range

Figure 9.

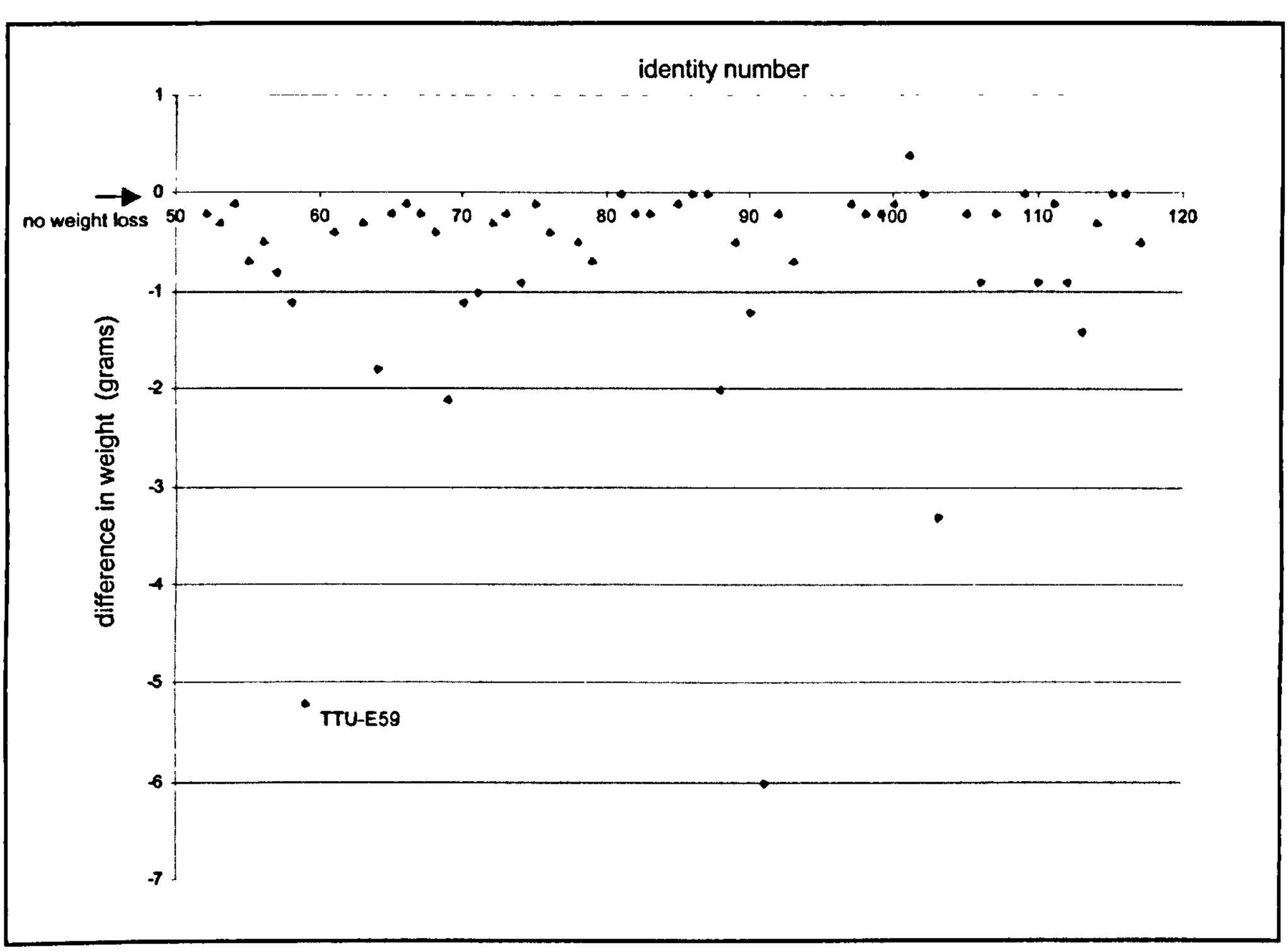

identity number
1
0
no weight loss
50
60
70
80
90
100
110
120
-1
-2
-3
-4
-5
-6
-7
difference in weight (grams)
TTU-E59

Figure 10.

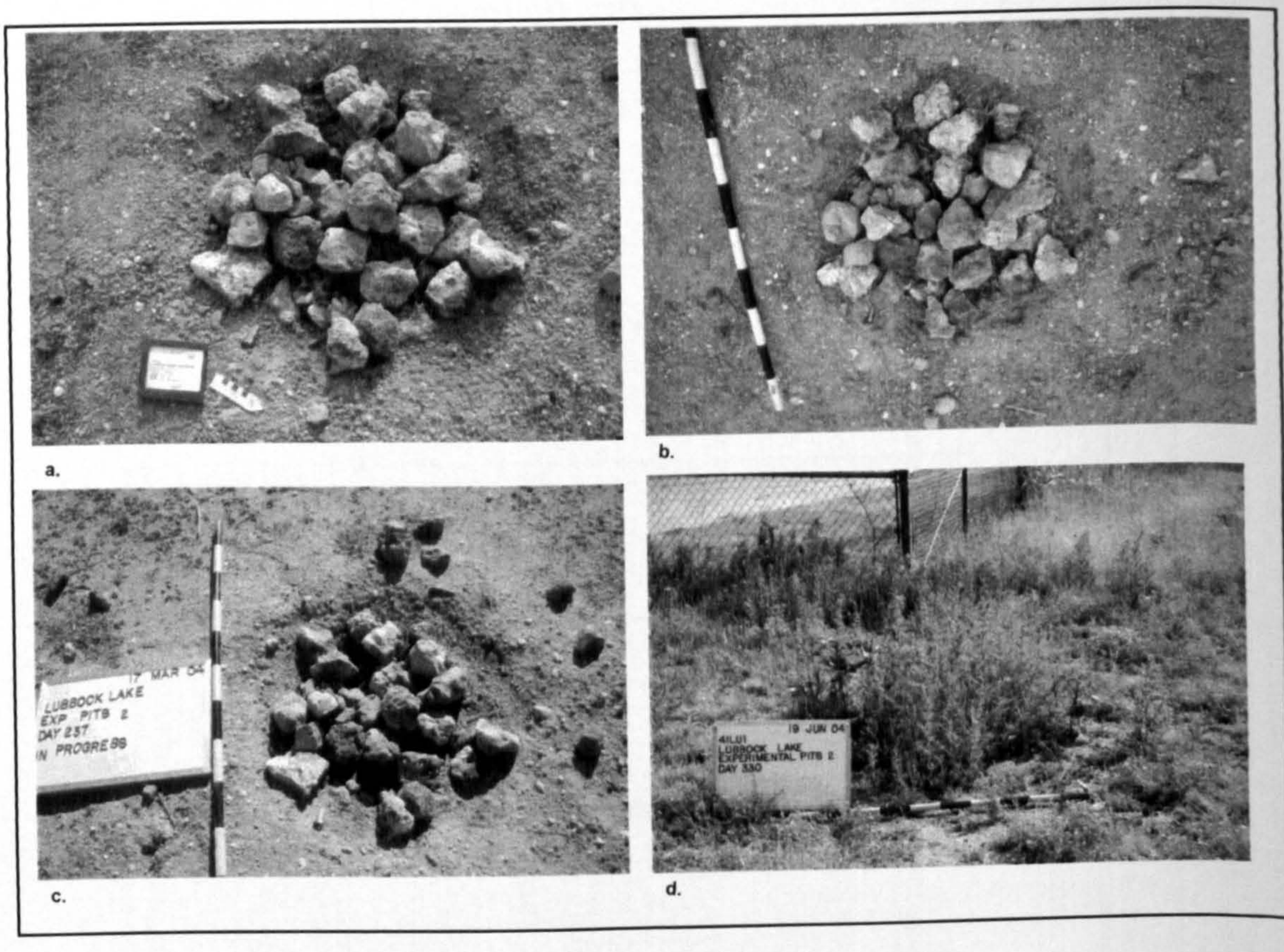

a.
b.
c.
17 MAR 04
LUBBOCK LAKE
EXP PITS 2
DAY 237
IN PROGRESS
d.
19 JUN 04
41LU1
LUBBOCK LAKE
EXPERIMENTAL PITS 2
DAY 330

Figure 11.

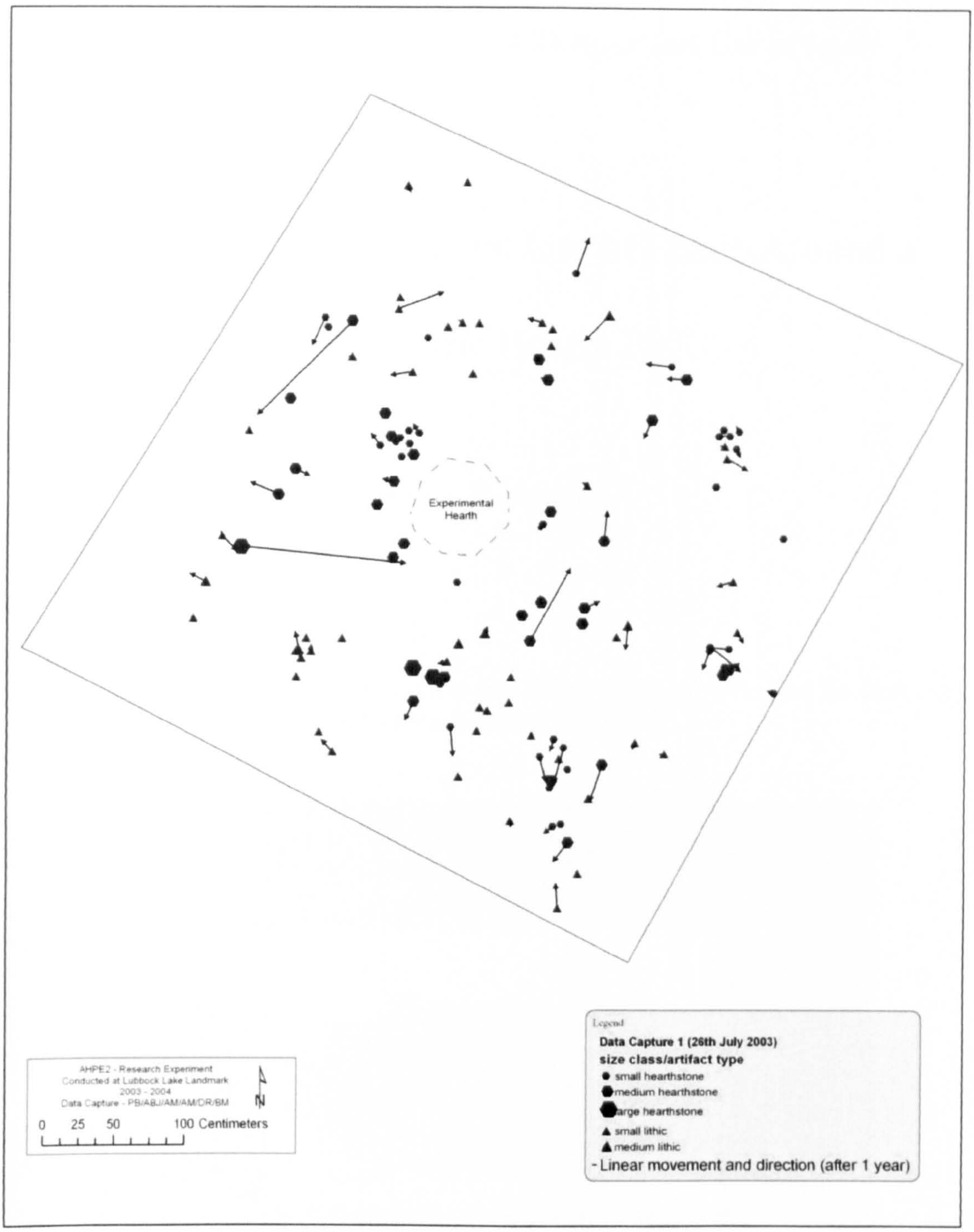
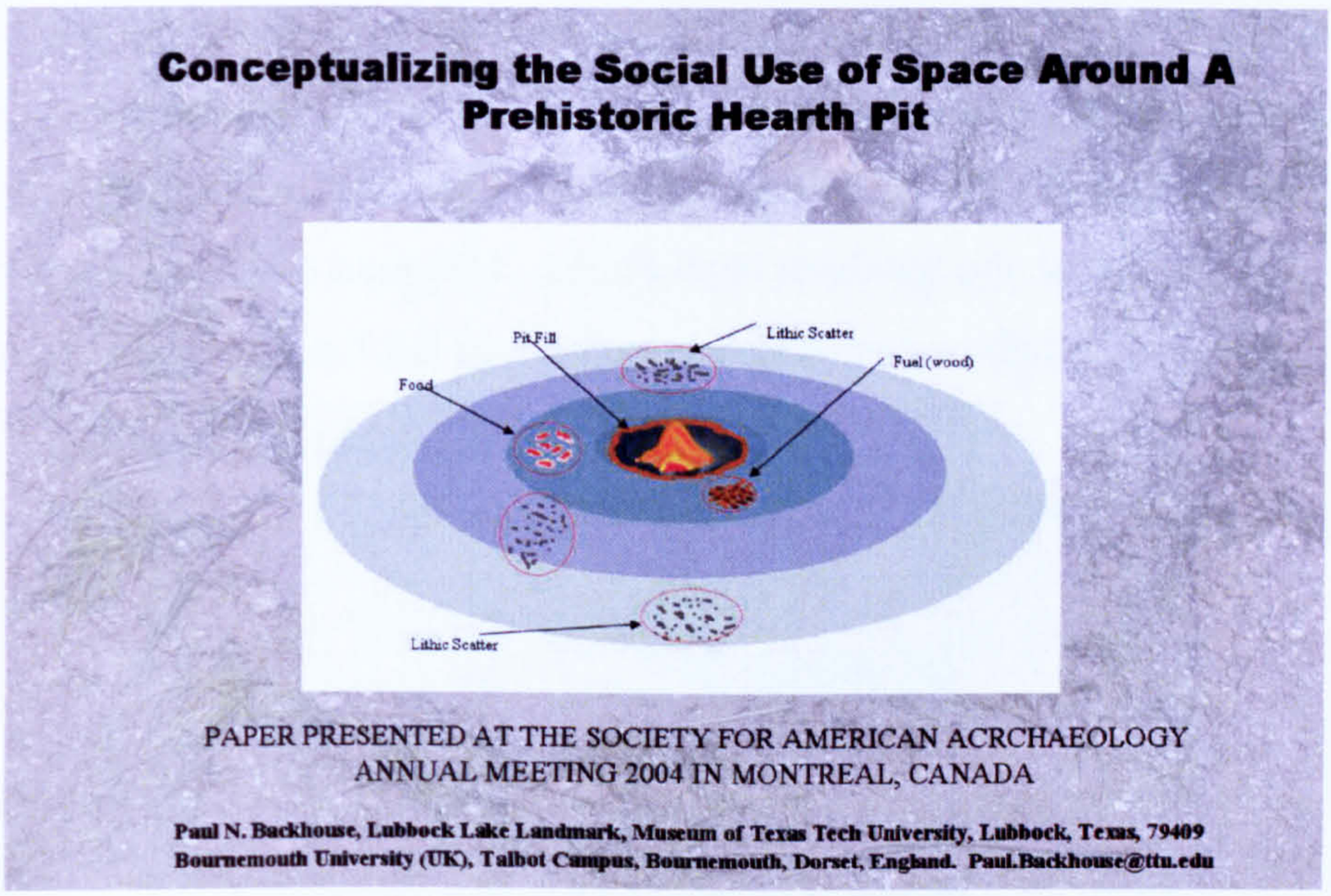

Experimental
Hearth
AHPE2 - Research Experiment
Conducted at Lubbock Lake Landmark
2003 - 2004
Data Capture - PB/ABJ/AM/AM/DR/BM
N
0 25 50 100 Centimeters
Legend
Data Capture 1 (26th July 2003)
size class/artifact type
small hearthstone
medium hearthstone
large hearthstone
small lithic
medium lithic
- Linear movement and direction (after 1 year)

Figure 12.

Conceptualizing the Social Use of Space Around a Prehistoric Hearth Pit

Paul N. Backhouse

Conference Paper originally presented at the 2004 Society of American Archaeology Conference, Montreal, Canada



PAPER PRESENTED IN: Plains and Rocky Mountain Archaeology (GS)
Chair: Bonnie Pitblado

Paul N. Backhouse, Museum of Texas Tech University and Bournemouth University (UK), Box 43191, Lubbock, TX 79409-3191, paul.backhouse@ttu.edu.

Abstract

Hearth pits are one of the single most ubiquitous features recorded from prehistoric hunter-gatherer contexts. Historically, a high degree of morphological variability exists within the components and perceived function of these structures. Previous research strategies have focused attention largely on aspects of their utilitarian or economic yield. A complimentary approach is offered which situates the hearth pit as a contextual center or locus of activity within a social framework of individual and group dynamics. The results of the investigation indicate that such an approach is extremely useful in examining the use of bounded and unbounded space at a site level. Experimental research was undertaken to examine the three physical outputs of shallow basin hearths heat, light, and smoke. The results indicate that these variables are potentially behaviorally significant but rarely examined from an archaeological perspective.

Globally, a wide range of thermal feature morphological variability has been documented from hunter-gatherer contexts. Within this range, basin type structures are commonly encountered. These features are characterized by high diameter to depth ratios and hot rocks are often but not always directly found in association. I examined the archaeological archives for the Texas portion of the Southern High Plains physiographic region (Figure 1) in order to determine the type and distribution of features represented in the regional record (Figure 2). A review of relevant site records suggests basin hearths are among the most common thermal feature type recorded on the Southern High Plains (based on a search of data held on file at the Texas Historical Commission). Archaeological evidence for habitation structure types is at best, ephemeral on the Southern High Plains. This most likely indicates that structures were typically portable or otherwise were built to last for significant periods of time.

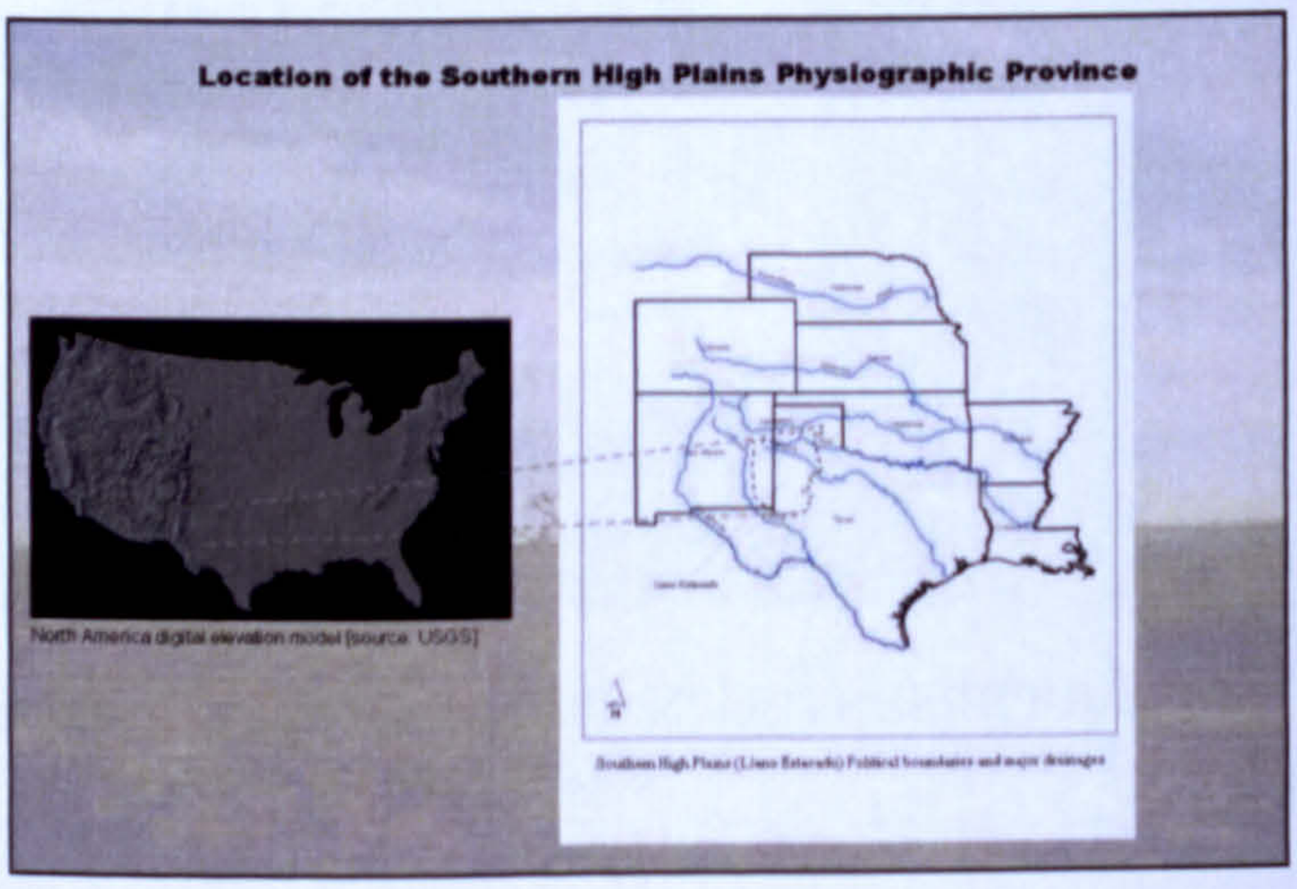


Figure 1. Location of the study area.

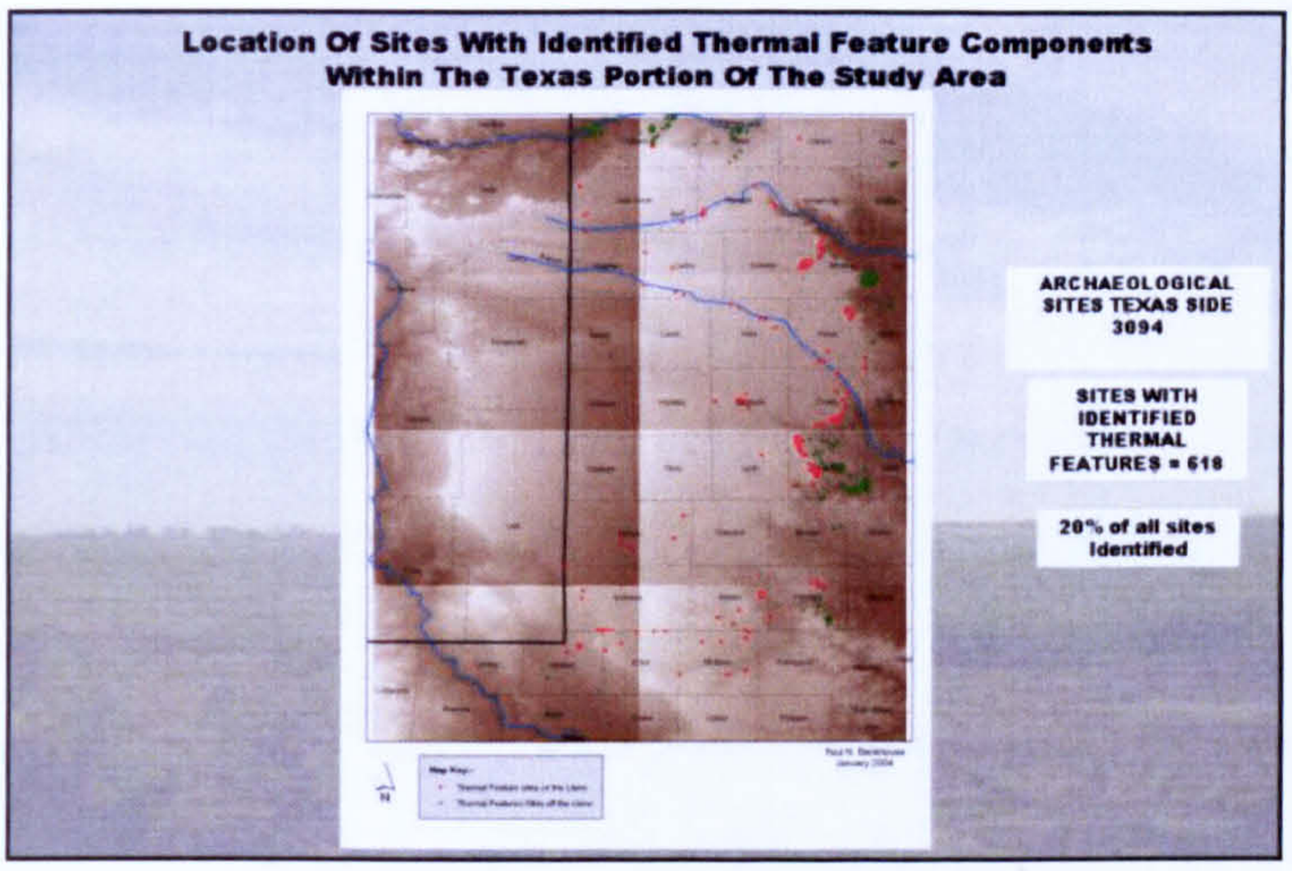


Figure 2. Distribution of archaeological sites within the Texas portion of the Southern High Plains study area.

Examination of the distribution of sites when observed at a higher spatial resolution (Figure 3) suggests that the location of sites with evidence for fire technology is somewhat predictable. Sites tend to be clustered along the edges of the caprock escarpment and along the course of the incised draw systems. The simple explanation for this distribution is that these areas are also those in which abundant firewood is available. The distribution is most likely more complex, however, and the role of site formation processes require greater investigation in this environment. It is also perhaps interesting to note the lack of sites with thermal features in relationship to the numerous playa lakes that can be seen pock marking the region (Sabin and Holliday 1995). These important sources of water might be expected to exhibit more evidence for past human activities (e.g., Litwinonek *et al.* 2003) and are likely underrepresented in the regional record.

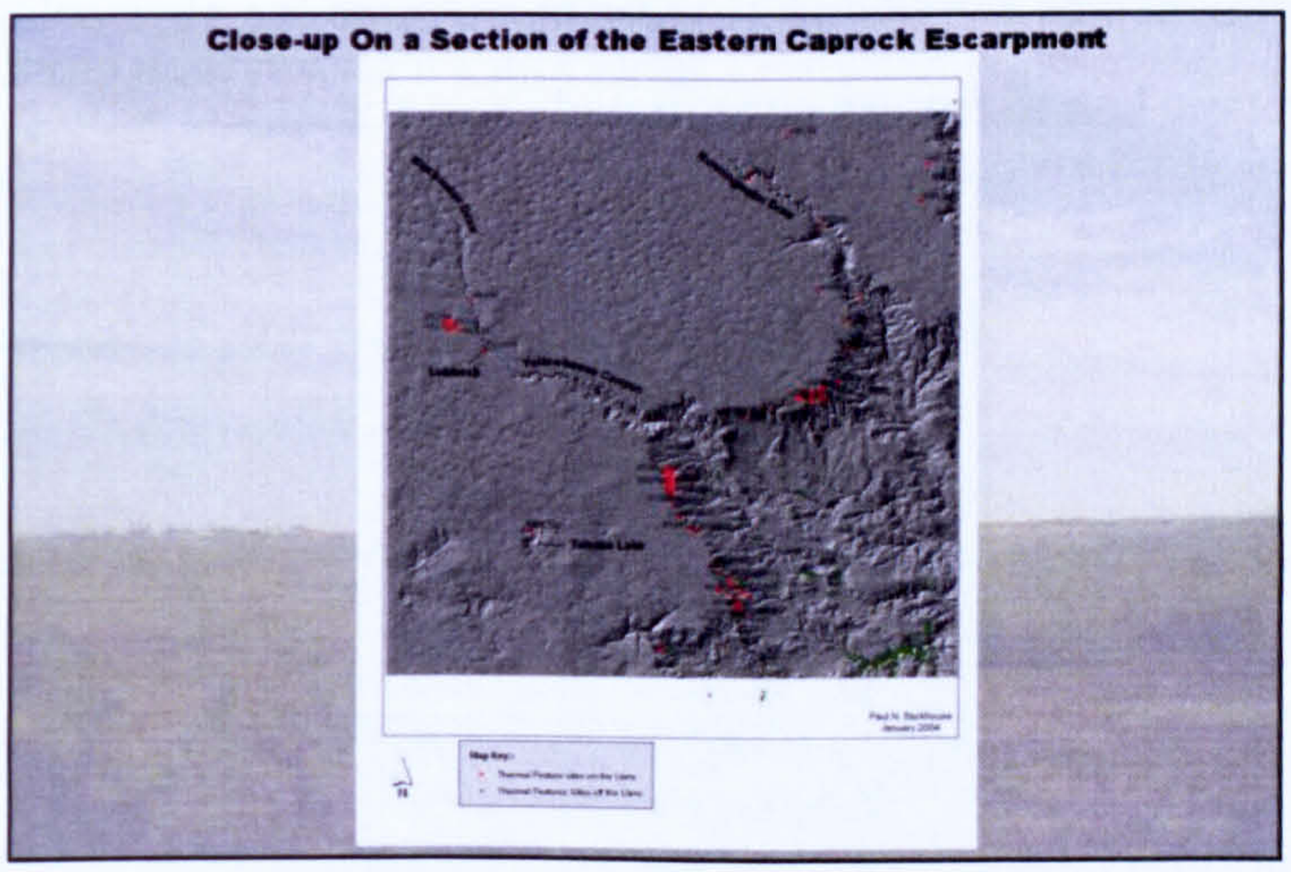


Figure 3. Detailed distribution of archaeological sites along the southeastern portion of the Southern High Plains study area.

BACKGROUND

Ethnographically internal and external basin hearths have been observed as gathering foci for people within hunter-gather camps (*c.f.* Binford 1977; 1978; 1983; 1987; Yellen 1977; O'Connell *et al.* 1991; Fisher and Strickland 1991; Kelly 1995) . The negotiation and interaction of people directly and indirectly using exterior hearths is rarely theorized as the archaeological residues of this interaction are seldom recovered. This should not however dissuade archaeologists from exploring variability within this feature type and the surrounding cultural debris at a fine-grained focus. The social contextual relationship of these features is usually implicitly rather than explicitly defined. An example of this implicit association is Marcel Ottes exploration of fire as a catalyst for evolutionary development:

> Fire constitutes a gathering agent of the social group, to exchange ideas, transmit knowledge and maintain individual cohesion. In the common meaning, the domestic "hearth" has more symbolic meaning than technological. This hearth is the place where one is reassured, protected and among friends. This "radiant" location around the fire constitutes from now on the basis of human society, where it is formed, consolidated and transformed. (Otte 2002:9)

RESEARCH DESIGN

The research design outlined here attempts to explore basin hearth features recorded in the archaeological record from an experimental actualistic perspective in order to gather data on purely physical variables (Figure 4). Implicit to this approach are a number of assumptions and limitations which constrain the interpretative possibilities of the wider project (Figure 5). Within this research framework a simple experiment was conducted in order to examine the physical inputs and outputs of a basin type hearth feature constructed in an actualistic setting.



Figure 4. Research design for the examination of exterior basin hearths.

Assumptions and Limitations

ASSUMPTIONS

1. The manifestation of physical transformations of energy, such as heat, light and smoke occurring when a hearth basin is being used are analogous through time.

2. External basin hearths often represent a focal point for people within hunter-gatherer camps.

3. Activities involving, and in proximity to, basin hearths (such as cooking) can leave archaeological signatures.

4. At a general physiological level people respond similarly to discomfort e.g. heat and cold.

LIMITATIONS

1. The psychological effects encountered while conducting the experimental component of the research are not necessarily similar to those experienced by prehistoric populations.

2. The physical constraints prehistoric populations judged to be comfortable or uncomfortable are not the same as those archaeologists felt while conducting the experimental work.

3. The archaeological excavation of campsites often encounters a palimpsest of material resultant of multiple occupations and/or post depositional processes which may obscure or destroy the potential for detailed analysis.

4. Cleaning and maintaining activities undertaken by prehistoric populations, around the hearth area may obscure or destroy spatial patterns of cultural debris.

Figure 5. Assumptions and limitations of the research project.

EXPERIMENT DESIGN

In contrast with the large number of studies which concentrate on the economic output of thermal features (e.g. Dering 1999; Smith 2001) the human influence of these three physical outputs has not been considered from an archaeological perspective. Furthermore where thermal features are considered as dynamic components of site structure interpretation tends to attempt to historicize the human activity around them (e.g. Gamble 2005). Empirical examinations of heat, light, and smoke transfer have yet to be undertaken. This is perhaps surprising given that thermal features such as hearths are often recorded during fieldwork. These features then often yield technologically meaningful data in terms of geometry, fuel type, fuel loading, hot-rock use, hot-rock type, and operation sequence. Experimental construction of morphologically similar thermal features as those encountered in the archaeological record holds significant potential for technological research trajectories.

An experiment was designed with which to test the possibility of measuring the physical output of basin hearth features. The research hypothesis being that thermal features may have more actively structured human behaviors than is generally accepted from models based largely on the ethnographic record.

In igniting a fire within the hearth, three physical energetic outputs are immediately initiated (Figure 6). Firstly heat is generated from the fire. The transfer of heat is dependant on the prevailing weather conditions and type of fuel burned. Hearth design and heat often are assumed to be a direct function of food processing. However, clearly non-culinary relationships of warmth may be involved in heat transfer. Testing of the relative density and distribution of artifacts at different distances surrounding the hearth can be archaeologically examined as a function of heat output.

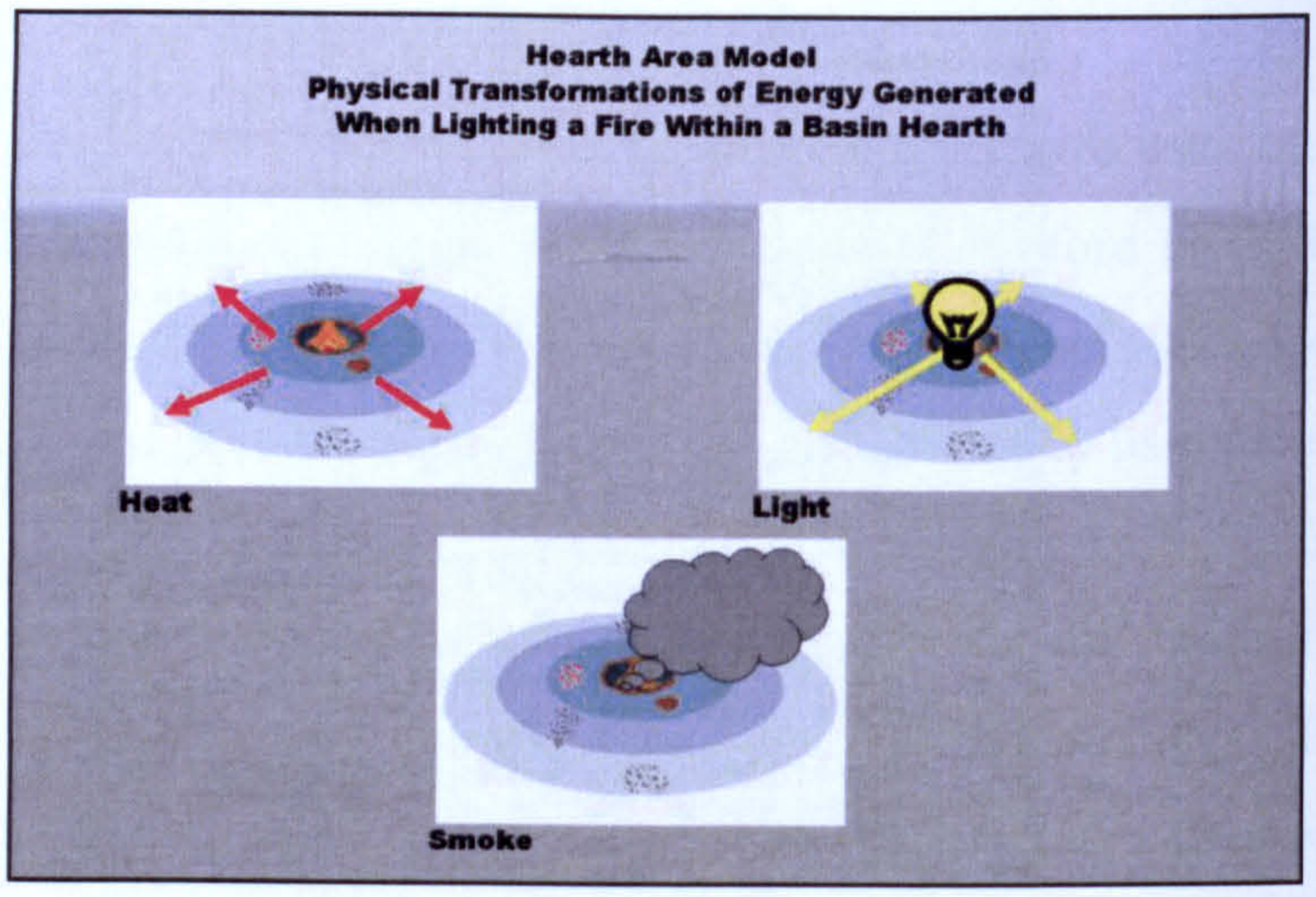


Figure 6. Diagram illustrating the three basic physical outputs of a simple basin hearth feature.

The second physical effect is smoke. On the southern high plains the prevailing wind direction is from the south with average wind speeds of around 12.5 mph (NOAA data). Hearth area assemblage distributions might be reasonably expected therefore to be more dense on the south side of hearths upwind of the smoke.

The third physical factor is light, the transfer of which again is dependant on weather conditions, fuel type, and fuel quantity. Light would obviously be essential at night and if hearths provided a main source, then activities that required light such as knapping, weaving, and cooking would have had to occur in close proximity to the light. Quantification of the amount of light emitted at various distances from the hearth may provide useful analytical units in the interpretation of associated archaeological debris.

METHODOLOGY

A basin-type pit was excavated by hand within the experimental research area at Lubbock Lake Landmark, Texas. The basin was morphologically similar to those identified in the archaeological record and measured ca. 75cm in diameter. A line of four distance markers (wooden stakes) were positioned at 1 meter increments from the center of the basin to a distance of four meters from the basin (Figure 6). These four markers represent the stations at which instrument readings were recorded during the experiment.

Hearth Experiment 3 – Set up and Burn Images



Figure 1. Experiment setup, fuel weighing system in the background. Wooden stakes mark stations set at meter intervals away from the experimental hearth. Bundles of fuel next to each station. Fuel was weighed to standardize the fuel load therefore all bundles 5,900g of dead mesquite limbs (*Prosopis glanulosa*).



Figure 2. Experimental setup, hearth is empty in the foreground. The Ogallala caliche cobbles pile will be added after an initial burn of mesquite fuel. The caliche hot-rocks were weighed prior to beginning the experiment and weighed 13,000g. Analytic and safety equipment can be seen in the lower left of the picture.



Figure 3. Fuel and caliche weighing system. A tripod was setup and a balance scale hung below it. A metal bucket was used to collect the fuel and hot-rocks. The bucket weighed 700g which was compensated for in subsequent calculations.



Figure 4. Initial hearth firing, 8:30pm light levels are dropping flames initially burn fairly cleanly with little or no smoke. Caliche ready to be added to the hearth.



Figure 5. 8:50pm caliche added with the remainder of the initial Mesquite limbs. Smoke becoming a factor as ember beds begin to develop at the base of the hearth basin.



Figure 6. 9:00pm Light levels becoming very low. Ember bed has developed within the hearth basin. Smoke continues to be significant Wind direction generally toward the monitoring stations.

Paul N. Backhouse 20th June 2004
Based on data recorded 19th June 2004 Hearth Experiment 3, LLL&BU

Figure 7. Methodological stages in the setup of the experiment.

Heat measurements were recorded in degrees centigrade at each recording station using a Barant Type K thermocouple. Light was recorded in foot candles, with readings taken at each station using a General Electric visible light meter. Ambient heat and light readings were taken in between objective readings using the same instruments previously described. Smoke was not quantified during the experiment but indirect observations were noted throughout the experiment. Safety equipment consisted of a fire extinguisher, fire proof clothing, and a garden hose.

Medium sized air dried limbs of Honey Mesquite (*Prosopis glanulosa*) were placed in the excavated basin. Additionally, bundles of fuel were placed next to each station (1 through 4). The bundles were weighed to standardize the fuel load (5,900g per bundle). The fuel in placed in the basin was the first to be ignited. After 20 minutes of burning caliche hot-rocks weighing ca. 13,000g were added on top of the still burning fuel. After an additional half an hour, an ember bed began to form in the base of the basin and the hot-rocks settled with and on top of this layer.

After an hour had elapsed since the original fuel had been added to the basin the limbs had broken down to a well developed ember bed. The first bundle of additional fuel from station 1, located 1 meter from the basin, was added to the fire. Heat and light readings were recorded at 5 minute intervals from this station. All readings were taken facing toward the feature at a height of ca. 0.5m above the modern ground surface. This height was selected to simulate the rough chest height of a person in a sitting position.

After an hour had elapsed (12 readings) then the bundle of fuel from the next station was added to the fire and the recording process was repeated for the new station. When all four stations had been occupied and all four fuel bundles burned then the experiment was terminated. The experiment was conducted in clear night time conditions on the 19th June 2004 with a light (average 10mph) easterly wind, and a temperature range of 79°C at 9pm and 72°C at 1am.

RESULTS

The heat output data illustrates demonstrates the simple predictable relationship between decreasing heat radiation as distance from the feature is increased (Figure 8). The decreasing production of heat is also evident as a function of time and this is the expected result as fuel becomes expended over the course of the experiment. It is interesting to note that after one hour there is very little heat given off from the fuel, confirming that mesquite is a quick burning fuel type and that almost constant fuel procurement or significant stockpiling may have been necessary to maintain facilities useful for keeping humans warm. The results also indicate that at distances of over two meters from the center of the facility that there is very little benefit to be gained for humans in terms of heat.

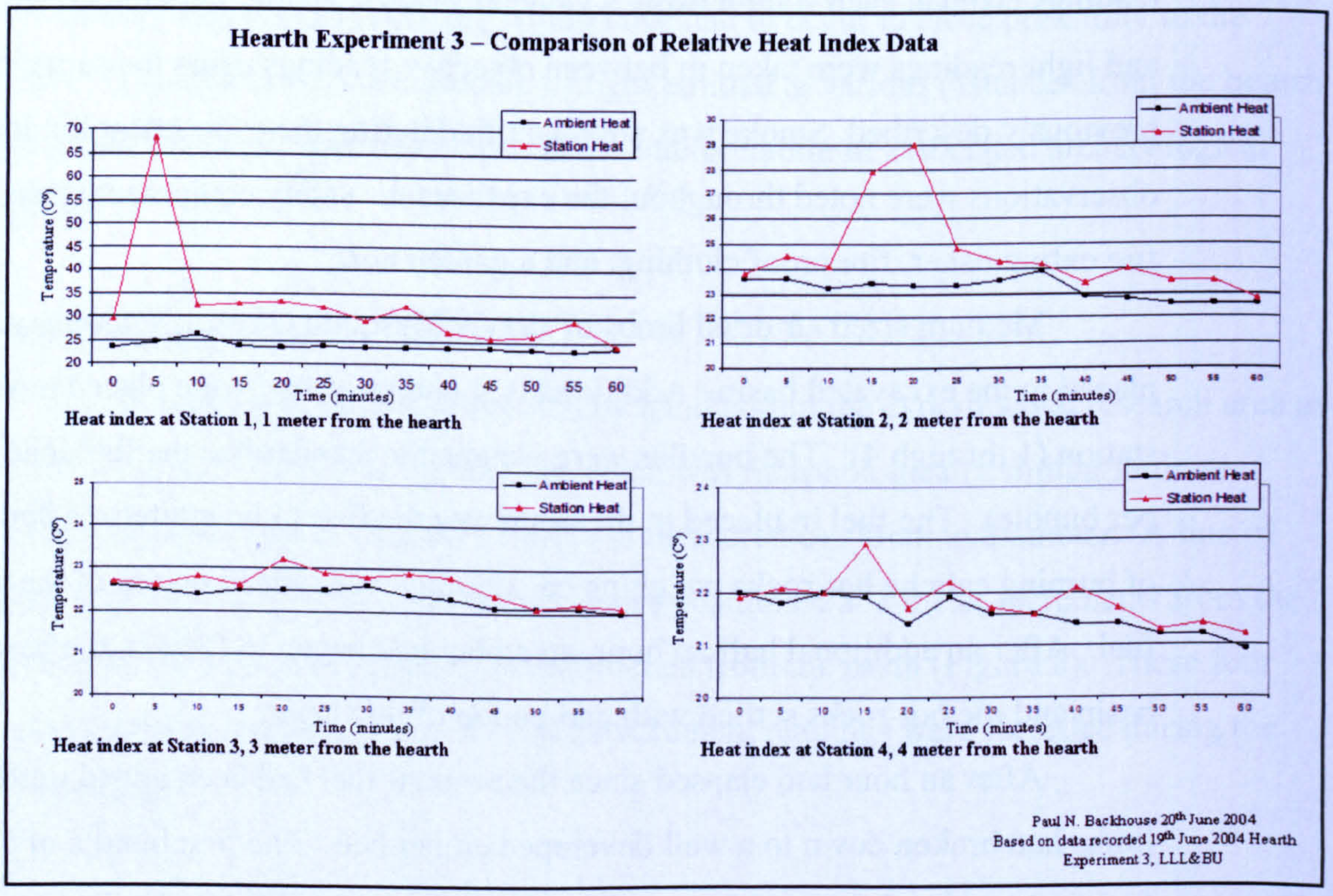


Figure 8. Heat recorded at incremental distances from the experimental feature during the course of the experiment.

The results obtained on the measurement of light emitted by the fire during the course of the experiment were less conclusive (Figure 9). The ambiguity of the results is most likely the result of the low resolution equipment being used (a photographic light meter) and the relatively bright indirect lighting that could not be systematically excluded. Nevertheless, the results suggest that the production of most light occurred early in the experiment when flames were at there highest and that only at distances within 1 meter of the fire could the production of light be measurably differentiated from the background "noise".

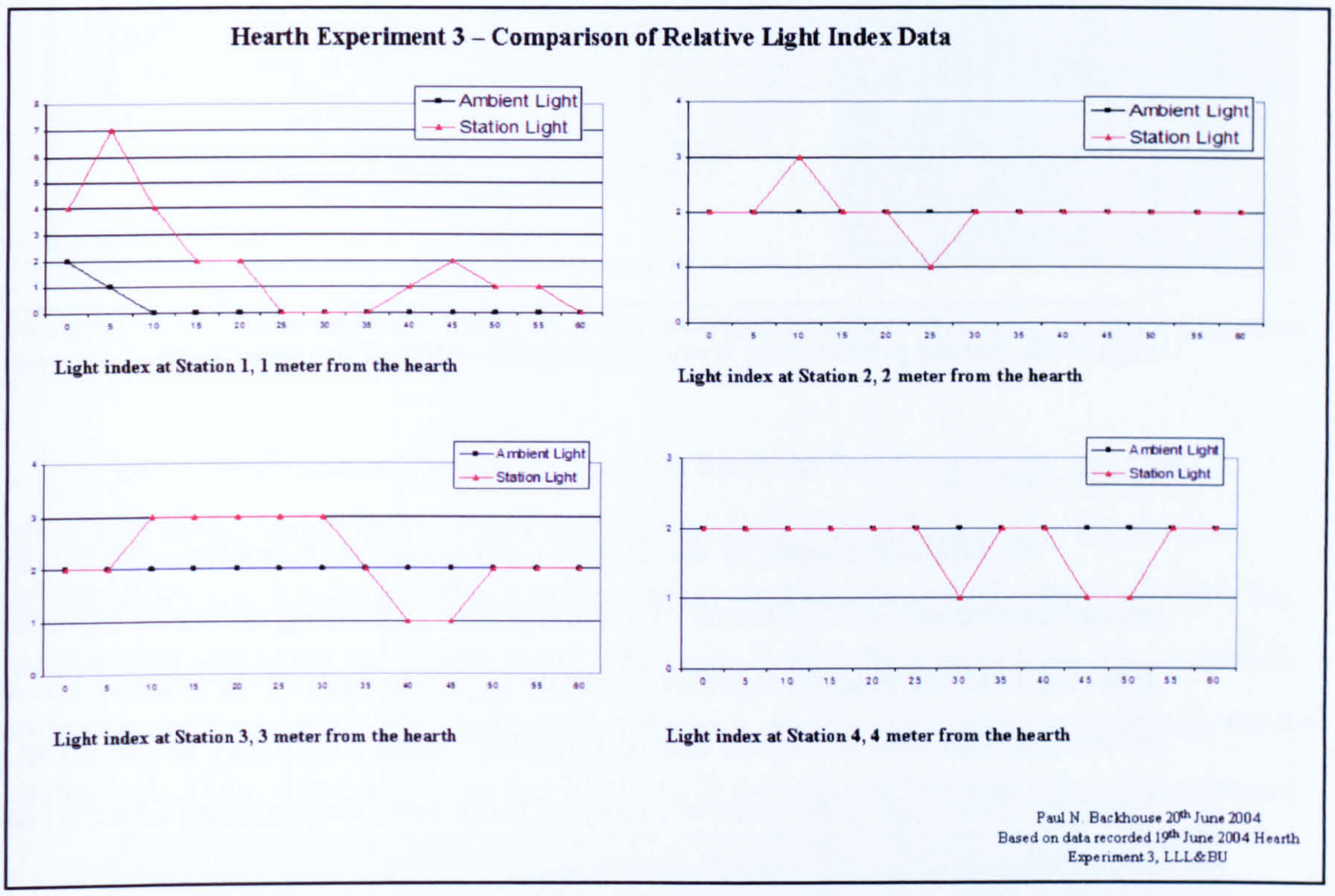
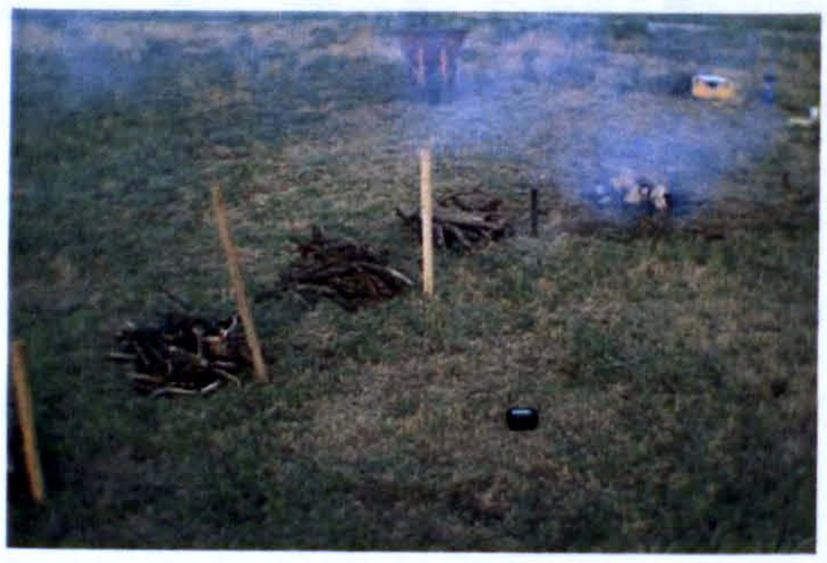


Figure 9. Light recorded at incremental distances from the experimental feature during the course of the experiment.

Observations recorded during experimental mesquite burning suggested, that smoke was most significant at distances less than 3m from the fire and most prevalent during the initial burning of branches and grasses before ember beds develop within the hearth (Figure 10). Smoke appeared to represent a fairly random hazard effecting different areas around the hearth at different times. Archaeologically this situation might be manifested by distributions of debris which are likely to spread around the full circumference of the hearth. This condition is likely to be most pronounced within 3m of the hearth.

Hearth Experiment 3 – Observations during initial burn Images



a.



b.

These two images were taken ca. 9pm as light was fading. The initial flames have died down in the hearth and the caliche is beginning to settle onto the now developed ember bed within the hearth. Smoke becomes fairly significant at this stage making it extremely hard to work in close proximity to the hearth. The smoke almost constantly engulfs the area within the station 1 (1 meter) marker as in Figure a. During wind gusts the smoke pushes out further away from the hearth toward the outer station locations. Figure b shows smoke engulfing the area between station 2 and 3 (between 2-3 meters from the hearth). During experimentation smoke was not considered uncomfortable during the hour taking readings at Station 4 (4 meters from the hearth) and appears to be the effective limit of its influence under relatively normal conditions.

Paul N. Backhouse 20th June 2004
Based on data recorded 19th June 2004 Hearth Experiment 3, LLL&BU

Figure 10. Smoke produced by feature during the course of the experiment.

DISCUSSION

By modeling some of the factors outlined above a simple conceptual spatial model can be outlined in terms of arbitrary zones radiating outwards from the hearth. Expected archaeological signatures can be keyed to each of the zones. The zones are set at 1m intervals and are by no means bounded. Actors may stay in one zone, pass between zones, or be peripheral to any of the zones. The building block of inference being the human body, which has remained a standard unit (Binford 1978).

Zone 1 - The area closest to the hearth is also the smallest, movement and access to the hearth is most restricted (Figure 11). It is likely that only one or two people could intermittently occupy this area. It also is likely that any items within this zone are expendable, examples being firewood, or food and are likely to be associated directly with the hearth. The intense heat and smoke would often make this area uncomfortable and it is likely people involved with the creation and maintenance of the fire would intermittently enter the zone to perform specific tasks, none of which are likely to leave significant archaeological signatures.

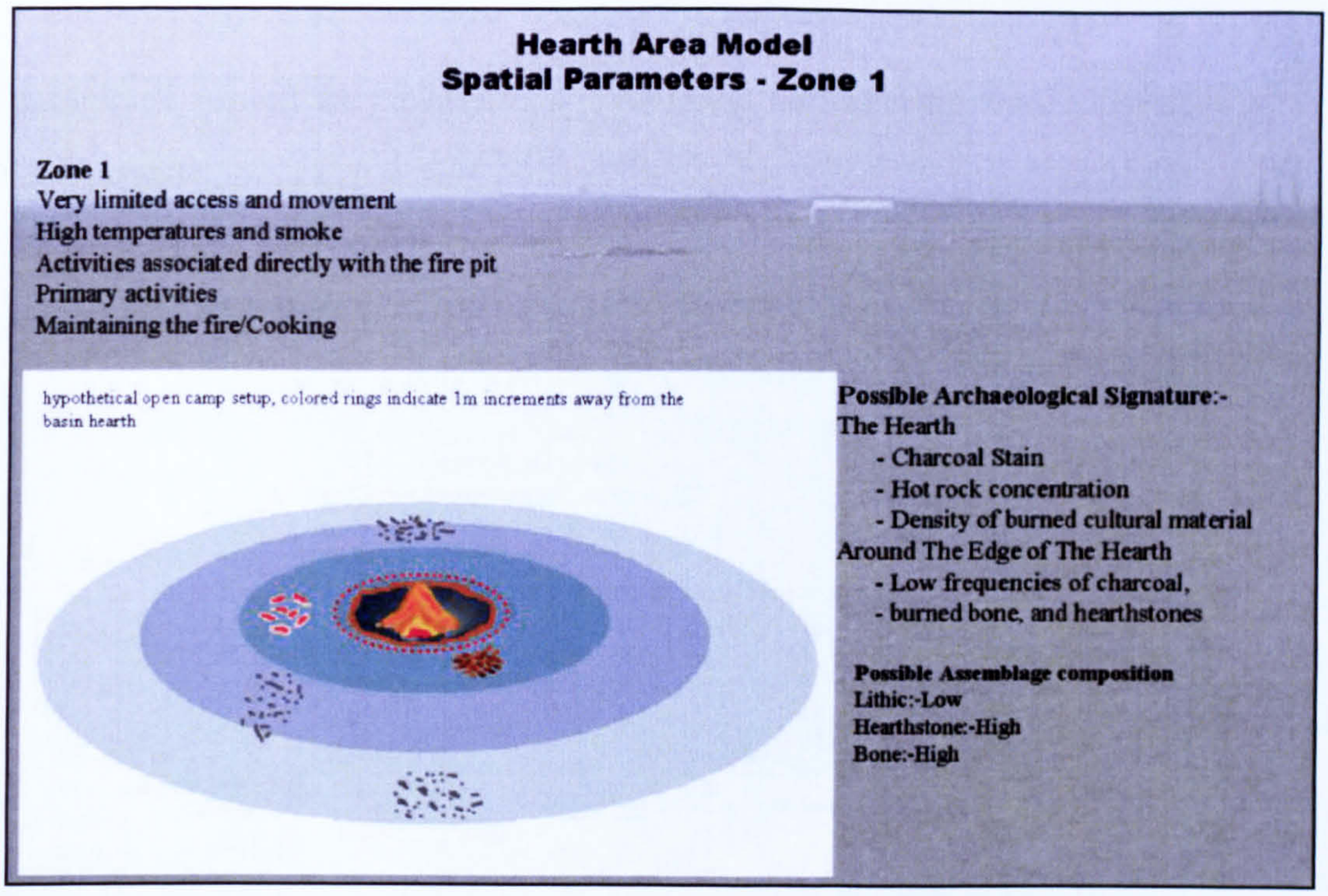


Figure 11. Behavioral model for human action that might be expected in zone 1, closest to a basin hearth type feature.

Activities occurring in zone 2 are also likely to be restricted by the heat generated in the hearth and the area around which to work (Figure 12). Unpleasant temperatures and smoke are likely to keep away people not directly involved with the maintaining and using the hearth itself. This zone is also the most likely area in which to store reserve fuel for the fire, additional hot rocks, and the ideal area to keep any food to be cooked. Again these activities are likely to leave minimal archaeological signatures.

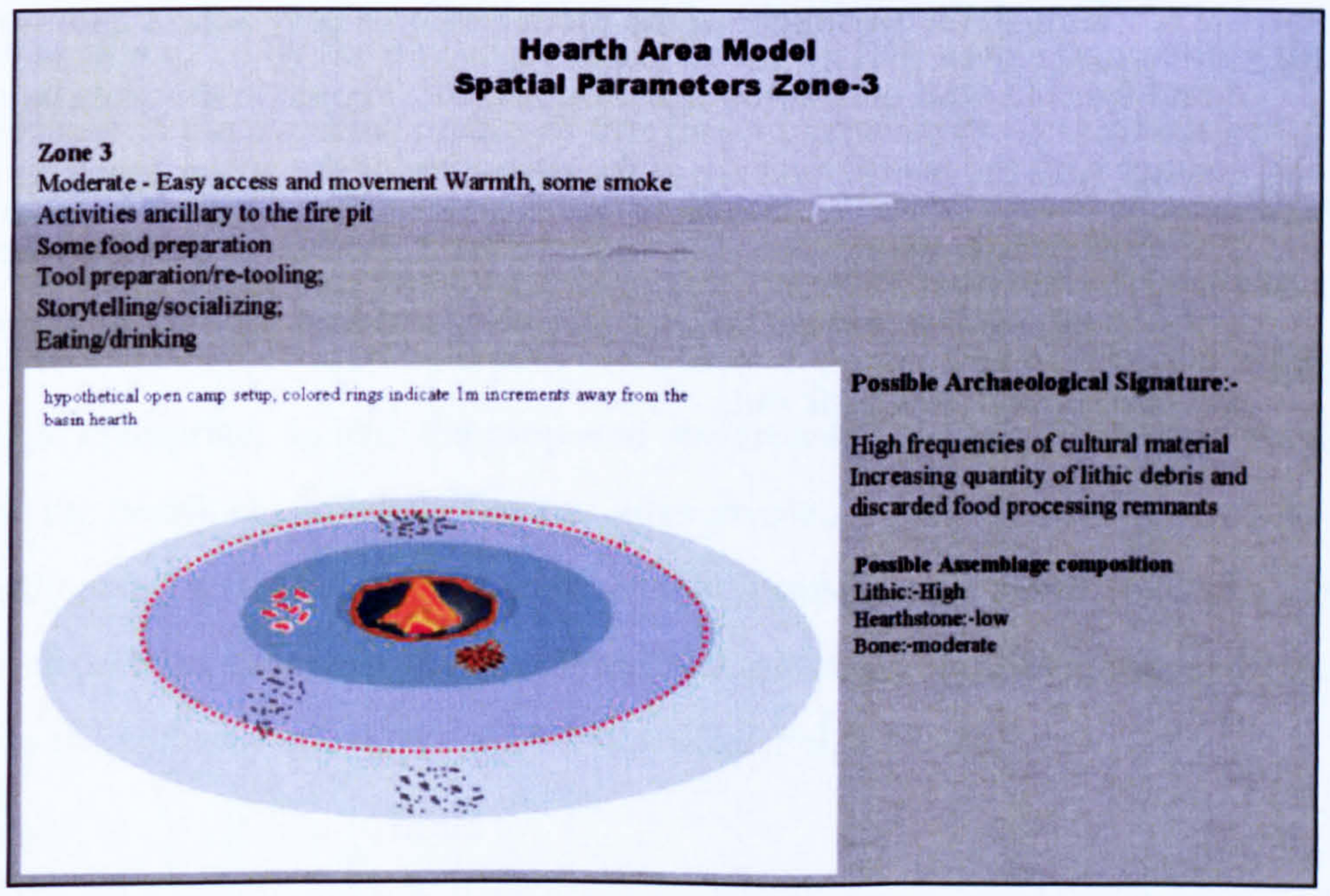


Figure 12. Behavioral model for human action that might be expected in zone 2 around a basin hearth type feature.

Zone 3 is sufficiently far enough away from the fire to gain light and derive some heat. Smoke is still a factor, however, and some shifting in position might be expected (Figure 13). Activities in this area are likely to be ancillary to the hearth itself. Flint knapping, food preparation, dialogue between group members, eating, drinking, and sleeping might be expected within this area.

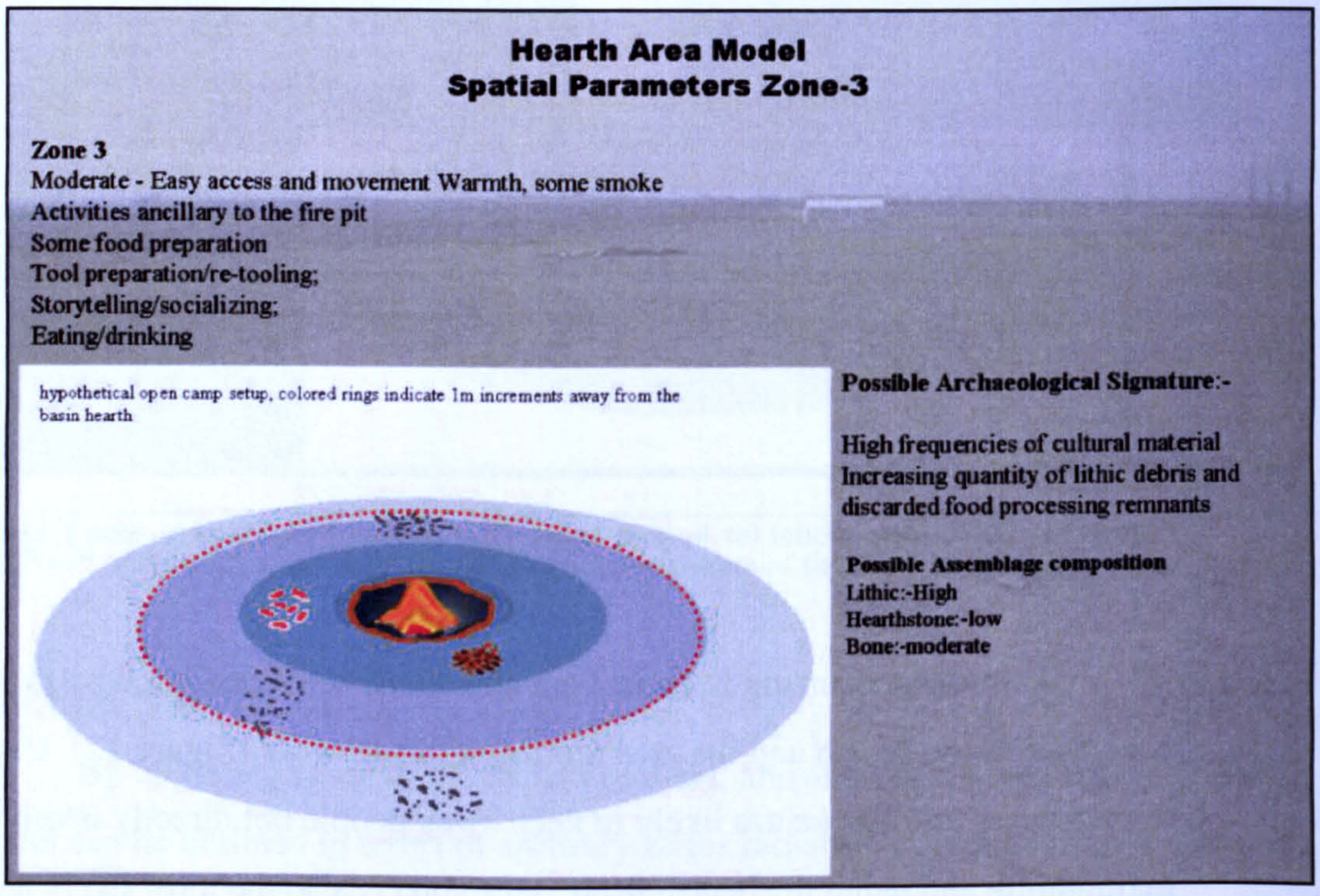


Figure 13. Behavioral model for human action that might be expected in zone 3 around a basin hearth type feature.

Zone 4, the periphery of the model, affords easy access and movement but little direct warmth, and only some light (Figure 14). People in this area have no direct contact with the hearth, and are at the periphery of the group based on the assumption that most people would likely be within zone 3. Activities here may be socially ambivalent, such as private talking, sleeping, children playing, or simply unrelated to the hearth, such as a look out.

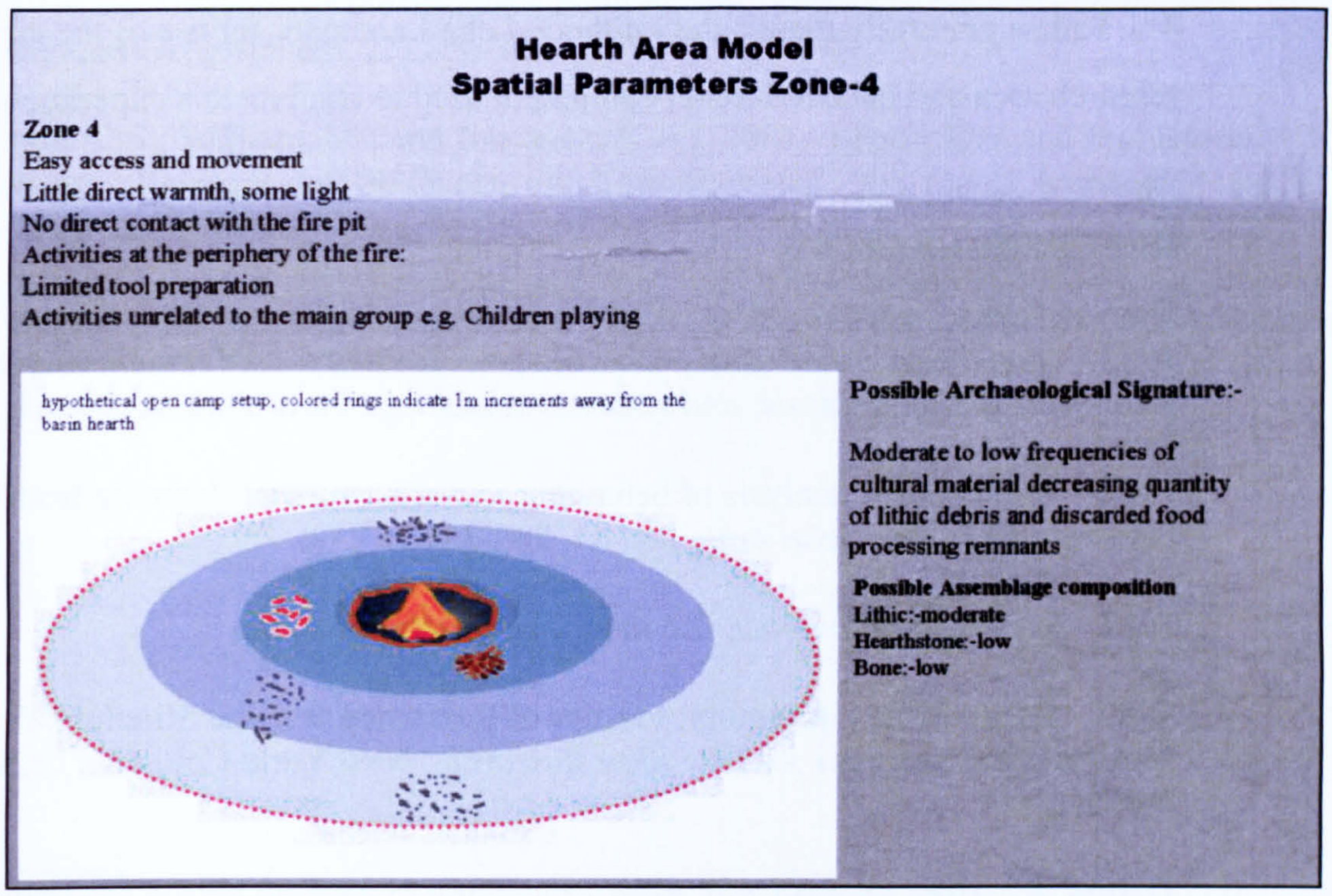


Figure 14. Behavioral model for human action that might be expected in zone 4 around a basin hearth type feature.

Conclusion

Clearly the application of this simple experiment does not lead to authoritative statements of past behavioural processes and that is not its intention. What the experiment does do is draw attention to the feature as a dynamic locus for human activities. Human behaviors occurring around such features, most likely were somewhat structured by the physical outputs of the facility itself. Importantly there is a clear division in the expected results of this project between the quantification of different variable types. Transformations of matter and energy, such as heat, light and smoke are more quantifiable and therefore easier to predict than transformations of information. The behavioural element of the investigation is by necessity a highly theoretical enterprise. In sum the proposed research model seeks to re-orient analytical focus on the hearth at site level. The activities involving and surrounding hearths differently result in archaeological residues that should not be examined in isolation. Further research is underway in order to test the applicability of the proposed research design to the archaeological record on the southern high plains.

ACKNOWLEDGMENTS

The author gratefully thanks the Lubbock Lake Landmark for use of the experimental research area and data collection equipment used to conduct this experiment.

REFERENCES CITED

Binford, L.R.,
1977. *For theory building in archaeology: essays on faunal remains, aquatic resources, spatial analysis, and systemic modelling.* New York: Academic Press.

1978. Dimensional analysis of behaviour and site structure: learning from an Eskimo hunting stand. *American Antiquity*, 43, 330-361.

1983. *In Pursuit of the Past.* London: Thames and Hudson.

1987. Researching Ambiguity: Frames of Reference and Site Structure. *In*: S. Kent, ed. *Method and Theory for Activity Area Research.* New York: Columbia University Press, 449-512

Dering, P., 1999. Earth-Oven Plant Processing in Archaic Period economies An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity*, 64(4), 659-674.

Fisher, J.W.; and Strickland, H.C., 1991. Dwellings and Fireplaces; Keys to Efe Pygmy Campsite Structure. *In*: C.S. Gamble and W.A. Boismier, eds. *Ethnoarchaeological Approaches to Mobile Campsites. Hunter-Gatherer and Pastrolist Case Studies*, Ann Arbor, Michigan, Ethnoarchaeological Series 1, 215-236.

Gamble, C., 2005. *The Hominid Individual in Context; Archaeological Investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts.* London: Routledge.

Kelly, R.L., 1995. *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways.* London: Smithsonian Institution Press.

Litwinonek, L.; Johnson, E.; Holliday, V.T., 2003. The Playas of the Southern High Plains: An Archipelago of Human Occupation for 12,000 Years on the North American Grasslands. *In*: In Marcel Kornfeld and Alan J. Osborn, eds. *Islands On The Plains Ecological, Social, and Ritual Use of Landscapes.* Salt Lake City: University of Utah Press.

O'Connell, J.F.; Hawkes, K.; and Blurton Jones, N., 1991. Distribution of refuse-producing activities at Hazda residential base camps: Implications for analyses of site structure. *In*: E.M. Kroll and T. D. Price, eds. *The Interpretation of Archaeological Spatial Patterning.* New York: Plenum, 61-76.

Otte, M., 2002. Fire as an Evolutionary Factor. *In*: D. Gheorghiu, ed. *Fire in Archaeology.* BAR International Series, S1089. Oxford: Archaeopress, 7-10.

Sabin, T. and Holliday, V.T., 1995. Morphological and Spatial Relationships of Playas and Lunettes on the Southern High Plains. *Annals of the Association of American Geographers*, 25, 286-305.

Smith, C.S.; William, M.; and Johansen, K.A., 2001. Sego Lilies and Prehistoric Foragers: Return Rates, Pit Ovens, and Carbohydrates. *Journal of Archaeological Science*, 28, 169-183.

Yellen, J., 1977. *Archaeological approaches to the present: Models for reconstructing the past*. New York: Academic Press.

Where Were the Hearths: An Experimental Investigation of the Archaeological Signature of Prehistoric Fire Technology in the Alluvial Gravels of the Southern Plains

Paul N. Backhouse and Eileen Johnson

Manuscript originally published in Journal of Archaeological Science, 2007, 34: 1367-1378.

Paul N. Backhouse, Museum of Texas Tech University, Lubbock, TX, 79409 and Bournemouth University School of Conservation Sciences, Bournemouth, UK, paul.backhouse@ttu.edu.

Eileen Johnson, Museum of Texas Tech University, Lubbock, TX, 79409, eileen.johnson@ttu.edu.

Abstract

The interpretation that a rock has been subjected to cultural utilization is a basic element of hunter-gatherer research. The fracture mechanics of the flaked stone tool production process are well understood and the material residues are routinely identified during fieldwork. Conversely, non-percussion processes such as hot-rock technology, that can result in rock fracture, are less well understood. An experimental study has been developed to examine the fractured gravels observed at a prehistoric site on the Southern Plains (USA). The experiment has sought to determine whether cultural or natural agencies were responsible for the production of the angularly fractured rocks. The positive results of the experiment indicate that not only were humans most likely responsible for the breakages, but also that the fractured rocks often exhibit distinctive morphologies that may be identified during fieldwork. This simple experimental methodology is applicable to other hunter-gatherer sites where the depositional environment is not conducive to the structural preservation of features such as hearths.

Keywords:- hot-rock technology, Southern Plains, experiment, Ogallala Formation.

Survey-based fieldwork has been initiated in order to examine the archaeological potential of an area along the eastern escarpment of the Southern High Plains (Fig. 1). The escarpment and adjacent Rolling Plains represent a dynamic geomorphic setting in which westward escarpment retreat proceeds through backwasting and the headward extension of existing streams [18:18]. Limited prior research suggests this setting was repeatedly occupied by both historic and prehistoric indigenous populations (e.g. [5]).

Survey at 41GR146 (PLK-Locality 1) indicated that an extensive Ogallala Fm. gravel terrace had been utilized heavily as a source for flaked stone tool production (Fig. 2). In addition to the flaked stone debris, several lines of evidence hinted that limited residential activities also were taking place at this site. Evidence included the recovery of a number of ceramic sherds, a stone pendant, and several broken projectile points; a relatively high frequency of discarded stone tools; and the fracturing *in situ* of many of the Ogallala Fm. gravels. The dynamic geomorphological setting of the site had resulted in significant erosion and it is unlikely that any features remain to be recorded (Fig. 2).

The angular fractured Ogallala Fm. gravels recorded at 41GR146 exhibited no evidence of impact damage as would be the case in stone tool production (e.g. [1, 12, 32, 37]) and individual cobbles often could be refitted completely (Fig. 3). This observation left two alternative hypotheses: mechanical weathering; or cultural utilization as in hot-rock technology. Examination of local climate data recorded for Post, Texas (16.49°C average annual temperature, 48cm/yr average annual

precipitation) indicated that only slight weathering is expected to occur in this environment [52:19].

The use of hearthstones in hot-rock technology has been well documented on the neighboring Southern High Plains [2, 25, 27, 28, 29]. Investigations at PLK-Locality 4, a campsite near 41GR146, has resulted in the contextual identification of fractured Ogallala Fm. gravel within a discrete cluster of hearthstones (burned caliche) and charcoal. Additionally, thermally altered Ogallala gravels have been identified at over 100 sites in the Garza County area (Fig. 1). Some of the fractured material then may represent the remains of localized thermal features, such as hearths and ovens, that are no longer archaeologically visible due to on-going erosion processes.

The positive identification of lithic material exhibiting evidence for cultural utilization and the interpretation of its performance characteristics in thermal technology have clear archaeological implications [9, 29]. Based on observation of thermally altered Ogallala Fm. gravels at multiple sites ca. 10km to the east of 41GR146, Boyd [6:115] has hypothesized that a notable difference likely existed in heat retention and fracturability between the varied lithic materials available within the gravels. Selective gathering, therefore, potentially is occurring between materials with obvious differences in morphology. This selectivity may have been necessary in order to maximize their suitability for different hot-rock technologies. The criteria used to identify culturally burned rocks, however, are not stated and empirical studies have been lacking in comparing the thermal properties of hot-rock resources encountered in the West Texas area. A series of actualistic experiments has been designed in order to test the validity of the cultural utilization hypothesis.

Thermal Features, Hearthstones, and the Experimental Method

Recognition of the physical evidence for the domestic fire technologies utilized by hunter-gatherer populations as manifest in the archaeological record is relatively commonplace globally [e.g., 21, 41, 47, 50]. The experimental investigation of the physical mechanics of features such as hearths and ovens has received sporadic but increasing interest, particularly from North American researchers [e.g., 13, 42, 44, 51].

Hearthstones often appear to have been utilized in large numbers within these features [e.g., 4, 9, 35, 46]. With their high potential for preservation, attention is becoming more focused on these ubiquitous artifacts [35]. Questions, therefore, regarding hearthstone use and performance characteristics have dominated the experimental literature [e.g., 2, 9, 29, 34]. Despite this emphasis on examining

hearthstone technology, relatively few studies have attempted to examine the thermal characteristics of hearthstones from a geologic perspective.

An early experiment was conducted with glacial gravels collected from Broome County, New York [31]. Various quartzite, sandstone, and granite cobbles were heated in a maple, pine scrap, and elm wood fires [31:24]. Observations of the specimens following heating suggested the rocks were affected in different ways by the fire. The variation in the effects of heating to the variously tested rock types was not quantified. Nevertheless, discoloration (reddening and blackening) and spalling of larger specimens frequently were recorded [31:25].

Several important studies have examined the effects of the thermal alteration of rock from a flaked stone tool perspective [e.g., 36, 37]. While these studies focus on the thermal characteristics of microcrystalline materials (i.e., chert), some mechanics are likely applicable to other lithologies. Notably, these studies indicate that rocks heated rapidly were more likely to fracture than those heated incrementally over longer periods [36, 37]. The identification of critical temperatures at which materials fracture (typically between 350°C and 400°C [36:42]) is pertinent to the present investigation as it suggests that a predictable relationship between temperature and fracture might be established for any given material. This relationship would have important implications for the functional interpretation of hearthstone technologies encountered in the archaeological record.

Geologic testing of lithic materials indicate that the thermal conductivity of individual rocks is controlled by their mineral content, porosity, pore fluid, and anisotropy [11:123]. Quartz is highly susceptible to thermal expansion and shows an increase in volume of 3.76% when heated from room temperature to 570°C [43, 53]. Fracturing, however, is found to be possible well below this temperature. Most recently, the effects of range and prescribed fire on different artifact classes have been examined experimentally [e.g., 10]. This research confirms that simulated quartzite artifacts (primary flakes) were likely to fracture when rapidly heated above 550°C [10:224]. Color change due to mineral oxidation often is recorded as a feature of this intense heating [10].

Experimental heating of rock in order to determine its archaeological significance is not a new concept. However, the relationship between firing temperature and morphological transformation in quartzite is poorly understood from an archaeological perspective. Furthermore, little attempt has been made to characterize the morphological variation in this material as a potential indicator useful for field

identification when the structural features that once constrained these rocks are no longer detectable. Therefore, the geologic characterization and context is of critical importance in situating experimental methods that seek to determine the usefulness of a particular rock as a heat reservoir and, therefore, a potential hearthstone.

Ogallala Formation Gravels

Deposition of the Ogallala Fm. during the Miocene-Pliocene is a result of sedimentation, originating from the rising Rocky Mountains to the west [55]. The Formation covers an area of ca. 450,660 square kilometers of the Great Plains, underlying parts of eight states: Texas, New Mexico, Colorado, Oklahoma, Kansas, Nebraska, Wyoming, and South Dakota [17, 33, 40, 48, 54].

On the Southern High Plains, deposition occurred as both alluvial sediments that at least partly fill older, more geographically limited, paleovalleys, and more widespread aeolian sediments that cap the paleouplands and fluvial sections [19:4]. Termination of deposition was precipitated by the incursion of the Pecos River system to the west and the Canadian River system to the north [55]. The pedogenic development of a thick, relatively erosion resistant, layer of calcrete in the upper portion of the Ogallala Fm. has prevented further downward erosion [7, 14, 38].

The eastern escarpment of the Southern High Plains represents a dynamic geomorphic setting in which a westward retreat of the escarpment proceeds through backwasting and the headward extension of existing streams [18:18]. This process is critical to understanding the geomorphic context of the lithic material recorded at 41GR146 because the original boundary of the Ogallala Fm. is estimated to be some 320km to the east of its current location [18]. Two large type III lake basins (Lazy S and Spring Creek) on the escarpment adjacent to the investigation area suggest that the Ogallala Fm. is relatively thin along this section (less than 61m). The unit, therefore, would be prone to salt dissolution as the Mesozoic fractures that may control the dissolution process would be nearer the surface [39:229]. Based on Gustavson's [18:45] projected former escarpment position data, the caprock may have retreated west of the investigation area by ca. 35ka.

Despite a strong presence as lithic tool stone in the archaeological deposits at numerous sites on the Southern High Plains [23], only a few studies have examined the lithologic variation of the Ogallala Fm. gravels from an archaeological perspective (Table 1). These studies provide a useful baseline with which to establish an empirical framework for the further investigation of local Ogallala Fm. gravel exposures at

41GR146. Potter member quartzite is a common constituent of Ogallala Fm. gravels (Table 1) and is the principal rock unit found in fractured clusters at 41GR146.

Research Hypothesis

Hypothesis testing simply sought to establish whether rapid intense heating could cause the morphological breakdown of individual cobbles. The null hypothesis, therefore, is rejected if a direct causal relationship between heating and thermal fracturing can be established.

H_o = When subjected to intense heating, Potter member quartzite does not fracture into smaller angular pieces and, therefore, the specimens observed at 41GR146 are not the result of thermal fracturing caused by cultural activity.

H_{a1} = When subjected to intense heating, Potter member quartzite does fracture into smaller angular pieces and, therefore, the specimens observed at 41GR146 could result from thermal fracturing caused by cultural activity.

Should the null hypothesis be rejected, then three subsequent research questions are framed in order to assess the potential economic viability of selecting Potter member quartzite as a hot-rock resource:

1) Does fracturing occur at temperatures above those associated with prairie fires?

2) Are Potter member quartzite cobbles useful heat reservoirs, rendering them suitable for hot-rock technology?

3) Are Potter member quartzite cobles more economically efficient, in terms of the amount of heat and/or length of time heat is retained, than other locally available rock types?

Methodology

In order to test the research hypothesis, a sample of four distinct (and culturally unmodified) rock types were collected from the Ogallala Formation (Fig. 4). Three were from the gravels and the fourth (caliche) from an exposed section of the caprock escarpment (Table 2). The gravel specimens comprised Potter member quartzite cobbles collected from two separate locations and labeled as light (typically light brownish gray) and dark (typically yellowish brown) types dependant on the dominant cobble coloration at the collection location. Both colorations appear to be lithologically identical. Small well-rounded purple quartzite cobbles comprised the other gravel rock

type tested. Of these four types, the Potter member quartzite (Groups B and D) most often was observed broken in angular fragments on the surface of the two sites.

A representative sample of nine specimens, of similar size and shape, was selected from each of the collected rock types. In order to obtain core temperature readings, a small (5mm) diameter hole was drilled into the interior of three of the specimens of each rock type. Twelve specimens were drilled in total. The depth of drilling varied depending on the specimen morphology, with the objective of drilling the probe hole to the core of the specimen. The drilled specimens subsequently were identified as the "target" specimens. An electronic temperature probe, Barant Type K, was used for all temperature measurements.

Four experimental basin hearths (1-4) were excavated within the experimental area at the Lubbock Lake Landmark. The basins were identical morphologically following the shallow basin-type design set out in previous experiments [2] and common in the archaeological record of the Southern High Plains [25, 26]. Honey mesquite (*Prosopis glanulosa)* was selected as the primary incendiary material, based on its frequent identification in archaeological contexts [2]. A standard weight of fuel was used for each of the experimental hearths (11,000g) and each rock was heated for a period of six hours. Thermocouple recording took place at 15-minute intervals throughout the duration of each experiment (Fig. 5). Weather data was not recorded for the experiment because the focus of the experiment was on examining the thermal dynamics of individual hearthstones rather than the attendant hearth facility.

Three specimens of the same type were used for each experiment, only one of which (the target specimen) was monitored. The other two were retained for control and to observe any fracturing. The ignition of the four experimental hearths was staggered to allow for the temperature recording in each at appropriate increments.

One day was required to complete one set of specimens (all four material types). Three days of experimentation, therefore, were required to cycle through all three specimens of each of the four rock types. All target specimens were inspected, drilled, photographed, and weighed prior to experimentation. The experiment was terminated when the target specimen fractured or six hours had passed since the test specimens had been added to the hearth. Upon completion of the experiment, all specimens again were weighed and the resultant number of fractured pieces recorded.

Results

The results of the experiment indicated that all four rock types tested were susceptible to thermal fracturing (Table 3). Comparison of fracturing between control

and target specimen groups indicated that the target specimens generally are representative and do not appear to have been affected negatively by the drilling process. Of the four rock types, caliche (Group A) and purple quartzite (Group C) proved the most resistant to breakage (Fig. 6). In contrast, both the dark (Group B) and light (Group D) Potter member quartzite were the most likely to fracture (Fig. 6). Examination of the post-burn fractures by size class illustrated that the target Potter member quartzite specimens tend to break into numerous small pieces <25g pieces (Fig. 6).

The fracturing results clearly indicate that Potter member quartzite is highly susceptible to thermal spalling (Fig. 7). The null hypothesis, therefore, is rejected in favor of the alternate. The morphology of detached fractured pieces is variable between all the experimental specimens. The production, however, of long curvilinear spalls that split away from the cortical surface of the target specimens appears a fairly constant phenomenon (Fig. 8). The propagation of these spalls could be heard in the form of high-pitched cracking noises (decrepitation) that occurred throughout the early stages of the experiments.

The spalls suggest that the thermal stresses operating on the outer portions of the rock exceeded its tensile strength and resulted in physical failure [e.g., 30]. The conductive heat transfer mechanism must have elevated the outer nodule temperatures rapidly (in relation to the measured core temperature) and, therefore, focused thermal stress across the surfaces of the tested cobble. Fracture nearly always occurred after the peak core temperature was achieved. This situation indicates that thermal shock was initiated during the initial firing but was not immediately physically manifest in flake detachment.

A discolored reddened rind (10R4/2) developed on some of the experimentally burned Potter member quartzite specimens (Fig. 7). The dark Potter member specimens (Group B) appeared to be more susceptible to this process, although further experimentation would be required to qualify this relationship.

An examination of the mean temperature dissipation curve (Fig. 9) allows for a basic assessment of the three economic research questions identified in the research design. The curve indicates that all four rock types acquired similar upper temperature readings (between 358°C [caliche] and 420°C [light Potter member]) within the first 30 minutes of the experiment. Insertion of the thermocouple into the target specimen has proven to be a reliable method for examining temperature dissipation over time, substantially reducing the variability in temperature curves produced by indirect

methods [2]. Roughly similar temperature curves are produced by all four rock types indicating very little variation in terms of their heat-retentive properties.

If the first two temperature readings are excluded, then comparison of the mean temperature dissipation per 15-minute interval indicates that all four material types are comparable in terms of thermal retention: caliche, 11.9°C; dark Potter member, 13.8°C; light Potter member, 13.4°C; and purple quartzite, 12.7°C. These data indicate that little or no economic benefit occurs in preferentially selecting one rock type over another, assuming thermal retention of heat is the prime motivator in hot-rock selection. The thermal retention characteristics of experimentally heated Potter member quartzite are comparable to that of caliche (a well-known hot-rock resource [2, 28, 29]). Potter member quartzite, then, is a useful, but brittle heat reservoir suitable for utilization in hot-rock technology. Potter member quartzite, however, comprises no significant advantage over the other source types in terms of heat retention.

Discussion

Experimental research proved that Potter member quartzite recovered from the Ogallala Fm. gravels are responsive to thermal alteration processes. Furthermore, these processes tend to result in the fracturing of individual cobbles in a fashion morphologically identical to specimens observed and recovered in the field from within archaeological contexts. The presented experiment sought to examine only the susceptibility of the selected gravels to thermal shock. The physical mechanisms that result in the propagation of thermal spalling in metamorphic rocks are complex and require further investigation [cf. 20]. Subsequent analysis should qualify the relationship between the core temperature, exterior temperature, and likelihood for thermal spalling over the course of rapid heating and subsequent cooling events.

The experiment illustrates that all four rock types potentially would have been useful as constituent elements in hot-rock technology. This temperature range is in broad agreement with previous experiments using mesquite as a fuel source [2]. Data from natural range fires tend to be less than 400°C although temperatures near 700°C can be reached under optimal conditions [45]. These data indicate that range fires may remain a possible causal explanation in the break up of individual cobbles.

A range fire, however, swept through the western portions of 41GR146 during spring of 2006. The fire resulted in the scorching and incineration of the vegetation throughout a large portion of the site. Systematic survey and recording of the exposed gravels in these areas demonstrated that the fire had not resulted in any new breakup of the exposed cobbles. This evidence, then, indicated that range fires typically are neither

hot enough nor intense enough in this environment to cause the type of morphological transformations observed on the lithic material during experimentation.

Range fires, therefore, are only a very remote and unlikely causal factor. The landscape setting of Ogallala Fm. exposures reinforces this interpretation, as the gravels tend to be exposed on heavily eroded terraces with very limited to nonexistent fuel loadings. This conclusion is in general agreement with more rigorous experimental research concerning range fires in mixed-grass environments [10].

The variation observed in fracture rates between the tested rock types, although beyond the scope of this paper, may have been a significant factor when selecting rocks for utilization in different technological processes. Studies on the Northern Plains [9] suggest that the fracturability of different rock types is important when considering technological utilization strategies. Furthermore, that research suggests that quartzite river cobbles are ideally suited to stone boiling activities [9:93]. Little is known currently, however, about the abundance or technological range of different thermal structures (e.g., hearths, ovens) along the eastern escarpment of the Southern High Plains with which to assess the relevance of this interpretation.

Human modification through thermal fracturing is not the only mechanism for specimen degradation in this environment. Mechanical weathering processes also can result in angular fractures. Common to all processes of physical weathering is the establishment of sufficient stress within the rock so that it breaks [8:52]. These physical processes most likely are operating at time-scales far greater than those observed archaeologically. Specific physical weathering processes include: particle erosion; expansion in cracks or along grain boundaries by freezing water or crystallizing salts; fire; and thermal expansion and contraction of the constituent minerals [8:52].

Field observations suggest that thermal stress processes may be operating to cause the *in situ* breakage of alluvial cobbles and boulders in the surficial stream terrace and pediment gravel deposits of West Texas (Lehman, personal communication, 2006). Causal variables associated with thermal stress include: freeze/thaw events; grass fires; daily temperature contrasts; and cultural alteration. Results of the experimentation have demonstrated that cultural alteration is viable and that grass fires are a most unlikely cause in this landscape setting. Inadequate data currently are available to assess the effect of mechanical weathering through thermal stress at longer time-scales as a result of freeze/thaw events or daily temperature contrasts. Anecdotal evidence suggests that the sheer volume of observed broken cobbles must be related to one of these two long-term weathering mechanisms (Lehman, personal communication, 2006).

Both natural and cultural thermal processes, most likely then, are causing the break-up of Ogallala Fm. gravels and specifically the angular fracturing of Potter quartzite. The role of context is crucial in differentiating between long-term natural and short-term cultural processes. Two additional and potentially significant secondary results of the experiment may help field researchers determine which rocks were likely the result of cultural utilization as hearthstones. The development of a grayish-red rind at the surface of experimentally heated specimens and the detachment of long curvilinear spalls both appear to be consistent by-products of the intense heating of Potter member quartzite. Limited heat-treatment experiments previously conducted on Ogallala Fm. quartzite collected from western Oklahoma and northwest Texas [24] appear to corroborate the findings of the present study. The heat-treated debitage is characterized by a reddened cortex, gray and black color, and numerous potlid flakes detached from the exposed surfaces [24:8]. Additional field observations and experimentation are required in order to substantiate the validity of these observations.

Building on this baseline dataset, high-resolution approaches such as the archaeomagnetic method [15] would be useful in the further development of models for understanding hot-rock technology on the Southern Plains. This method has yielded significant insights into hot-rock firing temperature, use history, and the role of site formation processes in assessing the structural integrity of individual hot-rock features [16]. Despite its high potential, archaeomagnetic analysis currently is not widely used, perhaps because it requires specialized collection strategies, partial destruction of the targeted specimen, and significant expertise in paleomagnetic analysis to be successful.

Conclusion

Identification of hot-rock scatters as the remnants of abandoned and deflated thermal features in eroded landscapes is not always a straightforward matter. Experimental research examining the physical properties of potential hot-rocks, in terms of heat-retention and structural integrity, prove to be a useful heuristic exercise. The experimental data indicate that when subjected to intense heating, Potter member quartzite does fracture into small angular pieces that are useful heat reservoirs, rendering them suitable for hot-rock technology. These results indicate that the selective use of Potter member quartzite as a hot-rock component in thermal features is confirmed by its presence in contextual association with other burned hot-rock types in discrete feature locations.

Potter member quartzite was found to confer no advantage, however, in terms of heat retention in relation to other locally available rocks. The possibility remains that

mechanical weathering processes also may result in the generation of angular Potter member quartzite through thermal alteration. Nevertheless, secondary results of the experimental research identified two macroscopic characteristics that may prove useful in the discrimination of culturally modified Potter member quartzite. These characteristics were the presence of reddened rind on the outer surface of an angularly fractured Potter member cobble and the identification of a large curvilinear spall morphology that is the result of detachment from a larger Potter member cobble during heating. These results underscore the need for and potential to develop a method for identifying Ogallala Fm. hot-rocks based on macroscopic characteristics. Furthermore, this research underlines the value of caution and context when examining potential hot-rock clusters encountered during archaeological survey.

Acknowledgements

The authors extend their sincere thanks to the landowners for generously granting access to the ranch. Doug Cunningham (Museum of Texas Tech University) initially identified and successfully communicated the importance of research at the two localities surveyed during the 2005 fieldseason; his passion for the exploration of this landscape made the present research possible. Photography was provided by Tara Backhouse (Museum of Texas Tech University). The authors thank Vance T. Holliday (University of Arizona) for comments on an earlier draft. Any errors or omissions, however, are the responsibility of the authors. This research was funded by the Museum of Texas Tech University. The manuscript represents part of the ongoing Lubbock Lake Landmark regional research into grasslands hunter-gatherers and adaptation to ecological change.

References

[1] W. Andrefsky, Jr., Lithics: Macroscopic Approaches to Analysis, Cambridge University Press, Cambridge, 1998.

[2] P.N. Backhouse, E. Johnson, A. Brackenreed-Johnston, B. Buchanan, Experimental Hearths and the Thermal Alteration of Caliche on the Southern High Plains, Georarchaeology: an international journal 20 (2005) 695-716.

[3] L.D. Banks, From Mountains Peaks to Alligators' Stomachs: A Review of Lithic Sources in the Trans-Mississippi South, the Southern Plains, and Adjacent Southwest, Oklahoma Anthropological Society Memoir, Norman, OK, (1990) 4.

[4] S.L. Black, Studying the Hearths of the Greater Edwards Plateau, in: M.B. Collins, D.B. Hudler, S.L. Black (Eds.), Pavo Real (41BX52): A Paleoindian and Archaic Camp and Workshop on the Balcones Escarpment, South-Central Texas, Studies in Archaeology 41, Texas Archaeological Research Laboratory, University of Texas, Austin, TX, 2003, pp. 375-405.

[5] D.K. Boyd, The Palo Duro Complex: Redefining the Early Ceramic Period in the Caprock Canyonlands, Bulletin of the Texas Archaeological Society 66 (1995) 461-518.

[6] D.K. Boyd, M.D. Freeman, M.D. Blum, E.R. Prewit, M. Quigg, Justiceburg Reservoir, Garza and Kent Counties, Texas: Phase I Cultural Resources Investigations on the Double Mountain Fork of the Brazos River. Prewitt and Associates, Inc., Austin, TX Reports of Investigations 66 (1 & 2) (1989) 1-643.

[7] F.H. Bretz, L. Hornberg, Caliche in southeastern New Mexico, Journal of Geology 57 (1949) 491-511.

[8] P.W. Brikeland, Pedology, Weathering, and Geomorphological Research, Oxford University Press, London, 1974.

[9] J.W. Brink, B. Dawe, Hot Rocks as Scarce Resources, Plains Anthropologist 48 (2003) 85-104.

[10] B.A. Buenger, The Impact of Wildland and Prescribed Fire on Archaeological Resources, PhD dissertation, University of Kansas, Lawrence, Kansas, 2003.

[11] C. Clauser, E. Huenges, Thermal Conductivity of Rocks and Minerals, in: T.J. Ahrens (Ed.), Rock Physics and Phase Relations: A Handbook of Physical Constants, Florida, The American Geophysical Union, 1995 pp. 105-126.

[12] B. Cotterell, J. Kaminga, The Formation of Flakes, American Antiquity 52 (1987) 675-708.

[13] P. Dering, Earth-Oven Plant Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America, American Antiquity 64 (1999) 659-674.

[14] L.H. Gile, F.F. Peterson, R.B. Grossman, Morphological and Genetic Sequences of Carbonate Accumulation in Desert Soils, Soil Science 101 (1966) 347-360.

[15] W. Gose, Paleomagnetic Studies of Burned Rocks. Journal of Archaeological Science 27 (2000) 409-421.

[16] W. Gose, K.S. Collins, M.B. Collins, Paleomagnetic Studies From the Moore-Hancock Farmstead, Austin, Texas. Journal of Field Archaeology, 21 (1994) 125-129.

[17] T.C. Gustavson (Ed.), Geologic Framework and Regional Hydrology: Upper Cenozoic Blackwater Draw and Ogallala Formations, Great Plains, Bureau of Economic Geology, University of Texas, Austin, TX, 1990.

[18] T.C. Gustavson, W.W. Simpkins, Geomorphic Processes and Rates of Retreat Affecting the Caprock Escarpment, Texas Panhandle, Bureau of Economic Geology, Report of Investigations No. 180, University of Texas, Austin, TX, 1989.

[19] T.C. Gustavson, D.A. Winkler, Depositional Facies of the Miocene-Pliocene Ogallala Formation, Northwestern Texas and Eastern New Mexico, in: T.C. Gustavson (Ed.), Geologic Framework and Regional Hydrology: Upper Cenozoic Blackwater Draw and Ogallala Formations, Great Plains, Bureau of Economic Geology, University of Texas, Austin, TX, 1990, pp. 3-9.

[20] M.H.H Hettema, K.-H.A.A Wolf, C.J. De Pater, The Influence of Steam Pressure on Thermal Spalling of Sedimentary Rock: Theory and Experiments, International Journal of Rock Mechanics and Mining Sciences 35(1) (1998) 3-15.

[21] S.J. Holdaway, P.C. Fanning, M. Jones, J. Shiner, D.C. Witter, G. Nicholls, Variability in the Chronology of Late Holocene Aboriginal Occupation on the Arid Margin of Southeastern Australia, Journal of Archaeological Science 29 (2002) 351-363.

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

[23] V.T. Holliday, C.M. Welty, Lithic Tool Resources of the Eastern Llano Estacado, Bulletin of the Texas Archaeological Society 52 (1981) 201-214.

[24] S. Hurst, K.J. Rebnegger, The Hidden Virtues of Ogallala Quartzite. Paper presented at the 57th Annual Plains Anthropological Conference, Sioux Falls SD.

[25] E. Johnson (Ed.), Lubbock Lake. Late Quaternary Studies on the Southern High Plains, Texas A&M University Press, College Station, 1987.
[26] E. Johnson, Landscapes and Peoples of the Llano Estacado, in: L.L. Scheiber, B. Clark (Eds.), Archaeological Landscapes on the High Plains, University of Colorado Press, Boulder, in press.

[27] E. Johnson, V.T. Holliday, Archaeology and Late Quaternary Environments of the Southern High Plains, in: T. K. Perttula (Ed.), The Prehistory of Texas. Texas A&M University Press, College Station, 2004, pp. 283-295.

[28] N. Ladkin, K.L. O'Brien, Burned Caliche from the 1989 and 1990 Survey and Excavations, in: E. Johnson (Ed.), Late Holocene Investigations at the Lubbock Lake Landmark: Volume 2 The 1989 and 1990 Work, Lubbock Lake Landmark Quaternary Research Center, 1995, pp. 281-312.

[29] C. Lintz, Experimental Thermal Discoloration and Heat Conductivity Studies of Caliche from Eastern New Mexico, Geoarchaeology: an international journal 4 (1989) 319-346.

[30] R.L. Marovelli, T.S. Chen, and K.F. Veith, Thermal Fragmentation of Rock, Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers 235 (1966) 1-15.

[31] E.E. McDowell-Loudan, Fire - Cracked Rock: Preliminary Experiments To Determine Its Nature And Significance In Archaeological Contexts, The Chesopiean 21(1) (1983) 20-29.

[32] G.H. Odell, Lithic Analysis, Kluwer Academic/Plenum Publishers, New York, 2004.

[33] W.R. Osterkamp, M.M. Fenton, T.C. Gustavson, R.F. Hadley, V.T. Holliday, R.B. Morrison, T.J. Toy, The Great Plains, in: W.L. Graf (Ed.), Geomorphic Systems of North America, Centennial Special Volume 2, The Geologic Society of America, Boulder, CO, 1987, pp. 163-210.

[34] P. Pagoulatos, Experimental Burned Rock Studies on the Edwards Plateau: A View From Camp Bullis, Texas, North American Archaeologist 26 (2006) 289-329.

[35] M.D. Petraglia, The Heated and the Broken: Thermally Altered Stone, Human Behavior, and Archaeological Site Formation, North American Archaeologist 23 (2002) 241-269.

[36] B.A. Purdy, Investigations Concerning The Thermal Alteration of Silica Minerals: An Archaeological Approach, Tebiwa 17 (1974) 37-66.

[37] B. A. Purdy, Fractures for the Archaeologist, in: E. Swanson (Ed.), Lithic Technology Making and Using Stone Tools, World Anthropology, Chicago, 1975, pp. 133-141.

[38] C.C. Reeves Jr., Caliche: Origin, Classification, Morphology and Uses, Estacado Books, Lubbock, 1976.

[39] C.C. Reeves Jr., A Proposed Sequential Development of Lake Basins, Southern High Plains, Texas and New Mexico, in: T. C. Gustavson (Ed.), Geologic Framework and Regional Hydrology: Upper Cenozoic Blackwater Draw and Ogallala Formations, Great Plains, Bureau of Economic Geology. Austin: University of Texas, Austin, TX, 1990, pp. 209-232.

[40] C.C. Reeves Jr., J.A. Reeves, "The Ogallala Aquifer" (vol. 1). Estacado Books, Lubbock, 1996.

[41] S. Schiegl, P. Stockhammer, C. Scott, L. Wadley, A Mineralogical and Phytolith Study of the Middle Stone Age Hearths in Sibudu Cave, KwaZulu-Natal, South Africa, South African Journal of Science 100 (2004) 185-194.

[42] D. Shockey, An Experimental Inquiry into the Thermal Characteristics of Square and Round Hearths, Oklahoma Anthropological Society Bulletin 46 (1997) 25-33.

[43] B.J. Skinner, Thermal Expansion, in: S.P. Clark, Jr., (Ed.), Handbook of Physical Constants – Revised Edition. The Geologic Society of America Memoir 97, Washington, D.C., 1966, pp. 76-96.

[44] C.S. Smith, W. Martin, and K.A. Johansen, Sego Lilies and Prehistoric Foragers: Return Rates, Pit Ovens, and Carbohydrates, Journal of Archaeological Science 28 (2001) 169-183.

[45] K.J. Stinson, H.A. Wright, Temperatures of head fires in the southern mixed prairie of Texas, Journal of Range Management 22 (1969) 169-174.

[46] A.P. Sullivan III, R.A. Cook, M.P. Purtill, P.M. Uphus, Economic and Land-Use Implications of Prehistoric Fire-Cracked-Rock Piles, Northern Arizona. Journal of Field Archaeology 28 (2001) 367-382.

[47] A.V. Thoms, Cook-Stone Technology in North-America: Evolutionary Changes in Domestic Fire Structures During the Holocene, in: M. Frère-Sautot, (Ed.), Le Feu Domestique et Ses Structures au Néothlique et Âges des Métaux. Âctes du Colloque de Bourg-en-Bresse et Breune, Monique Mergoil, Montagnac, France, Prèhistories, 9, 2003, pp. 87-96.

[48] W.D. Thornbury, Regional geomorphology of the United States, John Wiley and Sons: New York, 1965.

[49] S. Tomka, D. Boyd, Artifact Analysis, in: D. Boyd, J.T. Abbott, W.A. Bryan, C.M. Garvey, S.A. Tomka, R.C. Fields (Eds.), Phase II Investigations at Prehistoric and Rock Art Sites, Justiceberg Reservoir, Garza and Kent Counties, Texas, Volume II. Austin: Prewitt and Associates, Austin, TX, 1990, pp. 379-480.

[50] M. Vaquero, I. Pastó, The Definition of Spatial Units in Middle Palaeolithic Sites: The Hearth-Related Assemblages, Journal of Archaeological Science 28 (2001) 1209-1220.

[51] L. Wandsnider, The Roasted and the Boiled: Food Composition and Heat Treatment with Special Emphasis on Pit-Hearth Cooking, Journal of Anthropological Archaeology 16 (1997) 1-48.

[52] M.R. Waters, Principles of Geoarchaeology A North American Perspective, The University of Arizona Press, Tucson, 1992.

[53] E.M. Winkler, Stone: Properties, Durability in Man's Environment, Springer-Verlag, New York, 1973.

[54] D.J. Wishart (Ed.), Encyclopedia of the Great Plains, University of Nebraska Press, Lincoln, 2004.

[55] W.W. Wood, S. Stokes, J. Rich, Implications of Water Supply for Indigenous Americans during Holocene Aridity Phases on the Southern High Plains, USA, Quaternary Research 58 (2002) 139-148.

Table List

Table 1. Summary data for previous archaeological identification of Ogallala Fm. material suitable for the production of stone tools.

Table 2. Summary of the four rock types selected from the available Ogallala Fm. gravels for experimental research.

Table 3. Summary of thermal fracturing recorded post experimentation.

Figure List

Fig. 1. Southeastern section of the Southern High Plains physiographic province showing location of 41GR146 and sites with thermally altered Potter member quartzite identified in Garza County, TX; note the
cluster of sites directly east of 41GR146 are the result of a large municipal survey project (Justiceburg Reservoir) [4].

Fig. 2. An exposure of Ogallala Fm. gravels within an erosion feature along the upper terrace at 41GR146.

Fig. 3. An example of a Potter member quartzite cobble with nearby refits: a) typical section of exposed Ogallala Fm. gravels observed at 41GR146 with the locations of refitting pieces indicated; b) refitted cobble using the indicated pieces.

Fig. 4. Target specimens selected for each examined rock type prior to experimentation.

Fig. 5. experiment in progress; a) experimental area overview; b) obtaining a temperature reading on a target specimen using the thermocouple probe; c) fractured dark Potter member quartzite during experiment.

Fig. 6. Summary of fracturing, on target specimens, post burn by material type.

Fig. 7. Example of the break up of a Potter member quartzite specimen (dark Potter member, Control Sample 3B) following heating.

Fig. 8. Example of a curvilinear flake removed from a Potter member quartzite specimen (dark Potter member control sample 3A) following heating.

Fig. 9. Mean specimen temperature dissipation curve.

Table 1. Summary data for previous archaeological identification of Ogallala Fm. material suitable for the production of stone tools.

Material	Grain Size	Color	Size	*Reference*
Quartzite	medium to coarse	light	~	*22 , 23, 49*
Quartzite	medium	dark gray to black	~	*22 , 23*
Quartzite	~	pink, purple, red	pebble-nodule	*22 , 23, 49*
Jasper	fine	red, brown, yellow	~	*22 , 23*
Chert	fine to coarse	medium to dark-gray, dark-blue, white, red	5 to 10cm	*22 , 23, 49*
Siltstone Potter Chert	very-fine to coarse	dense, gray to brown, silica cemented	8 to 20+ cm	*3, 22 , 23, 49*
Potter Quartzite	various	various	~	*22 , 23*
Silicified Caliche	~	~	~	*22 , 23, 49*
Opalized Caliche	~	~	~	*22 , 23, 49*
Petrified Wood	~	~	~	*22 , 23, 49*
Sandstone	~	~	~	*49*

Table 2. Summary of the four rock types selected from the available Ogallala Fm. gravels for experimental research.

Designation	Description	Average Size (g)	Color Range (Geologic Society of America Rock-Color Chart)	*Previous Archaeological Association with Hot-Rock Technology ?*
A	Caliche	1167.5	N5, N6, N7, 5Y6/1	*yes*
B	Potter member Quartzite (Dark)	1351	10YR5/4, 10YR6/2, 10YR6/6, 10YR7/4	*yes*
C	Purple Quartzite	692.5	5Y4/1. 5Y6/1, 10YR5/4, 10YR6/2, 10YR6/6	*no*
D	*Potter member Quartzite (Light)*	*1975*	*5R4/2, 5YR4/1, 5YR6/1, 10YR4/2, 10YR5/4, 10R4/2*	*yes*

Table 3. Summary of thermal fracturing recorded post-experimentation.

Group	Identifier	Specimen Fractured (Y/N)	Total No. of Pieces	No. of Pieces 1-25g	No. of Pieces 25-150g	No. of Pieces >150g
A	TS1	N	1	0	0	1
A	CS1A	N	1	0	0	1
A	CS1B	N	1	0	0	1
A	TS2	N	1	0	0	1
A	CS2A	N	1	0	0	1
A	CS2B	N	1	0	0	1
A	TS3	Y	2	1	0	1
A	CS3A	N	1	0	0	1
A	CS3B	N	1	0	0	1
B	TS1	N	1	0	0	1
B	CS1A	N	1	0	0	1
B	CS1B	Y	2	0	1	1
B	TS2	Y	2	0	0	2
B	CS2A	Y	5	3	0	2
B	CS2B	N	1	0	0	1
B	TS3	Y	13	10	2	1
B	CS3A	Y	4	1	2	1
B	CS3B	Y	18	6	12	0
C	TS1	N	1	0	0	1

Group	Identifier	Specimen Fractured (Y/N)	Total No. of Pieces	No. of Pieces 1-25g	No. of Pieces 25-150g	No. of Pieces >150g
C	CS1A	N	1	0	0	1
C	CS1B	N	1	0	0	1
C	TS2	N	1	0	0	1
C	CS2A	N	1	0	0	1
C	CS2B	N	1	0	0	1
C	TS3	N	1	0	0	1
C	CS3A	N	1	0	0	1
C	CS3B	Y	6	4	0	2
D	TS1	Y	2	0	0	2
D	CS1A	Y	2	0	0	2
D	CS1B	Y	11	8	2	1
D	TS2	Y	13	9	2	2
D	CS2A	Y	8	5	2	1
D	CS2B	Y	8	7	0	1
D	TS3	Y	7	5	0	3
D	CS3A	Y	2	0	1	1
D	CS3B	N	1	0	0	1

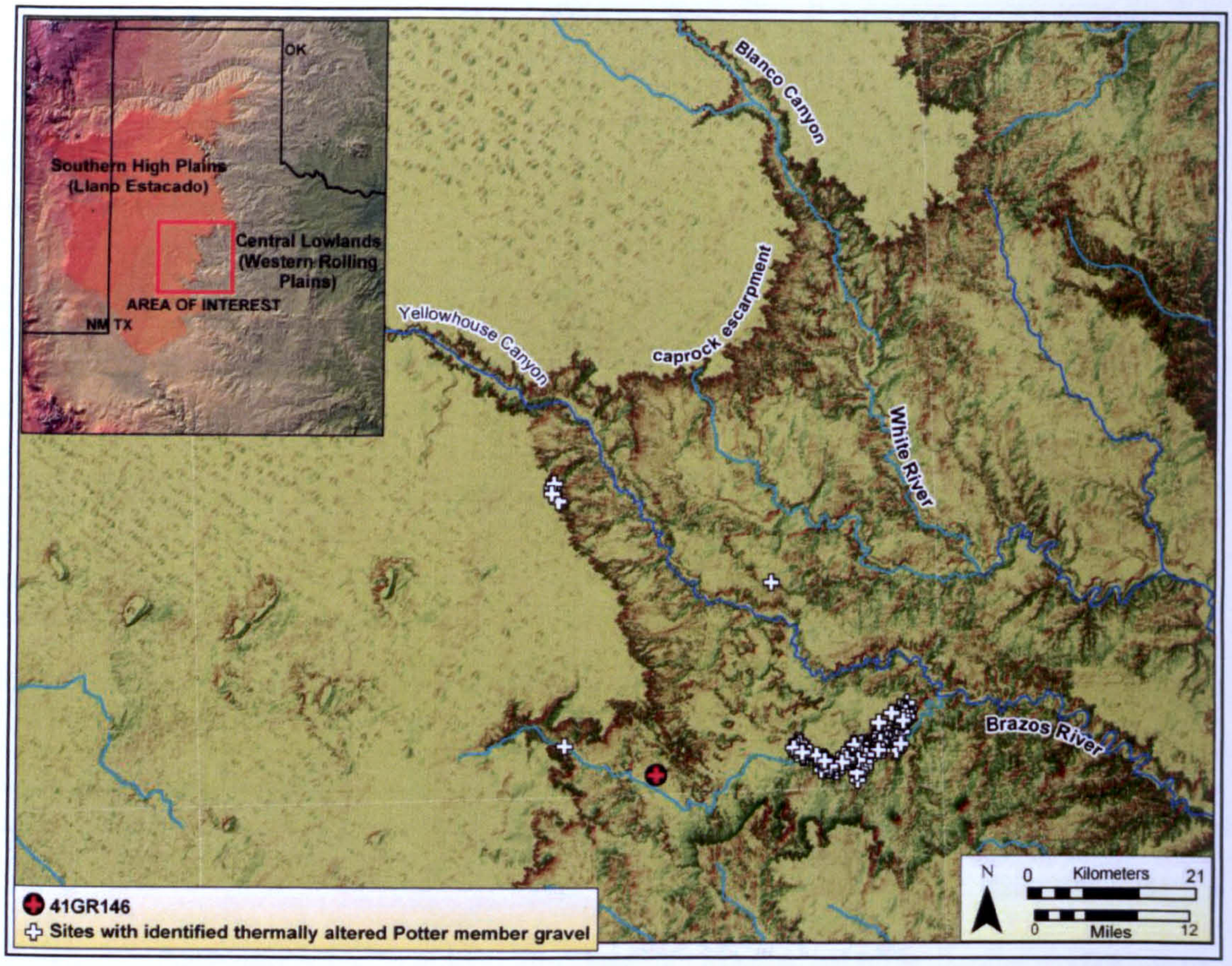
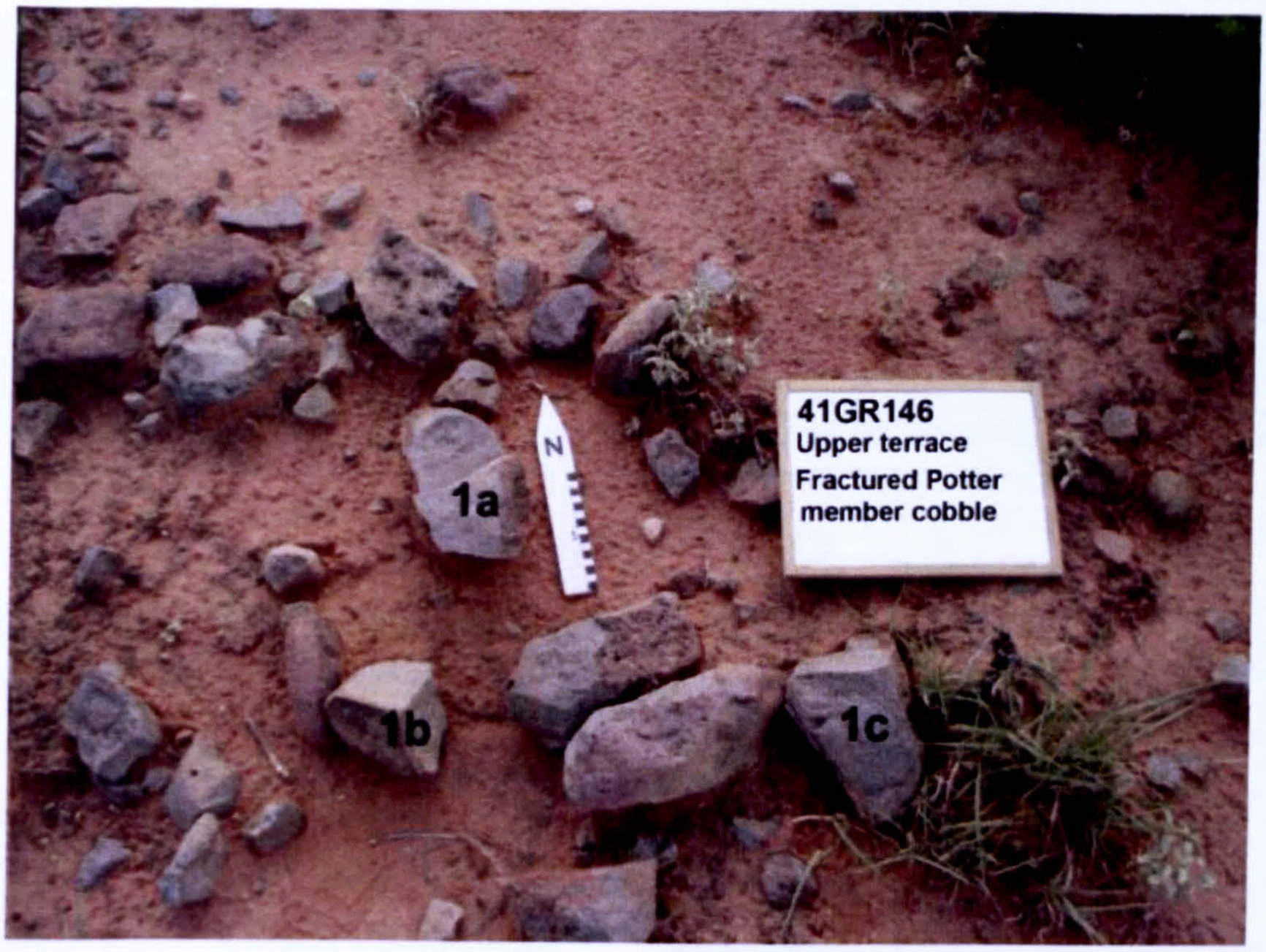


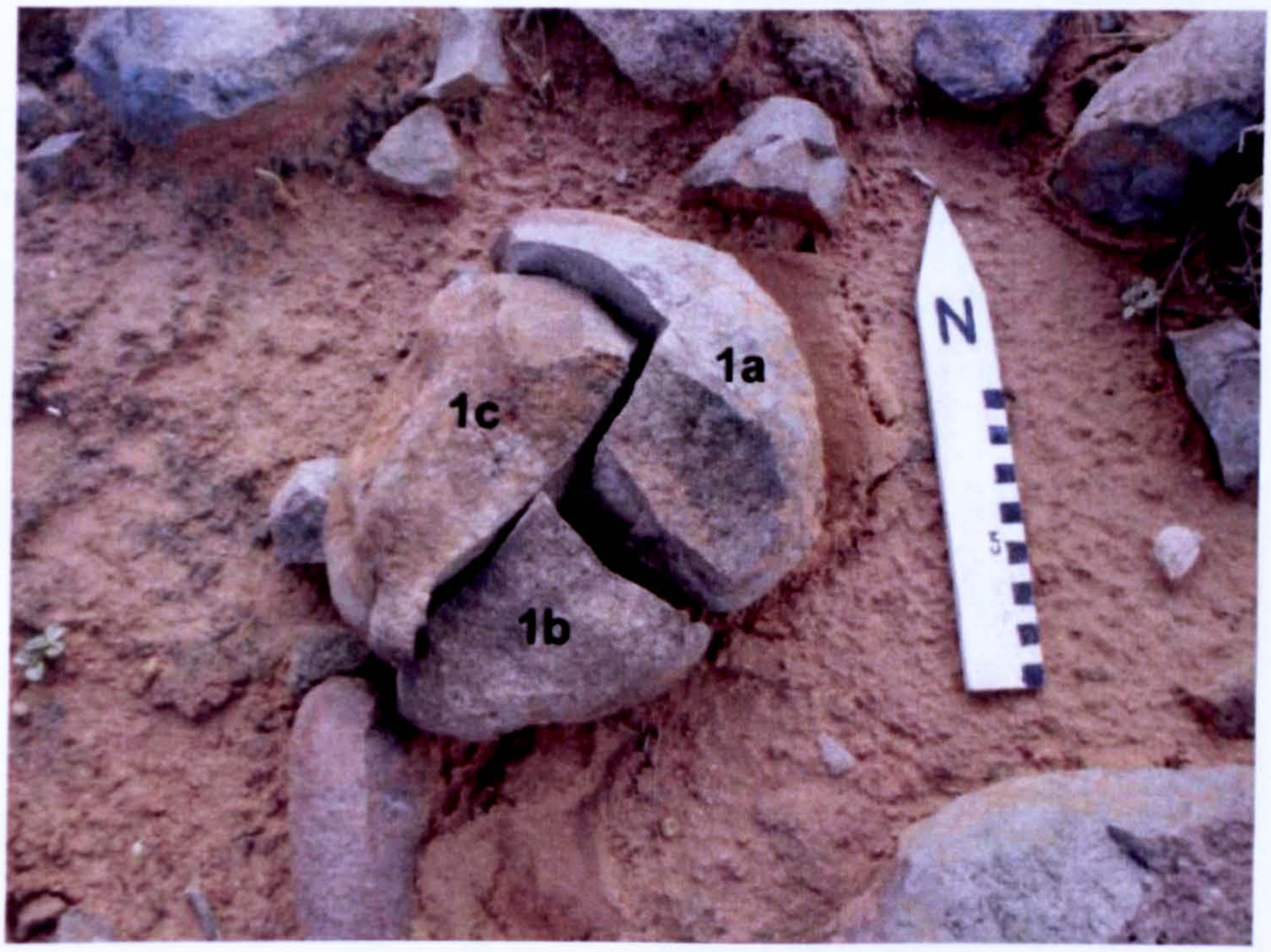
Fig. 1. Southeastern section of the Southern High Plains physiographic province showing location of 41GR146 and sites with thermally altered Potter member quartzite identified in Garza County, TX; note the cluster of sites directly east of 41GR146 are the result of a large municipal survey project (Justiceburg Reservoir) [4].



Fig. 2. An exposure of Ogallala Fm. gravels within an erosion feature along the upper terrace at 41GR146.



a.



b.

Fig. 3. An example of a Potter member quartzite cobble with nearby refits: a) typical section of exposed Ogallala Fm. gravels observed at 41GR146 with the locations of refitting pieces indicated; b) refitted cobble using the indicated pieces.

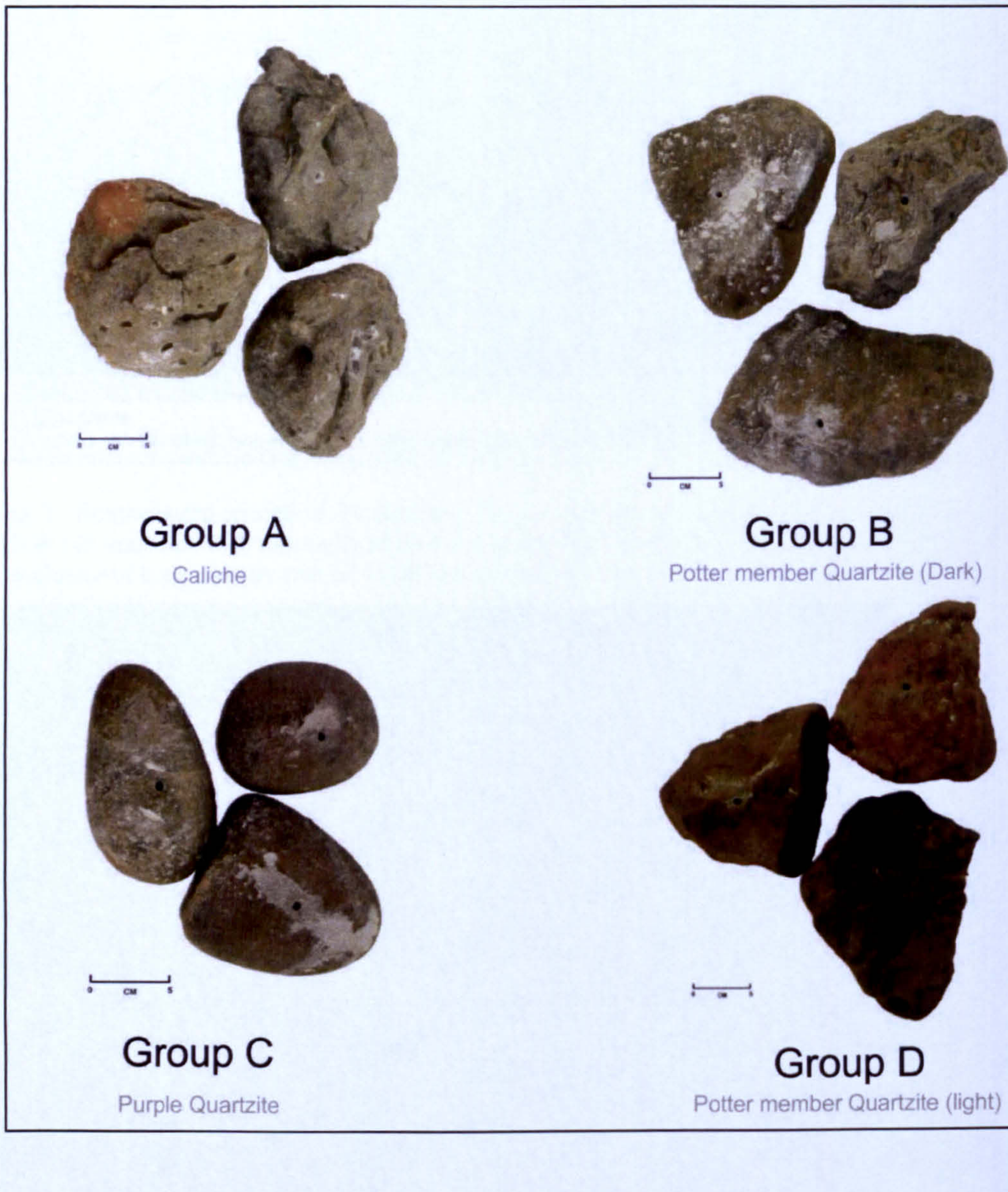


Fig. 4. Target specimens selected for each examined rock type prior to experimentation.



Fig. 5. experiment in progress; a) experimental area overview; b) obtaining a temperature reading on a target specimen using the thermocouple probe; c) fractured dark Potter member quartzite during experiment.

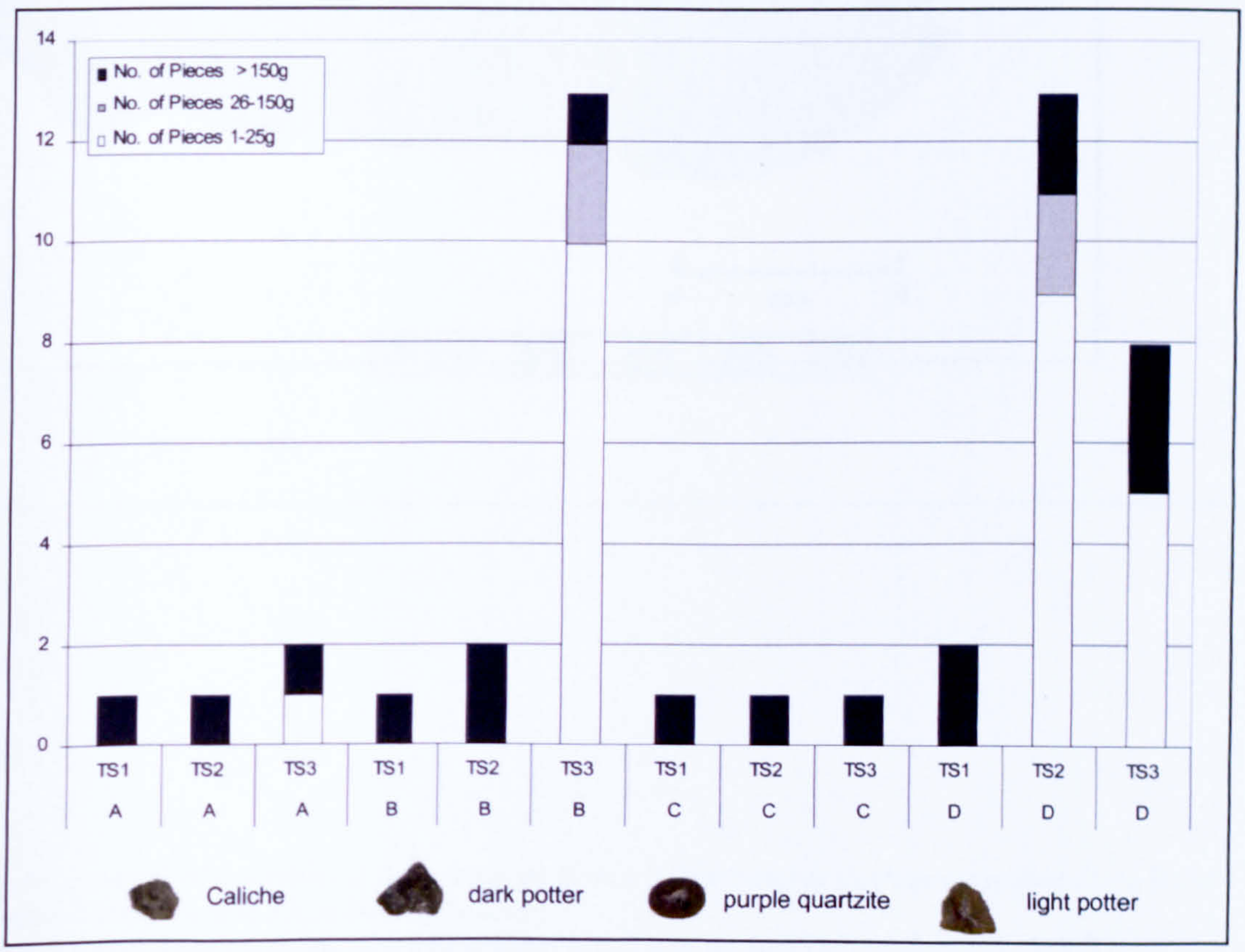


Fig. 6. Summary of fracturing, on target specimens, post burn by material type.



Fig. 7. Example of the break up of a Potter member quartzite specimen (dark Potter member, Control Sample 3B) following heating.



Fig. 8. Example of a curvilinear flake removed from a Potter member quartzite specimen (dark Potter member control sample 3A) following heating.

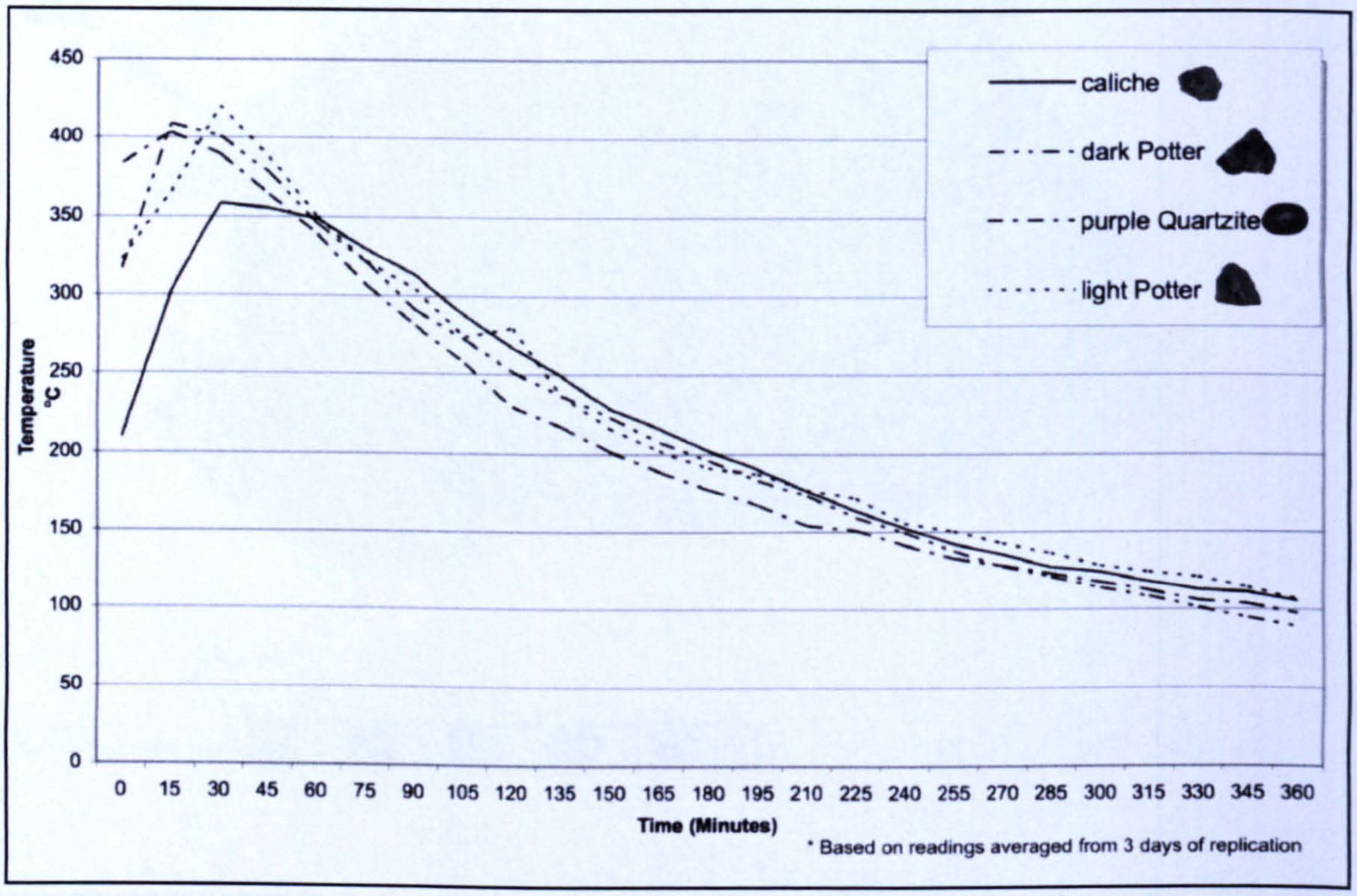


Fig. 9. Mean specimen temperature dissipation curve.

Interview with Ray Olachia while Building an Experimental Earth Oven

Transcript

An informal interview took place with the verbal consent of Ray Olachia (RO) during the morning of the 17th of June 2005 at the Lubbock Lake Landmark, Texas. The interview was recorded during a hands on teaching program with a group of High School teachers (Tr). Activity was centered around the creation and use of an experimental earth oven located within the experimental research area at the Lubbock Lake site. Media recording, by the author (PB), for the purposes of ethnographic research consisted of digital voice recording (RCA Digital Voice Recorder) and digital photography (Sony Cyber-shot camera). The following is an edited transcript of the field recording. Editing has been primarily undertaken in order to remove redundant statements and comments which were not perceived to be relevant to the line of questioning i.e. understanding earth oven technology.

Note:
Ray Olachia is part Mescalero and Jicarilla Apache and Yaki (northern New Mexico group). The historically recorded range for these peoples is along the Pecos and Rio Grande river valleys. The Pecos river valleys forms the western boundary of the Southern High Plains dataset and any information Ray has may be directly relevant to understanding the archaeological record in that area. The information is also relevant to understanding oven feature, and hot-rock cooking technology. A process which have been identified in the archaeological record of the Southern High Plains and Southern British study areas. Ray gave his verbal consent to the recording of this interview prior to the commencement of this dialogue. The Lubbock Lake Landmark Education Specialist, Sue Shore (SS) was present throughout the experiment and interview.

Time Track	Person	Activity
File 1 - 0.00 9:20am	RO	New Rocks, OK, that's why you call them rock pits. Piles and piles of rocks because they didn't use the same rocks over and over.
	Tr	Called a dead pit
	RO	Sir?
	Tr	That's what we call a dead pit
	RO	Yeah
	Tr	Where's it legal to get a rock (mumbles)? {at Lubbock Lake}
	RO	Er, we can even get them off of the wall *{Caliche retaining wall}*
	Tr	OHHH!
	RO	OK, there may be some down at the end over here going inside the fence go and look in the ditch, big ditch over there.
	Tr	Just a bunch of rocks?
	RO	Yeah, go, go GO!, that's good, that's good, that's good, that's good, allright with some of these other rocks lets start lining the pit. OK (mumbles)
	RO	When you go to these places, and find these earth ovens you'll find piles of burnt rock.
	PB	Right
	RO	They don't use them and reuse them they put news ones on all the time. Ok. Because the old ones do not hold the heat that the new ones seem to hold.
	PB	So there's an idea there that to get a new one (hearthstone) is better?
	RO	So that's why you'll find, that rock pit are huge because people are getting new rocks to, to cook with, and all the old ones are piled up all around.
1.40	PB	So even if you had to go a long way to get the new rocks, you'd still get rid of them? *{points at the old rocks}*
	RO	They are doing this in an area where the rock is available
	PB	So its not hard to go and get it then?
	RO	Just like they are going to be, where the water is available, although there on the Pecos the water is available for miles. Then on the other side there is about a half mile from the Rio Grande so they are not right on the edge of the water source, but....
	PB	*{cuts in}*They're pretty close?
2.19	RO	They're pretty close, but you'll find tons and tons of I mean piles all around the pit of the burnt rock.
	PB	Can you still see the pit in that case?
	RO	Oh, yeah you can see the burnt rock on top, because you line the bottom with rock and you can see the top OK
2.40	PB	So, would you have a similar ring around the edge like we kind of done here

Time Track	Person	Activity
		{points to the experimental pit with the surrounding ring of caliche hearthstones}
	RO	We're going to line it *{turns back to group}* that's looking good. Looking good
9:24am 4.56	RO	Can I have your attention, Ok we have the pit and normally they would be a lot bigger, but the burnt rock is used up, it won't work so we take it out and replace it with new rocks, so literally if you keep doing this you are going to have a pile of rocks burnt. That why when you go out in the southwest you will find (mumbles)… they got a big pile and I am talking big sometimes ten to 15 feet high where they threw they burnt rock. They do this with the same ones over and over again creating big piles of rock, so err, using new rocks when they start. Now we are going to do now…..
	Tr	Did they use some of the harder rocks further south?
	RO	Further south Some, Not all, OK where are my fire builders?
	Trs	*{argue humorously among themselves and assign one of their own as the firebuilder…Max}*
6.38	RO	OK what we are going to do is we are going to start a small fire get it going then we add, errrm, more wood until we have a big roaring fire in the pit itself. What we are trying to do is get maximum heat on those rocks, because the rocks are what's going to cook our food.
	RO	Ok who has a match
	SS	I sent two boxes down
	Trs	*{General mumbling}*
7.32	RO	Ok, I am going to have to rub two people together
	RO	Where the hell is the box of matches?
	SS	{finds matches}
8.02	RO	Ok we are going to start the fire small and start adding to it, Do we have some tinder?
	SS	Yeah you can pull up the grass right here
	RO	Dry grass? Ok, some is still green
	Trs	*{Start trying to light kindling in the pit}*
	RO	The best side to light it from is over here *{points to downwind side of pit}* because the wind is going to blow and make like a torch.
	Tr	Fire in the hole
	RO	Couple of you get over here to stop the wind *{on the windward side of the pit}*
	RO	A lot of scouts that I work with will go and gather a pile of wood, pile it all on and try and light it, you need to start with a little fire and start adding little pieces.
	SS	Fire!!
	PB	Ray, I noticed when they started building the fire (the teachers) that it was mainly the guys, that came in to build it, is that something that would have happened traditionally?
	RO	No, what would have happened traditionally was a woman took care of the camp and builds the fire
	PB	OK, so the guys wouldn't have been involved?
	RO	The guys would have been out hunting and playing games
		{general sniggering}
	SS	Ohh, is this another one of those "women's" jobs?
	RO	{*Changing conversation back to starting the fire*} Yeah, women were, if you can find a tall tube like a reed punch it all the way through and blow through it, you don't need to blow it hard, barely blow it
	Tr	We have got fire
	SS	There you go
	RO	In the beginning.. How many of you have seen the movie eeeeerrrrrr, quest for fire?
		{general talk about the inaccuracy of the movie}
	RO	That's good, lets start stacking the big stuff
	RO	Lets start adding a little more
	Tr	Not a typical Indian burn, unless we are trying to (mumbles)
	RO	Right
	Tr	Right

Time Track	Person	Activity
	RO	Ok, Contrary to popular belief you don't cook on the flame
	Tr	You Don't?
	RO	You cook with the coals
	RO	We are going to cover what we put in here with dirt, pile a few more rocks on top of it that means we are going to have to find a few more rocks, we need to cover it with rocks and dirt ok, we have plenty of dirt here and there *{points to mounded areas around the pit}*
		{Teachers disperse to look for rocks}
17.40	PB	Where did you learn to build fires like this Ray?
9:47am	RO	When I was a kid, we cooked underground. Dig a pit with a cow in it underground.
	PB	In the same kind of style as this?
	RO	Yes, We dug the hole, I know, I dug the hole!!
	PB	Your going to remember that!! {laughs}
	RO	We lined it with rock, put the, er, fire to heat it up and then, er, depending what we were cooking, line it with grass or something and, er, cook whatever we were cooking, if we were cooking a pig we would cook it in the skin because the skin acts as the insulation.
	PB	Right
	RO	If your cooking meat you cover it up , because of the air (mumbles) cover it up my dad would put a piece of tin on top, because, you know we had that instead of rock but earth ovens they use rocks. So the rocks on the surface.
	PB	So but er we cook.....{trails off}
	RO	We cook all the time because I dug the holes!
	PB	Laughs
	RO	The earth ovens.. they were bigger holes because you are talking about throwing a pig in there
	PB	Right, Right that's going to be pretty big?
	RO	And again you cover it with tin and er leave it over night and the next day you go dig it up again and (mumbles)
	PB	So its like about 24 hours from putting it in there to taking it back out again?
	RO	Yeah, what were going to do is after a while we'll put the meat in there we will cover it with rocks and then throw some dirt on top of it to cut off the air from the meat we are cooking or whatever we are cooking and then build another fire on top of it.
	PB	Ok
	RO	And then let the fire die out
	PB	Was there any need...or, how did you choose to make an oven was there ever a need just to make a regular fire?
	RO	Earth oven again first of all we are heating the rocks
	PB	Right
	RO	We are going to.....That may be enough right there *{indicates to the teachers to stop adding wood to the pit}* then one.....somebody bring the shovels...
	RO	Was that a piece of wood that popped *{chunk of material flies out of the fire}*
	Tr	Yeah
	RO	OK
	RO	So the problem with wet rocks is that they'll blow and scatter stuff around that's why you want to make sure the rocks are dry
	PB	OK, So you would dig the pit and leave it like you did, maybe overnight or something, before you light the fire?
21.00	RO	What you do is, usually you find them along a stream (the rocks) but you don't want to find the ones in the water. Er on the edge because they're dry, what you do is line the pit, build your fire, and then take out the fire, put your stuff in there (food to be cooked), cover it with rocks, cover it with dirt, and then build (trails off)
	PB	Was there any kind of food that you would cook without making an oven? Would you always use an oven?
	RO	Oh sure, err, any kind of meat can be done that way, but primarily in the desert you are going to be cooking lechuguilla (*Agave lechuguilla*), and Sotol *(Dasylirion wheeleri)*, and the er. Looks like an onion on the Sotol the root, the

Time Track	Person	Activity
		er Agave. Agave and Sotol and lechuguilla if eaten raw there poisonous they have to cook at least 36 hours ok because if you cut in before that they may be poisonous and when you take it out (of the oven) its going to look like a jelly and you suck out the material and it becomes edible and you are left with the fibers you can use those.
	PB	For….
	RO	Cordage
	PB	Oh, right, Is there a way to tell….How do you tell when they are done is there a point when they're safe.
	RO	Time, its about time and there was trial and error
	PB	So, someone learnt the hard way probably!
	RO	Yeah probably 4 or 5 thousand years ago
	PB	How much food could you get from one of these ovens? How often could you use it?
	RO	One would really be twice this big {*this one is ca. 3ft/1m in diameter*} if your going to cook plants
	PB	Right
	RO	Because your cooking for everybody, (mumbles), ok, every year, the Mescalero, that's my people. Actually the word Mescalero comes from the Spanish meaning the gathers of Mescal. They have a Mescal ceremony they go gather the mescal and they take the leaves off and they take part of the err bulb and then root ok and that's what they cook. The Sotol you dig it up and you have what looks like a big onion,ok, and you cook that
	PB	Is there any preparation before you put it in there? Or just cut it off and put it in there?
	RO	Just cut it off, washing, er, washing stuff like this today you got to cook and wash it off fires gonna take care of that
	PB	Right OK, you don't need to worry about that, you cut out a step, fantastic
	PB	What about wood, is there any favored wood or whatever's around?
	RO	Whatever you can find Ok one of the things about a camp is that the leader would find a camp that provided water and firewood
	PB	OK
	RO	And it usually along the stream, somewhere near a stream. Water is essential to life is water. They don't believe in anything without water. Ok so they had to have water
	PB	So if it was a kind of shopping list its got to have water, its got to have firewood, Yes, this is where we are going to camp
	RO	Those were the 2 basic elements that were chosen for a campsite
	PB	Right
	RO	And they stayed there until the resources were mostly used up. They didn't strip it because they wanted to…they moved around and eventually 2or 3 years later they came back again.. If you strip it what have you got?
	PB	There's going to be nothing to come back too.
	RO	No, they had plenty of resources available wherever they made there camp. That was a criteria, find a place that had firewood, and the rocks, and the errr water, and if it had those 3 elements then you are in good shape. But there was a leader who would find these places. Say Ok your traveling anywhere along the river it may not be good but you find a good spot and that's where you settle down.
2	PB	So he (the leader) tells everyone, this is it we are stopping here for the night? Is there any idea of er special place or did that develop from these resource areas?
	RO	They had areas where they came back to you can tell that by the rock middens, These things are just piled and maybe 30-40ft around ok so since they are not using the same rocks over again
	PB	They're getting new ones each time, so the idea of coming back to that place as a special place even though its got loads of rocks already used…..
	RO	But we are talking maybe 2 or 3 years latter
	PB	ok
	RO	The next time they come they may camp maybe a mile away from this site and

Time Track	Person	Activity
		er the next time maybe a mile that way *{points in opposite direction}*
	PB	But they would kind of know it (the first campsite) is there?
	RO	Oh Yeah, along the Pecos its just a desolate desert and all you find is Mesquite er not so much mesquite but stool, and the other the prisimins and this the Texas Prisimin the short bushy like this only for a very short time do they have fruits edible fruits, they don't go for a long time the fruit is ripe and its gone
	PB	You need to be in the right place at the right time
	RO	The animals also want some of this you know
	PB	Ahhhh
	RO	So your competing with the animals but the animal will also become part of your food, so lizards, snakes, frogs not frogs so much because some of them tend to be poisonous, so but birds, porcupines, raccoons, armadillos, armadillos are late entrants to the SW. The mesquite is also late, there are pictures in the 1850's around fort Stockton and there's no Mesquite
	PB	Do you think that could be something to do with the natives themselves burning off the Mesquite?
	RO	Its either the cows or you know the herbivores that ate and brought the seeds just like anything else if there's a seed its going to blow or be carried by a birds or whatever to a new location
	Tr	Isn't that some of the longhorn on the cattle drives also wasn't they….
	RO	Oh yeah, they would eat out there and on the way leave a trail of… and eventually that dung would it's a good thing it's a good, good germinator the heat from the body of the animal will help germinate the seed err the mountain laurel this stuff right here, goats will eat the pods but when they do they're will be a 2 or 3 mile (mumbles) of where the tree lives so there spreading I find in the Conduct? Area I find where goats have dropped and theres no Mountain Laurel are growing along the river but I find seed up on top of hills because the goats have (mumbles)
	SS	Hey Ray *{points at hearth}*
	RO	A little more and then spread it out *{a bed of coals is beginning to develop in the pit and the flames are dying down}* we want to try and heat all the rocks
30.12	PB	*{Talks to the teachers about his research and the types of experiments that we have conducted into prehistoric fire technology}*
9:55am 35.30	RO	*{explains the next stage in the creation of the oven will be ready in an hour when the ember bed is fully developed, group breaks for 1 hour}*
10:46am File 2		*{Group returns and spread out the embers in the pit before adding to the food to be cooked which is wrapped in up in soaked burlap sacking material. The food parcel is placed inside the pit, covered with hearthstones and then buried by a layer of soil. A fire is then constructed and burned on top of the soil layer.}* *Conversation resumes as I am taking a temperature reading on the sediment layer just before the 2nd fire layer is ignited*
18.00	RO	Is that hot enough for you?
	PB	I reckon, its pretty warm in there
	RO	That's why you cook your rock and its spent, spent, that's why if you keep going pretty soon your going to have burnt rock all around, and that's some more evidence , you know that you have for a rock midden.
	PB	Right
	RO	There's burnt rock all the way around.
	PB	When you bring food out of here, traditionally would you have the food right next to where you cooked it or would you take it away somewhere else? Because your going to have all these hot-rocks around here
	RO	No, no hot-rocks to them sitting over there *{gestures to a group of teachers sitting about 15meters away}* your not going to worry about them. OK so you could go back to the campsite or you could take them off to the side it depends how hungry you are.
	PB	Laughs, so there wasn't any rule involved in where… {Ray cut in}
	RO	OK we need to get some more firewood guys, more firewood
		{Ray leaves to arrange firewood within the pit, and ignites it with some coals removed from the first fire. Ray leaves with teachers to complete their basket weaving project}

Photographic Documentation



9:22am Ray Olachia, supervises the teachers who are lining of the experimental oven.



9:27am Building the first fire within the pit



9:57am First fire, within the pit burning



10:22am Ember bed develops as first fire dies down



10:43am Embers are spread out and some removed from the oven for later use



10:46am Temperature reading within the pit on the layer of coals (720°F/345°C)



10:51am Preparing the food to be cooked, prickly pear cactus pads are added to multiple layers of water soaked burlap.



10:53am Food parcel added to the pit and layer of fresh hearthstones being added on top.



10:54am Hearthstone layer almost complete covering the entire food parcel.



10:55am Layer of sediment added on top of hearthstones



10:59am The coals previously removed from the pit are added back on top of the earth layer



11:01am More fuel added for a second layer of burning on top of the soil



11:54am 2nd fire dies down and the oven is left for 24hrs for the food to cook



12:59pm Monitoring the temperature of the oven with the thermocouple.

Appendix 6 – Summary of the Southern High Plains Dataset

data alphabetically sorted by County of site discovery

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41AD22	TX	Andrews	true	4000	Unknown	1	2			false	1970-1979
41AD24	TX	Andrews	true	600	Unknown	1	15			false	1970-1979
41AD25	TX	Andrews	true	5000	Archaic (Typo)	2	15			false	1970-1979
41AD26	TX	Andrews	true	2400	Unknown	1	3	2		false	1970-1979
41AD31	TX	Andrews	true	900	Unknown	2	2			false	1980-1989
41AD32	TX	Andrews	true	35000	Unknown	2	15			false	1980-1989
41AD34	TX	Andrews	true	11700	Unknown	2	5			false	1980-1989
41AD35	TX	Andrews	true	82500	Unknown	-	15			false	1980-1989
41AD45	TX	Andrews	true	64	Unknown	2	12			false	1980-1989
41AD48	TX	Andrews	true	4850	Archaic (Typo)	3	5			false	1980-1989
41AD49	TX	Andrews	true	30000	Unknown	1	15			false	1990-1999
41BI1	TX	Briscoe	false	1200	Unknown	1	1			false	1970-1979
41BI10	TX	Briscoe	true	800	Archaic (Typo)	3	2			false	1970-1979
41BI101	TX	Briscoe	true	*	Unknown	1	15			false	1970-1979
41BI107	TX	Briscoe	true	*	Unknown	3	2			false	1970-1979
41BI11	TX	Briscoe	true	500	Unknown	1	2			false	1970-1979
41BI110	TX	Briscoe	true	6857.5	Unknown	1	2			false	1970-1979
41BI111	TX	Briscoe	true	3251	Unknown	1	2			false	1970-1979
41BI115	TX	Briscoe	true	12191.5	Unknown	1	2			false	1970-1979
41BI12	TX	Briscoe	true	180	Unknown	1	7			false	1970-1979
41BI120	TX	Briscoe	true	2675.5	Unknown	1	15			false	Unknown
41BI135	TX	Briscoe	true	170	Unknown	3	2			false	1970-1979
41BI14	TX	Briscoe	true	800	Unknown	2	2			false	1970-1979
41BI143	TX	Briscoe	true	*	Archaic (Typo)	3	2			false	1970-1979
41BI15	TX	Briscoe	true	70	Unknown	1	2			false	1970-1979
41BI153	TX	Briscoe	true	1575	Archaic (Typo)	3	2			false	1970-1979
41BI16	TX	Briscoe	true	30	Unknown	3	2			false	1970-1979
41BI175	TX	Briscoe	true	*	Archaic (Typo)	2	2			false	1970-1979
41BI187	TX	Briscoe	true	*	Unknown	1	15			false	1970-1979
41BI20	TX	Briscoe	true	9000	Unknown	2	10			true	1970-1979
41BI213	TX	Briscoe	true	*	Unknown	2	15			false	1970-1979
41BI216	TX	Briscoe	true	*	Unknown	1	2			false	1970-1979
41BI22	TX	Briscoe	true	1200	Unknown	1	2			false	1970-1979
41BI22	TX	Briscoe	true	1200	Archaic (Typo)	1	2			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41BI24	TX	Briscoe	true	15	Unknown	2	15			false	1970-1979
41BI243	TX	Briscoe	true	•	Unknown	2	8			false	1970-1979
41BI244	TX	Briscoe	true	•	Unknown	2	8			false	1970-1979
41BI258	TX	Briscoe	true	•	Unknown	2	2			false	1970-1979
41BI260	TX	Briscoe	true	•	Unknown	3	2			false	1970-1979
41BI286	TX	Briscoe	true	•	Unknown	2	2			false	1970-1979
41BI291	TX	Briscoe	true	3000	Archaic (Typo)	2	15			false	1970-1979
41BI294	TX	Briscoe	true	3825	Archaic (Typo)	3	15			false	1970-1979
41BI298	TX	Briscoe	true	120	Archaic (Typo)	3	2			false	1970-1979
41BI301	TX	Briscoe	true	1800	Unknown	3	15			false	1970-1979
41BI312	TX	Briscoe	true	10000	Archaic (Typo)	2	2			false	1970-1979
41BI316	TX	Briscoe	true	50	Unknown	2	2			false	1970-1979
41BI319	TX	Briscoe	true	5625	Archaic (Typo)	2	2			true	1970-1979
41BI323	TX	Briscoe	true	3375	Archaic (Typo)	1	2			false	1970-1979
41BI328	TX	Briscoe	true	9	Unknown	2	2			false	1970-1979
41BI33	TX	Briscoe	true	2000	Unknown	2	15			false	1970-1979
41BI332	TX	Briscoe	true	2800	Archaic (Typo)	2	2			false	1970-1979
41BI334	TX	Briscoe	true	2500	Unknown	3	2			false	1970-1979
41BI335	TX	Briscoe	true	33.75	Unknown	2	2			false	1970-1979
41BI336	TX	Briscoe	true	1875	Unknown	3	2			false	1970-1979
41BI339	TX	Briscoe	true	26250	Archaic (Typo)	3	2			false	1970-1979
41BI34	TX	Briscoe	true	50	Unknown	2	15			false	1970-1979
41BI341	TX	Briscoe	true	200	Unknown	1	2			false	1970-1979
41BI345	TX	Briscoe	true	150	Unknown	3	2			false	1970-1979
41BI346	TX	Briscoe	true	4800	Unknown	2	2			false	1970-1979
41BI348	TX	Briscoe	true	3900	Unknown	2	2			false	1970-1979
41BI350	TX	Briscoe	true	3750	Unknown	1	2			false	1970-1979
41BI351	TX	Briscoe	true	16	Unknown	2	2			false	1970-1979
41BI353	TX	Briscoe	true	1500	Unknown	2	2			false	1970-1979
41BI355	TX	Briscoe	true	1750	Unknown	3	2			false	1970-1979
41BI362	TX	Briscoe	true	50	Unknown	2	2			false	1970-1979
41BI365	TX	Briscoe	true	3750	Archaic (Typo)	3	2			false	1970-1979
41BI366	TX	Briscoe	true	12000	Unknown	3	2			false	1970-1979
41BI367	TX	Briscoe	true	28	Unknown	2	2			false	1970-1979
41BI373	TX	Briscoe	true	600	Unknown	2	2			false	1970-1979
41BI374	TX	Briscoe	true	800	Unknown	2	2			false	1970-1979
41BI376	TX	Briscoe	true	25	Unknown	2	2			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41BI38	TX	Briscoe	true	600	Unknown	2	2			false	1970-1979
41BI380	TX	Briscoe	true	4125	Unknown	3	2			false	1970-1979
41BI384	TX	Briscoe	true	375	Unknown	2	2			false	1970-1979
41BI390	TX	Briscoe	true	5000	Archaic (Typo)	2	2			false	1970-1979
41BI391	TX	Briscoe	true	50	Unknown	3	2			false	1970-1979
41BI393	TX	Briscoe	true	1200	Unknown	3	2			false	1970-1979
41BI395	TX	Briscoe	true	24000	Archaic (Typo)	1	2			false	1970-1979
41BI396	TX	Briscoe	true	2400	Unknown	1	2			false	1970-1979
41BI397	TX	Briscoe	true	1200	Archaic (Typo)	1	2			false	1970-1979
41BI398	TX	Briscoe	true	900	Unknown	1	2			false	1970-1979
41BI40	TX	Briscoe	true	600	Unknown	2	15			false	1970-1979
41BI400	TX	Briscoe	true	625	Archaic (Typo)	1	2	2		false	1970-1979
41BI402	TX	Briscoe	true	8000	Unknown	1	2			false	1970-1979
41BI412	TX	Briscoe	true	1125	Unknown	1	2			false	1970-1979
41BI417	TX	Briscoe	true	52500	Unknown	1	2			false	1970-1979
41BI420	TX	Briscoe	true	125	Unknown	3	2			false	1970-1979
41BI421	TX	Briscoe	true	4000	Unknown	1	2			false	1970-1979
41BI425	TX	Briscoe	true	50	Unknown	2	2			false	1970-1979
41BI429	TX	Briscoe	true	50	Unknown	2	2			false	1970-1979
41BI43	TX	Briscoe	true	20	Unknown	2	2			false	1970-1979
41BI430	TX	Briscoe	true	75	Archaic (Typo)	3	2			false	1970-1979
41BI432	TX	Briscoe	true	50	Unknown	3	2			false	1970-1979
41BI433	TX	Briscoe	true	15	Unknown	2	2			false	1970-1979
41BI435	TX	Briscoe	true	15	Unknown	1	2			false	1970-1979
41BI436	TX	Briscoe	true	9	Unknown	1	2			false	1970-1979
41BI437	TX	Briscoe	true	9	Unknown	1	2			false	1970-1979
41BI438	TX	Briscoe	true	50	Unknown	1	2			false	1970-1979
41BI44	TX	Briscoe	true	100	Unknown	4	15			false	1970-1979
41BI44	TX	Briscoe	true	204	Unknown	3	2			false	1970-1979
41BI442	TX	Briscoe	true	1200000	Unknown	2	15			false	1970-1979
41BI443	TX	Briscoe	true	540	Unknown	3	3			true	1970-1979
41BI449	TX	Briscoe	true	5250	Multicomponent	1	15			false	1970-1979
41BI452	TX	Briscoe	true	7000	Multicomponent	2	4			false	1970-1979
41BI455	TX	Briscoe	true	1500	Unknown	1	7			false	1970-1979
41BI46	TX	Briscoe	true	2400	Unknown	1	15			false	1970-1979
41BI46	TX	Briscoe	true	2400	Unknown	1	15			false	1970-1979
41BI461	TX	Briscoe	true	11000	Multicomponent	1	8			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41BI466	TX	Briscoe	true	3500	Archaic (Typo)	1	15			false	1970-1979
41BI48	TX	Briscoe	true	50	Unknown	1	2			false	1970-1979
41BI484	TX	Briscoe	true	270	Unknown	1	15			false	1970-1979
41BI49	TX	Briscoe	true	250	Unknown	3	2			false	1970-1979
41BI496	TX	Briscoe	true	960	Unknown	1	15			false	1970-1979
41BI5	TX	Briscoe	true	800	Unknown	1	2			false	1970-1979
41BI503	TX	Briscoe	true	10000	Unknown	1	15			false	1980-1989
41BI511	TX	Briscoe	true	10800	Multicomponent	1	2			false	1980-1989
41BI516	TX	Briscoe	true	22750	Unknown	1	2			false	1980-1989
41BI517	TX	Briscoe	true	952	Unknown	1	15			false	1980-1989
41BI534	TX	Briscoe	true	212000	Unknown	1	15			false	1990-1999
41BI54	TX	Briscoe	true	1500	Unknown	1	15			false	1970-1979
41BI57	TX	Briscoe	true	•	Unknown	2	8			false	1970-1979
41BI59	TX	Briscoe	true	•	Archaic (Typo)	1	8			false	1970-1979
41BI6	TX	Briscoe	true	600	Unknown	2	2			false	1970-1979
41BI64	TX	Briscoe	true	1000	Multicomponent	1	1			false	Unknown
41BI65	TX	Briscoe	true	1045	Unknown	1	15			false	Unknown
41BI66	TX	Briscoe	true	•	Unknown	1	15			false	Unknown
41BI67	TX	Briscoe	true	•	Unknown	1	15			false	Unknown
41BI68	TX	Briscoe	true	1045	Unknown	1	15			false	1970-1979
41BI69	TX	Briscoe	true	•	Unknown	1	2			false	1970-1979
41BI71	TX	Briscoe	true	•	Unknown	1	15			false	1970-1979
41BI81	TX	Briscoe	true	•	Unknown	2	15			false	1970-1979
41BI83	TX	Briscoe	true	20903	Archaic (Typo)	2	15			true	1970-1979
41BI90	TX	Briscoe	true	2787	Unknown	1	15			false	1970-1979
41BI94	TX	Briscoe	true	•	Unknown	2	2			false	1970-1979
41CZ23	TX	Carson	false	4674	Unknown	2	11			false	1990-1999
41CZ79	TX	Carson	true	2000	Unknown	2	8			false	1990-1999
41CAS1	TX	Castro	true	2023	Unknown	1	15			true	1960-1969
41CAS19	TX	Castro	true	•	Unknown	3	8			false	1980-1989
41CAS2	TX	Castro	true	1045	Unknown	2	1			false	1970-1979
41CAS27	TX	Castro	false	•	Unknown	1	15			true	1960-1969
LA-100179	NM	Chaves	false	62	Unknown	2	15			false	1990-1999
LA-100183	NM	Chaves	false	3000	Unknown	1	15			false	1990-1999
LA-100184	NM	Chaves	false	7500	Unknown	3	15			false	1990-1999
LA-100185	NM	Chaves	false	750	Unknown	2	15			true	1990-1999
LA100188	NM	Chaves	false	62	Unknown	2	15			false	1990-1999
LA100191	NM	Chaves	false	3000	Unknown	2	15			false	1990-1999

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA100195	NM	Chaves	false	3000	Unknown	3	15			false	1990-1999
LA103211	NM	Chaves	false	10200	Unknown	2	15			false	1990-1999
LA103233	NM	Chaves	true	16800	Multicomponent	2	15			true	1990-1999
LA103698	NM	Chaves	true	9600	Unknown	3	15			false	1990-1999
LA103702	NM	Chaves	true	70875	Unknown	3	15			false	1990-1999
LA103703	NM	Chaves	true	127400	Ceramic/Mogollon (Typo)	1	3			true	1990-1999
LA103706	NM	Chaves	true	375	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA103707	NM	Chaves	true	450	Unknown	2	15			false	1990-1999
LA103708	NM	Chaves	true	50000	Unknown	2	3			false	1990-1999
LA103759	NM	Chaves	true	495000	Unknown	1	15			false	1990-1999
LA103760	NM	Chaves	true	16000	Unknown	2	15			false	1990-1999
LA105192	NM	Chaves	true	103125	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA105194	NM	Chaves	true	652500	Ceramic/Mogollon (Typo)	1	3	15		true	1990-1999
LA105195	NM	Chaves	true	15600	Ceramic/Mogollon (Typo)	3	2	15		true	1990-1999
LA105227	NM	Chaves	true	16800	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA105603	NM	Chaves	true	5000	Unknown	3	15			false	1990-1999
LA105612	NM	Chaves	true	360000	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
LA105829	NM	Chaves	true	16500	Archaic (Typo)	2	4			false	1990-1999
LA107643	NM	Chaves	true	945	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA107646	NM	Chaves	true	160000	Archaic (Typo)	5	2			false	1990-1999
LA109333	NM	Chaves	true	60000	Ceramic/Mogollon (Typo)	3	2	15		true	1990-1999
LA109334	NM	Chaves	true	75000	Ceramic/Mogollon (Typo)	6	2	15		true	1990-1999
LA109476	NM	Chaves	true	1995	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA109484	NM	Chaves	true	2243	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA110956	NM	Chaves	true	1	Unknown	2	8			false	1990-1999
LA111636	NM	Chaves	true	540	Unknown	2	2			false	1990-1999
LA112999	NM	Chaves	true	12900	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA115381	NM	Chaves	true	6400	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA115385	NM	Chaves	true	6400	Unknown	3	15			false	1990-1999
LA115387	NM	Chaves	true	15000	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
LA117446	NM	Chaves	true	2600	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA127498	NM	Chaves	true	15500	Ceramic/Mogollon (Typo)	2	9			true	1990-1999
LA12887	NM	Chaves	false	300	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA12944	NM	Chaves	true	2800	Ceramic/Mogollon (Typo)	2	15			true	1970-1979
LA13006	NM	Chaves	false	30000	Unknown	1	15			true	1970-1979
LA14338	NM	Chaves	false	300	Ceramic/Mogollon (Typo)	1	15			true	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA20271	NM	Chaves	false	750	Unknown	2	15			false	1970-1979
LA27691	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA32231	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA32234	NM	Chaves	true	30000	Multicomponent	1	15			true	1970-1979
LA32236	NM	Chaves	true	30000	Multicomponent	1	15			true	Unknown
LA32240	NM	Chaves	false	30000	Multicomponent	1	15			true	1970-1979
LA32243	NM	Chaves	false	30000	Multicomponent	1	15			true	1970-1979
LA32247	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA32255	NM	Chaves	true	30000	Multicomponent	1	15			true	1970-1979
LA32256	NM	Chaves	true	7500	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA32548	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA32593	NM	Chaves	false	750	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA32594	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA32902	NM	Chaves	true	30000	Unknown	3	15			false	1980-1989
LA33130	NM	Chaves	true	30000	Ceramic/Mogollon (Typo)	2	15			true	1970-1979
LA34403	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA35933	NM	Chaves	true	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA36558	NM	Chaves	false	750	Unknown	3	15			false	1980-1989
LA38834	NM	Chaves	false	3000	Unknown	4	15			false	1980-1989
LA39154	NM	Chaves	true	*	Ceramic/Mogollon (Typo)	1	2			true	1990-1999
LA39185	NM	Chaves	false	7500	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA39187	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA39899	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA39900	NM	Chaves	false	12	Unknown	1	15			false	1980-1989
LA39901	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA39907	NM	Chaves	false	7500	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA39908	NM	Chaves	false	3000	Unknown	3	15			false	1980-1989
LA39909	NM	Chaves	false	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA39910	NM	Chaves	false	3000	Unknown	3	15			false	1980-1989
LA43751	NM	Chaves	false	300	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA43764	NM	Chaves	false	30000	Unknown	3	15			false	1970-1979
LA44814	NM	Chaves	true	*	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA44815	NM	Chaves	false	780	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA44821	NM	Chaves	false	3000	Unknown	1	15			false	1980-1989
LA45945	NM	Chaves	true	3000000	Ceramic/Mogollon (Typo)	1	3			true	1990-1999
LA46287	NM	Chaves	false	62	Ceramic/Mogollon (Typo)	1	15			true	
LA46448	NM	Chaves	false	3000	Multicomponent	3	15			true	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA46543	NM	Chaves	false	192	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA46544	NM	Chaves	false	2100	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA46557	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA47197	NM	Chaves	false	750	Unknown	2	15			false	1980-1989
LA47203	NM	Chaves	true	775000	Ceramic/Mogollon (Typo)	1	3	15		true	1990-1999
LA47394	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA47907	NM	Chaves	false	7500	Unknown	4	15			true	1980-1989
LA47908	NM	Chaves	false	7500	Unknown	1	15			false	1980-1989
LA48235	NM	Chaves	false	3000	Unknown	2	15			false	1980-1989
LA48236	NM	Chaves	false	20475	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
LA48952	NM	Chaves	false	3000	Unknown	2	15			false	1980-1989
LA48953	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA48955	NM	Chaves	false	7500	Unknown	1	15			false	1980-1989
LA49453	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA49466	NM	Chaves	false	7500	Unknown	4	15			true	1980-1989
LA49467	NM	Chaves	true	*	Unknown	3	15			true	1980-1989
LA49722	NM	Chaves	false	300	Unknown	3	15			false	1980-1989
LA49794	NM	Chaves	false	750	Unknown		15			false	1980-1989
LA49803	NM	Chaves	false	30000	Multicomponent	1	15			true	1980-1989
LA49804	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA49805	NM	Chaves	false	750	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA49814	NM	Chaves	false	12	Unknown	2	15			false	1980-1989
LA49815	NM	Chaves	false	300	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA49816	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
A49973	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA50468	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA52394	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA53448	NM	Chaves	true	3000	Unknown	3	15			false	1980-1989
LA67571	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA67872	NM	Chaves	false	*	Ceramic/Mogollon (Typo)	3	15			false	1980-1989
LA67873	NM	Chaves	true	2800000	Multicomponent	5	2	15		false	1990-1999
LA68990	NM	Chaves	false	62	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA68991	NM	Chaves	false	7500	Unknown	3	15			false	1980-1989
LA68992	NM	Chaves	false	7500	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA68993	NM	Chaves	false	1457	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA69133	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA69134	NM	Chaves	false	7500	Ceramic/Mogollon (Typo)	3	3	15		true	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA72414	NM	Chaves	false	300	Unknown	2	15			false	1980-1989
LA72415	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA73748	NM	Chaves	false	7500	Unknown	3	15			false	1980-1989
LA75265	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	3	3	15		false	1980-1989
LA75266	NM	Chaves	true	133900	Ceramic/Mogollon (Typo)	1	3	15		true	1990-1999
LA77943	NM	Chaves	false	3000	Ceramic/Mogollon (Typo)	1	15			false	1980-1989
LA77950	NM	Chaves	false	750	Unknown	2	15			false	1980-1989
LA77951	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA80243	NM	Chaves	true	345	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA80244	NM	Chaves	true	2700	Ceramic/Mogollon (Typo)	3	15			false	1990-1999
LA80245	NM	Chaves	true	225	Ceramic/Mogollon (Typo)	3	2			true	1980-1989
LA80246	NM	Chaves	true	2025	Ceramic/Mogollon (Typo)	2	2			false	1980-1989
LA80247	NM	Chaves	true	105	Ceramic/Mogollon (Typo)	3	15			false	1980-1989
LA80255	NM	Chaves	true	8281	Ceramic/Mogollon (Typo)	3	7	15		false	1980-1989
LA8041	NM	Chaves	false	30000	Unknown	1	15			false	1960-1969
LA8046	NM	Chaves	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1960-1969
LA82649	NM	Chaves	false	750	Unknown	2	15			false	1980-1989
LA83689	NM	Chaves	false	300	Unknown	3	15			false	1980-1989
LA83981	NM	Chaves	true	7500	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA84668	NM	Chaves	true	7500	Ceramic/Mogollon (Typo)	2	15			false	1990-1999
LA87022	NM	Chaves	false	30000	Archaic (Typo)	3	15			false	1990-1999
LA99426	NM	Chaves	true	3000	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
41CR3	TX	Crane	true	*	Unknown	1	15	0	0	true	Unknown
41CB103	TX	Crosby	true	2317	Unknown	3	2			false	1990-1999
41CB107	TX	Crosby	true	7556	Unknown	3	2			true	2000-2010
41CB110	TX	Crosby	true	1482	Protohistoric (Typo)	4	8			false	2000-2010
41CB112	TX	Crosby	true	1388	Unknown	2	8			false	2000-2010
41CB119	TX	Crosby	true	381	Unknown	3	2			false	2000-2010
41CB120	TX	Crosby	true	2625	Unknown	3	8			false	2000-2010
41CB121	TX	Crosby	false	987	Unknown	1	1			false	2000-2010
41CB124	TX	Crosby	true	369	Unknown	2	2			false	2000-2010
41CB137	TX	Crosby	true	316	Unknown	1	1			false	2000-2010
41CB139	TX	Crosby	true	252	Unknown	3	2			false	2000-2010
41CB140	TX	Crosby	true	140	Unknown	3	2			false	2000-2010
41CB142	TX	Crosby	true	271	Unknown	2	2			false	2000-2010
41CB143	TX	Crosby	true	170	Unknown	3	2			false	2000-2010
41CB148	TX	Crosby	false	6750	Unknown		1			true	2000-2010

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41CB33	TX	Crosby	true	60.	Unknown	3	8			false	1990-1999
41CB36	TX	Crosby	false	*	Unknown	3	15			true	1990-1999
41CB47	TX	Crosby	true	30600	Archaic (Typo)	3	2			false	2000-2010
41CB51	TX	Crosby	true	*	Unknown	2	8			false	1990-1999
41CB70	TX	Crosby	true	315000	Unknown	3	8			false	1990-1999
41CB75	TX	Crosby	false	8000	Unknown	1	1			false	1990-1999
41CB79	TX	Crosby	true	*	Unknown	2	12			false	1990-1999
41CB82	TX	Crosby	true	20000	Unknown	3	7			false	1990-1999
41CB84	TX	Crosby	false	40000	Unknown	3	7			false	1990-1999
41CB88	TX	Crosby	false	20000	Unknown	3	7			false	1990-1999
41CB93	TX	Crosby	true	7057	Multicomponent	2	2			false	1990-1999
41CB97	TX	Crosby	true	1907	Unknown	3	2			false	1990-1999
LA57433	NM	Curry	false	3000	Unknown	2	15			false	1980-1989
LA75225	NM	Curry	false	3000	Archaic (Typo)	2	15			false	1970-1979
LA102113	NM	De Baca	true	16800	Unknown	2	2			false	1990-1999
LA111917	NM	De Baca	true	18000	Multicomponent	3	2	3	9	true	1990-1999
LA111918	NM	De Baca	true	6300	Multicomponent	2	15			false	1990-1999
LA138382	NM	De Baca	true	150	Unknown	2	4			false	2000-2010
LA138383	NM	De Baca	true	35	Unknown	2	1			false	2000-2010
LA8007	NM	De Baca	false	7500	Unknown	1	15			false	1960-1969
LA8792	NM	De Baca	false	3000	Ceramic/Mogollon (Typo)	1	15			true	1960-1969
LA8816	NM	De Baca	false	27664	Multicomponent	1	15			true	1960-1969
LA8820	NM	De Baca	false	900	Multicomponent	1	15			true	1960-1969
LA8821	NM	De Baca	false	3000	Ceramic/Mogollon (Typo)	1	15			true	1960-1969
LA8832	NM	De Baca	false	30000	Unknown	2	15			true	1960-1969
41DF11	TX	Deaf Smith	false	20000			15			false	1980-1989
41DF2	TX	Deaf Smith	true	185		2	2	15		false	1970-1979
41DF3	TX	Deaf Smith	true	*	Protohistoric (Typo)	1	15			true	1920-1929
41DF6	TX	Deaf Smith	true	325	Unknown	3	2			false	1980-1989
LA8791	TX	DeBaca	false	7500	Ceramic/Mogollon (Typo)	2	15			true	1960-1969
41DK10	TX	Dickens	true	808	Unknown	1	2			false	1960-1969
41DK3	TX	Dickens	true	1625	Unknown	3	2			false	1960-1969
41DY25	TX	Donley	true	4	Unknown	3	4	3		false	1990-1999
41EC10	TX	Ector	true	202343	Unknown	1	2	15		true	1970-1979
41EC11	TX	Ector	true	5000	Unknown	1	2			false	1970-1979
41EC13	TX	Ector	true	20234	Unknown	2	2			false	1970-1979
41EC14	TX	Ector	true	*	Unknown	1	15			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41EC6	TX	Ector	true	20000	Unknown	4	2	15		false	1990-1999
41EC7	TX	Ector	true	200000	Unknown	1	1			false	1990-1999
41EC8	TX	Ector	true	*	Unknown	1	15			true	1970-1979
41EC9	TX	Ector	true	12140	Multicomponent	1	15			true	1970-1979
LA-100015	TX	Eddy	true	1426	Multicomponent	3	4			true	1990-1999
LA100391	NM	Eddy	true	1125	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA100733	NM	Eddy	true	6496	Unknown	2	11			false	1990-1999
LA100736	NM	Eddy	true	1258	Ceramic/Mogollon (Typo)	2	11			true	1990-1999
LA100738	NM	Eddy	true	6302	Ceramic/Mogollon (Typo)	2	15			false	1990-1999
LA100739	NM	Eddy	false	2989	Unknown	3	5			false	1990-1999
LA100740	NM	Eddy	true	6916	Ceramic/Mogollon (Typo)	2	5			true	1990-1999
LA100743	NM	Eddy	true	39772	Ceramic/Mogollon (Typo)	3	15	5		true	1990-1999
LA100745	NM	Eddy	true	6264	Unknown	2	15			false	1990-1999
LA100746	NM	Eddy	true	2440	Unknown	3	15			false	1990-1999
LA100747	NM	Eddy	true	1566	Unknown	3	15			false	2000-2010
LA100748	NM	Eddy	true	1896	Unknown	2	5			false	1990-1999
LA100749	NM	Eddy	true	4116	Ceramic/Mogollon (Typo)	3	6			true	1990-1999
LA100750	NM	Eddy	true	6344	Unknown	2	15			false	1990-1999
LA100751	NM	Eddy	true	3025	Ceramic/Mogollon (Typo)	2	5			true	1990-1999
LA100753	NM	Eddy	true	288	Ceramic/Mogollon (Typo)	3	5			true	2000-2010
LA100754	NM	Eddy	true	1	Unknown	2	6			false	1990-1999
LA100755	NM	Eddy	true	315	Unknown	2	5			false	1990-1999
LA100757	NM	Eddy	true	8760	Unknown	3	15	5		false	1990-1999
LA100758	NM	Eddy	true	231	Unknown	2	5			false	1990-1999
LA100760	NM	Eddy	true	9125	Ceramic/Mogollon (Typo)	3	5	2		true	1990-1999
LA100765	NM	Eddy	true	12056	Ceramic/Mogollon (Typo)	3	4	2		true	2000-2010
LA100766	NM	Eddy	true	7802	Unknown	2	5			false	1990-1999
LA100767	NM	Eddy	true	6527	Unknown	3	5	2		false	1990-1999
LA100768	NM	Eddy	true	6162	Unknown	4	2	15		false	1990-1999
LA101464	NM	Eddy	true	6486	Unknown		6	2		false	1990-1999
LA101466	NM	Eddy	true	3496	Ceramic/Mogollon (Typo)	3	2	5		true	1990-1999
LA101469	NM	Eddy	true	4672	Ceramic/Mogollon (Typo)	3	3	15		true	1990-1999
LA101470	NM	Eddy	true	2744	Unknown	3	15			false	1990-1999
LA101472	NM	Eddy	true	6205	Unknown	2	15			false	1990-1999
LA101473	NM	Eddy	true	207200	Multicomponent	2	3			true	1990-1999
LA101475	NM	Eddy	true	8918	Unknown	3	6	2		false	1990-1999
LA101477	NM	Eddy	true	5876	Unknown	2	15			false	1990-1999

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA101480	NM	Eddy	true	45750	Unknown	6	15	3		false	2000-2010
LA101481	NM	Eddy	true	17632	Ceramic/Mogollon (Typo)	3	2			true	2000-2010
LA101482	NM	Eddy	true	8453	Ceramic/Mogollon (Typo)	2	5			true	1990-1999
LA101483	NM	Eddy	true	4420	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA101484	NM	Eddy	true	7462	Unknown	2	6			false	1990-1999
LA101485	NM	Eddy	true	8918	Unknown	2	2			false	1990-1999
LA101486	NM	Eddy	true	10001	Unknown	2	6			false	1990-1999
LA101487	NM	Eddy	true	94117	Ceramic/Mogollon (Typo)	3	5	15		true	2000-2010
LA101488	NM	Eddy	true	8512	Multicomponent	3	2	15		true	1990-1999
LA102534	NM	Eddy	true	19200	Ceramic/Mogollon (Typo)	2	4			true	1990-1999
LA102535	NM	Eddy	true	13200	Ceramic/Mogollon (Typo)	4	2			true	1990-1999
LA102536	NM	Eddy	true	800	Unknown	3	2			false	1990-1999
LA102538	NM	Eddy	true	6875	Unknown	3	2			false	1990-1999
LA102540	NM	Eddy	true	1170	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA102542	NM	Eddy	true	18304	Unknown	4	2	15		false	1990-1999
LA102544	NM	Eddy	true	14040	Unknown	5	2			false	1990-1999
LA104107	NM	Eddy	true	1600	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA104110	NM	Eddy	false	1800	Ceramic/Mogollon (Typo)	3	3	15		true	1990-1999
LA105813	NM	Eddy	false	140625	Unknown	1	15			false	1990-1999
LA108008	NM	Eddy	true	2	Unknown	2	4			false	1990-1999
LA108207	NM	Eddy	true	1674	Ceramic/Mogollon (Typo)	2	4			true	1990-1999
LA108660	NM	Eddy	true	3790	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA108921	NM	Eddy	true	560	Unknown	2	4			false	1990-1999
LA108922	NM	Eddy	true	12025	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA108923	NM	Eddy	true	8000	Ceramic/Mogollon (Typo)	2	4			true	1990-1999
LA108924	NM	Eddy	true	7000	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA108929	NM	Eddy	true	6600	Unknown	3	2			false	1990-1999
LA108930	NM	Eddy	true	2000	Ceramic/Mogollon (Typo)	3				true	1990-1999
LA108932	NM	Eddy	true	396	Multicomponent	2	2			true	1990-1999
LA108933	NM	Eddy	true	340	Ceramic/Mogollon (Typo)	2	4			true	1990-1999
LA109303	NM	Eddy	true	13500	Ceramic/Mogollon (Typo)	5	2			true	1990-1999
LA109304	NM	Eddy	true	1360	Ceramic/Mogollon (Typo)	2	2			false	1990-1999
LA109375	NM	Eddy	true	1050	Ceramic/Mogollon (Typo)	2	3			true	1990-1999
LA109503	NM	Eddy	true	8832	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA110169	NM	Eddy	true	15725	Ceramic/Mogollon (Typo)	3	4			true	1990-1999
LA110372	NM	Eddy	true	17000	Unknown	3	2			true	1990-1999
LA112425	NM	Eddy	true	700	Ceramic/Mogollon (Typo)	2	4			true	2000-2010

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA112439	NM	Eddy	true	1394	Ceramic/Mogollon (Typo)	3	2			true	
LA112440	NM	Eddy	true	10350	Ceramic/Mogollon (Typo)	3	3	2		true	2000-2010
LA112465	NM	Eddy	true	1200	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA112480	NM	Eddy	true	9600	Ceramic/Mogollon (Typo)	4	2			true	2000-2010
LA114536	NM	Eddy	true	2475	Ceramic/Mogollon (Typo)	2	11			true	1990-1999
LA116479	NM	Eddy	true	14274	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA117527	NM	Eddy	true	13600	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA121579	NM	Eddy	true	*	Unknown	1	2	15		false	1990-1999
LA128517	NM	Eddy	true	6400	Unknown	3	3	2		false	1990-1999
LA128987	NM	Eddy	false	1	Unknown	2	5			false	1990-1999
LA129118	NM	Eddy	true	1	Unknown	2	15			false	1990-1999
LA130927	NM	Eddy	true	766	Ceramic/Mogollon (Typo)	3	1			true	1990-1999
LA134693	NM	Eddy	true	4750	Ceramic/Mogollon (Typo)	3	2			true	2000-2010
LA135878	NM	Eddy	false	360	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA15901	NM	Eddy	false	3364	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA20973	NM	Eddy	true	600	Ceramic/Mogollon (Typo)	3	3			true	1970-1979
LA25660	NM	Eddy	true	600	Ceramic/Mogollon (Typo)	2	3			true	1970-1979
LA25661	NM	Eddy	true	105	Unknown	3	5			false	1990-1999
LA25662	NM	Eddy	true	5000	Ceramic/Mogollon (Typo)	2	3			true	1990-1999
LA25982	NM	Eddy	false	30000	Ceramic/Mogollon (Typo)	4	15			true	1980-1989
LA29498	NM	Eddy	true	4100	Unknown	2	15			false	1990-1999
LA32225	NM	Eddy	true	10000	Ceramic/Mogollon (Typo)		15			true	1990-1999
LA32245	NM	Eddy	true	653400	Multicomponent	1	15			true	1990-1999
LA32268	NM	Eddy	true	30000	Ceramic/Mogollon (Typo)	1	15			true	Unknown
LA32276	NM	Eddy	true	25340	Ceramic/Mogollon (Dated)	2	3			true	1980-1989
LA32277	NM	Eddy	true	87420	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA32279	NM	Eddy	false	11250	Multicomponent	1	15			true	1990-1999
LA32511	NM	Eddy	true	30000	Unknown	1	15			true	1980-1989
LA32776	NM	Eddy	true	15000	Ceramic/Mogollon (Typo)	4	2			true	1990-1999
LA33017	NM	Eddy	true	26007	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA34072	NM	Eddy	true	3000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA34138	NM	Eddy	false	3000	Unknown	1	15			false	1980-1989
LA34371	NM	Eddy	false	300	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA37484	NM	Eddy	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA37485	NM	Eddy	false	300	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA37486	NM	Eddy	false	3000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA37487	NM	Eddy	false	3000	Unknown	2	15			false	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA37509	NM	Eddy	false	3000	Unknown	1	15			false	1980-1989
LA37658	NM	Eddy	true	250000	Ceramic/Mogollon (Typo)	1	2			true	1990-1999
LA37663	NM	Eddy	false	30000	Unknown	4	15			false	1980-1989
LA37922	NM	Eddy	true	3150	Unknown	2	2			false	1990-1999
LA38821	NM	Eddy	true	8345	Ceramic/Mogollon (Typo)	3	4			true	2000-2010
LA38822	NM	Eddy	true	50	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA39913	NM	Eddy	true	10000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA39914	NM	Eddy	true	625	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA43312	NM	Eddy	false	30000	Multicomponent	1	15			true	1980-1989
LA43314	NM	Eddy	false	750	Ceramic/Mogollon (Typo)	3	15			true	1970-1979
LA43315	NM	Eddy	true	9000	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA43316	NM	Eddy	true	1500	Ceramic/Mogollon (Typo)	3	11			true	1970-1979
LA43319	NM	Eddy	true	500000	Ceramic/Mogollon (Typo)	1	15			true	2000-2010
LA43321	NM	Eddy	true	300	Unknown	2	15			false	1980-1989
LA44812	NM	Eddy	false	900	Unknown	2	15			false	1980-1989
LA45237	NM	Eddy	false	300	Unknown	2	15			false	1980-1989
LA46195	NM	Eddy	false	750	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA46444	NM	Eddy	true	655	Unknown	2	15			false	1980-1989
LA46445	NM	Eddy	true	10000	Ceramic/Mogollon (Typo)	1	3	15		true	1990-1999
LA46618	NM	Eddy	true	96000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA48272	NM	Eddy	false	7500	Archaic (Typo)	2	15			false	1980-1989
LA48795	NM	Eddy	true	68000	Ceramic/Mogollon (Typo)	1	15			true	2000-2010
LA49435	NM	Eddy	false	300	Ceramic/Mogollon (Typo)	3	15			false	1980-1989
LA49641	NM	Eddy	true	7500	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA49981	NM	Eddy	true	750	Unknown	3	15			false	1980-1989
LA50483	NM	Eddy	true	450000	Archaic (Typo)	3	15			false	1980-1989
LA50828	NM	Eddy	false	3000	Unknown	2	15			false	1980-1989
LA51084	NM	Eddy	true	9000	Ceramic/Mogollon (Typo)	4	3	15		true	1990-1999
LA51085	NM	Eddy	true	1140	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA51485	NM	Eddy	true	3000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA51486	NM	Eddy	true	750	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA59951	NM	Eddy	false	30000	Unknown	3	15			false	1980-1989
LA60610	NM	Eddy	true	36	Unknown	2	15			false	1990-1999
LA60673	NM	Eddy	true	2500	Ceramic/Mogollon (Typo)	1	15			true	2000-2010
LA61244	NM	Eddy	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA64622	NM	Eddy	false	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA64623	NM	Eddy	true	1500	Unknown	2	15			false	1990-1999

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA64963	NM	Eddy	true	33600	Unknown	3	15			false	1990-1999
LA65399	NM	Eddy	true	400	Unknown	2	15			false	1980-1989
LA66505	NM	Eddy	false	3000	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA66520	NM	Eddy	false	300	Unknown	2	15			false	1980-1989
LA66909	NM	Eddy	false	250	Archaic (Typo)	3	15			false	1980-1989
LA66910	NM	Eddy	true	132	Ceramic/Mogollon (Typo)	3	3	2		true	1980-1989
LA67572	NM	Eddy	true	45	Unknown	2	2			false	1980-1989
LA68376	NM	Eddy	true	27816	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA68985	NM	Eddy	true	182250	Multicomponent	2	15			true	2000-2010
LA68997	NM	Eddy	false	62	Unknown	2	15			false	1980-1989
LA71204	NM	Eddy	true	34984	Multicomponent	3	15			false	1990-1999
LA71833	NM	Eddy	false	144	Unknown	2	15			false	1980-1989
LA72391	NM	Eddy	true	225	Unknown	2	2			false	1980-1989
LA75267	NM	Eddy	true	6552	Unknown	2	15			false	2000-2010
LA75268	NM	Eddy	false	204	Unknown	2	15			false	1990-1999
LA75433	NM	Eddy	true	42900	Ceramic/Mogollon (Typo)	3	2	5	8	true	2000-2010
LA75701	NM	Eddy	false	7500	Ceramic/Mogollon (Typo)	1	15			false	1980-1989
LA75703	NM	Eddy	true	30000	Ceramic/Mogollon (Typo)	1	15			true	1980-1989
LA75708	NM	Eddy	true	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA75709	NM	Eddy	true	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA77514	NM	Eddy	true	3000	Unknown	3	15			false	1980-1989
LA79062	NM	Eddy	true	7500	Unknown	2	15			false	1990-1999
LA79063	NM	Eddy	true	300	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA79567	NM	Eddy	true	84100	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA81271	NM	Eddy	false	57000	Unknown		2			false	1990-1999
LA83584	NM	Eddy	true	30000	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA83650	NM	Eddy	true	1000	Ceramic/Mogollon (Typo)	3	15			true	2000-2010
LA83678	NM	Eddy	true	450300	Unknown	8	2			false	2000-2010
LA83680	NM	Eddy	true	64800	Ceramic/Mogollon (Dated)	4	3			true	2000-2010
LA84656	NM	Eddy	false	30000	Ceramic/Mogollon (Typo)	4	15			true	1990-1999
LA84693	NM	Eddy	true	3000	Unknown	2	15			false	1990-1999
LA86183	NM	Eddy	true	102940	Ceramic/Mogollon (Typo)	3	3	2		true	1990-1999
LA86196	NM	Eddy	true	7102	Ceramic/Mogollon (Typo)	3	15			true	2000-2010
LA87023	NM	Eddy	true	71048	Ceramic/Mogollon (Typo)	7	2	3		true	2000-2010
LA89658	NM	Eddy	true	24	Unknown	2	2			false	1990-1999
LA98794	NM	Eddy	true	30000	Unknown	3	15			false	1990-1999
LA99640	NM	Eddy	true	43200	Ceramic/Mogollon (Typo)	3	2			true	1990-1999

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41FL1	TX	Floyd	true	*	Unknown	1	8			false	1950-1959
41FL14	TX	Floyd	false	*	Unknown	1	15			true	1970-1979
41FL15	TX	Floyd	false	*	Unknown	1	15			false	1970-1979
41FL16	TX	Floyd	false	*	Unknown	1	15			false	1970-1979
41FL17	TX	Floyd	true	27871	Unknown	2	15			false	1960-1969
41FL25	TX	Floyd	false	*		1	15			false	1970-1979
41FL29	TX	Floyd	true	*	Unknown	1	10			false	1970-1979
41FL48	TX	Floyd	true	30000	Unknown	1	8			false	1970-1979
41FL7	TX	Floyd	false	*	Unknown	1	15			false	1970-1979
41FL74	TX	Floyd	true	2500	Unknown	1	8			false	1990-1999
41FL75	TX	Floyd	false	*	Unknown	2	15			false	Unknown
41FL75	TX	Floyd	true	*	Unknown	2	2			false	1990-1999
41FL76	TX	Floyd	true	6136	Unknown	3	13	12	8	true	1990-1999
41LU43	TX	Floyd	false	*	Unknown	1	15			false	1970-1979
41GA10	TX	Gaines	true	*	Unknown	1	1			true	1980-1989
41GA48	TX	Gaines	true	5000	Unknown	1	2			false	1990-1999
41GA51	TX	Gaines	true	400	Unknown	2	2			false	1990-1999
41GA61	TX	Gaines	false	*	Ceramic/Mogollon (Typo)	3	3			true	1990-1999
41GA7	TX	Gaines	true	4046	Unknown	1	1			false	1930-1939
41GR1	TX	Garza	false	900	Protohistoric (Typo)	1	15			false	1960-1969
41GR12	TX	Garza	true	*	Unknown	3	15			true	1960-1969
41GR120	TX	Garza	true	7800	Archaic (Typo)	4	12	2	3	false	1960-1969
41GR13	TX	Garza	true	30000	Multicomponent	3	2			false	1970-1979
41GR14	TX	Garza	true	*	Unknown	1	15			false	1960-1969
41GR16	TX	Garza	false	*	Unknown	1	15			false	1960-1969
41GR17	TX	Garza	false	*	Unknown	1	15			false	1960-1969
41GR178	TX	Garza	false	*	Unknown	1	15			false	Unknown
41GR179	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR18	TX	Garza	true	*	Unknown	1	15			false	1960-1969
41GR180	TX	Garza	false	*	Unknown	1	15			false	Unknown
41GR182	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR183	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR184	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR185	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR186	TX	Garza	true	*	Unknown	1	15			true	Unknown
41GR187	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR188	TX	Garza	true	*	Unknown	1	3	15		false	1970-1979
41GR19	TX	Garza	true	*	Unknown	1	15			false	1960-1969
41GR190	TX	Garza	false	*	Unknown	2	15			false	Unknown
41GR191	TX	Garza	true	*	Unknown	1	2	8		false	Unknown
41GR192	TX	Garza	true	*	Unknown	1	15			false	1970-1979
41GR193	TX	Garza	true	*	Unknown	1	1			false	1970-1979
41GR194	TX	Garza	true	*	Unknown	1	15			false	1970-

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
											1979
41GR195	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR196	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR197	TX	Garza	true	*	Unknown	1	15			false	1970-1979
41GR198	TX	Garza	false	*	Unknown	1	15			false	Unknown
41GR199	TX	Garza	true	*		1	15			false	Unknown
41GR20	TX	Garza	false	*	Unknown	1	15			false	1960-1969
41GR200	TX	Garza	true	*	Unknown		15			false	Unknown
41GR201	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR202	TX	Garza	false	*	Unknown	1	15			false	Unknown
41GR209	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR21	TX	Garza	true	*	Unknown	1	15			false	1960-1969
41GR210	TX	Garza	false	*	Unknown	2	15			false	Unknown
41GR211	TX	Garza	true	*	Unknown	1	1			false	Unknown
41GR213	TX	Garza	true	*	Unknown	1	15			false	1970-1979
41GR214	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR216	TX	Garza	true	*	Unknown	2	15			false	Unknown
41GR220	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR221	TX	Garza	true	*		1	15			false	1970-1979
41GR222	TX	Garza	true	*	Unknown	1	15			false	1970-1979
41GR223	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR224	TX	Garza	false	*	Unknown	2	15			false	Unknown
41GR225	TX	Garza	false	*	Unknown	1	15			false	1970-1979
41GR226	TX	Garza	true	*	Unknown	2	15			false	Unknown
41GR228	TX	Garza	true	*	Unknown	1	15			false	1970-1979
41GR229	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR230	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR232	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR236	TX	Garza	false	*	Unknown	1	15			false	Unknown
41GR237	TX	Garza	false	*	Unknown	1	1			false	Unknown
41GR277	TX	Garza	true	13000	Unknown	3	2			false	1980-1989
41GR47	TX	Garza	false	28900	Unknown	2	11			false	1980-1989
41GR478	TX	Garza	true	4000	Unknown	2	8			false	1980-1989
41GR607	TX	Garza	true	*	Unknown	1	2			false	1990-1999
41GR620	TX	Garza	true	*	Unknown	4	2	5		false	1990-1999
41GR621	TX	Garza	true	8000	Multicomponent	2	2			true	1990-1999
41GR623	TX	Garza	true	3200	Archaic (Typo)	2	2			false	1990-1999
41GR628	TX	Garza	true	1800	Unknown	1	15			false	1990-1999
41GR630	TX	Garza	true	400000	Archaic (Typo)	1	15			false	1990-1999
41GR632	TX	Garza	true	10000	Unknown	1	2			false	1990-1999
41GR635	TX	Garza	true	9000	Unknown	3	2			false	1990-1999
41GR636	TX	Garza	true	10000	Unknown	3	2			false	1990-1999
41GR640	TX	Garza	true	*	Archaic (Typo)	1	15			false	1990-1999
41GR646	TX	Garza	true	5000	Unknown	3	2			false	1990-1999
41GR647	TX	Garza	true	1875	Unknown	3	2			false	1990-1999
41GR652	TX	Garza	true	10000	Unknown	3	2			false	1990-1999
41GR653	TX	Garza	true	20	Unknown	3	2			false	1990-1999
41GR655	TX	Garza	true	2500	Unknown	3	2			false	1990-

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
											1999
41GR657	TX	Garza	true	*	Unknown	1	2			true	1990-1999
41GR658	TX	Garza	true	1400	Unknown	3	2			false	1990-1999
41GR659	TX	Garza	true	60000	Archaic (Typo)	5	8	2		false	1990-1999
41GR665	TX	Garza	true	1000	Unknown	3	2			false	1990-1999
41GR666	TX	Garza	true	7500	Unknown	3	8			false	1990-1999
41GR667	TX	Garza	true	750	Unknown	3	2			false	1990-1999
41GR668	TX	Garza	true	120000	Multicomponent	1	2			false	1990-1999
41GR669	TX	Garza	true	7500	Unknown	4	2			false	1990-1999
41GR671	TX	Garza	true	30000	Unknown	4	15			false	1990-1999
41GR672	TX	Garza	true	37500	Unknown	3	2			false	1990-1999
41GR673	TX	Garza	true	*	Unknown	5	2			false	1990-1999
41GR8	TX	Garza	true	*	Unknown	1	15			false	Unknown
41GR9	TX	Garza	true	*	Unknown	1	1			false	1960-1969
41GY12	TX	Gray	true	*	Unknown	2	2			false	1970-1979
41GY15	TX	Gray	true	*	Unknown	2	2			false	1970-1979
41GY17	TX	Gray	true	*	Unknown	2	12			false	1970-1979
41GY21	TX	Gray	true	*	Unknown	1	2			false	1970-1979
41GY22	TX	Gray	true	*	Unknown	2	2			false	1970-1979
41GY23	TX	Gray	true	*	Unknown	1	1			false	1970-1979
41GY25	TX	Gray	true	*	Unknown	2	2			false	1970-1979
41GY41	TX	Gray	true	40000	Archaic (Typo)	2	15			false	1980-1989
41GY43	TX	Gray	true	7500	Unknown	3	2			false	1980-1989
41GY46	TX	Gray	true	457		1	1			false	1980-1989
41GY49	TX	Gray	true	9	Unknown	2	2			false	1980-1989
41GY54	TX	Gray	true	750	Protohistoric (Typo)	1	2			false	1980-1989
41GY59	TX	Gray	true	37500	Unknown	1	2			false	1980-1989
41GY7	TX	Gray	true	*		2	2			false	1970-1979
4GY9	TX	Gray	true	*	Unknown	2	2			false	1970-1979
LA6767	TX	Guadalupe	false	*	Ceramic/Mogollon (Typo)	1	15			true	1960-1969
41HA2	TX	Hale	true	315	Unknown	2	2			false	1980-1989
41HA3	TX	Hale	true	72	Unknown	1	1			false	1970-1979
41HA5	TX	Hale	true	90000	Unknown	1	2			true	1970-1979
41HA53	TX	Hale	true	*	Unknown	2	15			false	1970-1979
41HA57	TX	Hale	true	*	Unknown	2	8			false	1970-1979
41HW13	TX	Howard	false	*	Unknown	1	1			false	1970-1979
41HW15	TX	Howard	true	4047	Unknown	1	2	3		false	1970-1979
41HW20	TX	Howard	false	10117.5	Unknown	1	15			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41HW22	TX	Howard	false	2024	Unknown	1	15			false	1970-1979
41HW23	TX	Howard	false	8094	Unknown	1	15			false	1970-1979
41HW36	TX	Howard	false	8094	Archaic (Typo)	1	15			false	1970-1979
41HW37	TX	Howard	false	26306	Unknown	1	15			true	1970-1979
41HW38	TX	Howard	false	10118	Archaic (Typo)	2	15			false	1970-1979
41HW40	TX	Howard	true	60705	Multicomponent	1	15			false	1970-1979
41HW45	TX	Howard	false	90	Unknown	1	15			true	1930-1939
41HW59	TX	Howard	true	24800	Unknown	3	2			false	1990-1999
41HW7	TX	Howard	false	*	Unknown	2	15			false	1970-1979
41HW73	TX	Howard	true	120	Unknown	3	2			false	1990-1999
41HC124	TX	Hutchinson	true	62500	Unknown	1	3	0	0	true	0
41LA1	TX	Lamb	false	*	Archaic (Typo)	1	15			false	1970-1979
LA-100331	NM	Lea	true	47520	Unknown	2	15			false	1990-1999
LA100721	NM	Lea	true	10370	Unknown	3	3	15		false	1990-1999
LA100906	NM	Lea	true	93750	Ceramic/Mogollon (Typo)	5	3			true	1990-1999
LA101131	NM	Lea	false	3000	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA102505	NM	Lea	false	11200	Ceramic/Mogollon (Typo)	3	3			true	1990-1999
LA102509	NM	Lea	true	165000	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA102510	NM	Lea	true	5600	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA104006	NM	Lea	true	11200	Ceramic/Mogollon (Typo)	2	4			true	1990-1999
LA104474	NM	Lea	true	945	Unknown	2	2			false	1990-1999
LA105180	NM	Lea	true	3640	Ceramic/Mogollon (Typo)	2	3			true	1990-1999
LA105225	NM	Lea	true	5776	Ceramic/Mogollon (Typo)	2	3			false	1990-1999
LA105226	NM	Lea	true	200	Unknown	2	5			false	1990-1999
LA105443	NM	Lea	true	1505	Multicomponent	3	2			false	1990-1999
LA105770	NM	Lea	true	174000	Unknown	4	2			false	1990-1999
LA105771	NM	Lea	true	770	Unknown	3	2			false	1990-1999
LA105773	NM	Lea	true	700	Unknown	2	2			false	1990-1999
LA105775	NM	Lea	true	117000	Ceramic/Mogollon (Typo)	8	3	2		true	1990-1999
LA105884	NM	Lea	true	2800	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA105885	NM	Lea	true	96	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA105886	NM	Lea	true	600	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA105888	NM	Lea	true	625	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA105889	NM	Lea	true	9100	Ceramic/Mogollon (Typo)	3	6			true	1990-1999
LA105890	NM	Lea	true	8400	Unknown	3	2			false	1990-1999
LA105912	NM	Lea	true	400	Unknown	2	2			false	1990-1999
LA105935	NM	Lea	true	80	Unknown	2	2			false	1990-1999
LA106322	NM	Lea	true	1620	Unknown	2	2			false	1990-

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
											1999
LA106323	NM	Lea	true	9900	Unknown	3	3	2		false	1990-1999
LA106325	NM	Lea	true	51200	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA106729	NM	Lea	true	5212	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA106730	NM	Lea	true	24840	Ceramic/Mogollon (Typo)	4	3	5		true	1990-1999
LA106731	NM	Lea	true	8900	Unknown	3	4	2		false	1990-1999
LA106732	NM	Lea	true	9800	Multicomponent	3	2			true	1990-1999
LA106734	NM	Lea	true	4800	Ceramic/Mogollon (Typo)	3	3	2		true	1990-1999
LA106735	NM	Lea	true	45000	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA106737	NM	Lea	true	200	Unknown	2	2			false	1990-1999
LA106742	NM	Lea	true	418	Unknown	2	2			false	1990-1999
LA106751	NM	Lea	true	1631	Unknown	2	2			false	1990-1999
LA106752	NM	Lea	true	200	Unknown	2	2			false	1990-1999
LA106753	NM	Lea	true	960	Unknown	2	2			false	1990-1999
LA106758	NM	Lea	true	14030	Ceramic/Mogollon (Typo)	3	3	2		true	1990-1999
LA106759	NM	Lea	true	1278	Unknown	3	3	6		false	1990-1999
LA106761	NM	Lea	true	23291	Unknown	3	2			false	1990-1999
LA106763	NM	Lea	true	2530	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA106869	NM	Lea	true	1541	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA107122	NM	Lea	true	50000	Ceramic/Mogollon (Typo)	1	2			false	1990-1999
LA107696	NM	Lea	true	3000	Ceramic/Mogollon (Typo)	3	2	3		false	1990-1999
LA108415	NM	Lea	true	7800	Unknown	2	6			false	1990-1999
LA108916	NM	Lea	true	2562	Archaic (Typo)	3	4			false	1990-1999
LA108917	NM	Lea	true	3726	Unknown	2	2			false	1990-1999
LA108925	NM	Lea	true	67600	Ceramic/Mogollon (Typo)	5	2			true	1990-1999
LA108926	NM	Lea	true	19575	Ceramic/Mogollon (Typo)	3	2	3		true	1990-1999
LA108927	NM	Lea	true	1125	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA108928	NM	Lea	true	560	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA108931	NM	Lea	true	273	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA108956	NM	Lea	true	4180	Ceramic/Mogollon (Typo)	3	2	4		true	1990-1999
LA109208	NM	Lea	true	31889	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA109210	NM	Lea	true	7920	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA109346	NM	Lea	true	11700	Unknown	3	4	2		false	1990-1999
LA109348	NM	Lea	true	12500	Unknown	3	2			false	1990-1999
LA109544	NM	Lea	true	5600	Unknown	2	2			false	1990-1999
LA109547	NM	Lea	true	169	Unknown	2	2			false	1990-1999
LA109549	NM	Lea	true	6000	Unknown	2	2			false	1990-1999

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA109552	NM	Lea	true	2000	Unknown	2	2			false	1990-1999
LA109560	NM	Lea	true	71250	Ceramic/Mogollon (Typo)	3	3	4		true	1990-1999
LA109561	NM	Lea	true	3250	Multicomponent	2	4			true	1990-1999
LA109563	NM	Lea	true	2000	Ceramic/Mogollon (Typo)	3	3	2		true	2000-2010
LA109593	NM	Lea	true	60000	Unknown		2			false	1990-1999
LA109721	NM	Lea	true	47250	Ceramic/Mogollon (Typo)		1			true	1990-1999
LA109926	NM	Lea	true	17600	Ceramic/Mogollon (Typo)	4	2	5		true	1990-1999
LA109927	NM	Lea	true	106900	Ceramic/Mogollon (Typo)	3	3			true	1990-1999
LA109928	NM	Lea	true	5600	Archaic (Typo)	2	2			false	1990-1999
LA109929	NM	Lea	true	30000	Unknown	2	2			false	1990-1999
LA109930	NM	Lea	true	19300	Multicomponent	2	2			true	1990-1999
LA110821	NM	Lea	true	11250	Multicomponent	1	2			true	1990-1999
LA111136	NM	Lea	true	2889	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA112587	NM	Lea	true	6958	Ceramic/Mogollon (Typo)	2	3			true	1990-1999
LA117242	NM	Lea	true	3444	Ceramic/Mogollon (Typo)	3	3			true	1990-1999
LA12948	NM	Lea	false	3000	Unknown	3	15			false	1970-1979
LA132312	NM	Lea	true	4370	Ceramic/Mogollon (Typo)	3	11			true	2000-2010
LA134116	NM	Lea	true	7000	Unknown	4	2			false	2000-2010
LA134320	NM	Lea	true	7480	Ceramic/Mogollon (Typo)	3	2	9		true	2000-2010
LA134918	NM	Lea	true	1375	Ceramic/Mogollon (Typo)	3	2			true	2000-2010
LA136251	NM	Lea	true	300	Ceramic/Mogollon (Typo)	3	3	2		true	Unknown
LA19211	NM	Lea	false	1200	Ceramic/Mogollon (Typo)	2	15			true	1970-1979
LA19990	NM	Lea	false	30000	Unknown	1	15			false	1970-1979
LA19995	NM	Lea	false	30000	Unknown	1	15			true	1970-1979
LA19997	NM	Lea	true	1600	Ceramic/Mogollon (Typo)	1	3			true	1980-1989
LA20307	NM	Lea	true	25	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA20887	NM	Lea	false	12	Ceramic/Mogollon (Typo)	1	15			true	1970-1979
LA25668	NM	Lea	true	99900	Multicomponent	1	3	2	15	true	1990-1999
LA26301	NM	Lea	true	10000	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA26754	NM	Lea	true	176	Unknown	3	3			false	1970-1979
LA26996	NM	Lea	true	35	Ceramic/Mogollon (Typo)	2	4			true	1970-1979
LA29497	NM	Lea	true	288	Ceramic/Mogollon (Typo)	4	3	2		true	1980-1989
LA29620	NM	Lea	true	15180	Ceramic/Mogollon (Typo)	1	3			true	2000-2010
LA30600	NM	Lea	true	480	Ceramic/Mogollon (Typo)	2	4			true	1980-1989
LA30601	NM	Lea	true	418	Unknown	3	8			false	1980-1989
LA31793	NM	Lea	true	234600	Ceramic/Mogollon (Typo)	3	2			true	1990-1999
LA32226	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	1	15			true	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA32228	NM	Lea	true	950400	Multicomponent	8	2			true	1990-1999
LA32619	NM	Lea	true	7808	Ceramic/Mogollon (Typo)	4	3	8		true	2000-2010
LA33076	NM	Lea	true	325000	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
LA34671	NM	Lea	true	300	Unknown	2	15			false	1980-1989
LA35594	NM	Lea	true	270	Ceramic/Mogollon (Typo)	2	4			true	1980-1989
LA35652	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	1	15			true	Unknown
LA35657	NM	Lea	true	75000	Ceramic/Mogollon (Typo)	4	2			true	1990-1999
LA35665	NM	Lea	false	30000	Multicomponent	5	15			true	1990-1999
LA35670	NM	Lea	true	30000	Ceramic/Mogollon (Typo)	3	15			true	1970-1979
LA35671	NM	Lea	true	30000	Multicomponent	1	15			true	Unknown
LA35679	NM	Lea	false	*	Unknown	1	15			false	Unknown
LA35680	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	1	15			true	Unknown
LA36322	NM	Lea	false	100	Ceramic/Mogollon (Typo)	2	11			true	1980-1989
LA37336	NM	Lea	true	3500	Ceramic/Mogollon (Typo)	2	2			true	1980-1989
LA37548	NM	Lea	false	100	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA38351	NM	Lea	true	16	Unknown	2	15			false	1980-1989
LA38352	NM	Lea	false	9	Unknown	2	15			false	1980-1989
LA38353	NM	Lea	true	16	Unknown	2	2			false	1980-1989
LA38354	NM	Lea	true	180	Unknown	2	2			false	1980-1989
LA38356	NM	Lea	true	300	Unknown	2	2			false	1980-1989
LA38357	NM	Lea	true	50	Unknown	2	8			false	1980-1989
LA38358	NM	Lea	true	2500	Unknown	2	2			false	1980-1989
LA38472	NM	Lea	false	3000	Unknown	3	15			false	1980-1989
LA38474	NM	Lea	false	62	Unknown	2	15			false	1980-1989
LA38475	NM	Lea	false	3000	Unknown	1	15			true	1980-1989
LA38833	NM	Lea	true	30000	Unknown	3	15			false	1980-1989
LA38841	NM	Lea	true	3000	Unknown	2	15			false	1980-1989
LA38842	NM	Lea	false	3000	Unknown	3	15			false	1980-1989
LA39893	NM	Lea	true	115200	Ceramic/Mogollon (Typo)	1	2			true	1990-1999
LA43359	NM	Lea	true	12000	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
LA43369	NM	Lea	false	30000	Unknown	1	15			false	1970-1979
LA43386	NM	Lea	true	130500	Multicomponent	1	15			false	1970-1979
LA43388	NM	Lea	true	394800	Multicomponent	1	3	2		true	1990-1999
LA43390	NM	Lea	true	30000	Unknown	1	15			false	1970-1979
LA43391	NM	Lea	true	30000	Paleoindian (typo)	1	15			false	1970-1979
LA43393	NM	Lea	true	21600	Archaic (Typo)	3	8			true	1990-1999
LA43525	NM	Lea	false	30000	Multicomponent	1	15			true	Unknown
LA43719	NM	Lea	true	30000	Unknown	1	15			false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA43962	NM	Lea	true	750	Unknown	2	15			false	1980-1989
LA44794	NM	Lea	true	15400	Unknown	4	2	11		false	
LA45409	NM	Lea	false	12	Unknown	2	15			false	1980-1989
LA48273	NM	Lea	true	25	Unknown	2	2			false	1980-1989
LA49450	NM	Lea	false	2700	Unknown	2	15			false	1980-1989
LA49478	NM	Lea	true	750	Unknown	1	15			false	1990-1999
LA49480	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA49782	NM	Lea	false	7500	Ceramic/Mogollon (Typo)	3	15			false	1980-1989
LA50456	NM	Lea	false	84	Ceramic/Mogollon (Typo)	3	15			true	1970-1979
LA50498	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA51089	NM	Lea	false	7500	Unknown	2	15			false	1980-1989
LA51102	NM	Lea	false	12	Unknown	2	15			false	1980-1989
LA51497	NM	Lea	true	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA51718	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1980-1989
LA51812	NM	Lea	true	196999	Ceramic/Mogollon (Typo)	5	15			true	1980-1989
LA51842	NM	Lea	true	600	Unknown	1	15			false	1980-1989
LA53430	NM	Lea	true	120000	Ceramic/Mogollon (Typo)	5	2			true	1990-1999
LA53461	NM	Lea	true	3640	Unknown	2	15			false	1980-1989
LA53463	NM	Lea	true	3944	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA53469	NM	Lea	true	30000	Unknown	3	15			false	1980-1989
LA53844	NM	Lea	true	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA53847	NM	Lea	true	62	Unknown	2	15			false	1980-1989
LA53849	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	4	15			true	2000-2010
LA53928	NM	Lea	true	1500	Unknown	2	2			false	1990-1999
LA53993	NM	Lea	true	7500	Unknown	2	15			false	1980-1989
LA53994	NM	Lea	true	3000	Unknown	3	15			false	1980-1989
LA54114	NM	Lea	false	3000	Archaic (Typo)	3	15			false	1980-1989
LA54674	NM	Lea	false	400	Ceramic/Mogollon (Typo)	2	5			true	1980-1989
LA55989	NM	Lea	true	4800	Unknown	2	15			false	1980-1989
LA59284	NM	Lea	false	6750	Multicomponent	3	15			true	1990-1999
LA59589	NM	Lea	true	27600	Ceramic/Mogollon (Typo)	5	2			true	1990-1999
LA64498	NM	Lea	true	30400	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA65341	NM	Lea	false	2100	Unknown	2	15			false	1980-1989
LA66000	NM	Lea	true	53613	Unknown	3	15			false	1990-1999
LA66515	NM	Lea	false	16800	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA66587	NM	Lea	false	3000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA67595	NM	Lea	false	7500	Multicomponent	3	15			false	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
LA68483	NM	Lea	false	300	Unknown	2	15			true	1980-1989
LA68914	NM	Lea	true	8100	Ceramic/Mogollon (Typo)	3	2			true	1980-1989
LA70270	NM	Lea	false	186	Unknown	2	15			false	1980-1989
LA71826	NM	Lea	false	46900	Unknown	3	15			false	1980-1989
LA76481	NM	Lea	true	7500	Unknown	1	2	15		false	1980-1989
LA77126	NM	Lea	true	300	Unknown	2	15			false	1970-1979
LA77128	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	4	15			true	1970-1979
LA78610	NM	Lea	true	7500	Ceramic/Mogollon (Typo)	1	15			false	1980-1989
LA78611	NM	Lea	false	7500	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA78612	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	1	15			false	1990-1999
LA78613	NM	Lea	false	3000	Ceramic/Mogollon (Typo)	1	15			true	2000-2010
LA78645	NM	Lea	true	20400	Ceramic/Mogollon (Typo)	3	15			true	1990-1999
LA79982	NM	Lea	true	3000	Unknown	3	2			true	1990-1999
LA79987	NM	Lea	true	70300	Archaic (Typo)	3	2			false	1990-1999
LA80209	NM	Lea	false	62	Unknown	2	15			false	1980-1989
LA80250	NM	Lea	false	5460	Ceramic/Mogollon (Typo)	3	15			false	1980-1989
LA8048	NM	Lea	false	3000	Ceramic/Mogollon (Typo)	1	15			true	1960-1969
LA81446	NM	Lea	false	7500	Ceramic/Mogollon (Typo)	2	15			false	1980-1989
LA81449	NM	Lea	true	7200	Ceramic/Mogollon (Typo)	2	2			true	1990-1999
LA83815	NM	Lea	true	30000	Unknown	2	15			false	1980-1989
LA83818	NM	Lea	false	30000	Ceramic/Mogollon (Typo)	2	15			true	1980-1989
LA84990	NM	Lea	true	30000	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA86120	NM	Lea	true	30000	Ceramic/Mogollon (Typo)	3	3	2		true	1990-1999
LA86124	NM	Lea	true	30000	Ceramic/Mogollon (Typo)	3	3	2		true	1990-1999
LA87039	NM	Lea	true	3000	Ceramic/Mogollon (Typo)	2	15			true	1990-1999
LA98795	NM	Lea	true	18544	Unknown	2	11			true	1990-1999
41LU1	TX	Lubbock	true	*	Multicomponent	8	12	14	3	true	1980-1989
41LU118	TX	Lubbock	true	40000	Multicomponent	3	12	2		false	2000-2010
41LU129, Jones Station #1	TX	Lubbock	true	*	Multicomponent	2	12			false	2000-2010
41LU27	TX	Lubbock	true	*	Unknown	3	2	0	0	false	1980-1989
41LU29	TX	Lubbock	true	18000	Multicomponent	2	2	0	0	false	1970-1979
41LU3	TX	Lubbock	true	*	Multicomponent	3	2	3		true	1970-1979
41LU31	TX	Lubbock	true	*	Unknown	3	2	0	0	false	0
41LU35 The Nash Site	TX	Lubbock	true	167.23	Unknown	3	15			true	Unknown
41LU5	TX	Lubbock	true	42000	Unknown	3	2	0	0	false	1980-1989
41LU6	TX	Lubbock	true	1143	Multicomponent	4	14	3		false	1970-1979

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41LU64	TX	Lubbock	true	*	Unknown	2	2	0	0	false	1980-1989
41LU65	TX	Lubbock	true	*	Multicomponent	3	8			false	1980-1989
41LU66	TX	Lubbock	true	*	Unknown	2	2			false	1980-1989
41LU67	TX	Lubbock	true		Unknown	2	2	0	0	false	1980-1989
41LU68	TX	Lubbock	true	*	Protohistoric (Dated)	2	12			false	1980-1989
41LU73	TX	Lubbock	true		Unknown	1	2	0	0	false	0
41LU74	TX	Lubbock	true		Ceramic/Mogollon (Dated)	2	12	0	0	false	1980-1989
41LU75	TX	Lubbock	true	*	Multicomponent	3	13			true	1980-1989
41LU83	TX	Lubbock	true	25	Multicomponent	2	12			false	1980-1989
41LU84	TX	Lubbock	true	60	Unknown	1	1			false	1980-1989
41LU85	TX	Lubbock	true	22400	Unknown	3	2	0	0	false	0
41LU87	TX	Lubbock	false	*	Unknown		3			false	1990-1999
41LY52, Area 14	TX	Lynn	true	25	Protohistoric (Dated)	2	14			false	2000-2010
41MT1	TX	Martin	false	*	Paleoindian (typo)	1	15			false	1960-1969
41MT12	TX	Martin	true	*	Multicomponent	2	12			false	1990-1999
41MT2	TX	Martin	true	*	Protohistoric (Typo)	1	8	2		false	1970-1979
41MT21	TX	Martin	true	12800	Archaic (Typo)	1	1			false	1990-1999
41MT24	TX	Martin	true	1575	Unknown	1	1			false	1990-1999
41MT32	TX	Martin	true	6000	Unknown	1	1			false	1990-1999
41MT39	TX	Martin	true	82500	Ceramic/Mogollon (Dated)	3	2	3		false	1990-1999
41MT7	TX	Martin	true	14000	Unknown	1	2			true	1980-1989
41MD11	TX	Midland	true	*	Unknown	1	4			true	1960-1969
41MD12	TX	Midland	true	209031	Unknown	1	15			true	1960-1969
41MD16	TX	Midland	true	*	Multicomponent	4	2			false	1990-1999
41MD20	TX	Midland	true	*	Unknown	2	7			true	1970-1979
41MD27	TX	Midland	true	149	Protohistoric (Typo)	2	15			false	1970-1979
41MD28	TX	Midland	true	25071	Unknown	1	1			false	1980-1989
41MD29	TX	Midland	false	400	Unknown	2	15			false	1980-1989
41MD32	TX	Midland	false	*	Archaic (Typo)	2	15			false	1980-1989
41MY10	TX	Motley	true	30000	Protohistoric (Typo)	3	8			true	1990-1999
41MY18	TX	Motley	true	600	Archaic (Typo)	3	2			false	2000-2010
41MY19	TX	Motley	true	1500	Unknown	1	7			false	2000-2010
41MY20	TX	Motley	true	1350	Protohistoric (Typo)	1	15			false	2000-2010
41MY7	TX	Motley	false	755	Unknown	1	15			false	1970-1979
41OL101	TX	Oldham	true	800	Unknown	3	2			false	1980-1989
41OL105	TX	Oldham	true	600	Unknown	3	2			false	1980-1989
41OL108	TX	Oldham	true	400	Unknown	3	2			false	1980-1989
41OL111	TX	Oldham	true	50	Unknown	3	2			false	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41OL112	TX	Oldham	true	1250	Unknown	1	1			false	1980-1989
41OL113	TX	Oldham	true	3000	Unknown	1	1			false	1980-1989
41OL115	TX	Oldham	true	25	Unknown	2	2			false	1980-1989
41OL116	TX	Oldham	true	600	Unknown	3	2			false	1980-1989
41OL1180	TX	Oldham	true	22500	Unknown	4	2			false	1980-1989
41OL119	TX	Oldham	true	100	Unknown	2	2			true	1980-1989
41OL123	TX	Oldham	true	250	Unknown	3	2			false	1980-1989
41OL127	TX	Oldham	true	1000	Unknown	1	2			false	1980-1989
41OL130	TX	Oldham	true	1200	Unknown	3	2			false	1980-1989
41OL131	TX	Oldham	true	800	Unknown	3	2			false	1980-1989
41OL134	TX	Oldham	true	1250	Unknown	2	8			true	1980-1989
41OL172	TX	Oldham	true	10500	Unknown	1	2			false	1980-1989
41OL173	TX	Oldham	true	20000	Unknown	1	12	2		false	1980-1989
41OL174	TX	Oldham	true	60000	Unknown	4	2			true	1980-1989
41OL178	TX	Oldham	true	1250	Archaic (Typo)	2	2			false	1980-1989
41OL184	TX	Oldham	true	3500	Unknown	3	2			false	1980-1989
41OL28.2	TX	Oldham	true	46500	Ceramic/Mogollon (Typo)	1	15			true	1990-1999
41OL281	TX	Oldham	true	3500	Protohistoric (Typo)	1	15			true	1980-1989
41OL283	TX	Oldham	true	4200	Protohistoric (Typo)	1	1			false	1980-1989
41OL287	TX	Oldham	true	6666	Unknown	1	8			false	1990-1999
41OL288	TX	Oldham	true	14400	Unknown	4	4			true	1990-1999
41OL289	TX	Oldham	true	64050	Unknown	3	2			true	1990-1999
41OL29.2	TX	Oldham	true	770000	Archaic (Typo)	1	2			false	1990-1999
41OL293	TX	Oldham	true	4056	Unknown	2	2			false	1990-1999
41OL295	TX	Oldham	true	*	Unknown	2	11			false	1990-1999
41OL297	TX	Oldham	true	*	Unknown	2	2			false	1990-1999
41OL30	TX	Oldham	true	100	Unknown	1	2			false	1970-1979
41OL31	TX	Oldham	true	400	Unknown	1	8			false	1970-1979
41OL32	TX	Oldham	true	25	Unknown	2	8			false	1970-1979
41OL36	TX	Oldham	false	100	Unknown	3	15			true	1970-1979
41OL37	TX	Oldham	true	4	Unknown	2	2			false	1970-1979
41OL38	TX	Oldham	true	4	Unknown	2	2			false	1970-1979
41OL39	TX	Oldham	true	1600	Archaic (Typo)	2	2			false	1970-1979
41OL98	TX	Oldham	true	3000	Unknown	1	2			false	1980-1989
41PM2	TX	Parmer	true	*	Unknown	1	1			false	1970-1979
41PT115	TX	Potter	true	7500	Unknown	3	8			false	1980-1989
41PT122	TX	Potter	true	3750	Unknown	2	2			false	1980-1989

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41PT124	TX	Potter	true	157500	Archaic (Typo)	1	2			false	1980-1989
41PT126	TX	Potter	true	5625	Unknown	3	2	14		false	1980-1989
41PT137	TX	Potter	true	15000	Unknown	3	15			false	1980-1989
41PT138	TX	Potter	true	60000	Unknown	3	2			false	1980-1989
41PT162	TX	Potter	true	12650	Unknown	3	2			false	1990-1999
41PT185	TX	Potter	true	*	Archaic (Typo)	3	8			false	1990-1999
41PT277	TX	Potter	true	4047	Unknown	6	2			false	2000-2010
41PT307	TX	Potter	true	3	Unknown	2	2			false	2000-2010
41PT59	TX	Potter	false	*	Unknown	1	15			false	1970-1979
41PT60	TX	Potter	true	*	Unknown	2	2			false	1970-1979
41PT74	TX	Potter	true	60000	Unknown	2	2			false	1980-1989
41PT78	TX	Potter	true	2400	Archaic (Typo)	2	2			false	1980-1989
LA100593	NM	Quay	true	450	Unknown	2	6			false	1990-1999
LA104890	NM	Quay	true	64	Multicomponent	3	8	15		true	1990-1999
LA138126	NM	Quay	true	1200	Unknown	3	7			false	2000-2010
LA138127	NM	Quay	true	100	Unknown	2	15			false	2000-2010
LA138128	NM	Quay	true	3500	Unknown	4	15			false	2000-2010
LA138130	NM	Quay	true	20	Unknown	2	15			false	2000-2010
LA3900	NM	Quay	false	12	Unknown	2	15			false	1960-1969
LA50341	NM	Quay	false	1400	Unknown	2	15			false	1980-1989
LA70461	NM	Quay	false	3000	Unknown	3	15			false	1980-1989
LA88008	NM	Quay	false	750	Unknown	3	15			false	1990-1999
LA88009	NM	Quay	false	62	Protohistoric (Typo)	1	15			false	1990-1999
41RD24	TX	Randall	true	*	Unknown	1	15			false	1950-1959
41RD3	TX	Randall	true	35000	Archaic (Typo)	3	2	15		false	2000-2010
41RD31	TX	Randall	true	*	Unknown	3	2			false	1970-1979
41RD34	TX	Randall	true	3750	Archaic (Typo)	1	15			false	1970-1979
41RD35	TX	Randall	true	*	Protohistoric (Typo)	1	15			true	1970-1979
41RD50	TX	Randall	true	*	Archaic (Typo)	1	2			false	2000-2010
41RD57	TX	Randall	true	1.2	Unknown	2	2			true	2000-2010
41RD58	TX	Randall	true	60	Unknown	2	2			false	2000-2010
41RD65	TX	Randall	true	48125	Unknown	3	2	15		false	2000-2010
41RD66	TX	Randall	false	3000	Unknown	3	7	11		false	2000-2010
41RD67	TX	Randall	true	600	Unknown	3	2			false	2000-2010
41RD69	TX	Randall	true	*	Unknown	1	4			false	2000-2010
41RD70	TX	Randall	false	600	Unknown	1	3			false	2000-2010
41RD71	TX	Randall	false	1000	Unknown	1	3			false	2000-2010

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41RD76	TX	Randall	false	900	Multicomponent	3	15			false	1960-1969
41RD78	TX	Randall	false	*	Multicomponent	1	3	15		true	1950-1959
41RB20	TX	Roberts	true	*	Unknown	2	2	0	0	false	1970-1979
41RB24	TX	Roberts	true	*	Unknown	2	2	0	0	false	1970-1979
LA107647	NM	Roosevelt	true	660	Unknown	3	2			false	1990-1999
LA107651	NM	Roosevelt	true	10400	Multicomponent		2			false	1990-1999
LA127518	NM	Roosevelt	true	38950	Multicomponent	3	2			true	1990-1999
LA127519	NM	Roosevelt	true	18500	Unknown	4	2			true	1990-1999
LA130783	NM	Roosevelt	true	90000	Unknown	3	2	15		false	1990-1999
LA133093	NM	Roosevelt	true	33600	Multicomponent	4	2			true	2000-2010
LA135619	NM	Roosevelt	true	3200	Unknown	3	2			false	2000-2010
LA35497	NM	Roosevelt	false	30000	Ceramic/Mogollon (Typo)	3	15			true	1970-1979
LA46322	NM	Roosevelt	true	300	Ceramic/Mogollon (Typo)	3	15			true	1970-1979
LA46323	NM	Roosevelt	false	62	Ceramic/Mogollon (Typo)	2	15			true	1970-1979
LA46324	NM	Roosevelt	false	300	Unknown	2	15			false	Unknown
LA46325	NM	Roosevelt	false	750	Ceramic/Mogollon (Typo)	2	15			true	1970-1979
LA52285	NM	Roosevelt	true	7500	Unknown	2	15			false	1980-1989
LA55710	NM	Roosevelt	false	3600	Protohistoric (Typo)	2	15			false	1980-1989
LA6209	NM	Roosevelt	false	*	Paleoindian (typo)	2	15			false	1960-1969
LA64783	NM	Roosevelt	false	7500	Unknown	4	15			false	1980-1989
LA66373	NM	Roosevelt	true	3200	Archaic (Typo)	2	11			false	2000-2010
LA75239	NM	Roosevelt	false	30000	Ceramic/Mogollon (Typo)	4	15			false	1980-1989
LA80252	NM	Roosevelt	true	4876	Ceramic/Mogollon (Typo)	2	2			true	1980-1989
LA83733	NM	Roosevelt	true	*	Multicomponent	3	6	2		true	Unknown
LA87370	NM	Roosevelt	true	*	Multicomponent	2	2			true	1980-1989
LA87372	NM	Roosevelt	true	57525	Ceramic/Mogollon (Typo)	4	2			true	1980-1989
41SW1	TX	Swisher	true	6000	Unknown	3	2			false	1970-1979
41SW11	TX	Swisher	true	600	Unknown	1	2			false	1970-1979
41SW16	TX	Swisher	true	800	Unknown	3	2			false	1970-1979
41SW2	TX	Swisher	true	1400	Unknown	1	2			false	1970-1979
41SW3	TX	Swisher	true	1800	Unknown	3	2			false	1970-1979
41SW4	TX	Swisher	true	6000	Unknown	2	2			false	1970-1979
41SW5	TX	Swisher	true	2100	Unknown	1	1			false	1970-1979
41SW6	TX	Swisher	true	800	Unknown	1	1			false	1970-1979
41SW7	TX	Swisher	true	9000	Unknown	1	1			false	1970-1979
41TY106	TX	Terry	true	*	Unknown	1	15			false	1980-1989
LA50305	NM	Unknown	false	*	Unknown	3	15			false	2000-2010
41WK53	TX	Winkler	true	3600	Unknown	2	2			false	2000-2010

Site	State	County	Hot Rock Use	Site Size (m^2)	Component	No. of LTF†	HK (1) ††	HK (2) ††	HK (3) ††	Ceramics	Decade of Research
41WK60	TX	Winkler	true	2500	Unknown	3	2			false	2000-2010
41WK65	TX	Winkler	true	600	Unknown	2	5			false	2000-2010

† where number of LTF: 1 = unknown, 2 = 1 LTF, 3 = 2 to 5LTF, 4 = 6 to 10 LTF, 5 = 11 to 20 LTF, 6 = 21 to 30 LTF, 7 = 31 to 40 LTF, 8 = 41+ LTF

†† where HK: 1 = no feature, 2 = hot-rock cluster, 3 = dispersed hearth, 4 = dispersed hearth with hot-rocks, 5 = hearth, 6 = hearth with hot-rocks, 7 = ephemeral hearth, 8 = ephemeral hearth with hot-rocks, 9 = disturbed pit, 10 = disturbed pit with hot-rocks, 11 = fire basin, 12 = fire basin with hot-rocks, 13 = fire pit, 14 = fire pit with hot rocks, 15 = insufficient data to assign a type.

Spatial datasets excluded, for full complete site data refer to the Texas Archeological Sites Atlas Restricted Information Access database. Available from http://nueces.thc.state.tx.us/; or New Mexico Archeological Records Management Section. Available from http://potsuii.arms.state.nm.us/