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# Agate Basin Archaeology at Beacon Island, North Dakota

Edited by

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PCRG
PaleoCultural Research Group

**Agate Basin Archaeology at Beacon Island, North Dakota**

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# Abstract

Beacon Island (32MN234) is a multi-component archaeological site in present-day western North Dakota containing a well-preserved Agate Basin-age bison kill-butchery locality. Spread across the sloping sides of a shallow kettle basin, the Agate Basin component consists of the butchered remains of at least 29 *Bison antiquus*, along with projectile point fragments, other stone tools, and flaking debris. In 2002 and 2006, the State Historical Society of North Dakota and Paleocultural Research Group jointly carried out archaeological, geoarchaeological, and geophysical field investigations at the site. Archaeological excavation, which featured intensive piece-plotting of individual specimens combined with fine-mesh waterscreen sediment processing, ultimately exposed 121.5 sq. m of the Agate Basin occupation area.

The occupation occurred early in a period of relative landscape stability marked by a well-developed paleosol, known regionally as the Leonard, that formed during the Younger-Dryas stadial. Multiple independent lines of evidence indicate that the kettle basin intermittently held water during and after Agate Basin times, supporting a locally boggy or marshy microenvironment. Outside the basin, the local plant community at the time of the occupation was a mesic, cool-season ($C_3$) grassland, punctuated by stands of shrubby vegetation, perhaps including dwarf birch.

The bonebed at Beacon Island is the most precisely dated Agate Basin component. Four radiocarbon assays, two on bone and two on charcoal, produced statistically equivalent ages with a weighted mean age of 10,326±28 $^{14}$C yr B.P. Stratigraphic, faunal, and other data indicate that the excavated remains represent a single, short term occupation that occurred during early-to-mid winter. The bonebed was subsequently buried rapidly, preserving spatially discrete activity areas.

The Beacon Island hunters thoroughly butchered the majority of the bison brought down in the kill, preparing both forelimbs and hindlimbs for transport to a secondary processing locality or camp, and breaking open long bones to extract marrow. They also recovered and refurbished serviceable point fragments, only leaving behind segments deemed unsuitable for further use as weaponry or fragments lost in minimally butchered carcasses. The notable lack of stone tools not directly related to hunting and butchery indicates that the hunters focused their efforts narrowly on carcass processing and weaponry rejuvenation. Combined with the fact that the occupation was brief, these stone tool data point to a logistical, rather than residential, mobility strategy.

The raw materials the hunters used to produce stone tools reflect both their intimate familiarity with the local landscape as well as their limited interactions with Agate Basin groups living farther south and west. Apart from two pieces of flaking debris from a distant source, all of the toolstone in the assemblage occurs within about 90 km of the site. High-quality Knife River Flint, the most abundant material in the assemblage, is found in numerous localities within a one- or two-day walk.

Metric and other data on the Beacon Island projectile point assemblage, combined with similar data on specimens from other Agate Basin components, indicates that Agate Basin flintknappers produced weapons conforming to at least two different morphological modes. Most of the complete, unreworked Agate Basin points in the comparative sample exhibit a standardized length-to-width ratio of about 4.2, but vary greatly in size, from roughly 55 mm to 135 mm long. A smaller number of points, all of which come from the Agate Basin site located in eastern Wyoming, exhibit length-to-width ratios between 6.4 and more than 7.3 and therefore are much longer in relation to their width than the standard-ratio points. The existence of at least two Agate Basin original point morphologies suggests that there may also have been at least two distinct rejuvenation strategies. The more-common standard-ratio points likely were re-tipped, perhaps while still hafted, while broken segments of the longer megapoints were entirely re-worked into new weapons.

Accompanying the Agate Basin points in the Beacon Island assemblage is one that conforms to the technological characteristics of the Goshen point type. The co-occurrence of these types may denote interaction between contemporaneous, but culturally distinct, Paleoindian groups.

## Table of Contents

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## List of Figures

## List of Tables

## Acknowledgements

Two individual's vision and tenacity made this project possible. Together, Stanley A. Ahler, co-founder and long-time Research Director of Paleocultural Research Group (PCRG), and Fern E. Swenson, Director of the Archaeology and Historic Preservation Division and Deputy State Historic Preservation Officer of the State Historical Society of North Dakota (SHSND), immediately recognized Beacon Island's unparalleled significance and worked tirelessly over many years to design and fund the research effort needed to gather data from this critically threatened resource. Without their hard work and dedication the record of Agate Basin occupation at Beacon Island would have been lost.

The principal members of the research team are identified as contributors to this report and to previous reports (listed in appendix E). Just three of these people—Carl R. Falk, Jennie Lee, and George Crawford—were involved in the project from the beginning. Carl contributed to all phases of the effort, helping to design the research program and grant proposals, providing invaluable technical guidance on various aspects of the analysis, and writing sections of this report. His insights were particularly helpful in crafting the successful Save America's Treasures grant proposal that funded much of the work. Jennie made major contributions to the complex fieldwork in 2002 and 2006 and designed and supervised the faunal study that is the project's backbone. George is the only person who participated in every field session. He also prepared topographic and other maps of the site, analyzed portions of the modified stone assemblage, and wrote sections of five technical reports.

SHSND Research Archaeologist Tim Reed was a key member of the field crew in both 2002 and 2006. Dr. Fred Sellet, now at the University of Kansas, served as Field Director for the 2006 excavation program. Stance Hurst served as Assistant Field Director. Kimberley Spurr was Co-Principal Investigator along with Stan Ahler on the Beacon Island Remote Sensing Project, which Bob and Kay Nickel carried in 2006. Elgin Crows Breast, Three Affiliated Tribes (TAT) Cultural Preservation Officer, Calvin Grinnell, TAT Tribal Historian, and Amy Mossett, TAT Director of Tourism, provided invaluable assistance and support for the 2002 field effort. Elgin and Calvin also lent their support to subsequent phases of the project. Perry No Tears Brady served as TAT Monitor in 2006. A cumulative roster of all the people who participated in the field investigations is given in appendix F of this report.

Stacey Bennett, working for the SHSND in 2007-2008, coordinated the massive processing and sorting effort necessary before analysis of the September 2002 and 2006 collections could begin. She was assisted in this by a supremely dedicated cadre of volunteers that included Doug Wurtz, David Nix, Mary Diebel, Mikiel Ottmar, Brittney Babel, and William Woodworth. Later, working as PCRG's Lab Supervisor, Bennett supervised or carried out critical aspects of the laboratory analysis, including almost nine months spent analyzing the plotted bison remains recovered in September 2002 and 2006. Chris Johnston, PCRG's Lab Supervisor in 2010-2011, coordinated the final stages of collection sorting and quantification. He also analyzed portions of the flaking debris assemblage. Jacob Lueck, a University of Colorado undergraduate student produced many of the graphics that appear in this report. CU students Chris Gilson and Allison Reynolds ably assisted with collection processing and data entry at PCRG's Broomfield lab. Greg Harlin, working closely with the research team, created the superb illustration depicting the Agate Basin occupation at Beacon Island that appears on the cover of this report.

John Craig donated the use of his boat to ferry people and equipment between the island and the mainland during the May 2002 session. Kent and Connie Hjelmstad graciously allowed the very large 2006 field crew to camp on their property near the site. Jeff Stephenson and Dr. John Demboski at the Denver Museum of Nature and Science lent PCRG modern bison and antelope skeletons to assist with identification and coding of excavated specimens. Dr. Larry Todd provided invaluable assistance with the mandibular dentition analysis. Dr. Danny Walker generously arranged access to the University of Wyoming Department of Anthropology's comparative osteology collection for that analysis. Doug Wurtz assisted with the mollusk analysis. Eugene Gryba provided technical information to Stan Ahler on Agate Basin archaeology in Canada. Lee Bement contributed helpful suggestions on aspects of the faunal analyses. Phil Geib's remarkable abilities as field archaeologist proved crucial to the success of the 2002 fieldwork. Phil and Larry Todd also reviewed sections of the report and provided valuable editorial and substantive comments. PCRG member Dr. Craig Lee provided sage advice on multiple aspects of the analysis.

Initial and on-going funding for the work was provided by the SHSND through Historic Preservation Matching Grants awarded to PCRG (Project Nos. 38-01-16434-30 and 38-02-17654-27). The SHSND also contributed equipment, personnel, and technical expertise to the project. The project's single largest funding source was a Save America's Treasures grant awarded to the SHSND by the National Park Service (Grant No. 38-06-ML0449). Amy Munson, SHSND Grants and Contracts Officer, expertly administered multiple grants and agreements related to the project over the course of many years. The U.S. Army Corps of Engineers (USACE) also provided significant funding for portions of the fieldwork. Larry Janis and Julie Price, both Program Managers for Cultural Resources with the USACE Omaha District, and Becky Otto, USACE District Archaeologist, provided invaluable logistical and administrative support for the project. Bill Bicknell, Biologist with the U.S. Fish and Wildlife Service, was instrumental in coordinating access to the site. Funding for the stable isotope analyses and for AMS radiocarbon dating of sediment samples was provided by the Kansas Geological Survey.

# About the Contributors

**Stacey D. Bennett** is a graduate assistant at Eastern New Mexico University. She received her B.A. from Northern Arizona University in 2007. Currently, Stacey is conducting Master's thesis research at the Blackwater Draw National Landmark. Her archaeological fieldwork initially focused on Plains Village sites along the Missouri River in North Dakota under the direction of Dr. Stanley A. Ahler. She has participated in fieldwork in North Dakota, Nebraska, Arizona, Colorado, and New Mexico, primarily for non-profit and university-based research organizations. Stacey became a member and employee of Paleocultural Research Group in 2003 as a Northern Arizona University student. Her family and love of the ocean keep her tied to her native Florida, but her professional interests in Paleoindian archaeology, bison studies, and prehistoric yucca-fiber utilization keep her rooted in the west.

**George T. Crawford** is site archaeologist at Blackwater Draw National Landmark, Eastern New Mexico University. George received his B.A. (1988) and his M.A. (1994) in Anthropology from the University of Missouri. Much of his career has revolved around, somewhat accidentally, Paleoindian studies. George's professional fieldwork has included overseeing excavations and recording historic, Mississippian, Oneota, Great Oasis, Middle Missouri, Plains Village, Puebloan, Archaic, and Paleoindian sites. He has performed fieldwork in Missouri, Iowa, Illinois, North Dakota, Texas, New Mexico, Arizona, Utah, California, and in Great Britain, primarily for university-based research units. As an archaeologist, he is interested in preindustrial technology, quantitative analysis, cartography, and Geographic Information Systems (GIS) as tools for analyzing human behavior. The rest of George's time is spent replicating primitive technologies and studying the processes and strategies of pre-industrial lifeways in different environments.

**Carl R. Falk** is a consulting archaeologist. Formerly with the National Park Service's Midwest Archeological Center and the Department of Anthropology, University of Nebraska-Lincoln, Falk is a co-founder of Paleocultural Research Group. He has over 45 years of professional experience with a primary interest in the North American Great Plains and specialization in the archaeology and zooarchaeology of Late Prehistoric period village horticulturalists living within the Middle Missouri and Central Plains subareas. He has authored and co-authored numerous articles and technical reports, as well as papers presented at national and international conferences.

**Greg Harlin** is a partner with Wood Ronsaville Harlin, Inc., an Annapolis based illustration studio. His historical re-creation paintings have brought renewed life to archaeological discoveries from the earliest fossil records to turn-of-the-century America. His work has appeared in books, magazines, television and museums for clients that include National Geographic, the National Park Service, the Smithsonian, The Field Museum, The Frank H. McClung Museum, and The Frazier Historical Arms Museum. He has also illustrated five children's books: *We the People* by Lynne Cheney, *Hanukkah at Valley Forge*, *Dangerous Crossing*, and *Paul Revere's Midnight Ride* by Stephen Krenskey, and *Mississippi* by Dianne Seibert. His work has earned awards from The Society of Illustrators, Communication Arts, Spectrum, and American Illustration.

**Christopher M. Johnston** is a graduate student at Colorado State University. He received his B.A. in Anthropology from the University of Colorado in 2010. Chris started his career as a work-study student at Paleocultural Research Group in 2009. Since then he was worked for the Forest Service and for a CRM company. He also has continued working with new PCRG work-study students in the lab as well as assisting on many PCRG field projects. His research interests include the peopling of the Americas, Paleoindian lithic technology, and, more broadly, the archaeology and prehistory of Colorado and the Great Plains.

**Marvin Kay** is professor of Anthropology at the University of Arkansas-Fayetteville. He has a lifelong interest in the North American Plains and in primitive technology. He was a friend of the late Stanley A. Ahler, who first interested him in Beacon Island research.

**Jo Ann Kvamme** has been the Program Coordinator for the Environmental Dynamics Program at the University of Arkansas for nine years. She has worked on GIS projects and has been active in archaeological research throughout the West for nearly 25 years. For the past 14 years she has actively collected geophysical data at archaeological sites, particularly from electrical resistivity surveys.

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**Jennifer Borresen Lee** received a B.S. in Sociology/Anthropology from Montana State University in 1997 and a M.A. in Anthropology from the University of Tennessee, Knoxville in 2002. Her Master's thesis analyzes the bison remains recovered from the Frazier site, an Agate Basin-age site in northeastern Colorado. Lee is currently the lab manager and a project manager at Metcalf Archaeological Consultants, Inc. in Wheat Ridge, Colorado, where she has worked as an archaeologist for nearly 10 years. She has been a participating member of Paleocultural Research Group since 2000 and has been involved with the Beacon Island project since initial testing occurred in May 2002.

**Rolfe D. Mandel** is senior scientist and executive director of the Odyssey Geoarchaeological Research Program at the Kansas Geological Survey, and professor in the Department of Anthropology at the University of Kansas. He has spent over 30 years working with archaeologists on projects throughout the United States and eastern Mediterranean. Mandel is especially interested in soils and landscape evolution, and the effects of geologic processes on the archaeological record. From 1999-2004 he was Editor-in-Chief of *Geoarchaeology: An International Journal*, and his work has been published in a number of books and professional journals. The Geological Society of America has recognized his achievements with two prestigious awards: the George Rapp Award for outstanding contributions to the interdisciplinary field of archaeological geology, and the 2010 Kirk Bryan Award for Excellence.

**Mark D. Mitchell** is Research Director for Paleocultural Research Group. Previously, he worked for several cultural resource management firms and for the U. S. Forest Service in Colorado, Wyoming, and Kansas. Mitchell's research interests center on the archaeology of the Northern Plains, with an emphasis on the farming villages of the Middle Missouri. He also studies lithic and ceramic technology, geoarchaeology, American Indian art, and the history of archaeology. His research has appeared in *Plains Anthropologist, Antiquity, American Antiquity, Southwestern Lore*, *Colorado Archaeology,* and in a number of book chapters. He recently co-edited *Across A Great Divide: Continuity and Change in Native North American Societies, 1400-1900,* published by the University of Arizona Press (2010).

**Laura R. Murphy** is a doctoral student in Anthropology at the University of Kansas, and a graduate research assistant at the Kansas Geological Survey in Lawrence, Kansas. She specializes in geoarchaeology, and her research interests include Quaternary geology and pedology, stable isotope analyses, phytolith analysis, and micromorphology. Laura earned her Bachelor's degree from The Ohio State University and her Master's degree from the University of Kansas.

**Paul R. Picha** is chief archaeologist for the State Historical Society of North Dakota (SHSND). He has been an archaeologist with the SHSND since 1994. The past 17 years Picha has been involved with collaborative archaeological investigations at Menoken, Huff, Fort Clark, and Double Ditch State Historic Sites in North Dakota. His research for the last two decades has focused on prehistoric and historical archaeology of the northern Great Plains and on the history of early exploration and historical cartography. Other interdisciplinary research interests include reporting molluscan remains from archaeological sites. Picha has a M.A. (Anthropology, 1996) from the University of Missouri-Columbia and a B.A. (Anthropology, 1978) from Hamline University, St. Paul.

**Holmes A. Semken, Jr.** is a retired professor of Geology at the University of Iowa who specializes in Quaternary vertebrate paleontology. He is primarily interested in the paleoecology, biogeography, taphonomy and zooarchaeology of rodents and insectivores from late Pleistocene and Holocene deposits. Archaeological sites from the northern Great Plains and cave faunas of eastern North America have been his primary focus but he completed excavation of partial skeletons of four giant ground sloths from southwest Iowa in 2009. This rekindled his interest in the impact of megamammals on the environment and vice versa.

# 1

## Project Overview

*Mark D. Mitchell*

Though first defined more than 50 years ago (Roberts 1961; Wheeler 1954), the Agate Basin complex remains today among the least well understood Paleoindian technocomplexes. Surface finds of Agate Basin points are comparatively rare, particularly relative to Folsom points, which date very nearly to the same time period (Stanford 1999). Just a handful of Agate Basin components have been excavated, all of them scattered along the far western margin of the Plains (figure 1.1) (Kornfeld et al. 2010; Stanford 1999). Among these excavated components, only the work in Area 2 at the Agate Basin site has been described in detail (Frison and Stanford, eds. 1982). Interpretations of several excavated collections are complicated by the presence of multiple Paleoindian occupations (Frison 1984; Haynes and Agogino 1966; Sellet 2001). Recent analyses of curated faunal and chipped stone assemblages from the Frazier, Hell Gap, and Agate Basin sites provide valuable new insights (Borresen 2002; Byers 2009; Hill 2008; Lee et al. 2011; Sellet 1999; Slessman 2004), but investigation of the newly discovered Beacon Island site (32MN234) offers a unique opportunity to better understand Agate Basin lifeways.

This report describes the results of a 10-year study of the Agate Basin occupation at Beacon Island. This chapter introduces the site and the project, and lays out the major research questions guiding the fieldwork and subsequent laboratory analyses.

### Site and Project Overview

Beacon Island is a multi-component site located near the confluence of the Missouri and Little Knife rivers in western North Dakota (figure 1.2). Covering roughly 0.9 ha (2.2 ac), the site preserves evidence of multiple Paleoindian through Late Prehistoric occupations. The site is arbitrarily partitioned into four non-contiguous sectors, designated Areas A, B, F, and T; artifacts and features also occur outside these defined areas. Area A, the focus of this report, contains the Agate Basin occupation, along with at least two sparse Holocene-age occupations. Data and interpretations on artifacts and faunal remains recovered from other areas of the site are provided by Ahler and Crawford (2003b), Ahler, Crawford, Lee, and Ritter (2003), Ahler, Frison, and McGonigal (2002), Crawford and Ahler (2003), and Haberman and Schneider (1975).

Fieldwork in Area A was carried out during nine sessions, including one in 2001, three in 2002, and five in 2006. The field investigation followed a phased approach, beginning with reconnaissance, evaluation, and testing, then proceeding to mitigation and, ultimately, data recovery. Reconnaissance in 2001 confirmed the potential importance of the site for Agate Basin research. Excavation in 2002 focused on recovering materials eroding from the edge of the exposed bonebed and on defining the extent of intact Agate Basin deposits. In 2006, block excavations were carried out in the densest part of the bonebed.

Field methods included sediment coring, controlled surface collection, geophysical surveys, hand excavation, and profile sampling. Excavation techniques were designed to provide a high-resolution record of the Agate Basin component and so emphasized intensive piece-plotting of individual specimens, coupled with fine-mesh waterscreen processing of virtually all excavated sediment. A total of 127.5 sq. m were opened up in Area A, all but 6 sq. m of which exposed Agate Basin-age deposits. Altogether, 52.8 cu. m of sediment were excavated and screened, including 38.8 cu. m assigned to the lithostratigraphic unit containing the Agate Basin component.

Many organizations and individuals contributed to the project. The investigation was a cooperative effort jointly managed by the State Historical Society of North Dakota (SHSND) and Paleocultural Research Group (PCRG), a member-supported, non-profit organization devoted to research and education in Plains archaeology. The SHSND provided institutional support and overall direction for the project. PCRG staff and research affiliates designed and supervised the field investigation and carried out the artifact and faunal studies.

Initial and on-going funding for the work was provided by the SHSND and the U.S. Army Corps of Engineers (USACE). The single largest funding source was a Save America's Treasures grant awarded to the SHSND by the National Park Service (Grant No. 38-06-ML0449). The fieldwork was carried out under the terms

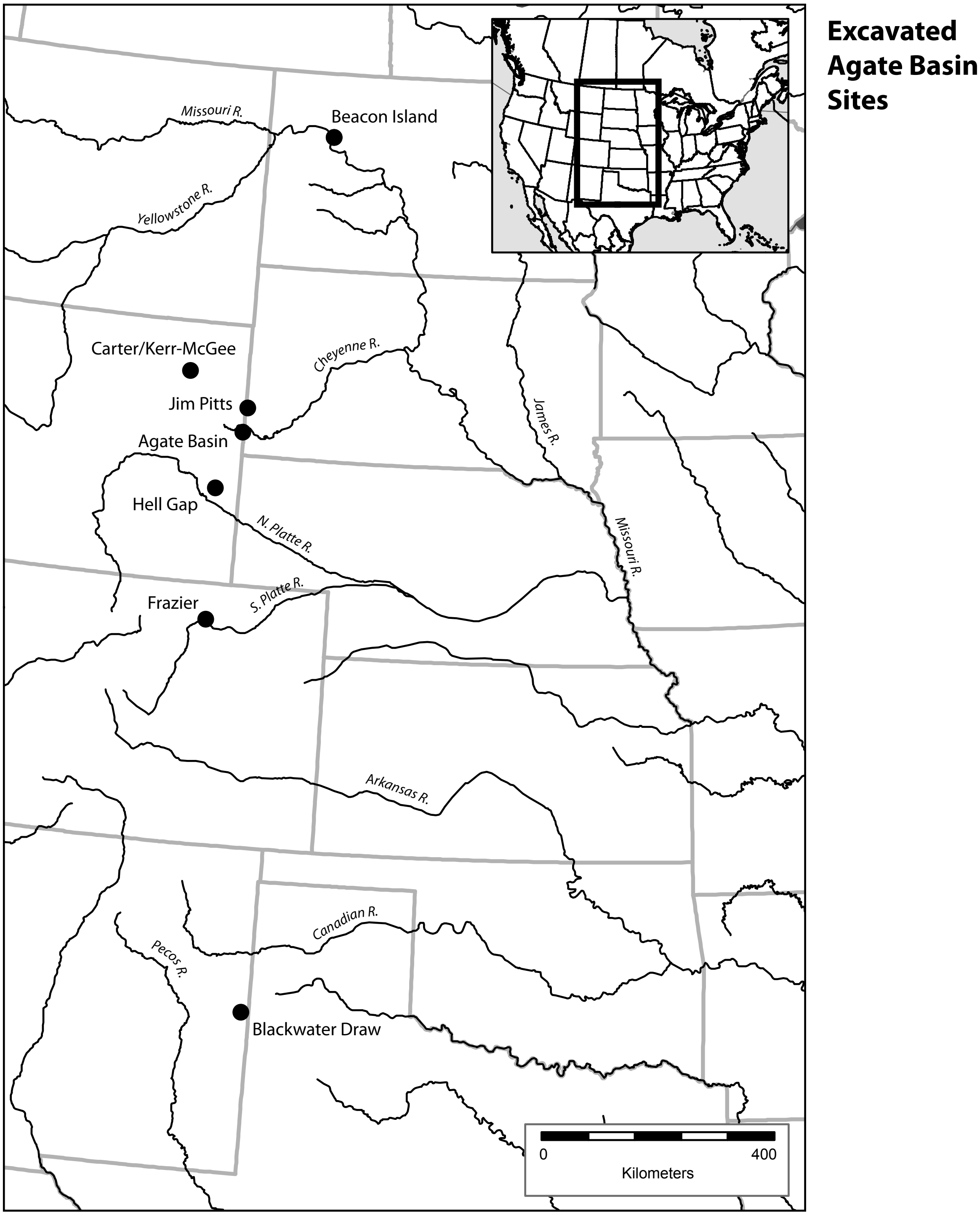


Figure 1.1. Map showing the locations of sites with excavated Agate Basin collections.

of three Archaeological Resources Protection Act permits issued to PCRG by the USACE (DACW45-3-01-6037, DACW45-3-05-6015, and DACW45-3-09-6082). The Tribal Business Council of the Three Affiliated Tribes (Mandan, Hidatsa, and Arikara Nation) also supported the project (Resolution No. 05-22-NH).

Numerous PCRG staff and volunteers, along with SHSND Historic Preservation Division staff, donated their time and talents to the project. Stanley A. Ahler, PCRG's long-time research director, was the driving force behind the project from the beginning. He developed the project research design (Ahler and Swenson 2005), secured

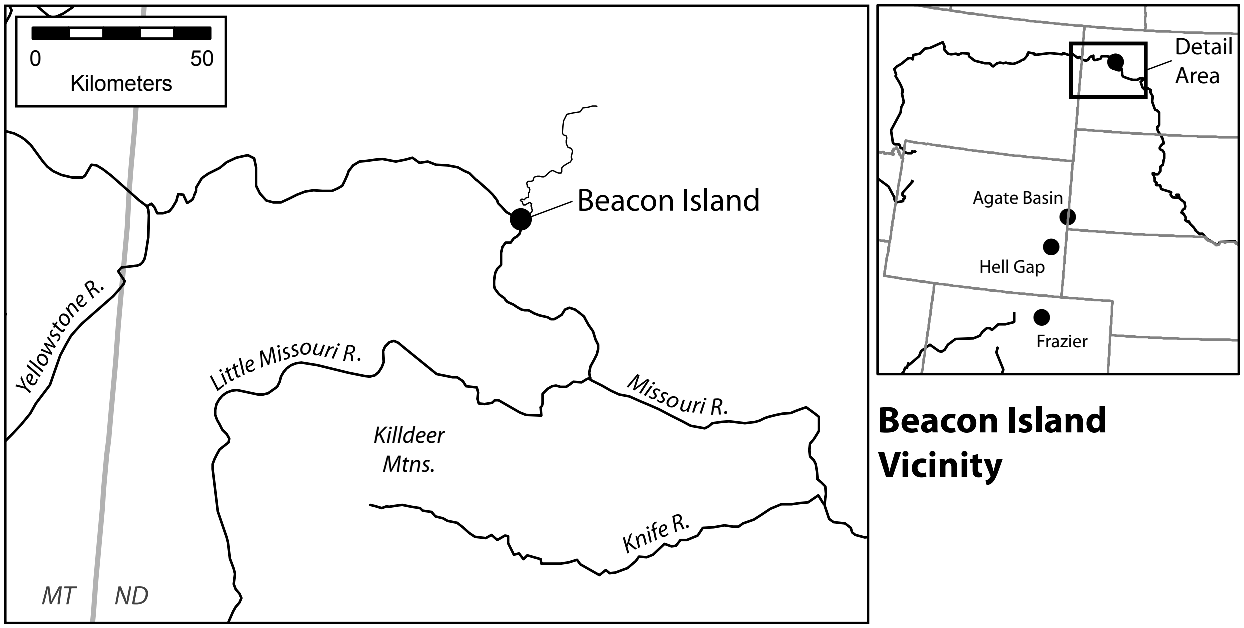


Figure 1.2. Map showing the location of the Beacon Island site in western North Dakota.

sources of funding, and directed the field investigation in 2002. Frédéric Sellet directed the fieldwork in 2006, with the assistance of Stance Hurst, George Crawford, Stacey Bennett, and Fern Swenson. Mark Mitchell took on the role of principal investigator in 2008, coordinating the analytic work and editing this report.

### A Brief Synopsis of Agate Basin Archaeology

Archaeologists' current understanding of the Agate Basin complex is based primarily on data from three excavated sites: Frazier and Agate Basin, both kill-butchery localities, and Hell Gap, a campsite.

Technologically, the Agate Basin complex is defined primarily by its distinctive weaponry: unstemmed lanceolate projectile points that exhibit parallel to convex blade margins, straight to convex bases, and thick, lenticular cross-sections (figure 1.3). Even the longest Agate Basin points are longitudinally flat and symmetrical and have very straight, even margins (Bradley 2009a, 2010). They were manufactured by initial percussion reduction on a biface, followed by extensive unpatterned comedial to transmedial pressure flaking. Final pressure retouch was selective and was invasive or abrupt (Bradley 2009a). Lateral grinding or polishing commonly extends along one- to two-thirds of an Agate Basin point's length.

Serial rejuvenation and re-use is a fundamental feature of Agate Basin weaponry technology. Indeed, Bradley (2009a:265) argues that Agate Basin points were designed with "a built-in capacity to sustain significant damage and breakage, with the resulting fragments being useful as projectile points with a minimum of reworking." Evidence of such reworking can be seen in all Agate Basin point assemblages. In fact, retrieval and rejuvenation of damaged weaponry was so common that only a small fraction of the documented population of nominally "complete" Agate Basin points retain their original size and form.

Other chipped stone artifacts associated with Agate Basin weaponry include large flake tools, side and end scrapers, gravers, notched tools, and non-weaponry bifaces, many of which exhibit an asymmetrical, bipointed outline form. A similar tool kit is associated with a number of other Paleoindian point types, including Folsom and Hell Gap (Stanford 1999:312). Stanford (1999:313) describes the lithic raw materials making up excavated Agate Basin assemblages as "highly extralocal." At the Frazier site, for instance, more than 13 percent of the combined tool and flaking debris assemblage is made from Alibates agatized dolomite that comes from quarries more than 500 km to the south (Slessman 2004). Non-local materials, including Knife River Flint from western North Dakota, are present in the Agate Basin assemblage (Frison and Stanford 1982a). However, local materials make up the majority of the flaked stone assemblages at both sites, including silicified wood and Morrison Formation quartzite at Frazier and Mississippian and Pennsylvanian cherts at Agate Basin. Virtually all of the lithic raw material used at Hell Gap comes from local sources (Larson 2009; Sellet 1999).

Groundstone tools are rare in Agate Basin assemblages. A sandstone shaft abrader was recovered

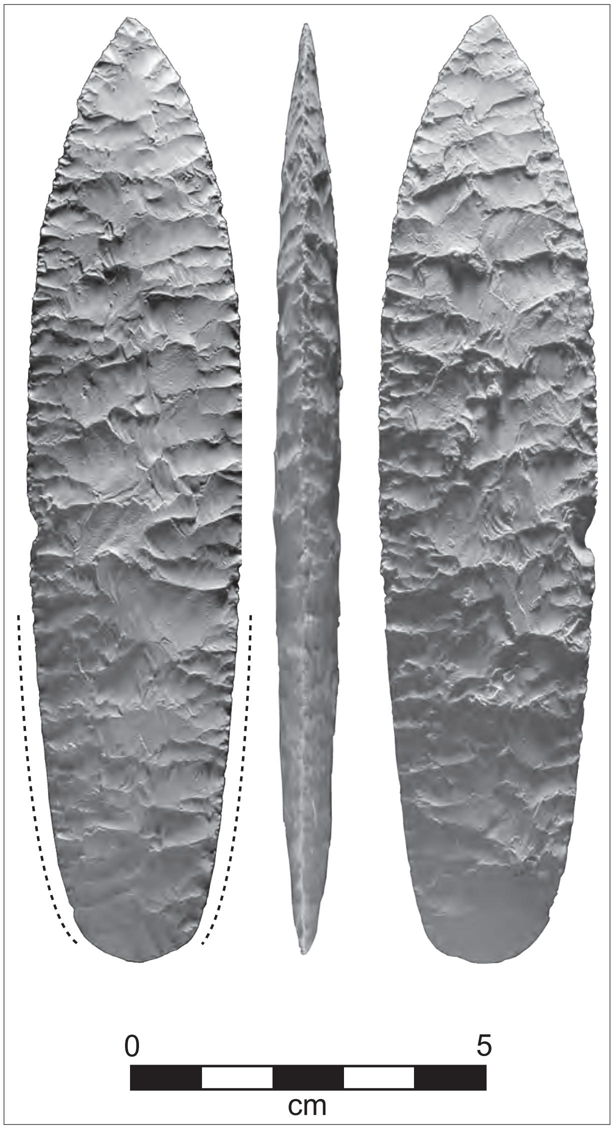


Figure 1.3. A complete, unmodified Agate Basin projectile point from Beacon Island. Dotted lines indicate the extent of lateral grinding. (Ahler 2003a:Figure 70 [BI4]).

from the Frazier site (Slessman 2004), and the Area 2 Agate Basin site assemblage includes three hammerstones (Frison and Stanford 1982a:123). Modified bone tools are equally rare. One expedient bone tool and several modified pieces of uncertain function come from Agate Basin contexts at the Agate Basin site (Frison and Craig 1982). Excavation in Agate Basin deposits at Hell Gap produced a bone needle and a bone awl (Irwin-Williams et al. 1973; Kornfeld and Larson 2009). Three possible expedient bone tools are present in the Frazier site assemblage (Borresen 2002:72-73).

The lack of functional diversity among excavated Agate Basin components limits interpretations of subsistence practices. Agate Basin, the best-known site, is a kill-butchery locality, as is the Frazier site. At both, Agate Basin hunters brought down a large number of animals, from which they extracted high-utility limb packages for transport to secondary processing localities. The archaeofauna from the Hell Gap site, a camp, is dominated by bison, though deer or pronghorn bones are also present (Byers 2009; Rapson and Niven 2009). Skeletal element frequencies indicate that bison limb packages similar to those removed from Agate Basin and Frazier were transported to Hell Gap. Utility indices and bone modification data suggest that the specific packages brought to Hell Gap were intended to maximize the production of marrow fat as well as meat (Byers 2002, 2009).

Irwin-Williams and others (1973) put the age of the Agate Basin complex between 10,500 and 10,000 $^{14}$C yr B.P. Stanford (1999) suggests a somewhat narrower range, from 10,500 to 10,250 $^{14}$C yr B.P. The Agate Basin components at the Agate Basin and Hell Gap sites occur immediately above Folsom components; the same relationship may also occur at Blackwater Draw (Haynes and Agogino 1966). Stanford (1999:312) argues that these stratigraphic data, along with the near contemporaneity of Folsom and Agate Basin radiocarbon ages, suggest that the Agate Basin and Folsom complexes (as well as the Goshen complex) may have been partly contemporaneous. Sellet and others (2009) advance a similar argument, using data from the Jim Pitts site in western South Dakota.

## The Agate Basin Site

Located roughly 10 km south of the Black Hills, the Agate Basin site preserves multiple Paleoindian kill-butchery occupations, including Folsom, Agate Basin, and Hell Gap (Frison and Stanford, eds. 1982). Agate Basin artifacts are present in several parts of the site (Agogino and Frankforter 1960; Frison 1982d; Roberts 1943, 1961), but the best-preserved and most thoroughly studied component occurs in Area 2, where it is separated from the underlying Folsom component by 20 to 30 cm of sterile sediment. The monograph describing the University of Wyoming's work in Area 2 remains the most comprehensive account of Agate Basin archaeology (Frison and Stanford, eds. 1982).

The Area 2 Agate Basin component contains the remains of at least 53 bison (Hill 2008), along with 191 tools or tool fragments and 1,478 pieces of flaking debris larger than 1/4 inch (Craig 1983:Appendices G, H, and M). The tool assemblage includes 76 points or point fragments. Metric data on a selection of comparatively complete points are presented in Bradley (1982:Table 3.9) and the locations of 62 specimens are mapped in Frison and Stanford (1982a:Figure 2.77).

Frison and Stanford (1982a) argue that the Agate Basin component represents a series of closely spaced kill events that occurred during the late winter or early spring. They also infer that the hunters stacked partially dismembered carcasses into one or two "meat piles" which subsequently froze (Frison and Stanford 1982a:79). Meat was extracted as needed from these piles over the course of the occupation.

Hill (2008) offers a different interpretation, using data from his analysis of the curated faunal collection combined with data on the stone tool assemblage. Hill argues that the Area 2 remains represent the kill location itself and, moreover, that the site represents a single kill event that took place in early- to mid-winter. He suggests that the hunters selectively removed for transport high-utility proximal limb elements, aiming to maximize the total nutrition of the transported packages. He also suggests that the many metapodials displaying green fractures were processed for their marrow, which the hunters consumed while dismembering carcasses. Thus, Hill (2008:59) argues that the Area 2 Agate Basin assemblage "points to a logistical hunting strategy in which a group of hunters searched for game to provision the consumer population occupying a nearby foraging hub."

Nothing is definitively known about the manner of the Area 2 kill. However, using data on modern bison behavior and on the ancient configuration of the Agate Basin arroyo, Frison (1982b; see also Kornfeld et al. 2010:226-232) suggests that Agate Basin hunters drove the target bison herd up the drainage, eventually trapping them between the steep walls of the arroyo at a natural headcut or constructed barrier.

Together, Frison and Stanford's (1982a) description of the excavated chipped stone assemblage from Area 2 and Bradley's (1982) technological study of projectile points, other chipped stone tools, and flaking debris constitute the first and still most comprehensive account of Agate Basin lithic technology. Their analyses identify the key steps and stages of Agate Basin point manufacturing. and document the characteristic use-life trajectories of Agate Basin weaponry. They also identify the range of activities associated with bison procurement at the site.

### The Hell Gap Site

The Hell Gap site is a stratified, multi-component campsite located in a sheltered valley in east-central Wyoming (Irwin-Williams et al. 1973; Larson et al., eds. 2009). A complete sequence of Paleoindian cultural complexes, apart from Clovis, is present at Hell Gap. Agate Basin is the best represented at the site, with Agate Basin points having been recovered from all four Paleoindian-age excavation localities.

An initial round of major fieldwork at Hell Gap, led by George Agogino, Cynthia Irwin-Williams, and Henry Irwin, took place between 1961 and 1966 (Knudson 2009), and over the last 20 years researchers from the University of Wyoming and elsewhere have continued and extended that work. A comprehensive account of Agate Basin archaeology at Hell Gap is not yet available; however, data and interpretations on aspects of Agate Basin lithic technology are discussed by Bradley (2009a), Hashizume (2009), Kornfeld (2009), Larson (2009), and Sellet (1999). Analyses of Agate Basin subsistence are provided by Byers (2002, 2009) and Rapson and Niven (2009). Other aspects of the Agate Basin record at Hell Gap are covered by Irwin-Williams and others (1973).

Byers's (2002, 2009) study of the Locality II archaeofauna indicates that complete or nearly-complete bison limbs were transported to the site from one or more kill localities. Patterns of bone modification indicate that a portion of the transported bones were processed on site for their marrow content. Rapson and Niven (2009:123, 130) make a similar argument for the Agate Basin archaeofauna from Locality I.

Sellet (1999) partitions the Agate Basin modified stone assemblage from Locality I into two lots, one from the Main block (Level 2) and one from the East block (Level 2e), based on their provenience and distinctive attributes. His minimum analytical nodule analysis of the stone tools and flaking debris making up these two aggregates indicates that the Level 2e assemblage represents intensive tool production in anticipation of future use, representing what he describes as a "gearing up strategy" (Sellet 1999:235). Tool production was less intensive in the Main block (Level 2), which Sellet (1999:238) argues represents a series of sequential but overlapping Agate Basin occupations. However, Rapson and Niven (2009:Figure 9.1) identify a bone refit between the Main block and the East block, suggesting that Level 2 and Level 2e may have been contemporaneous or nearly so (see also Larson 2009:234).

Bradley's (2009a:264-266) analysis of Agate Basin weaponry from Hell Gap builds on his earlier study of the Agate Basin site assemblage. He identifies three stages in the production of Agate Basin points. Initial regularization and shaping occurred during the early stage of production, while biface thinning occurred mostly during the middle stage. The proportions achieved during the middle stage were maintained during late-stage shaping. Finishing slightly reduced the points' width without reducing their thickness. Bradley (2009a:265) suggests this pattern indicates that the point's characteristically flat longitudinal cross-section was achieved during the middle production stage by "widely spaced, full-face and to some extent controlled overshot flaking."

Excavation in Hell Gap Locality II revealed the presence of two superimposed Agate Basin structures, each roughly 2 m in diameter (Irwin-Williams et al. 1973). The spatial relationships of the post molds defining them point either to structure remodeling during an extended occupation or to a closely timed re-occupation of the same landform.

### The Frazier Site

Frazier is the lone single-component Agate Basin site. Located in the South Platte River valley in northeastern Colorado, the site preserves the remains of a kill-butchery event where hunters brought down at least 44 bison and prepared complete limb elements for transport to a secondary processing site (Borresen 2002). H. Marie Wormington excavated the site between 1965 and 1967 but never completed analyses of the recovered artifacts and faunal remains. However, studies of the curated bison bone and modified stone assemblages recently have been completed (Borresen 2002; Slessman 2004).

Borresen's (2002) analysis of the Frazier bison remains indicate that the kill took place in the late winter or early spring. A variety of processes affected the composition of the archaeofauna, including density-mediated attrition and archaeological field methods. However, skeletal element profiles and utility indices show that Frazier, like Area 2 at the Agate Basin site, represents a kill-butchery locale, from which high-utility limb elements were selectively removed for transport. Unlike Agate Basin, at Frazier complete or near-complete limbs were processed for transport, including low-utility metacarpals. Given the differing seasons of occupation (early- to mid-winter at Agate Basin and late winter to early spring at Frazier), this difference may point to season-dependent variations in carcass use. The selective removal of metapodials at Frazier bolsters Byers's (2002) view that Agate Basin groups were not "fat-indifferent," but rather sought out within-bone nutrients.

A wide range of flaked stone tool types is present in the Frazier assemblage, including gravers, notched tools, end and side scrapers, and bifaces (Slessman 2004). Stone tool production focused on both early-stage reduction of local materials and late-stage reduction or maintenance of tools made from non-local materials. Non-local lithic resources in the assemblage include Alibates agatized dolomite, obtained from quarries in the Texas Panhandle, 500 km to the south. Hartville Uplift chert from east-central Wyoming some 220 km away is also well represented. By contrast, only about 2 percent of the assemblage is made from Flattop chalcedony, a high-quality toolstone that outcrops about 100 km away. However, other local materials dominate the flaking debris and stone tool assemblages. Minimum analytical nodule analysis, individual flake analysis, and technological analysis of the stone tool inventory lead Slessman (2004) to conclude that the Frazier site is best viewed as a logistical or short-term camp.

Function-specific activity areas are preserved at Frazier (Slessman 2004). Bison were killed and dismembered on the east side of the site. Additional carcass processing and other activities took place on the west side, adjacent to a large hearth feature. In this regard Frazier is similar to a number of other Late Paleoindian sites exhibiting well-defined site structure.

Newly obtained dates on curated charcoal indicate that the Frazier site occupation occurred between 10,200 and 10,100 $^{14}$C yr B.P. (Lee et al. 2011). Older dates on butchered bison bone likely reflect sample degradation and depleted-carbon contamination.

### Other Excavated Sites Yielding Agate Basin Points

Two Agate Basin points come from subsurface contexts at the Jim Pitts site located on the southern end of the Black Hills (Sellet et al. 2009). Both points occur in the Leonard Paleosol and are associated with radiocarbon dates averaging about 10,200 $^{14}$C yr B.P. Multiple Goshen points, along with a Folsom point and several other Paleoindian point types, were recovered from the same stratigraphic contexts.

Agate Basin points have been recovered from a variety of subsurface contexts at Blackwater Draw Locality No. 1. Agogino and Rovner (1969) suggest that an intact Agate Basin occupation may occur in a black humus layer above a set of lithostratigraphic units containing Folsom artifacts. Contemporaneous Agate Basin and Folsom occupations may also exist at the site (Haynes and Agogino 1966). However, Agate Basin points occur in mixed contexts as well (Haynes and Agogino 1966; Johnson and Holliday 1997). These Blackwater Draw assemblages are not precisely dated and some may post-date 10,000 $^{14}$C yr B.P.

A stratigraphically discrete occupation layer containing both Agate Basin and Hell Gap points occurs at the Carter/Kerr-McGee site in Wyoming's Powder River basin (Frison 1984). No date is available for this occupation, but it occurs above a Folsom occupation dated at 10,400 $^{14}$C yr B.P.

### Agate Basin-like Lanceolate Point Assemblages

Lanceolate points superficially similar to Agate Basin weaponry from Frazier, Hell Gap, and Agate Basin come from a number of excavated sites in the Plains and adjacent regions, including the Grant Lake site in Canada's Northwest Territories (Wright 1976), the Packard site in Oklahoma (Wyckoff 1985), the Cherokee

Sewer site in Iowa (Anderson and Semken 1980), the Lubbock Lake site in Texas (Knudson et al. 1998), the Allen site in Nebraska (Bamforth and Becker 2007), and several sites in the Bighorn Canyon on the Wyoming-Montana border (Husted 1969).

Substantial surface collections of Agate Basin-like points are reported from the Parkhill site in Saskatchewan (Ebell 1980), and the Silver Mound site (Hill 1994) and the Kreisel Cache (Carr and Boszhardt 2002) in Wisconsin. Fishel (1988) tallies surface finds of unstemmed lanceolate points from Wisconsin and Illinois. Benders (2010) analyzes surface finds from Alberta and Saskatchewan. Smaller surface collections are reported from many localities across northern and northeastern North America (e.g. Buchner and Pettipas 1990; Gryba 1976, 1977; Lepper 1999; Stanzeski 1996).

Stanford (1999) calls attention to the fact that most excavated "Agate Basin-like" assemblages appear to post-date 10,000 $^{14}$C yr B.P. and so may represent descendant groups or entirely unrelated technocomplexes. Unraveling the relationships, if any, between "classic" Agate Basin assemblages and these later lanceolate point assemblages requires detailed technological analyses (Frison and Stanford 1982b). For example, Stanford (1999) observes that the Packard site assemblage exhibits extensive modification and re-purposing of spent projectiles, a feature not especially prominent in classic Agate Basin assemblages. Similarly, Knudson and others (1998) show that attribute analysis of complete assemblages is crucial to identifying inter-assemblage relationships. Their examination of lanceloate points from the Lubbock Lake site reveals both similarities and differences with Agate Basin and Hell Gap points from Colorado and Wyoming. Technological analysis can also help distinguish among superficially similar, but historically unrelated, lanceolate types. For instance, Stewart (1991) shows that key attributes of early Holocene "Northern Plano" points from the Northwest Territories differ from those of morphologically similar, but more recent, points from the same region. Lepper (1999) makes the case that lanceolate forms continued to be produced in the American Midcontinent into Late Archaic times.

## Beacon Island Research Design Summary

The Beacon Island project is structured around six primary research domains: the site's landscape setting, the taphonomy, chronology, and content of the associated artifacts and faunal remains, and Agate Basin mobility strategies and cultural relationships (Ahler and Swenson 2005). In this section, each of these domains is further partitioned into a series of specific research questions. The datasets marshalled in the balance of the report to answer these questions are also identified.

### Site Setting and Paleoenvironment

Data bearing on the site's geomorphic and environmental setting, along with interpretations of local and regional ecological dynamics over time, provide a necessary backdrop for understanding the Agate Basin occupation at Beacon Island. What did the landscape look like at the time of the kill and how was the site situated relative to the features of that landscape? How did the environment experienced by Agate Basin hunters differ from earlier or later environments in the region? Stratigraphic data, discussed in chapter 3, in combination with data derived from the geoarchaeological study described in chapter 2, are used to establish the ancient topographic setting as well as the general characteristics of the local landscape. Data on sediment deposition and soil formation (chapter 2), micromammal remains (chapter 8), gastropods (chapter 9), and stable carbon isotopes and plant phytoliths (chapter 10) define the ecological context of the occupation at several different spatial and temporal scales.

### Site and Assemblage Taphonomy

What factors affected the Agate Basin-age deposits in Area A following the kill? How well do the deposits reflect the spatial structure of the activities occurring there? To what extent might artifacts deposited during later occupations be mixed with Agate Basin-age artifacts? An understanding of site formation processes is crucial for answering substantive questions about site function and spatial structure. Inferences about the rate of and processes responsible for post-occupation sediment accumulation (chapter 2), as well as data on stone tool conjoins, on the distribution of tools and flaking debris (chapter 6), and the condition of the bison remains (chapter 5), provide evidence about the integrity of the archaeological deposits investigated in Area A. Stratigraphic and other data obtained during the field investigation (chapter 3) are used to assess the potential for cross-component mixing. Stratigraphic data also provide evidence of the extent of both ancient and recent erosion.

### Chronology, Occupation Duration, and Site Seasonality

When was the site occupied? Do the deposits at Beacon Island reflect a single occupation, or multiple occupations occurring over some period of time? During what season was the kill made? The occupation is dated by radiocarbon assays on both bone and charcoal samples directly associated with the bonebed (appendix A). Pedological data, combined with radiocarbon assays on sediment overlying the bonebed, provide additional chronological evidence (chapter 2). Data on site stratigraphy and the vertical distributions of faunal remains and artifacts (chapter 3) are used to generate inferences on the number and duration of occupations represented by the deposits. These inferences are bolstered by data on lithic conjoins and refits and on the horizontal distributions of stone tools and flaking debris (chapter 6). Inferences about the season of the kill are supported by data on bison dentition eruption and wear patterns (chapter 5).

Archaeological Content, Site Function, and Activity Areas

What range of activities occurred in Area A and how were they spatially organized? Data on skeletal element frequencies (chapter 5) and on the condition and distribution of bison remains are used to determine whether the kill took place on- or off-site. These data also support inferences about butchery practices, transport decisions, and carcass processing intensity. Data on the stone tool and flaking debris assemblages (chapter 6) provide evidence on the range of activities occuring at the site as well as on aspects of Agate Basin lithic technology. The distributions of burned and unburned stone artifacts and faunal remains, along with the locations of hearth features (chapter 3), provide data on the spatial structure of these activities.

Agate Basin Mobility Patterns

The Agate Basin component in Area A offers only a snapshot of the behavior of an Agate Basin band that likely was on the move much of the time. Analysis of the raw materials they used to produce stone tools (chapter 6) provides clues about where they had been prior to their stop at Beacon Island and about their familiarity with the local and regional landscape. Studies of the stone tools (chapters 6 and 7) and flaking debris (chapter 6), offer evidence about how technological activities were organized relative to subsistence pursuits and other activities. Data on the bison remains (chapter 5) and stone tools and flaking debris (chapter 6) are used to support inferences on the composition of the group responsible for the Beacon Island kill.

Agate Basin Cultural Relationships

What evidence do the artifacts and faunal remains recovered from Beacon Island provide about the social or cultural relationships among Agate Basin bands, or between Agate Basin groups and other Paleoindian groups? Data bearing on this question come from studies of weaponry morphology, weaponry production technology, and raw material usage (chapter 6), as well as bison butchery practices (chapter 5).

## Organization of the Report

Chapters 2 through 11 present data and inferences needed to answer these questions. In chapter 2, Rolfe Mandel presents the results of his geoarchaeological study of Area A. Mark Mitchell describes excavation strategies and techniques and summarizes the results of the field investigation in chapter 3. Chapter 4 defines the analytic units used in the balance of the report to structure studies of artifacts, faunal remains, and other materials. It also describes the innovative geographic information system Kenneth and Jo Ann Kvamme developed to aid analysis and interpretation. In chapter 5, Jennifer Lee and others describe the results of their intensive analysis of more than 3,300 piece-plotted bison bones. Mark Mitchell and Christopher Johnston present the results of their technological analysis of the flaking debris and stone tool assemblages in chapter 6. In chapter 7, Marvin Kay discusses the results of his high-power use-wear study of a portion of the excavated weaponry collection.

Chapters 8, 9, and 10 present data on the ancient environment. In chapter 8, Carl Falk and Holmes Semken describe the results of their study of micromammal remains from Area A. Chapter 9 covers Paul Picha's study of Area A gastropod samples. In chapter 10, Laura Murphy and Rolfe Mandel present the results of their stable carbon isotope and plant phytolith studies.

Chapter 11 tallies a variety of rare artifact types, including ochre and bone beads, and briefly discusses other materials not subject to intensive analysis. The final chapter summarizes and discusses the major findings of each of these studies, organized according to the research domains and questions outlined here.

# 2

## Geoarchaeology of Area A

*Rolfe D. Mandel*

This chapter presents the results of a geoarchaeological study of Area A at the Beacon Island site. The investigation focused on the stratigraphy, sedimentology, paleopedology, and geochronology of the site. Previous investigations by Timpson and Ahler (2002) and Timpson (2003) were instrumental in describing the geomorphology of the Beacon Island site and placing the cultural deposits into a well-defined stratigraphic context. However, those studies were not designed to provide detailed information about the soils at the site. Descriptions of soil profiles (i.e., soil horizons) were not presented and no interpretations were made about soil-forming processes that may have affected the archaeological record at the site. Understanding the paleopedology of the site is especially important because the cultural deposits are associated with a buried paleosol. Also, defining the soil stratigraphy provides a basis for identifying cycles of sedimentation and landscape stability, which in turn is crucial for reconstructing the history of basin filling at the site. The present study not only details the paleopedolgy of Beacon Island, but it builds on the work of previous investigations by providing additional stratigraphic and sedimentological information along with new radiocarbon ages.

### Physiography

The Beacon Island site is in the Coteau du Missouri division of the Missouri Plateau. The Missouri Plateau is the largest subprovince of the Great Plains physiographic province (Fenneman 1931). The Coteau du Missouri, or "hills of the Missouri," is a glacial landscape characterized by gently rolling end moraines interspersed with kettle holes. This landscape formed during the Mankato substage of the Wisconsin glacial episode (Flint 1955), and runs roughly parallel to the Missouri River in a long diagonal belt through North Dakota.

The Coteau du Missouri is separated from the main part of the Missouri Plateau by the Missouri River trench. The term "trench" is more appropriate than "valley" because the cut made by the river into the plateau is deep, generally narrow, and very steep. The bluffs range in height from 100 m to more than 150 m above the trench floor. The Missouri River trench is considered a product of glacial meltwater cutting into the soft bedrock (Flint 1955).

Zones of closely spaced, steep-sided ravines descending into the Missouri River trench commonly are referred to as "the breaks." These ravines or draws often extend several kilometers back into the adjacent plateau.

### Geomorphology and Geology

Beacon Island is a remnant of a high strath terrace of the Missouri River that was cut into bedrock. This terrace forms the interfluve between the Missouri River and the Little Knife River located about 1 km southeast of the site (Ahler, Timpson, and Crawford 2003:20). Quaternary deposits at Beacon Island mantle the Paleocene-age Sentinel Butte Formation, a bedrock unit generally consisting of poorly lithified siltstones, claystones, and mudstones with subordinate amounts of lignite and fine-grained sandstones (Clayton, Moran, and Bluemle 1980). Outcrops of the Sentinel Butte Formation are common in the area around the island. Also, ice-thrust blocks of intact Sentinel Butte rocks were identified at multiple locations along the exposed face of the hill that forms the highest ground in the southwestern part of the island (Ahler, Timpson, and Crawford 2003:21).

The oldest Quaternary deposits at Beacon Island consist of late-Wisconsinan glacial drift. According to Clayton (1972), the terminal edge of the Wisconsinan ice front was in the area of Beacon Island around 16,000-15,000 B.P., and he named the glacial deposits associated with this ice front the Lostwood Drift. Clayton suggested that an insulating blanket provided by supraglacial sediment delayed the final melt-out of the Lostwood ice until 9000-8000 B.P. However, based on the sedimentological evidence, ice was not present at Beacon Island during the early Holocene.

At Beacon Island, the Lostwood Drift consists of pebbly to cobbly matrix-supported till that has been modified by soil development. The prominent hill on the island is mostly comprised of a thick deposit of glacial till that has not yet been removed by lake erosion. Elsewhere on the island, a thinner deposit of till of the same age occurs. Erosion of the till by fluctuations of Lake Sakakawea has produced prominent boulder lag deposits, especially along the shore of the island (figure 2.1).

Before the creation of Lake Sakakawea, it is likely that everywhere on Beacon Island silty eolian deposits mantled the glacial till. These eolian deposits comprise the Oahe Formation, a formal lithostratigraphic unit named by Clayton (1972) and described and defined by Bickley (1972) and Clayton and others (1976). The Oahe Formation was originally defined to include only sediment that contains a large proportion of silt and little or no sand or gravel. This material was considered to be largely eolian sediment deposited on uplands and high alluvial terraces during late-Wisconsinan and Holocene times. Clayton and others (1976) subdivided the Oahe Formation into four members: the Mallard Island, Aggie Brown, Pick City, and Riverdale. Buried soils developed in the Aggie Brown and Riverdale members were informally named the Leonard and Thompson paleosols, respectively.

Although members of the Oahe Formation were defined on the basis of color, Clayton and others (1976) suggest that sediments composing these deposits were emplaced on the landscape during specific periods. They propose the following chronology for the members: Mallard Island (ca. 13,000-10,000 B.P.), Aggie Brown (ca. 10,000-8000 B.P.), Pick City (ca. 8000-5000 B.P.), and Riverdale (5000 B.P.-modern). However, this chronology is not based on actual radiocarbon ages determined on materials from the deposits. Instead, lacking adequate data for numerical dating, Clayton and others (1976) propose a simple model of hill-slope response to climatic change to correlate Oahe Formation members with numerically dated late-Quaternary climatic episodes (figure 2.2). According to this model, soils formed during relatively moist climatic episodes, when hillslopes and bluffs were stable because of adequate vegetative cover. During intervening dry periods, vegetative cover was reduced on uplands, resulting in landscape instability and hillslope erosion. Dry periods also experienced frequent dust storms and deposition of eolian sediments on the bluffs. Clayton and others (1976) suggested that the Aggie Brown Member and associated Leonard Paleosol formed during the cool, moist climates of the terminal Wisconsin and early Holocene, and that the Pick City Member dates to the warm, dry middle Holocene. The Riverdale Member and associated buried soils are considered products of relatively dry and moist late Holocene episodes, respectively.

The chronology originally proposed by Clayton and others (1976) for the Oahe Formation is generally accurate. However, archaeological studies such as at Beacon Island continue to refine it. Also, some aspects of Clayton's climatic model have proven to be difficult to confirm (Artz 1995, 2000). For example, Coogan (1983, 1987) determined that the entire package of sediments comprising the Oahe Formation is rarely preserved at any one locality because the Holocene geomorphic record

Figure 2.1. Erosion of glacial till has produced prominent boulder lag deposits on the shore of Beacon Island. View to the west.

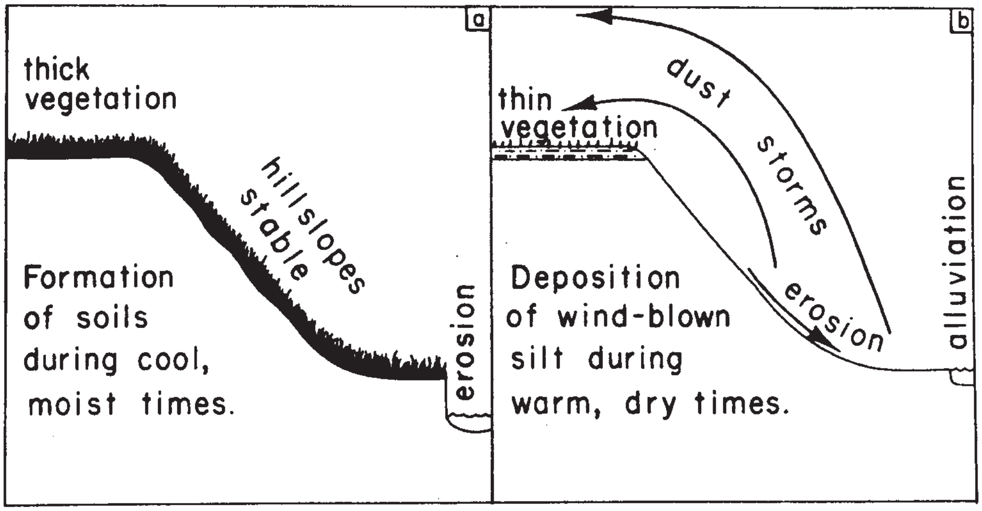


Figure 2.2. The simple model of hill-slope response to climatic change proposed by Clayton and others (1976).

on uplands adjacent to the Missouri River Trench is primarily erosional, not depositional. In fact, the eolian record at many localities in the Dakotas appears to be entirely late Holocene in age (Artz 2000). Also, evidence confirming the paleoclimatic implications suggested by Clayton and his coworkers has been elusive (Barnosky et al. 1987). Nevertheless, the Oahe Formation model continues to be used to interpret the natural stratigraphy of archaeological sites and to estimate their relative ages.

In 1979, the Oahe Formation was expanded to include all sediments above the late-Wisconsinan Coleharbor Group (Clayton and Moran 1979). As such, the formation is no longer restricted to eolian silt (loess) such as that found at the type section; it includes clay, silt, sand and gravel. Clayton and others (1980) recognize three lithogenetic subdivisions of the Oahe Formation: (1) eolian, (2) paludal/lacustrine, and (3) alluvial. At Beacon Island, the Oahe Formation includes eolian, colluvial, and paludal lithofacies.

Archaeological and geoarchaeological investigations at Beacon Island have focused on the Aggie Brown Member, which is represented by the thick, organic-rich cumulic A horizon of the Leonard Paleosol. The Agate Basin cultural deposits mostly are located in the lower 10-15 cm of the Aggie Brown Member, though they also extend into a “mixing zone” below the Aggie Brown and continue into the upper 10 cm of the underlying Mallard Island Member.

## Methods

### Field Methods

The first phase of the field investigation involved a reconnaissance survey. At this early stage of the study, landforms previously identified on topographic maps and aerial photographs were field checked. Following the reconnaissance, three profiles in Area A were selected for study and sampling (figure 2.3). Detailed descriptions of the three soil profiles were made in the field using standard procedures and terminology outlined by Birkeland (1999) and Scheoneberger and others (2002). However, in Profile 3, where more than one buried soil is present, the horizon nomenclature presented by Holliday (2004:339) was used. Specifically, the buried soils were numbered consecutively from the top of the profile downward, with the number following the suffix “b.” Stages of carbonate morphology were defined according to the classification scheme of Birkeland (1999:Table A-4).

### Laboratory Methods

Physical and chemical analyses were performed to characterize and confirm field descriptions of stratigraphic units and soils and to assist in interpretation of depositional processes and post-depositional weathering. Standard USDA procedures (Soil Survey Staff 1982) were used to collect bulk soil samples weighing approximately 1 kg from each of the three geo-profiles.

Bulk soil samples from the profiles were air dried at the Kansas Geological Survey and mechanically split into equal halves. One split of samples was decalcified with 0.5 N HCL and submitted to the University of Kansas W. M. Keck Paleoenvironmental and Environmental Stable Isotope Laboratory to determine organic carbon (C) content. Those samples were analyzed on a Costech ECS 4010 Elemental Analyzer in conjunction with a series of atropine standards (Costech Code 031042) of known

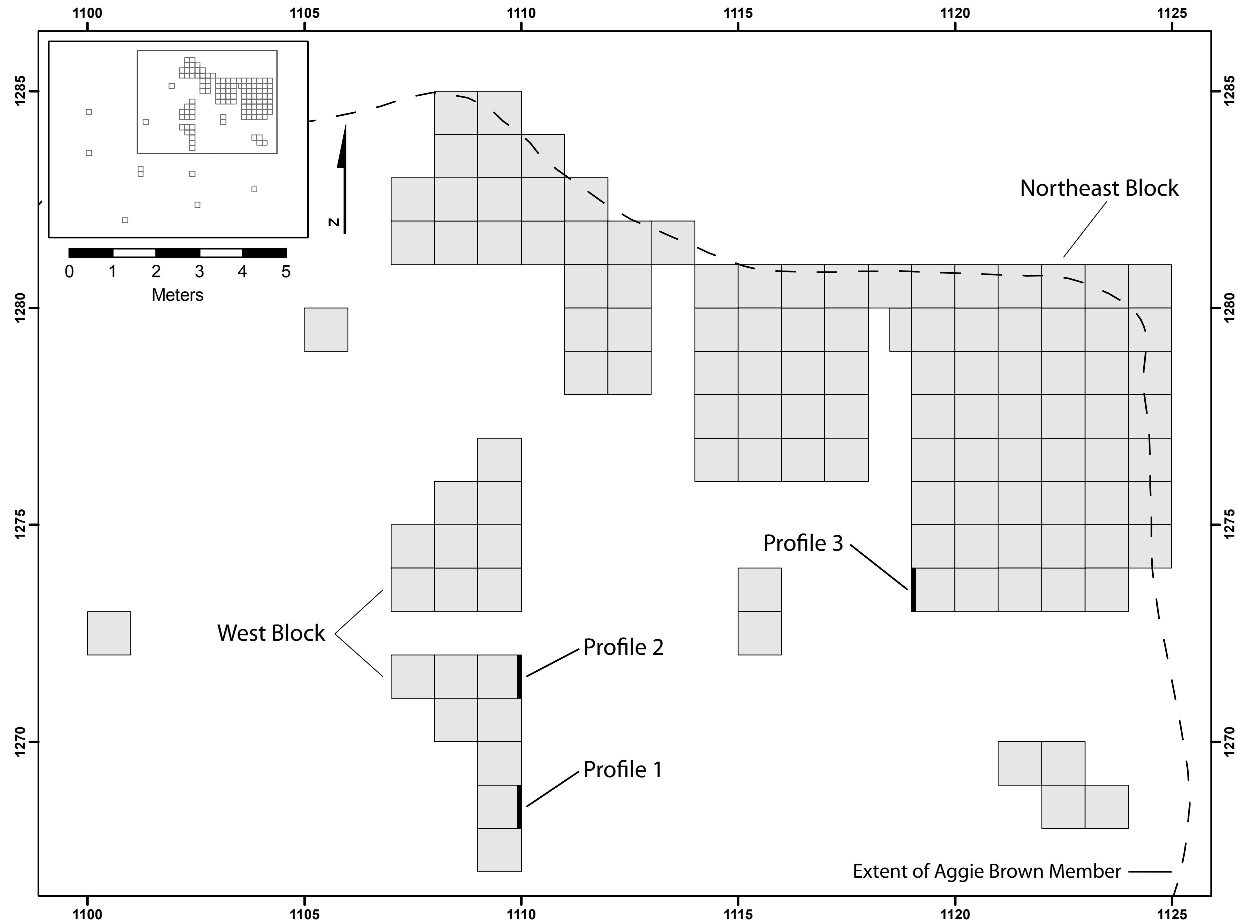


Figure 2.3. Map showing the locations of Profiles 1, 2 and 3 in Area A (see chapter 3 for additional information on excavation block layout).

percent C. From the analyzed standards, the Costech EAS32 software generates a calibration curve measuring area (Vs) versus weight (mg C). Knowing the carbon content of the standard and noting individual sample weights along with measured voltages, the software is then able to generate relative percent C content for each analyzed sample. Typical standard calibration $r^2$ values are better than 0.9998.

The grain-size distribution of the samples was determined using a slightly modified version of the pipette method (Gee and Bauder 1986). The samples were dispersed in a sodium hexametaphosphate solution and shaken on a reciprocal shaker overnight. Silt and clay aliquots were drawn from the appropriate pipette depth based on particle-size settling velocity, oven dried, and weighed to the nearest mg. Wet sieving recovered the sand fraction. The results, presented as weight percentages, total to 100 percent of the less-than-2-mm mineral fraction. Loess standards were used for inter-run comparisons of grain-size data.

Two bulk soil samples from the Leonard Paleosol developed in the Aggie Brown Member were submitted to the Illinois Geological Survey Isotope Geochemistry Laboratory for AMS radiocarbon dating. The samples underwent standard pretreatment, including removal of rootlets and calcium carbonate. Radiocarbon ages were determined on the total decalcified soil carbon at the Keck Carbon Cycle AMS Laboratory at the University of California at Irvine.

## Results of the Investigation

### Profiles 1 and 2

Profiles 1 and 2 in the west excavation block are representative of the soil stratigraphy observed near the deepest part of the kettle basin (figure 2.4) (see chapter 3 for data on the ancient topography of Area A). Profile 1 is slightly south of the center of the basin compared to Profile 2. The bison bone bed is not as dense in the area of Profiles 1 and 2 compared to the Profile 3, which is located near the base of the east slope of the basin.

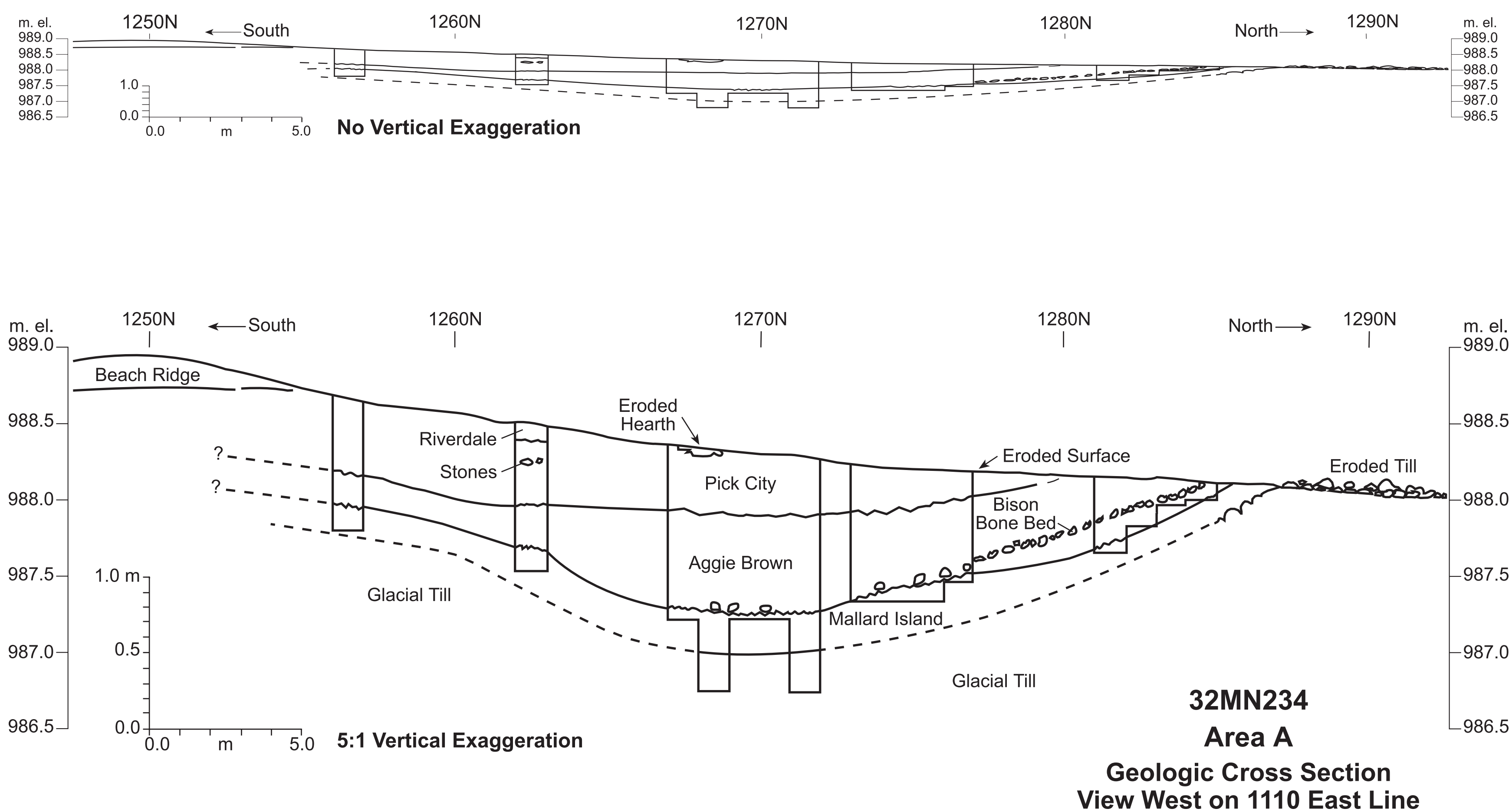


Figure 2.4. Geological cross-section of Area A.

In Profile 1 (figures 2.5 and 2.6), an 8-cm-thick veneer of modern lakebed sediment overlies the Pick City Member of the Oahe Formation (figure 2.7). The Pick City Member is 28 cm thick and consists of loess with a fairly homogenous silt loam texture (table 2.1). The surface soil is represented by a truncated light brownish gray (10YR 6/2-2.5Y 6/2, dry) Bk horizon with stage I carbonate morphology (table 2.2); the A horizon has been stripped off by the wave action of Lake Sakakawea. A clear, smooth boundary separates the Pick City Member from the underlying Aggie Brown Member.

The Aggie Brown Member is 71 cm thick in Profile 1 and is represented by a paleosol (Leonard) with an overthickened, cumulic A horizon (2Ak1b-2Ak7b) formed in silty paludal deposits (figure 2.6). Cumulic soils receive influxes of parent material while pedogenesis is occurring, but the rate of sedimentation is so slow that soil development keeps up with deposition (Nikiforoff 1949; Birkeland 1999:165). In such soils, the A horizon builds up through time, and it not unusual for the A horizon to look stratified. Because cumulic soils have parent material continuously added to their surfaces, their features are partly sedimentologic and partly pedogenic (Birkeland 1999:165).

Overthickened A horizons like the one developed in the Aggie Brown Member at Beacon Island are common in cumulic soils (Birkeland 1999:166). Organic enrichment of the paleosol is due either to deposition of organic-matter-rich sediment from upslope when the soil

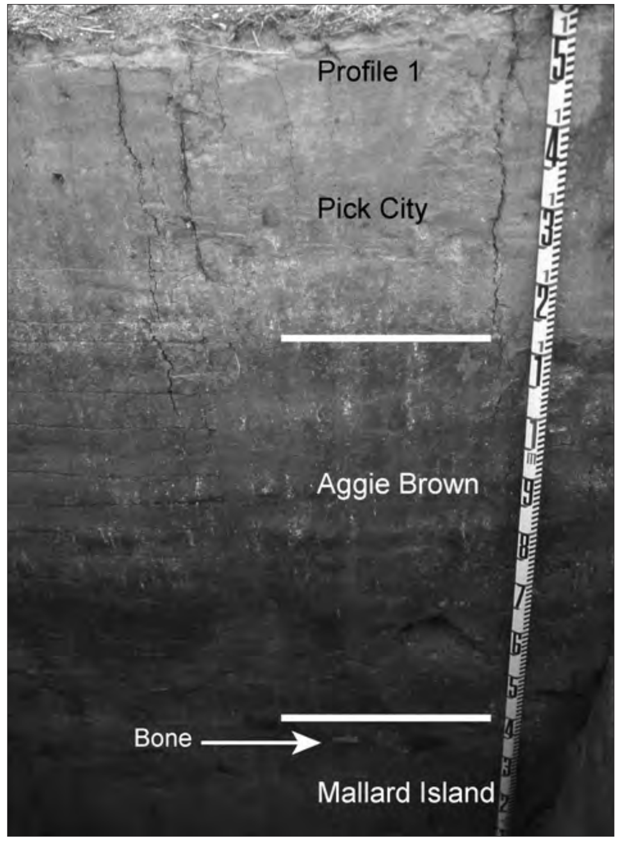


Figure 2.6. Close-up of Profile 1 showing three members of the Oahe Formation and bison bone associated with the Agate Basin cultural component.

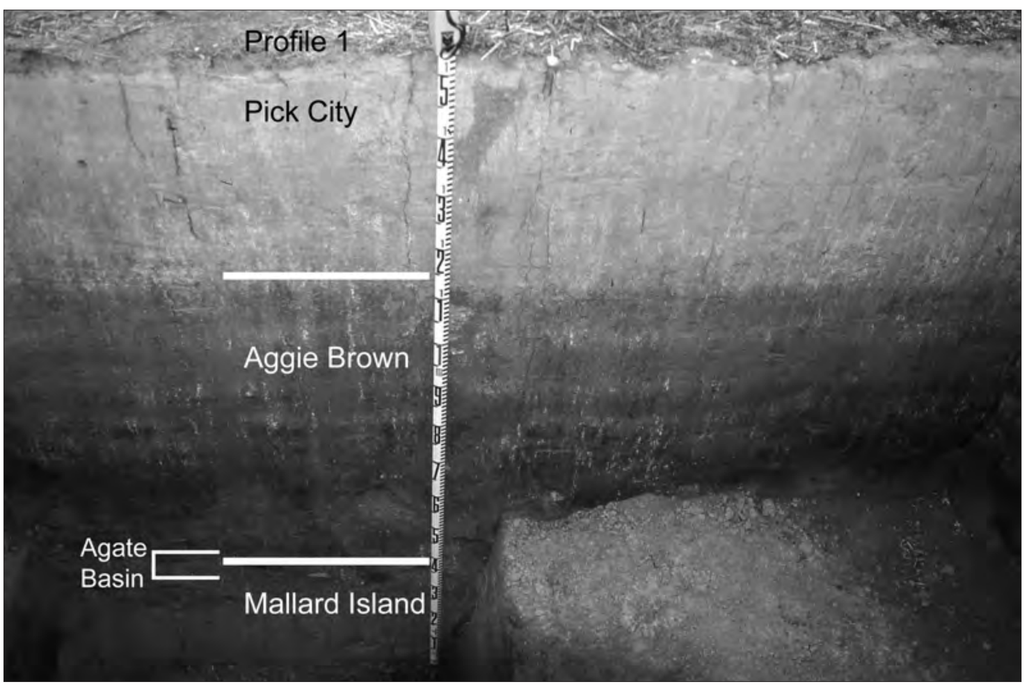


Figure 2.5. Profile 1 in Area A showing three members of the Oahe Formation and the stratigraphic position of the Agate Basin cultural component.

Table 2.1. Grain size[a] and organic carbon data for Profile 1, Area A.

| | | Sand | Silt | | | Clay | Textural | Organic |
|---|---|---|---|---|---|---|---|---|
| Soil Horizons | Depth (cm) | Total | C | F | Total | Total | Class[b] | Carbon (%) |
| Bk1 | 8-12 | **8.8** | 44.7 | 23.1 | **67.8** | **23.4** | SiL | 0.77 |
| | 12-17 | **11.1** | 39.4 | 25.0 | **64.4** | 24.5 | SiL | 0.80 |
| | 17-24 | **11.8** | 37.3 | 25.6 | **62.9** | **25.3** | SiL | 0.72 |
| Bk2 | 24-30 | **10.5** | 36.4 | 26.4 | **62.8** | **26.6** | SiL | 0.83 |
| | 30-36 | **11.7** | 35.5 | 26.1 | **61.6** | **26.8** | SiL | 0.79 |
| 2Ak1b | 36-41 | **6.6** | 29.2 | 34.9 | **64.1** | **29.2** | SiCL | 1.66 |
| | 41-47 | **6.8** | 31.0 | 39.0 | **70.0** | **23.3** | SiL | 1.81 |
| 2Ak2b | 47-54 | **7.4** | 35.2 | 39.1 | **74.3** | **18.3** | SiL | 1.41 |
| 2Ak3b | 54-58 | **12.0** | 37.5 | 37.7 | **75.2** | **12.8** | SiL | 2.22 |
| | 58-62 | **9.8** | 37.7 | 40.0 | **77.7** | **12.5** | SiL | 1.99 |
| 2Ak4b | 62-67 | **10.9** | 39.1 | 35.9 | **75.0** | **14.2** | SiL | 1.87 |
| 2Ak5b | 67-72 | **10.0** | 36.4 | 40.1 | **76.5** | **13.4** | SiL | 2.18 |
| 2Ak6b | 72-77 | **5.6** | 31.0 | 48.5 | **79.5** | **14.9** | SiL | 2.18 |
| 2Ak7b | 77-82 | **4.6** | 30.3 | 47.8 | **78.1** | **17.3** | SiL | 2.00 |
| | 82-87 | **6.8** | 31.2 | 45.2 | 76.4 | **16.8** | SiL | 1.94 |
| | 87-92 | **13.0** | 35.5 | 38.2 | **73.7** | **13.4** | SiL | 2.44 |
| | 92-97 | **12.1** | 37.3 | 34.9 | **72.2** | **15.7** | SiL | 1.96 |
| | 97-102 | **9.3** | 41.0 | 32.7 | **73.7** | **17.0** | SiL | 1.42 |
| 2ABkb | 102-107 | 10.0 | 42.4 | 24.9 | **67.3** | **22.7** | SiL | 0.89 |
| 3Bk1b | 107-112 | **13.0** | 44.8 | 19.6 | **64.4** | **22.7** | SiL | 0.45 |
| | 112-117 | **8.7** | 49.0 | 19.0 | **68.0** | **23.3** | SiL | 0.29 |
| | 117-122 | **11.2** | 48.5 | 18.1 | **66.6** | 22.2 | SiL | 0.37 |
| | 122-127 | **12.0** | 51.4 | 15.8 | **67.2** | **20.9** | SiL | 0.38 |
| | 127-131 | **13.1** | 46.7 | 17.6 | **64.3** | **22.6** | SiL | 0.43 |
| 3Bk2b | 131-136 | **20.3** | 36.4 | 19.6 | **56.0** | **23.7** | SiL | 0.35 |
| | 136-141 | **19.7** | 40.0 | 17.8 | **57.8** | **22.6** | SiL | 0.35 |
| | 141-146 | **18.6** | 46.0 | 15.3 | **61.3** | **20.0** | SiL | 0.28 |
| | 146-150 | **16.0** | 48.4 | 16.0 | **64.4** | **19.6** | SiL | 0.29 |

[a] Particle-size limits (mm): Sand (Total) = 2.0 - 0.05; Silt (Total)= 0.05 -0.002, Coarse (C) = 0.05 - 0.005, Fine (F) = 0.005 - 0.002; Clay (Total) = <0.002

[b] Textural classes: SiL= silt loam; SiCL= silty clay loam

was at the surface; to *in situ* organic-matter accumulation at the site while sediment was accumulating; or to a combination of both processes. The cumulative origin of the Leonard Paleosol is indicated by the highly irregular organic-carbon content with depth in the soil profile (figure 2.7 and table 2.1). In noncumulative soils, organic carbon steadily decreases with depth.

With the exception of the upper 5 cm of the 2Ak1b horizon, which is silty clay loam, the cumulic A horizon formed in the Aggie Brown Member has a silt loam texture (figure 2.7 and table 2.1). Fine silt tends to dominate over coarse silt through most of the Aggie Brown Member. This probably occurs because fine silt was more readily transported into the kettle pond by slopewash.

Secondary calcium carbonate accumulation is apparent throughout the A horizon of the Leonard Paleosol in Profile 1 (table 2.2), but carbonate morphology does not exceed stage I. Also, there are many biogenic features, especially worm casts and open insect burrows, and krotovina up to about 20 cm in diameter occur in the 2Ak4b and deeper soil horizons within the Leonard Paleosol.

Bison bones comprising the Agate Basin cultural component occur in the 2Ak7b horizon and upper 4 cm of the 2ABkb horizon. The 2Ak7b horizon is the deepest and most organically enriched portion of the cumulic A horizon, with organic carbon contents ranging between 2.44 and 1.42 percent (figure 2.7 and table 2.1). These high values may be due to the cultural deposits (i.e., bison remains, charcoal, etc.), but A-horizon material derived from upslope, and detrital organic matter that accumulated on the floor of the kettle pond also may have enriched the 2Ak7b horizon.

Organic carbon content declines to 0.89 percent in the 2ABkb, a transitional horizon between the cumulic A horizon of the Leonard Paleosol and the 3Bk1b horizon

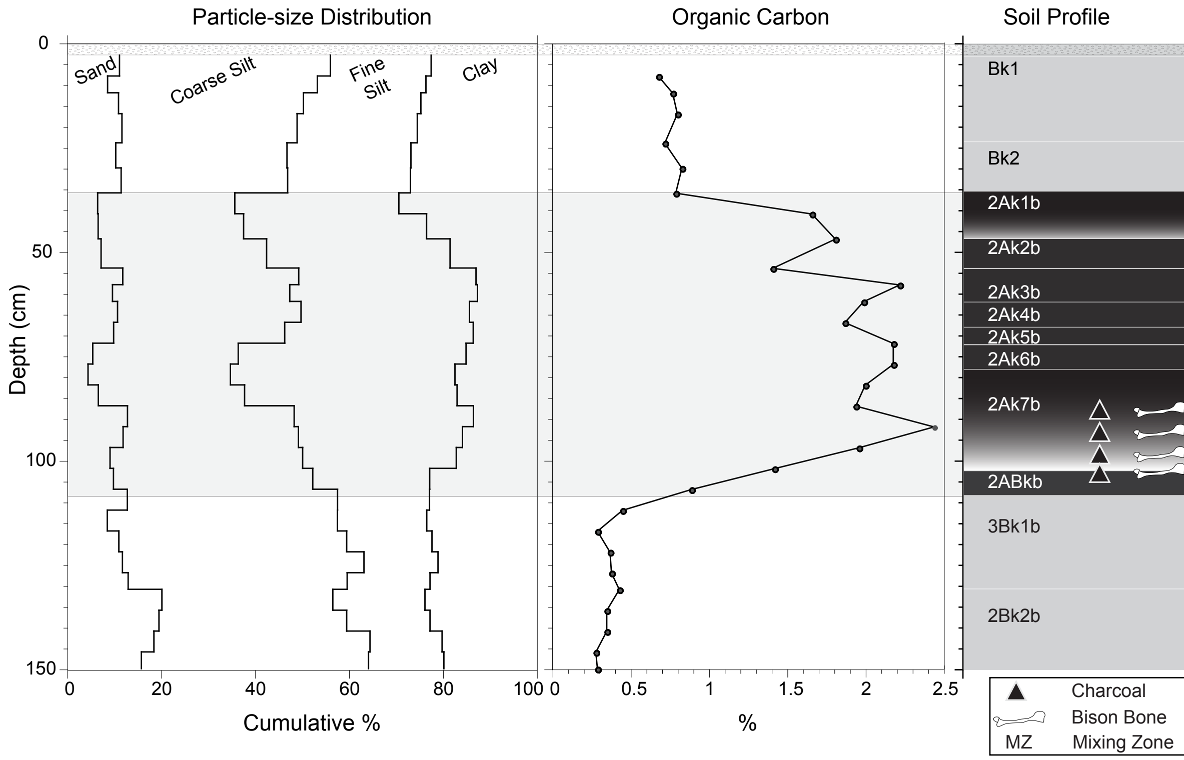


Figure 2.7. Diagram showing particle-size distribution and organic carbon content of samples collected from Profile 1. The stratigraphy, soil horizonation, and distribution of cultural deposits in Profile 1 also are shown.

developed in the Mallard Island Member. In this report the 2ABkb horizon is referred to as a "mixing zone" because bioturbation and other pedogenic processes have erased an abrupt or clear boundary that may have existed between the Aggie Brown and Mallard Island members. Within the "mixing zone," paludal deposits comprising the Aggie Brown Member grade into the underlying loess comprising the Mallard Island Member; there is no distinct boundary separating the two different parent materials. Also, bison bones associated with the Agate Basin cultural component occur in the "mixing zone" and may have been displaced downward from the 2Ak7b horizon through bioturbation, including trampling by bison. There are many biogenic features in the 2ABkb horizon, including krotovina that are up to 20 cm in diameter.

The Mallard Island Member is at a depth of 107-150+ cm below the surface and is comprised of pedogenically modified loess. The Mallard Island Member has lower organic carbon content and tends to be sandier compared to the other stratigraphic units in Profile 1 (figure 2.7 and table 2.1). The 3Bk1b and 3Bk2b horizons developed in the Mallard Island consist of light olive brown (2.5YR 5/3-5/4, dry) silt loam with stage I carbonate morphology. These horizons appear to be genetically related to the Leonard Paleosol, so for now only one buried soil was identified in Profile 1. Additional research, including micromorphological analysis, is needed to determine whether a truncated paleosol is present at the top of the Mallard Island Member.

The soil stratigraphy recorded in Profile 2 is identical to the soil stratigraphy observed in Profile 1. In Profile 2, a thin veneer of modern lakebed sediment overlies the Pick City Member, which in turn mantles the Aggie Brown Member, and the Mallard Island Member comprises the lower 45 cm of the profile (figures 2.8 and 2.9). There is some internal variability, however, within the cumulic A horizon of the Leonard Paleosol formed in the Aggie Brown Member. Specifically, five horizons compose the cumulic A horizon (2Ak1b-2Ak5b) in Profile 2 (table 2.3), whereas seven horizons compose the cumulic A horizon (2Ak1b-2Ak7b) in Profile 1.

Like Profile 1, bison bones were found at the bottom of the cumulic A horizon of the Leonard Paleosol (the lower 5 cm of the 2Ak5b) and in the 2ABkb horizon. Also, a small concentration of bone fragments was recorded in the upper 8 cm of the 3Bk1b horizon developed in the Mallard Island Member, but the fragments appear to be in a krotovina.

The grain-size and organic-carbon data for Profile 2 are remarkably similar to the data for Profile 1 (figure 2.9 and table 2.4). For example, the Pick City Member

Table 2.2. Description of Profile 1, Area A, Beacon Island site.

| Depth (cm) | Soil Horizon | Description |
|---|---|---|
| 0-8 | - - | Modern lakebed sand. |
| | | **Pick City Member** |
| 3-24 | Bk1 | Light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist, weak fine prismatic structure parting to weak fine subangular blocky; hard, friable; common films and threads of calcium carbonate; common worm casts; common open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 24-36 | Bk2 | Light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist, moderate medium and fine prismatic structure parting to weak fine subangular blocky; hard, friable; many films and threads of calcium carbonate; common worm casts; common open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| | | **Aggie Brown Member** |
| 36-47 | 2Ak1b | Gray (10YR 5/1) silt loam, very dark gray (10YR 3/1) moist; weak fine prismatic structure parting to weak medium and fine granular; hard, friable; many films and threads of calcium carbonate; many worm casts; many open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 47-54 | 2Ak2b | Grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure parting to weak fine granular; hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| 54-62 | 2Ak3b | Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; very weak fine prismatic structure parting to weak fine granular; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 62-67 | 2Ak4b | Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; few krotovina ≤ 20 cm in diameter; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| 67-72 | 2Ak5b | Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; very weak fine prismatic structure parting to weak fine granular; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; common open insect burrows; common krotovina ≤ 20 cm in diameter; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 72-77 | 2Ak6b | Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; few krotovina ≤ 20 cm in diameter; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| 77-102 | 2Ak7b | Very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; weak fine granular structure; slightly hard, friable; **common bison bone and flecks of charcoal throughout the horizon;** few films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common very fine and few fine and medium roots; many fine and very fine pores; gradual smooth boundary. |
| 102-107 | 2ABkb | Dark grayish brown (10YR 4/2) to brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) moist; common fine prominent strong brown (7.5YR 4/6) mottles; weak fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; **few bison bone and flecks of charcoal in the upper 4 cm of the horizon;** few films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common very fine and few fine and medium roots; many fine and very fine pores; gradual smooth boundary. |

Table 2.2. Description of Profile 1, Area A, Beacon Island site (continued).

| Depth (cm) | Soil Horizon | Description |
|---|---|---|
| | | **Mallard Island Member** |
| 107-131 | 3Bk1b | Light olive brown (2.5YR 5/3) silt loam, olive brown (2.5Y 4/3) moist; many fine distinct yellowish brown (10YR 5/6) and common fine prominent strong brown (7.5YR 46) mottles; weak medium and fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; few films and common threads of calcium carbonate; common worm casts; common open insect burrows; few krotovina ≤ 20 cm in diameter filled with dark gray (10YR 4/1) to very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; few very fine roots; common fine and many very fine pores; gradual smooth boundary. |
| 131-150 | 3Bk2b | Light olive brown (2.5YR 5/4) silt loam, olive brown (2.5Y 4/4) moist; many fine and medium distinct yellowish brown (10YR 5/6) and few fine prominent strong brown (7.5YR 46) mottles; common gray (10YR 6/1) and light gray (10YR 7/1) reduction zones along macro-pores; weak medium prismatic structure parting to weak fine subangular blocky; slightly hard, friable; few to common fine threads of calcium carbonate; common worm casts; common open insect burrows; few krotovina ≤ 20 cm in diameter filled with dark gray (10YR 4/1) to very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; few very fine roots; common fine and many very fine pores. |

has a fairly homogenous silt loam texture, and the Mallard Island Member is sandier compared to the other stratigraphic units. The Aggie Brown Member has the highest proportion of silt in the profile, with fine silt dominating the silt fraction at most depths within this stratigraphic unit. Also, the cumulic A horizon of the Leonard Paleosol (Aggie Brown Member) is enriched with organic carbon, but the organic carbon content is highly irregular with depth (figure 2.9).

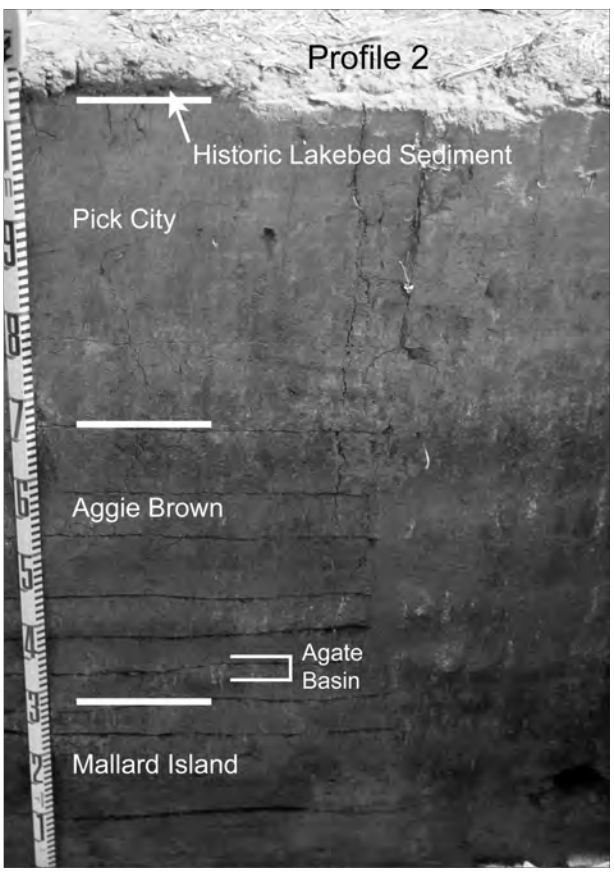


Figure 2.8. Profile 2 in Area A showing the three members of the Oahe Formation and the stratigraphic position of the Agate Basin Cultural component.

To gain a better understanding of the numerical age of the sedimentary units at the Beacon Island site, bulk soil samples were collected from Profile 2 for radiocarbon dating. Soil organic matter from the upper 10 cm of the 2Ak1b and 2Ak3b horizons yielded AMS radiocarbon ages of 7980±25 yr B.P. (ISGS-A1774) and 8740±25 yr B.P. (ISGS-A1773), respectively (table 2.5). The significance of these radiocarbon ages is discussed at the end of this chapter.

Profile 3

Profile 3 (figures 2.10 and 2.11) is located east of Profiles 1 and 2 (figure 2.3) and is slightly higher on the slope of the kettle basin. All of the stratigraphic units observed in Profiles 1 and 2 occur in Profile 3, plus the Lostwood Drift was exposed in the lower 10 cm of Profile 3 (figures 2.9 and 2.12 and table 2.6). However, the members of the Oahe Formation, especially the Aggie Brown, are much thinner in Profile 3 compared to the other profiles. For example, the Pick City Member is only 15 cm thick, probably because of erosion. Although the Aggie Brown Member has a cumulic A horizon (Leonard Paleosol), it is only 38 cm thick. The absence of an overthickened A horizon is due to landscape position. Whereas the deeper part of the kettle basin is a zone of net sediment accumulation (i.e., it is a sediment trap), the shallower fringe of the basin did not receive as much sediment and it probably experienced some erosion, thus providing

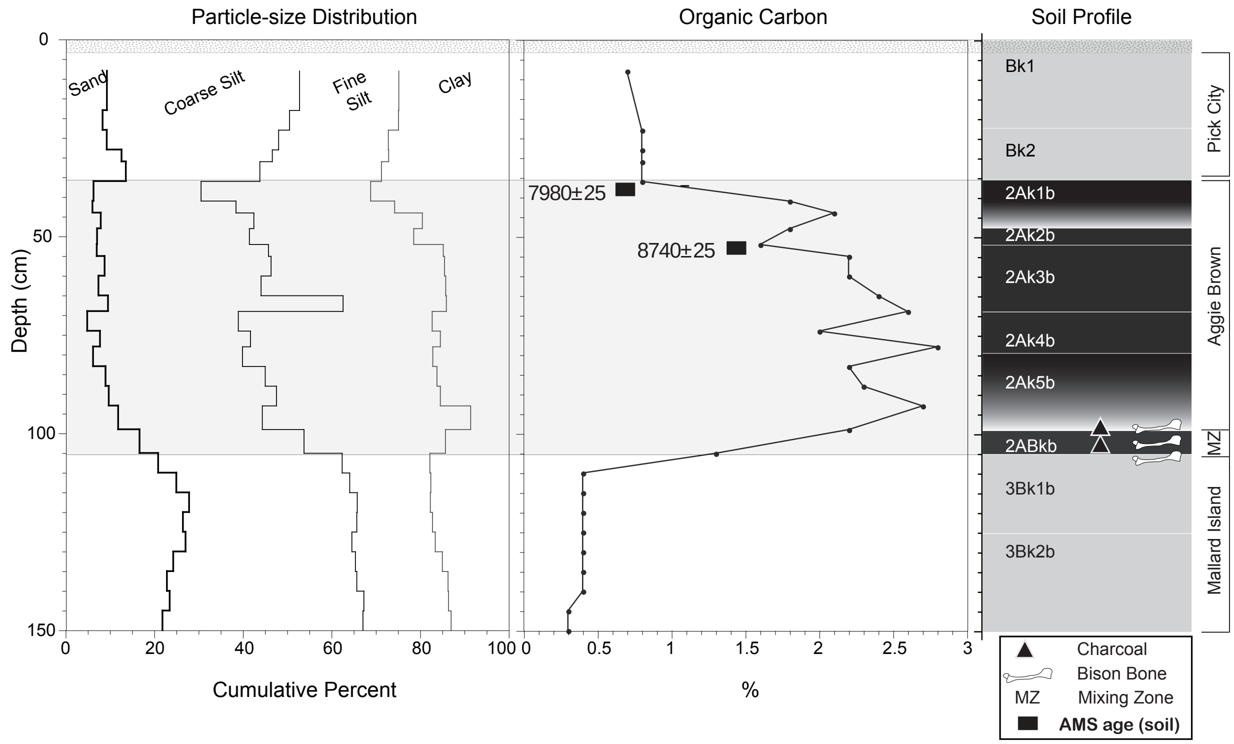


Figure 2.9. Diagram showing particle-size distribution and organic carbon content of samples collected from Profile 2. The stratigraphy, soil horizonation, and distribution of cultural deposits in Profile 2 also are shown.

Table 2.3. Description of Profile 2, Area A, Beacon Island site.

| Depth (cm) | Soil Horizons | Description |
|---|---|---|
| 0-3 | - - | Modern lakebed sand. |
| | | **Pick City Member** |
| 3-23 | Bk1 | Light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist, weak fine prismatic structure parting to weak fine subangular blocky; hard, friable; common films and threads of calcium carbonate; common worm casts; common open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 23-36 | Bk2 | Light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist, moderate medium and fine prismatic structure parting to weak fine subangular blocky; hard, friable; many films and threads of calcium carbonate; common worm casts; common open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| | | **Aggie Brown Member** |
| 36-48 | 2Ak1b | Gray (10YR 5/1) silt loam, very dark gray (10YR 3/1) moist; weak fine prismatic structure parting to weak medium and fine granular; hard, friable; many films and threads of calcium carbonate; many worm casts; many open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |
| 48-52 | 2Ak2b | Grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure parting to weak fine granular; hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| 52-69 | 2Ak3b | Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; very weak fine prismatic structure parting to weak fine granular; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common fine and very fine and few medium roots; many fine and very fine pores; gradual smooth boundary. |

Table 2.3. Description of Profile 2, Area A, Beacon Island site (continued).

| Depth (cm) | Soil Horizons | Description |
|---|---|---|
| 69-78 | 2Ak4b | Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; slightly hard, friable; common films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common fine and very fine and few medium roots; many fine and very fine pores; clear smooth boundary. |
| 78-99 | 2Ak5b | Dark gray (10YR 4/1) to very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; weak fine granular structure; slightly hard, friable; **common bison bone and flecks of charcoal in the lower 5 cm of horizon**; few films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common very fine and few fine and medium roots; many fine and very fine pores; gradual smooth boundary. |
| 99-105 | 2ABkb | Dark grayish brown (10YR 4/2) to brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) moist; common fine prominent strong brown (7.5YR 4/6) mottles; weak fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; **common bison bone and flecks of charcoal throughout the horizon**; few films and threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina ≤ 20 cm in diameter; common very fine and few fine and medium roots; many fine and very fine pores; gradual smooth boundary. |
| | | **Mallard Island Member** |
| 105-125 | 3Bk1b | Light olive brown (2.5YR 5/3) silt loam, olive brown (2.5Y 4/3) moist; many fine distinct yellowish brown (10YR 5/6) and common fine prominent strong brown (7.5YR 46) mottles; weak medium and fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; **small concentration of bone fragments in the upper 8 cm of horizon (krotovina?)**; few films and common threads of calcium carbonate; common worm casts; common open insect burrows; common krotovina ≤ 20 cm in diameter filled with Dark gray (10YR 4/1) to very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; few very fine roots; common fine and many very fine pores; gradual smooth boundary. |
| 125-150 | 3Bk2b | Light olive brown (2.5YR 5/4) silt loam, olive brown (2.5Y 4/4) moist; many fine and medium distinct yellowish brown (10YR 5/6) and few fine prominent strong brown (7.5YR 46) mottles; common gray (10YR 6/1) and light gray (10YR 7/1) reduction zones along macro-pores; weak medium prismatic structure parting to weak fine subangular blocky; slightly hard, friable; few to common fine threads of calcium carbonate; common worm casts; common open insect burrows; few krotovina ≤ 20 cm in diameter filled with dark gray (10YR 4/1) to very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; few very fine roots; common fine and many very fine pores. |


Figure 2.10. Profile 3 and the bison bonebed in Area A. View to the northwest.

Table 2.4. Grain size[a] and organic carbon data for Profile 2, Area A.

| | | Sand | Silt | | | Clay | Textural | Organic |
|---|---|---|---|---|---|---|---|---|
| Soil Horizons | Depth (cm) | Total | C | F | Total | Total | Class[b] | Carbon (%) |
| Bk1 | 8-18 | **9.2** | 43.6 | 22.4 | **66.0** | **24.9** | SiL | 0.7 |
| | 18-23 | **8.2** | 42.3 | 24.6 | **66.9** | **25.0** | SiL | 0.8 |
| Bk2 | 23-28 | **9.1** | 38.9 | 24.7 | **63.6** | **27.3** | SiL | 0.8 |
| | 28-31 | **12.5** | 34.1 | 26.3 | **60.4** | **27.2** | SiL | 0.8 |
| | 31-36 | **13.4** | 30.3 | 27.4 | **57.7** | **28.8** | SiL | 0.8 |
| 2Ak1b | 36-41 | **6.1** | 24.3 | 38.3 | **62.6** | **31.3** | SiL | 1.8 |
| | 41-44 | **5.9** | 32.5 | 35.8 | **68.3** | **25.9** | SiL | 2.1 |
| | 44-48 | **7.8** | 34.6 | 38.0 | **72.6** | **19.6** | SiL | 1.8 |
| 2Ak2b | 48-52 | **7.0** | 34.5 | 37.1 | **71.6** | **21.5** | SiL | 1.6 |
| 2Ak3b | 52-55 | **6.9** | 38.8 | 39.5 | **78.3** | **14.9** | SiL | 2.2 |
| | 55-60 | **8.6** | 37.7 | 39.1 | **76.8** | **14.6** | SiL | 2.2 |
| | 60-65 | **7.2** | 36.8 | 41.8 | **78.6** | **14.3** | SiL | 2.4 |
| | 65-69 | **9.4** | 53.1 | 23.3 | **76.4** | **14.2** | SiL | 2.6 |
| 2Ak4b | 69-74 | **4.7** | 34.2 | 43.7 | **77.9** | **17.4** | SiL | 2.0 |
| | 74-78 | **7.6** | 34.0 | 42.9 | **76.9** | **15.6** | SiL | 2.8 |
| 2Ak5b | 78-83 | **6.0** | 33.8 | 43.0 | **76.8** | **17.2** | SiL | 2.2 |
| | 83-88 | **8.9** | 36.1 | 38.7 | **74.8** | **16.3** | SiL | 2.3 |
| | 88-93 | **9.6** | 37.9 | 37.0 | **74.9** | **15.6** | SiL | 2.7 |
| | 93-99 | **11.7** | 32.6 | 47.0 | **79.6** | **8.6** | SiL | 2.2 |
| 2ABkb | 99-105 | **16.5** | 37.2 | 31.9 | **69.1** | **14.5** | SiL | 1.3 |
| 3Bk1b | 105-110 | **20.7** | 41.6 | 19.8 | **61.4** | **17.8** | SiL | 0.4 |
| | 110-115 | **24.8** | 39.2 | 18.3 | **57.5** | **17.7** | SiL | 0.4 |
| | 115-120 | **27.7** | 38.0 | 16.5 | **54.5** | **17.7** | SiL | 0.4 |
| | 120-125 | **26.3** | 39.3 | 17.1 | **56.4** | **17.3** | SiL | 0.4 |
| 3Bk2b | 125-130 | **26.9** | 37.6 | 18.8 | **56.4** | **16.7** | SiL | 0.4 |
| | 130-135 | **24.1** | 41.2 | 19.6 | **60.8** | **15.2** | SiL | 0.4 |
| | 135-140 | **22.7** | 42.9 | 20.6 | **63.5** | **13.8** | SiL | 0.4 |
| | 140-145 | **23.3** | 43.9 | 19.1 | **63.0** | **13.7** | SiL | 0.3 |
| | 145-150 | **21.7** | 45.3 | 19.9 | **65.2** | **13.0** | SiL | 0.3 |

[a] Particle-size limits (mm): Sand (Total) = 2.0 - 0.05; Silt (Total)= 0.05 -0.002, Coarse (C) = 0.05 - 0.005, Fine (F) = 0.005 - 0.002; Clay (Total) = <0.002

[b] Textural class: SiL= silt loam

Table 2.5. Radiocarbon ages determined on soil organic matter from the Leonard paleosol, Profile 2.

| Soil Horizon | Sample Depth (m) | $^{14}$C Age[a] (yr B.P.) | Cal. Age[b] (yr B.P.) | Median Cal. Age (yr B.P.) | $\delta^{13}$C (‰) | Laboratory No. |
|---|---|---|---|---|---|---|
| 2Ak1b | 0.36-0.46 | 7980±25 | 8725-8994 | 8874 | -24.2 | ISGS-A1774 |
| 2Ak3b | 0.52-0.62 | 8740±25 | 9572-9887 | 9704 | -24.0 | ISGS-A1773 |

[a] Ages were determined by accelerator mass spectrometry (AMS).

[b] Calibration to calendar years (2 sigma) was performed with CALIB 5.0.1 (Stuiver and Reimer 1993) using calibration dataset intcal04.14c (Reimer et al. 2004).

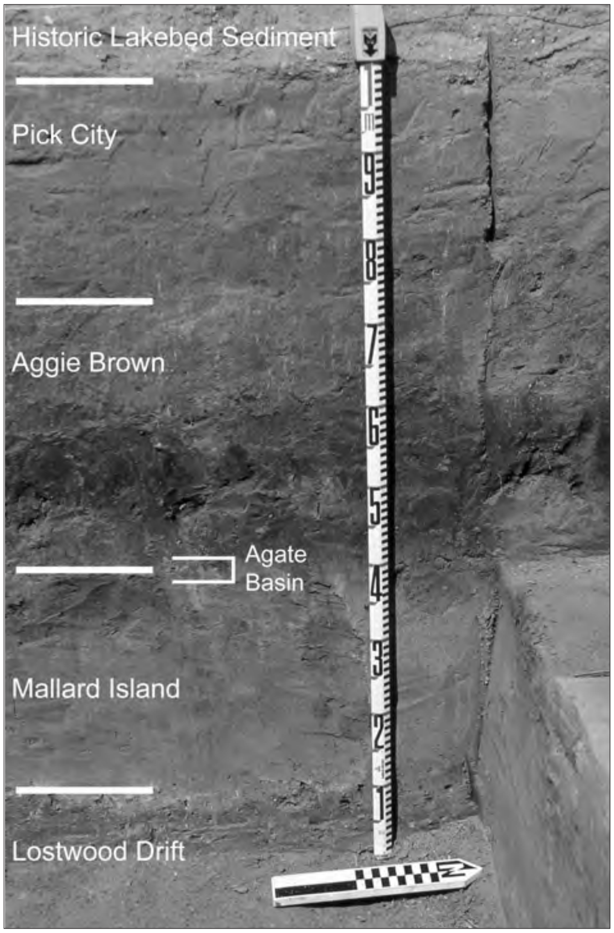


Figure 2.11. Profile 3 in Area A showing three members of the Oahe Formation, the Lostwood Drift, and the stratigraphic position of the Agate Basin cultural component.

sediment to deeper parts of the basin.

During the investigation of Profile 3, only a single bulk soil sample was collected from each soil horizon for physical and chemical analyses. Consequently, the resolution of the grain-size and organic-carbon data is not as high as it is for Profiles 1 and 2. Nevertheless, the general patterns observed in the data for Profiles 1 and 2 are detectable in Profile 3 (figure 2.12 and table 2.7). For example, organic carbon content dramatically increases down-profile going from the Pick City Member to the Aggie Brown Member, and there is great variability in the organic carbon content within the cumulic A horizon comprising most of the Aggie Brown Member (Leonard Paleosol). Also, the Mallard Island Member is sandier compared to the other members of the Oahe Formation, though it is not as sandy as the Lostwood Drift.

A dense concentration of bison bones occurs in the lower 5 cm of the 2ABkb1 horizon and in the upper 5 cm of the 2ABkb1 horizon (mixing zone). A few bones also were recorded in the upper 5-10 cm of the Mallard Island Member immediately north of Profile 3. The bones in the Mallard Island Member probably were translocated downward, perhaps by trampling or other forms of bioturbation.

## Discussion and Conclusions

Information gleaned from the geomorphological investigation sheds light on the history of landscape evolution at Beacon Island. Recognition of that history is crucial for understanding site formation processes that affected the archaeological record. Although the numerical chronology of the site is not robust, enough radiocarbon

Table 2.6. Description of Profile 3, Area A, Beacon Island site.

| Depth (cm) | Soil Horizons | Description |
|---|---|---|
| 0-9 | - - | Modern lakebed sand. |
| | | **Pick City Member** |
| 9-24 | Bk | Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist, weak fine prismatic structure parting to weak fine subangular blocky; hard, friable; few films and common fine threads of calcium carbonate; common worm casts; many open insect burrows; many fine and very fine roots; many fine and very fine pores; clear smooth boundary. |
| | | **Aggie Brown Member** |
| 24-34 | 2Ak1b1 | Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure parting to weak fine granular; hard, friable; common films and many fine threads of calcium carbonate; common worm casts; many open insect burrows; many fine and very fine roots; many fine and very fine pores; clear smooth boundary. |
| 34-48 | 2Ak2b1 | Dark gray (10YR 4/1) to dark grayish brown (10YR 4/2) silt loam, very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure parting to weak fine granular; hard, friable; common films and many fine threads of calcium carbonate; common worm casts; many open insect burrows; many fine and very fine roots; many fine and very fine pores; clear smooth boundary. |

Table 2.6. Description of Profile 3, Area A, Beacon Island site (continued).

| Depth (cm) | Soil Horizons | Description |
|---|---|---|
| 48-62 | 2Ak3b1 | Very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2) silt loam, black (10YR 2/1) to very dark brown (10YR 2/2) moist; weak fine granular structure; hard, friable; **common bison bone in lower 5 cm of horizon**; few films and common fine threads of calcium carbonate; many worm casts; many open insect burrows; common krotovina 2-5 cm in diameter filled with brown (10YR 5/3) to yellowish brown (10YR 5/4) silt loam; many fine and very fine roots; many fine and very fine pores; gradual smooth boundary. |
| 62-71 | 2ABkb1 | Grayish brown (10YR 5/2) to brown (10YR 5/3) silt loam, dark grayish brown (10YR 4/2) to brown (10YR 4/3) moist; few fine prominent yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak fine subangular blocky structure; hard, friable; **common bison bone in upper 5 cm of horizon**; few fine threads of calcium carbonate; common worm casts; common open insect burrows; common krotovina 2-5 cm in diameter filled with brown (10YR 5/3) to yellowish brown (10YR 5/4) silt loam; many fine and very fine roots; many fine and very fine pores; gradual smooth boundary. |
| | | **Mallard Island Member** |
| 71-88 | 3Bk1b1 | Brown (10YR 5/3) to yellowish brown (10YR 5/4) silt loam, brown (10YR 4/3) to dark yellowish brown (10YR 4/4) moist; common fine prominent yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak medium prismatic structure parting to weak fine subangular blocky; hard, friable; common to many encrusted threads of calcium carbonate; common worm casts; common open insect burrows; many fine and very fine pores; gradual smooth boundary. |
| 88-100 | 3Bk2b1 | Light olive brown (2.5Y 5/3 to 2.5Y 5/4) silt loam, olive brown (2.5Y 4/3 to 2.5Y 4/4) moist; common fine prominent yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) and few fine prominent yellowish red (5YR 4/6) mottles; weak medium prismatic structure parting to weak fine subangular blocky; hard, friable; common to few fine threads of calcium carbonate; few worm casts; few open insect burrows; many fine and very fine pores; abrupt smooth boundary. |
| | | **Lostwood Glacial Drift** |
| 100-110 | 4Bkb2 | Dark grayish brown (2.5Y 4/2) loam, dark grayish brown (2.5Y 4/2) to very dark grayish brown (2.5Y 3/2) moist; common fine faint yellowish brown (10YR 5/4) and few fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak fine subangular blocky structure; hard, friable; common films and threads of calcium carbonate; common pebbles and few cobbles scattered through the matrix; few open insect burrows. |

Table 2.7. Grain size[a] and organic carbon data for Profile 3, Area A.

| | | Sand | Silt | | | Clay | Textural | Organic |
|---|---|---|---|---|---|---|---|---|
| Soil Horizons | Depth (cm) | Total | C | F | Total | Total | Class[b] | Carbon (%) |
| Bk | 9-24 | **17.3** | 46.3 | 24.8 | **71.1** | **11.6** | SiL | 0.59 |
| 2Ak1b1 | 24-34 | **13.6** | 47.2 | 34.0 | **81.2** | **5.2** | SiL | 1.19 |
| 2Ak2b1 | 34-48 | **9.6** | 38.3 | 32.9 | **71.2** | **19.1** | SiL | 1.39 |
| 2Ak3b1 | 48-62 | **13.9** | 36.1 | 32.7 | **68.8** | **17.3** | SiL | 1.77 |
| 2ABkb1 | 62-71 | **19.3** | 39.5 | 24.6 | **64.1** | **16.6** | SiL | 0.68 |
| 3Bk1b1 | 71-88 | **22.9** | 39.1 | 23.0 | **62.0** | **15.0** | SiL | 0.51 |
| 3Bk2b1 | 88-100 | **19.9** | 45.1 | 23.5 | **68.6** | **11.5** | SiL | 0.41 |
| 4Bkb2 | 100-110 | **40.4** | 16.2 | 21.5 | **37.7** | **21.9** | L | 0.87 |

[a] Particle-size limits (mm): Sand (Total) = 2.0 - 0.05; Silt (Total)= 0.05 -0.002, Coarse (C) = 0.05 - 0.005, Fine (F) = 0.005 - 0.002; Clay (Total) = <0.002

[b] Textural classes: SiL= silt loam; L= loam

ages are available to place the cultural deposits and the Aggie Brown Member into a chronological framework.

Based on the stratigraphic evidence and radiocarbon ages, the kettle basin at the Beacon Island site formed before approximately 10,300 $^{14}$C yr B.P., presumably around 16,000-15,000 B.P. when the terminal ice front

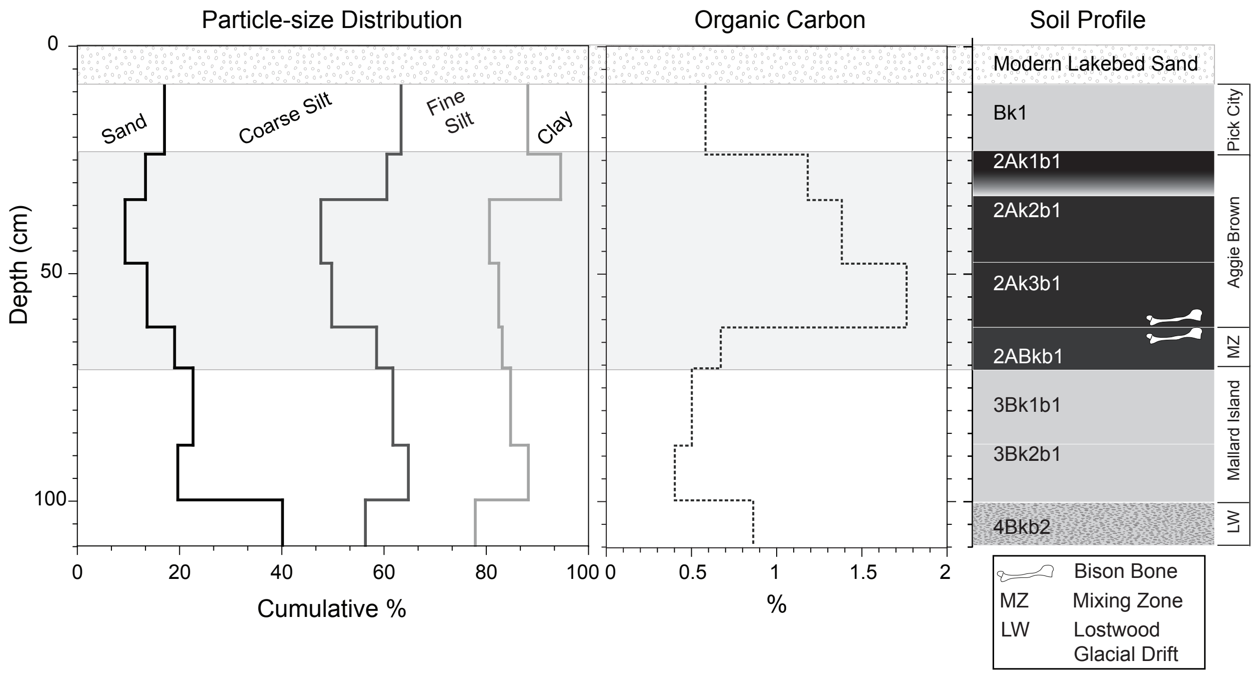


Figure 2.12. Diagram showing particle-size distribution and organic carbon content of samples collected from Profile 3. The stratigraphy, soil horizonation and distribution of cultural deposits in Profile 3 also are shown.

was in the region. Initially, the kettle basin trapped eolian sediment, the slightly sandy loess comprising the Mallard Island Member. Conditions probably were relatively dry when the Mallard Island Member aggraded, which accounts for the presence of loess and the absence of paludal deposits immediately above the late-Wicosnsinan glacial till that floors the kettle basin (figure 2.4). However, at about 10,300 $^{14}$C yr B.P., paludal deposits comprising the Aggie Brown Member began to accumulate in the kettle basin, suggesting a shift to wetter climatic conditions. Paludal settings typically are marsh-like environments where the water is shallow and grasses, rushes, reeds, typhas, sedges, and other herbaceous plants dominate the vegetation community. It seems more than a coincidence that the presence of bison and humans at Beacon Island at about 10,300 $^{14}$C yr B.P. coincides with the shift to mesic conditions.

At about that time, sediment was delivered to the kettle basin by sheetwash and airfall, but the contribution of loess to the Aggie Brown Member probably was insignificant. In low relief landscapes like the one at the Beacon Island site, loess deposition forms a blanket of sediment that is uniformly thick across topographic highs and lows across a small area. This is one of the most distinct signatures of loess (see Mason et al. 2008). However, at Beacon Island, the Aggie Brown Member is about 70 cm thick in the area of Profiles 1 and 2, but only 47 cm thick in the area of Profile 3, and even thinner along the rim of the kettle basin. The variation in the thickness of the Aggie Brown Member over such a small area is attributed to sheet erosion on the rim and near-rim portion of the kettle basin and the accumulation of the eroded loess first as sheetwash, then as paludal sediment in the bowl of the kettle basin. Ruhe (1969:147) documented similar spatial patterns of erosion and sedimentation at kettle ponds on the Des Moines Lobe in north-central Iowa. The initial contributions of sheetwash to the kettle basin at Beacon Island apparently were sufficient enough to quickly bury the Agate Basin bonebed, thereby isolating it from intensive post-depositional disturbance processes (see chapter 3).

Paludal deposits continued to aggrade at Beacon Island after 10,300 $^{14}$C yr B.P., resulting in deep burial of the Agate Basin cultural deposits. However, sedimentaion was at a relatively slow rate, allowing soil development to keep up with deposition. This cumulization process resulted in the formation of an overthickened A horizon typical of the Leonard Paleosol and other Younger Dryas-age paleosols across much of the Plains (Mandel 2008). The cumulic A horizon of the Leonard Paleosol at Beacon Island is multi-storied, indicating that episodes of sedimentation were followed by brief periods of landscape stability. This pattern probably reflects cycles of water accumulation (episodes of paludal sedimentation) and drying (periods of landscape stability and soil formation) in the kettle basin.

Based on the radiocarbon ages determined on soil organic matter from the 2Ak3b and 2Ak1b horizons of the Leonard Paleosol, up-building of the Aggie Brown Member slowed around 8700 $^{14}C$ yr B.P. and ceased by about 8000 $^{14}C$ yr B.P. The accumulation of the loess that comprises the Pick City Member was underway soon after 8000 $^{14}C$ yr B.P. and probably marks the beginning of the Altithermal climatic episode in northwestern North Dakota. This interpretation is supported by the phytolith and stable carbon isotope data (chapter 10).

In sum, the association of the Agate Basin bonebed with paludal deposits underscores the significance of kettle ponds as locations for human activities through time. As focal points for water, animals, and plant resources, kettle ponds were attractive to human groups in the Northern Plains. At Beacon Island, the age of the bison bonebed indicates that the kettle pond was a kill site about 10,300 $^{14}C$ years ago. However, older sedimentary deposits are present within and adjacent to the kettle basin, and these may contain earlier archaeological evidence. Future research should focus on these deposits.

# 3

## Archaeological Field Investigations in Area A

*Mark D. Mitchell*

This chapter describes the geophysics, coring, and excavation carried out in Area A and summarizes the major findings of that work. The presentation integrates data obtained during nine separate field sessions at the site, one in 2001, three in 2002, and five in 2006. It recaps previously published descriptions and interpretations and presents additional, previously unpublished data. The chapter begins with a brief synopsis of the field program, laying out the major activities undertaken during each phase of the project. Details are provided on the scope of the work and on the goals pursued. Following a description of excavation techniques and documentation procedures, the chapter then turns to a discussion of the project's findings.

The presentation is based on data from a variety of sources, including individual level forms; unit and block profiles; provenience catalogs; photographs; total station data files; daily activity logs kept by George Crawford and Stance Hurst; a series of interim field reports prepared by Stanley A. Ahler and other members of the research team; and the monograph describing the May 2002 fieldwork edited by Ahler (2003). The most important sources for data on stratigraphic relationships and the distribution of faunal remains and artifacts are Ahler's monograph and excavation level forms prepared by Stacey Bennett, Jennie Lee, and Phil Geib. Mark Mitchell wrote the chapter, with input from numerous individuals who participated in the fieldwork, including Stacey Bennett, George Crawford, Jennie Lee, Rolfe Mandel, Paul Picha, Kimberly Spurr, and Fern Swenson. A bibliography of previously published reports can be found in appendix E. Appendix F presents a comprehensive list of field crew members.

### Overview of the Field Investigation

The archaeology of Beacon Island was first documented in 1974 (Haberman and Schneider 1975). At the time, the elevation of the surface of Lake Sakakawea was 1842 ft., just 2.4 m (8 ft.) below the maximum "normal operations" pool elevation, and as a result the site was exposed on five small islands. The largest two of the islands were surveyed. The field crew documented a hearth eroding from an active cutbank and several more exposed on the wave-cut beach, along with concentrations of bone, chipped stone tools, pottery, burned rock, and flaking debris (Haberman and Schneider 1975:69-70, 75). Projectile points recovered during the survey include a Folsom base, a possible Late Paleoindian midsection, and a series of Archaic and Late Prehistoric fragments. Haberman and Schneider (1975:117-121) rank Beacon Island among the most significant sites they documented in their shoreline survey.

In the years following this initial recording, local collectors picked up projectile points from the site ranging in age from Clovis to Late Prehistoric (Ahler and Crawford 2003c). Among these items, the most significant is a collection of 12 Folsom points and point preforms described and analyzed by Ahler, Frison, and McGonigal (2002). In early 2000, owing to widespread drought, the level of Lake Sakakawea dropped to about 1838 ft., exposing a larger area than was visible in 1974, and visitors to the site began finding numerous Agate Basin points on the north side of the island. The large number of recovered points, along with the presence of numerous bison bone fragments, suggested that an Agate Basin-age kill or butchery locality was preserved in this part of the site. In 2001, the State Historical Society of North Dakota (SHSND) provided funding for archaeological testing and evaluation work designed to document the extent and condition of Agate Basin-age deposits on the island.

Planning for the project began with a site visit in June 2001 (Timpson, Ahler, and Crawford 2003). This reconnaissance confirmed the presence of numerous eroded hearths scattered across the island. It also documented extensive areas of fine-grained, artifact-bearing sediment. Examination of the north-central part of the island, where Agate Basin points and faunal remains previously had been found on the surface, revealed the presence of intact archaeological deposits exposed at the surface, deposits that appeared to contain abundant bison remains and that covered an area at least tens of square meters in size.

To prepare for the fieldwork planned for 2002, the research team obtained and analyzed aerial photographs of the island (figure 3.1). The goal of this effort was to identify the portions of the island most likely to contain

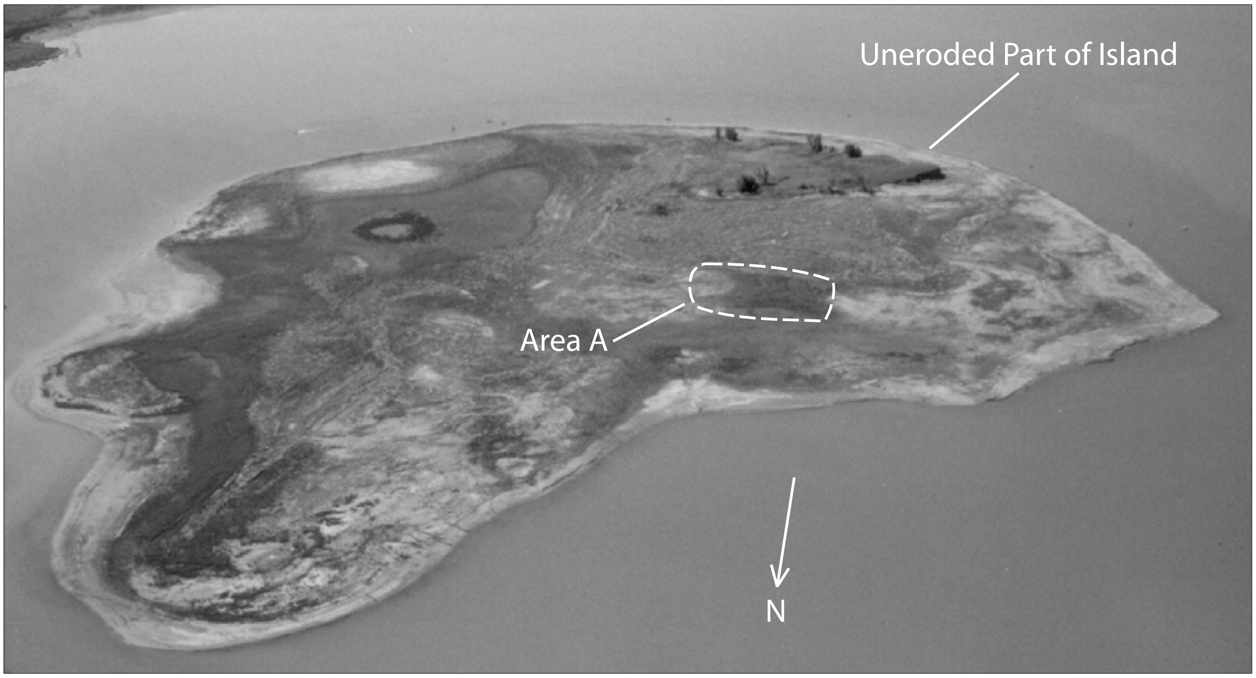


Figure 3.1. Aerial view of Beacon Island, looking south.

intact cultural deposits. Photographs taken in 2000 and 2001 show that much of the island's surface is covered by an eroded boulder lag formed from glacial till, indicating that Holocene deposits have been entirely stripped away. Other parts of the island have been subject to alternating periods of erosion and deposition. The analysis identified two areas likely to contain intact archaeological deposits. The largest encompasses much of the western half of the island, including the uneroded and partially eroded remnants of the pre-lake landform, along with an adjacent zone of localized erosion and deposition. A second, smaller area possibly containing archaeological deposits was also identified on the northeast edge of the island.

Fieldwork on Beacon Island began in earnest on May 17, 2002 (figure 3.2). Over the course of a ten-day field session, the 12-person crew—made up of Paleocultural Research Group (PCRG) staff and volunteers—surveyed portions of the site, carried out a systematic coring program, and opened a series of formal test units. The crew identified and documented four discrete parts of the island containing artifacts and other materials, which they designated Areas A, B, F, and T (figure 3.3). Area A, containing the Agate Basin component, received the most attention, but intact cultural deposits were documented in Area B and Area F and are likely present in Area T. The field methods used and results obtained in Areas B, F, and T are reported in Ahler and Crawford (2003b), Ahler, Crawford, Lee and Ritter (2003), Ahler, Timpson and Crawford (2003), and Crawford and Ahler (2003).

Figure 3.2. The field camp on Beacon Island, May 2002.

The fieldwork in Area A combined surface mapping and controlled surface collection with systematic hand coring and excavation. The topographic map the crew prepared shows modern surface features and the extent of the boulder lag bounding the remnant portion of the Oahe Formation containing the Agate Basin component (figure 3.4). An auger was used to investigate the paleotopography of Area A and a one-inch Oakfield probe was used to document subsurface stratigraphy and to gauge the extent and density of cultural deposits. A total of 12 1 x 1 m test units were excavated into and through the Agate Basin bonebed (figures 3.5 and 3.6). The principal goals of this work were to determine whether intact cultural deposits were present and, if so, to estimate their extent and sample their content.

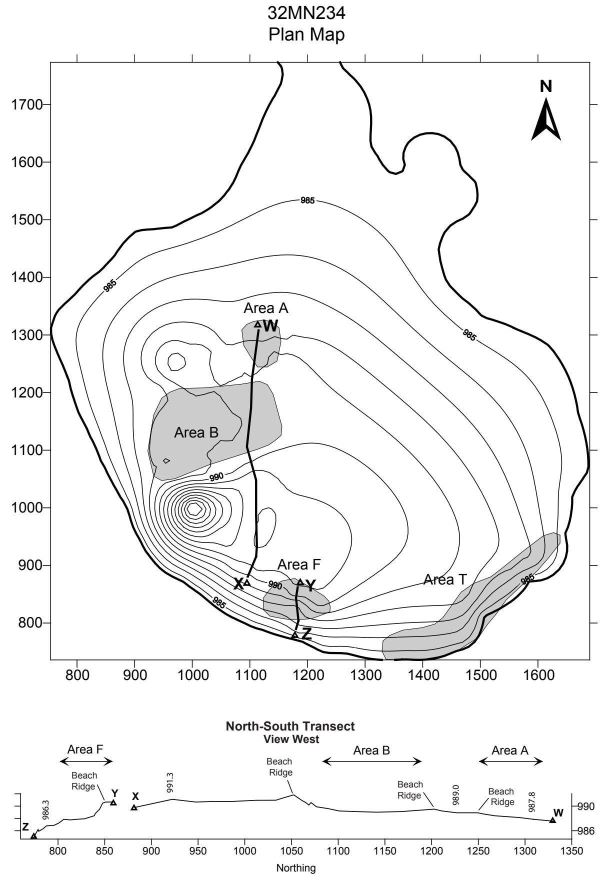


Figure 3.3. Plan and cross-section of Beacon Island, showing the locations of archaeological areas defined in May 2002.

Following the conclusion of the May 2002 field session, the U. S. Army Corps of Engineers (USACE) provided funding for two additional field sessions in Area A, together totaling about four weeks long. This phase of the project, a collaborative effort involving the SHSND, PCRG, USACE, and the Three Affiliated Tribes (TAT, or the Mandan, Hidatsa, and Arikara Nation), was carried out in September 2002 (Ahler, Crawford, and Timpson 2002). The goals of the September fieldwork were to gather information necessary for planning a larger-scale mitigation project and to obtain additional data from the part of Area A most vulnerable to erosion. To salvage actively eroding deposits, 15 new 1 x 1 m units were excavated along the northern edge of the intact cultural horizon (figure 3.5). Another eight units, arranged in two small blocks, were opened on the eastern side of Area A to investigate the part of the site believed to contain the densest concentration of butchered bone. Eleven more units were opened up west and south of the main bonebed to define the extent and character of intact cultural deposits; one of these units (square 1308NE1055) is 18 m north and 20 m west of the area depicted in figure 3.5. Altogether, the 23-person crew excavated 34 new 1 x 1 meter units and completed work on three units begun in May (squares 1282NE1110, 1283NE1109, and 1284NE1109).

In 2005, the National Park Service awarded a Save America's Treasures (SAT) grant to the SHSND for data recovery excavations in Area A and for subsequent lab analyses (Ahler, Swenson, Sellet, Spurr, Madden, Mandel, and Hurst 2006). The USACE and the SHSND

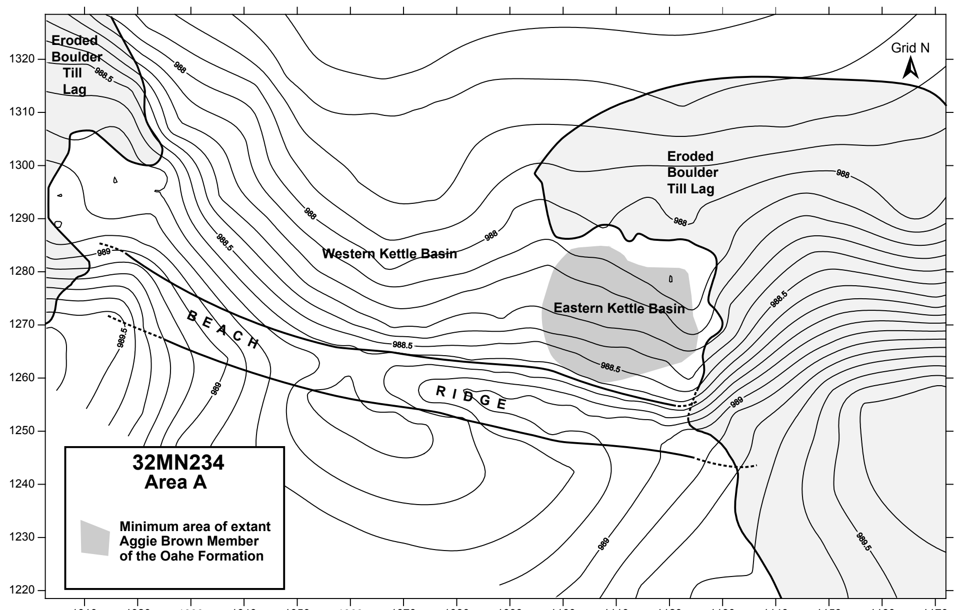


Figure 3.4. Topographic map of Area A, showing features of the modern surface and the approximate extent of Aggie Brown Member sediment.


Figure 3.5. Map of Area A excavations, showing the scope of work undertaken during each major phase of the project.

also provided substantial additional funding for the 2006 field season (Ahler, Swenson, Spurr, Mandel, Madden, Sellet, Hurst, and Crawford 2006). Beginning on June 13, the research team spent a total of 49 days working in Area A, with crews ranging in size from four to 20 people. The first session, roughly two weeks long, was devoted to site preparation and geophysical surveys (Spurr, Nickel, and Ahler 2007). This work, which was funded by the SHSND, was undertaken to define the extent of the bonebed more precisely and to search for hearths or other features within or adjacent to the bonebed. Two techniques were used (Spurr, Nickel, and Ahler 2007:17-20) (figure 3.7). Ground-penetrating radar (GPR) was used to investigate the area tested in 2002 (figure 3.8). A 900-sq. m block was surveyed with a 400 MHz antenna, while a slightly larger area, extending an additional 5 m to the east, was surveyed with a 250 MHz antenna. A magnetic gradiometer was used to search for thermal features across a broad area, covering 3,600 sq. m south and west of the bonebed. The GPR survey failed to reveal subsurface anomalies related to the Agate Basin component. The magnetic survey documented as many as ten monopole anomalies possibly representing cultural features. Thirty-five one-inch boreholes and two 1 x 1 m test units were excavated to investigate these anomalies. This work provided information about the stratigraphy of Area A, but failed to locate intact cultural features.

Four nine-day work sessions followed the geophysical

Figure 3.6. Excavation in progress, May 2002.

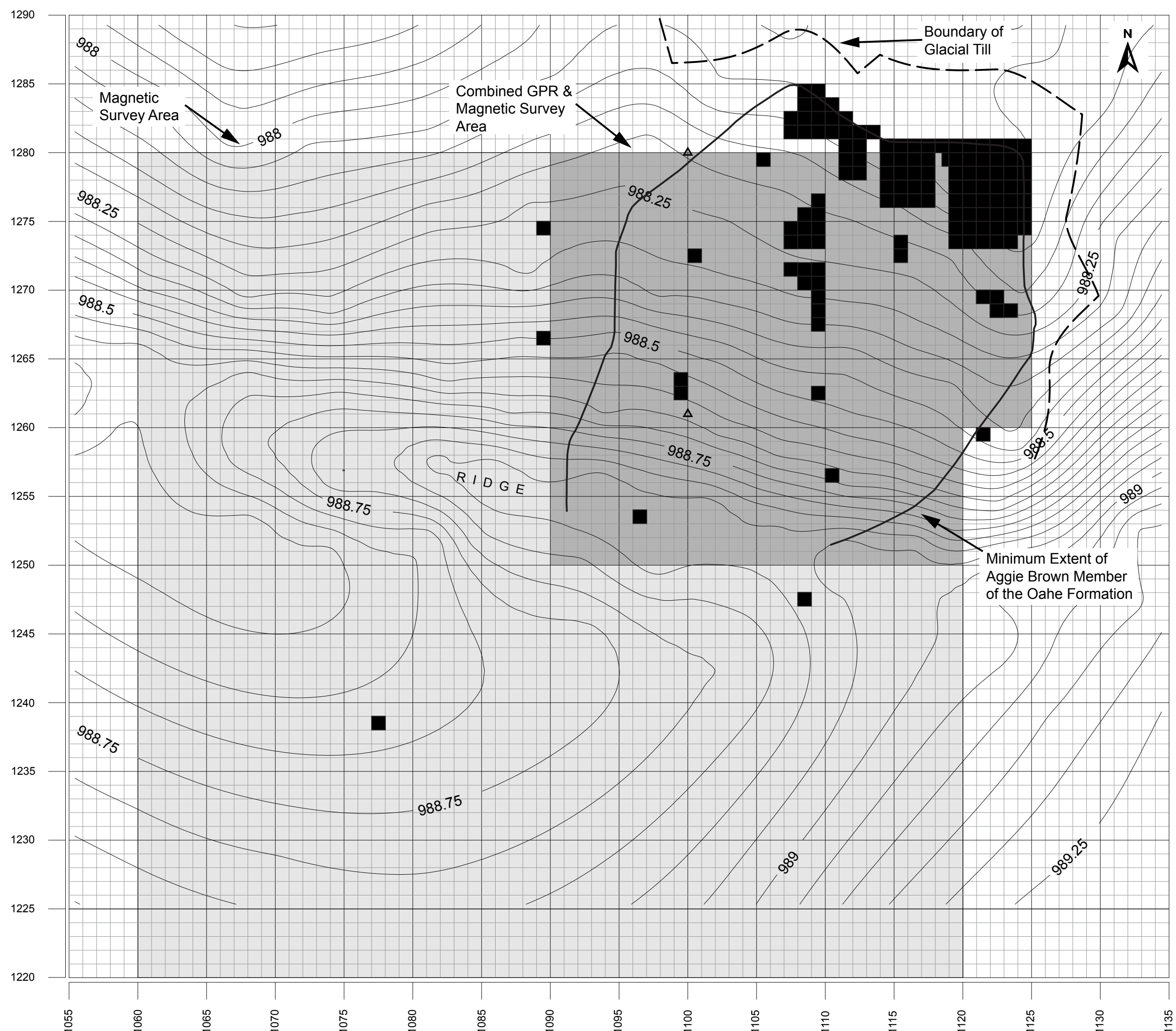


Figure 3.7. Map showing the modern topography of Area A and the extent of the geophysical survey blocks.

Figure 3.8. Robert Nickel (right) and Kay Nickel conducting the GPR survey of Area A.

surveys. Work during Sessions 1 and 2 (June 26-July 4 and July 10-July 18) was funded by the NPS's SAT grant, while work during Sessions 3 and 4 (July 24-August 1 and August 7-August 15) was funded by the USACE. Forty new 1 x 1 m units, along with a single 1 m x 50 cm unit, were opened during the first two sessions. Further excavation was also carried out in one unit originally begun in 2002. During the last two sessions, 39 more units were opened and work continued in 12 units begun earlier in the summer or in 2002 (figure 3.5).

The 2006 mitigation effort had two major goals. The first was to expose a substantial portion of the bonebed to obtain data on Agate Basin hunting and carcass processing practices, on site seasonality, and on lithic technology. This goal was achieved by opening three excavation blocks immediately south of the salvage trench excavated in September 2002 (figure 3.9). The largest of these encompasses the northeast edge of the preserved Agate Basin-age deposits in Area A, where previous work had exposed a dense mass of butchered bone (figure 3.10).

The second major goal was to investigate a potential associated camp area located south and west of the main bonebed. Data obtained during the 2002 testing and salvage efforts suggested that a range of activities other than bison processing may also have been carried out in Area A at the time of the kill. To investigation this possibility a north-south trench was opened west of the

Figure 3.9. Excavation in progress, June 2006.

Figure 3.10. Bob Gardner working in the dense mass of bone.

bonebed (figure 3.11).

Altogether, 127.5 sq. m of Area A was excavated during 2002 and 2006. All but six units exposed the Agate Basin component. The total volume of excavated, screened sediment is roughly 52.8 cu. m. Table 3.1 summarizes information about each phase of the field investigation.

## Field Methods

Throughout the project, the research team used field methods designed to capture a high-resolution record of the Agate Basin component. The basic strategy involved intensive piece-plotting of individual specimens, coupled with fine-mesh waterscreen processing of excavated sediment. However, the specific excavation techniques, strategies, and documentation methods varied slightly during each phase of the project. The following sections provide an overview of the field methods used; additional details are presented in the reports listed in appendix E.

### Site Grid and Datums

Horizontal and vertical control for all excavation, mapping, and surface collection at Beacon Island was based on a standard northing and easting grid system. Initially, a master site datum was established on the uneroded part of the island and marked by a wooden stake. This datum was assigned an arbitrary position of 1000NE1000, Z1000.000. For work in Area A specifically, major subdatums, shown in figure 3.5, were set at 1280NE1100, Z988.192 (Station 3388) and 1261NE1100, Z988.595 (Station 3389). Both were marked with steel reinforcing rods set flush with the modern ground surface. In 2006, these subdatums initially were removed to facilitate the magnetic gradiometry survey (Spurr, Nickel, and Ahler 2007:17). After the geophysical investigation was complete a new rebar

Figure 3.11. Fern Swenson and Paul Picha profiling in the west block.

Table 3.1. Summary of field investigations in Area A.

| Year | Session Number | Session Name | Date(s) | Goals | Field Activities | Excavated Area[a] (sq. m) | Excavated Volume[b] (cu. m) |
|---|---|---|---|---|---|---|---|
| 2001 | 1 | | 6/24 | Project planning | Reconnaissance survey; aerial photo interpretation | n/a | n/a |
| 2002 | 2 | May | 5/17-5/27 | Testing | Survey, coring, controlled surface collection, excavation | 12 | 5.072 |
| | 3 | September Session 1 | 9/6-9/13 | Testing, data recovery | Excavation | 22 | 9.244 |
| | 4 | September Session 2 | 9/18-9/26 | Testing, data recovery | Excavation | 12 | 6.297 |
| 2006 | 5 | Remote Sensing | 6/13-6/24 | Testing | Geophysical surveys, excavation | 2 | 0.270 |
| | 6 | Session 1 | 6/26-7/4 | Data recovery | Excavation | 24.5 | 2.885 |
| | 7 | Session 2 | 7/10-7/18 | Data recovery | Excavation | 16 | 4.810 |
| | 8 | Session 3 | 7/24-8/1 | Data recovery | Excavation | 21 | 13.135 |
| | 9 | Session 4 | 8/7-8/15 | Data recovery | Excavation | 18 | 11.094 |
| Total | | | | | | 127.5 | 52.807 |

[a] Excluding units carried over from previous sessions.
[b] Excluding unscreened excavated sediment; see text for details.

subdatum was established at 1282NE1128, Z988.064 (Station 4000), immediately east of the main bonebed. This subdatum was used to collect the bulk of the position data recorded in 2006. Backsights were reestablished close to the original locations of the major subdatums set in 2002, at 1280NE1100, Z988.187 and 1261NE1100, Z988.575. Toward the end of the 2006 sessions, a second temporary datum point was set at 1289NE1109, Z987.989 (Station 4230). Grid north is aligned to magnetic north, as observed on a hand-held compass. In May 2002, magnetic north was 9 degrees, 25 minutes east of true north. Positions within the grid system were measured with a Nikon total station and recorded electronically and by hand in the site catalog and on excavation level forms. Excavation squares are designated by the nominal position of their southwest corners.

## Excavation and Recovery Methods

Excavation in Area A was conducted entirely by hand, but the specific techniques used varied slightly for each of the five defined stratigraphic units present there. The uppermost unit comprises recent lakebed deposits, a mixture of poorly sorted sand and gravel and, in some cases, laminated and unlaminated fine-grained sediment. This stratum was removed with shovels and trowels. During the May 2002 session, lakebed sediment was passed through 1/4-inch hardware cloth. In September 2002, this material was waterscreened through 1/16-inch mesh, though in a few cases it was simply stockpiled nearby without screening. In 2006, lakebed sediment was not screened.

The other four stratigraphic units together make up the Oahe Formation; these units are described in detail in chapter 2. Intact Riverdale Member sediment, a grayish-brown silt deposited in the middle to late Holocene, and Pick City Member sediment, a yellow-brown silt deposited in the early Holocene, was removed with shovels and trowels, but was screened to recover artifacts and faunal remains (a few exceptions to this are described later). In-situ specimens encountered in these strata were piece-plotted; however, just 55 plotted items (less than 2 percent of the specimens recovered by piece plotting) are assigned to Riverdale or Pick City contexts. Forty-one items come from a single excavation unit (see discussion of square 1308NE1055 in the Holocene Components section). Some of the 55 plots assigned to Holocene contexts may have been displaced upward by burrowing animals from the underlying terminal Pleistocene/early Holocene Aggie Brown Member, a dark gray to black silt.

Excavation in the Aggie Brown was conducted entirely with trowels, bamboo picks, and small wooden tools. A total of 3,257 catalog numbers are assigned to plotted specimens recovered from this stratum. In a number of units, excavation continued into the underlying Mallard Island Member, a brown to yellow-brown silt laid down in the late Pleistocene. Trowels were used to excavate this stratum. No plotted specimens are assigned to the Mallard Island, but bone pieces and artifacts were sorted from Mallard Island waterscreen lots.

Excavation occurred in both arbitrary and natural levels. In all cases, recent lakebed sediment was removed as a natural layer. Riverdale and Pick City sediment was generally excavated in arbitrary 10-cm-thick levels. In a few cases, where the contact between the Pick City and Aggie Brown members was especially well defined, excavation stopped at the base of the Pick City and a new level was begun in the Aggie Brown under a separate catalog number. During the 2002 sessions, considerable effort was devoted to documenting the morphology of the contact between the Aggie Brown and the underlying Mallard Island, and this often involved excavating deep, irregular pockets of Aggie Brown sediment extending into the upper part of the Mallard Island. During the September 2002 sessions, excavation stopped following the removal of one 10-cm level below the base of the Agate Basin-age cultural horizon. In 2006, excavation typically ceased just below the base of the Agate Basin component, in the transition zone between the Aggie Brown and the Mallard Island, though pockets of Aggie Brown sometimes were followed out into the floor of the unit.

Two level numbering systems were used. During the 2002 sessions, level numbers were assigned independently for each excavation unit, with the surface-most level designated level 1, regardless of absolute elevation or thickness. Subsequent level numbers were assigned sequentially with increasing depth. In 2006, a site-wide, elevation-based system was used. In this system level 1 designates excavation increments with a beginning elevation falling between 989.999 and 989.900, level 2 designates increments with a beginning elevation between 989.899 and 989.800, and so forth. In this chapter, excavation levels tied to this system are called "standard levels," (SL) to differentiate them from the general levels (GL) used in 2002. Where an excavation increment is roughly equally divided between two standard levels both the upper and lower level numbers are given. (A list of standard level elevations is given in appendix G.) These differences in level numbering do not affect interpretations of measured profiles or plot depths because a single coordinate system was used during all phases of the project.

Because the research strategy emphasized high-resolution data collection, the field effort focused on exposing, mapping, and photographing individual specimens prior to removal. All stone artifacts, identifiable bones, and bone fragments larger than 5 cm in maximum dimension were plotted. A faunal analyst was present on-site throughout the project to make preliminary field identifications of bone pieces (including element and side), and every effort was made to isolate individual elements. This was largely successful, though subsequent coding in the lab revealed that about seven percent of the plotted faunal items (227 catalog numbers) actually included more than one element. Six catalog numbers incorporated ten or more separate elements. Most specimens were wrapped in aluminum foil as they were removed from the ground because the bone is both fragmented and fragile. Some especially large elements, or clusters of densely packed elements, were encased in plaster or foam jackets for transport to the lab (figure 3.12).

Throughout the project, the coordinates of plotted specimens were measured with a Nikon total station. In 2002, position data were collected from the bottom of each plotted specimen at the approximate center point. (In a few cases, position data were mistakenly collected from the top of an item, but were later corrected by subtracting the thickness of the specimen). Recorded positions were rounded to the nearest centimeter. In 2006, position data were collected from the top of each plotted specimen before it was removed. Data also were selectively collected on the ends of elongated items. All position data were recorded electronically, but only the center point data were recorded manually in the catalog and on level forms. The majority of 2006 data were collected using a short mini-prism to maximize accuracy (figure 3.13). The 2006 total station data file records positions to the millimeter or tenth of a millimeter. However, close inspection of backsight data suggests that this level of precision is not warranted, and so all position data in the combined project catalog are rounded to the nearest centimeter.

Figure 3.12. Stance Hurst jacketing a metapodial.

Figure 3.13. Stance Hurst using the “peanut” prism.

Positions were also measured on the corners of some excavation units, on various features of the modern surface, and on the contacts between major stratigraphic units. In each case, individual excavation squares are designated by the nominal coordinates of their southwest corner. A unit number was assigned to excavation squares opened in May 2002, but this practice was not continued during subsequent work sessions.

At the conclusion of the each major phase of the project open excavation units were lined with black plastic and backfilled with recently deposited sediment from the beach ridge on the southern edge of Area A. A small front-end loader was used to accomplish this work in 2006.

The vast majority of all excavated, undisturbed sediment was waterscreened through 1/16-inch-mesh screen. During the May 2002 field session, constant volume samples amounting to one-ninth (11 percent) of each excavated level (apart from the first level consisting of recent lakebed sediment), were waterscreened by hand in screen boxes in shallow water near the lake shoreline. These samples generally were taken from the southwest corner of the unit. The remainder of the sediment from each level (89 percent) was dryscreened through 1/4-inch hardware cloth. There was one exception to this procedure: in square 1270NE1109, an 80-cm-thick level was removed without screening to expose a deeply buried part of the Agate Basin component. Sediment removed in this unscreened level came from the Pick City Member and the upper part of the Aggie Brown Member.

With a few minor exceptions, all excavated sediment was waterscreened during the September 2002 sessions. In several cases, recent lakebed sediment was removed without screening. In square 1263NE1109, about 70 cm of Pick City Member sediment was removed as a single level without screening, again to more quickly expose the Agate Basin component, which is deeply buried in this part of Area A. In 2006, all undisturbed sediment was waterscreened, but recent lakebed sediment was not screened.

For the September work, a waterscreening station was constructed on the north edge of Area A and water was pumped from the lake shore roughly 225 m away. In 2006, the waterscreening station was located some 70 m north-northwest of the bonebed and water was pumped 200 m from the lake shore (figure 3.14). Throughout the project, washed screen residue was dried on canvas cots, and when dry was placed in paper bags labeled with the catalog number and provenience information. No sorting of watersceen samples occurred on site.

Table 3.2 provides data on the volume of processed sediment, organized by stratigraphic unit and processing method. Overall, 48.1 cu. m (91.9 percent) was processed with fine-mesh waterscreen recovery, while 4.7 cu. m (8.9 percent) was dryscreened through 1/4-inch hardware cloth.

Table 3.2. Excavation volume data[a].

| Stratum | Dryscreened Volume (cu. m) | Waterscreened Volume (cu. m) | Total (cu. m) |
|---|---|---|---|
| Lakebed | 0.181 | 1.004 | 1.185 |
| Riverdale | | 1.605 | 1.605 |
| Pick City | 0.939 | 7.808 | 8.747 |
| Aggie Brown | 3.332 | 35.446 | 38.778 |
| Mallard Island | | 2.222 | 2.222 |
| Indeterminate | 0.270 | | 0.270 |
| Total | 4.722 | 48.085 | 52.807 |

[a] Excluding unscreened excavation levels; see text for details.

## Documentation

The research team used standard forms to document each excavation level. In addition to basic provenience data, the forms used for the 2002 sessions include spaces for excavators to write short narratives describing the sediment and artifacts they observed, as well as problems or special situations they encountered. The forms also provide a gridded block for drawing a plan map of the base of the level and a table for recording position and other data on piece plots associated with that level. A similar form was used in 2006, but the gridded map block was replaced with an expanded piece plot table.

In 2002, an on-site, provenience- and recovery-based field catalog was maintained. Catalog numbers were assigned as new excavation levels were begun, or as piece-plotted specimens were collected. During the May session, separate catalog numbers were assigned to each plotted item. During the September sessions, a multi-plot system was used, in which a single catalog number was assigned to all the plots from each level and individual specimens were assigned separate letter designations, beginning with "A." When the field catalogs for each

Figure 3.14. Stacey Bennett delivering sediment to the waterscreen station, with Michael Krause processing samples, June 2006.

major phase of the project were combined in the lab, these alphanumeric designations were converted to decimal equivalents (see appendix G).

A similar field catalog was kept in 2006. However, during Session 1, consecutive catalog number assignments were not made as excavation progressed and this later caused some confusion in recording data on piece plots, in completing level forms, and in organizing and cross-checking both plotted materials and non-plotted waterscreen samples. These initial problems were resolved during the break between Sessions 1 and 2 and catalog numbers subsequently were assigned as needed when work began on a new level or when plotted items were removed. To minimize the potential for damage during waterscreening, separate lot numbers were assigned to bone fragments from each level falling below the minimum plot size. Provenience data associated with these "general level recovery" lots are the same as those associated with the waterscreen lots from the same unit and level. During the analysis phase of the project, corresponding general level recovery and waterscreen samples were combined and the general level recovery catalog numbers were retired. Table 3.3 lists the catalog number sequences assigned during each major phase of the excavation program.

*Mapping*

Two rather different methods were used to map artifacts, faunal remains, and sediment changes. In 2002, standard plan views were drawn of the base of each excavation level. Where bone was particularly dense, multiple maps of each level were sometimes made. In 2006, photography rather than sketch-mapping was used to record the positions and orientation of plotted bones and artifacts. Digital photographs were taken of the base of each excavated level. In the densest part of the bonebed several photographs were taken of each level. To minimize optical parallax, a tripod with a lateral extension arm was used to center the camera over the unit (figure 3.15; see discussion in chapter 4 on the creation of a photo mosaic of the bonebed). In most cases, three shots were taken of the base of each level: one shot showing the entire unit; one with a north arrow; and one with a dry-erase board listing the southwest corner coordinate, the level number, and the date. The photographs were then printed on-site and catalog numbers for each plotted item were written directly on the print. These prints, along with the general level maps produced in 2002, were an important dataset used during the faunal analysis. They also formed the starting point for the creation of the site-wide GIS.

In retrospect, the application of photographic mapping techniques at Beacon Island can be judged only moderately successful. Photography minimizes certain kinds of mapping errors but introduces others. Photographs of deep excavation levels commonly are distorted by optical parallax. Strong shadows in many photographs limit the visibility of some specimens. Because the Beacon Island archaeofauna is highly fragmented, the photographs often do not clearly show the shapes of plotted specimens; hand mapping likely

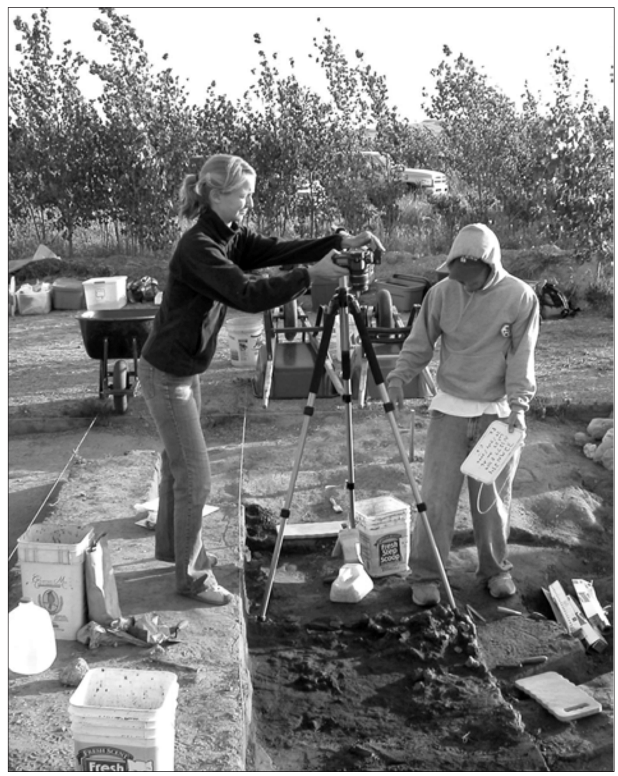

Figure 3.15. Kristina Kossel taking level photographs.

Table 3.3. Catalog numbers assigned to provenience units from Area A.

| Field Year | Catalog Numbers | Number of Bulk Provenience Lots | Number of Plotted Items | Total |
|---|---|---|---|---|
| May 2002 | 1001-1509 | 131 | 368 | 499 |
| September 2002 | 1601-1979 | 205 | 549 | 754 |
| 2006[a] | 7000-11030 | 370 | 2599 | 2969 |
| Total | | 706 | 3516 | 4222 |

[a] Includes two catalog numbers assigned to specimens from Area P; see text for details.

would have captured that information more precisely. Most importantly, though, the photographs provide only limited information on the depositional context of plotted specimens. In many cases, efforts to clean the floor of the level by sweeping obscured the contacts between depositional units as well as the boundaries of krotovina. In addition, the process of hand mapping such contacts commonly encourages excavators to write notes about them on the level form. Overall, a combination of photographic and hand mapping likely would have produced a more complete, and more readily interpretable, spatial dataset.

*Profiles*

In 2002, the crew drew measured sections showing at least one, but more commonly two or three, walls of each excavation unit. The scale of these drawings is uniformly 1:7.874 (1 inch representing 20 cm). For the much larger area opened in 2006, profiles mostly were limited to the long walls bounding the major excavation blocks. The scale of these drawings is 1:19.685 (1 inch representing 50 cm). Because the bonebed dips both to the south and west in the major excavation blocks, and because the contact between the Aggie Brown and Mallard Island members is irregular, the lack of larger-scale unit profiles represents a significant gap in the excavation record, a gap only partially mitigated by total station data collected on the elevation of the Aggie Brown-Mallard Island contact.

Three deep sondages were opened in 2006 to better observe the contact between the Aggie Brown and Mallard Island members and to provide profiles for detailed soil descriptions and paleoenvironmental sampling. These included 1.55 m sections of the east walls of 1268NE1109 (Profile 1) and 1271NE1109 (Profile 2), and a 1.4 m section on the west wall of 1273NE1119 (Profile 3). Pedological and geological data from these sections are presented in chapter 2. Paleoenvironmental data are presented in chapter 10.

## Surface Finds

The controlled surface collections of chipped stone tools, burned rock, flaking debris and faunal remains made in May 2002 are described by Ahler and Crawford (2003a), Ahler and Ritter (2003), and Lee (2003b) and their major findings are reiterated here. A total of 740 pieces of bone comprises the surface sample, of which 110 are identified as bison bones; this figure does not include bones eroding from the exposed margin of the Aggie Brown Member. These specimens, representing a minimum of two individuals, were concentrated in the eroded till just east of the main bonebed (figures 3.16 and 3.17). In addition, prior to May 2002, local collectors picked up at least 19 complete bones and 158 bone fragments from Area A. One of these specimens is a fragment of a domestic pig humerus (Karpinsky 2002). The remainder represents a minimum of four late Pleistocene or early Holocene bison, including one immature and three mature individuals.

Ahler and Crawford (2003a:52) argue that the concentration of bone pieces observed in 2002 may represent a collector's pile, formed when visitors gathered remains for inspection and possible analysis. They suggest that this may explain why the bones comprising the early, uncontrolled surface collection are in better condition and are more complete than the May 2002 surface sample. However, excavation data from September 2002 and 2006 shows that the surface concentration of bone scrap begins just east of the eastern edge of the intact, buried bonebed, suggesting that their location may in fact accurately reflect the original extent of the Agate Basin occupation.

The distributions of flaking debris and burned rocks differ from that of the bone (figure 3.17). Flaking debris occurs primarily well north of the bonebed, in two east-west strips about 10 m apart that parallel the modern topography. The northernmost strip also contains a concentration of burned rocks. Ahler and Crawford (2003a) argue that these linear arrangements were produced by wave action as the lake was receding in 2000. Both patinated and unpatinated KRF flakes occur in these strand lines, suggesting that the artifacts comprising them date to several different time periods, from Paleoindian to Late Prehistoric. However, patinated KRF artifacts also occur in post-Paleoindian contexts

Figure 3.16. Photograph of bone fragments on the surface.

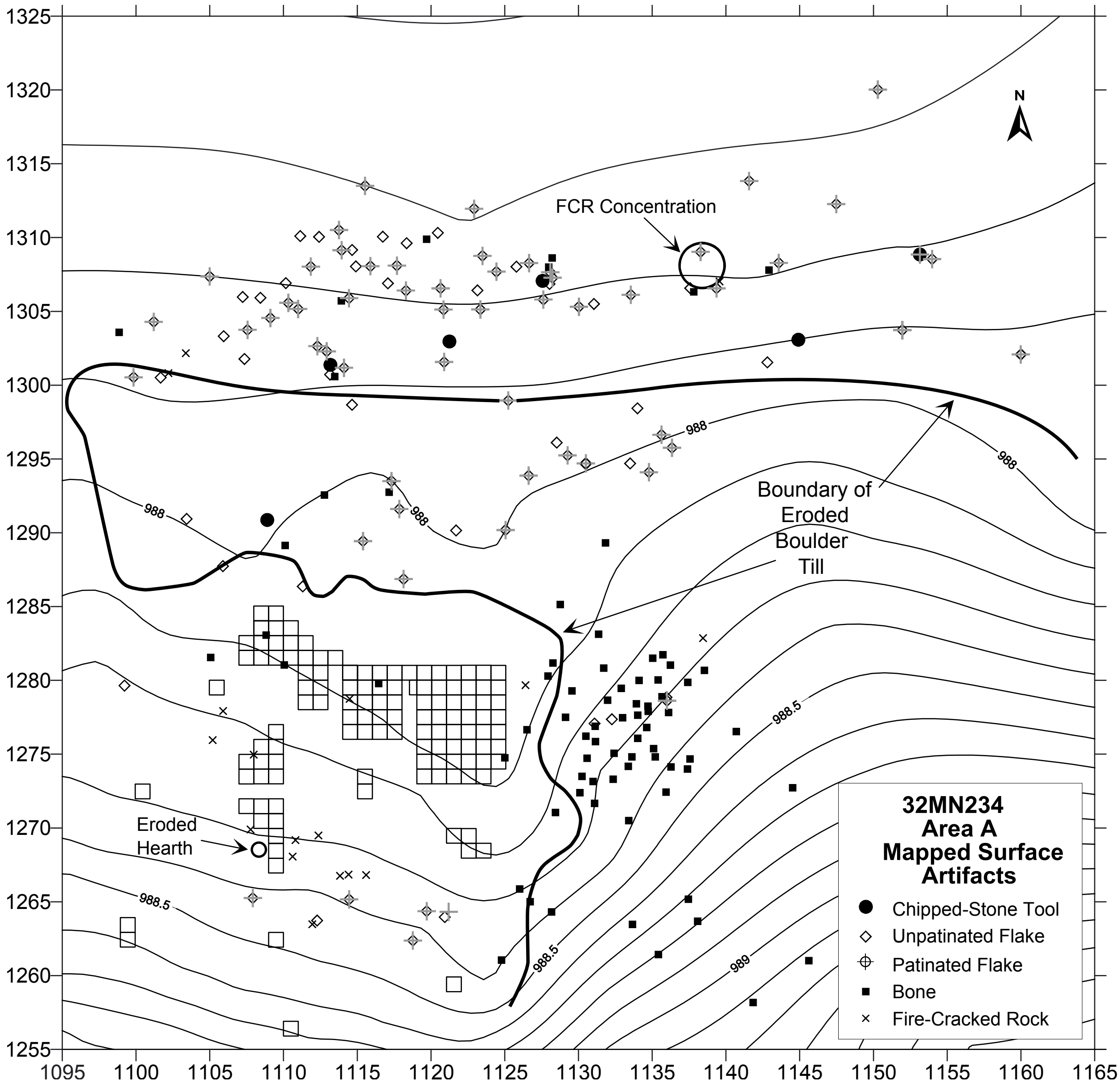


Figure 3.17. Map showing the distribution of bone, modified stone, and burned rock on the surface of Area A.

at Beacon Island: about 15 percent of the flaking debris recovered from Riverdale Member excavation contexts exhibits some degree of patination, as does a little more than 25 percent from Pick City Member contexts. This suggests that patination alone is not a clear indicator of great antiquity.

Only four items made from Antelope Chert, a raw material that may be an index for the Agate Basin component (see chapter 6), occur in the surface collection. One of these is a nodule of stone located just 5 m north of a sizeable concentration of Antelope Chert flakes, cores, and tested cobbles directly associated with the bonebed. Another is a size grade 2 flake located about 4 m northwest of the concentration. The other two items were recovered 15 and 20 m to the north, respectively, in the northern strand line. While there is no definitive way to gauge the original extent of the Agate Basin component, if one uses the distributions of surface bone fragments and Antelope Chert artifacts as a rough guide, the occupation may once have covered around 1600 sq. m.

A small cluster of patinated and unpatinated KRF flakes also occurs on the surface south of the bonebed, where they are associated with a number of burned rocks, including a 90 x 65 cm concentration of such rocks interpreted as a partially eroded, Archaic-age hearth. As discussed later, in the Holocene Components section, there is evidence for one or more buried components overlying the Agate Basin bonebed in this part of Area A. Taken together, these findings suggest that many of the chipped stone tools and pieces of flaking debris recovered by controlled surface collection in May 2002 derive from components more recent in age than the Agate Basin bonebed.

The research team also collected 80 pieces of flaking debris and nine stone tools from lakebed gravels overlying intact Oahe Formation sediment. One of the tools comes from 1308NE1055 (not shown on figure 3.17), well away from the remnant area of Aggie Brown Member sediment containing the Agate Basin component. Three tools were recovered from directly above the bonebed. One is a fragment of an expedient biface made from gray quartzite, a material not present in the Agate Basin assemblage. Anoher is the distal end of an Agate Basin point made from Antelope Chert, recovered from square 1274NE1121. The third is also an Agate Basin point fragment from the eroded surface of the bonebed in square 1278NE1121.

The remaining five tools were recovered from widely scattered locations. They include two Folsom point fragments, one from the beach ridge south of the preserved remnant of Aggie Brown Member sediment and one from eroded till or lakebed sediment on the northeast edge of the island, a portion of the site designated Area P. Two others are more-recent projectile point fragments, one from Area P and one from the eroded till some 65 m north of the excavation blocks. No provenience data are available on the last item, a patterned flake tool (scraper) exhibiting bipolar recycling.

Three pieces of flaking debris come from the surface of the isolated test unit at square 1308NE1055. Thirty others come from the scattered 1 x 1 m and 1 x 2 m test units located west and south of area where the Agate Basin component is exposed on the surface. A portion of these likely derive from the early Holocene component in this area, represented by the surface hearth and by subsurface artifacts and features identified during the excavation, which are discussed in the next section.

The remaining 47 flakes recovered from lakebed sediment come from directly above the bonebed. Forty-one of the 47 flakes are made from KRF, half of which are patinated. Most of these exhibit moderate to pronounced patination. It therefore seems likely that the majority of these items derive from the bonebed itself.

These surface data confirm evidence previously obtained from other parts of the island showing that the Little Knife River confluence was occupied repeatedly over many millennia and, moreover, that archaeological deposits dating to many different periods were once preserved there. However, they also suggest that the Agate Basin component probably did not extend north much beyond the 1295 north grid line or east beyond the 1140 east grid line (figure 3.17). Additional data on the surface collection of stone tools and flaking debris can be found in chapter 6.

## Holocene Components

Buried cultural materials post-dating the Agate Basin component occur in two parts of Area A. One is well north and west of the bonebed. There, a single 1 x 1 m excavation unit (at square 1308NE1055; not shown on figure 3.5) exposed a relatively complete section of the Oahe Formation containing at least two discrete Holocene-age components. The upper 30 to 35 cm of the unit consists of fine to very fine, laminated and unlaminated lakebed deposits (figure 3.18). Beneath this recent sediment lies a well developed soil formed in Riverdale and Pick City Member sediment. About 45 cm of the Riverdale Member is preserved. Clayton and others (1976) suggest that the Riverdale usually is about 1 m thick. In Area F at Beacon Island, located roughly 450 m south of Area A, about 70 cm is preserved (Ahler and Crawford 2003b). Riverdale Member sediment exposed in 1308NE1055 may therefore represent only the lower half. Clayton and others (1976:7) define the lower part of the Riverdale as the Thompson paleosol, which began forming during Middle Archaic times.

Beneath the Riverdale Member is just over 1 m of Pick City Member sediment. This is 15 or 20 cm thicker than the section of the Pick City exposed in Area F and some 70 cm thicker than in other parts of Area A where the Riverdale-Pick City contact is preserved. Excavation in 1308NE1055 ceased at the top of the Aggie Brown Member, which lies nearly 2 m below the modern surface. Coring through the floor of the unit revealed the presence of Mallard Island Member sediment and Lostwood Drift glacial till.

Flaking debris occurs throughout the section, but is concentrated in GLs 9 and 10 (987.08-986.88; SLs 30 and 31) in the Riverdale member and especially in GLs 18 and 19 (986.18-985.98; SLs 39 and 40) in the Pick City Member (figure 3.19). Based on its stratigraphic position, the upper component likely dates to the middle or late Holocene. It occurs at and below the base of the A horizon; if this indeed represents the Thompson soil, then the upper component likely dates to around 5000 B.P., or perhaps somewhat earlier. The lower component may date to the early Holocene. It occurs quite close to the base of the unit mapped in the field as the Pick City Member, which Clayton and others (1976) believe began accumulating around 8500 B.P. Note, however, that this lower component is associated with a series of weakly developed fossil A horizons. Elsewhere in Area A, the upper part of the Aggie Brown exhibits a similar

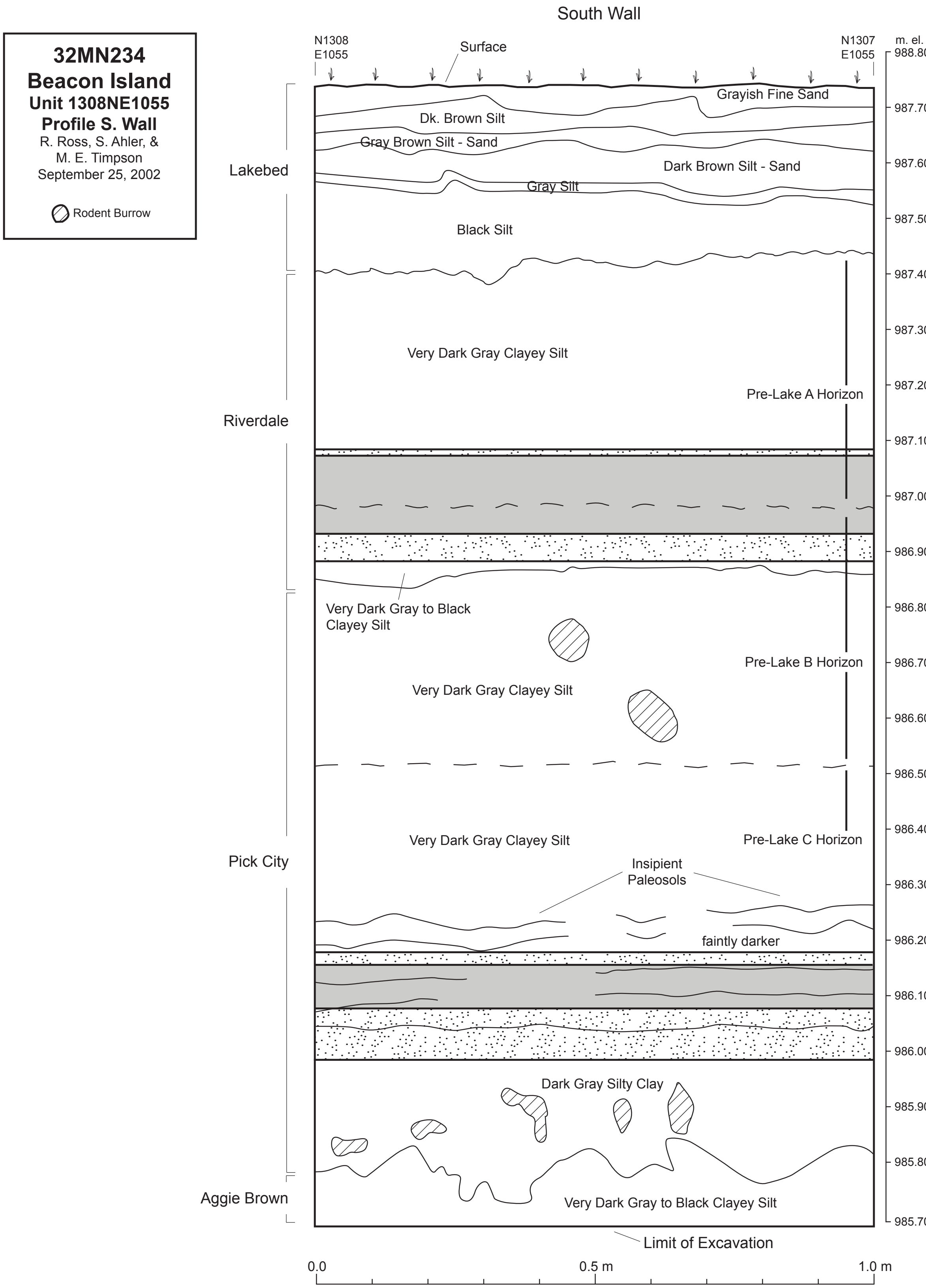


Figure 3.18. South wall profile of square 1308NE1055 showing upper and lower Holocene-age components. Stippled bands represent the upper and lower limits of the general levels included in each component; shaded bands represent the limits of plotted specimens.

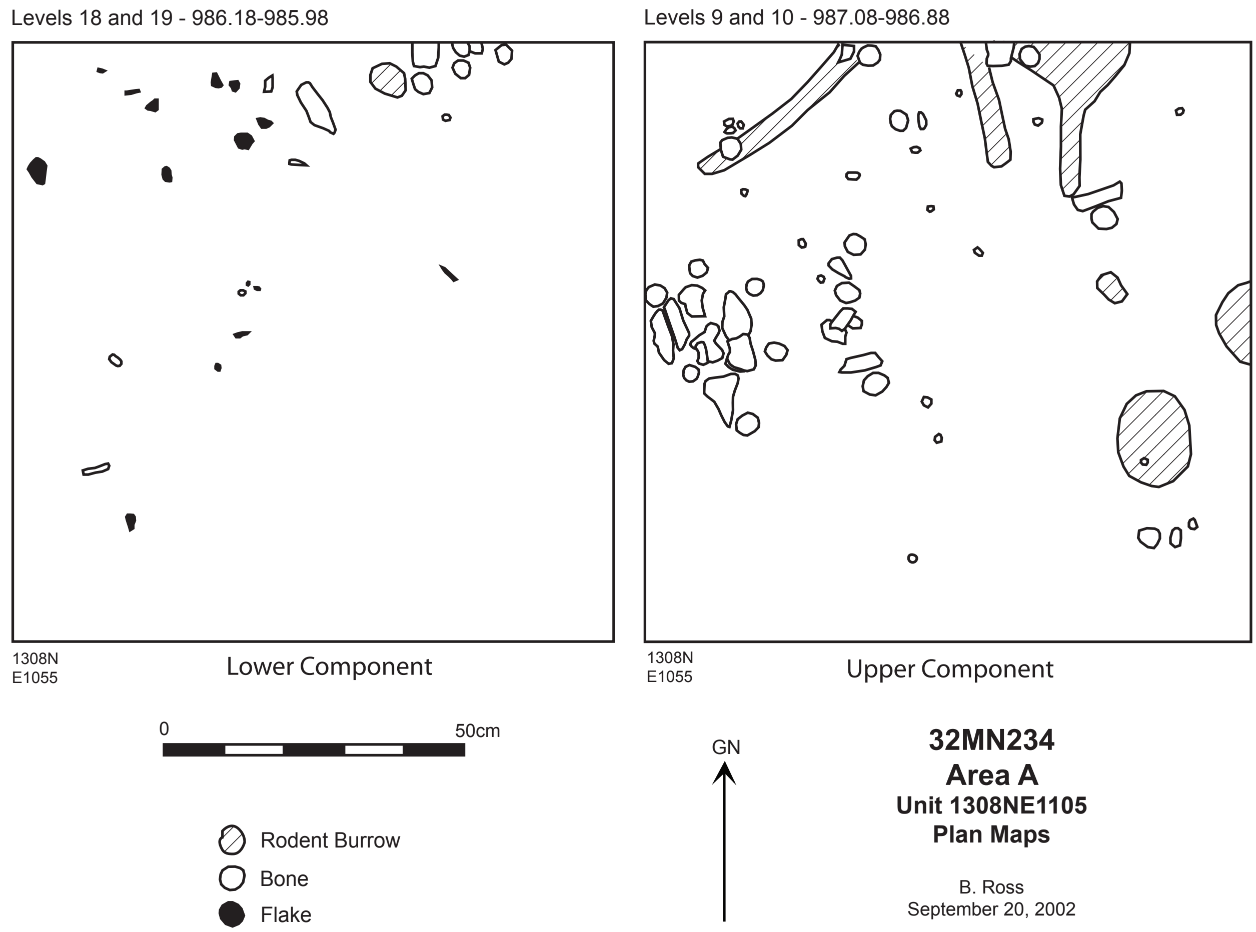


Figure 3.19. Plan maps of the upper (right) and lower Holocene-age components exposed in square 1308NE1055.

series of alternating lighter and darker bands produced by intermittent pulses of deposition. Thus, it is possible that the lower component in square 1308NE1055, while apparently more recent than Agate Basin times, could also be Paleoindian in age. Unfortunately, no diagnostic artifacts occur in either the upper or lower components and no associated radiocarbon dates are available.

Altogether, 914 flakes were recovered from this square, or just under one-third of all the flaking debris from Area A. Forty-four flakes, in size grades 3 through 5, occur in GLs 9 and 10 (the upper component), while 727, in size grades 2 through 5, occur in GLs 18 and 19. The density of flaking debris in the lower component is by far the highest documented anywhere in Area A. Five stone tools, all made from KRF, were recovered from excavated contexts in 1308NE1055, three of which come from the lower component. Burned rock is present in both components, though the largest single burned stone comes from GL 11, slightly below the plotted bones in the upper component. Together, just less than 40 percent by weight of the burned rock from all Riverdale and Pick City member contexts in Area A comes from 1308NE1055.

Bones are present in both components. Fifteen plotted bison bones occur in GL 9 and GL 10 (with a mean elevation of 987.00), while ten occur in GL 18 and GL 19 (mean elevation 986.11). Bone fragments sorted from waterscreen lots occur in both components, but are particularly abundant in the lower. In fact, bone fragments are more common by weight in the lower component in 1308NE1055 than they are in Riverdale Member or Pick City Member sediment anywhere else in Area A. Burned bone does not occur in the upper component, but both burned and calcined fragments are present in the lower.

These data, particularly the high density of flaking debris associated with the lower component, suggest that this part of Area A preserves a very significant record of early Holocene use of the region. Apart from this finding though, data from 1308NE1055 also have implications for the interpretation of the Agate Basin component. In this unit, the top of the Aggie Brown Member lies at about 985.80, more than 2 m below the top of the

Aggie in the eastern kettle basin, where the Agate Basin component occurs. This elevation difference indicates that the sequence exposed in 1308NE1055 lies in a topographic feature entirely separate from that preserved in the eastern part of Area A. Very likely, this feature is an adjacent kettle basin, the floor of which is 2 m or more lower than the floor of the basin containing the Agate Basin component.

The Riverdale and Pick City members also directly overlie a portion of the Agate Basin component (figure 3.20). On the north and east only the lowest decimeter or so of the Pick City Member is preserved, but on the south and west as much as 40 cm is preserved. The difference is due to the fact that the modern surface rises, and the Aggie Brown Member dips, to the south. Evidence for an intact occupation level in this part of Area A comes from four scattered excavation units (squares 1253NE1096, 1256NE1110, 1262NE1099, and 1262NE1109). Data from square 1256NE1110 presents the clearest picture. In GL 4 of that unit (988.45-988.35; SL 16/17), the excavators encountered burned rocks and charcoal-stained soil (figure 3.21). They plotted one size grade 4 flake in this level and four size grade 5 flakes were sorted from screened sediment. No bone was plotted in this level, but roughly 30 g of bone scrap was sorted from the level lot, or about 5 percent by weight of all the bone fragments recovered from Pick City Member contexts.

Three more flakes and a single stone tool were recovered in each of the next two levels (GL 5 and GL 6). However, both stone tools are made from Antelope


Figure 3.20. Map of Area A showing the estimated extent of preserved Pick City Member sediment.

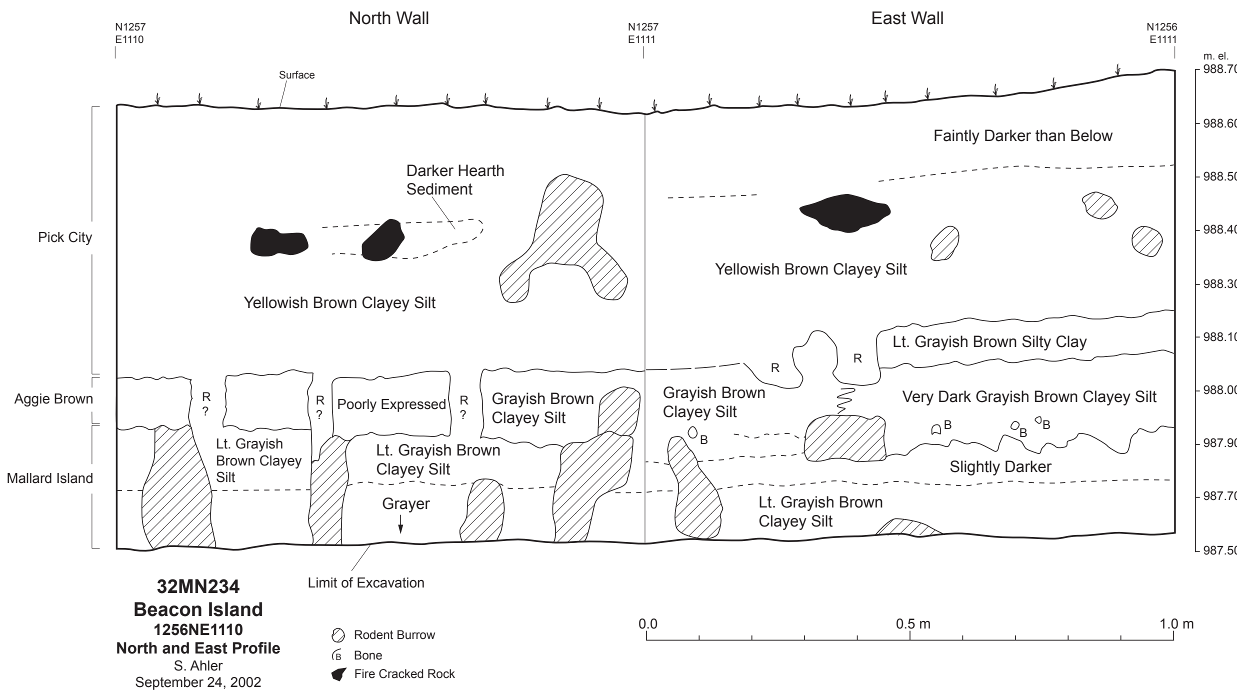


Figure 3.21. North and east wall profiles of square 1256NE1110.

Chert, a material that commonly occurs in the Agate Basin component but appears to be very rare or absent in more recent deposits. The excavators observed fragments of burnt bone in GL 5, though they appeared to be associated with krotovina. A small patch of Aggie Brown sediment was noted on the east side of the unit. In fact, GL 6, though nominally assigned to the Pick City Member based on measured profiles, may span the boundary with the Aggie Brown; the excavator noted patches of Aggie Brown Member sediment throughout the unit at this level. Nevertheless, the presence of the hearth in this excavation square clearly indicates that this part of Area A was also occupied subsequent to Agate Basin times, probably in the early Holocene judging by the hearth's stratigraphic position.

No evidence of other features was observed in Pick City Member sediment in the other three units in the southwest part of Area A (1253NE1096, 1262NE1099, and 1262NE1109). However, flaking debris, bone pieces, and burned rocks are present in each. In 1253NE1096, 20 flakes were sorted from screened sediment from three levels assigned to the Pick City Member, ranging in elevation from 988.69 to 988.29 (SLs 14 through 17). Thirteen of these come from SL 14. Another 22 flakes were recovered from three levels assigned to the Pick City Member in 1262NE1099 (988.21-987.91). One of these (from GL 7, 988.11-987.98; SL 20) is made from Antelope Chert, again suggesting that burrowing animals may have transported some items upward. Nine more flakes come from three levels in 1262NE1109 (988.47-988.10); six of these specimens fall into size grades 2 or 3. Just one stone tool, a biface fragment made from KRF found in 1262NE1109 (GL 2, 988.47-988.30; SL 16/17), is associated with these deposits. A moderate amount of fragmented bone, amounting to about 20 percent by weight of the bone recovered from waterscreen lots assigned to the Pick City Member, was recovered from these three units. Most of this comes from 1262NE1099. Burned rock is largely absent.

In sum, data from these four scattered units indicate that an early Holocene-age occupation overlies the southwestern extent of the Agate Basin component. Together, flakes from these four units amount to roughly 41 percent of the 156 flakes recovered from Pick City Member sediment in the eastern kettle basin. These units also contain about 45 percent by weight of the bone fragments and 82 percent by weight of the burned rock (nearly all of which occurs in 1256NE1110, the square containing the hearth). Much of this material occurs at an elevation of around 988.40, which is approximately the same elevation as the partially eroded hearth documented on the surface slightly to the north (figure 3.17).

These materials can only be described as sparse. The hearth documented in 1256NE1110 notwithstanding, this occupation is not likely to contribute significant information about the prehistory of the region, particularly in view of the possibility that some of the items assigned to this Pick City-age component may have been displaced upward from the Agate Basin component.

Artifacts and bones also occur in Pick City Member sediment directly overlying the densest part of the Agate Basin bonebed. These include five plotted bison bones (four of which come from just above the bonebed in 1274NE1109 [GL 3; 988.10-988.00]); 92 flakes; ten stone tools; and a light scatter of bone fragments. However, the distributions of these items do not suggest the presence of an intact occupation zone. No features were documented and many of these items may have been displaced upward. Additional data on the faunal specimens, flaking debris, and stone tools recovered from Pick City and Riverdale contexts are presented in chapters 5 and 6.

**Agate Basin Component**

To facilitate discussion of the Agate Basin component, the main excavation area is partitioned into four multi-unit blocks, each designated by their cardinal or semi-cardinal positions (figure 3.22). The largest block, consisting of 48.5 contiguous excavation squares, is designated the northeast block (figure 3.23). The densest mass of butchered bone occurs in this block. The north block, made up of 20 contiguous squares, is separated from the northeast block by a 1-m-wide, north-south balk. The northwest block, a somewhat irregular, stair-stepped arrangement of 23 excavation squares, also contains a dense scatter of butchered bone. The west block is made up of seventeen units, separated into two sub-blocks by an east-west balk (figure 3.24). Isolated 1 x 1 m excavation units are referenced in this discussion by their southwest corner coordinates.

Topography of the Ancient Landscape and Extent of Intact Agate Basin-Age Deposits

Roughly 800 to 850 sq. m of Aggie Brown Member sediment is preserved in the eastern kettle basin in Area A (figures 3.4 and 3.20). On the north and east, only a thin remnant remains but about 70 cm is preserved near

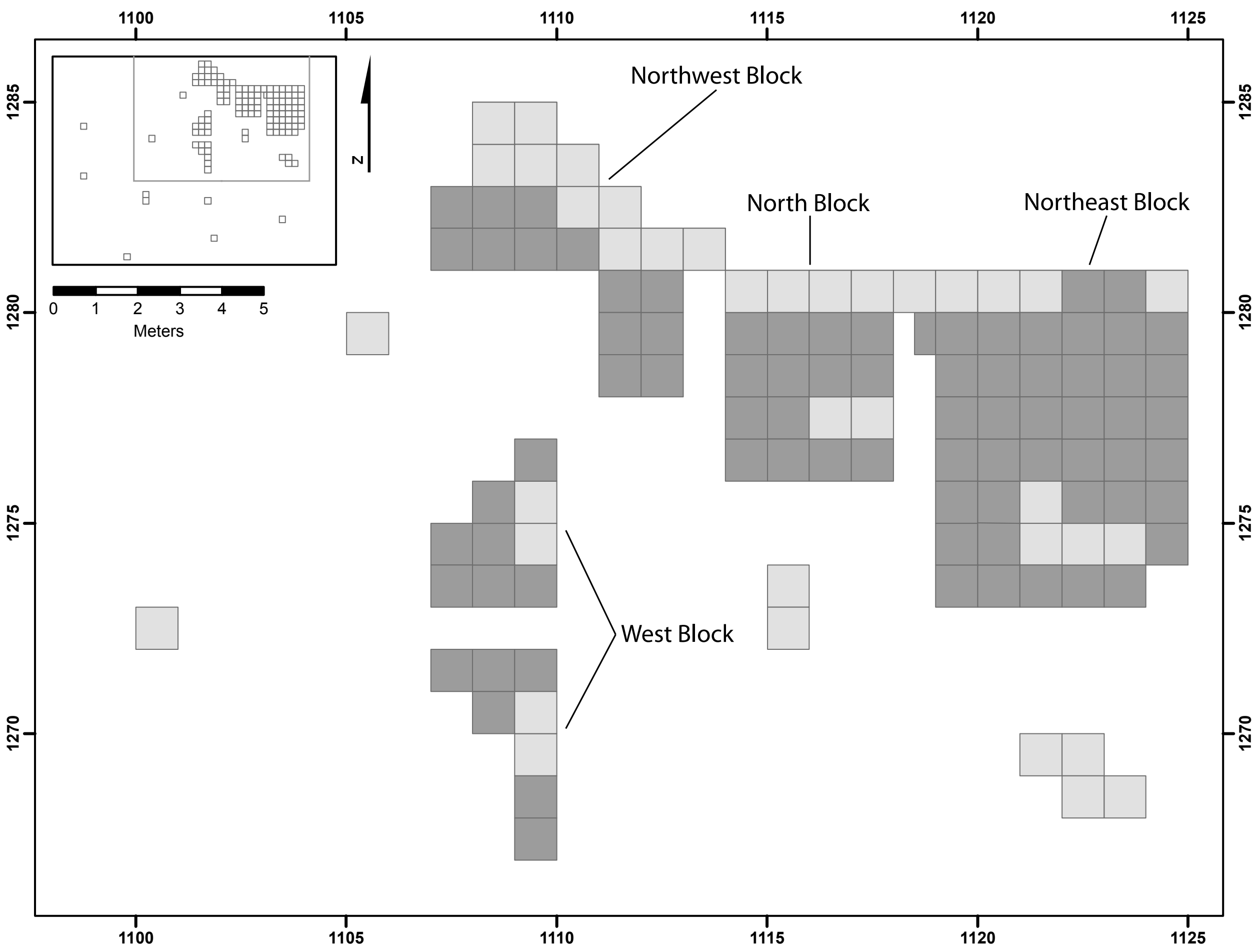


Figure 3.22. Plan map of the four major excavation blocks in Area A. Light shading indicates units excavated in 2002.

Figure 3.23. Excavation in progress in the northeast block. View to the southwest.

Figure 3.24. Excavation in progress in the west block. View to the south-southwest.

the center of the basin, adjacent to square 1272NE1110 in the west block. The Aggie Brown is somewhat thinner in the southwest part of the basin, ranging in thickness from 30 to 40 cm. Data from test units scattered around the basin provide information on the spatial limits of intact Aggie Brown Member sediment as well as on the basin's size and morphology and the position of the Agate Basin occupation within it.

Stratigraphic data from two 1 x 1 m units on the west side of the eastern kettle basin demonstrate that there is a definite western edge to Aggie Brown Member sediment, likely created by ancient landscape erosion. In squares 1266NE1089 and 1274NE1089, Riverdale Member sediment lies unconformably on Mallard Island Member sediment, indicating that both the Pick City and Aggie Brown were stripped away by slope wash or wind erosion (figure 3.25) (Ahler, Crawford, and Timpson 2002). Conceivably, the upper portion of the Mallard Island Member may also have been removed by erosion. The timing of this erosion event is uncertain because it is not known whether the preserved section of the Riverdale Member represents the upper or lower submember, both of which show evidence of soil formation (Clayton, Moran, and Bickley 1976). In any case, these data suggest that recent wave action is not exclusively responsible for the removal of Oahe Formation sediment in Area A; instead a portion may have been stripped away in the middle to late Holocene (cf. Coogan 1983, 1987).

In addition to bracketing the western limit of the Agate Basin component, data from these two units provide information about the morphology of the kettle basin. The section exposed in each shows that the remnant upper surface of the Mallard Island is at least 60 to 95 higher than it is in the apparent center of the basin, indicating that both units lie on the basin's western slope.

Most of the Oahe Formation has eroded away south and west of the beach ridge marking the nominal southern boundary of Area A. An isolated 1 x 1 m unit on the west end of the ridge (at 1238NE1077) exposed Mallard

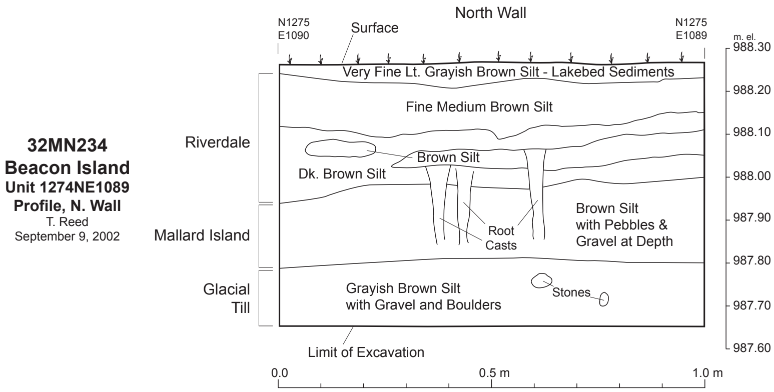


Figure 3.25. North wall profile of square 1274NE1089.

Island sediment outcropping at the surface (figure 3.5). No artifacts or faunal remains were recovered from this unit. A second square on the crest of the beach ridge (at 1247NE1108) exposed 35 to 40 of very dark gray silt interpreted in the field as the Aggie Brown Member (Spurr, Nickel, and Ahler 2007). Three KRF flakes were recovered from this unit, two in lakebed sediment in SL 12/13 (988.88-988.70) and one in SL 16 (988.49-988.40), near the top of the Mallard Island Member. As is the case in the two westernmost test units the upper surface of the Mallard Island lies at about 988.40 in square 1247NE1108, indicating that this unit falls on the southern slope of the kettle basin. Given the similarities between this unit and the two westernmost units, the very dark gray silt layer exposed in it may represent one of the submembers of the Riverdale, rather than the Aggie Brown.

The southeastern limit of Aggie Brown Member sediment was observed in square 1259NE1121. A thin wedge of Aggie Brown, no more than 6 cm thick, was exposed in the northwest corner of that unit, directly beneath a layer of lakebed sediment. Continued excavation exposed roughly 55 cm of Mallard Island sediment, underlain by till. The preserved upper surface of the Mallard Island Member lies at 988.40 in this square, an elevation similar to that observed in 1247NE1108 on the south and 1266NE1089 on the west.

Data from square 1253NE1096 (figure 3.26) provides additional information about the morphology of the basin. The section exposed in this unit includes the Pick City, Aggie Brown, and Mallard Island members. The top of the Mallard Island lies at 987.95, well below the elevation observed in 1247NE1108, located just 13 m to the southeast, or in 1266NE1089, 15 m to the northwest. In square 1253NE1096, both the Mallard Island and the Aggie Brown members dip to the north

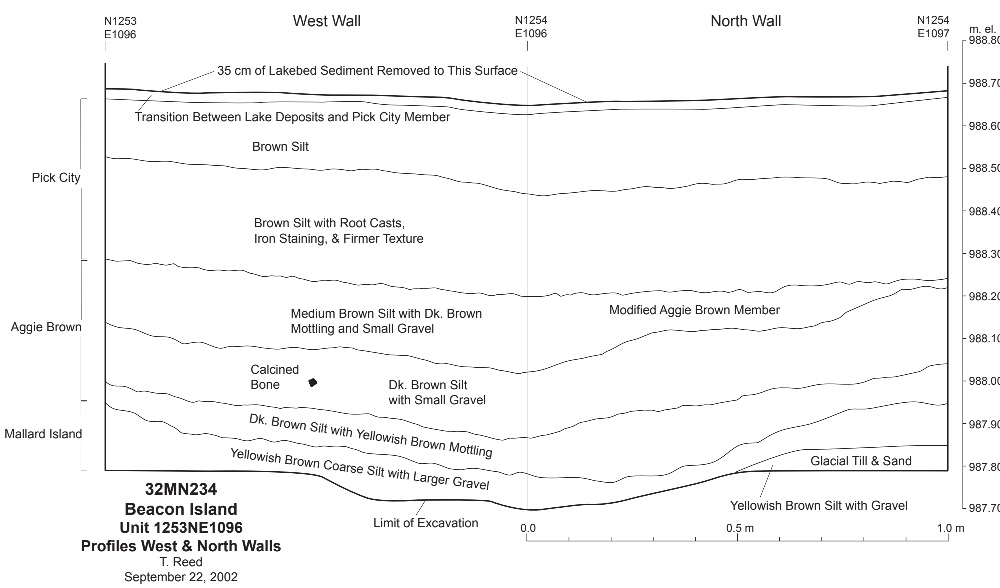


Figure 3.26. West and north wall profiles of square 1253NE1096.

and west, filling what appears to be a shallow channel cut into the underlying till. Flaking debris, along with two burned Agate Basin point fragments, were sorted from waterscreen samples recovered from these channel fill deposits. Bison bones were also recovered from these strata, many of them burned. However, the character of the bones from this unit is markedly different from that of the bones recovered from all other parts of the Agate Basin component. They are denser and more darkly stained and so initially were interpreted as having been burned. However, further examination suggests that many are in fact partially mineralized, possibly due to burial in saturated sediment. These data suggest that the shallow channel exposed in 1253NE1096 drained the kettle basin containing the Agate Basin component into another, lower basin, likely located to the south. Note, however, that the base of this channel is higher than the floor of the basin, indicating that water periodically pooled there.

Figure 3.27 summarizes data on the elevation of the upper surface of the Mallard Island Member observed in various excavation units. The highest elevations occur on the east, west, and south. The lowest elevation, representing the floor of the kettle basin, occurs at about 1271NE1110. From this it is clear that the Agate Basin component spreads across the floor as well as the north and east slopes of the pothole. The bonebed itself lies mainly on the slopes, but the elevation difference

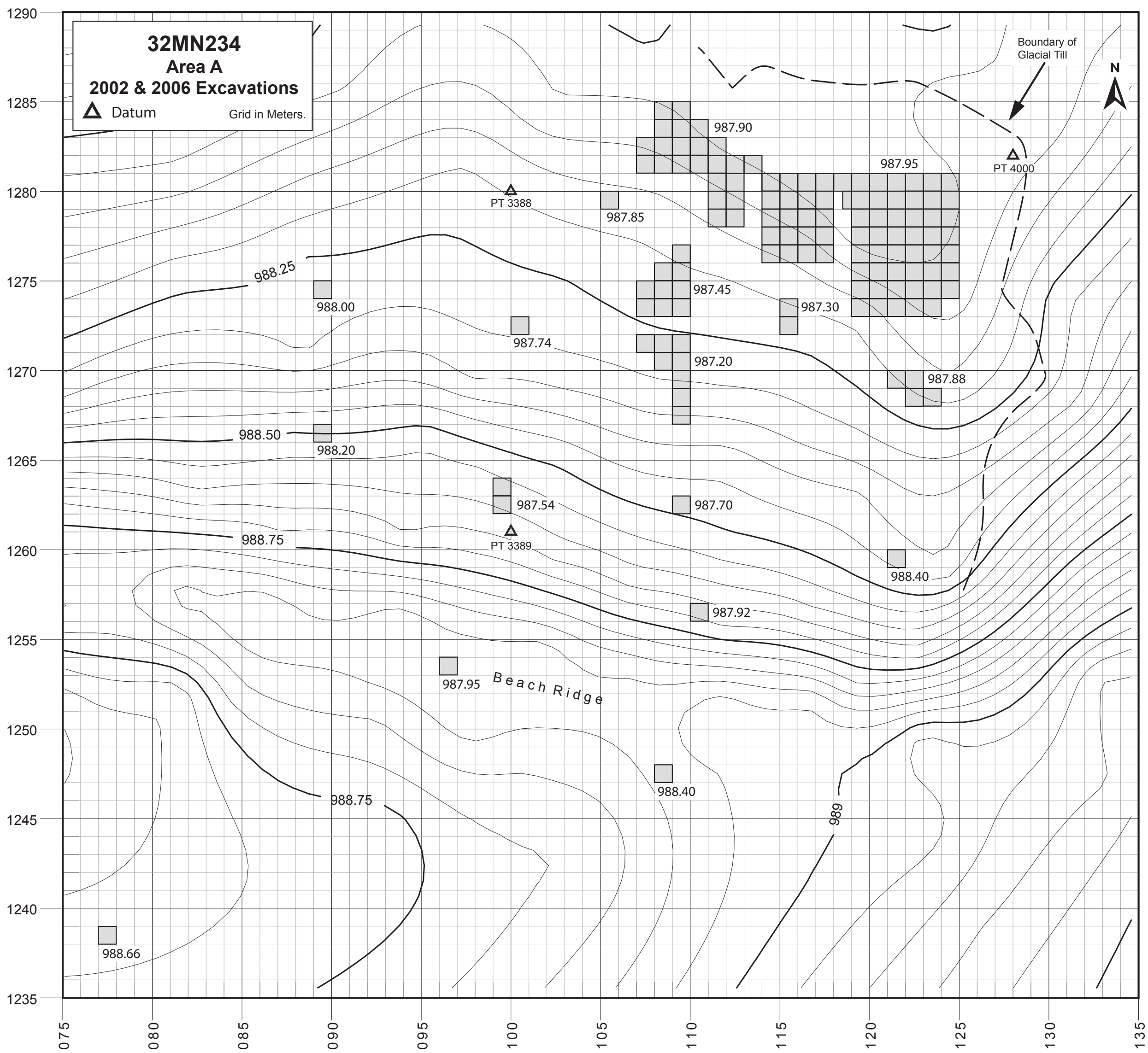


Figure 3.27. Elevations of the top of the Mallard Island Member observed in excavation units in the eastern kettle basin.

between the floor of the basin and the highest part of the preserved bonebed is just 50 to 60 cm. (Additional data on the topography of the bonebed are presented later in the chapter). The original maximum depth of the pothole cannot be determined from the data currently available, but the distribution of till to the north and east suggests that it may have been just a few meters deep during Paleoindian times. In any case, the basin containing the bonebed appears to have been just one of several adjacent basins of varying depth that were separated by low sills or connected by intermittent channels. Again, stratigraphic data from 1253NE1096 suggests that another, deeper basin is located to the south. Data from 1308NE1055 (discussed previously in the Holocene Components section) demonstrates that a third basin, at least two meters deeper than the basin containing the Agate Basin component, is located to the northwest. Coring revealed that a basin is located roughly 40 m west of the bonebed (Ahler and Crawford 2003a; Timpson 2003), and this may be the same feature encountered in 1308NE1055.

Figure 3.28. Photograph of the west wall of square 1278NE1119. The Agate Basin component occurs in the dark layer in the center of the image.

Stratigraphic Position of the Agate Basin Component

The stratigraphic position of the Agate Basin component can be defined relative to the lithostratigraphic units of the Oahe Formation as well as to local soil horizons (see chapter 2 for detailed discussions of the geology and pedology of Area A). Descriptively, the Agate Basin component is contained within a black to very dark gray silt loam (figure 3.28). Many excavators describe this layer as "sticky." Some report observing a few rounded pebbles within it. In most places, this dark layer is underlain by an olive brown to dark olive brown silt loam. Some excavators describe this underlying unit as coarser, an observation confirmed by textural analysis (chapter 2). In other places, these two units are separated by a "transitional" zone that exhibits properties both of the dark layer and of the underlying olive brown layer.

In terms of lithostratigraphic units, the Agate Basin component occurs at or near the base of the Aggie Brown Member (figure 3.29). Recall from chapter 2 that Clayton and others (1976) initially defined the Oahe Formation based on their analysis of loess deposits at the Riverdale section, located on the left bank of the Missouri, some 140 km downstream from Beacon Island. Later, recognizing that the color differences used to define the units of the Oahe Formation could be traced laterally into lithologically distinct strata, Clayton and Moran (1979) redefined the Oahe Formation to include all material above the Quaternary Coleharbor Group. The properties of the Aggie Brown Member at Beacon Island differ from those at the Riverdale section. At Beacon, the Aggie Brown consists of re-worked loess, including slopewash, eolian, and pond deposits, rather than primarily eolian sediment. At the Riverdale section, the Aggie Brown Member varies from 10 cm to 50 cm thick but at Beacon Island it is up to 70 cm thick. Finally, Clayton and others' (1976:5) original description split the Aggie Brown into two submembers, the lower of which is generally light brown and redder than any other part of the Oahe Formation. This lower submember is not present at Beacon Island.

Beneath the Aggie Brown is the Mallard Island Member. Clayton and others (1976:9) argue that the top of the Mallard Island represents the end of Late Wisconsinan glaciation. Haynes (2008:6523) suggests that the Aggie Brown lies unconformably on the Mallard Island and that the upper part of the Mallard may preserve the Bw horizon of a soil that formed before the onset of the Younger Dryas. As discussed in chapter 2, micromorphological analysis is needed to determine whether the upper surface of the Mallard Island represents a truncated paleosol.

The character of the sediment containing the Agate Basin component at Beacon Island is determined primarily by soil horizonation that has partially obscured the boundaries between the lithostratigraphic units of the Oahe Formation. The dark layer containing bison bone and artifacts represents the A horizon of a well-developed soil that began forming shortly after the initial deposition of the Aggie Brown Member. In Area A, this horizon is generally about 10 to 15 cm thick, but in places can be up to 20 cm thick. Following a period of landscape stability represented by this soil, deposition of Aggie Brown

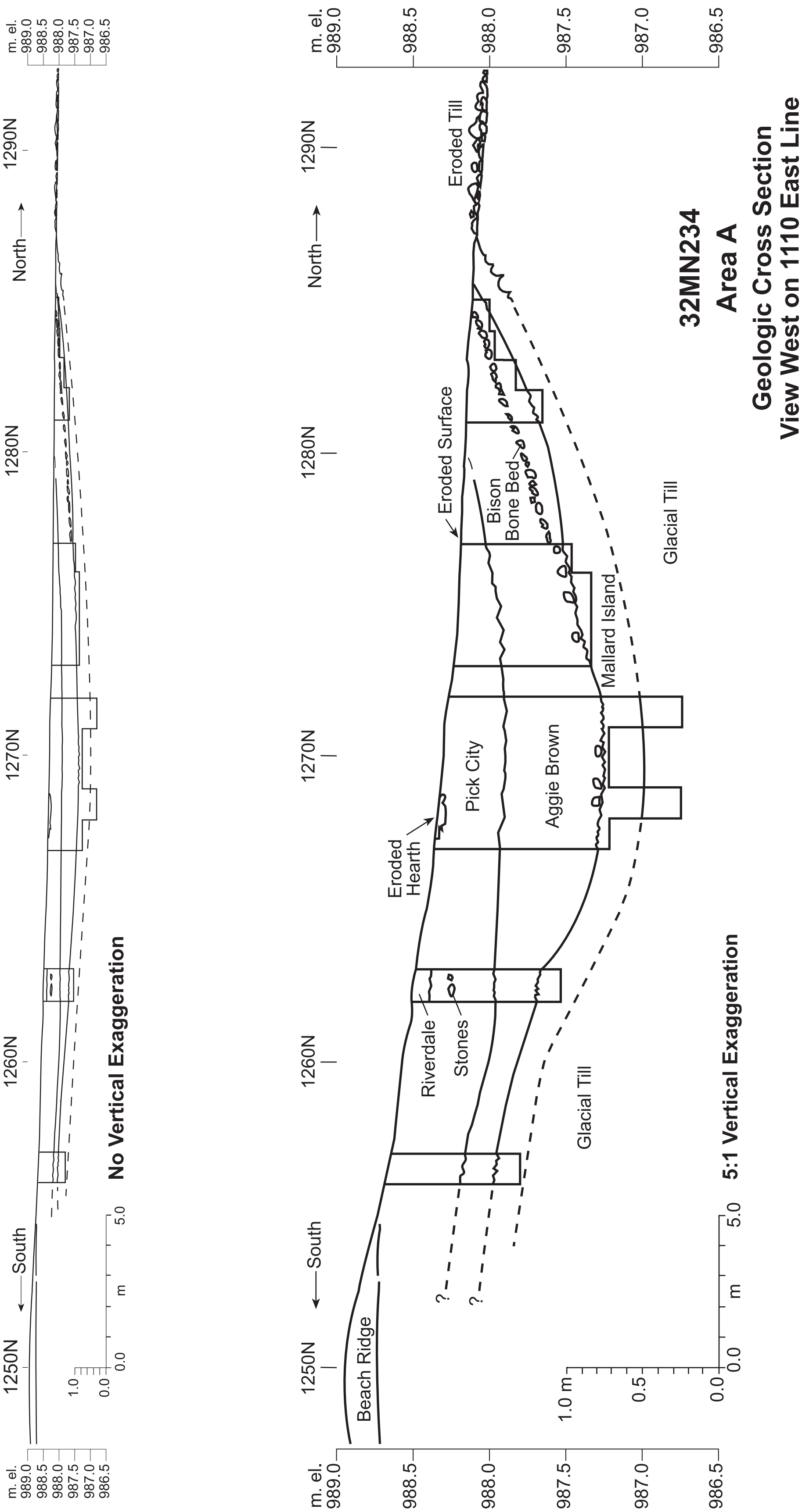


Figure 3.29. Geologic cross-section of Area A.

Member sediment resumed, resulting in the formation of a cumulic soil. Near the center of the kettle basin, where deposition may have occurred somewhat more rapidly, the upper part of the Aggie Brown exhibits alternating light and darker bands (figure 3.30). The lighter bands represent wetter periods, during which sediment accumulated more rapidly, while the darker bands represent periods of surface stability during drier periods (chapter 2). Radiocarbon dates on sediment samples from the middle and upper parts of the Aggie Brown (reported in chapter 2), indicate that this punctuated, but generally slow, aggradation of the Aggie Brown Member continued until about 8000 B.P.

Toward the edge of the basin, the alternating light and dark bands are less pronounced and the Aggie Brown exhibits just one or two overthickened A horizons. For this reason, the designations given to the soil horizons containing the Agate Basin component differ from place to place across the site, depending on the position within the kettle basin (figure 3.31). On the slope of the basin, bone occurs within A horizon sediment, 10 or 15 cm above the Aggie Brown-Mallard Island contact (figure 3.32). On the floor of the basin, bone mostly occurs in a relatively thin AB horizon, on or just above the Aggie Brown-Mallard Island contact (figure 3.33). This AB horizon apparently is not expressed in every excavation unit. Periodic ponding within the basin may be partly responsible for determining the extent of this AB horizon, although it may simply be that it was not recognized as a distinct pedostratigraphic unit by all excavators, particularly during the early phases of the project in 2002.

Figure 3.30. Photograph of west wall of square 1271NE1107. The Agate Basin component occurs at the base of the cumulic soil.

The B horizon of the soil containing the Agate Basin component formed in Mallard Island Member sediment, as well as in underlying till. A small amount of bone occurs in the uppermost part of this B horizon. However, in virtually every case, artifacts and faunal remains recovered from beneath the A horizon were simply displaced downward, either by post-occupation trampling or by burrowing mammals or insects (see next section).

Though questions remain about the precise temporal relationship between the Agate Basin occupation and the onset of Aggie Brown Member deposition, it seems clear that the occupation occurred early in a period of relative landscape stability represented by the well-developed A horizon, known regionally as the Leonard paleosol, which formed during the Younger-Dryas climatic episode. Later, the rate of aggradation incresed slightly, resulting in the formation of a multi-storied cumulic soil in the upper portion of the Aggie Brown Member.

*Morphology of the Stratigraphic Contact Below the Bonebed*

As mentioned, the dark horizon containing the Agate Basin component is underlain by a distinctly lighter stratum. While these two layers exhibit clear color (and textural) differences, the contact between them is complex and its morphology varies across the kettle basin. In most places, the contact is gradual, reflecting its pedogenic origin. On the slopes of the kettle basin, it is generally depicted in small-scale block profiles as smooth, rising uniformly to the north and west in the northeast block and to the north in the north block and in the northwest block. At a larger scale, as seen in plan view in individual excavation units, the contact can be described as wavy. In many units in the northeast and north blocks, excavators note that small pockets of dark sediment, often containing bone fragments, extend several cm into the underlying lighter-colored stratum (figure 3.34). On the floor of the basin, the contact is even more irregular, exhibiting a series of narrow, closely spaced depressions, ranging in depth from 10 to 15 cm.

A number of relatively large depressions also were observed on the slope of the basin. A particularly large pit occurs in the southeast corner of the north block, in square 1276NE1117 (figure 3.35). In the southeast corner of that unit, dark silt laom extends at least 54 cm into lighter, sandier sediment. Judging by the block profile, the pit likely was around 80 cm in diameter. However, bison bones do not extend into the pit. A somewhat similar, though shallower, pit was observed in the southwest corner of square 1276NE1119 and northwest corner of 1275NE1119, on the west edge of the northeast block (figure 3.31). Given the proximity of these two

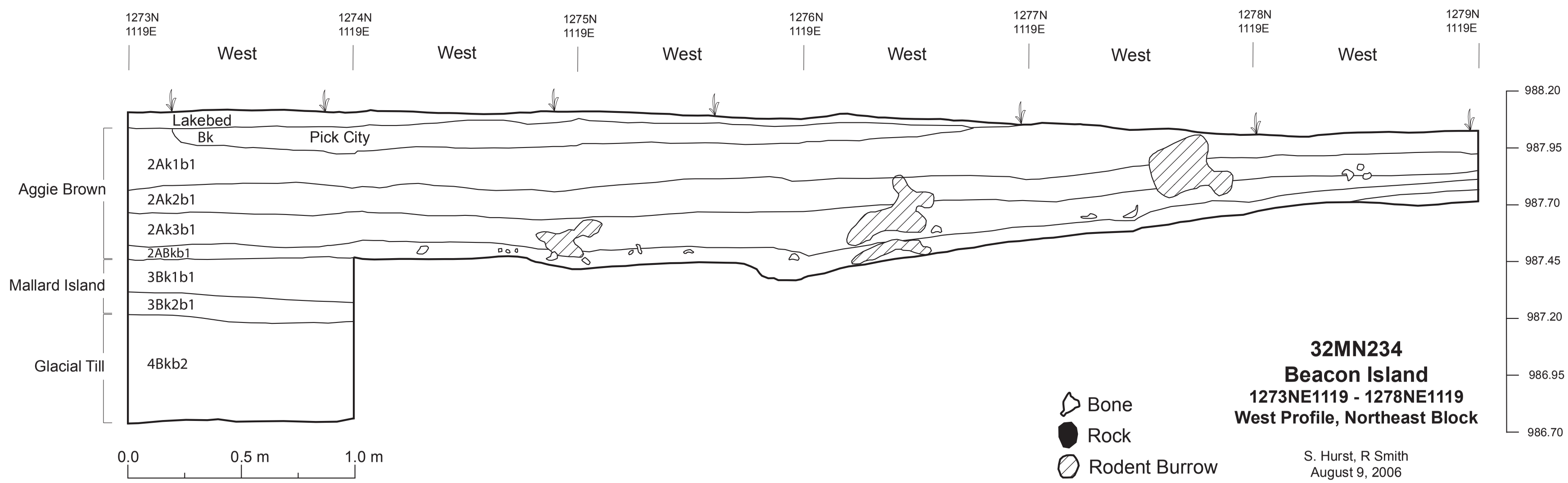


Figure 3.31. West wall profile of the northeast block. Table 2.5 gives descriptions of the strata.

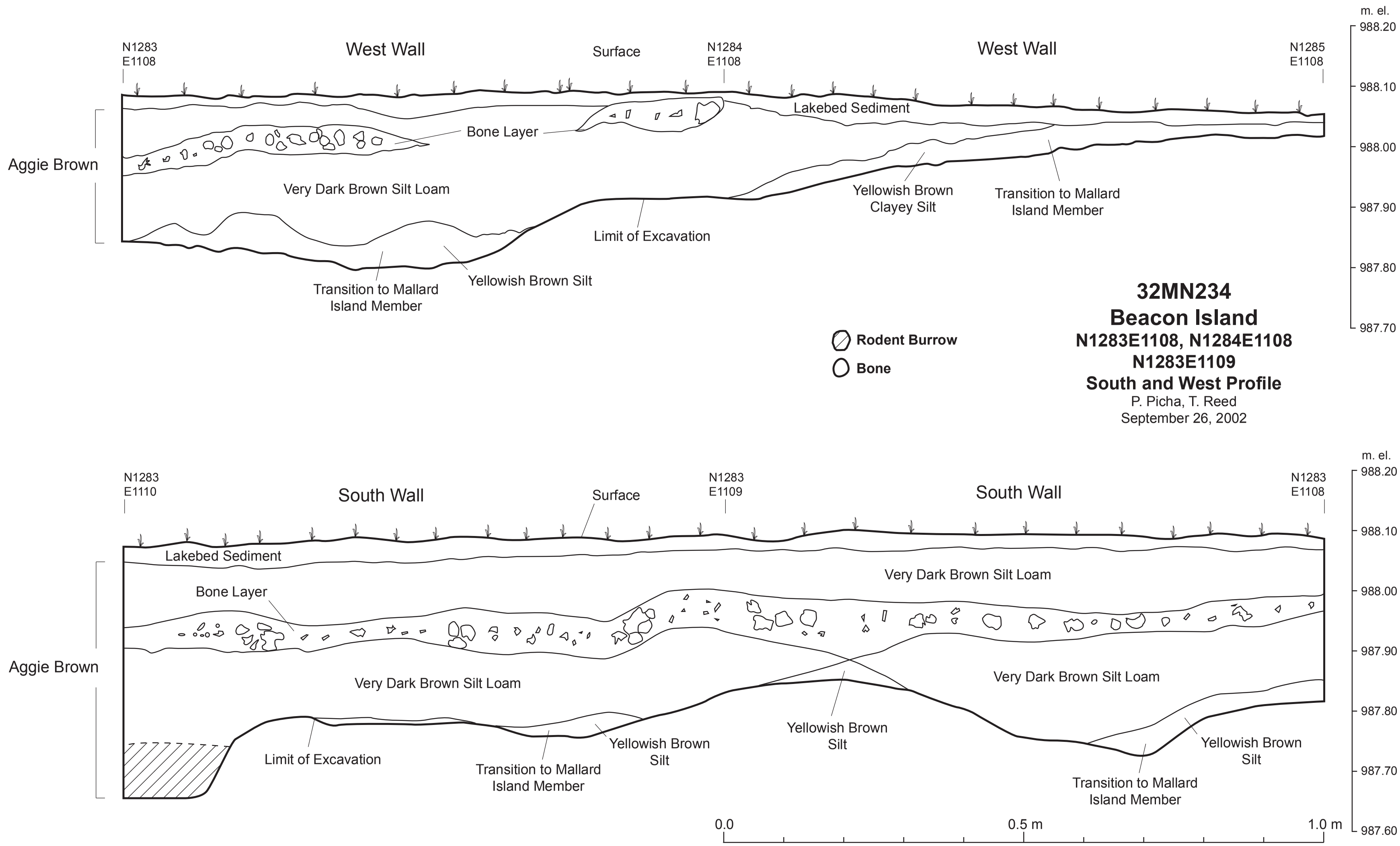


Figure 3.32. West and south wall profiles of squares 1283NE1108, 1283NE1109, and 1284NE1108 in the northwest block.

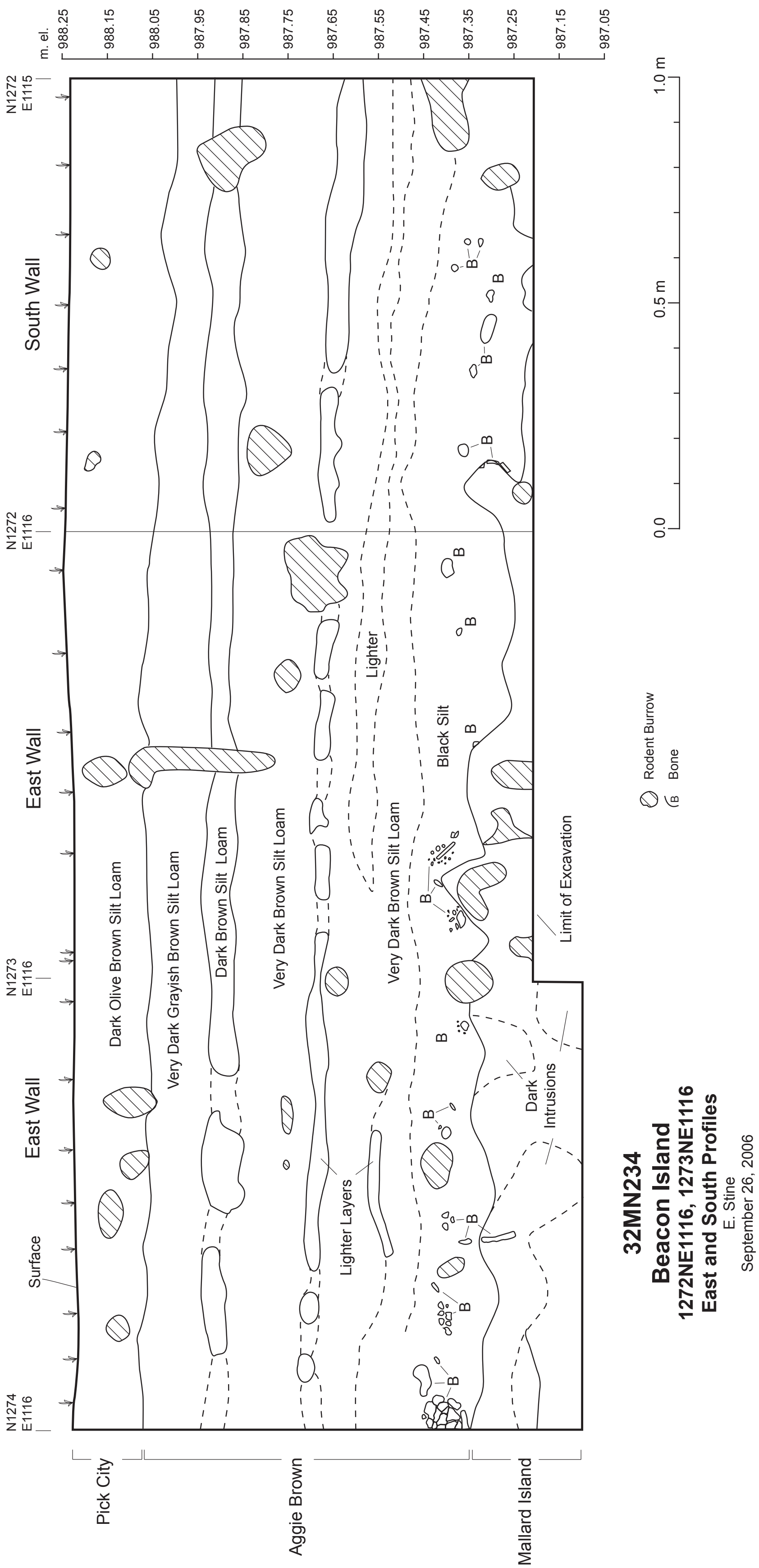


Figure 3.33. South and east wall profiles of squares 1272NE1115 and 1273NE1115.


Figure 3.34. Small pits and undulations in the upper surface of the Mallard Island Member.

pits, separated only by the 1-m-wide balk, they may in fact represent a single feature. However, bone fragments were found at the base of the pit in 1276NE1119, but not in 1276NE1117. Relatively large, deep pits were also observed on the north edge of the basin, in the northwest block (figure 3.32). However, as was the case in square 1276NE1117 in the north block, bone occurs above, not within, these depressions.

Several mechanical processes are responsible for shaping this contact. The most obvious, and most widespread, is burrowing by small mammals and insects. Animal burrows, filled with both lighter and darker sediment, run throughout the lower part of the Aggie Brown Member and the upper part of the Mallard Island (figure 3.36). The majority of these likely date to late Pleistocene or early Holocene times, though a number of more-recent burrows are evident as well. In square 1272NE1115, for instance, excavators observed both recent and ancient burrows in GL 6 and GL 7 (987.80-987.60; SL 23 and SL 24), some 30 or 40 cm above the bonebed. It seems likely that some of the burrows in the bonebed itself also are recent. Much older burrows were observed in Mallard Island Member sediment in square 1259NE1121. Given the density of burrows in the upper part of the major buried A horizon containing the bonebed, it is likely that much of this activity post-dates the Agate Basin occupation.

Cracks filled with overlying sediment, indicative of intermittent dry periods, were also observed in the excavation. They occur within the dark stratum containing the Agate Basin component, as well as in older and more recent strata. In square 1277NE1116, in the north block, a complex network of cracks, along with animal burrows, was mapped in GL 5 (987.70-987.52; SL 24/25), at the base of the bonebed. Similar features were observed beneath the bonebed in square 1274NE1107 in the west block (figure 3.37). A similar network was documented in square 1269NE1109, on the south end of the west block, in GL 6 (987.93-987.80; SL 21/22), 50 to 55 cm above the bonebed.

The irregularity of the contact on the floor of the kettle basin is due partly to burrowing, but it also likely reflects trampling by bison or other large mammals. For instance, in square 1262NE1109 excavators mapped a series of circular to oblong micro-depressions in the upper surface of the dark olive sediment that are 15 to 20 cm in diameter and 4 to 6 cm deep. These features may have originated in the overlying dark layer, only becoming visible as that stratum was removed. A clearer example of trampling comes from the northeast excavation block. There, two approximately linear, subparallel arrangements of such micro-depressions run roughly northeast-southwest, down the slope of the kettle basin (figures 3.38 and 3.39). The pit lines likely represent trails formed by animals drawn to water ponded in the basin. The origins of these features were not determined in the field, so it is not clear whether they pre-date or post-date the Agate Basin occupation. However, the fact that bison bone occurs within some—but not all—of them suggests that such trailing occurred both before and after the kill. The fact that they seem to be most evident in the floor of the basin likely reflects differences in soil moisture. In some units (for instance, in squares 1262NE1099 and 1263NE1099 [figure 3.40]), the combination of rodent burrowing and trampling has produced an A/B horizon, with discontinuous patches of A, AB, and B horizon strata intermixed.

The origins of the large pits or depressions seen in several parts of the excavation are not known. As mentioned previously, the bonebed occurs above, rather than in, most of them. Most seem to be too large to represent animal burrows or dens. All of them are filled with relatively uniform dark silt loam. Given the fact that the occupation took place early in the development of the major soil at the base of the Aggie Brown, no obvious explanation for these features is evident.

*Thickness and Internal Structure of the Bonebed*

Elevation data on plotted bone specimens can be used to gauge the thickness of the Agate Basin cultural deposit. Because the original ground surface rises from the center of the kettle basin (at about 1271NE1110), absolute elevation data are aggregated separately for each excavation unit. (Even though the sedimentary units and soil strata filling the basin rise perceptibly to the

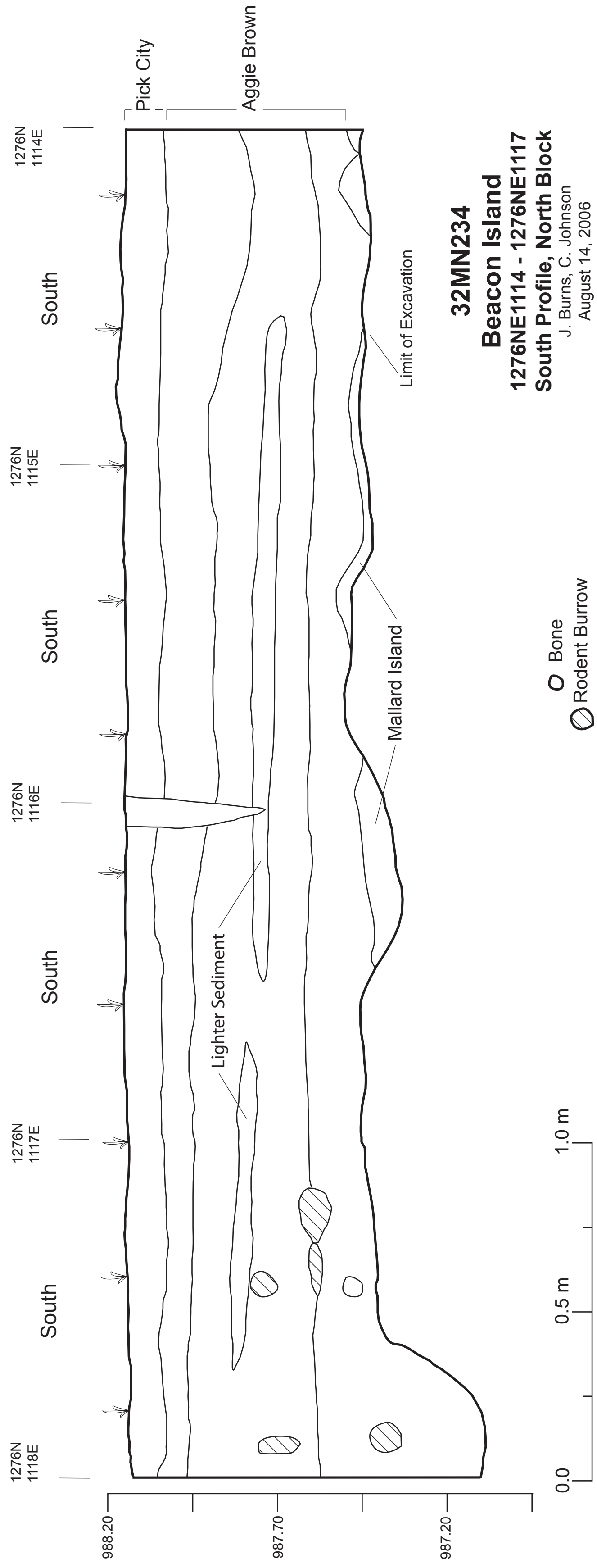


Figure 3.35. South wall profile of the north block.


Figure 3.36. Krotovina in Pick City, Aggie Brown, and Mallard Island Member sediment.

north and east within each unit of the main excavation blocks, this intra-unit slope is not considered here. For this reason the elevation ranges discussed in this section overestimate the total thickness of the bonebed). A total of 3,101 elevation measurements were taken on faunal remains assigned to the Aggie Brown Member in Area A. Six specimens are excluded from this analysis because they are separated from the Agate Basin occupation level by one to three sterile excavation levels and therefore likely were recovered from animal burrows. That leaves a total of 3,095 measurements. The number of elevation points per square ranges from one to 136 with a mean of just less than 28. Two squares in the west block containing just one plotted bone are excluded from the analysis (1267NE1109 and 1274NE1109).

The thickness of the cultural deposit can be measured in both absolute and statistical terms. Turning first to an absolute measure, figure 3.41 gives the difference, in cm, between the highest and lowest plotted bone elevations in each square. Across the excavated portion of the site, elevation differences range from 1 cm to 42 cm. The mean difference is 13.2±7.3 cm. Many of the smallest values occur along the northern edge of the bonebed, where

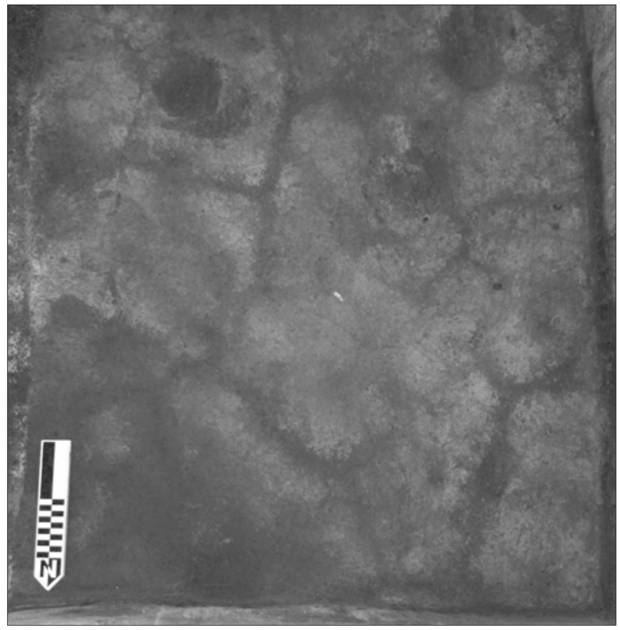


Figure 3.37. Drying cracks in the Mallard Island Member, square 1274NE1107.

Figure 3.38. Probable large animal trails in the upper surface of the Mallard Island Member in the northeast block.

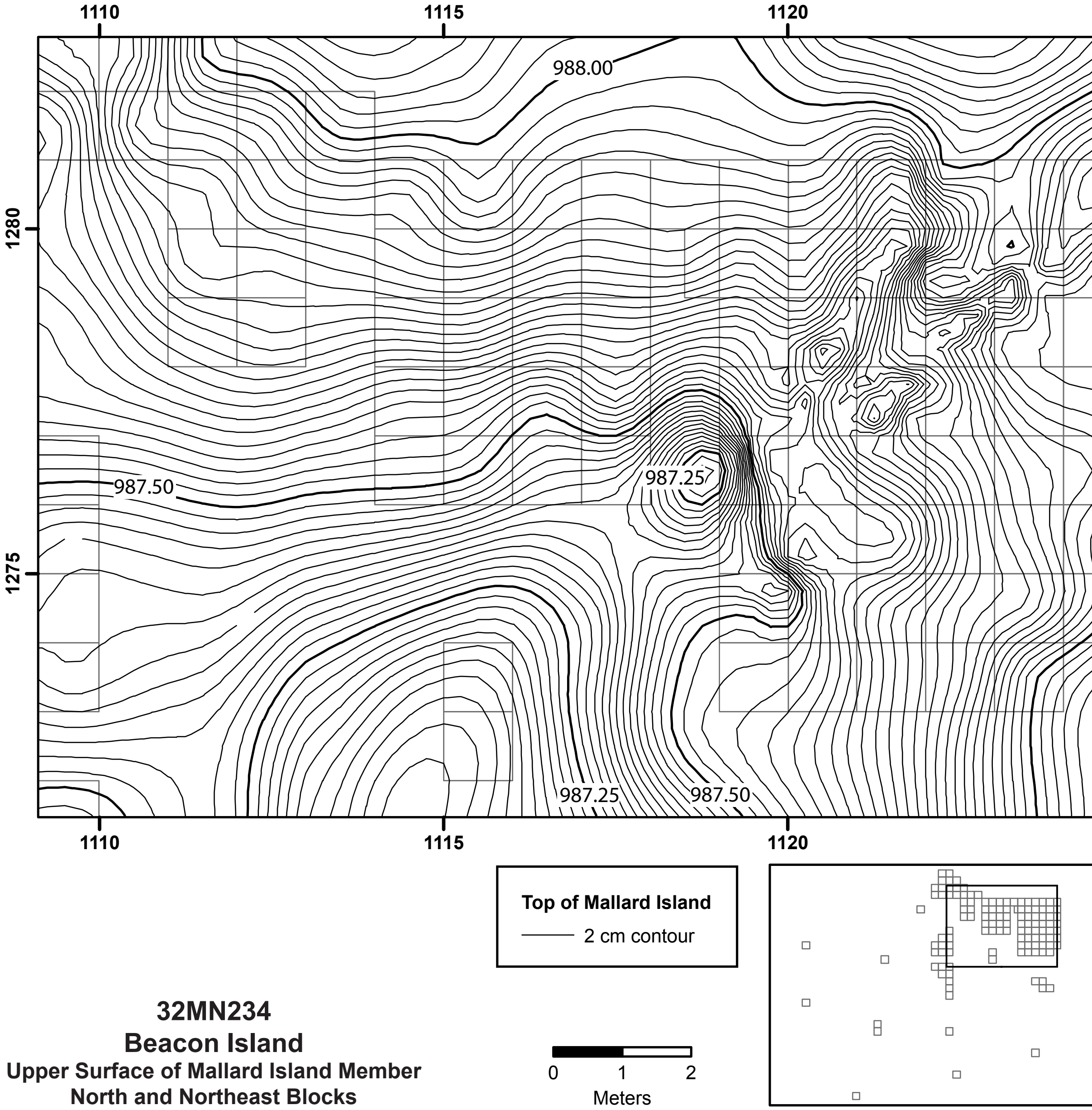


Figure 3.39. Topography of the upper surface of the Mallard Island Member.

surface erosion has stripped away part of the bonebed. The deposit is also relatively thin in the west block; however, just 83 plotted bones occur there. The northeast block contains the densest mass of bone. Excluding the northernmost and easternmost units (those impacted by erosion), a total of 2,034 plots fall in the remaining 35 contiguous squares making up the block (i.e., between 1273N-1279N and E1119-E1123). The mean elevation range for these 35 units is 17.3±6.7 cm. The minimum range is 5 and the maximum is 42 cm.

Overall, the range of plotted bone elevations exceeds 30 cm in just four excavation squares. Two of these units are located on the western edge of the northeast block. Square 1276NE1119 contains an especially dense mass of bone, including 126 plotted items and about 8.1 kg of unplotted bone fragments sorted from waterscreen lots. The vast majority of the unplotted bone comes from SL 24 and SL 25 (987.70-987.50), as do 116 of the plots. The mean plot elevation falls on the break between these two levels, at 987.59. Plotted items include a substantially complete mandible, several articulated vertebrae, and an articulated tibia and astragalus. In this square, the bonebed dips unusually steeply toward the southwest, into a small depression (or perhaps large krotovina),

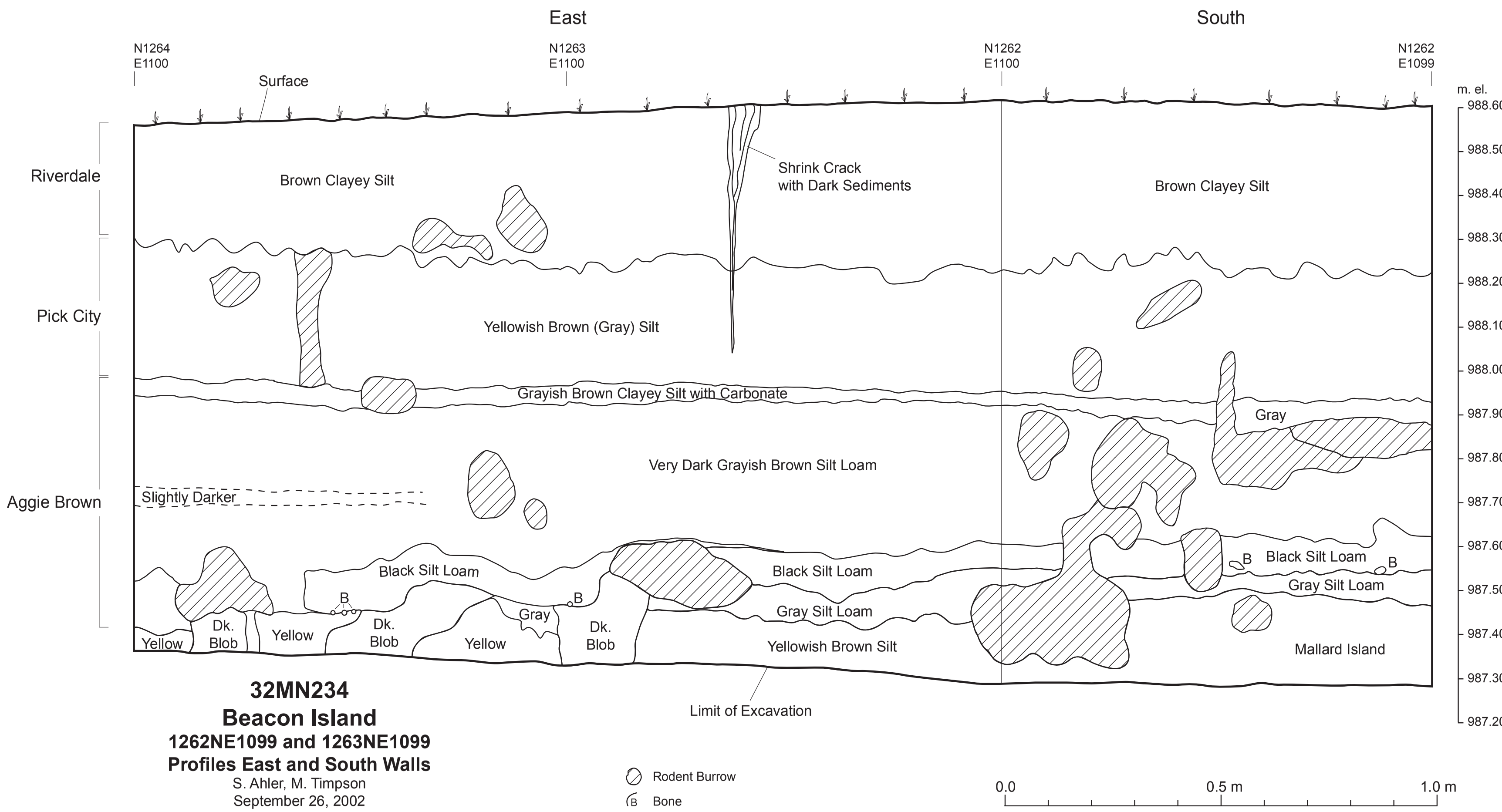


Figure 3.40. East and south wall profiles of square 1262NE1099 and 1263NE1099.

| | 1096 | 1099 | 1105 | 1107 | 1108 | 1109 | 1110 | 1111 | 1112 | 1113 | 1114 | 1115 | 1116 | 1117 | 1118 | 1119 | 1120 | 1121 | 1122 | 1123 | 1124 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1284 | | | | | 9 | 14 | | | | | | | | | | | | | | | |
| 1283 | | | | | 13 | 31 | 14 | | | | | | | | | | | | | | |
| 1282 | | | | 6 | 21 | 12 | 19 | 8 | | | | | | | | | | | | | |
| 1281 | | | | 6 | 14 | 14 | 9 | 11 | 2 | 3 | | | | | | | | | | | |
| 1280 | | | | | | | | 7 | 2 | | 8 | 1 | 9 | | | 4 | 3 | 2 | 4 | 7 | |
| 1279 | | | 7 | | | | | 15 | 9 | | 17 | 3 | 15 | 18 | 13 | 13 | 18 | 14 | 5 | 10 | 14 |
| 1278 | | | | | | | | 7 | 9 | | 9 | 13 | 9 | 15 | | 12 | 17 | 16 | 21 | 12 | 2 |
| 1277 | | | | | | | | | | | 11 | 10 | 17 | 18 | | 19 | 15 | 23 | 23 | 9 | 6 |
| 1276 | | | | | | 11 | | | | | 8 | 19 | 22 | 18 | | 42 | 21 | 13 | 16 | 13 | 7 |
| 1275 | | | | | 8 | | | | | | | | | | | 31 | 16 | 22 | 14 | 14 | |
| 1274 | | | | | 6 | 0 | | | | | | | | | | 18 | 27 | 22 | 16 | 13 | 13 |
| 1273 | | | | | 11 | 9 | | | | | | 28 | | | | 20 | 10 | 15 | 17 | 16 | |
| 1272 | | | | | | | | | | | | 19 | | | | | | | | | |
| 1271 | | | | | 9 | 35 | | | | | | | | | | | | | | | |
| 1270 | | | | | | 9 | | | | | | | | | | | | | | | |
| 1269 | | | | | | 11 | | | | | | | | | | | | 15 | 15 | | |
| 1268 | | | | | | | | | | | | | | | | | | | 18 | 13 | |
| 1267 | | | | | | 0 | | | | | | | | | | | | | | | |
| 1263 | | 19 | | | | | | | | | | | | | | | | | | | |
| 1262 | | 2 | | | | 10 | | | | | | | | | | | | | | | |
| 1256 | | | | | | | 2 | | | | | | | | | | | | | | |
| 1253 | 5 | | | | | | | | | | | | | | | | | | | | |

Figure 3.41. Absolute range in cm of plotted bone elevations in the main excavation blocks. Shading indicates units with plotted elevation ranges greater than 30 cm; see text.

which is visible on the west wall profile of the block (figure 3.31). This depression continues to the south into square 1275NE1119, where the range of plotted elevations also exceeds 30 cm. Sixty-nine plots, with a mean elevation of 987.57, occur in this square. Just less than 4.0 kg of unplotted bone were sorted from level lots from this square, 3.4 kg of which come from SL 25 (987.60-987.50). Thus, in this part of the site, the dense, jumbled mass of bone ranges from 10 to 20 cm thick, with much smaller amounts recovered from above and below this primary zone. The data further suggest that bone accumulated in a shallow pit in this area. However, the origin of the pit is unknown.

An elevation range greater than 30 cm also occurs in square 1283NE1109 in the northwest block. A total of 51 plots, with a mean elevation of 988.00, come from this unit. Unplotted bone totaling about 3.4 kg is associated with these plotted specimens. (This unit was primarily excavated in May 2002, using a combination of dryscreen and waterscreen recovery and so this value is not fully comparable to the values from 1276NE1119 and 1275NE1119 that were excavated with full waterscreen recovery). Thirty-two of the plots come from GL 2 (988.06-988.00; SL 20), as does 1.3 kg of bone scrap. Another 17 plots and 1.8 kg of unplotted bone come from GL 3 and GL 4 (988.00-987.86; SL 21 and SL 22). A single plot and just 18 g of bone were recovered from deeper pockets of Aggie Brown sediment intruded into the Mallard Island Member. In this square, then, bone is not as dense as it is on the west side of the northeast block and the apparent thickness of the cultural layer here mostly reflects the presence of one bone displaced downward by burrowing animals or by post-occupation trampling.

Still another situation occurs in the west block. In square 1271NE1109, near the center of that block, the range of plotted elevations is 35 cm, about three times thicker than in any other adjacent units. Seventeen plots occur in this unit. Their mean elevation is 987.23, the lowest recorded anywhere in the excavation. About 1.5 kg of bone fragments is associated with these plots. However, most of this material (1.4 kg of bone and 12 of the 17 plots) come from SL 27 and 28 (987.43-987.20). Several closely stacked bones, including fragments of a single mandible, also are present in an oblong depression extending another 15 cm or so into the Mallard Island Member (figure 3.42). This pit, which is roughly 35 cm in diameter, is probably too large to have been created by burrowing animals. However, it is not known whether it represents a cultural feature or simply a natural basin. In any case, the apparent thickness of the bonebed in this square is due mainly to the presence of this basin.

It is clear from these data that plot elevation ranges reflect a number of factors in addition to the mean thickness of the Agate Basin cultural deposit. The most important factor is the transport of a relatively small fraction of the faunal assemblage downward into krotovina in the Mallard Island Member. The presence of localized depressions and bone piles also affects maximum thickness values. It is worth noting that the recovery of bones displaced by faunalturbation is determined in part by the extent of the excavation. In some units, excavation continued well into the Mallard Island, but in others work stopped just below the base of the Aggie Brown, leaving pockets of Aggie Brown in place.

Another way to gauge the thickness of the cultural deposit is to examine the dispersion of plotted elevations around the mean elevation for each square. The standard deviation of each unit's mean elevation provides one such measure. That is, the standard deviation of the mean elevation is equal to half the distance over which roughly two-thirds of the elevation measurements fall. (It should be noted that this is an estimate, in part because plot elevations are not normally distributed relative to depth. However, a visual inspection of skewness values for each square indicates that most elevation distributions are roughly symmetrical). Among units with ten or more plots, the mean standard deviation of the mean elevation is 0.0385±0.0138 m, which yields an estimated mean bonebed thickness of 7.7±2.8 cm. Based on this calculation, the bonebed varies from 2.9 to 19.5 cm thick, with a median value of 7.1 cm. Although these figures represent estimates, rather than direct measurements,

Figure 3.42. The bone-filled depression in square 1271NE1109.

they accord well with observations made in the field. Most excavators note that the main concentration of bone occurs in a layer 5 to 10 cm thick.

No stratification within the bone layer was observed in the field. In fairness, the color and texture of the soil horizons in which the bonebed occurs would have made the identification of small-scale depositional strata difficult. In fact, pedogenesis itself could have obliterated evidence of such post-occupation strata. However, in most of the units, the vast majority of the bone was recovered from one, or at most two, excavation levels. In no case were discrete masses of bone separated by a layer of sediment containing fewer bones or bone fragments. Along with the mean thickness data, these observations strongly suggest that the Agate Basin component represents a single depositional event. Moreover, the mean elevation of the bonebed generally tracks the upper surface of the Mallard Island Member. Figure 3.43 gives the mean elevation of plotted bone from each square. The bonebed undulates slightly, but in general rises evenly from the center of the basin. By and large, the slope of the occupation surface varies from 5 to 10 percent, or 5 to 10 cm per meter. Figure 3.44 illustrates the south and west walls of the northeast block, showing this trend.

## Cultural Features

One Agate Basin-age cultural feature, a small, unlined basin hearth, was documented in square 1272NE1115 (figure 3.45). The hearth was first observed at the base of GL 10 (987.30; SL 27), beneath a moderately dense scatter of highly fragmented bone. Twenty plots with a mean elevation of 987.34, along with 1.6 kg of additional bone scrap, were recovered from this level. At this elevation, the feature was mapped as a series of discontinuous patches of oxidized sediment, covering an area roughly 70 cm long and 45 cm wide (figure 3.46). In GL 11 (987.30-987.20; SL 28), five more plotted bones (mean elevation 987.26) and 0.2 kg of unplotted bone scraps was recovered. At an elevation of 987.20 m, the feature was mapped as a single patch of oxidized sediment about 30 cm in diameter. A number of rodent burrows run through it. The base of the hearth lies at the undulating, patchy contact between the Aggie Brown and Mallard Island members. A profile of the feature was not drawn.

The original dimensions of this hearth are difficult to determine, given the extent of animal burrowing, but it appears to have been roughly 50 cm long, 30 cm wide, and 10 to 12 cm thick. A bulk sample was taken of the feature fill, which contains abundant charcoal, ash, and small fragments of burned and unburned bone. Three of the five bones plotted in GL 11 are burned, but none of the 20 bones plotted in the level above the hearth (GL 10) are. Eight pieces of flaking debris, four of which are burned, were recovered from GL 10; two burned flakes were recovered from GL 11 and two more come from within the feature itself. Three pieces of charcoal scattered outside the oxidized perimeter of the feature were plotted in GL 10.

### *Spatial Distribution of Charcoal and Burned Bones*

Although no other features associated with the Agate Basin component were identified, burned items and scattered charcoal were observed elsewhere in the excavation. In square 1279NE1121, in the northeast block, excavators noted patches of compact, reddish sediment in SL 22 (987-90-987.80), immediately below the base of the bonebed but slightly above the Aggie Brown-Mallard Island contact. Previously, in SL 21, they had observed a number of burned bone fragments, scattered pieces of charcoal, and patches of gray sediment they interpreted as ash; however, they were unable to define the boundaries of a feature. Pieces of charcoal also occurred in SL 23 and SL 24 (987.80-987.60), along with fragments of burned rock and patches of oxidized sediment, though some of this material may have come from animal burrows. Burned bone fragments are more abundant in the squares surrounding 1279NE1121 that they are anywhere else in the northeast block (figure 3.47). Overall, the evidence suggests that at least one hearth originally was built in the northern part of the northeast block.

Excavators also observed burned bone pieces and numerous charcoal fragments on the south end of the west block in square 1269NE1109. Both were noted in GL 11 and GL 12 (987.40-987.20; SL 27 and SL 28), at the bottom of the dark silt layer. Two plotted charcoal fragments from GL 12 were selected for AMS radiocarbon dating, returning dates of 10,371±80 and 9911±105 B.P. (see appendix A). Patches of charcoal-enriched Aggie Brown Member sediment were also noted in these levels. However, no fire-cracked rock or burned flaking debris, and only a minor amount of burned bone, was recovered from this unit, suggesting that the source of the charcoal may have been some distance away. The hearth documented in 1272NE1115 is located roughly 7 m to the northeast, at about the same elevation.

Several other apparent concentrations of burned bone occur in other parts of the site. One such concentration is located on the north side of the northwest block, in squares 1284NE1109, 1283NE1109, and 1282NE1110. Another is located on the east edge of the north block, in squares 1277NE1116 and 1277NE1117. However, the excavators who worked in these units do not report observing pieces of charcoal within or beneath the bonebed. Very few plotted bones from these units exhibit evidence of burning. Fire-cracked rock is virtually absent,

| | 1096 | 1099 | 1105 | 1107 | 1108 | 1109 | 1110 | 1111 | 1112 | 1113 | 1114 | 1115 | 1116 | 1117 | 1118 | 1119 | 1120 | 1121 | 1122 | 1123 | 1124 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1284 | | | | | 8.01 | 8.03 | | | | | | | | | | | | | | | |
| 1283 | | | | | 8.00 | 8.00 | 7.99 | | | | | | | | | | | | | | |
| 1282 | | | | 7.94 | 7.91 | 7.91 | 7.95 | 8.04 | | | | | | | | | | | | | |
| 1281 | | | | 7.90 | 7.85 | 7.85 | 7.94 | 8.02 | 8.05 | 8.05 | | | | | | | | | | | |
| 1280 | | | | | | | | 7.92 | 8.00 | | 8.01 | 8.05 | 8.01 | | | 7.97 | 7.96 | 7.96 | 7.98 | 7.96 | |
| 1279 | | | 7.92 | | | | | 7.87 | 7.90 | | 7.92 | 7.89 | 7.93 | 7.89 | 7.90 | 7.90 | 7.92 | 7.95 | 7.98 | 7.98 | 7.99 |
| 1278 | | | | | | | | 7.80 | 7.79 | | 7.82 | 7.78 | 7.73 | 7.77 | | 7.77 | 7.83 | 7.88 | 7.94 | 8.01 | 8.05 |
| 1277 | | | | | | | | | | | 7.67 | 7.67 | 7.63 | 7.61 | | 7.68 | 7.76 | 7.82 | 7.92 | 7.99 | 8.04 |
| 1276 | | | | | | 7.57 | | | | | 7.55 | 7.57 | 7.53 | 7.54 | | 7.59 | 7.73 | 7.82 | 7.89 | 7.97 | 8.04 |
| 1275 | | | | | 7.53 | | | | | | | | | | | 7.57 | 7.72 | 7.84 | 7.91 | 7.97 | |
| 1274 | | | | | 7.47 | 7.46 | | | | | | | | | | 7.59 | 7.71 | 7.82 | 7.91 | 8.00 | 8.01 |
| 1273 | | | | | 7.40 | 7.38 | | | | | | 7.34 | | | | 7.65 | 7.72 | 7.82 | 7.92 | 8.02 | |
| 1272 | | | | | | | | | | | | 7.32 | | | | | | | | | |
| 1271 | | | | | 7.33 | 7.23 | | | | | | | | | | | | | | | |
| 1270 | | | | | | 7.26 | | | | | | | | | | | | | | | |
| 1269 | | | | | | 7.25 | | | | | | | | | | | | 7.79 | 7.94 | | |
| 1268 | | | | | | | | | | | | | | | | | | | 7.97 | 8.06 | |
| 1267 | | | | | | 7.39 | | | | | | | | | | | | | | | |
| 1263 | | 7.63 | | | | | | | | | | | | | | | | | | | |
| 1262 | | 7.49 | | | | 7.79 | | | | | | | | | | | | | | | |
| 1256 | | | | | | | 8.00 | | | | | | | | | | | | | | |
| 1253 | 7.99 | | | | | | | | | | | | | | | | | | | | |

Figure 3.43. Mean elevations of plotted bones in the main excavation blocks. The first two digits of the elevations (98X.XX) are omitted.

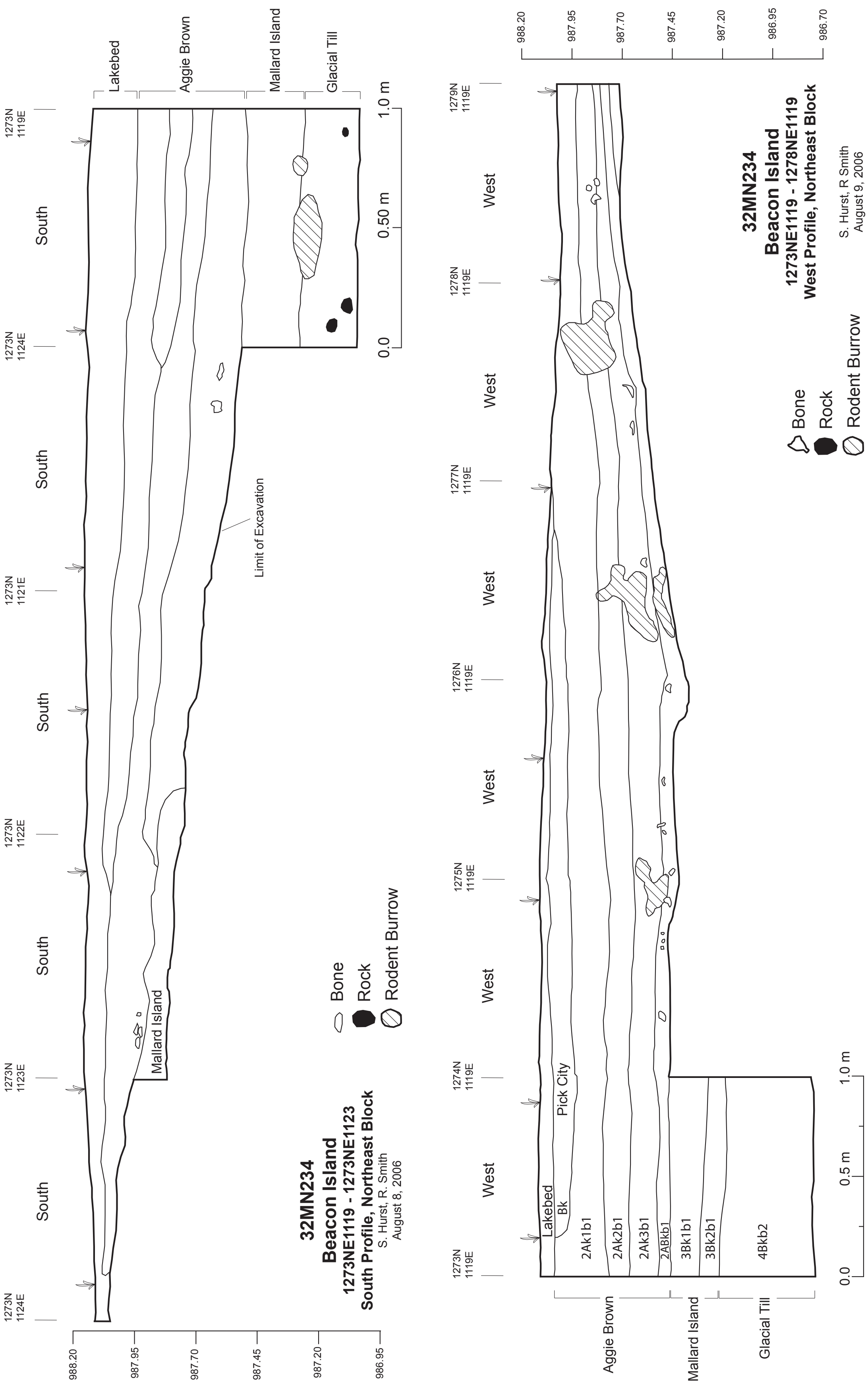


Figure 3.44. South wall (upper panel) and west wall profiles of the northeast block. Table 2.5 gives descriptions of the strata.

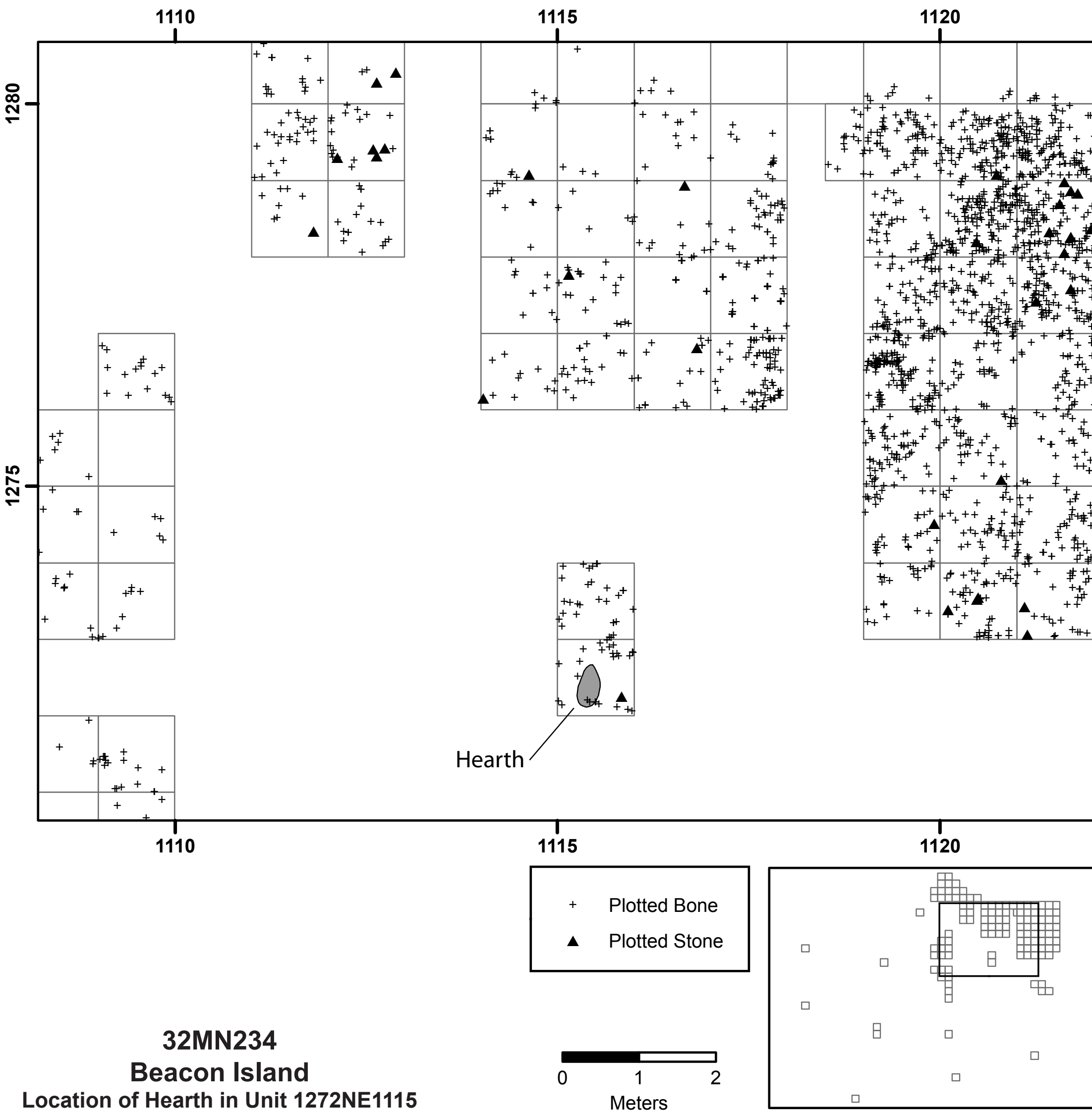


Figure 3.45. Map of bonebed showing the location of the hearth in 1272NE1115, along with plotted bones (crosses) and artifacts (filled triangles).

though a few flakes from these squares are burned. All of these squares were excavated in May 2002, and the lab analyses of materials from them were carried out in 2002 and 2003, well before the September 2002 and 2006 collections were analyzed in 2008 and 2009. Given the degree of organic staining on bones from the Aggie Brown Member, a rather conservative approach was taken during the latter phase of analysis to identifying evidence of burning. Thus, the apparent concentrations of burned bone in the northwest and north blocks almost certainly reflect differences in the lab procedures applied to the May 2002 collection, rather than to actual differences in the degree of burning in these units. (This difference does not apply to evidence for burning on plotted specimens, all of which were examined in detail by a faunal specialist).

*Possible Pit Features*

Two of the depressions described previously could also represent cultural features. The best candidate is the bone-filled pit observed in square 1271NE1109 in the west block (figure 3.42). Unlike the depressions on the northern slope of the kettle basin that appear to have filled before the Agate Basin occupation occurred, this pit is filled with a tightly packed cluster of bison bones. However, apart from the fact that it contains butchered bone, there is no direct evidence that it was excavated by the Agate Basin occupants of the site. Another possible cultural feature spans the southwest corner of

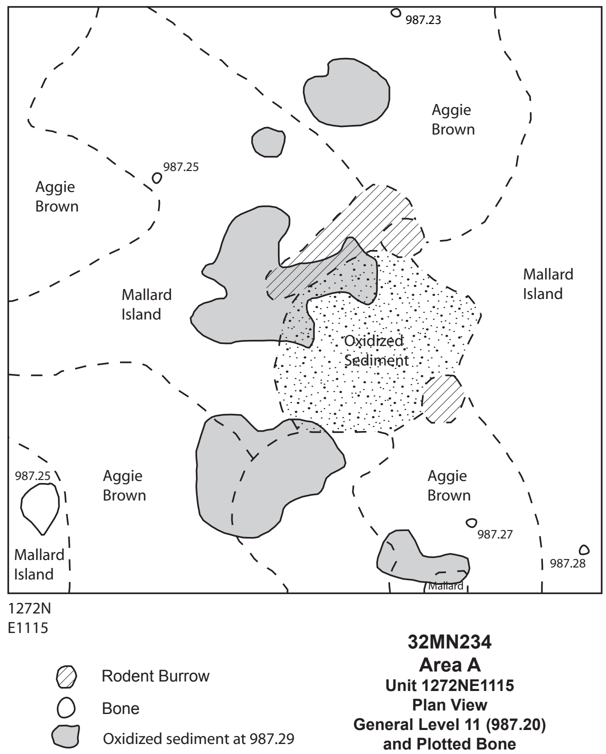


Figure 3.46. Plan views of hearth feature at 987.29 and 987.20.

Figure 3.47. Burned bones in square 1279NE1120, SL 26.

1276NE1119 and the northwest corner of it 1275NE1119. No plan maps of this depression were drawn, but narrative descriptions of the work in these excavation units suggest that the pit may be 50 to 100 cm in diameter and 10 cm deep. It, too, is filled with tightly packed bison bone, but, again, no direct evidence suggests a cultural origin.

Spatial Distribution of Faunal Remains and Chipped Stone Artifacts

Faunal remains are unevenly distributed across the site. Figure 3.48 shows the distribution of plotted items (indicated by small crosses) and non-plotted bone scrap in the main excavation blocks. By far the densest concentration of plotted bone occurs in the northeast block. Even within the northeast block, though, bone is unevenly distributed. The largest mass is located in the northern part of the block, in squares 1279NE1120, 1279NE1121, 1278NE1120, 1278NE1121, and 1278NE1122 (figure 3.49). More than 100 plots fall in each of these units, and nearly as many fall in the next row of squares to the south. In each of these units, bone occurs in a relatively thin layer. For instance, in 1279NE1121, 116 of 124 plots fall within SL 21 (988.00-987.90), as does 86 percent by weight of the unplotted bone. Similarly dense, discrete masses of jumbled bone occur in adjacent squares. As discussed previously, in the Bonebed Thickness and Internal Structure section, more than 100 plots also occur in square 1276NE1119, though in a somewhat thicker pile. A relatively dense concentration of plotted bone is also present in the northwest block (figure 3.50). Seventy-five plots occur in square 1283NE1108 in the northwest blcok and another 51 occur in 1283NE1109. It is worth observing that the vast majority of faunal specimens are located on the slope of the kettle basin. If post-occupation slopewash had significantly affected the distribution of faunal remains, one might expect a portion of the specimens to have been transported downhill, onto the floor of the basin, but this did not occur.

Interestingly, the distribution of unplotted bone fragments differs somewhat from the distribution of plotted items. This phenomenon is most apparent in the northwest block (figure 3.50). For instance, square 1283NE1108, with 75 plots, produced 3.9 kg of unplotted bone, while square 1282NE1108, the next unit to the south, contains just 37 plots but 4.2 kg of bone scrap. In turn, square 1281NE1108, one row farther south, contains just 15 plots, but 5.6 kg of bone scrap. A similar pattern occurs in adjacent squares. This pattern is not due to differences in recovery methods, because the bone weights given here only include specimens in size grades 1 through 3, all of which would have been recovered during dryscreening through 1/4-inch hardware cloth. Instead, the difference seems to reflect

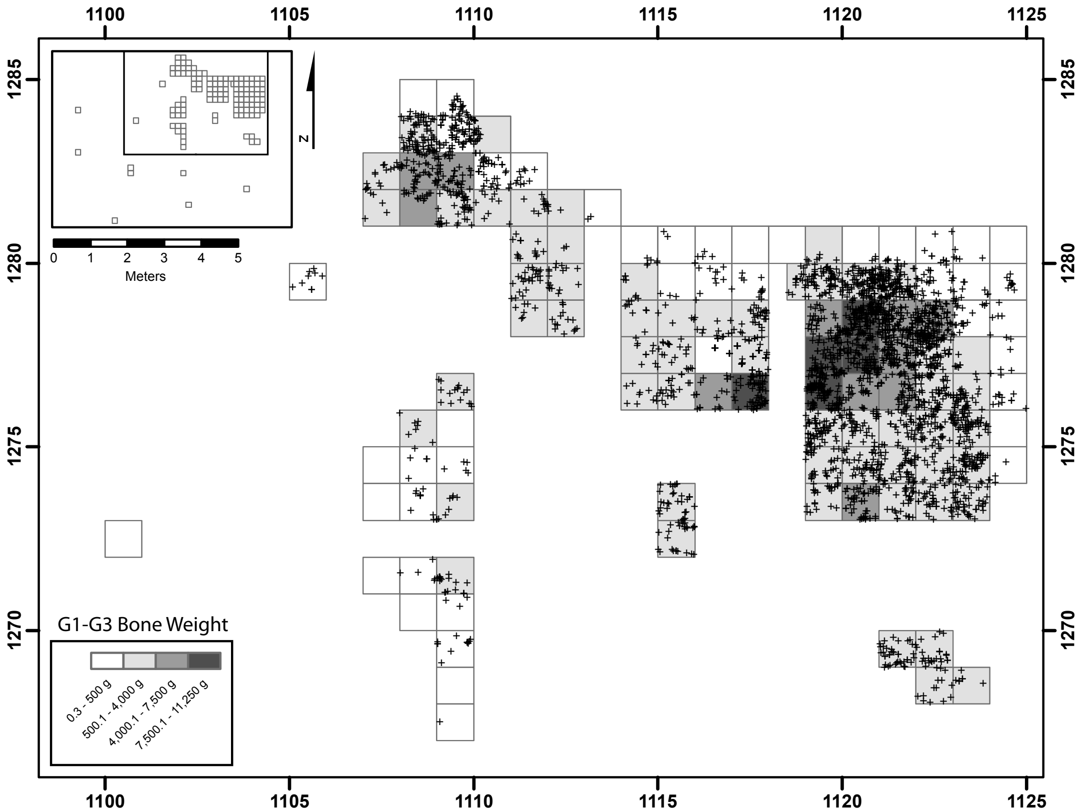


Figure 3.48. Map showing the locations of plotted bones (crosses) and weights of unplotted bone by square.

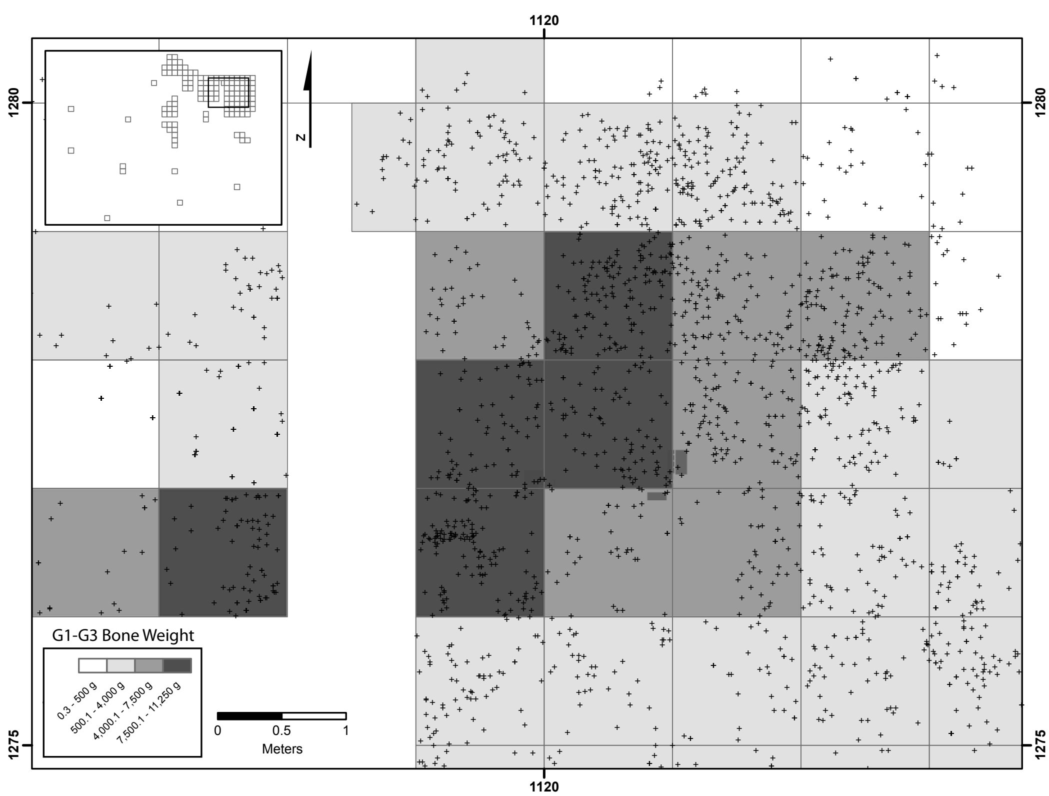


Figure 3.49. Map of the northeast block showing the locations of plotted bones (crosses) and weight of unplotted bone.

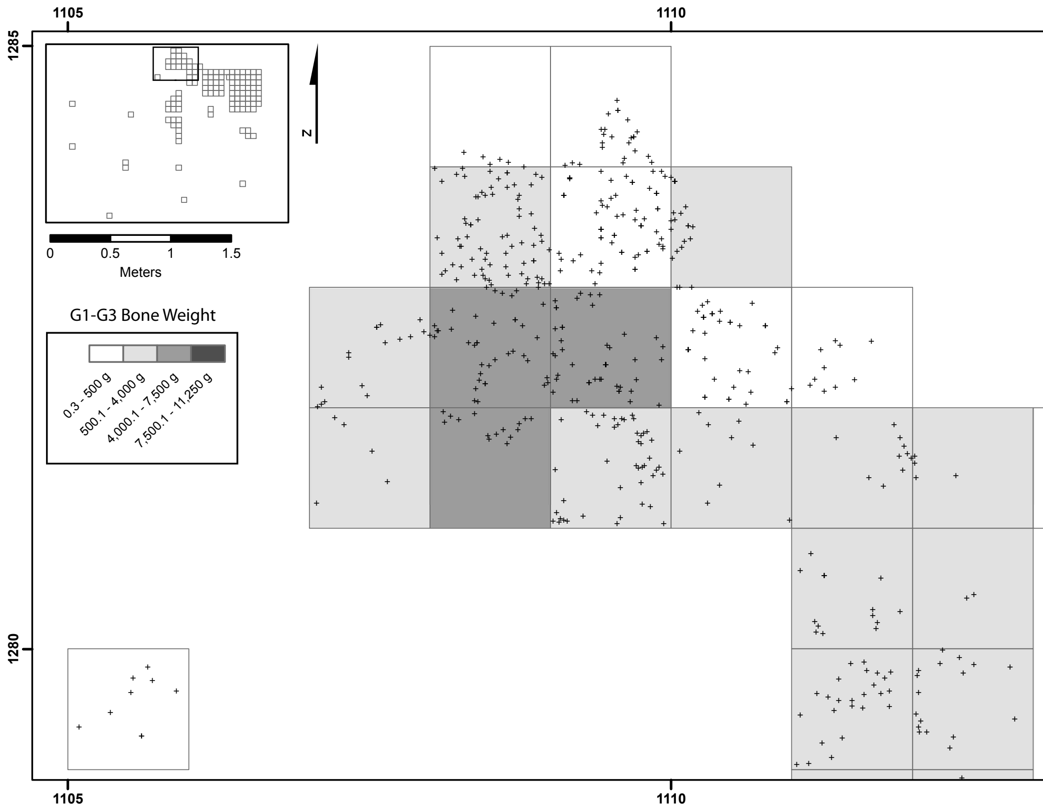


Figure 3.50. Map of the northwest block showing the locations of plotted bones (crosses) and weights of unplotted bone.

spatial patterning in the degree of bone fragmentation. While it is possible that this pattern results partly from post-occupational processes, or perhaps from differences in excavation technique, it is more likely that it reflects carcass processing patterns, and therefore discrete work areas within the bonebed.

A similar, though somewhat less marked pattern occurs in the northeast block (figure 3.49). For instance, 124 plots fall in square 1279NE1121, from which 2.0 kg of bone scrap were recovered from level lots. By contrast, square 1277NE1119 includes just 67 plots, but produced 11.2 kg of unplotted bone. Similarly, square 1276NE1117, on the east edge of the north block, includes 64 plots, but 8.4 kg of bone.

There also are notable "gaps" in the distribution of plotted bone. The most readily apparent occur in the east half of 1278NE1119 and in the four excavation units surrounding the 1276NE1121 grid point (figure 3.49). All of these squares were excavated in 2006 using a consistent set of recovery procedures and so these gaps are not due to differences in excavation technique. Additional data on spatial patterning of faunal elements are presented in chapter 5.

The distribution of stone artifacts differs in important ways from the distribution of butchered bone, though comparisons between the spatial distributions of faunal remains and modified stone are hampered somewhat by sample size differences. Figure 3.51 shows the distribution of plotted bones (indicated by small crosses) in the north and northeast blocks, along with the distribution of stone artifacts (small filled triangles) and coarse-fraction flaking debris (size grades 1 through 3) recovered from waterscreen lots. The largest concentration of plotted stone artifacts occurs in square 1278NE1121, within the largest concentration of plotted bones. However, by and large, the majority of plotted and unplotted stone artifacts come from locations around the periphery of the major concentrations of bone. Squares with notable concentrations of unplotted bone scrap, such as 1276NE1119 (in the northeast block) and 1276NE1117 (in the north block) produced no stone artifacts, and squares around the edge of the main concentration of bone, such as 1275NE1124, produced a number of flakes and plotted items, but little bone. A similar pattern is evident in the northwest block (figure 3.52). On the one hand, a small concentration of plotted items and flaking debris in that block is associated with the largest concentration of plotted faunal specimens (in square 1283NE1108). On the other hand, however, the greatest concentration of stone artifacts occurs outside the

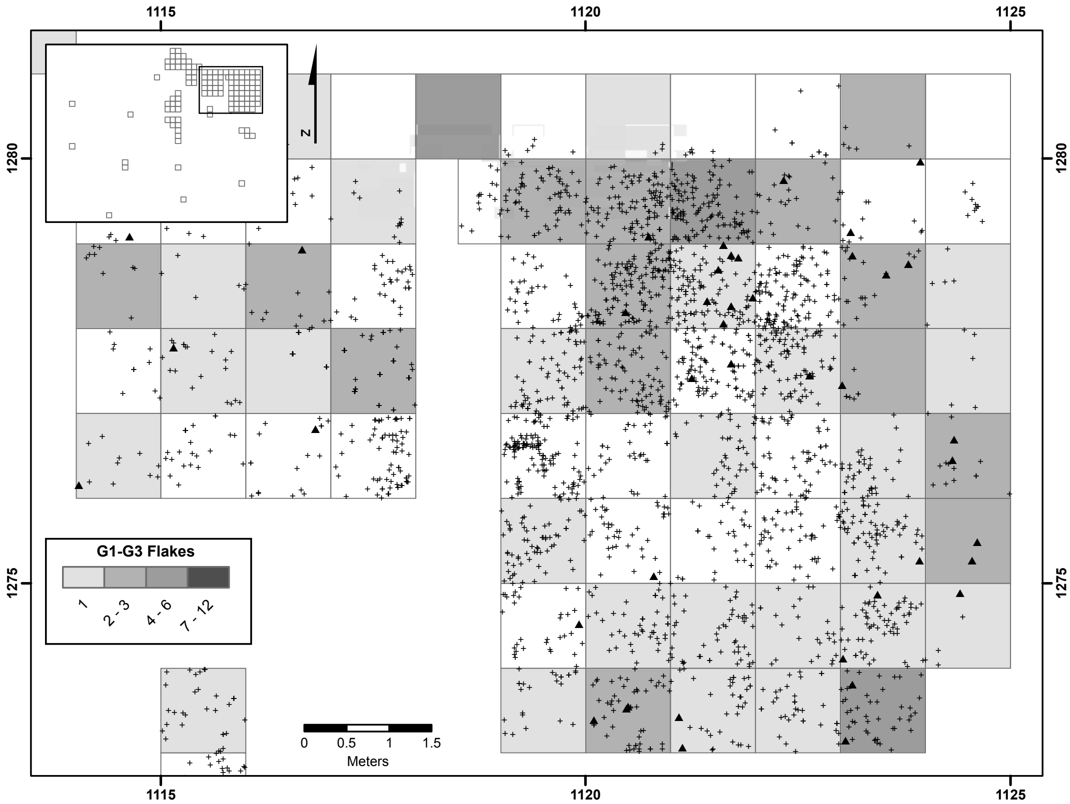


Figure 3.51. Map of the northeast block showing the locations of plotted stone artifacts (filled triangles), plotted bone (crosses), and the distribution of coarse-fraction flaking debris.

primary distribution of bone debris. As is the case in the northeast block, the squares that produced the most bone scrap failed to produce many stone artifacts. The largest single concentration of coarse-fraction flaking debris in Area A occurs on the southern end of the northwest block, in squares 1278NE1111 and 1279NE1112. These units produced just 1.5 and 0.6 kg of bone, respectively.

Like the differences in the distributions of bone pieces of different size discussed previously, the distribution of chipped stone artifacts suggest that relatively intact activity areas are preserved in Area A. A portion of the chipped stone is intermingled with larger plotted faunal remains, but not smaller bone scrap. These stone items likely were lost during butchery or discarded along with larger pieces of butchered bone. Other stone items, particularly flaking debris derived from tool production or maintenance activities, are distributed around the perimeter of the bone mass, in areas where carcasses were dismembered.

Data on the mean distance between conjoinable tool fragments (discussed in detail in chapter 6) further suggest that the Agate Basin component in Area A preserves relatively discrete butchery and discard areas. The mean distance between plotted, conjoinable fragments is 53.2 cm. Additional data on the distribution of flakes, chipped stone tools, and other stone artifacts are presented in chapter 6.

## Summary

Though the Agate Basin component currently is the best-documented use of Area A, it represents just one of many successive uses of this landscape. Pre-Agate Basin use is attested by the presence of Folsom artifacts; however, the character and context of earlier occupations are not clear. Evidence for later, Holocene-age use of Area A comes from a series of isolated test units northwest and southwest of the Agate Basin bonebed. Far and away the most significant of these is the early Holocene occupation represented by the lower component in square 1308NE1055. Intermittent occupation later in the Holocene is indicated by artifacts in Riverdale Member sediment and by diagnostic artifacts from surface contexts.

The Agate Basin occupation, dated at about 10,300 $^{14}$C yr B.P. (see appendix A), occurred early in a period of landscape stability marked by the formation of a well-developed soil, known regionally as the Leonard paleosol. The character of the strata containing bone and other artifacts is determined primarily by soil formation and

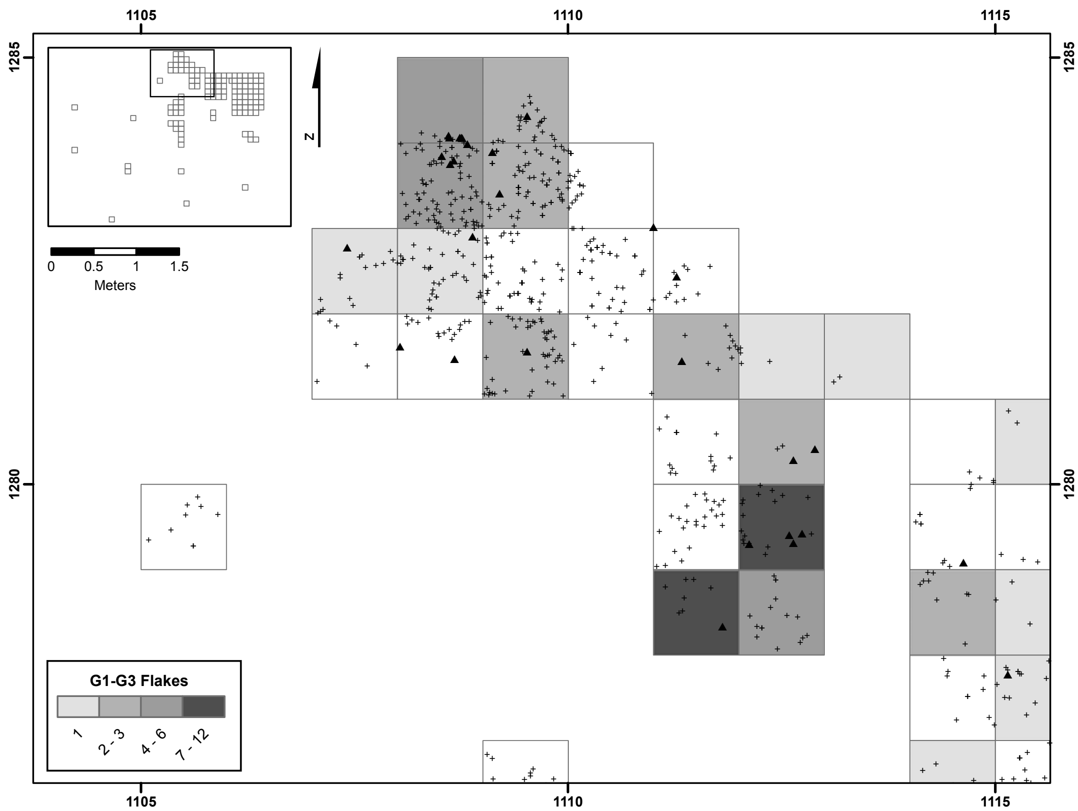


Figure 3.52. Map of the northwest block showing the locations of plotted stone artifacts (filled triangles), plotted bones (crosses), and the distribution of flaking debris.

secondarily by regional and local sediment deposition.

The Agate Basin cultural deposit, consisting primarily of a dense mass of butchered bison bone, represents a single depositional event. On average, the bonebed is just 5 to 10 cm thick. No gaps in the vertical distribution of bone were observed in the field. The bone deposit occurs on a single surface, which conforms to the original topography of the basin, as modeled by elevation data on the major stratigraphic contact beneath the bonebed.

The bonebed occurs within a shallow kettle basin. The pothole was dry at the time of the occupation, based on the fact that the hunters were able to build a small fire on the floor of the basin, but standing water may have been present in one of the other deeper basins located nearby. The butchery area spreads across the north and east slopes of the basin, while other activities were carried out on the floor of the basin to the southwest.

The Agate Basin component is remarkably well preserved. The most important post-depositional disturbance process has been burrowing by small mammals. Trailing by large animals may also have had some effect on the vertical distribution of faunal remains and artifacts, though at least some of the observed trails likely pre-date the occupation. Slopewash likely transported some smaller items (see chapter 2), such as the bones overlying the hearth feature documented in 1272NE1115. However, the location of the vast majority of the bone, on the slope rather than on the floor of the basin, suggests that such transport was limited. Moreover, the restricted vertical distribution of plotted and unplotted faunal remains, especially in the dense jumble of bone in the northeast block, suggests that churning of site sediments or lateral transport of faunal remains and artifacts was minimal. These interpretations are strongly supported by data on the distances between conjoinable tool fragments, a topic taken up in more detail in chapter 6. Taken together, these lines of evidence suggest that the Agate Basin occupation was buried relatively rapidly. Additional data bearing on the speed of burial are presented in chapters 2, 5, and 6.

In view of the evident integrity of the Agate Basin cultural deposits it is reasonable to conclude that discrete activity areas and discard zones are preserved within them. In fact, data on the distributions of artifacts and faunal remains strongly suggest that this is the case. In particular, the differential distribution of highly fragmented bone, relative to plotted specimens that typically are larger, seems to reflect discard patterns. Moreover, the divergent distribution of stone artifacts, scattered around the perimeter of the discard piles, likely reflects areas were animals were dismembered, stone tools were re-sharpened, and weaponry was recovered and refurbished for later use. In addition, one hearth was documented on the southwest edge of the major butchery area and evidence for another was observed on the northeast edge. Data on the distribution of burned flaking debris, and on the distribution of conjoinable cores and flakes made from Antelope Chert presented in chapter 6, also point to the preservation of discrete activity areas.

A portion of the Agate Basin component has been entirely stripped away by both recent and ancient erosion. The occupation may once have covered around 1,600 sq. m, though the data on which this estimate is based—the distribution of bone fragments and artifacts made from Antelope Chert recovered from the surface—admittedly is circumstantial. Roughly 800 sq. m of Aggie Brown Member sediment remains in the eastern kettle basin. Thus, roughly 50 percent of the Agate Basin component may have been lost to erosion. Nevertheless, the distribution of excavated faunal remains suggests that a significant fraction of the carcass processing area was exposed during the course of the field investigation.

No direct evidence for the location or method of the kill itself was obtained during the fieldwork. However, marked differences in the condition of the faunal specimens recovered from the surface relative to the condition of the excavated assemblage suggest that the kill took place just 10 or 15 m east of the butchery area (see chapter 5). This interpretation is bolstered by data on the completeness and fragmentation signature of the surface-collected projectile points relative to those in the excavated collection, a topic taken up in more detail in chapter 6.

# 4

## Lab Methods, Analytic Units, and GIS Mapping

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This chapter describes the methods used to process and organize specimens and samples recovered from Area A. The first section describes collection processing procedures and database development. The second defines the analytic units used to study faunal remains, modified stone artifacts, and other materials. The third describes the methods used to create the bonebed GIS.

### Level Lot Processing

The basic approach to collection processing followed the steps and methods PCRG commonly applies to samples from Plains Village sites in North Dakota. The first step in processing field samples involved size-grading. Size-grading improves the efficiency of the subsequent sorting process by allowing the sorter to examine batches of specimens that are all approximately the same size. Size-grading also permits the use of size-determined cut-offs for sorting different types of artifacts. In addition, size distributions of certain artifact classes are themselves useful for interpreting site formation processes and artifact production techniques.

Samples were manipulated or shaken over a set of five graduated screens with square mesh opening sizes (U.S. Standard Sieve Cloth) of 1.000 inch (size grade 1); 0.500 inch (size grade 2); 0.223 inch (size grade 3); 0.100 inch (size grade 4); and 0.046 inch (size grade 5). To minimize damage, artifacts and faunal remains were manipulated by hand through size grades 1 and 2 screens. Samples were shaken for a standard 30-second interval over the size grades 3 through 5 screens. Dryscreened samples from the May 2002 field session produced size grades 1 through 3 fractions, along with a residue of materials smaller than size grade 3. Waterscreened samples from all field sessions produced size grades 1 through 5 fractions. Due to the low density of charcoal or other organic remains, water floatation was not as a routine part of sample processing.

The second step in sample processing involved sorting into artifact and material classes. Basic sort classes occurring most commonly in excavated samples from Area A include bone, modified stone (including both stone tools and flaking debris), fire-cracked rock, shell, ochre or pigment, and natural rock. Particular emphasis was placed on the amount and distribution of burned bone, a possible indicator of hearth-centered bison processing or camp activities. A conservative approach was taken to identifying burned faunal remains, owing to the dark surface discoloration present on most specimens resulting from exposure to the organic-rich Aggie Brown Member. Only those specimens exhibiting blackening throughout were classified as “charred” and only those exhibiting a white or gray interior were classified as “calcined.” Nevertheless, the spatial analysis of burned bone presented in chapter 3 indicates that the sort criteria applied to the May 2002 samples were less strict than those applied to samples obtained in September 2002 or in 2006. Finally, in contrast with the sorting procedures for most Plains Village collections, flaking debris, stone tools, shell, and miscellaneous items were sorted from size grade 5 fractions, due primarily to the overall rarity of artifacts in Area A and to the desire to maximize the data available for analysis.

Owing to differences in the field methods used during each session, which are detailed in chapter 3, slightly different sort classes were used during the course of the lab work. Table 4.1 tallies sort classes by size grade and field session. The most important differences are in the treatment of the size grades 4 and 5 fractions. Size grade 4 fractions from the May 2002 level lots were completely sorted; those from all other field sessions were partially sorted, with the remainder of the sample classified as “unsorted residue.” Identifiable bone, comprising specimens for which both element and genus potentially could be determined, was not isolated from size grades 4 and 5 fractions from the May 2002 samples, but was from all other waterscreen samples. Similarly, charcoal pieces were not isolated from the May 2002 samples (in any size grade), but were from all other samples (in size grades 1 through 4).

Immediately after each major field effort, data held in the provenience- and recovery-based field catalog was entered into a Microsoft Access table. Catalog entries were then cross-checked against level forms, collection bags, and total station data files to identify and correct errors. For the 2006 field sessions, the catalog numbers assigned to “general level recovery” lots were retired and their associated contents re-assigned to waterscreen lots

Table 4.1. Sort classes for waterscreen (upper panel) and dryscreen (lower panel) level lots from Area A. X's in the body of the upper panel indicate that the listed material was sorted from the indicated size grade from samples obtained during all field sessions; numbers indicate sorting from samples obtained during selected field sessions[a].

| | | Size Grade | | | | |
|---|---|---|---|---|---|---|
| | Sort Class | G1 | G2 | G3 | G4 | G5 |
| 1/16-Inch Waterscreen Samples, All Sessions | Bone (Unburned) | X | X | X | 2-4 | |
| | Bone (Charred; blackened throughout) | X | X | X | 2-4 | |
| | Bone (Calcined; white, gray throughout) | X | X | X | 2-4 | |
| | Bone (ID[b]) | | | | 3-9 | 3-9 |
| | Natural Rock | X | X | X | 2-4 | |
| | Charcoal | 3-9 | 3-9 | 3-9 | 5-9 | |
| | Fire-cracked Rock | X | X | X | 2-4 | |
| | Modified Stone (Stone tools and flakes) | X | X | X | X | X |
| | Pottery[c] | 2 | 2 | 2 | 2 | |
| | Shell (All types)[d] | X | X | X | X | X |
| | Ochre/Pigment (Hematite or limonite) | X | X | X | X | 3-9[e] |
| | Historic Material (Metal, glass) | X | X | X | X | |
| | Miscellaneous[f] | X | X | X | X | X |
| | Unsorted Residue | | | | 5-9 | X |

| | | Size Grade | | | |
|---|---|---|---|---|---|
| | Sort Class | G1 | G2 | G3 | <G3 |
| 1/4-Inch Dryscreen Samples, May 2002 | Bone (Unburned) | X | X | X | |
| | Bone (Charred; blackened throughout) | X | X | X | X |
| | Bone (Calcined; white, gray throughout) | X | X | X | X |
| | Natural Rock | X | X | X | |
| | Fire-cracked Rock | X | X | X | X |
| | Modified Stone (Stone tools and flakes) | X | X | X | X |
| | Pottery[c] | X | X | X | X |
| | Shell (All types) | X | X | X | X |
| | Ochre/Pigment (Hematite or limonite) | X | X | X | X |
| | Historic Material (Metal, glass) | X | X | X | X |
| | Miscellaneous[f] | X | X | X | X |
| | Unsorted Residue | | | | X |

[a] Field sessions: 2=May 2002; 3=September 2002 Session 1; 4=September 2002 Session 2; 5=Remote Sensing; 6=2006 Session 1; 7=2006 Session 2; 8=2006 Session 3; 9=2006 Session 4. See table 3.1 for additional information on field sessions.
[b] ID bone includes specimens potentially identifiable to element and genus.
[c] For the May 2002 session, native earthenware pottery was sorted into a separate category. For all other sessions, pottery was included in the miscellaneous sort category.
[d] Shell from Session 2 (May 2002) was not quantified.
[e] Ochre and pigment not consistenly sorted from size grade 5 fractions.
[f] "Miscellaneous" items include fossils, seeds, ash, burned earth, unidentified organic materials, and other unclassified specimens.

from the same level and unit (see chapter 3). As sorting and basic quantification progressed, data on each sort class were entered into separate Access tables. At the conclusion of the project's collection processing phase, the Access database contained three tables for each material class, including one for the May 2002 session, one for the September 2002 sessions, and one for the 2006 sessions. These separate tables, along with corresponding field catalogs, were then combined into a single project database. During this process, the alphanumeric designations assigned to plotted specimens in September 2002 were converted to decimal equivalents (see chapter 3 and appendix G). Supplementary data on excavation volumes and analytic units were then entered into the combined catalog. Tables containing data obtained from intensive analyses of faunal remains, flaking debris, and stone tools were created as needed. Table 4.2 lists the 18 data tables comprising the final project database.

Table 4.2. Data tables comprising the final Microsoft Access project database.

| Table Name | Content | Fields | Records |
|---|---|---|---|
| AB Point Metric Data | Agate Basin point sample | 24 | 33 |
| All Stone Tools Sheet 1 | Stone tools (except Surface/Lakebed [SC] analytic unit) | 16 | 136 |
| All Stone Tools Sheet 2 | Stone tools (except Surface/Lakebed [SC] analytic unit) | 15 | 136 |
| Bone Quantification | Non-identifiable general level bone | 8 | 1,852 |
| Combined Catalog and Processing | Provenience data (all site areas, all analytic units) | 29 | 4,318 |
| CSFD | Chipped stone flaking debris (all size grades) | 12 | 1,401 |
| Dentition Measurements | Bison dentition | 15 | 48 |
| Excavation Volume | Calculated excavation volume | 3 | 680 |
| Faunal Data | Plotted bone | 38 | 3,491 |
| Final General Quantification | Sort classes other than modified stone and bone | 8 | 2,968 |
| Individual Flake Analysis | Chipped stone flaking debris (size grades 1, 2, and 3) | 16 | 144 |
| Metapodial Measurements | Bison metapodials | 15 | 12 |
| Non-bison Catalog Numbers | Catalog numbers associated with non-bison remains | 2 | 135 |
| Plotted Ochre | Plotted hematite, limonite, or pigment | 7 | 4 |
| Shell Quantification | Gastropods and bivalves | 10 | 598 |
| Square Designations | Alphanumeric unit designations | 5 | 3,962 |
| Surface Points | Agate Basin points in the Surface/Lakebed (SC) analytic unit | 26 | 21 |

### Analytic Unit Definitions

Analytic units provide a framework for analysis and comparison by aggregating discrete provenience lots that share spatial, depositional, and temporal properties. For the Area A collection, artifacts and other materials are partitioned into eight analytic units based on their lithostratigraphic context and method of recovery (table 4.3). Three analytic units are used to organize specimens collected from the surface. The "Surface/Lakebed—Area A (CC/GL)" unit combines items in the controlled surface collection sample obtained during the May 2002 session with items from lakebed sediment contexts excavated during the September 2002 sessions. A single item known to be from the surface of Area A but lacking specific provenience data is also included in this analytic unit. The specimens assigned to this analytic unit derive from several different stratigraphic contexts and so vary in age, from the late Pleistocene/early Holocene transition to the late Holocene.

The second analytic unit comprised of specimens from the surface, designated "Surface/Lakebed—Area A (SC)," consists of a sample of 21 large patterned bifaces obtained by artifact collectors in 2000 or 2001. All of these items are thought to come from Area A. Twenty of them are definite or probable Agate Basin points and point fragments; the other item assigned to this analytic unit is probably not a projectile point. The third surface analytic unit ("Surface/Lakebed—Area P") includes two items recovered from lakebed sediments on the northeastern edge of the island in an zone designated Area P. The boundaries of Area P are not defined, but it encompasses one or more wave-cut beaches marking the northeastern and eastern edge of the site during the lowest recent stand of Lake Sakakawea. A moderately dense scatter of artifacts and flaking debris occurs in this area, but just two items—a Folsom point base and a Late Prehistoric point—were collected.

Five analytic units are used to organize artifacts and materials recovered from intact subsurface deposits. One of these is reserved for artifacts from two excavation levels in square 1247NE1108, which exposed an undetermined stratum within the Oahe Formation. However, just three flakes and no tools or bone fragments were recovered from these two levels. All other excavation levels are assigned to one of the four lithostratigraphic units of the Oahe Formation, based on measured profiles, total station elevation data, and narrative sediment descriptions from excavation level forms (see chapter 2 for descriptions of these strata). Data from measured profiles were given the greatest weight in the assignment process. For simplicity's sake, all excavation levels are assigned to one of the four defined contexts rather than to an undefined "mixed" context, even though some levels clearly span more than one stratum. In such cases, the level was assigned to the more-recent stratum. This conservative decision was taken to minimize the possibility that the Aggie Brown Member analytic unit, which is the principal focus of the Area A investigation, incorporates artifacts and other materials dating to later time periods. However, in two cases, described in more detail later, diagnostic Agate Basin projectile point fragments were recovered from excavation levels that are assigned based on stratigraphic data to later analytic units. In these

Table 4.3. Summary of analytic units defined for Area A.

| Analytic Unit | Recovery Method(s) | Excavated Volume (cu. m) | Time Period |
|---|---|---|---|
| Surface/Lakebed—Area A (CC/GL) | Controlled surface collection; excavation | 1.185 | Mixed |
| Surface/Lakebed—Area A (SC) | Uncontrolled surface collection | n/a | Agate Basin |
| Surface/Lakebed—Area P | Uncontrolled surface collection | n/a | Mixed |
| Riverdale Member | Excavation | 1.605 | Middle or Late Holocene |
| Pick City Member | Excavation | 8.747 | Early Holocene |
| Aggie Brown Member | Excavation | 38.778 | Agate Basin |
| Mallard Island Member | Excavation | 2.222 | Agate Basin |
| Indeterminate | Excavation | 0.270 | Unknown |
| Total | | 52.807 | |

instances, the projectile point fragments themselves were assigned to the Aggie Brown analytic unit, but the other items from those levels were assigned to the more recent period. However, the number of artifacts associated with these transitional levels is quite small, largely because the Agate Basin component lies at the bottom of the Aggie Brown Member and because the overlying units contain only sparse remains.

The most recent Oahe Formation analytic unit is the Riverdale Member, which dates to the middle and late Holocene. Riverdale Member sediment was exposed only in a small number of excavation squares on the north and west edges of Area A. As detailed in chapter 3, it is not clear whether the upper or lower submember of the Riverdale was exposed. The Pick City Member, the next-oldest analytic unit, was exposed in about one-quarter of the excavation squares, all but one of them on the southwest side of the main bonebed. The single exception is square 1308NE1055, which exposed the full thickness of the Pick City Member and which contained evidence of at least two occupations. Specimens from Pick City contexts date to the early Holocene.

Virtually all of the bone, and the majority of the flaking debris and stone tools, are assigned to Aggie Brown Member contexts that date to the late Pleistocene/early Holocene transition. However, no artifacts or bones occur in many of the excavation levels assigned to the Aggie Brown Member, especially in the deepest part of the kettle basin, because the Agate Basin occupation is relatively thin and because it occurs at the base of the Aggie Brown. Two Agate Basin point fragments were recovered from excavation levels assigned on the basis of stratigraphic data to more-recent lithostratigraphic units. The distal end of one point was recovered from lakebed deposits just a few cm above the main bonebed in square 1274NE1121 (CN1768.01). A burned Agate Basin midsection was recovered from a level assigned to the Pick City Member in square 1275NE1108, 40 to 50 cm above the bonebed (CN9238.01). Both of these items are assigned to the Aggie Brown analytic unit, but all other items from these levels are assigned to the Surface/Lakebed (CC/GL) or Pick City analytic units, respectively. The burned, distal end of an Agate Basin point was also plotted on the surface in square 1278NE1121, within the main bonebed, and this item too is included in the Aggie Brown analytic unit (CN7230).

The oldest analytic unit is the Mallard Island. Mallard Island Member sediment was laid down in the late Pleistocene. A few flakes and a small amount of bone scrap, but no plotted bones or stone tools, are assigned to this analytic unit. Because there is no evidence that the eastern kettle basin in Area A was utilized prior to Agate Basin times, these few items are thought to be temporally associated with the bonebed, having been displaced downward by faunalturbation.

## Creating the GIS Database

*Kenneth L. Kvamme and Jo Ann Kvamme*

A geographical information system (GIS) is powerful software tool for the manipulation, analysis, and display of spatially distributed information. GIS has been long used in archaeology and has proved revolutionary for managing state-wide cultural resources data; spatial analyses of artifact distributions within sites or site locations within regions; and for a wide range of spatial models, including predictive models of archaeological site location and inter-visibility studies of sacred sites (Kvamme 1999). GIS is particularly useful for managing within-site data. All information may be displayed in map form or in data tables, charts, and histograms. Database queries may be made in several ways. One may query a data table, essentially a spreadsheet with rows holding information about individual objects and columns representing variables. Elements that meet a search condition are then highlighted in the table, but since all GIS information is linked to spatial coordinates, a map of selected objects is simultaneously generated. For example, one may make a query for all tibias showing cut marks; the result will include a table as well as a map showing all tibias with cut marks. Searches and queries may also be made in the other direction. One may point to an object or objects in a GIS map causing all information about the object(s) to be displayed in data tables.

Several key concepts are central to an understanding of GIS. One is that all information is linked to real world spatial coordinates, which permits maps to be generated and spatial relationships between objects to be realized. Spatial coordinates in the Beacon Island GIS correspond to the excavation grid system. A second concept is that of layers. Each thematic map in a GIS is known as a layer, which may be called up as needed. In the Beacon Island database, distinct layers for bison bones and for lithic artifacts of various types are generated. A third concept pertains to the type of spatial data representation. Vector layers hold information about discrete objects and may represent them by points, lines, or polygons. In the Beacon Island database, some vector layers hold points that represent the loci of lithic artifacts or the center-points of bones. Other vector layers are represented by polygons that represent objects that occupy significant areas, such as larger bones or features. Raster layers, on the other hand, are more suited for data that vary continuously, such as counts or weights of lithics by meter square or of elevations systematically recorded meter-by-meter. Indeed, raster data occur in square units, organized in rows and columns, with each element holding a number that represents a single variable of interest, such as an elevation or lithic count. All imagery occurs in a raster format, including photographs and scans, where individual elements (pixels) represent colors or tones that vary continuously across an image. Raster and vector data types are employed in the Beacon Island database. Several recent textbooks have been written about GIS in archaeology to which the reader is referred for further information (Conolly and Lake 2006; Wheatley and Gillings 2002).

Setting up a GIS database for Beacon Island was a straightforward process because GIS tools are now well developed, but it was also challenging owing to the large number of spatial objects, primarily bone, that had to be encoded. Because GIS includes a graphical interface that permits all database objects to be displayed in map form it was desirable to encode the approximate shape of each bone. This meant that the outline of each bone had to be manually digitized, a process that required the drawing of each one on a computer screen. This process was complicated by the fact that, in 2006, maps of the excavated bones were not created. Rather, vertical digital photographs were taken of the exposed bones in each 1 x 1 m square as the primary means of documenting their positions. With the bonebed exhibiting some thickness, many of the squares had to be photographed several times in order to image all of the bones. This means that the shape of each of the bones had to be interpreted in the photographs. In addition to bone, other datasets encoded include lithic artifacts, a single archaeological feature, and basic elevation data for the site surface as well as certain subsurface stratigraphic units.

The following sections describe the Beacon Island GIS database and the various procedures employed in its creation. The project included three stages: (1) pre-processing of the digital images of the bonebed and creation of site-wide photo-composite maps of the bonebed in four "virtual" levels or image slices; (2) interpretation of the photo-composite maps by PCRG faunal analysts; and (3) creation of the actual GIS databases, which itself included multiple stages of development. Pre-processing of the 217 vertical digital images of the bonebed was performed using Adobe Photoshop. All GIS development utilized the ArcMap version 9.2 or 9.3 developed by the Environmental Systems Research Institute (ESRI). The extensive data tables holding archaeological data were exported from Microsoft Access tables, first into Microsoft Excel spreadsheets and then into ArcMap.

### Pre-Processing of the Bonebed Imagery

As the bonebed was exposed during excavations, each 1 x 1 m square was digitally imaged in a near-vertical format at high resolution (about 1600-1900 pixels [px] per meter [.53-.62 mm/px]) (see chapter 3 for additional details on field documentation methods). Often, where bone was most dense, multiple images were taken of successive slices of the bonebed as it was excavated. The imagery is clear, but suffers from five problems:

1. Shadows from excavation unit walls caused differential image brightness, making it difficult to readily visualize bones in many of the images.
2. In the vertical images of each 1 x 1 m unit, bright orange corner nails, accurately placed by total station survey methods, could readily be discerned at the level of the ground surface, but the same corner points could only be inferred at the level of the bonebed (at some depth below the surface) owing to optical parallax.
3. The images were not acquired in an exact vertical plane, although all were near-vertical. This meant that each 1 x 1 m square is actually portrayed as a trapezium—a quadrilateral plane figure with no two sides exactly parallel. Nor were the sides of the same length.
4. The resolution of the imagery is too high for easy handling in a GIS database, considering that the area of excavation captured by the GIS forms a rectangle measuring 18 x 20 m and that imagery

from each meter unit had to be concatenated in the final database.

5. Each image included areas outside of the 1 x 1 m unit of interest.

Each of these problems was addressed in the 217 images of excavation squares representing four arbitrary slices of the bonebed. Although many of these problems could be solved by GIS, it was much more efficient and less time-consuming to address them using Photoshop. This was the largest task of the first principal stage of the project, which also included the concatenation of the images into composite image-maps of the four slices of the bonebed (described in the next section).

*Reducing the Shadow Problem*

Each image of a 1 x 1 m unit of a particular slice of the bonebed was inspected for significant wall or other shadows that degraded visualization of the bones. About 15 percent of the images include significant shadows. They were manipulated in Photoshop by selecting the shadowed pixels with appropriate tools and then brightening them by 20 to 60 percent (figure 4.1a).

*Dealing with Image Perspective*

In each image of a slice of the bonebed, approximate corner points of the 1 x 1 m unit at the level of the bonebed were visually inferred by projecting the downward slant of the surveyed corner nails visible at the ground surface (figure 4.1b). This process is believed to be accurate to within about a centimeter.

*Image Resolution, Rectification, and Resampling*

Given the 18 x 20 m region of the bonebed GIS it was determined that an ultimate spatial resolution of 2 mm/px (.002 m) or 500 px/m could be adequately handled by the software. This resolution yielded a final raster size of 9,000 x 10,000 px for each slice of the bonebed. This represented a three- to four-fold reduction in the initial image resolution (about 1600-1900 px/m; figure 4.1c). Nevertheless, the 500 px/m resolution provides sufficient

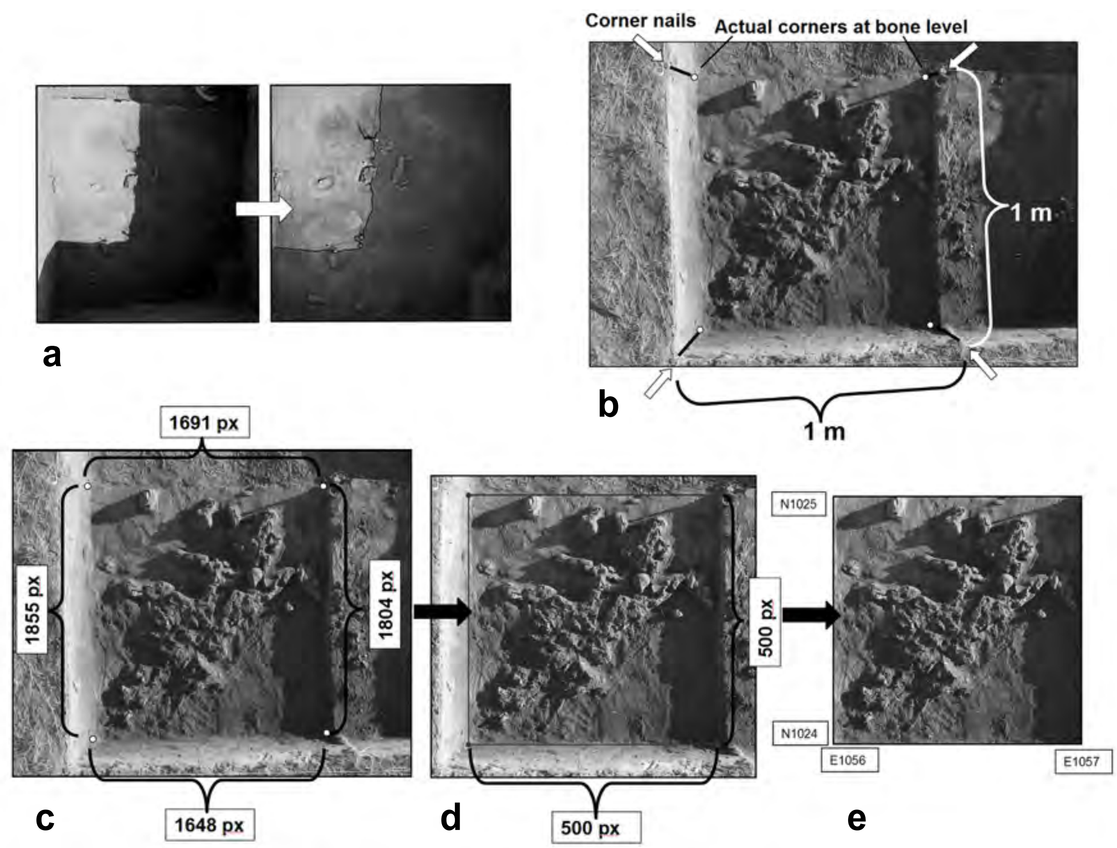


Figure 4.1. Pre-processing of the one-meter excavation unit images with Photoshop: a) reduction of the shadow effect, b) projecting the one-meter unit corner pints to the level of the bone bed, c) original unit boundaries illustrating a trapezium with sides of unequal length, d) each distorted image was rectified to form a 500 px square using Photoshop's bicubic spline resampling, e) each unit image was cropped at its boundaries.

image detail for visual inspection and identification of bone elements by a faunal analyst, the primary focus of the second stage of the project.

A template holding a square measuring 500 x 500 px was employed as a layer in Photoshop so each image of a 1 x 1 m square could be shrunk an appropriate amount to fit exactly this square template. Since the 1 x 1 m units in the imagery were not square, but formed trapeziums (figure 4.1c), Photoshop *distort* functions were employed to force the inferred corner points at the level of the bonebed to match the corner points of the template. In this manner, each image of a 1 x 1 m unit of a slice of the bonebed was rectified to its correct square form and resampled to 2 mm/px (figure 4.1d).

*Image Cropping*

The Photoshop crop tool was employed to crop each 1 x 1 m square at its exact unit boundary. The result of this process was the generation of a 500 x 500 px image for each level of each 1 x 1 m unit (figure 4.1e).

Building Image Composites for Each Slice of the Bonebed

For each of the four virtual slices of the bonebed, the 1 x 1 m unit images were assembled and concatenated in correct spatial position using Photoshop (figure 4.2a). Along with the photo imagery, 54 sketch maps of units excavated during the 2002 field season were also included (figure 4.2b). The end result was a photo-map of each slice of the bonebed that included the site coordinate system. These were returned to PCRG for additional analysis (figure 4.2c).

Turning the Bonebed Imagery into Line Drawings

The second stage of the project was completed by PCRG faunal analysts. It involved printing the photo-composite maps of each slice (figure 4.2c) at a large scale (3 inches representing 1 meter or 1:13.1). Each bone element larger than 5 cm in the imagery was manually traced onto vellum with a fine-point marker (figure 4.3).

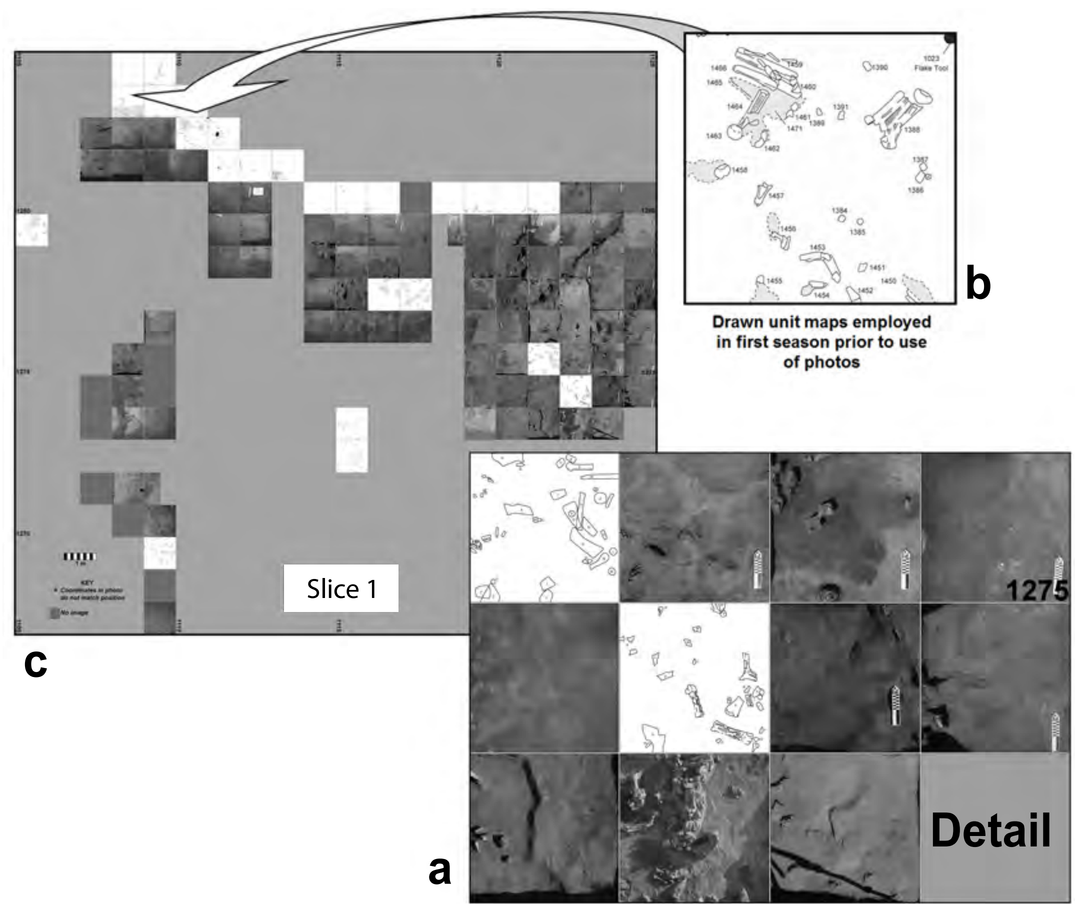


Figure 4.2. Layer composite image-maps were formed by a) concatenating the individual unit photos in correct spatial position that included b) drawn unit maps from the first season to achieve c) site-wide composite images in four slices, complete with scales and spatial coordinates (Slice 1 illustrated).

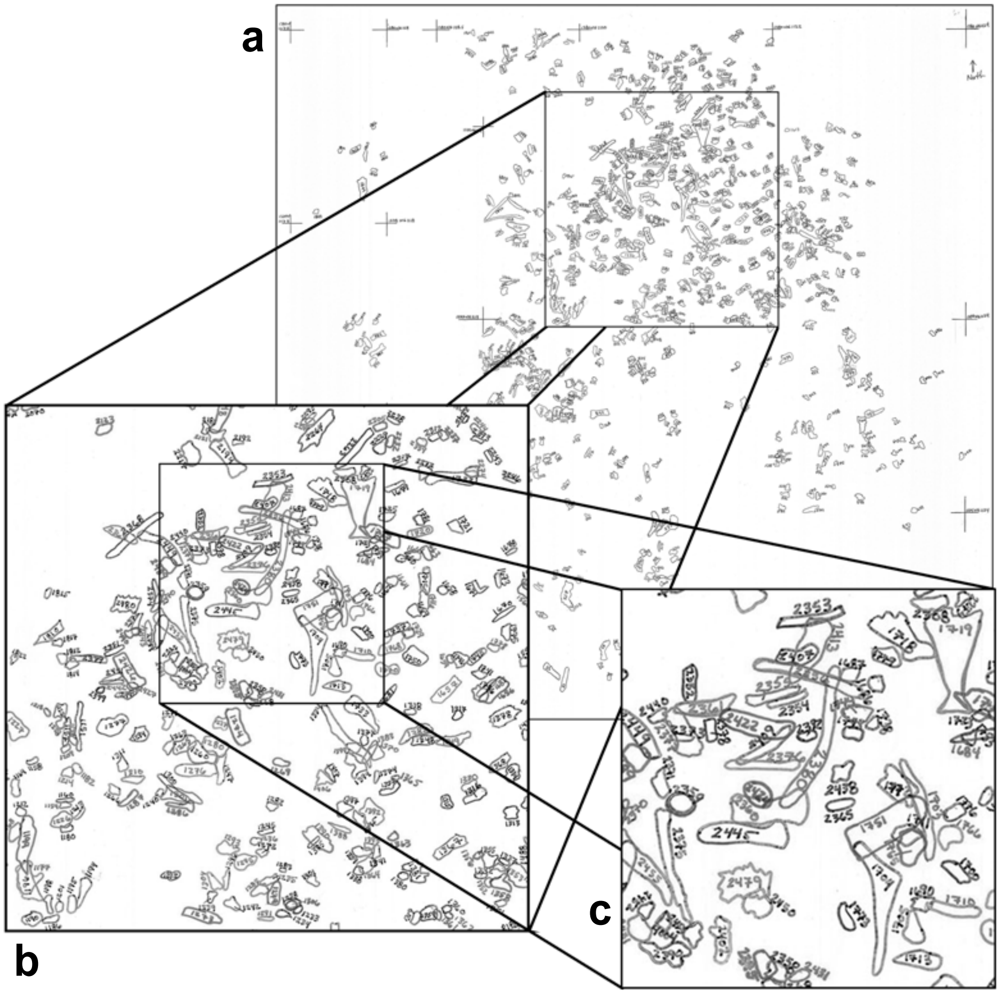


Figure 4.3. Bone elements larger than 5 cm were hand-traced from the photo-composites onto vellum and digitally scanned. a) One of the five traced map sections illustrating cross-hairs at unit corner points for ground control registration points, with b, c) illustrating increasingly larger scales. Various tones represent different colors in the original imagery (black, blue, red, and green).

This required consultation of field notes and other data because it was frequently difficult to distinguish between pieces of bone and masses of sediment. A total of 1,784 identified specimens larger than 5 cm was traced out of a total of 3,330 plotted bison bone pieces. Each bone was assigned a unique identifying number, written directly on the vellum, that could be linked with a single element (row) in an Excel spreadsheet that held data in up to 21 variables or fields. Separate vellum maps were generated for different slices and areas of the bonebed owing to its complexity, and several colors were employed to clarify individual bones in regions where many overlapped or were crowded together (shown in gray scales in figure 4.3). The maps also included the loci and outlines of 15 larger lithic artifacts as well as the single archaeological feature, a basin hearth. Critically, the maps contained a series of cross-hairs throughout to indicate the exact positions of grid corner points along with their spatial coordinates in the site's local coordinate system (figure 4.3a). These points were critical for the registration of the data in a GIS database.

PCRG scanned each of the vellum maps at high resolution and returned them for use in developing the GIS database. They also sent Excel spreadsheets containing data on all plotted items, not only identified specimens meeting the 5 cm minimum size threshold. Data also were compiled on unplotted bone weight by size grade and flaking debris by stone type and size grade for each excavation unit. Elevation points were also incorporated into the GIS.

## Creating the Vector Bonebed Layer

Creation of the bonebed database required a series of steps, including registration and resampling, digitization, and data coupling.

*Registration and Resampling*

The scans of the vellum line drawing of the bones, lithic artifacts, and the feature were registered to the site coordinate system using the drawn cross-hairs at grid corners (figure 4.3a) as ground control points and a standard affine transformation (Conolly and Lake 2006). The scans were also resampled down to 500 px/m to match the resolution of the composite bonebed imagery and maintain sufficiently small and efficient-to-manipulate layers.

*Digitizing and Vectorization*

Heads-up or on-screen digitizing was used to turn the traced bones in the scanned imagery to vector polygons in the form of ArcMap shapefiles. This process employed ArcEditor to click in significant turn-points along the edge of each bone element to convert it into a polygon describing its shape (figure 4.4). As each polygon was digitized its unique identifier was entered into the corresponding data table. Using this technique, 1,784 bones were vectorized with associated identifiers (figure 4.5a).

*"Joining" with the Microsoft Excel Data Table and Performing Queries*

The shapefile was "joined" with the Microsoft Excel table holding up to 21 fields of data for each faunal specimen by matching the unique identifier held in the table and the shapefile. The result is a searchable database of all bone elements (figure 4.5b).

The ability to conduct database searches and queries is illustrated in figure 4.6 using the ArcMap "Select by Attribute" query tool, which is based on Structured Query Language (SQL; Burrough and McDonnell 1998). Here, a simple search of the database for the bone element (EL) "humerus" (HM) reveals a selection for that bone type in tabular (shaded) and map (heavy outline) form.

A separate GIS layer was generated for all of the plotted bone (3,330 specimens), including 1,546 small or unidentified bones that were not vectorized. The position of each element in this database is indicated by a single {x, y} coordinate or point representing the center of each

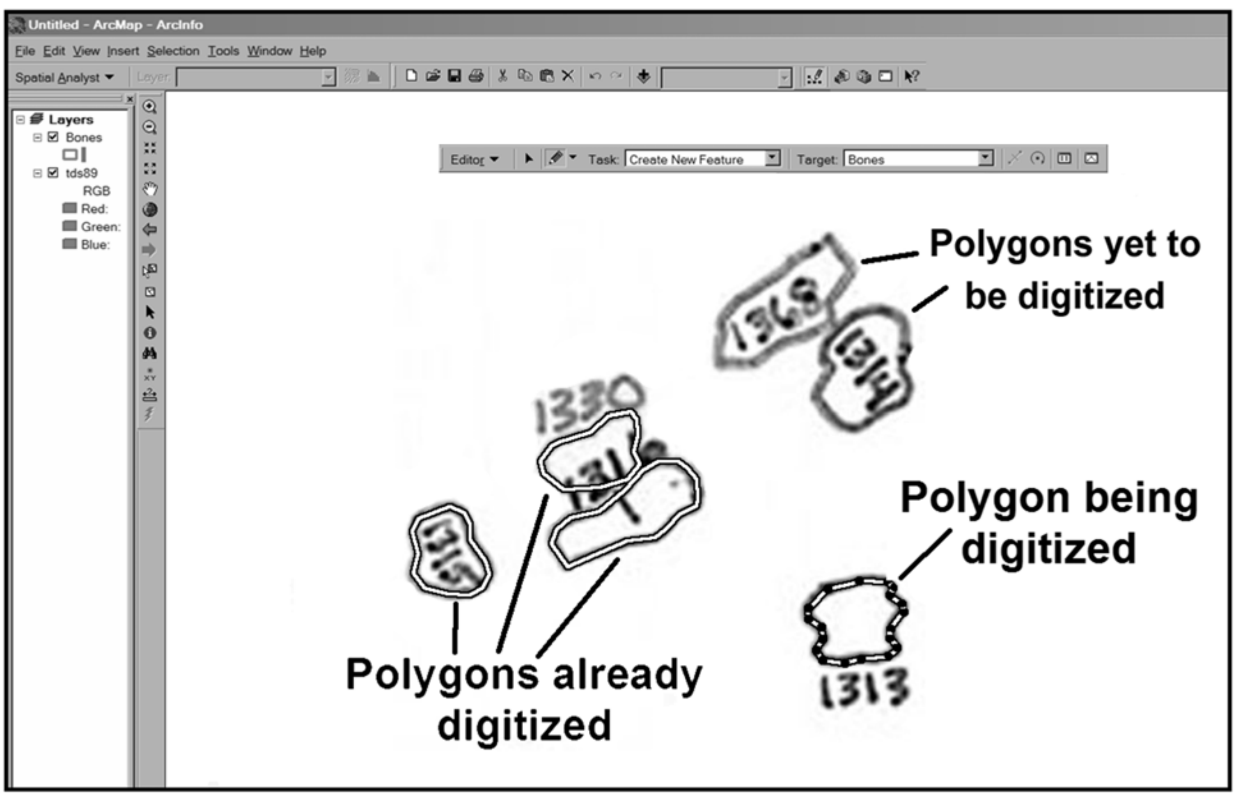


Figure 4.4. Digitizing polygons meant manually tracing each polygon in the scanned graphics by clicking at significant turning points along the perimeter of each, as illustrated for Polygon 1313. Concurrently, each unique identifier was entered into the shapefile's data table.

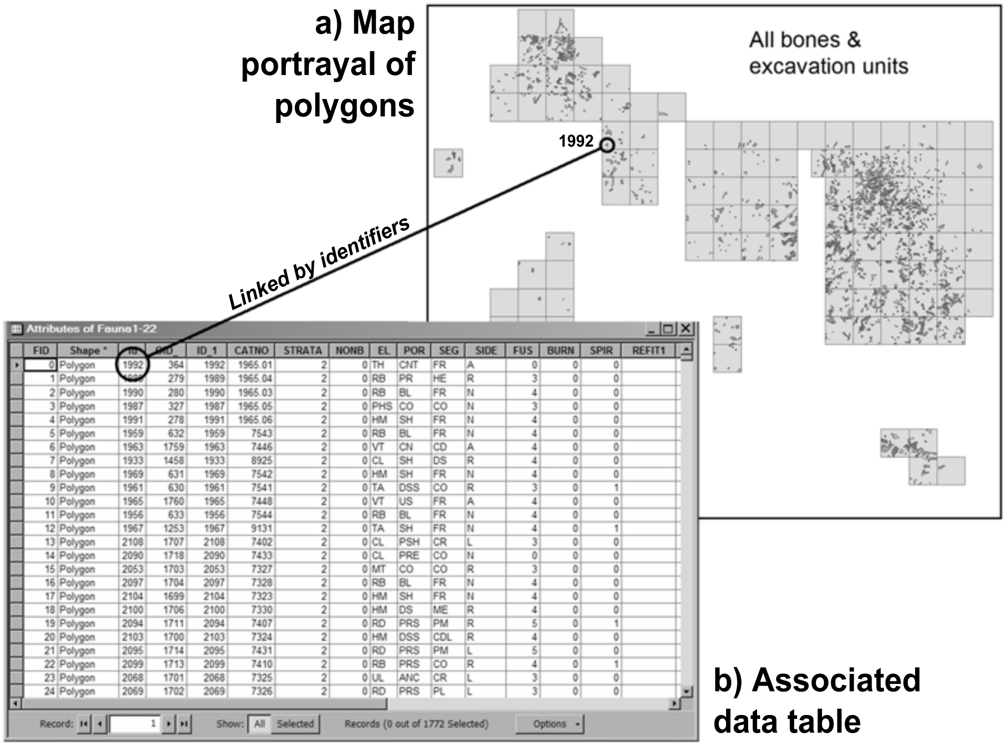


Figure 4.5. The completed fauna shapefile showing a) the polygon outlines of each bone element larger than 5 cm, and b) the associated data table created by “joining” an Microsoft Excel spreadsheet on the basis of the unique identifiers.

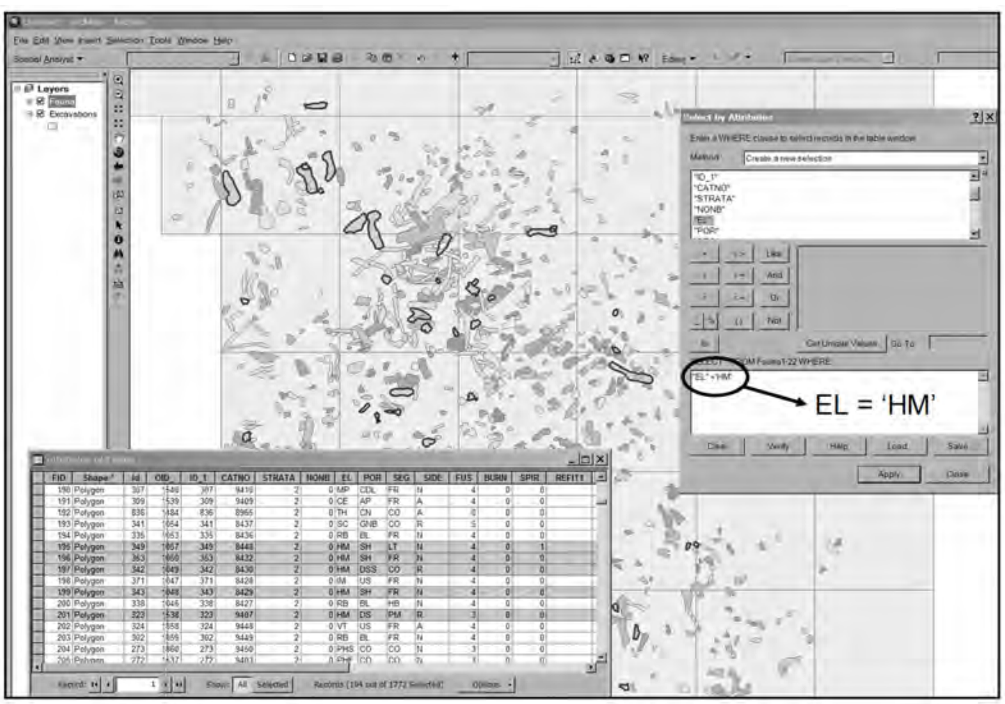


Figure 4.6. The final fauna database permits SQL searches through ArcMap’s “Select by Attribute” tool. This example shows a selection using the field “element” (EL) for the type “humerus” (HM), with the result in map (bold outline) and tabular (shaded rows) form.

bone, including the larger ones held in the bone polygon layer.

### Other Vector Layers

In addition to the point and polygon vector shapefiles generated for the bison bone data, several other vector layers were generated for the Beacon Island GIS. Vector layers occur in four possible formats and each vector file is linked with a data table that holds multiple fields of data about each element in the file. As traditionally defined in GIS, vector layers represent conventional map elements that may be characterized by points, lines, or polygons (Burrough and McDonnell 1998). All three of these types are utilized to represent elements of the Beacon Island data. A fourth type of vector layer is also included, which is known as a TIN model, or "triangulated irregular network." It is through the TIN model that vector layers can represent surfaces. Each elevation point recorded in the field represents the vertex of a triangle and every three points that make up a triangle define the surface of a plane. Technically, each triangle represents a polygon that encloses an area, but TIN models occupy a special category because collectively, the hundreds or thousands of triangles represent a surface as opposed to the discrete objects of a traditional polygon shapefile. Several TIN models occur in the database, although they were employed primarily as intermediate steps in the creation of raster digital elevation models (DEM). Each of the 22 vector layers generated in this project is listed and briefly described, by name and vector data type, in appendix I.

### Raster Layers

Raster layers occur in a gridded structure composed of cells holding measurements or counts. The cells are organized in a two-dimensional matrix composed of rows and columns. Rasters may also represent pictorial or image data, such as a JPEG or TIFF file, where the cells hold image brightness information, or they may represent surfaces where the cells hold measurements of some continuous phenomenon as it varies over space, such as an altitude (Burrough and McDonnell 1998). Many of the Beacon Island primary data sets occurred in a raster format, such as the bonebed photo imagery taken for each excavation unit as well as the resulting image composites. Several additional raster layers were generated for the Beacon Island database. Ten primary layers derived from photos or drawings from which most of the data were generated are listed in appendix I. Twenty-five secondary layers derived analytically or from data held in Excel files are also listed in appendix I. For the most part, this second group holds counts or weights of items (such as lithics or bones) per excavation square.

# 5

## Analysis of Bison Remains

*Jennifer Borresen Lee, Stacey D. Bennett, and George T. Crawford*

This chapter describes the piece-plotted bison remains recovered from Area A in 2002 and 2006 (table 5.1). The assemblage includes 3,473 specimens, of which 3,330 are assigned to Aggie Brown Member excavation contexts (see chapters 2, 3, and 4 for additional information on excavation contexts and analytic units). Lee (2003b) describes the surface assemblage, comprising 110 specimens. The 16 plotted specimens (collected under 18 catalog numbers) from Aggie Brown contexts representing species other than bison are described in chapter 8, along with other mammalian and non-mammalian remains sorted from general level lots.

Accompanying the plotted specimens that are the focus of this chapter is a total of just over 240 kg of bone scrap recovered by waterscreening (table 5.2). Analysis of a sample of this general level material demonstrates that it includes very few identifiable elements, virtually all of them representing bison. Additional data on the occurrence of identifiable elements in coarse fraction (size grades 1 through 3) waterscreen samples are presented in the next section.

Table 5.1. Counts of plotted faunal remains recovered from Area A, organized by analytic unit.

| Analytic Unit | Bison | Non-bison | Total |
|---|---|---|---|
| Surface/Lakebed (CC/GL) | 110 | | 110 |
| Riverdale | 15 | | 15 |
| Pick City | 18 | | 18 |
| Aggie Brown | 3330 | 16 | 3346 |
| Total | 3473 | 16 | 3489 |

Jennie Lee identified, analyzed, and wrote the initial description of the bison bone recovered during the May 2002 field investigation (Lee 2003a). Stacey Bennett, working under Lee's direction, identified and coded the bison remains obtained during September 2002 and 2006. Bennett also supervised the initial sorting and quantification of bone pieces from waterscreen lots. Carl Falk provided technical assistance with various aspects of the processing and analysis. Bennett and Lee together collected the metric and other data on complete and fragmented metapodials, calcanea, and dentition on which the herd composition and site seasonality interpretations are based. Bennett and George Crawford wrote the sections of the chapter dealing with those topics, with input from Lee and Mark Mitchell. Data on mandibular tooth eruption and wear data were generated by comparing the Beacon Island dentition with known age-at-death specimens maintained by the University of Wyoming's Department of Anthropology. Dr. Lawrence Todd aided Lee and Bennett in that analysis and also prepared the dentition drawings that appear in this chapter. Lee provided overall direction for the analysis and wrote the majority of the chapter.

### Overview of Zooarchaeological Methods

At the outset, a work flow protocol was established for the project that included sample handling procedures, data recording formats, coding conventions, and curation procedures. Specimens were first removed from their aluminum foil field packaging, and adhering sediment was removed using small brushes and wooden picks.

Table 5.2. Weight in grams of unplotted bone recovered from Area A, organized by analytic unit and size grade.

| | Size Grade | | | | |
|---|---|---|---|---|---|
| Analytic Unit | G1 | G2 | G3 | G4 | Total (g) |
| Surface/Lakebed (CC/GL) | 17.4 | 8.3 | 44.2 | 13.4 | 83.3 |
| Riverdale | | | 53.5 | 43.9 | 97.4 |
| Pick City | 67.9 | 83.3 | 229.1 | 177.6 | 557.9 |
| Aggie Brown | 11288.2 | 83018.6 | 131663.5 | 13535.5 | 239505.9 |
| Mallard Island | | 71.2 | 148.8 | 14.6 | 234.6 |
| Total (g) | 11373.5 | 83181.4 | 132139.1 | 13785.1 | 240479.1 |

Foam-jacketed specimens or specimen aggregates were opened and the associated sediment was screened and discarded. After identification and coding was complete, the specimens were re-bagged in archival polyethylene bags. Complete provenience information was recorded on each bag and the portion of the original paper bag containing provenience data was retained. A few specimens, mainly mandible and metapodial fragments, were temporarily left in their field packaging until metric data could be collected. When the analysis was complete, specimens were boxed by excavation square.

Piece-plotted items from each unit were first sorted into four groups according to element type and degree of fragmentation. Substantially complete bones were coded first, followed by rib and vertebrae fragments. Long bone fragments were identified and coded next. These fragments were then examined for refits and articulations. Finally, highly-fragmented specimens were examined and identified when possible. Items in this last category were systematically compared to previously identified fragments to identify refits or associations. As appropriate, field identifications, field notes, and level photos and drawings were consulted to assist with element identification and to help detect refits and associations. Complete or nearly complete specimens were bagged immediately, but most fragmentary elements were reexamined after the initial coding was complete to confirm the identification. Additional resources or other analysts sometimes were consulted on the identification of fragmentary specimens.

When a refit was identified between two or more plotted bone fragments found in close proximity they were coded as one segment and were subsumed under a single catalog number. Associations were made between re-fittable, but non-adjacent, fragments of a single element; between fragments that probably or possibly derived from a single element; and between distinct but articulated elements. However, in contrast with refits, associated fragments or elements retained their individual catalog numbers. In some cases, piece-plotted items were found to contain fragments of more than one element. In that event, the single catalog number was retained but each element was coded separately.

The bison remains were identified using two modern bison (*Bison bison*) skeletons: one in the possession of Jennie Lee and one loaned to PCRG by the Denver Museum of Nature and Science. To facilitate comparison with other bison bonebed studies, the remains were analyzed using a coding system developed by Todd (1987:121-122) and subsequently modified by Hill (2001). Analyses of Agate Basin-age bison remains from the Agate Basin site (Hill 2001), the Hell Gap site (Byers 2002, 2009) and the Frazier site (Borresen 2002), as well as several other Paleoindian sites, have all utilized the Todd method. Characteristics recorded for each identifiable specimen include element, portion, segment, side, fusion, diagnostic landmarks, breakage, and burning. Lee (2003a) notes that the surfaces of many of the bones recovered during the May 2002 testing program are poorly preserved or difficult to observe owing to carbonate build-up. Accordingly, surface modification data were not collected on the material collected in September 2002 and in 2006. The presence or absence of spiral or green fractures on long bone fragments was noted, but the frequencies of other fracture types were not tabulated.

The current study also added to and modified several of Hill's (2001) element landmarks in order to simplify (and maximize) the quantification process. The coding format, including landmark descriptions, is provided in appendix D. Modifications to Hill's landmarks include the addition of Landmark 3 Side and Landmark 4 Side for the cervical, thoracic, and lumbar vertebrae and Landmark 16 for the radius. Landmark 3 Side and Landmark 4 Side refer to the cranial and caudal articular processes, respectively, and were added because individual (i.e., right or left) articular processes are far more frequent than specimens preserving both processes. Landmark 16 (the styloid process of the ulna) was added to the radius because the distal ulna fuses to the radius and is therefore often present on distal radius fragments. The addition of this landmark simplifies quantification of MNE for the radius, ulna, and radius-ulna (RDU) specimens.

The Agate Basin bison remains were quantified by number of identified specimens (NISP), minimum number of individuals (MNI), minimum number of elements (MNE), and minimum number of animal units (MAU). Briefly, NISP is the total count of identified specimens, or fragments, per element. Bison bones unidentifiable to a specific element (e.g., long bone, cancellous bone, flat bone, unidentified tooth fragment) are quantified as NSP, rather than NISP (Lyman 2008). MNE denotes the minimum number of a particular element that is represented in an archaeofauna and provides a method of measuring portions of skeletons of individual species (Lyman 1994:102; Reitz and Wing 1999:215). It is based on the presence of overlapping landmarks. In general, the landmark occurring most frequently in the archaeofauna provides the MNE value for that element. In the present study, MNE values are presented both by side (when applicable) and as a comprehensive sum. As Hill (2001:31) notes, "when considered by side, these data are operational as MNI." MAU refers to the minimum number of animal units necessary to account for the specimens in an assemblage (Lyman 1994:105) and is useful as an indicator of differential transport and processing by humans (Binford 1978:70). To calculate MAU, MNE values are divided by the number of times a given element appears in a complete skeleton (Binford 1984:50-51). For instance, an MNE of four femurs yields an MAU of two. Standardized MAU (percent MAU) is then calculated by dividing each element MAU by the highest MAU in the assemblage and multiplying by 100 (Binford 1984:80-81; Binford and Bertram 1977). MNI is the minimum number of animals necessary to account for all identified specimens and is calculated based on the most frequently occurring element. For paired appendicular elements (and some axial elements), MNI per element can be obtained from MNE per side; the side with the larger MNE provides the MNI for that element. The element bearing the highest MNI provides the species MNI for the archaeofauna.

As a result of the careful excavation methods employed during the project, nearly all of the identifiable bison bone encountered was point-plotted (chapter 3). The majority of excavated sediment was water-screened through 1/16-inch mesh and the faunal remains and other archaeological materials were size graded and sorted. The size grades 4 and 5 (fine fraction) faunal material was sorted for identifiable small mammal and non-mammal remains while the size grades 1 through 3 (coarse fraction) material was examined for evidence of burning and weighed (chapter 4). The decision to leave the coarse fraction remains unsorted was based on several considerations, including time and budgetary constraints and an expectation that most identifiable large mammal bone would have been recognized during excavations and piece-plotted. That expectation was directly evaluated by Carl Falk, who examined the bone sorted from coarse-fraction waterscreen samples from the September 2002 excavation, which represent a cross-section of excavation contexts in terms of location within the site and depth of burial. Falk's analysis confirms the fact that nearly all the identifiable bone fragments occur in the plotted fraction of the sample: of the 41.6 kg of coarse-fraction faunal material recovered during the September 2002 fieldwork (17.5 percent of the total screened bone assemblage), just 20 bison skeletal elements were identified (table 5.3). Most are sesamoids and fragmentary carpals, and their exclusion from the analysis does not impact the results significantly enough to warrant examination of the size grades 1 through 3 waterscreen bone samples collected in 2006.

## Surface and Holocene Components

During the May 2002 field session at the site, 110 pieces of bison bone were recovered as part of a controlled surface collection of faunal remains, flaking debris, chipped stone tools, and burned rock (see figure 3.17); Lee (2003b) is a description and analysis of the surface bison remains. Another study of additional, surface-collected bone, likely from the same area, was carried out by Karpinski (2002). Lee's analysis of the bone in the

Table 5.3. Identifications for bison skeletal elements recovered during 2010 resort of coarse-fraction waterscreen samples (size grades 1 through 3) from the September 2002 field sessions.

| Cat. No. | Size Grade | Skeletal Element | Side | Portion | % present | Comment |
|---|---|---|---|---|---|---|
| 1691 | 1 | carpal ulnar | left | dorsal | 60 | |
| 1691 | 1 | carpal ulnar | right | body | 65 | 2 frags; dorsal in G-2, volar in G-1 |
| 1691 | 2 | carpal intermediate | right | dorsal | 15 | |
| 1691 | 2 | sesamoid proximal | unsided | body | 75 | |
| 1811 | 2 | metatarsal 2 | unsided | complete | 100 | left? |
| 1899 | 2 | carpal fused 2+3 | left | dorsal | 20 | |
| 1901 | 1 | tarsal fibular | left? | tuber | 7 | frag of unfused calcaneal tuber |
| 1920 | 2 | sesamoid proximal | unsided | complete | 100 | |
| 1920 | 2 | sesamoid proximal | unsided | body | 55 | |
| 1920 | 2 | metatarsal 2 | unsided | complete | 100 | left? |
| 1928 | 1 | carpal radial | left | body | 90 | 2 frags/refit; len. 5.6 cm |
| 1931 | 2 | ulna | left | lat facet | <5 | complete lateral facet |
| 1933 | 2 | sesamoid distal | unsided | body | 75 | |
| 1933 | 2 | metatarsal 2 | unsided | complete | 100 | right? |
| 1933 | 2 | lateral malleolus | left | body | 80 | |
| 1939 | 2 | sesamoid distal | unsided | complete | 100 | |
| 1939 | 2 | phalanx 3 | unsided | proximal | 5 | fragment/left half |
| 1959 | 1 | ulna | left | body | 7 | semi-lunar notch; len 6.7 cm |
| 1959 | 2 | ulna | right | body | 7 | semi-lunar notch; len 7.0 cm |
| 1959 | 2 | sesamoid proximal | unsided | complete | 100 | |

controlled surface collection indicates that a minimum of two bison are represented (based on left, distal humeri). Karpinski's (2002) data shows that four bison are represented by the uncontrolled surface collection (based on three right first ribs and several unfused specimens).

Bison remains recovered from buried, Holocene-age Riverdale Member and Pick City Member contexts total 15 and 18 specimens, respectively (table 5.1). All of the Riverdale material and 12 of the 18 Pick City specimens are from a single 1 x 1 m excavation unit (square 1308NE1055). Table 5.4 summarizes the bison remains from this unit. Within the unit, all except two of the post-Agate Basin-age bison specimens are associated either with GL9 and GL10 (in the Riverdale Member) or GL18 and GL19 (in the Pick City Member).

The remaining six specimens assigned to the Pick City Member analytic unit were recovered from the eastern kettle basin in Area A and include a mandibular molar fragment, a complete first phalanx, a complete second phalanx, a second phalanx fragment, a proximal sesamoid, and an unidentified fragment.

Table 5.4. Summary of bison remains from Holocene components in unit 1308NE1055.

| General Level | Element | Count |
|---|---|---|
| Riverdale Component | | |
| 9 | 4th carpal, complete, left | 1 |
| 9 | fused 2nd & 3rd carpal, complete, left | 1 |
| 9 | intermediate carpal, complete, left | 1 |
| 9 | long bone, shaft fragment | 2 |
| 9 | metacarpal, proximal fragment, left | 1 |
| 9 | metapodial, shaft fragment | 1 |
| 9 | unidentified fragment | 3 |
| 10 | 2nd phalanx, complete | 1 |
| 10 | humerus, distal fragment, right | 1 |
| 10 | long bone, shaft fragment | 3 |
| Subtotal | | 15 |
| Pick City Component | | |
| 12 | metapodial, distal condyle | 1 |
| 15 | rib, blade fragment | 1 |
| 18 | femur, shaft fragment | 1 |
| 18 | long bone, shaft fragment | 3 |
| 18 | phalange, distal fragment | 1 |
| 18 | rib, blade fragment | 1 |
| 18 | unidentified fragment | 1 |
| 19 | 1st phalanx, proximal | 1 |
| 19 | 2nd phalanx, complete | 1 |
| 19 | 3rd phalanx, proximal fragment | 1 |
| Subtotal | | 12 |

## Agate Basin Component

The vast majority of bison remains from Area A at Beacon Island were recovered from Aggie Brown Member sediment, in which the Agate Basin component occurs (chapters 2 and 3). These remains, comprising 3,330 plotted bones and bone fragments, represent a minimum of 29 bison. The following sections discuss taphonomy, bison skeletal element abundance, nutritional utility, bison bone distribution, site seasonality, and the population structure of the herd targeted by the Agate Basin hunters.

### Taphonomy

The recovery of several articulated elements suggests that post-depositional movement of bone resulting from fluvial or other processes was not significant. For instance, several sets of articulated vertebrae along with an articulated tibia and astragalus were recovered from unit 1276NE1119 and a vertebral column segment consisting of an atlas, an axis, and four cervical vertebrae was recovered from unit 1273NE1122, both in the northeast block. As discussed below, there are differences in skeletal element frequencies but these appear to be related more to carcass processing than to non-cultural taphonomic processes. There does not appear to be any bias against small elements in the assemblage; rather, all elements or element types (both small and large) are represented and are scattered together in the excavation blocks. Also, bone is densest along the upper slope of the kettle basin, particularly on the north and east sides. Recognizing that the slope of the kettle basin is gentle, this patterning nevertheless suggests that the remains were covered fairly rapidly, before water and gravity could have much impact. The conclusion that post-depositional lateral movement of the assemblage was limited is supported by data on the distribution of lithic refits and conjoins, which average just 53.2 cm apart. Chapter 6 presents more data on the modified stone refitting study.

As with many bison kill-butchery sites, the bone assemblage is highly fragmented. With the exception of several small, compact bones (e.g., carpals, tarsals, phalanges), just 22 specimens are complete, including a mandible, an atlas, an axis, a cervical vertebra, a scapula, 11 metacarpals, and six metatarsals. The heavy degree of fragmentation is undoubtedly a result of carcass processing by the site's inhabitants as well as natural attrition over the past 10,000 years. Fluctuations in the pool elevation of Lake Sakakawea, and resulting beach erosion, are directly responsible for the discovery of the site, and reservoir inundation could also have impacted the preservation of the bonebed. Though significant damage to bones, such as cortical lifting and cracking, by wet/dry cycles and fluctuations in water acidity has been demonstrated in lab experiments (Murphy 1981; Sheldon 1981), this issue was evaluated during the 2002 analysis of the bison remains and is thought to have had minimal impact on the assemblage (Lee 2003a:120). When articulated fragments removed from the field were examined it was observed that the fracture surfaces between adjacent and refittable pieces were coated with carbonate in the same way that carbonate coated the bone's exterior surfaces. There is very little likelihood that the advanced state of carbonate accumulation had anything to do with the recent presence of the reservoir. The majority of bone fragmentation, therefore, likely occurred shortly after the bone was deposited on the original ground surface. The absence of much evidence for differential degradation of upward-facing bone element surfaces indicates that the bones were deposited and then covered rather quickly with some thickness of sediment. They were then subjected to destructive forces while buried and early in their depositional history, such as trampling by large animals that continued to visit the kettle basin or by soil loading, leading to the fracture patterns observed today.

To test whether there is a relationship between the structural density of the bones and observed differences in identified skeletal element frequencies, volume bone mineral densities (Kreutzer 1992) were compared with percent MAU for the bison archaeofauna (table 5.5; see also figure 5.1). The test produces a significant correlation with a moderate, positive relationship ($r$=0.432, $p$=0.017; Spearman's rho), meaning that density-mediated attrition

Table 5.5. Bison bone volume density data.

| Element | Landmarks[a] | Percent MAU[b] | Rank | Vd Scan Site | Vd[c] | Rank |
|---|---|---|---|---|---|---|
| Cranium | | 13.2 | 5 | - | - | |
| Mandible | | 17.3 | 8 | DN8 | 0.79 | 30 |
| Atlas | | 26.4 | 12 | AT3 | 0.34 | 6 |
| Axis | | 60.4 | 28 | AX1 | 0.65 | 24 |
| Cervical | | 42.3 | 19 | CE2 | 0.62 | 22 |
| Thoracic | | 11.7 | 4 | TH1 | 0.42 | 14 |
| Lumbar | | 5.3 | 2 | LU2 | 0.11 | 1 |
| Rib | | 9.4 | 3 | RI1 | 0.27 | 3 |
| Scapula | | 30.2 | 13 | SP1 | 0.50 | 17 |
| PR Humerus | L1-6 | 20.8 | 9 | HU1 | 0.24 | 2 |
| DS Humerus | L7-13 | 56.6 | 27 | HU5 | 0.38 | 11 |
| PR Radius | L1-5 | 43.4 | 20.5 | RA1 | 0.48 | 15.5 |
| DS Radius | L8-11 | 45.3 | 22 | RA5 | 0.35 | 7.5 |
| PR Ulna | L1-4 | 39.6 | 16.5 | UL2 | 0.69 | 26 |
| DS Ulna | L7 | 24.5 | 10.5 | RA5 | 0.35 | 7.5 |
| Carpals | | 69.8 | 29 | LUNAR | 0.35 | 9 |
| PR Metacarpal | L1-4 | 52.8 | 26 | MC2 | 0.63 | 23 |
| DS Metacarpal | L5-8 | 47.2 | 23.5 | MC6 | 0.53 | 19.5 |
| Innominate | | 3.8 | 1 | AC1 | 0.53 | 19.5 |
| PR Femur | L1-4 | 37.7 | 15 | FE1 | 0.31 | 4 |
| DS Femur | L6-10 | 15.1 | 6.5 | FE5 | 0.36 | 10 |
| PR Tibia | L1-6 | 24.5 | 10.5 | TI3 | 0.76 | 28 |
| DS Tibia | L7-11 | 35.8 | 14 | TI5 | 0.41 | 12.5 |
| Astagalus | | 100 | 31 | AS1 | 0.72 | 27 |
| Calcaneus | | 50.9 | 25 | CA4 | 0.66 | 25 |
| Tarsals | | 71.7 | 30 | NC3 | 0.77 | 29 |
| PR Metatarsal | L1-4 | 47.2 | 23.5 | MR2 | 0.59 | 21 |
| DS Metatarsal | L5-8 | 39.6 | 16.5 | MR4 | 0.51 | 18 |
| Phalanx 1 | | 41.1 | 18 | P11 | 0.48 | 15.5 |
| Phalanx 2 | | 43.4 | 20.5 | P21 | 0.41 | 12.5 |
| Phalanx 3 | | 15.1 | 6.5 | P31 | 0.32 | 5 |

[a] Landmarks used to calculate the proximal (PR) and distal (DS) long bone frequencies (see landmark codes listed in appendix D).
[b] Percent MAU was recalculated to distinguish proximal (PR) and distal (DS) long bone portions.
[c] Volume density values from Kreutzer (1992); the density value for the most frequently occurring landmark was used.

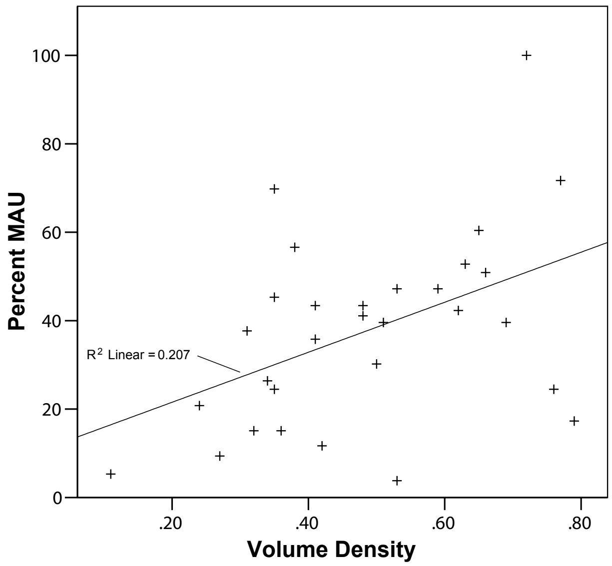


Figure 5.1. Plot of percent MAU values against bison bone volume density. (Regression line for reference only; see text).

has had some effect on the archaeofauna but that it is not the sole cause of variability in element representation.

Skeletal Element Abundance

Table 5.6 summarizes the Beacon Island bison remains from the Agate Basin component; the element profile is illustrated in figure 5.2. The upper axial skeleton (including the skull, mandible, and cervical vertebrae) is present in similar numbers to appendicular elements while several lower axial elements are much less frequent. These differences may be the result of non-human taphonomic processes such as density-mediated attrition or carnivore scavenging since axial bones are generally more fragile (e.g., their structure is delicate and their profile may be higher) than appendicular elements. The lower frequency of lower axial elements may also stem from the difficulty of identifying specific axial elements. In particular, fragments of cervical 3-5, thoracic 1-14, and lumbar 1-5 vertebrae tend to get lumped into general categories (cervical, thoracic, lumbar) or classified as unidentified

Table 5.6. Bison skeletal element abundance in the Area A Agate Basin-age assemblage.

| Element | Code | NISP | L | R | Unsided | MNE | MAU | Percent MAU |
|---|---|---|---|---|---|---|---|---|
| Cranium[a] | CRN | 38 | 3 | 3 | 1 | 7 | 3.5 | 13.2% |
| Mandible[a] | MR | 120 | 10 | 13 | 1 | 24 | 12.0 | 45.3% |
| Atlas | AT | 16 | - | - | 7 | 7 | 7.0 | 26.4% |
| Axis | AX | 25 | - | - | 16 | 16 | 16.0 | 60.4% |
| Cervical Vertebra (3-7) | CE | 124 | - | - | 56 | 56 | 11.2 | 42.3% |
| Thoracic Vertebra (1-14) | TH | 162 | - | - | 43 | 43 | 3.1 | 11.7% |
| Rib | RB | 466 | 27 | 32 | 11 | 70 | 2.5 | 9.4% |
| Lumbar Vertebra (1-5) | LM | 22 | - | - | 7 | 7 | 1.4 | 5.3% |
| Sacrum | SA | 4 | - | - | 2 | 2 | 2.0 | 7.5% |
| Caudal Vertebra | CA | 1 | - | - | - | 0 | 0.0 | 0.0% |
| Scapula | SC | 67 | 5 | 10 | 1 | 16 | 8.0 | 30.2% |
| Humerus | HM | 112 | 13 | 13 | 4 | 30 | 15.0 | 56.6% |
| Radius | RD | 83 | 9 | 15 | 1 | 25 | 12.5 | 48.1% |
| Radius-Ulna[b] | RDU | 11 | - | - | - | - | - | - |
| Ulna | UL | 56 | 10 | 11 | 3 | 24 | 12.0 | 45.3% |
| Radial Carpal | CPR | 36 | 17 | 17 | 0 | 34 | 17.0 | 64.2% |
| Intermediate Carpal | CPI | 38 | 24 | 11 | 1 | 36 | 18.0 | 67.9% |
| Ulnar Carpal | CPU | 36 | 18 | 14 | 0 | 32 | 16.0 | 60.4% |
| Second Carpal | CPS | 38 | 19 | 18 | 0 | 37 | 18.5 | 69.8% |
| Accessory Carpal | CPA | 19 | 8 | 10 | 0 | 18 | 9.0 | 34.0% |
| 4th Carpal | CPF | 34 | 20 | 11 | 0 | 31 | 15.5 | 58.5% |
| Metacarpal | MC | 55 | 13 | 11 | 7 | 31 | 15.5 | 58.5% |
| 5th Metacarpal | MCF | 2 | 0 | 2 | 0 | 2 | 1.0 | 3.8% |
| Innominate | IM | 20 | 1 | 1 | 0 | 2 | 1.0 | 3.8% |
| Femur | FM | 51 | 8 | 7 | 5 | 20 | 10.0 | 37.7% |
| Patella | PT | 2 | 0 | 1 | 0 | 1 | 0.5 | 1.9% |
| Tibia | TA | 107 | 8 | 11 | 2 | 21 | 10.5 | 39.6% |
| Lateral Malleolus | LTM | 18 | 6 | 11 | 0 | 17 | 8.5 | 32.1% |

Table 5.6. Bison skeletal element abundance (continued).

| Element | Code | NISP | L | R | Unsided | MNE | MAU | Percent MAU |
|---|---|---|---|---|---|---|---|---|
| Astragalus | AS | 61 | 23 | 29 | 1 | 53 | 26.5 | 100.0% |
| Calcaneus | CL | 66 | 10 | 16 | 1 | 27 | 13.5 | 50.9% |
| First Tarsal | TRF | | 0 | 0 | 0 | 0 | 0.0 | 0.0% |
| Fused Central & 4th Tarsal | TRC | 49 | 13 | 24 | 1 | 38 | 19.0 | 71.7% |
| Second Tarsal | TRS | 36 | 15 | 21 | 0 | 36 | 18.0 | 67.9% |
| Metatarsal | MT | 45 | 11 | 13 | 3 | 27 | 13.5 | 50.9% |
| 1st Phalanx | PHF | 116 | 0 | 0 | 87 | 87 | 10.9 | 41.1% |
| 2nd Phalanx | PHS | 133 | 0 | 0 | 92 | 92 | 11.5 | 43.4% |
| 3rd Phalanx | PHT | 41 | 0 | 0 | 32 | 32 | 4.0 | 15.1% |
| Proximal Sesamoid | SEP | 74 | 0 | 0 | 72 | 72 | 4.5 | 17.0% |
| Distal Sesamoid | SED | 16 | 0 | 0 | 15 | 15 | 1.9 | 7.2% |
| ID Specimen Subtotal | | 2400 | | | | | | |
| Element | Code | NSP[c] | | | | | | |
| indeterminate molar | MUN | 14 | | | | | | |
| indeterminate pre-molar | PUN | 1 | | | | | | |
| indeterminate tooth | TFR | 80 | | | | | | |
| indeterminate vertebra | VT | 119 | | | | | | |
| costal cartilage | CS | 1 | | | | | | |
| indeterminate carpal | CP | 7 | | | | | | |
| indeterminate tarsal | TR | 1 | | | | | | |
| indeterminate metapodial | MP | 45 | | | | | | |
| indeterminate phalanx | PH | 13 | | | | | | |
| indeterminate long bone | LB | 353 | | | | | | |
| cancellous bone | CB | 28 | | | | | | |
| flat bone | FB | 51 | | | | | | |
| unidentified | UN | 217 | | | | | | |
| Grand Total | | 3330 | | | | | | |

[a] Left and right counts based on element portions that occur on both sides of the skull (e.g., teeth, petrous portion).
[b] RDU data are included in the MNE calculations for RD and UL.
[c] See Lyman (2008).

vertebra, which results in low MNE (and percent MAU) values for the elements. With the exception of atlas and axis specimens, no vertebral fragments were identified beyond general type in the Beacon assemblage, and 119 unidentified vertebra fragments are present.

At least three crania and 23 mandibles (10 left and 13 right) are present, as indicated by the maxillary M1 and M2, the right mandibular M2, and the left mandibular M1. Isolated teeth dominate the dentition but 12 partial mandibular tooth rows or tooth sets are present, as are three partial maxillary sets. These sets are typically comprised of two teeth (most often the M1-M2 combination). Some of the tooth sets are not associated with the bony portions of the mandible or maxilla. Most of the cranial fragments are teeth or fragments of petrous portions. Ten petrosal fragments are present, and eight of these are unsided. A more thorough analysis of these fragments, as well as closer examination of the maxillary teeth, would undoubtedly increase the MNE for crania. Mandibular tooth eruption and wear data were compiled for the assemblage and are discussed in detail below.

The appendicular skeleton is best represented by carpals and tarsals, and these element types are also the most frequently occurring in the assemblage. Among the major limb elements (i.e., excluding the scapula and innominate), the distal humerus and the metacarpal are the most frequent, although all of the elements are present in comparable numbers (40-60 percent MAU). The low frequencies of scapulas and innominates are presumably due to their low bone mineral densities (which average 0.37 and 0.41, respectively).

Right astragali provide the MNI of 29 bison for the excavated portions of the bonebed. The MNI increases to 31 if the controlled-surface-collected right astragali are included (or 33 if right first ribs in the uncontrolled surface collection are included). The next most frequently occurring elements are the left intermediate carpal (CPI; n=24) and the right fused central and fourth tarsal (TRC; n=24). The relatively high numbers of carpals and tarsals are likely associated with their compact size, durability,

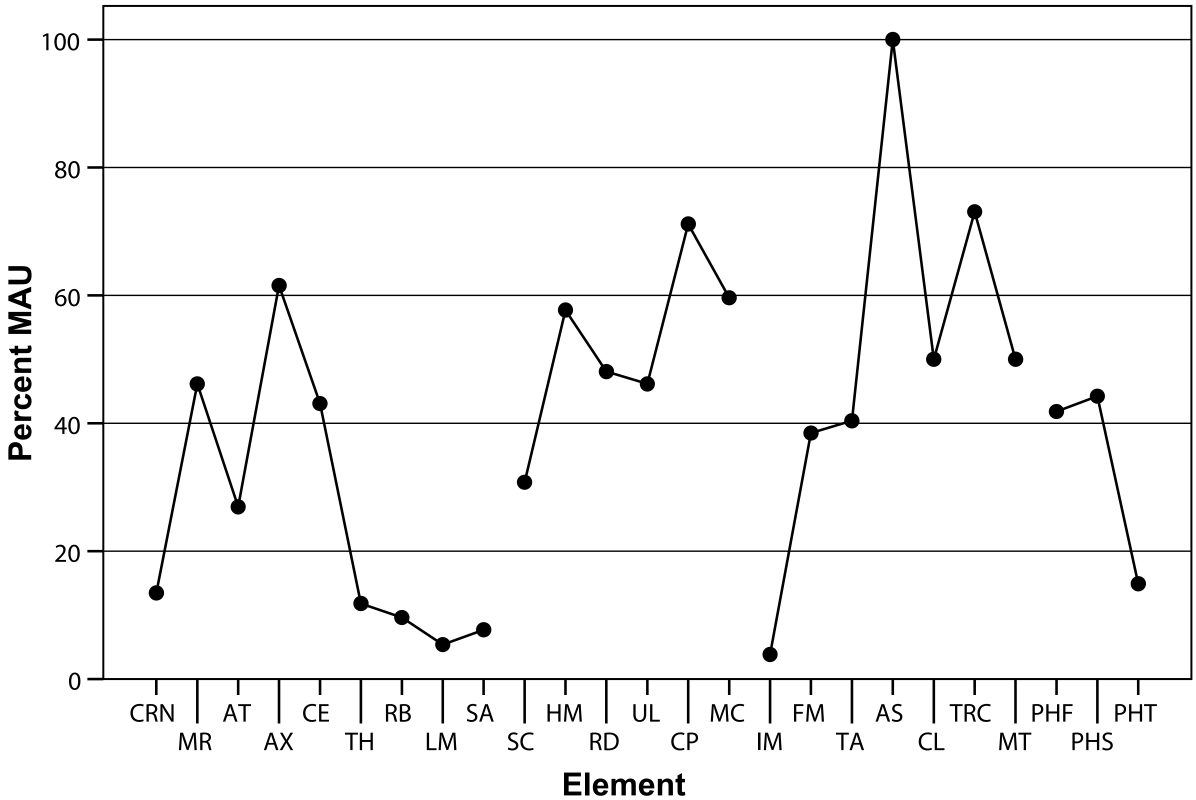


Figure 5.2. Bison skeletal element abundance in the Area A assemblage.

and ease of identification. The forelimb element profile suggests forelimbs were processed and/or transported as complete units (figure 5.3, upper panel).

With regard to the hindlimb, the most notable feature of the profile is the discrepancy between percent MAU values for the astragalus and calcaneus (figure 5.3, lower panel). These two elements are expected to be present in similar frequencies since they tightly articulate and are both robust and easily recognizable; however, calcanea are half as frequent as astragali in the assemblage. Both elements have comparable bone mineral densities (average densities are 0.67 for the astragalus and 0.60 for the calcaneus) so the incongruity is likely not a result of density-mediated attrition. Instead, it is probably due to carcass processing. The calcaneus may have been transported off-site still attached to the tibia while the astragalus was left behind with the metatarsal. The low relative frequency of the metatarsal (compared to the astragalus and fused central and fourth tarsal) may be a result of "marrow snacking," which resulted in the metatarsals (particularly the shafts) being fragmented and unrecognizable beyond general metapodial or long bone shaft fragments. There are 45 metapodial shaft fragments in the Beacon Island archaeofauna.

Striking similarities exist between the Beacon Island bison skeletal element profiles and those from other Agate Basin-age kill-butchery sites, including the Frazier site (Borresen 2002) and the Area 2 Agate Basin component at the Agate Basin site (Hill 2001) (figure 5.4). In particular, the appendicular element profiles, especially of the hindlimb, for the Frazier and Beacon Island assemblages are very similar. Axial skeleton representation is comparable in all three assemblages, although upper vertebrae are better-represented in the Beacon Island assemblage. Forelimb and hindlimb profiles for the Agate Basin assemblage suggest abandonment of low-utility, lower limb elements. At Beacon Island and Frazier, forelimbs appear to have been treated similarly, in that they were transported off-site as complete units. Profiles suggest that treatment of the hindlimb at the Beacon Island and Frazier sites was also comparable. At both sites, the MNI is based on astragali. Borresen (2002:80) suspects their high frequency at Frazier might be due to collection bias, in that they were targeted to provide a quick and easy MNI calculation. However, similar patterning at Beacon Island suggests their frequency is instead related to cultural behavior. The pattern observed in the hindlimb profiles may reflect disarticulation of the tibia/calcaneus and astragalus/metatarsal joint, with the former being transported off-site while the latter were abandoned and in the case of the metatarsals possibly processed on-site (i.e., marrow snacking). The reasons

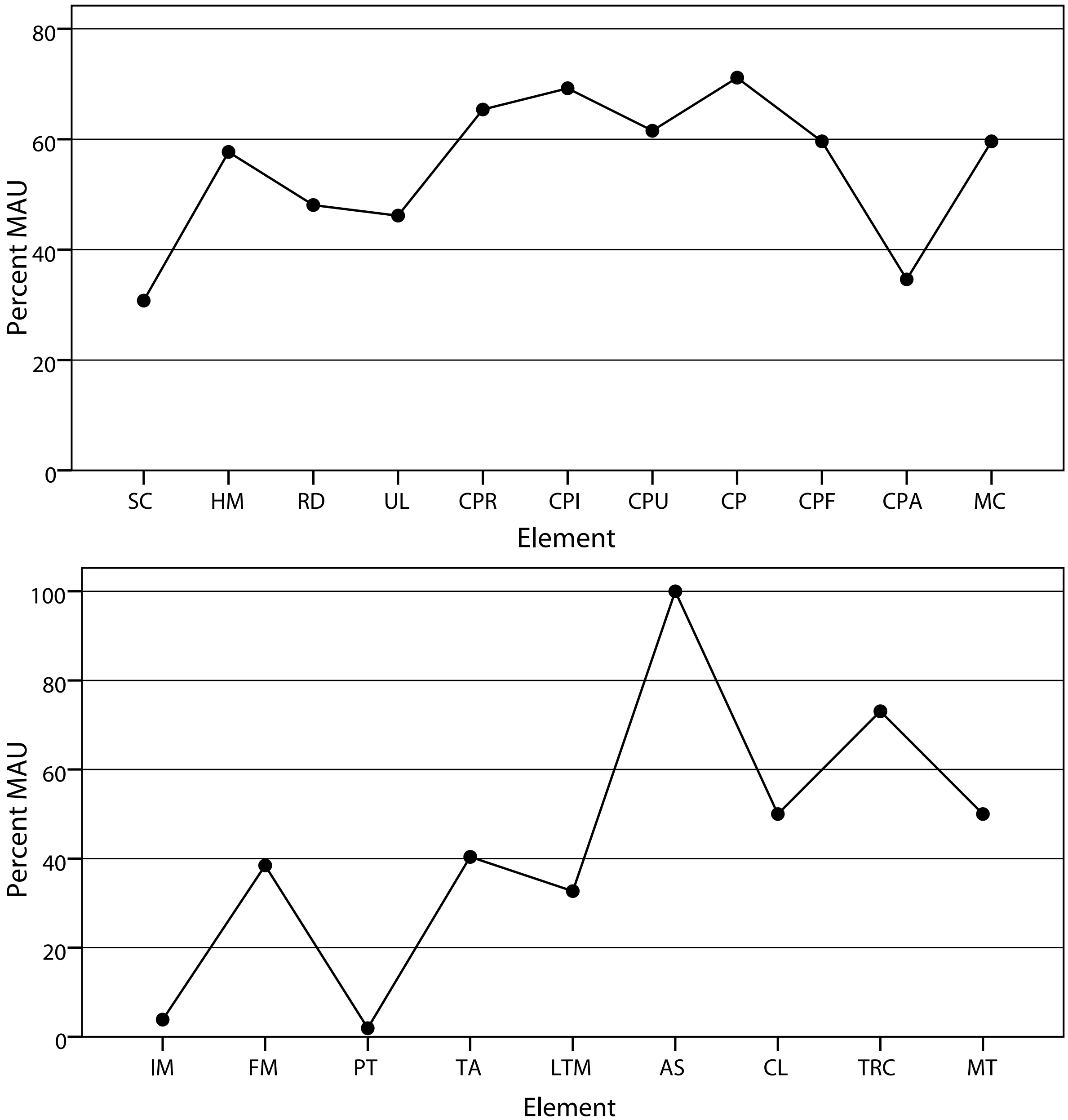


Figure 5.3. Bison forelimb (upper panel) and hindlimb (lower panel) profiles.

for the apparent differences in treatment of the forelimbs and hindlimbs are unclear. Metacarpals and metatarsals are present at both sites in comparable numbers and it is possible that the metacarpal was treated similarly to the metatarsal (e.g., abandoned on-site) but that the pattern is masked by equivalent percent MAU values for the anatomically adjacent carpals.

Bison Bone Utility Indices

Differential representation of bison skeletal elements in the Beacon Island archaeofauna helps clarify site function. For instance, a kill site would likely contain a prevalence of low-utility elements and, consequently, exhibit a reverse utility curve and a significant inverse rank-ordinal correlation between skeletal frequencies and utility values. In contrast, a secondary processing locale or camp should consist largely of high utility elements which, when plotted, produce a gourmet or bulk utility curve and a positive correlation between utility and ratio MAU. The Beacon Island percent MAU values were compared against a total products model ([S]MAVGTP), a skeletal fat model ([S]MAVGSKF), and a marrow fat model ([S]MAVGMF) using Emerson's (1990) bison

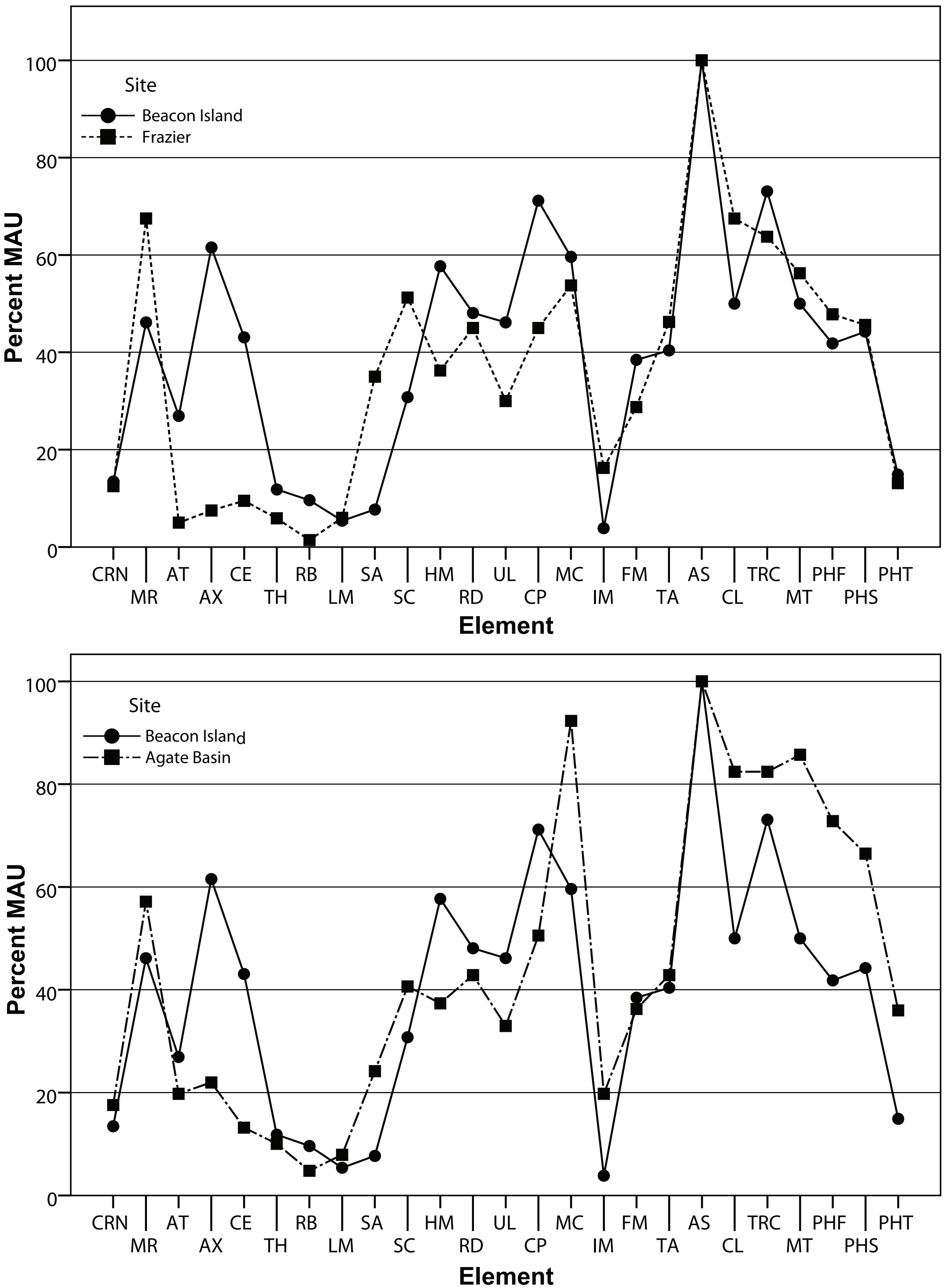


Figure 5.4. Comparison of the Beacon Island bison skeletal element profile with profiles for the Frazier site (upper panel) and the Agate Basin component at the Agate Basin site (lower panel).

Table 5.7. Summary of bison nutritional utility data.

| Element | Landmarks[a] | Percent MAU[b] | Rank | (s)AVGTP | Rank | (S)AVGSKF | Rank | (S)AVGMAR | Rank |
|---|---|---|---|---|---|---|---|---|---|
| Cranium | | 13.2 | 5 | 14.2 | 16.5 | - | | - | |
| Mandible | | 17.3 | 8 | 14.2 | 16.5 | - | | - | |
| Atlas | | 26.4 | 12 | 6.4 | 7 | 1.6 | 2 | - | |
| Axis | | 60.5 | 28 | 7.8 | 10 | 1.1 | 1 | - | |
| Cervical | | 42.3 | 19 | 56.6 | 26 | 3.3 | 3 | - | |
| Thoracic | | 11.7 | 4 | 84.7 | 30 | 16.8 | 4 | - | |
| Lumbar | | 5.3 | 2 | 82.9 | 29 | 18.3 | 5 | - | |
| Rib | | 9.4 | 3 | 100.0 | 31 | 38.7 | 13 | - | |
| Scapula | | 30.2 | 13 | 31.6 | 22.5 | 53.7 | 18 | 36.9 | 9 |
| PR Humerus | L1-6 | 20.8 | 9 | 31.6 | 22.5 | 95.6 | 26 | 71.5 | 19 |
| DS Humerus | L7-13 | 56.6 | 27 | 25.1 | 20 | 77.2 | 24 | 69.2 | 18 |
| PR Radius | L1-5 | 43.4 | 20.5 | 16.5 | 18 | 67.4 | 21 | 68.0 | 16 |
| DS Radius | L8-11 | 45.3 | 22 | 12.1 | 11.5 | 59.1 | 19.5 | 50.3 | 11.5 |
| PR Ulna | L1-4 | 39.6 | 16.5 | 20.8 | 19 | 72.3 | 23 | 68.6 | 17 |
| DS Ulna | L7 | 24.5 | 10.5 | 12.1 | 11.5 | 59.1 | 19.5 | 50.3 | 11.5 |
| Carpals | | 69.8 | 29 | 6.6 | 8 | 39.2 | 14 | 36.2 | 8 |
| PR Metacarpal | L1-4 | 52.8 | 26 | 3.9 | 5 | 29.2 | 10 | 29.2 | 7 |
| DS Metacarpal | L5-8 | 47.2 | 23.5 | 2.6 | 4 | 24.2 | 9 | 18.2 | 5 |
| Innominate | | 3.8 | 1 | 54.7 | 25 | 70.6 | 22 | 6.7 | 1 |
| PR Femur | L1-4 | 37.7 | 15 | 69.4 | 27.5 | 100.0 | 28.5 | 97.2 | 21 |
| DS Femur | L6-10 | 15.1 | 6.5 | 69.4 | 27.5 | 100.0 | 28.5 | 98.2 | 22 |
| PR Tibia | L1-6 | 24.5 | 10.5 | 40.8 | 24 | 97.1 | 27 | 100.0 | 23 |
| DS Tibia | L7-11 | 35.8 | 14 | 25.5 | 21 | 78.0 | 25 | 84.5 | 20 |
| Astagalus | | 100 | 31 | 13.6 | 14 | 51.6 | 16 | 55.2 | 14 |
| Calcaneus | | 50.9 | 25 | 13.6 | 14 | 51.6 | 16 | 55.2 | 14 |
| Tarsals | | 71.7 | 30 | 13.6 | 14 | 51.6 | 16 | 55.2 | 14 |
| PR Metatarsal | L1-4 | 47.2 | 23.5 | 7.5 | 9 | 37.5 | 12 | 40.6 | 10 |
| DS Metatarsal | L5-8 | 39.6 | 16.5 | 4.5 | 6 | 30.5 | 11 | 25.2 | 6 |
| Phalanx 1 | | 41.1 | 18 | 2.4 | 2 | 23.5 | 7 | 12.9 | 3 |
| Phalanx 2 | | 43.4 | 20.5 | 2.4 | 2 | 23.5 | 7 | 12.9 | 3 |
| Phalanx 3 | | 15.1 | 6.5 | 2.4 | 2 | 23.5 | 7 | 12.9 | 3 |

[a] Landmarks used to calculate the proximal (PR) and distal (DS) long bone frequencies (see landmark codes, appendix D).
[b] Percent MAU was recalculated to distinguish proximal (PR) and distal (DS) long bone portions.

nutritional utility data from four range-fed animals (table 5.7). The total products model measures the overall utility of the combined caloric yield of muscle protein, skeletal fat, and intramuscular and other dissectible fat; the skeletal fat model measures the utility of marrow and grease within-bone fat content; and the marrow fat model is based on marrow alone. No correlation exists between percent MAU and the skeletal fat model ($r$=-0.117, $p$ =0.545; Spearman's rho) or the marrow fat model ($r$=-0.073, $p$ =0.74). The correlation between percent MAU and the total products model is significant with a moderate to large inverse correlation ($r$=-0.516, p =0.003) (figure 5.5). Keeping in mind the moderate effect that density-

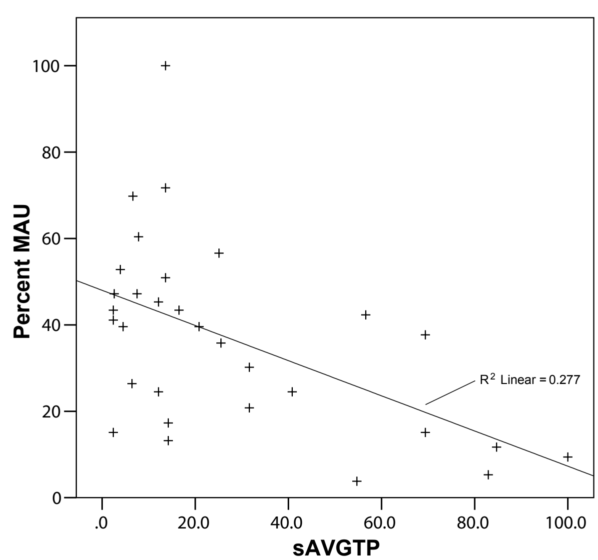


Figure 5.5. Plot of percent MAU values against bison total products utility. (Regression line for reference only).

mediated attrition has had on the assemblage, it can be deduced that the relative frequencies of the skeletal elements reflect transport decisions.

In sum, the utility data indicate there is not a strong selection for or against high utility elements, although when the assemblage is viewed more broadly (using the total products model) high utility elements do appear to have been selectively removed from the site. The utility data suggest that the Beacon Island inhabitants transported a major portion of the assemblage away from the site but also spent a considerable amount of time processing bison carcasses on-site. This is supported by the high degree of fragmentation (discussed in the next section) and is illustrated by the skeletal element profile, which generally reflects an even split in major element representation (figure 5.3).

## Bone Distribution

Bison bone is distributed most densely in the northeast and northwest excavation blocks, coinciding with the edge of the kettle basin. It is sparser to the south and west, where Aggie Brown Member deposits are more deeply buried. Figure 5.6 shows the distribution of all

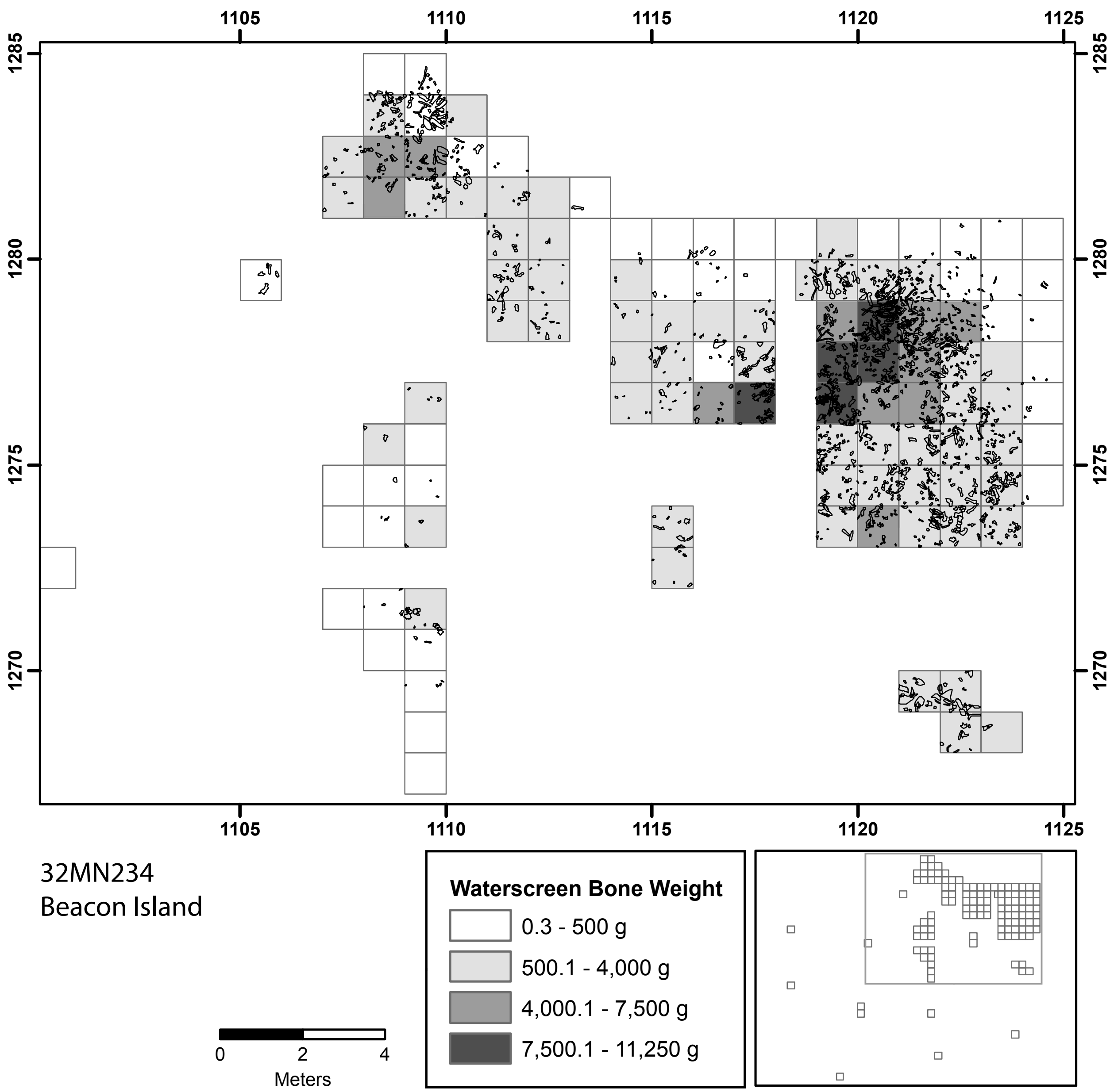


Figure 5.6. Map showing the distribution of plotted specimens and the weight of bone scrap recovered by waterscreening.

point-plotted bone larger than 5 cm, as well as the density of water-screened bone by weight.

While some patterning in overall distribution is visible, no patterning in element distribution is readily apparent. Two bone concentrations are notable near units 1283NE1109 and 1278NE1120, but each is comprised of a hodge-podge of elements that do not represent a meaningful cluster such as the meat cache described for the Agate Basin site (Frison and Stanford 1982a). Figure 5.7 illustrates the distribution of femur and tibia fragments relative to other elements in the northeast excavation block. The femur and tibia are anatomically adjacent to one another and are both high utility elements that likely would have been targeted by the site's inhabitants. Their high degree of fragmentation and general lack of co-occurrence supports the view that the assemblage represents the non-patterned, discarded remains of a heavily processed bison kill.

Very little surface modification was noted on the bison bone due to the high degree of fragmentation, carbonate encrustation, and other surface decay. Rodent-gnawed bones occur sparsely throughout the butchery area. A small number of bones exhibit tooth pits. A few exhibit cutmarks; however, carbonate encrustation

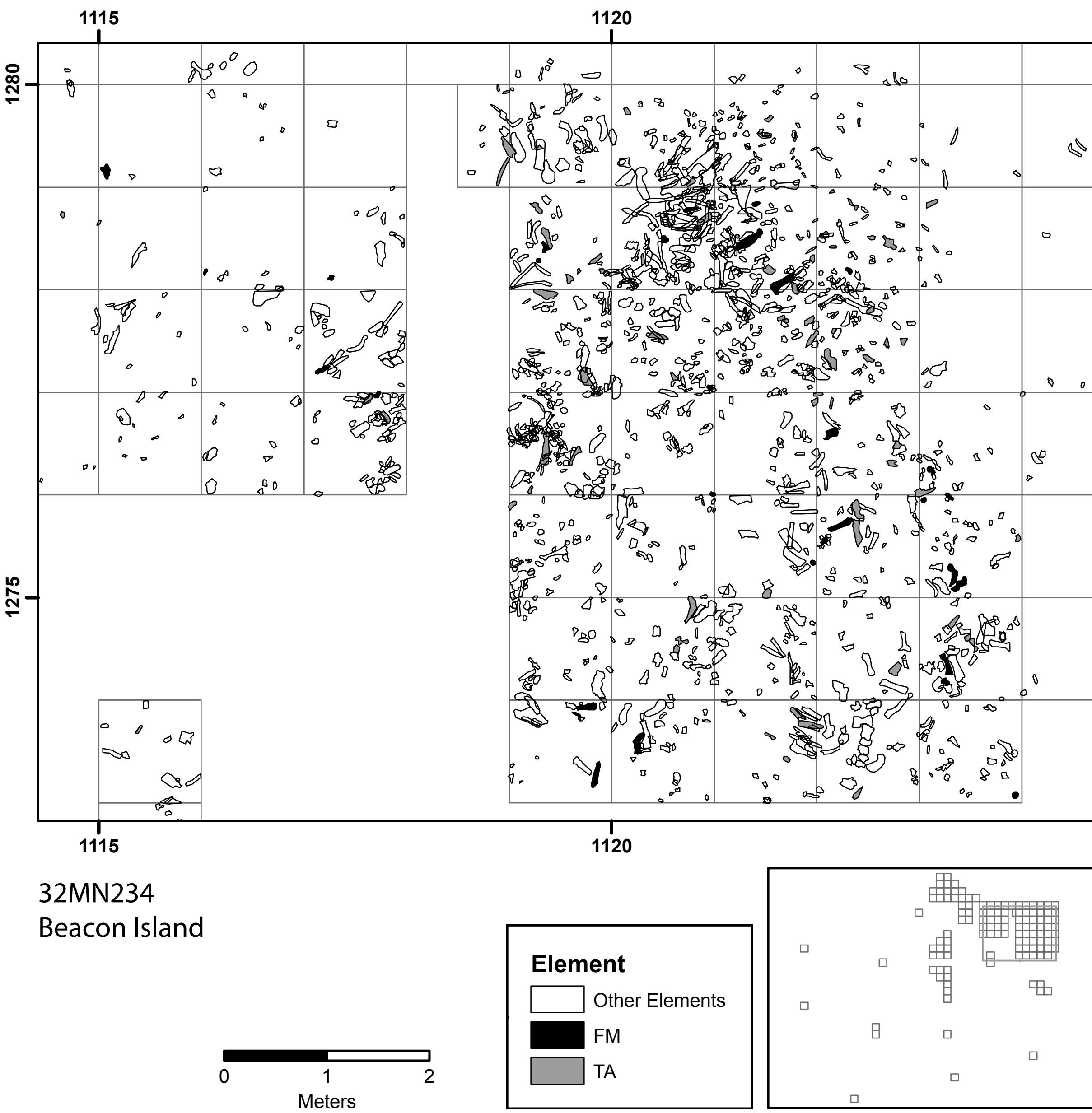


Figure 5.7. Map showing the distribution of plotted femur and tibia fragments in the northeast block.

masks most evidence of butchery. Only a small number of burned bones (n=123) was identified. Several burned fragments are within a meter of the hearth documented in unit 1272NE1115 and additional burned specimens are scattered throughout the 1 x 2 m block. Unplotted burned bone was also recovered from the fill of the hearth. Butchering-related bone modification is limited mainly to green (spiral) bone breakage, which was present on 394 bison specimens. Spiral fractures were observed on all the major limb bones, as well as three thoracic vertebra, an astragalus, a calcaneus, and two first phalanges.

The low number of complete elements in the assemblage, coupled with the relatively common occurrence of green-bone fractures, indicates a high degree of processing by humans, as opposed to fracture by non-cultural processes (table 5.8). Evidence of ungulate tracks observed during excavation (figures 3.38 and 3.39) suggests that trampling may account for some of the breakage but it is unlikely to have produced the extent of green-bone fracture observed in the assemblage. Over 30 percent of humerus, radius, and femur specimens and close to 50 percent of the tibia specimens are spirally fractured. The only complete major limb elements in the assemblage are 11 metacarpals and six metatarsals. This is not surprising given that metapodials are among the least likely of the long bones to be impacted by non-cultural processes due to their blocky structure and thick cortical walls. Experiments suggest that they are also only minimally impacted by ungulate trampling and are rarely broken due to gnawing by carnivores (Haynes 1991). Further, metapodials are relatively low in nutritional utility. That said, a relatively high proportion of metacarpal and metatarsal specimens (24 percent and 18 percent, respectively) are spirally-fractured, suggesting they were broken by the site's inhabitants for within-bone nutrients.

When compared with similar breakage data from the Agate Basin (Agate Basin component) and Frazier sites (table 5.9), it appears the Beacon Island bison were more heavily processed than animals comprising

Table 5.8. Long bone breakage data, Beacon Island site.

| | | Breakage Type | | | | | |
|---|---|---|---|---|---|---|---|
| Element | NISP | Complete | % | Green | % | Other | % |
| HM | 112 | | -- | 41 | 36.6% | 71 | 63.4% |
| RD[a] | 94 | | -- | 31 | 33.0% | 63 | 67.0% |
| MC | 55 | 11 | 20.0% | 13 | 23.6% | 31 | 56.4% |
| FM | 51 | | -- | 18 | 35.3% | 33 | 64.7% |
| TA | 107 | | -- | 50 | 46.7% | 57 | 53.3% |
| MT | 45 | 6 | 13.3% | 8 | 17.8% | 31 | 68.9% |
| Total | 464 | 17 | 3.7% | 161 | 34.7% | 286 | 61.6% |

[a] Includes RDU data.

Table 5.9. Long bone breakage data, Agate Basin and Frazier sites.

| | | | Breakage Type | | | | | |
|---|---|---|---|---|---|---|---|---|
| Site | Element | NISP | Complete | % | Green | % | Other | % |
| Agate Basin site, Agate Basin component[a] | HM | 62 | 1 | 1.6% | 9 | 14.5% | 52 | 83.9% |
| | RD | 58 | 11 | 19.0% | 8 | 13.8% | 39 | 67.2% |
| | MC | 147 | 28 | 19.0% | 30 | 20.4% | 89 | 60.5% |
| | FM | 80 | 2 | 2.5% | 9 | 11.3% | 69 | 86.3% |
| | TA | 78 | 4 | 5.1% | 7 | 9.0% | 67 | 85.9% |
| | MT | 130 | 24 | 18.5% | 36 | 27.7% | 70 | 53.8% |
| | Total | 555 | 70 | 12.6% | 99 | 17.8% | 386 | 69.5% |
| Frazier site[b] | HM | 84 | 1 | 1.2% | 23 | 27.4% | 60 | 71.4% |
| | RD | 99 | 3 | 3.0% | 8 | 8.1% | 88 | 88.9% |
| | MC | 98 | 12 | 12.2% | 3 | 3.1% | 83 | 84.7% |
| | FM | 56 | 0 | 0.0% | 6 | 10.7% | 50 | 89.3% |
| | TA | 105 | 0 | 0.0% | 31 | 29.5% | 74 | 70.5% |
| | MT | 114 | 13 | 11.4% | 7 | 6.1% | 94 | 82.5% |
| | Total | 556 | 29 | 5.2% | 78 | 14.0% | 449 | 80.8% |

[a] Data from Hill 2001:Table 3.25.
[b] Data from Borresen 2002:Table 5.6 and in the possession of Lee.

other Agate Basin assemblages. The overall green-bone fracture percent is at least double that of the Frazier and Agate Basin assemblages. Similar to Beacon, the Frazier site assemblage contains relatively few complete limb elements and those that are present are almost exclusively metapodials. Conversely, complete bones (dominated by metapodials but also including other limb elements) are much more prevalent at the Agate Basin site than at either Beacon Island or Frazier.

Population Structure and Site Seasonality

The degree of bone fragmentation, which reflects carcass processing and post-depositional processes, constrains what can be said about the ages, sexes, and season of death of the bison herd represented by the Area A assemblage (figure 5.8). Four basic strategies were used to assess structure of the target herd and the time of the kill, including metapodial ratio analysis, calcanea comparison, stages of bone epiphyseal fusion, and dental measurements and wear patterns. The dentition analysis provides the most reliable indicator of seasonality.

*Metapodial Ratio Analysis*

Metapodial ratio analysis is based on bison sexual dimorphism and the relative homogeneity within the sexes of a breeding population. In this analysis, various length and breadth measurements from the metapodials are plotted to define male and female clusters. This method works best when both sexes are represented in the sample and when the sample is significantly large. Even then, however, overlap of the sexes can occur. Measurements that are clearly within the male cluster can be inferred with more confidence than those that fall into the female cluster because specimens within the latter may include adult females and their young, both male and female.

Metacarpals and metatarsals were measured following the method Bedord (1974, 1978) applied to the Casper site bison assemblage. The present study utilized Bedord's numbering system, measurement descriptions, and inferences (table 5.10; see also appendix D). Thirteen individual measurements were collected to the nearest millimeter (mm) by a single analyst using digital sliding calipers, a ruler, and an osteometric board. For this method, metapodials need to be fully fused and essentially complete along the measured axes, though partial measurements also retain some utility. In this study, 16 specimens (11 metacarpals and 5 metatarsals) were complete enough to provide the necessary measurements for analysis. However, not all measurements were possible on every bone due to the condition of the specimens (figure 5.9).

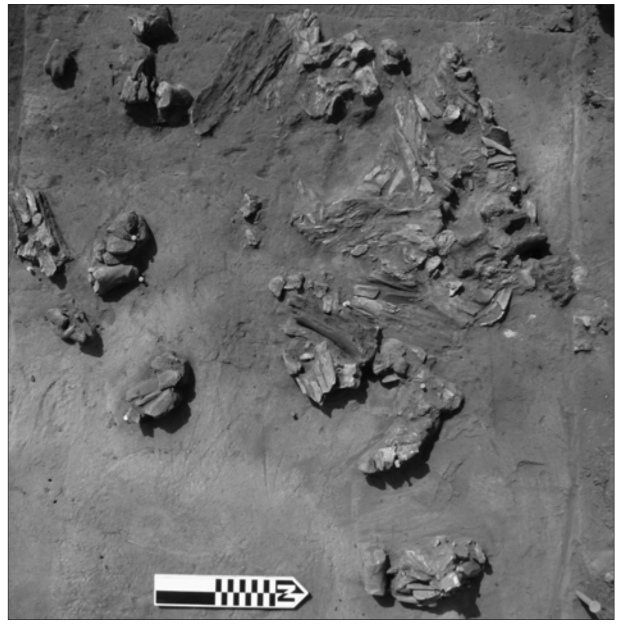

Figure 5.8. Fragmented bone exposed during excavation.

Table 5.10. Metapodial measurement descriptions.

| Measurement | Description |
|---|---|
| M1 | Maximum length |
| M2 | Transverse width |
| M3 | Transverse width at center of shaft |
| M4 | Transverse width of the distal end |
| M5 | Anterior-posterior width at center of shaft |
| M6 | Anterior-posterior width of proximal end |
| M7 | Anterior-posterior width of proximal end |
| M8 | Anterior-posterior width of distal end |
| M9 | Minimum anterior-posterior width of shaft |
| M10 | Minimum lateral width of shaft |
| M11 | Rotational length |
| M12 | Foramen to articular surface length, anterior |
| M13 | Foramen to articular surface length, posterior |

Bedord argues that the best indicator of sex is a plot of the transverse width of the distal end (M4) against a ratio of the transverse width at center of the shaft (M3) divided by the maximum length (M1) multiplied by 100. She refers to this composite index as Ratio 6 (Bedord 1974:226). Measurements of the metatarsals and metacarpals taken for this study are presented in tables 5.11 and 5.12. Six metacarpals from Beacon Island provided all the necessary data to plot the M4 measurement against Ratio 6. In figures 5.10 through 5.12, these data are plotted along with comparable data from three other Paleoindian sites, including the Agate Basin component at the Agate Basin site, the Casper site, and the Olsen-Chubbuck site (Frison, ed. 1974; Wheat 1972; Zeimens 1982). These comparisons indicate that

Figure 5.9. Example of a complete, but fractured metacarpal.

five bulls and one cow are represented in the Beacon Island assemblage.

While measurement data from the other 10 measurable metapodials (five metacarpals and five metatarsals) from Beacon Island did not permit the strict application of Bedord's method, a general comparison is warranted. Visual inspection of the data illustrated in figures 5.10, 5.11, and 5.12 show that the M4 measurement alone segregates the male and female groups. Values for M4 are available for seven of the 10 specimens (three metacarpals and four metatarsals) from Beacon Island. Of these, one metacarpal and three metatarsals clearly fall in the male range, while one metacarpal and one metatarsal are within the female range. One other metacarpal is on the lower end of the male range and so the sex of that animal is undetermined. The remaining three Beacon Island specimens lack M4 measurement data and so the sex of these specimens is also not determined. Table 5.13 summarizes these interpretations. The metric data do not suggest that any anatomically paired metapodials are present. In sum, five males and one female are clearly present in the sample of mature, measurable metacarpals from Beacon Island. The presence of another male and another female can be inferred. The metatarsal data

Table 5.11. Beacon Island bison metatarsal measurements.

| | | Measurement (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cat. No. | Side | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 |
| 1642.46 | R | | | | 82.4 | | | | | | | | | |
| 7327 | R | | | | 83.5 | | | | | | | | | |
| 7904 | R | | | 31.3 | 67.2 | 30.6 | | | 38.3 | 28.1 | | | | |
| 8402 | R | | 68.7 | 39.4 | | 37.6 | 64.0 | 64.5 | | 37.6 | 38.6 | | | |
| 8555 | L | | | | 82.0 | | | | 44.0 | | | | | |

Table 5.12. Beacon Island bison metacarpal measurements.

| | | Measurement (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cat. No. | Side | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 | M13 |
| 7818 | L | | | | 83.8 | | | | | | | | | |
| 8121 | L | 210 | 80.4 | 53.3 | 87.0 | 32.5 | 53.3 | 48.1 | 41.0 | 29.8 | 51.2 | 176.1 | 155.3 | 149.5 |
| 8601 | R | 217 | 79.0 | 53.9 | 81.0 | 30.8 | 58.5 | 46.7 | 43.0 | 30.3 | 52.0 | 186.6 | 165.5 | 159.1 |
| 8602 | L | 214 | | | 78.3 | 27.6 | | | 43.7 | | | | 164.7 | |
| 8836 | R | 219 | 88.6 | 58.4 | 90.0 | 35.7 | 57.5 | 50.8 | 45.0 | 31.6 | 57.5 | 185.2 | 162.3 | 152.9 |
| 8855 | R | | 77.5 | | | | | 46.1 | | | | | | |
| 8872 | R | | | 47.2 | | 30.3 | | | | 29.5 | 46.9 | | | |
| 8905 | L | 209 | 86.6 | 51.6 | 95.2 | 33.6 | | | 45.6 | | | | | |
| 9387 | R | | | | 73.3 | | | | 42.2 | | | | | |
| 9477 | L | 219 | 82.0 | 54.4 | 89.9 | 32.4 | 49.1 | 45.6 | 45.0 | 32.7 | 54.2 | 187.9 | 167.2 | 163.7 |
| 9972 | L | 198 | 69.5 | 37.5 | 74.7 | 28.0 | 42.0 | 43.9 | 38.9 | 28.2 | 37.4 | | 146.5 | |

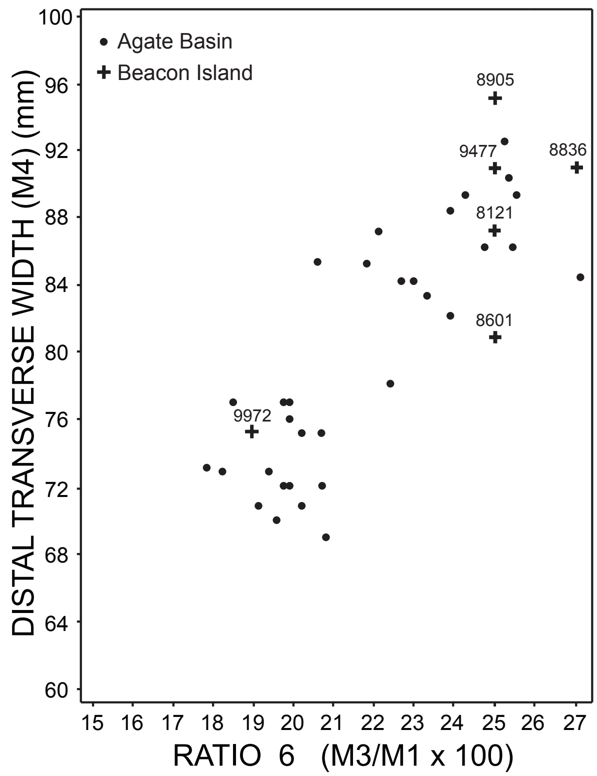


Figure 5.10. Comparison of bison metacarpals from Beacon Island and the Agate Basin site (AB component).

suggests there are three males and one female represented.

*Comparative Calcanea Measurements*

Like metric data on metapodial size, measurements taken on calcanea are useful for determining the sex of animals present in Paleoindian assemblages (Hill 1996). The relatively high mineral density, comparatively low food utility, and uncomplicated epiphyseal fusion of the tuber all make the calcaneus ideally suited for certain metric analyses (Hill 1996:231). Complete or nearly complete calcanea are relatively abundant in the Beacon Island assemblage. Eleven calcanea were measured using Hill's (1996:232) variables applied to the Mill Iron site assemblage. Descriptions of the 11 variables are provided in table 5.14.

Five of the eleven specimens chosen for measurement have unfused proximal tubers and are thus under 5.3 years of age (Bement and Basmajian 1996). Measurements CL10 and CL11 were designed specifically for collecting data on unfused specimens; however, they are not commonly included in comparative studies. Four measured specimens have fully fused proximal tubers. The degree of proximal fusion for the remaining two specimens is unknown due to their incompleteness. Measurements of the calcanea selected for study from

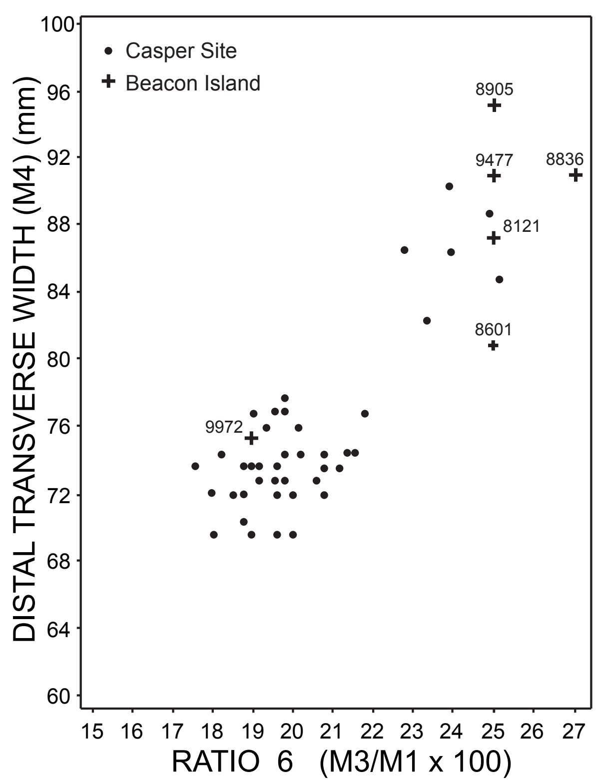


Figure 5.11. Comparison of bison metacarpals from Beacon Island and the Casper site.

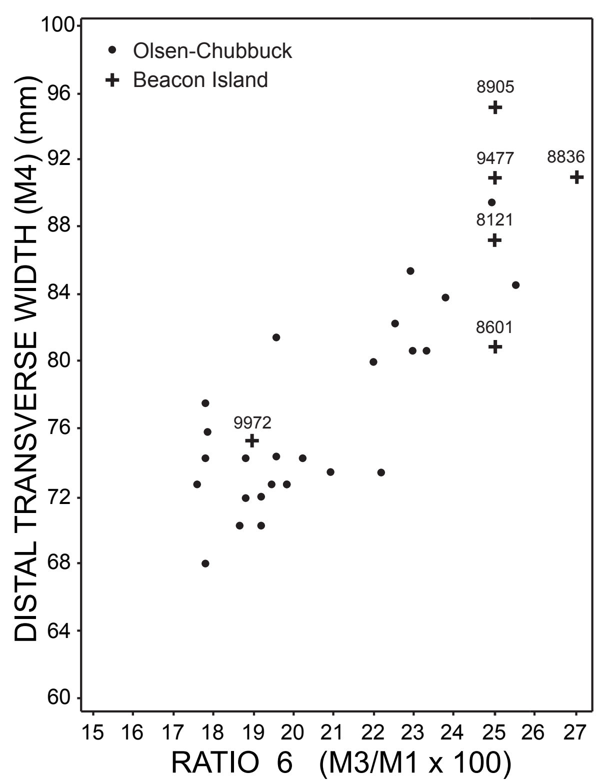


Figure 5.12. Comparison of bison metacarpals from Beacon Island and the Olsen-Chubbuck site.

Table 5.13. Sex determinations from metapodial measurements.

| Cat. No. | Element | Side | Sex | Method M4:Ratio 6 | Method M4 Only |
|---|---|---|---|---|---|
| 1642.46 | MT | R | Male? | | ✓ |
| 7327 | MT | R | Male? | | ✓ |
| 7818 | MC | L | Male? | | ✓ |
| 7904 | MT | R | Female? | | ✓ |
| 8121 | MC | L | Male | ✓ | |
| 8402 | MT | R | Indeterminate | | |
| 8555 | MT | L | Male? | | ✓ |
| 8601 | MC | R | Male | ✓ | |
| 8602 | MC | L | Indeterminate | | ✓ |
| 8836 | MC | R | Male | ✓ | |
| 8855 | MC | R | Indeterminate | | |
| 8872 | MC | R | Indeterminate | | |
| 8905 | MC | L | Male | ✓ | |
| 9387 | MC | R | Female? | | ✓ |
| 9477 | MC | L | Male | ✓ | |
| 9972 | MC | L | Female | ✓ | |

Table 5.14. Calcanea measurement descriptions.

| Measurement | Description |
|---|---|
| CL1 | Greatest length |
| CL2 | Greatest breadth proximal end |
| CL3 | Greatest depth of proximal end |
| CL4 | Greatest breadth |
| CL5 | Greatest depth |
| CL6 | Distal width |
| CL7 | Greatest length of naviculocuboid facet |
| CL8 | Greatest length of talus facet |
| CL9 | Greatest length of shaft |
| CL10 | Greatest length (unfused epiphysis) |
| CL11 | Greatest length of shaft (unfused epiphysis) |

Beacon Island are provided in table 5.15.

The calcanea data (for measurements CL1, CL4, CL5, and CL9) from the Beacon Island sample can be compared with corresponding measurements from several other bison bonebed sites presented in the Mill Iron site discussion. One Beacon Island specimen (CN8271) is confidently assigned to the male group based on measurements and visual assessment. Two additional large specimens are also likely male but were not included in the study due to their incompleteness. Catalog number 9668 is assigned to the female group based on a single measurement, and the remaining two, fully fused calcanea are also considered female based on measurements that fall within the female range. Thus, at least three males and three females appear to be represented in the calcanea sample.

*Bone Fusion and Landmark Coding*

To determine approximate age at death, zones of epiphyseal ossification were examined to assess the degree of bone fusion of 598 specimens. This number exaggerates the actual number of distinct elements initially deposited because many of the specimens are fragments and some may represent different portions of the same bone. Bone fusion data only permit the assignment of broad age ranges and so are less precise than dentition data.

The bones were examined and coded by a single analyst according to five degrees of ossification as described by Todd (1987) (table 5.16). In addition to coding for degree of fusion, visual verification of the various bone landmarks were made as present or absent and then used later to help determine the minimum number of animals in each age group. Because most bone landmarks are mutually exclusive, any overlap of landmarks per single-sided bone indicates multiple animals. Identification and coding of specific bone landmarks follow Hill's (2001) criteria. Degrees of fusion of individual elements were then applied to fusion rates for *Bison antiquus* provided by Bement and Basmajian (1996) (table 5.17). It is worth noting, though, that nutrition, climate, and other factors can affect the timing of bison bone ossification.

Once the specimens were fully coded and the data entered into a database, specific elements were isolated and then sorted by fusion codes for individual age evaluation. The minimum number of individuals (MNI) was determined for each degree of fusion class (codes 0 through 3) by an overlap of landmark demarcations

Table 5.15. Beacon Island bison calcaneus measurements.

| Cat. No. | Side | Fusion | Sex | Measurement (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CL1 | CL2 | CL3 | CL4 | CL5 | CL6 | CL7 | CL8 | CL9 | CL10 | CL11 |
| 1334 | R | 0 | I[a] | | | | | | | | | | | 79.7 |
| 1508 | R | 4 | I | | | | | | | 48.3 | | | | |
| 7935 | R | 4 | I | | | | | | | 46.2 | | | | |
| 8027 | R | 0 | I | | | | 50.0 | 57.0 | 49.4 | 42.3 | 33.4 | | 138.0 | 83.2 |
| 8271 | R | 3 | M | 185.0 | 53.0 | 54.0 | 65.0 | 70.0 | 59.3 | 49.0 | 45.2 | 121.8 | | |
| 8655 | R | 3 | F? | | 44.0 | 46.0 | | | | | | | | |
| 8913 | R | 0 | I | | | 0 | 67.0 | | 57.2 | | 41.2 | | | 93.3 |
| 8930 | L | 3 | F? | | 41.0 | 41.0 | | | | | | 110.3 | | |
| 9318 | R | 0 | I | | | | 59.0 | | 54.0 | | 35.8 | | | 92.9 |
| 9441 | L | 0 | I | 161.0 | 39.6 | | 54.0 | 66.0 | 53.9 | 43.6 | 36.8 | | 147.0 | 91.2 |
| 9668 | L | 3 | F | | | | | | | | | 102.7 | | |

[a] Indeterminate.

Table 5.16. Fusion codes.

| Code | Degree of epiphyseal fusion |
|---|---|
| 0 | Unfused |
| 1 | Partially fused |
| 2 | Fusing, but line still visible |
| 3 | Fully fused |
| 4 | Broken, can not determine degree of fusion |
| 5 | Not applicable (no zone of epiphyseal fusion) |

Table 5.17. Age of complete fusion for select *Bison antiquus* appendicular elements[a].

| Element | Age (years) |
|---|---|
| Proximal Humerus | 5.3 |
| Distal Humerus | 1.3 |
| Proximal Radius | 1.3 |
| Distal Radius | 5.3 |
| Proximal Ulna | 5.3 |
| Proximal Femur | 5.3 |
| Distal Femur | 5.3 |
| Proximal Tibia | 5.3 |
| Distal Tibia | 3.3 |
| Distal Metapodial | 3.3 |
| Calcaneus | 5.3 |

[a] Bement and Basmajian (1996).

per single-sided element. Elements chosen for fusion evaluation included the humerus, radius, ulna, metacarpal, femur, tibia, metatarsal, and calcaneus.

In the following paragraphs, individual landmarks are given alphanumeric designations. For instance, landmark 8 is designated L8. Bone and landmark codes are provided in appendix D. In some instances, certain landmarks provide more identifiable exclusivity and were chosen over less exclusive landmarks for higher accuracy. For example, the femoral head (L1) was chosen over the anterior shaft (L4) as a more accurate representation of a unique individual. The fusion data for the major limb elements (including the calcaneus) are summarized in table 5.18.

Initially, an element MNI was calculated for the assemblage regardless of sex or age (fusion) data (table 5.6). These element MNI values are based on element side and overlapping landmarks. For the purposes of determining the number of bison within exclusive age ranges based on fusion, specimens with unknown or un-recorded fusion (fusion codes 4 and 5) are excluded since they do not provide any useful information for assigning age groups and increase the risk of evaluating multiple portions of the same element. The result of their exclusion, however, is that the element MNI as summarized in table 5.18 does not always equal the sum of individuals determined by the fusion data.

**Humerus**. The presence of at least one bison under the age of 1.3 years is based on an unfused, left, medial condyle. A partially fused distal humerus suggests a bison just over 1.3 years of age is also present, and fully fused, left medial condyles indicate the presence of at least 13 adults.

**Radius**. One animal is under the age of 1.3 years. A single bison with a partially fused distal epiphysis is considered just beyond 5.3 years of age. A minimum of 15 bison are over the age of 1.3 years, with eight of those being younger than 5.3 years of age.

**Ulna**. Fully fused specimens suggest a minimum of three bison over 5.3 years of age.

**Metacarpal**. Two bison are under 3.3 years of age, two bison just over 3.3 years of age are represented by partially fused, left distal epiphyses, and seven bison are over 3.3 years based on fully fused, left and non-sided distal epiphyses.

**Femur**. Four bison are under 5.3 years old and four

Table 5.18. Minimum number of animals per age range determined by fusion stage of selected elements.

| | | Age Group (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Element | NISP | <1.3 | 1.3 | >1.3 | <3.3 | 3.3 | >3.3 | <5.3 | 5.3 | >5.3 |
| Humerus | 112 | | 1 | 10 | | | | | 1 | 2 |
| Radius | 94 | 1 | | 7 | | | | 8 | 1 | |
| Ulna | 56 | | | | | | | | | 3 |
| Metacarpal | 55 | | | | 2 | 2 | 7 | | | |
| Femur | 51 | | | | | | | 4 | | 4 |
| Tibia | 107 | | | | 2 | 1 | 6 | | | 2 |
| Metatarsal | 45 | | | | 3 | 2 | 6 | | | |
| Calcaneus | 66 | | | | | | | 5 | 1 | 6 |
| MNI by age | | 1 | 1 | 10 | 3 | 2 | 7 | 8 | 1 | 6 |

bison are over 5.3 years.

**Tibia**. Two bison are under 3.3 years of age based on unfused, left-sided distal portions. A single, partially fused distal tibia represents an animal just over 3.3 years of age. At least eight bison are older than 3.3 years based on fully fused distal epiphyses. Two of these also have fully fused proximal epiphyses, indicating they are from bison over the age of 5.3 years.

**Metatarsal**. Three bison are under 3.3 years of age based on unfused, left distal epiphyses. Two partially fused, right distal epiphyses represent bison just over 3.3 years of age. A minimum of six bison are over 3.3 years based on fully fused, right distal epiphyses.

**Calcaneus**. Five bison are under 5.3 years of age based on unfused, proximal epiphyses. A partially fused, right proximal end represents an animal just over 5.3 years. A minimum of six bison over 5.3 years of age are represented by fully fused proximal epiphyses.

The overall MNI represented by the faunal remains at Beacon Island is 29 based on astragali (table 5.6). Utilizing fusion data, this number of bison can be further subdivided into several broad age ranges. There are at least two calves or yearlings (at or under 1.3 years of age) in the kill based on left, distal humerus and right, proximal radius fusion data. At least six bison were older than 5.3 years at the time of death based on fused, proximal calcanea. Due to different rates of fusion for the proximal and distal articular ends of the humerus, radius, and tibia, it is difficult to determine the number of bison falling between 1.3 and 5.3 years of age. Very few complete long bones are present in the assemblage and most identified specimens are only fragments of the proximal or distal portions, making it impossible to determine whether proximal and distal fragments represent one or more animals. However, data on partially fused metapodials indicate that a minimum of two bison were just over the age of 3.3 years.

*Dentition Data*

The Beacon Island dentition assemblage comprises 225 specimens, including incisors, maxillary and mandibular premolars and molars, and unidentifiable fragments (table 5.19). Most of the Area A dentition consists of isolated teeth in poor condition. While metric data could be collected on a number of these specimens, 45 percent were in such poor shape they could not be identified beyond the category of skeletal element. Many of the isolated teeth collected in the field were extremely fragmentary; these were coded as complete but not measurable. The assemblage includes just five partial mandibular tooth rows. Reher and Frison (1980:59) suggest that a minimum of 200 mandibles are needed to derive seasonality assessments, although in a subsequent study of the Mill Iron dentition, Todd and others (1996) demonstrate that such assessments are possible from much smaller assemblages. However, the number of teeth used to assess season of death in the Mill Iron study is more than four times that of the Beacon Island sample described here.

The analytic methods used in this study replicate those used in the Mill Iron site dentition study as well as

Table 5.19. Summary of Beacon Island Area A bison dentition.

| Tooth | NISP |
|---|---|
| Maxillary molar | 17 |
| Maxillary premolar | 8 |
| Mandibular molar | 69 |
| Mandibular premolar | 21 |
| Incisor | 8 |
| Indeterminate molar | 14 |
| Indeterminate premolar | 1 |
| Tooth fragment | 87 |
| Total | 225 |

other bison kill site studies (Todd et al. 1996; Reher and Frison 1980; Clark and Wilson 1981). Measurements of individual teeth were confined to identifiable mandibular molars and followed the terminology and definitions outlined in the Mill Iron study. Molar measurements include: metaconid height (M), entoconid height (E), mesial width at the occlusal surface (MS), distal width at the occlusal surface (DS), length of occlusal surfaces (L), and distance from ectostylid to the occlusal surface (EC) (Todd et al. 1996:147-148) (see appendix D).

A sample of 18 isolated mandibular molars or sets of two molars was measured to the extent possible by their condition. In addition, five partial tooth rows within fragmented mandibles were compared to modern, known-age, bison mandibles to extract not only eruption stage data but also occlusal wear pattern data. To assign dental ages, the Beacon tooth sets were compared with known-age specimens at the University of Laramie as well as narrative descriptions published in Todd and others (1996). All dentition measurements were collected by Lee and Bennett using a sliding digital caliper graduated in 1/10-millimeter increments. Metric data are presented in table 5.20.

The five partial tooth sets formed the basis for defining Beacon Island dental age groups 3, 5, and 7. Following assignment of the five tooth rows to one of those three groups, an additional four groups were defined based on relative wear on isolated molars and molar sets. Dental group assignments were also aided by comparison of written descriptions from other bison sites, including the Hawken and Mill Iron sites (Frison et al. 1976; Todd et al. 1996). In sum, five tooth rows, one M1-M2 set, one M2-M3 set, and 16 isolated teeth are included in the mandibular dentition study. The dental age groups range from yearling to approximately 6.7 years. Overall, the Beacon Island mandibular dentitions appear more advanced than the modern, comparative assemblage, which has an N+0.6 dental age (equivalent to an early November death). They are most similar to those from the Hawken site (Frison et al. 1976:39-40; Todd et al. 1996:Table 8.5).

Group 1 (0.8-1.0 years)

Definition of Group 1 is based on one tooth: an isolated left, M1 (CN8200) (figure 5.13). It is in nearly full wear, with only a small, unconnected portion of dentine on the mesio-buccal hypoconid (facet V) and an island of enamel on the distal entoconid. The tooth exhibits similar (or slightly less) wear to the Mill Iron Group 2 (1.1-1.2 years) specimens and more advanced wear than the Hawken Group 1 (0.7 years) specimens (Todd et al. 1996:Figure 8.12). Thus, the Beacon Island Group 1 age range is slightly older than the other dental age groups, which fit an N+0.6-0.7 years estimate. This difference may be due to intra-cohort variability in birth spacing or tooth wear.

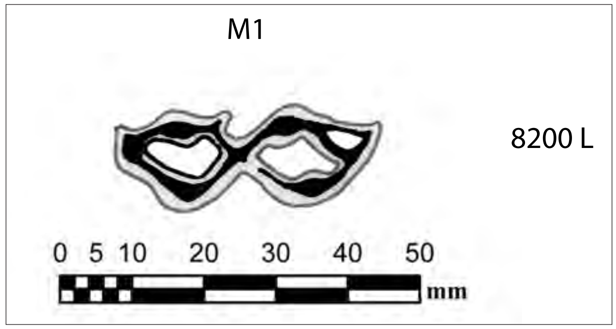


Figure 5.13. Dental Group 1 specimen.

Group 2/3 (1.6-2.7 years)

Four, isolated, unworn molars define this group and provide an MNI of 2. Because alveolar bone was badly deteriorated, the degree of eruption could not be assessed and so it was not possible to determine whether these specimens should be assigned to Group 2 or Group 3. CN9056 is an unworn, left M2 that is presumed to be unerupted. CN8197 is an unworn, left M2 and CN9357 is an unworn, left M3. These two teeth were found within a meter of each other and may be from the same animal. Lastly, CN8877 is an unworn, left M3 that was not examined in detail during the dentition analysis but is unworn. It has been tentatively assigned to this group as well.

Group 3 (2.6-2.7 years)

Group 3 is the largest of the dental age groups identified in the Beacon Island bison assemblage and served as a baseline (along with groups 5 and 7) against which other mandibular teeth were compared and grouped. Seven specimens, including two partial tooth rows and five isolated teeth, are present (figure 5.14). The Group 3 MNI is four based on right M2s. CN9853 is a partial right mandible that contains the fourth deciduous premolar, dP4, and three molars, M1, M2, and M3. The mandible itself is incomplete and damaged by compression, which is expressed as fragmentation and cranial shifting of the lingual side. The dP4 is erupted and heavily worn above the alveolus with a metaconid height of 11.5 mm. The infundibula are very small and narrow. The M1 is in full wear, with the ectostylid 1.0 mm from the occlusal surface and showing some polish. All occlusal cusps of the M2 are worn but the distal facets of the entoconid and hypoconid are not connected and its overall height is slightly lower than M1. The ectostylid of the M2

Table 5.20. Bison mandibular dentition data from the Beacon Island site.

| | | | | Measurements[a] | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | M1 | | | | | | M2 | | | | | | M3 | | | | | |
| Cat. No. | Teeth | Side | Age Grp. | M | E | MS | DS | L | EC | M | E | MS | DS | L | EC | M | E | MS | DS | L | EC |
| 1424 | M1 | R | 3 | >49.4 | >49.1 | 15.6 | 15.8 | 35.3 | 3.6 | | | | | | | | | | | | |
| 1436 | M1-M2 | R | 4 | 999 | 999 | 999 | 999 | 999 | 999 | >55.2 | >60.4 | 15.5 | 15.4 | 39.0 | 999 | | | | | | |
| 1467[b] | M1 | L | 4 | >39.1 | 999 | 999 | >17.3 | >32.2 | 999 | | | | | | | | | | | | |
| 1888.05[c] | M2 | R | 5 | | | | | | | >52.9 | 49.7 | 14.2 | 14.3 | 999 | 7.3 | | | | | | |
| 1888.07 | M1 | L | 3 | 44.2 | 999 | 13.6 | 999 | 32.7 | 3.6 | | | | | | | | | | | | |
| 8026[d] | M2 | R | 3? | | | | | | | 999 | 40.4 | 15.6 | 14.9 | 999 | 999 | | | | | | |
| 8067 | P4-M3 | R | 5 | 36.5 | >33.7 | 16.8 | 999 | 32.3 | in wear | 54.8 | 54.9 | 17.6 | 17.6 | 39.5 | 9.9 | 64.3 | 67.9 | 17.4 | 16.9 | 999 | 999 |
| 8197[e] | M2 | L | 2/3 | | | | | | | 999 | 999 | 999 | 11.7 | 42.5 | 999 | | | | | | |
| 8199 | M2 | R | 3 | | | | | | | 999 | 999 | 999 | 999 | 36.0 | 12.5 | | | | | | |
| 8200 | M1 | L | 1 | 54.9 | 58.1 | 13.2 | 13.8 | 34.5 | 999 | | | | | | | | | | | | |
| 8362 | M1-M3 | L | 5 | 34.9 | 33.7 | 16.5 | 17.9 | 33.2 | in wear | 54.6 | 55.8 | 17.8 | 17.6 | 38.5 | 10.3 | 66.2 | 67.5 | 15.9 | 16.6 | 48.7 | 12.1 |
| 8449 | M3 | R | 7 | | | | | | | | | | | | | 999 | 999 | 999 | 17.6 | 999 | in wear |
| 8529 | M2-M3 | L | 5 | | | | | | | 53.2 | 55.9 | 16.2 | 15.1 | 37.0 | 3.5 | >57.8 | 999 | >14.7 | 999 | 999 | 999 |
| 8590 | M3 | R | 7 | | | | | | | | | | | | | >54.0 | 56.6 | 16.3 | 16.3 | >47.3 | in wear |
| 8886 | M1 | L | 3 | 999 | 999 | 999 | 999 | 999 | 999 | | | | | | | | | | | | |
| 9000 | M3 | L | 7 | | | | | | | | | | | | | 999 | >53.0 | 999 | 999 | 999 | 999 |
| 9056[e] | M2 | L | 2/3 | | | | | | | >62.1 | 999 | 14.8 | 14.8 | 40.5 | 20.0 | | | | | | |
| 9143 | M2 | R | 3 | | | | | | | 70.5 | 66.9 | 999 | 999 | 999 | 15.5 | | | | | | |
| 9357[e] | M3 | L | 2/3 | | | | | | | | | | | | | >71.3 | 999 | 15.2 | 16.1 | 51.1 | 15.5 |
| 9502 | M1-M3 | R | 3 | 47.3 | 49.1 | 14.0 | 14.9 | 35.0 | 3.2 | 65.9 | 70.8 | 15.1 | 14.9 | 39.0 | 999 | 74.3 | 999 | 15.5 | 999 | 50.6 | 999 |
| 9769 | M1 | L | 4 | >38.9 | 999 | 999 | 999 | 36.4 | in wear | | | | | | | | | | | | |
| 9851 | P4-M2 | R | 7 | 999 | 999 | 999 | 999 | 27.8 | in wear | >32.3 | 34.5 | 19.4 | 19.6 | 34.8 | in wear | | | | | | |
| 9853 | dP4-M3 | R | 3 | 999 | 999 | 13.5 | 14.2 | 31.8 | 1.0 | 999 | 999 | 13.9 | 12.9 | 40.2 | 12.9 | 999 | 999 | 999 | 999 | 45.1 | 999 |

Note: Tooth portions that could not be measured are marked “999.”

[a] M, metaconid height; E, entoconid height; MS, occlusal width, mesial; DS, occlusal width, distal; L, occlusal length; EC ectostylid distance to wear; see appendix D.

[b] Nearly complete.

[c] Nearly complete; tip of metaconid broken.

[d] Not re-measured during wear analysis.

[e] Unworn.

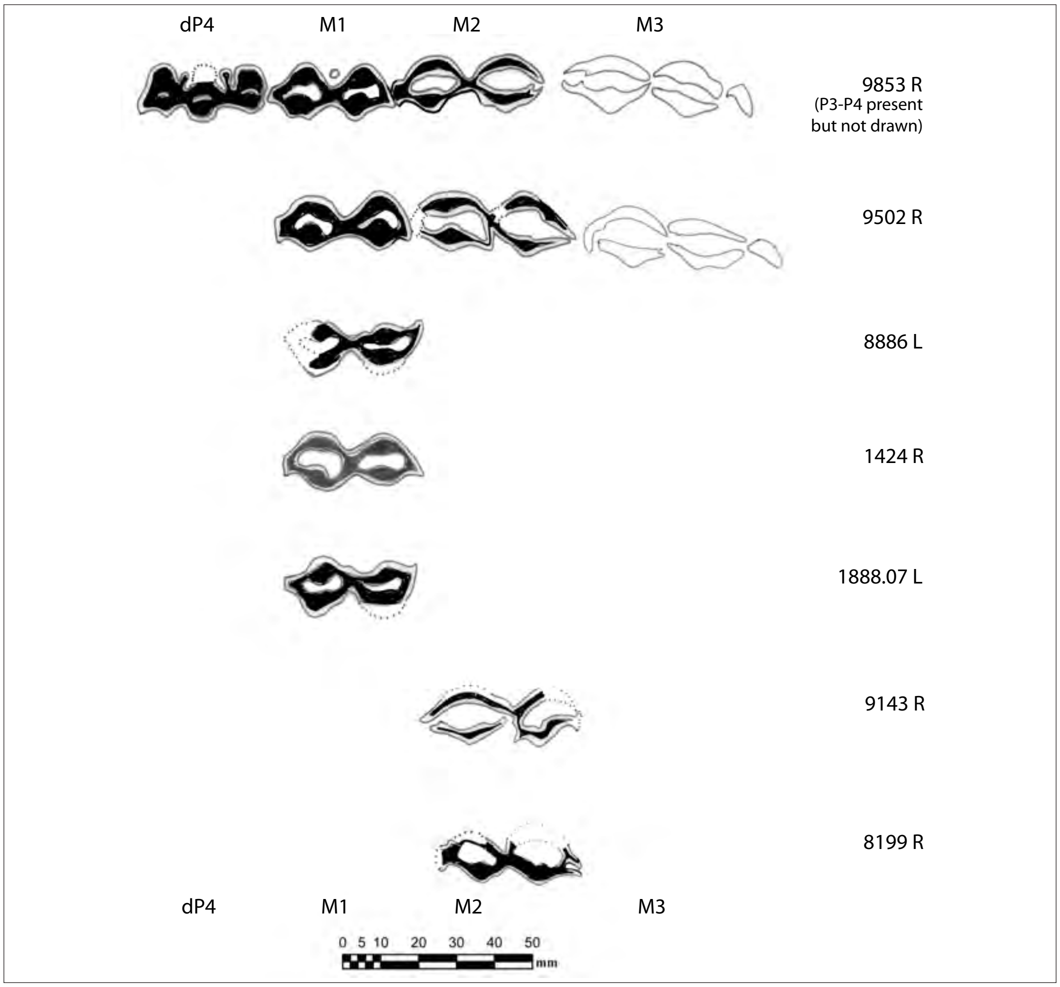


Figure 5.14. Dental Group 3 specimens.

measures 12.9 mm from the occlusal surface and is barely erupted beyond the alveolus. The M3 is unworn but the metaconid is at or near the alveolus. The hypoconulid is visible within the mandible.

The other partial tooth row (CN9502) is from the right side and consists of two permanent premolars (P3 and P4), M1, M2 and M3. Fragments of the mandibular bone are present but the teeth are loose. Damage to the occlusal surface of P3 prohibits any type of wear observations. P4 appears unworn but could be newly erupted since the dP4 was not identified among the mandibular remains. The M1 is in full wear, with the ectostylid 3.2 mm from the occlusal surface. Similar to CN9853, the M2 is in wear but the infundibula are large and the distal facets of the entoconid and hypoconid are not connected. The dentine connecting the distal facets of the metaconid and protoconid is very thin. The M3 is unworn and its degree of eruption is uncertain given the fragmented state of the mandible.

The remaining Group 3 specimens are isolated teeth, including CN1424 (right M1), CN1888.07 (left M1), CN8199 (right M2), CN8886 (left M1), and CN9143 (right M2). CN8026, a right M2, has also tentatively been assigned to this age group based entirely on metric data; it is not included in the wear analysis. Wear on the isolated M1s closely mirrors that observed on the two partial tooth rows. With regard to the M2s, CN8199 is similar to the tooth row specimens but the distal facets of the entoconid and hypoconid are only in partial wear. CN9143 is less worn and may belong to a slightly younger animal. The infundibula are large and neither the mesial nor the distal facets of the metaconid are connected. The distal portion of the hypoconid is damaged but it appears that the hypoconid and entoconid facets are not connected. The other facets on the tooth are connected by only a thin line of dentine. The tooth is similar to the M2s described from the Mill Iron Group 3 dentitions (2.0-2.2 years) and could therefore represent an out-of-season birth.

Generally, the Beacon Island Group 3 specimens are similar to the Hawken Group 3 (2.7 years) mandibles but appear to be slightly younger. The majority of the nine Hawken Group 3 dentitions illustrated in Todd and others (1996:Figure 8.14) show minimal wear on the mesial M3 facets. No wear is present on the Beacon Island Group 3 M3s. Similarly, the Hawken M2s seem to be more worn than those from Beacon Island. For these reasons, Beacon Island Group 3 was defined as ranging from 2.6-2.7 years.

Group 4 (3.6-3.7 years)

No tooth rows are assigned to Group 4. Definition of the group is based on two, isolated (and incomplete) molars (CN1467 and CN9769) and a damaged M1-M2 set (CN1436). The MNI for the group is two based on left M1s. It is possible that CN1467 and CN9769 belong to Group 3 and that CN1436 is closer in age to Group 5 based on degree of wear. Metric data offer some support for placement in Group 4 but, in general, metrics do not appear to be a predictable indicator of specific age group, especially given the small sample represented at Beacon Island and the fact that metric data for the dentitions are often incomplete due to the amount of damage they have sustained. Metaconid height is among the most useful metric but is only available for one of the five specimens assigned to this group.

CN1467 and CN9769 are both left M1s. CN1467 is missing much of the buccal side, particularly on the mesial end. It is in full wear and the infundibula are large but it is unclear whether the ectostylid is in wear due to damage. The distal width of the occlusal surface is at least 17.3 mm, which is approximately 2 mm wider than the other Group 3 M1s and suggests a greater degree of wear. CN9769 is damaged on the buccal side but is complete enough to show it is in full wear and that all facets are connected. The ectostylid is in wear but is unconnected to the remainder of the tooth. Very little metric data could be gathered on the tooth but its occlusal length is only very slightly (1.0 mm) greater than the nearest Group 3 M1 (metrically). Again, this may indicate slightly more wear and, by extension, an older animal.

CN1436 is a right M1 and M2 set. The M1 is very fragmented and could not be measured or assessed for wear. The M2 is damaged on the mesial end (facets I and II, extending through the ectostylid) and also on facet VIII but it is assumed based on the remaining degree of wear that the tooth is in full wear and all facets are connected. The ectostylid is not in wear and its distance to the occlusal surface could not be measured due to damage.

Group 5 (4.6-4.7 years)

Two partial tooth rows, one M2-M3 set, and an isolated M2 are included in Group 5, providing an MNI of two for the group based on both left and right M2s (figure 5.15). CN8362 is a nearly complete tooth row containing two premolars, P3 and P4, and all three molars, M1, M2, and M3. None of the mandibular bone is present. The P3 and P4 are heavily worn. The M1 is in wear, with the ectostylid connected to the main part of the tooth. The M2 is also in wear, but the ectostylid is 10.3 mm from the occlusal surface. The M3 is in wear and the hypoconulid is connected to the entoconid by a thin line of dentine. A hypoplasia was noted on the buccal side of the M3 approximately 7.2 mm from the alveolus. It measures 2.6 mm in diameter.

CN8067 consists of all three molars. M1 is in full wear and the ectostylid is connected to the rest of the tooth. The infundibula are small in relation to the amount of exposed dentine. The M2 is also in full wear although the ectostylid is still 9.9 mm from the occlusal surface. Again, the infundibula appear small in relation to the exposed dentine. The hypoconulid on the M3 is broken off but is clearly attached to the entoconid via continuous dentine.

CN8529 is a left M2 and M3. The M2 is in full wear and shows some damage to the mesial protoconid. The ectostylid is 3.5 mm from the occlusal surface. The M3 is damaged on the buccal side and is also missing the distal hypoconulid. That said, the four anterior cusps are in full wear and the hypoconulid is connected to the entoconid. Lastly, CN1888.05 is a right M2 in full wear. The ectostylid is 7.3 mm from the occlusal surface.

Given the degree of wear on the hypoconulids of the three Group 5 M3s, there is little doubt that the tooth rows are from animals older than 4.5 years. A review of the eruption and wear for bison from eight bison assemblages of varying seasonalities (as summarized in Todd and others [1996:Tables 8.4 and 8.5]) indicates that connection of the hypoconulid with the entoconid does not occur before 4.5 years. That connection is present on all three of the Beacon Island Group 5 M3s and, in the case of CN8362, the hypoconulid is in full wear. The M2 ectostylid for the Hawken Group 5 (4.7 years) dentitions are described as "usually in wear." In contrast, it is not in wear on any of the four Beacon Island Group 5 M2s and instead ranges from 3.5 mm to 10.3 mm from wear, suggesting the teeth are younger than the Hawken specimens.

Group 6 (5.6-5.7 years)

No dentition is positively assigned to this age group, although it is possible that two, isolated M3s currently included in Group 7 (CN8590 and CN9000) are instead closer to this age.

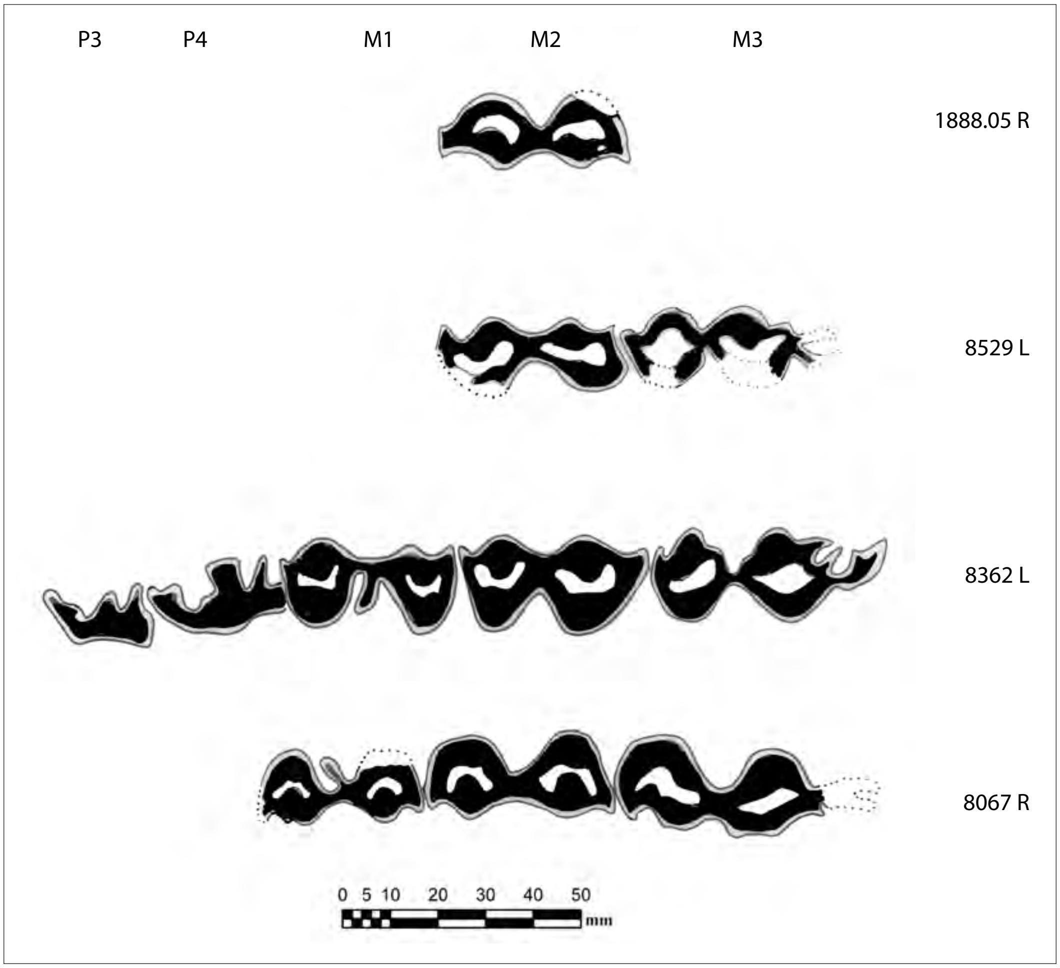


Figure 5.15. Dental Group 5 specimens.

Group 7 (6.6-6.7 years)

Four specimens are assigned to this group, including a partial tooth row and three, isolated M3s. The MNI for the group is 2 based on right M3s. CN9851 is a partial right mandible containing the P4, M1 and M2 (figure 5.17). The mandible and teeth are damaged from compression, which has caused fragmentation and shifting of the dental ramus and significant damage to the lingual side of the M1. All three teeth are in full wear. The ectostylid on the M1 is connected to the remainder of the tooth, and the infundibula are small relative to the amount of exposed dentine, particularly the distal infundibulum. The ectostylid on the M2 is in wear but is teardrop-shaped and not connected to the rest of the tooth. Using the Mill Iron dentition as a guide, this tooth row is likely from an animal between the ages of 6 and 7 years since M2 ectostylids reportedly enter wear around 6.0-6.2 years (Mill Iron Group 7) and are generally connected to the M2s by 7.0-7.2 years (Mill Iron Group 8; Todd et al. 1996:161).

Both CN8449 and CN8590 are isolated, right M3s. CN8449 is damaged on the mesial and distal ends. It is in full wear, with the hypoconulid connected to the rest of the tooth. The infundibula are notably large, and the ectostylid is in wear but is not connected to the rest of the tooth. CN8590 is in full wear, although the exposed dentine on the hypoconulid is restricted to a thin line on the buccal side. The ectostylid is also in wear. This tooth may be from a younger animal than CN8449, perhaps belonging in Group 6. CN9000 is an isolated, left M3 in full wear. The mesial end is broken and the hypoconulid is damaged; however, the latter is connected to the entoconid via exposed dentine. A small island of enamel is present on facet VIII. The distance from the ectostylid to the occlusal surface was not able to be measured due to tooth damage but, unlike other Group 7 specimens, it is not in wear. As with CN8590, it is possible this specimen belongs in Group 6. However, assuming this dental age group closely compares with the Hawken site remains (as has been the case with the previous groups), the two M3s with ectostylids in wear are

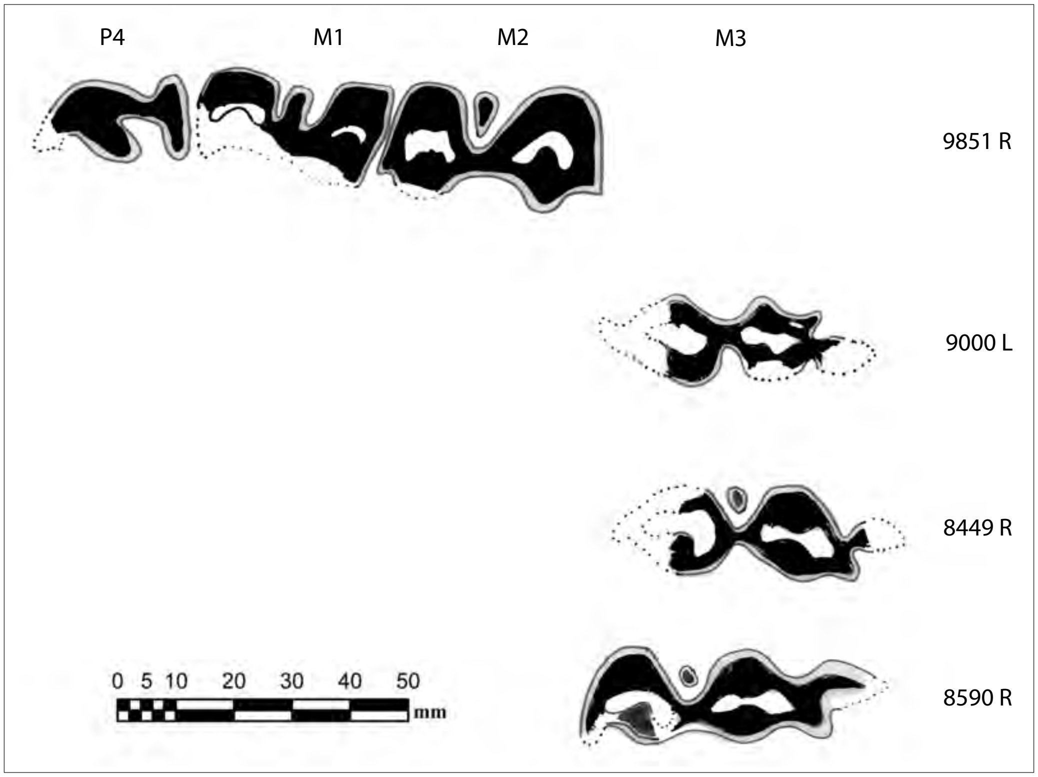


Figure 5.16. Dental Group 7 specimens.

consistent with animals around 6.7 years old (Hawken Group 7; Frison et al. 1976:39). Further support for the group's age is provided by the Mill Iron site, where the M3 ectostylid is unworn at 6.0-6.2 years but is usually in wear by 7.0-7.2 years (Group 8; Todd et al. 1996:161). As noted above, wear on the P4-M2 tooth row (CN9851) also appears slightly more advanced than Mill Iron Group 7 (6.0-6.2 years) but not as extensive as Group 8.

Worth noting is the fact that a partial tooth row from Group 7 (CN9851) was recovered in the same unit and level (and about 10 cm from) as a Group 3 tooth row (CN9853). These two mandibles represent two individuals with a considerable age difference that were recovered in proximity to one another, further supporting a high degree of carcass processing at the site.

*Summary and Discussion of Herd Composition and Seasonality Interpretations*

The Beacon Island herd comprised a minimum of 29 to 33 animals. The MNI represented in the excavated assemblage is 29 and four animals are represented in the surface assemblage studied by Karpinski (2002). (However, insufficient data are available on the surface assemblage to compare it directly to the excavated assemblage). Tooth eruption and wear data, along with epiphyseal fusion data, indicate that the herd incorporated animals of different ages, from calves or yearlings to mature animals nearly seven years old. Both mature males and mature females are well represented, based on the sizes of recovered metapodials and calceanea. The apparent under-representation of immature animals, both in the fusion and the dentition data, may be related to taphonomic issues and is worth further investigation. Finally, the dentition data indicate that the animals were killed between N+0.6 and N+0.7 years (roughly 31 to 36 weeks) after they were born.

The precision of bison kill seasonality assessments depends on an assumption of birth synchrony. Walde (2006) uses an analysis of bison fetal development data to suggest that assumptions about the lengths of modern bison breeding and calving seasons may not be warranted. Citing data obtained by Pac and Frey (1991), Walde notes that fetal animals taken during a mid-winter cull in Yellowstone National Park were conceived over a period spanning more than 17 weeks, from June 26 to October 24. This would presumably result in an equally lengthy birthing period (assuming a constant gestation), which would affect the precision of seasonality estimates based on tooth eruption and wear patterns.

However, research on the bison herd at Badlands State Park suggests there is a notable degree of birth synchrony in bison, particularly among animals with access to good nutrition (Berger and Cunningham 1994). Recent research also indicates that some latitudinal variation in birth periods exists. Bison herds in more northern regions or those experiencing longer, harsher winters have later median birth dates than those in southern locations (Berger and Cunningham 1994:118). For example, while the earliest births in Yellowstone National Park and Wood Bison Park (Canada) typically commenced in early May, the first births in Oklahoma occurred from March 10 to April 7. Berger and Cunningham's (1994:Table 6.1) five-year study (1985-1989) of the Badlands herd revealed a highly predictable median birth date (May 2-8), as well as a predictable date range for the earliest births (April 3-8). Births at the National Bison Range in western Montana reportedly began slightly later. The lengthy breeding season reported in Walde (2006) for the Yellowstone bison may therefore have been the result of specific environmental factors, such as poor forage or range restrictions.

The Beacon Island site is geographically most comparable to the National Bison Range, suggesting that the median birth date for the Beacon herd was mid-May, but that births may have begun as early as mid-April. It is further postulated based on other lines of evidence from the site (including micromammals [chapter 8], gastropods [chapter 9], and phytoliths and stable carbon isotope results [chapter 10]) that the Beacon Island bison herd had access to high-quality forage due to the generally moist conditions occurring in the region at the time. This may have resulted in a shorter rut and greater birth synchrony. Thus, the minimum age-at-death inferred from tooth eruption and wear patterns (N+0.6 years) indicates a late December kill. The maximum (N+0.7 years) indicates a late January or early February kill.

The presence of a number of mature bulls in the Beacon Island target herd is unexpected, given the fact that the kill was made in the winter. Data provided by McHugh (1958:14-16) suggest that large herds comprised of both males and females and animals of widely varying ages come together most commonly during the rut. Using census data collected in Yellowstone National Park from 1951 to 1953, McHugh identified two types of herds. His "bull groups" consisted of one to 12 males and, occasionally, a few cows. The mean number of animals in the bull groups observed in Yellowstone ranged from 4.7 down to 1.2 animals. The majority of the animals in McHugh's second herd type, which he calls "cow groups," were females. Immature animals and bulls were also present, but mature bulls (older than four years) comprised a very small fraction (0 to 0.4 animals on average) of the cow group population outside the breeding season. The mean sizes of cow groups ranged from 16.7 to 20.3 animals. During the rut, however, the mean size of cow groups grew to more than 115 animals, of which nearly one-tenth were bulls older than four. Assuming modern bison biology is a suitable guide, the age and sex profiles of the target herd at Beacon Island implies that it was a cow group formed during the rut. Dentition data, however, indicate the site was occupied well after the rut, during the mid-winter months. The sex ratio represented by the archaeological assemblage may therefore not mirror the ratio of the kill assemblage (Speth 1983). The apparently high male-to-female ratio suggested by the metapodial and calcanea data may indicate that bones from larger males were preferentially left behind or not processed for marrow on-site. Meat or marrow from larger males may have been less desirable to the hunters than meat or marrow from cows or immature animals because the former were fat-depleted from the rut. Male bison can lose up to 10% of their normal body weight as a result of the rut, and therefore often enter the winter in relatively poor condition (Speth 1983:105). While they can begin to slowly rebound during the winter months, they do not reach their peak until late spring-early summer. Alternately, females have greater fat reserves going into winter, and do not hit a nutritional low until mid- to late-spring, near calving time (Speth 1983:105).

## Summary

Archaeological investigations at the Beacon Island site exposed and documented a large, well-preserved, Agate Basin-age bison bonebed. Butchered bison remains also were recovered from younger cultural components at the site. In particular, an intensive, early-Holocene occupation on the western edge of Area A, exposed in a single 1 x 1 m test unit at square 1308NE1055, offers an area of focus for future research.

Data on the distribution, breakage, and skeletal element abundance of the Agate Basin-age bison remains indicate that, while post-depositional processes have affected the archaeofauna to an extent, the make-up, distribution, and condition of the assemblage are largely the result of human activity. The inhabitants of the site killed and butchered approximately 29 to 33 bison during the early- to mid-winter. The surface collection of several complete or nearly complete bones and Agate Basin projectile points (discussed in chapter 6), just east of the main excavation block, suggests the kill was located there but has since eroded, and that several whole carcasses may have been abandoned by the site occupants. The occupants appear to have remained at the site long enough to intensively process some of the bison before transporting high-utility (likely upper) limb units off-site. This intensive processing and transport was likely targeted at a specific demographic (e.g., prime-age females), thus skewing the population profile toward less female representation than might have existed in the original kill population.

The addition of the Beacon Island site to the broader Agate Basin dataset allows for more robust statements about Agate Basin lifeways. Bison skeletal element abundance and butchery intensity at known Agate Basin bison kill-butchery sites suggest continuity in butchery practices among different Agate Basin-age hunting bands, although the Beacon Island herd appears to have been more intensively processed than the Agate Basin (Agate Basin component) assemblage. In terms of seasonality, the Beacon Island site's occupation during the winter is consistent with the seasonality of the Agate Basin and Frazier sites. The prevalence of winter bison kills during Paleoindian times is an interesting phenomenon and is worthy of additional study.

# 6

## Technological Analysis of the Modified Stone Assemblage

*Mark D. Mitchell and Christopher M. Johnston*

This chapter presents data on the flaking debris and stone tools from Area A. The assemblage under study combines all specimens recovered from the site, including items obtained in the May 2002 session that are described and analyzed by Ahler (2003b), Ahler and Crawford (2003a), and Ahler and Ritter (2003), as well as a collection of projectile points recovered from the surface in 2000 or 2001 (Ahler 2003a; Ahler and McGonigal 2001).

Several analysts collected the data reported here. Stan Ahler and George Crawford carried out the initial analysis of stone tools in the controlled surface collection and the May 2002 excavated collection. Mark Mitchell coded additional variables for these specimens in conjunction with his analysis of the stone tools recovered in September 2002 and in 2006. Mitchell also collected metric and other data on the excavated projectile point assemblage. Ahler and Mitchell independently examined the 21 Agate Basin-age artifacts in the surface collection. Ahler and Kelly Ritter collected data on chipped stone flaking debris recovered during the May 2002 field investigation. Stacey Bennett studied the fine-fraction (size grades 4 and 5) flaking debris recovered in September 2002 and in 2006. Chris Johnston analyzed the coarse-fraction (size grades 1 through 3) flaking debris from all field sessions. Johnston also conducted the refitting study, carried out the initial spatial analysis of the flaking debris assemblage, and compiled comparative metric data on projectile points from Agate Basin components at the Hell Gap, Frazier, and Agate Basin sites. Mitchell integrated these datasets and wrote the chapter, with input from Johnston.

### Overview of Analytic Methods

The modified stone aggregate was first partitioned into two classes: chipped stone flaking debris and stone tools. A tool is defined as any intentionally shaped object, an item exhibiting use-wear, or a remnant nodule of raw material from which flakes were struck. Intentionally shaped objects range in complexity from simple flakes with retouched edges to items produced by flaking, pecking, grinding, or some combination of these techniques. Flaking debris, by contrast, consists of detached pieces discarded during lithic reduction (Shott 2004) and therefore lacking evidence of use or modification other than that produced by transport, trampling, or other post-depositional factors.

The analysis developed in this chapter focuses on the assemblage's technological, rather than functional, properties. Technological analyses emphasize the steps and stages of stone tool manufacturing. The most important production variable in the system used here is "technological class." A tool's technological class is defined primarily by the dominant method used to manufacture it and secondarily by the initial form of the raw material blank (Ahler, Root, and Feiler 1994). Each class incorporates a sequence of production techniques. Sequences range from simple and expedient to complex and staged. For example, patterned large thin bifaces, the most abundant stone tool class at Beacon Island, are produced by sequential soft-hammer percussion flaking and, to a lesser degree, pressure flaking applied to flake blanks or tabular pieces of stone. Flake tools, by contrast, may exhibit nothing more than simple edge modification, either through extensive use or by marginal retouch. Table 6.1 summarizes the attributes of each technological class.

Determinations about manufacturing stage and technological trajectory depend in part on the concept of "patternedness." Patterned tools exhibit bilateral symmetry whereas unpatterned tools generally are asymmetrical, with their form dictated mainly by the shape of the original input blank. Use-wear traces, though not rigorously quantified in this analysis, provide additional information about whether the production process was complete when an artifact was lost or discarded. Variables designed to capture supplementary technological data include "use phase," "reason for rejection," "original input blank," and "heat treatment class." Data also were collected on other dimensions of stone tool variation, including raw material and post-depositional alteration.

Technological analysis of flaking debris focuses on flake size distributions and on the details of striking platform type and preparation. Two datasets were collected on the flaking debris aggregate. A basic suite of variables was coded for all sizes of flaking

Table 6.1. Stone tool technological class definitions.

| Technological Class | Description |
|---|---|
| Small patterned biface | Produced by controlled and sequenced pressure flaking on small, thin flake blanks. When finished, artifacts in this class exhibit continuous bifacial retouch and are symmetrical in plan view and cross section. Includes arrow points, drills, and small cutting tools. |
| Large patterned biface | Produced by controlled and sequenced percussion flaking on various blank types. Symmetrical in plan view and cross section. Pressure flaking also is used, which sometimes obliterates evidence of earlier manufacturing stages. Includes dart points and hafted and unhafted bifacial cutting tools. |
| Unpatterned biface | Produced by hard hammer percussion on tabular, pebble, or flake blanks; pressure flaking is used only rarely. Tools in this class are not symmetrical and often exhibit discontinuous bifacial edging. |
| Patterned flake tool | Produced by pressure flaking on flake or tabular blanks. Consists moslty of hides scrapers. This class does not occur in the Beacon Island assemblage. |
| Unpatterned flake tool | Produced by use-flaking or pressure-flaking on a flake blank. Edge modification is highly variable and may be discontinuous. Unpatterned flake tools lack symmetry. Includes a wide variety of tools used for many different tasks. |
| Large bifacial core tool | Produced by free-hand percussion on large cobble blanks of coarse material. This class does not occur in the Beacon Island assemblage. |
| Non-bipolar core | Produced by free-hand, nonbifacial percussion on various blank types. May be irregular or symmetrical. Includes cores and tested cobbles. |
| Bipolar core/tool | Produced only or mainly by bipolar percussion. Irregular in plan view and cross section. Includes cores used for flake production, punches or wedges fractured during use, and tested cobbles. |
| Unpatterned groundstone | Produced by pecking or grinding or formed by use on various blank types. Irregular in plan view and cross section. Includes abrading tools, hammerstones, and bipolar anvils. |
| Patterned groundstone | Produced by pecking or grinding on various blank types. Includes abrading tools, celts, mauls, beads, and other decorative items. This class does not occur in the Beacon Island assemblage. |
| Retouched plate tool | Produced by free-hand percussion flaking and pressure flaking on tabular or platy blanks. Tools in this class may exhibit unifacial or bifacial edging, but generally are asymmetrical in plan view. Includes a wide variety of tools used for many different tasks. |

debris (size grades 1 through 5) from all analytic units. These variables include size grade, raw material type, presence of cortex, patination intensity, and burning. The occurrence of intentional heat-treatment was not recorded for flaking debris. Rather, signs of heat alteration such as color or luster change, stress cracking, and so forth were taken as an indication that the flake had been burned. Burning and patination were recorded only for specimens of Knife River flint (KRF). Experience has shown that evidence of these two attributes often is clearly seen in KRF, whereas such evidence may be difficult to detect in certain other material types. Finally, counts and weights were recorded for each sort group. This basic dataset was collected to assess raw material procurement patterns; differences in the ways different raw materials were used; the presence of intra-site activities areas; and post-depositional alteration to the assemblage.

To gather additional data on the technological procedures used to produce and modify Agate Basin-age stone tools in Area A, an individual-flake analysis was applied to the coarse-fraction (size grades 1 through 3) flake aggregate recovered from Aggie Brown Member contexts. Variables considered in this phase of the analysis include flake types, flake size, striking platform morphology, and striking platform preparation method.

Complete lists of the variables and attributes coded in the stone tool and flaking debris studies are given in appendix C. Additional discussion on the analytic methods applied to the collection can be found in Ahler (2002), Ahler, Kellet, and Crawford (2003), Ahler, Root, and Feiler (1994), Ahler and Toom (1993), and Root and others (1999).

## Collection Overview and Raw Material Use

The Area A flaking debris assemblage includes a total of 3,134 specimens (table 6.2). This figure combines actual counts of flakes in the coarse fraction (size grades 1 through 3) with estimated and actual counts of flakes in the fine fraction (size grades 4 and 5). Such estimates are necessary because fine-mesh waterscreening was only used to process a portion of the sediment excavated during the May 2002 session. Recall from chapter 3 that constant-volume samples, amounting to one-ninth of

Table 6.2. Actual and estimated counts of flaking debris, organized by size grade and analytic unit. Values for size grades 1 through 3 flakes are actual counts. Values for size grades 4 and 5 flakes are estimates; actual counts are given in parentheses.

| | Size Grade | | | | | |
|---|---|---|---|---|---|---|
| Analytic Unit | G1 | G2 | G3 | G4 | G5 | Total |
| Surface/Lakebed (CC/GL) | 4 | 44 | 128 | 24 (23) | 32 (32) | 232 (7%) |
| Riverdale | | | 8 | 33 (33) | 58 (58) | 99 (3%) |
| Pick City | | 10 | 97 | 297 (296) | 568 (562) | 972 (31%) |
| Aggie Brown | 2 | 16 | 127 | 634 (603) | 1025 (972) | 1804 (58%) |
| Mallard Island | | | 1 | 7 (7) | 16 (16) | 24 (<1%) |
| Indeterminate | | 1 | 1 | 1 (1) | | 3 (<0.1%) |
| Total | 6 | 71 | 362 | 996 (963) | 1699 (1640) | 3134 (3042) |

each excavation level (a 33 x 33 x 10 cm block), were waterscreened during that session. The balance, or eight-ninths of each excavation level, was dryscreened through ¼-inch hardware cloth. In their analysis of the flaking debris recovered during the May 2002 field investigation, Ahler and Ritter (2003) multiplied the number of flakes smaller than ¼-inch (size grades 4 and 5) that were sorted from the constant volume samples by a factor of nine to estimate the total number present in each full level.

The suitability of this multiplier can now be assessed using the larger excavated sample now in hand. Table 6.3 compares the density of size grade 4 flakes in the May 2002 waterscreen samples with density data from the combined September 2002 and 2006 collections. A total of 31 size grade 4 flakes were recovered from May 2002 constant volume samples. When multiplied by 9, this gives an estimate of 279 flakes, or just over 72 flakes per cu. m. By contrast, the overall density of size grade 4 flakes in the larger September 2002 and 2006 sample (recovered entirely by waterscreening) is just over 16 flakes per cu. m, with a range of 0 to 155 flakes from each excavation square. Thus, the estimated density for the May 2002 units using the nine-fold multiplier is more than four times as great as the actual mean density for all other units.

The excavation squares opened in May 2002 are representative of excavated area as a whole. They are distributed across the kettle basin. Some are located on the thin eroded edge of the bonebed, but others are located closer to the center of the pothole, where the bonebed is more deeply buried. These deeper units exposed relatively thick sections of the Aggie Brown Member. In addition, the May 2002 units penetrated portions of the Agate Basin component exhibiting comparatively dense accumulations of bones and artifacts, but also portions where artifacts are more widely dispersed. Because the May 2002 units do not differ from the September 2002 and 2006 units according to these measures, a multiplier which produces a density value closer to the mean density for the site as a whole seems more appropriate. Accordingly, a factor of 2, rather than 9, was used to provide size grade 4 flake count estimates. This multiplier yields a mean density of just over 16 flakes per cu. m for the May 2002 units, with a range of 0 to 84 flakes per excavation square. The same multiplier was used to estimate size grade 5 flake counts. Similar adjustments also were made to the number of flakes in May 2002 excavation levels assigned to the Surface/Lakebed (CC/GL) and Pick City Member analytic units. It is unclear why the nine-fold factor seems to produce a significant over-estimate, but it may have to do with the overall scarcity of flakes in the deposits.

Chapter 4 defines the eight analytic units used to organize artifacts and faunal remains from Area A. The flaking debris assemblage comes from six of these units. Over half of the assemblage was recovered from Aggie Brown Member contexts. Another third is assigned to Pick City Member sediment; however, 84 percent of these comes from a single 1 x 1 m excavation unit (square 1308NE1055). The surface collection (which includes both plotted specimens and items recovered from excavated lakebed sediment) makes up 7 percent of

Table 6.3. Flake density and count estimation data.

| Sample | Vol. (cu. m) | G4 Count | Actual Density | Min. | Max. | G4 Adjsuted Count (X2) | Est. Density | Min. | Max. | G4 Adjusted Count (X9) | Est. Density | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 3.835 | 31 | 8.083 | 0 | 7 | 62 | 16.167 | 0 | 84 | 279 | 72.751 | 0 | 378 |
| Sept.+2006 | 34.825 | 572 | 16.425 | 0 | 155 | | | | | | | | |

the assemblage. The balance, just 4 percent, comes from Riverdale, Mallard Island, and undetermined contexts combined.

A total of 153 specimens make up the complete stone tool assemblage from Area A. Two distinct production modes were applied to two of the specimens, yielding a total of 155 distinct technological cases (table 6.4). The values in table 6.4 represent actual counts; no estimation factor is applied because no stone tools were sorted from the constant volume samples recovered in May 2002.

Like the flaking debris assemblage, the stone tool aggregate is partitioned among six analytic units. Fifty-eight percent of the stone tool assemblage is assigned to Aggie Brown Member contexts. Thirty-two percent comes from surface contexts. Just less than half of these are Agate Basin projectile point fragments recovered by artifact collectors from the surface adjacent to the excavation blocks. Another 9 percent of the tools comes from Pick City contexts. Only two tools (1 percent) were recovered from excavated Riverdale Member contexts.

### Major Raw Material Types in the Flaking Debris Assemblage

Table 6.5 breaks down the flaking debris assemblage by material type. Nineteen raw materials are represented.

Table 6.4. Stone tool counts organized by size grade and analytic unit.

| | Size Grade | | | | | |
|---|---|---|---|---|---|---|
| Analytic Unit | G1 | G2 | G3 | G4 | G5 | Total |
| Surface/Lakebed—Area A (CC/GL) | 2 | 15 | 9 | | | 26 (17%) |
| Surface/Lakebed—Area A (SC) | | | | | | 21[a] (14%) |
| Surface/Lakebed—Area P | | 1 | 1 | | | 2 (1%) |
| Riverdale Member | | | 2 | | | 2 (1%) |
| Pick City Member | 1 | 5 | 7 | 1 | | 14 (9%) |
| Aggie Brown Member | 11 | 31 | 36 | 11 | 1 | 90 (58%) |
| Total | 35 | 52 | 55 | 12 | 1 | 155 |

[a] No size grade data are available for this analytic unit.

Table 6.5. Flake counts organized by raw material type and analytic unit.

| | Analytic Unit | | | | | | |
|---|---|---|---|---|---|---|---|
| Raw Material Type | Surface/ Lakebed (CC/GL) | Riverdale | Pick City | Aggie Brown | Mallard Island | Indeterminate | Total |
| Smooth gray TRSS | 1 | | 1 | 4 | | | 6 |
| Coarse yellow TRSS | | 3 | | | | | 3 |
| Swan River Chert | 8 | | 53 | 73 | 6 | | 140 (4%) |
| chert/jasper | | | 1 | 6 | | | 7 |
| White River Group Silicate | | | | 2 | | | 2 |
| clear/gray chalcedony | 3 | | 15 | 11 | | | 29 |
| yellow/brown chalcedony | | | 2 | 6 | 1 | | 9 |
| dark brown chalcedony | 2 | 1 | 5 | 3 | | | 11 |
| basaltic | 1 | | | 3 | | | 4 |
| quartz | 1 | | | | | | 1 |
| porcellanite | | | | 3 | | | 3 |
| granitic | | | | 1 | | | 1 |
| Knife River Flint | 208 | 95 | 885 | 1496 | 17 | 3 | 2704 (86%) |
| metaquartzite | 1 | | 2 | 5 | | | 8 |
| silicified wood | 1 | | | 4 | | | 5 |
| moss agate | 1 | | | | | | 1 |
| Antelope Chert | 4 | | 2 | 163 | | | 169 (5%) |
| silcrete | | | | 1 | | | 1 |
| schist | | | 1 | 4 | | | 5 |
| unclassified | 1 | | 5 | 19 | | | 25 |
| Total | 232 | 99 | 972 | 1804 | 24 | 3 | 3134 |

However, just three types comprise 96 percent of the assemblage. The dominant material is Knife River Flint (KRF). KRF is a distinctive, high-quality, blonde to dark brown chert. No in-place outcrops of KRF have been documented, but the original geologic source may be the HS bed of the Eocene/Paleocene Golden Valley Formation (Clayton et al. 1970). It could also have formed in the Oligocene/Miocene Arikaree Formation, which forms the caprock of the Killdeer Mountains (Murphy 2001). Secondary deposits of KRF cobbles are common in Pleistocene-age alluvium and residual lag gravels in portions of the Knife River basin, especially in Dunn and Mercer counties (figure 6.1). Dozens of quarry localities are known in this area, dubbed the "primary source area," which runs roughly from the Killdeers eastward to the town of Hazen, and from the Little Missouri River valley south to the divide between the Heart River and Knife River basins. The Lynch quarry, located some 75 km due

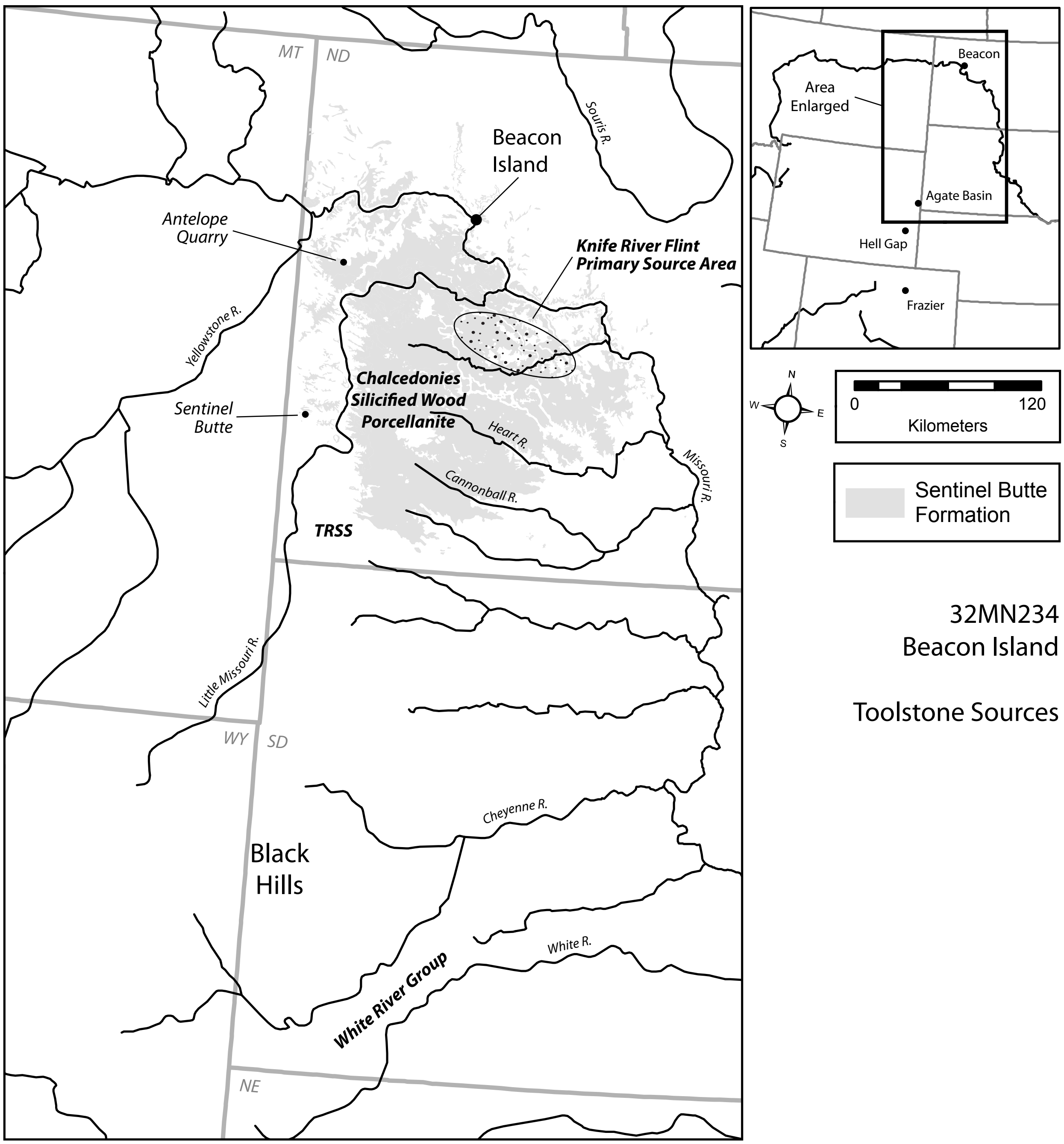


Figure 6.1. Map showing sources of the lithic raw materials present in the Beacon Island assemblage.

south of Beacon Island, is the largest documented quarry locality, covering 32 ha and consisting of hundreds of separate quarry pits. However, productive quarries exist somewhat closer to Beacon Island (Ahler 1986). One projectile point in the Beacon Island surface collection is made from a form of KRF that is common along the Little Missouri River north of the primary source area.

KRF nodules also occur in surface lag deposits across a broad region encompassing much of southwest North Dakota and parts of eastern Montana (Ahler 1986, 2002). In addition, KRF occurs in Pleistocene and Holocene alluvium in the western tributaries of the Missouri in North Dakota (Ahler 1977), and in Missouri River gravels from the mouth of the Knife River as far south as Buffalo County, South Dakota (Ahler 1995). Small nodules have been reported from eastern North Dakota (Gregg 1987). However, cobbles from these lag and alluvial sources typically are smaller, and can be of lower quality, than those found in the primary source area. Given the fact that larger cobbles suitable making Agate Basin weaponry occur most abundantly within the primary source area, which is also nearer at hand, it is likely that the KRF used at Beacon Island came from one or more of the quarries along Spring Creek. For that reason KRF can be considered a near-local raw material at Beacon.

The second most abundant material in the Area A assemblage is Antelope Chert, a coarse- to fine-grained opaque stone ranging in color from brown to brick red to purple (Beckes et al. 1987). Antelope Chert contains abundant fossil plant parts, as well as fossil gastropods, distinguishing it from otherwise superficially similar forms of porcellanite. Only one source of toolstone-quality Antelope Chert has been documented, in McKenzie County, some 90 km southwest of Beacon Island. Antelope Chert is a rather minor constituent of regional archaeological assemblages, occurring mostly within about 55 km of the McKenzie County quarry, though it may be present in a few Plains Village-age assemblages located farther away on the Missouri (Beckes et al. 1987).

However, it is possible that Antelope Chert outcrops across a relatively broad swath of western North Dakota. The potential distribution of Antelope Chert is conterminous with the contact between the Sentinel Butte Formation and the underlying Bullion Creek Formation, both Paleocene in age, where exposures of silicified lignite also are comparatively common (figure 6.1). This contact extends through a number of counties in southwest North Dakota, but is particularly well expressed in the Little Missouri River valley. This contact zone is also preserved north of the Missouri River in Mountrail County, just a few km west of Beacon Island, where it extends northward from the Missouri, up the White Earth River valley (figure 6.2). As discussed later in this chapter, the quality of the Antelope Chert at Beacon Island varies from good to poor, possibly indicating that more than one source was used. However, Beckes and others (1987) note that Antelope Chert weathers rapidly, and weathering may have accentuated the brittleness of the fracture planes present in some of the specimens in the Beacon assemblage. Given the extent and distribution of the Sentinel Butte-Bullion Creek contact, Antelope Chert should be considered a local to near-local raw material.

At Beacon Island, Antelope Chert may constitute an index material for the Agate Basin occupation. Just three non-projectile tools and six flakes made from Antelope Chert occur in analytic units other than the Aggie Brown. All three of the tools and two of the flakes come from lower Pick City contexts. One flake tool and one exhausted, burned core were recovered from the base of the Pick City Member in square 1256NE1110. The flake tool was recovered from GL 6, which spans the Aggie Brown-Pick City contact and is 10 to 20 cm above the main Agate Basin occupation. The core was recovered from GL 5. Another flake tool was recovered from Pick City sediment in square 1274NE1119, a few cm above the Aggie Brown-Pick City contact, and about 40 cm above the Agate Basin bonebed.

The two Antelope Chert flakes from Pick City contexts are both size grade 4 specimens. One comes from an excavation level just above the Aggie Brown-Pick City contact in square 1262NE1099 (GL 7). The other comes from a similar stratigraphic position in square 1272NE1100. Recall that at least one Agate Basin point midsection, coincidentally also made from Antelope Chert, was recovered from a level assigned on the basis of stratigraphic data to the Pick City Member in 1275NE1108, some 40 or 50 cm above the Agate Basin occupation zone (see chapter 4).

The remaining four Antelope Chert items from non-Aggie Brown contexts occur in the Surface/Lakebed (CC/GL) analytic unit. This unit is temporally mixed, but certainly includes specimens of Agate Basin age. All four specimens were recovered from the eroded boulder till north of the excavation blocks. One carries a heavy coating of carbonate. Two others are large chunks of relatively poor quality raw material, initially identified as possibly naturally occurring cobbles. However, similar chunks of raw material, classified as cores and pieces of tested raw material, occur in the excavated assemblage from the northwest excavation block, just 10 to 15 m south of the pieces recovered from the surface. Taken together, these data suggest that Antelope Chert was not used by the post-Agate Basin occupants of Area A. If so, the stratigraphic positions of such items in buried contexts gives some indication of the extent of post-occupation bioturbation in this part of the site.

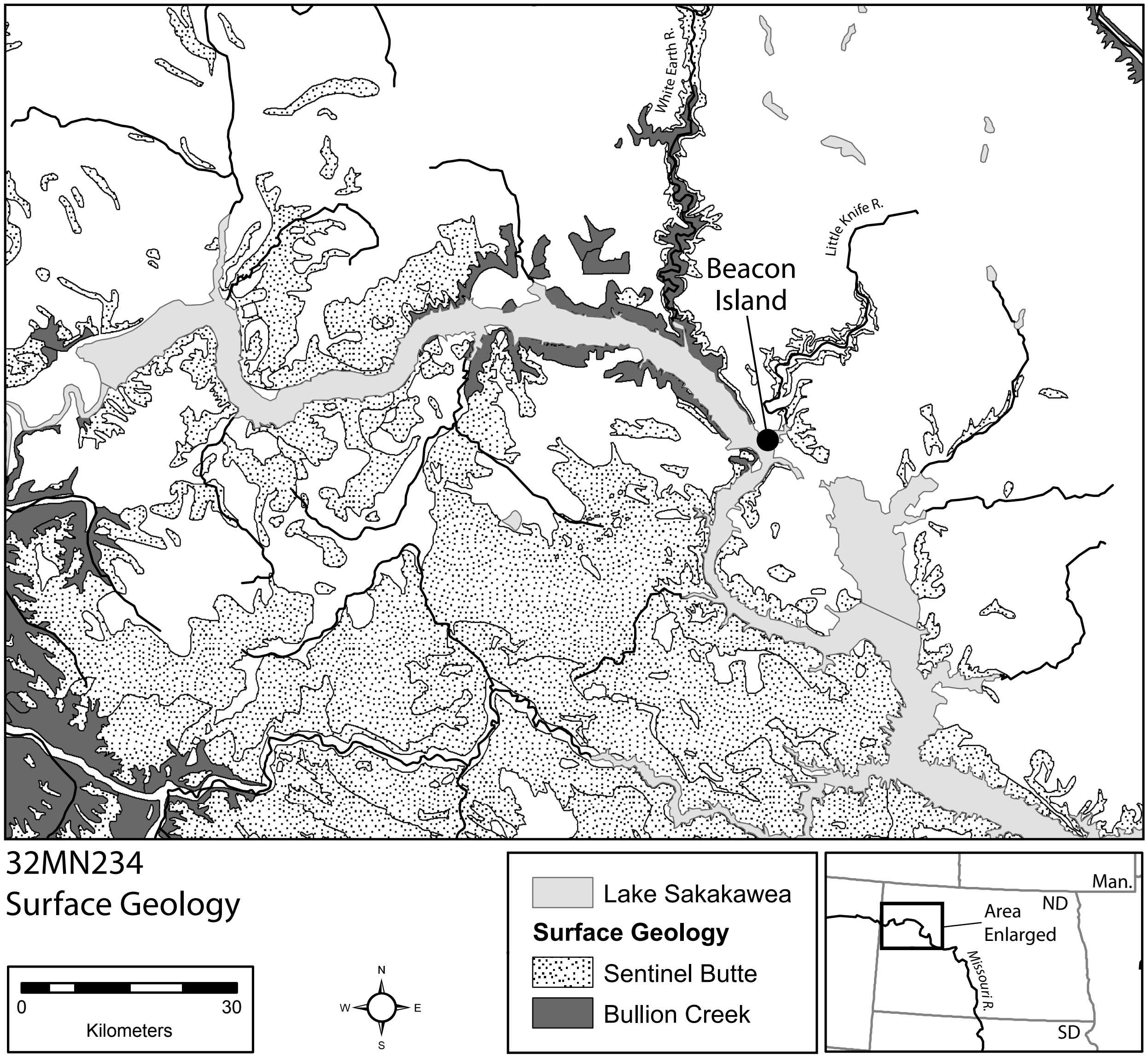


Figure 6.2. Surface geology in the vicinity of Beacon Island.

About 4 percent of the Area A flakes are made from Swan River Chert. Swan River Chert is a highly variable stone found in Wisconsinan till throughout northern North Dakota (Low 1996). Nodules may also be present in till deposits within the KRF primary source area. The bedrock source is located in southwest Manitoba. Its name notwithstanding, Swan River Chert varies in texture from quartzite to microcrystalline chert. Its color ranges from white to tan to black to orange and red. The latter colors may develop in heat-treated pieces. Crystal-lined vugs are common. In view of its distribution, Swan River Chert can be considered a locally available raw material; in fact, a large unmodified Swan River Chert boulder of moderate quality was observed in till deposits on Beacon Island during the May 2002 field session.

Minor Raw Material Types in the Flaking Debris Assemblage

Apart from a small number of specimens, all the other materials present in the Area A assemblage come from source localities in southwest North Dakota (Ahler 1977; Ahler, Feiler, Badorek, and Smail 2002). For instance, chalcedonies (clear/gray, yellow/brown, and dark brown varieties), along with silicified woods, occur abundantly in surface lag and alluvial deposits in the headwater streams of the Missouri's major western tributaries in North Dakota, including the Heart and Cannonball rivers (figure 6.1). Tongue River silicified sediment (TRSS) occurs in numerous outcrops west of the Missouri, especially south of the Cannonball River, though the only documented quarry is located in northwest South Dakota (Keyser and Fagan 1987). Porcellanite is found throughout the Little Missouri River valley, though it also occurs farther away in southeast Montana and northeast Wyoming.

One exotic material is definitely present in the collection. Oligocene-age White River Group Silicate, a high-quality, opaque to translucent cryptocrystalline stone ranging in color from white to brown to purple to gray, outcrops in eastern Wyoming, northeast Colorado, and western Nebraska and South Dakota (Hoard et al. 1993). Local varieties of this material go by a number of different names, including Flattop Chalcedony, West Horse Chert, Table Mountain Chalcedony, and Scenic Chalcedony, with the latter bearing some resemblance to KRF. In view of the potential interpretive significance of the two pieces of this material in the Beacon Island Agate Basin assemblage, special effort was made to confirm the identification through close comparisons with several different hand samples. The larger of the two archaeological specimens (size grade 3) is translucent and light grayish brown in color. However, the color pattern is quite different from that of KRF. The smaller flake (also size grade 3) bears distinctive white to gray cortex. The nearest source of this material is roughly 475 km due south of Beacon Island, in the upper reaches of the White and Cheyenne rivers (figure 6.1).

A few flakes made from opaque cherts of unknown provenance may also derive from distant sources. Primary geologic sources of these materials are located to the west and southwest in Montana and Wyoming. However, pebbles and cobbles of knappable opaque chert also are present in alluvial and glacial deposits in the primary KRF source area and elsewhere in southwest North Dakota. No flakes exhibiting the distinctive properties of Hartville Uplift Chert (Reher 1991) are present in the Beacon Island assemblage.

*Raw Material Misclassification*

The difficulty of determining raw material type increases with decreasing artifact size. Misidentification is a concern for the Beacon Island analysis because roughly 57 percent of the collection falls in the smallest size grade (grade 5). Studies of size-dependent misclassification in Plains Village-age assemblages demonstrate that certain material types are especially susceptible (Ahler 2002). One of the most significant problems is distinguishing between clear/gray chalcedony and silicified wood. However, both of these materials are rare in the Beacon Island assemblage and both derive from the same source area. A similar problem exists for dark brown chalcedony and KRF. Given the dominance of KRF in the collection it is possible that some specimens of dark brown chalcedony are misclassified as KRF.

As discussed in the previous section, some brown varieties of White River Group Silicate also can be confused with KRF. The two flakes from Beacon Island positively assigned to that source fall in the coarse fraction and so it seems probable that some White River Group Silicate flakes may also be present in the fine fraction but were misclassified as KRF. Finally, smooth gray TRSS and porcellanite can easily be distinguished in larger size grades but in the smallest size grades they may be more difficult to differentiate. In fact, all of the smooth gray TRSS flakes in the Beacon assemblage occur in the size grade 5 fraction. No tools made from smooth gray TRSS are present in the collection (see next section), suggesting that these flakes may be misclassified. The remaining rare material types in the collection are visually distinctive and are not likely subject to misclassification.

Another challenge is the presence of naturally occurring pebbles of flakable stone in the Oahe Formation at Beacon Island. Most of these are tan to white to light gray opaque chert, though semi-translucent yellow and red pieces also occur. The later may be Swan River Chert. A few pieces of a gray, slatey material somewhat similar to porcellanite are present in the natural rock collection as well. A wide variety of coarse materials, including metaquartzite, granite, and quartz, occur in the till beneath the site. It is possible that a few of the specimens assigned to these coarse material types may be naturally produced flakes. Conversely, it is also possible—and perhaps more likely—that flakes of these materials in the fine fraction were classified as natural rocks.

For these reasons the analysis takes a conservative approach to flake recognition and raw material identification. Pieces of flakeable stone bearing any visual evidence of surface weathering (other than patination) were considered to be naturally occurring, especially in the smallest size grades. In addition, greater use was made in this analysis of the "unclassified" raw material group than typically has been the case in analyses of Plains Village-age collections to which similar analytic methods have been applied. Despite these cautions, though, it is likely that White River Group Silicate and dark brown chalcedony flakes are slightly underrepresented relative to their actual occurrence in the collection, and that KRF flakes are correspondingly slightly overrepresented.

Raw Material Types in the Stone Tool Assemblage

By and large, the range of raw materials represented in the stone tool collection closely parallels that of the flaking debris assemblage (table 6.6). KRF, Antelope Chert, and Swan River Chert are the most abundant materials. However, relative to the abundance of flakes, tools made from Antelope Chert are overrepresented and

Table 6.6. Stone tool counts organized by raw material type, analytic unit, and technological class. Subtotals for selected analytic units are *italicized*.

| Analytic Unit and Technological Class | Raw Material Type: Quartzite | Swan River | Clear/Gray Chal. | Porcellanite | Granitic | Compact Sandstone | KRF | Metaq. | Siltstone/ Mudstone | Silicified Wood | Antelope Chert | Schist | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Surface—Area A (CC/GL)** | | | | | | | | | | | | | |
| Small Patterned Biface | | 1 | | | | | | | | | | | 1 |
| Large Patterned Biface | | | | | | | 2 | | | | | | 2 |
| Unpatterned Biface | 1 | | | | | | | | | | | | 1 |
| Unpatterned Flake Tool | | 2 | | | | | 10 | | | | | 1 | 13 |
| Tested Raw Material | | | | | | | 1 | | | | | | 1 |
| Core | | | | | | | 2 | | | | | | 2 |
| Bipolar Core/Wedge | | | | | | | 4 | | | 1 | | | 5 |
| Plate Tool | | | | | | | 1 | | | | | | 1 |
| *Subtotal* | *1* | *3* | | | | | *20* | | | *1* | | *1* | *26 (17%)* |
| **Surface—Area A (SC)** | | | | | | | | | | | | | |
| Large Patterned Biface | | 3 | | 3 | | | 8 | | | | 7 | | 21 |
| **Surface—Area P** | | | | | | | | | | | | | |
| Large Patterned Biface | | | | | | | 1 | | | 1 | | | 2 |
| **Riverdale Member** | | | | | | | | | | | | | |
| Unpatterned Flake Tool | | | | | | | 2 | | | | | | 2 |
| **Pick City Member** | | | | | | | | | | | | | |
| Large Patterned Biface | | | | | | | 2 | | | | | | 2 |
| Unpatterned Flake Tool | | | | | | | 7 | | | | 2 | | 9 |
| Core | | | | | | | 1 | | | | 1 | | 2 |
| Unpatterned Groundstone | | | | | 1 | | | | | | | | 1 |
| *Subtotal* | | | | | *1* | | *10* | | | | *3* | | *14 (9%)* |
| **Aggie Brown Member** | | | | | | | | | | | | | |
| Small Patterned Biface | | | | | | | 1 | | | | | | 1 |
| Large Patterned Biface | | 1 | 2 | | | | 42 | | | | 12 | | 57 |
| Unpatterned Biface | | | | | | | 2 | | | | | | 2 |
| Unpatterned Flake Tool | | | | | | | 12 | | | | 4 | | 16 |
| Core Tool | | | | | | | | 1 | | | | | 1 |
| Tested Raw Material | | | | | | | | | | | 2 | | 2 |
| Core | | | | | | | 2 | | | | 2 | | 4 |
| Bipolar Nodule | | | | | | | 1 | | | | | | 1 |
| Unpatterned Groundstone | | | | | 2 | 1 | | 1 | 1 | | | | 5 |
| Plate Tool | | | | | | | 1 | | | | | | 1 |
| *Subtotal* | | *1* | *2* | | *2* | *1* | *61* | *2* | *1* | | *20* | | *90 (58%)* |
| **Total** | 1 | 7 (5%) | 2 | 3 | 3 | 1 | 103 (66%) | 2 | 1 | 2 | 30 (19%) | 1 | 155 |

those made from KRF are underrepresented. In addition, three Agate Basin point fragments (in the Surface—Area A (SC) analytic unit) are made from porcellanite, two of the red variety and one of the gray, but just three pieces of porcellanite flakes (all of the gray variety) are present in the collection. The significance of this pattern is considered later in the chapter.

The two tool fragments in the excavated assemblage identified as clear/gray chalcedony (which conjoin to form a single Agate Basin point) likely are made from Sentinel Butte Flint, a translucent light gray to light brownish gray stone exhibiting moderate to good conchoidal fracture (Blikre 1993). The single documented source of this material is the eponymous Sentinel Butte, located some 160 km southwest of Beacon Island (figure 6.1). Knappable stone occurs there both as nodular chert and as tabular chalcedony, the latter of which rarely is found in archaeological assemblages. The best material comes mainly from the top of the butte, a remnant of the South Heart Member of the Chadron Formation of Eocene age (Murphy, Hoganson, and Forsman 1993). (Archaeologists commonly refer to the toolstone found on Sentinel Butte as "Miocene chert"). Knappable stone can also be found in gravel lag deposits and alluvium around the butte. However, Root and others (1999:Table 12) caution that chert exhibiting both macroscopic properties and short-wave UV response similar to the material from Sentinel Butte also occurs in the Killdeer Mountains and in gravel deposits along Spring Creek in the KRF primary source area. Overall, then, the Sentinel Butte-like point from Beacon Island is best viewed as a possibly non-local item.

### Patination Intensity in Knife River Flint

Patination in KRF is due to chemical weathering (Ahler 1986:73-75; Ahler, Root, and Feiler 1994; VanNest 1985). Under certain conditions, silica is removed from the surface of a KRF artifact, producing a thin, cloudy to opaque off-white rind. Patina formation is a time-dependent process, but it is also affected by a variety of other factors, including temperature and the pH of the intrastratal solutions to which an artifact is exposed (Ahler 1986:74). No simple formula for the rate of patination is possible, because both the occurrence and properties of groundwater and soil moisture fluctuate at several different time scales. Moreover, several lines of evidence suggest that patination may be a non-linear or even reversible process (Ahler, Root, and Feiler 1994:113). Nevertheless, two contexts are probably most conducive to patina formation. One is lengthy surface exposure, especially on barren ground. In that case, heat provided by direct sunlight could speed the formation of a patina (Ahler 1986:74). Such surface exposure could explain the occurrence of differential patination, in which one face of an artifact is more intensely patinated than the other. The second context conducive to patina formation is burial in alkaline sediment, combined with groundwater movement that carries silica away from an artifact's surface. Such conditions may be enhanced in porous sediments containing buried, carbonate-rich soil horizons.

Root and others (1986:440-446) offer four generalizations about the relationship between patination intensity and time. First, the absence of visible patination has no chronological implications: unpatinated artifacts can occur in any assemblage. Second, artifacts bearing moderate to pronounced patination likely are at least 1,500 years old. Third, assembalges in which one-fifth or more of the artifacts exhibit pronounced patination, likely are at least 5,000 years old. Finally, assemblages with multi-modal "patination signatures" probably incorporate artifacts dating to more than one time period.

Table 6.7 organizes data on patination intensity in KRF flaking debris from Beacon Island by analytic unit (see also figure 6.3). Nearly all of the specimens for which patination intensity is coded as "indeterminate" are burned, a process which can obscure evidence of patination. Three patterns are evident in these data. First, all analytic units include patinated specimens. For the Holocene components in Area A, the frequency of patinated artifacts (in all intensity classes combined) ranges from 20 to 30 percent. If the vertical distribution of Antelope Chert artifacts, discussed previously, is any

Table 6.7. Patination intensity in KRF flaking debris.

| | Patination Intensity Class | | | | | |
|---|---|---|---|---|---|---|
| Analytic Unit | absent | light | moderate | pronounced | indeterminate | Total |
| Surface/Lakebed (CC/GL) | 40.9% | 5.8% | 29.3% | 21.6% | 2.4% | 208 |
| Riverdale | 80.0% | 6.3% | 4.2% | 3.2% | 6.3% | 95 |
| Pick City | 71.4% | 15.4% | 5.1% | 5.1% | 3.1% | 885 |
| Aggie Brown | 21.3% | 11.3% | 18.3% | 33.8% | 15.2% | 1496 |
| Mallard Island | 64.7% | 35.3% | | | | 17 |
| Total | 1123 (41.6%) | 329 (12.2%) | 384 (14.2%) | 599 (22.2%) | 266 (9.8%) | 2701 |

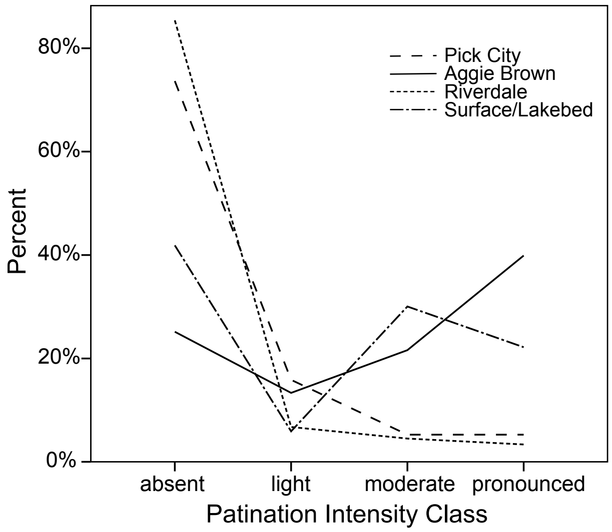


Figure 6.3. Patination intensity in KRF flaking debris.

guide, some of the patinated KRF artifacts recovered from Pick City Member sediment may originally have been deposited in the Agate Basin component and were transported upward by burrowing animals. However, it is clear that patinated artifacts also occur in more recent Riverdale Member contexts.

Second, artifacts exhibiting pronounced patination are most common in Aggie Brown contexts. However, as Ahler and Ritter (2003) note for the smaller May 2002 collection, the Aggie Brown assemblage exhibits a bimodal distribution, with just over one-fifth of the flakes lacking visible patination. The cause of this pattern is not known, though it may be that some of the apparently unpatinated flakes have undergone "depatination" or re-silicification. Interestingly, the majority of the very small assemblage recovered from Mallard Island Member sediment is also unpatinated. How this might relate to depositional context is not clear.

Finally, the bimodal patination signature of the Surface/Lakebed assemblage is similar to that of the sample as a whole, again confirming the fact that this analytic unit incorporates specimens of markedly different ages. However, as discussed in chapter 3, the distribution of Antelope Chert artifacts on the surface suggests that much of the surface assemblage derives from contexts other than the Agate Basin butchery locality. It is therefore possible that a portion of the surface assemblage derives from one or more unrelated late Pleistocene/early Holocene occupations.

The majority of the Agate Basin points made from KRF in both the excavated and surface collections exhibit differential patination. The significance of this pattern is considered later in the chapter, in the Agate Basin Assemblage section.

## Surface/Lakebed Assemblage

Area A

As discussed in chapters 3 and 4, most of the flaking debris and stone tools in the Surface/Lakebed (CC/GL) analytic unit were recovered in May 2002 (by both controlled surface collection and excavation) and these items are described and illustrated in Ahler (2003b), Ahler and Crawford (2003a), and Ahler and Ritter (2003). Again, based on the patination intensity profile of the KRF flaking debris, the artifacts included in this analytic unit derive from more than one cultural component.

In their analysis of the May 2002 flaking debris assemblage, Ahler and Ritter (2003) observe that the range of raw materials represented in the surface assemblage is broader than that represented in the excavated assemblage. They suggest that the comparative richness of the surface collection could indicate that a materially distinctive, mid- to late-Holocene component, now almost entirely eroded away, was once present in Area A. However, no particular differences are evident between in the suite of raw materials present in the surface assemblage and those present in the larger excavated assemblage now available.

Twenty-six stone tools occur in the Surface/Lakebed (CC/GL) collection (table 6.8, figure 6.4). Three-quarters are made from KRF. While there is no way to determine the age of the specimens in this assemblage, 35 percent do exhibit pronounced patination and another 25 percent exhibit moderate patination, suggesting that many of these items originally were associated with the Agate Basin component (table 6.9; note that none of the tools exhibit "light" patination).

Unpatterned flake tools make up half of this assemblage. One particularly notable flake tool is a small graver found roughly 10 m east and 15 m north of the bonebed (figure 6.4g). A morphologically and functionally similar tool was recovered from the Agate Basin component in the west excavation block (in square 1276NE1109). Tools of this type likely were used to cut shallow grooves or incise small lines in wood or bone. The single small patterned biface is a crude side-notched arrow point made from Swan River Chert (figure 6.4f). The large patterned bifaces include a Folsom point mid-section (figure 6.4e) and a margin fragment of a generalized cutting tool, both made from KRF. The Folsom point exhibits broad flutes on both faces. On the margins, small, evenly spaced pressure flake removals intrude somewhat larger flake scars but not the flutes. The lower two-thirds of both edges are lightly ground. The specimen exhibits strong differential patination, with one face exhibiting pronounced patination but the other only very light patination. Small flake removals on the broken margins suggest that the point may have been transported

Table 6.8. Counts of stone tools in the Surface/Lakebed (CC/GL) analytic unit, organized by raw material type and technological class.

| | Raw Material Type | | | | | |
|---|---|---|---|---|---|---|
| Technological Class | orthoquartzite | Swan River Chert | Knife River Flint | silicified wood | schist | Total |
| small patterned biface | | 1 | | | | 1 |
| large patterned biface | | | 2 | | | 2 |
| unpatterned biface | 1 | | | | | 1 |
| unpatterned flake tool | | 2 | 10 | | 1 | 13 |
| tested raw material | | | 1 | | | 1 |
| core | | | 2 | | | 2 |
| bipolar nodule/wedge | | | 4 | 1 | | 5 |
| tabular plate tool | | | 1 | | | 1 |
| Total | 1 | 3 | 20 | 1 | 1 | 26 |

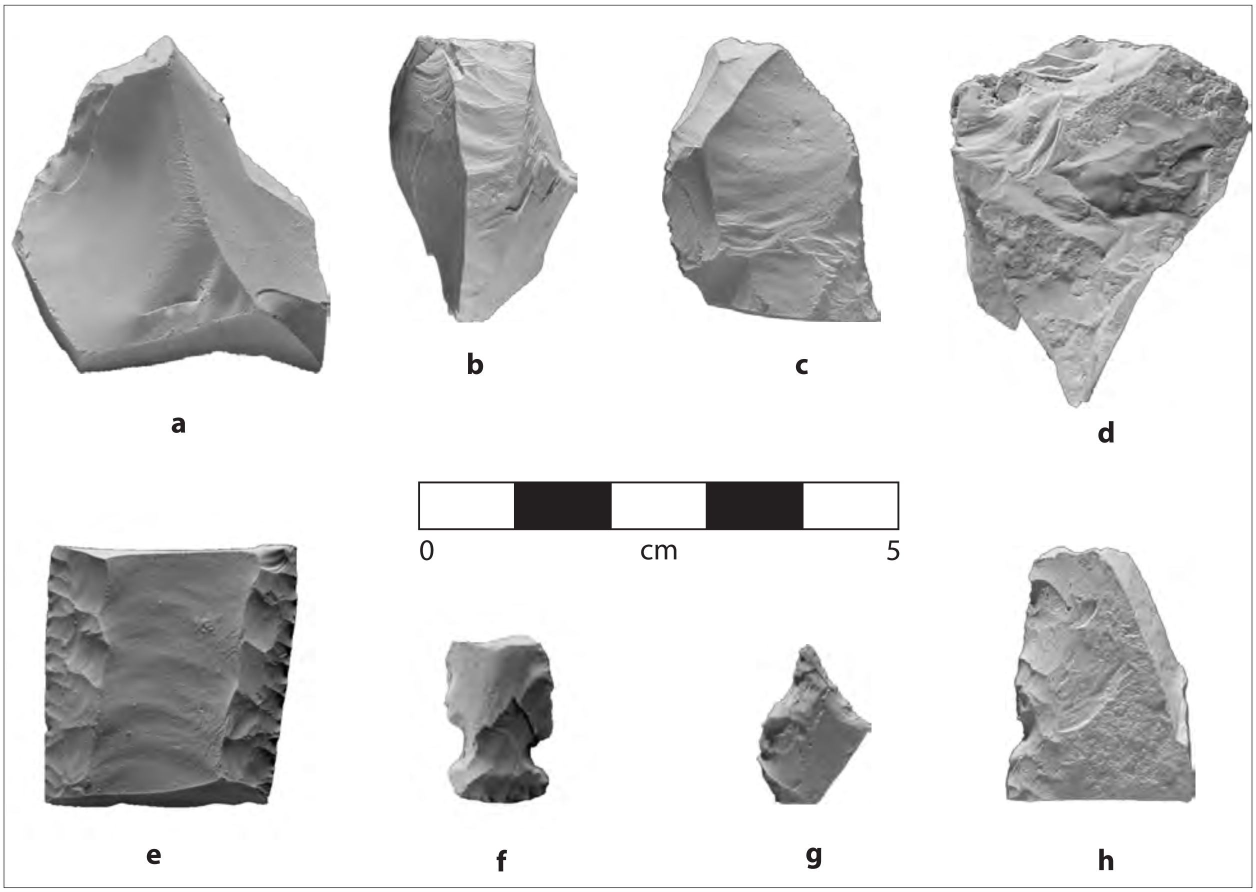


Figure 6.4. Stone tools in the Surface/Lakebed (CC/GL) analytic unit. a: freehand core fragment; b: patinated bipolar nodule; c, h: unpatterned flake tools; d: bipolarly tested raw material; e: Folsom point midsection; f: side-notched arrowpoint; g: graver (a-d, g, and h from Ahler [2003b:Figure 64]).

some distance after it was discarded.

Five bipolar nodules are present in the surface collection. Two of the four specimens made from KRF are unpatinated. One other exhibits moderate patination (figure 6.4b) and the fourth is burned. This suggests that bipolar reduction was applied to KRF during Agate Basin times; this inference is discussed in more detail later in the Agate Basin Assemblage section.

Area P

Two specimens were collected from Area P, an undefined

Table 6.9. Patination intensity and burning data on stone tools in the Surface/Lakebed (CC/GL) analytic unit.

| | | Patination Intensity | | | | |
|---|---|---|---|---|---|---|
| Burning | Technological Class | absent | moderate | pronounced | indeterminate | Total |
| unburned | large patterned biface | | 1 | 1 | | 2 |
| | unpatterned flake tool | 2 | 3 | 5 | | 10 |
| | tested raw material | 1 | | | | 1 |
| | core | 1 | | 1 | | 2 |
| | bipolar nodule | 2 | 1 | | | 3 |
| | tabular plate tool | 1 | | | | 1 |
| burned | bipolar nodule | | | | 1 | 1 |

part of the site east of Area A (figure 6.5). One is the base of a Folsom point made from a tabular piece of silicified wood. The flute is rather short on the reverse face, ending at the margin of a concave irregularity in the stone in which the cortical surface of the original cobble is preserved. The flute on the obverse face has been partially intruded by subsequent basal and marginal pressure flaking (figure 6.5a). The specimen is somewhat asymmetrical and does not exhibit the small, well-placed marginal flake removals characteristic of Folsom technology. Though both edges are ground, the specimen otherwise appears to be unfinished. The other artifact recovered from Area P is the base of a side-notched dart point made from KRF. The base is straight and the notches appear to be broad.

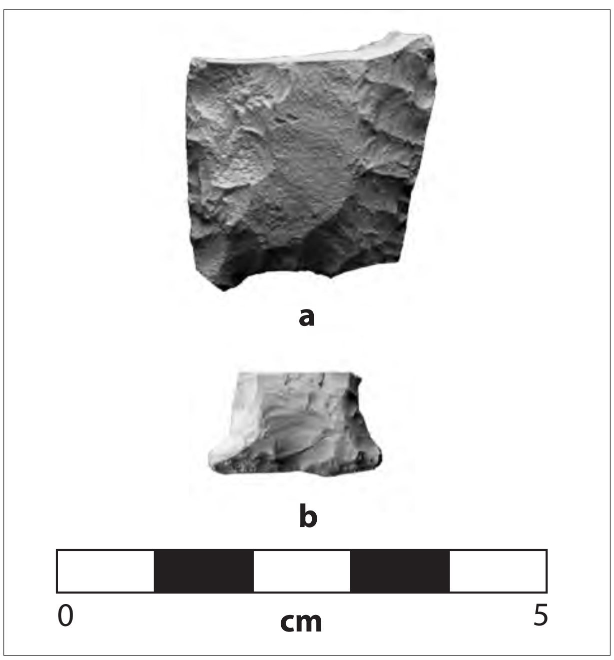


Figure 6.5. Stone tools from Area P.

**Holocene Assemblage**

Flaking debris or stone tools were recovered from Holocene-age sediment in 32 excavation units in Area A. However, the majority of the specimens come from a single unit (1308NE1055), located north and west of the bonebed. Accordingly, this discussion is partitioned into two subsections, with the first summarizing data from the excavation units in the kettle basin proper and the second summarizing data from 1308NE1055. Tables 6.10, 6.11, and 6.12 present basic data on the Holocene-age assemblage from these units. Table 6.10 organizes data on the flaking debris aggregate by analytic unit and raw material type. Data on stone tools recovered from kettle basin units are summarized in table 6.11. Table 6.12 tallies flakes and stone tools recovered from square 1308NE1055, organized by excavation level. Two tools assigned to Holocene-age contexts are illustrated in figure 6.6.

Kettle Basin Units

A total of 186 pieces of flaking debris and 11 stone tools occur in Riverdale and Pick City contexts in the eastern kettle basin. Most of these were recovered from units located on the southwest part of the basin. KRF is the dominant raw material. The range of material types represented in the Pick City assemblage is broader than that in the Riverdale assemblage. About 13 percent of the flakes from these contexts are burned.

Three of the 11 tools from Holocene strata in the eastern kettle basin are made from Antelope Chert (CN 1785, 1803, and 8364). As discussed previously, these items may have been displaced from the Agate Basin component. Two of them, a burned core fragment and a small fragment of a flake tool, were recovered from square 1256NE1110. The third, a distal fragment of a large retouched flake tool (figure 6.6a), comes from square 1274NE1119, just above the Pick City-Aggie Brown contact and about 40 cm above the bonebed, This specimen is quite similar to four others recovered from

Table 6.10. Counts of flakes from Holocene contexts in Area A, organized by analytic unit and raw material type.

| | Analytic Unit | | | |
|---|---|---|---|---|
| | Riverdale Member | | Pick City Member | |
| Raw Material Type | Kettle Basin Units | 1308NE1055 | Kettle Basin Units | 1308NE1055 |
| Smooth Gray TRSS | | | 1 | |
| Coarse Yellow TRSS | | 3 | | |
| Swan River Chert | | | 18 | 35 |
| chert/jasper | | | 1 | |
| clear/gray chalcedony | | | 4 | 11 |
| yellow/brown chalcedony | | | 1 | 1 |
| dark brown chalcedony | 1 | | | 5 |
| Knife River Flint | 22 | 73 | 128 | 757 |
| metaquartzite | | | 2 | |
| Antelope Chert | | | 2 | |
| schist | | | 1 | |
| unclassified | | | 5 | |
| Total | 23 | 76 | 163 | 809 |

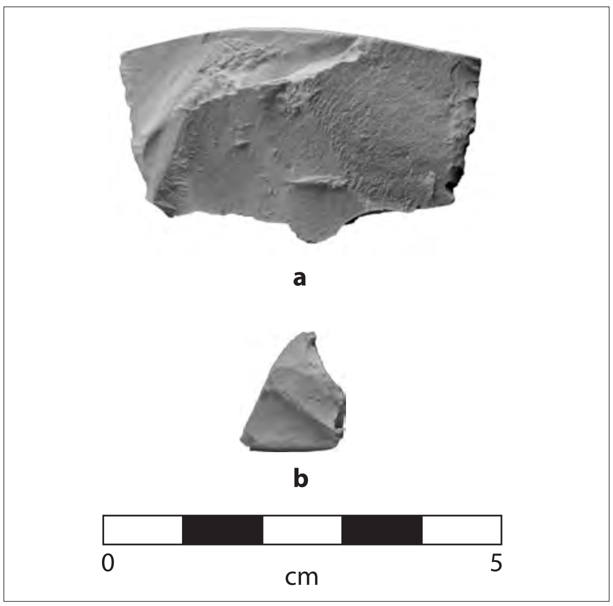


Figure 6.6. Tools from Holocene contexts. a: Antelope Chert flake tool possibly displaced from the Agate Basin bonebed; b: KRF biface (Ahler 2003b:Figure 65).

Aggie Brown Member contexts.

Seven stone tools recovered from Holocene-age sediment in the kettle basin area are made from KRF. They include an exhausted core fragment, a biface fragment (figure 6.6b), and five unpatterned flake tools. Two of the flake tools come from Riverdale Member contexts in square 1262NE1099. Both are simple utilized flakes, exhibiting only use-alteration. Two of the three flake tools assigned to the Pick City Member are retouched. Ahler (2003b:93) describes the biface fragment, which was broken during manufacture.

A single groundstone tool fragment was recovered from Pick City Member sediment in the eastern kettle basin. Made from a granite cobble, this broken specimen exhibits a single worn face, marked by short, parallel striations and minimal surface smoothing.

Ahler (2003b:92) notes the recovery of two unmodified cobbles of siltstone and limestone from Holocene contexts in square 1262NE1109, which he interprets as manuports. Because the processes responsible for the deposition of Oahe Formation sediment at Beacon Island are primarily airfall and slopewash (see chapter 2), it

Table 6.11. Counts of tools from Holocene contexts in the eastern kettle basin, organized by analytic unit, technological class, and raw material type.

| | | Raw Material Type | | | |
|---|---|---|---|---|---|
| Analytic Unit | Technological Class | granitic | Knife River Flint | Antelope Chert | Total |
| Riverdale | unpatterned flake tool | | 2 | | 2 |
| Pick City | large patterned biface | | 1 | | 1 |
| | unpatterned flake tool | | 3 | 2 | 5 |
| | core | | 1 | 1 | 2 |
| | unpatterned groundstone | 1 | | | 1 |
| Total | | 1 | 7 | 3 | 11 |

seems likely that these large cobbles, which weigh 415 and 175 g respectively, do represent manuports. In fact, a number of large clasts of varying lithology, but which lack evidence of use-wear or other modifications, were recovered from a variety of contexts in Area A. Data on some of these items are presented in the next section.

Square 1308NE1055

The first five general levels in square 1308NE1055 exposed recent lakebed sediment. Intact Oahe Formation sediment was exposed in GL 6 through GL 22. Levels 6 through 11 are assigned to the Riverdale Member, levels 12 through 21 are assigned to the Pick City, and level 22 is assigned to the Aggie Brown. Flaking debris occurs in every Holocene level in square 1308NE1055, though it is concentrated in two zones (table 6.12; shaded rows indicate cultural components). (No artifacts were recovered from the Aggie Brown Member in GL 22). As detailed in chapter 3, the upper zone or component falls in GL 9 and GL 10 in the Riverdale Member. Fifteen plotted bison bones and about 37 g of bone scrap occur in these levels. The lower component falls in GL 18 and GL 19 in the Pick City Member, from which 10 plotted bones and 157 g of bone scrap were recovered. Only KRF is present in the upper component. A wider range of stone tool raw material types is represented in the lower component, including Swan River Chert and various chalcedonies.

Patination is absent or light on KRF artifacts from Pick City contexts in 1308NE1055 (table 6.13). However, the frequency of KRF flakes exhibiting pronounced patination in the lowest level assigned to the Pick City (GL 21) suggests that some mixing may have occurred with an older components Unfortunately, excavation did not progress deeper than GL 22 and so it is not known whether older occupations are present in this area.

Table 6.14 tallies size grade data on the flaking debris from 1308NE1055 made from KRF. Though the Riverdale Member sample is small, the relatively high frequency of size grade 5 flakes suggests that tool maintenance, rather than tool production, was the principal activity carried out in this part of Area A during upper component times. Tool production may have been more important during the lower component occupation, given the larger proportions of flakes in the coarse fraction. Few flakes from 1308NE1055 are burned: only 3.9 percent of the flaking debris from Riverdale contexts and 1.4 percent of the flaking debris from Pick City contexts exhibits evidence of burning.

No tools are associated with the bone and flaking debris in the upper component. Three tools were recovered from GL 18 and GL 19, none of which are temporally diagnostic (table 6.12). They include one large patterned biface fragment and two flake tools. Two

Table 6.12. Counts of flakes and chipped stone tools from square 1308NE1055, organized by analytic unit, general level number, and raw material type. Cultural components are indicated by shading.

| | | Flaking Debris | | | | | | | Stone Tools |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw Material Type | | | | | | | Raw Material |
| AU | General Level | Coarse yellow TRSS | Swan River Chert | clear/gray chalcedony | yellow/brown chalcedony | dark brown chalcedony | Knife River Flint | Total | Knife River Flint |
| Riverdale | 6 | | | | | | 5 | 5 | |
| | 7 | 3 | | | | | 6 | 9 | |
| | 8 | | | | | | 6 | 6 | |
| | 9 | | | | | | 12 | 12 | |
| | 10 | | | | | | 32 | 32 | |
| | 11 | | | | | | 12 | 12 | |
| | *Riverdale Total* | *3* | | | | | *73* | *76* | |
| Pick City | 12 | | | | | | 3 | 3 | 1 |
| | 13 | | | 1 | 1 | | 5 | 7 | |
| | 14 | | 2 | | | | 6 | 8 | |
| | 16 | | 1 | | | | | 1 | |
| | 17 | | | | | | 3 | 3 | |
| | 18 | | 25 | | | 5 | 433 | 463 | 2 |
| | 19 | | 6 | 10 | | | 248 | 264 | 1 |
| | 20 | | 1 | | | | 25 | 26 | |
| | 21 | | | | | | 34 | 34 | 1 |
| | *Pick City Total* | | *35* | *11* | *1* | *5* | *757* | *809* | *5* |

Table 6.13. Patination intensity in KRF flaking debris from Pick City Member contexts in square 1308NE1055, organized by general level number.

| | Patination Intensity | | | | | |
|---|---|---|---|---|---|---|
| General Level | absent | light | moderate | pronounced | indeterminate | Total |
| 12 | 100.0% | | | | | 3 |
| 13 | 100.0% | | | | | 5 |
| 14 | 83.3% | | 16.7% | | | 6 |
| 17 | 100.0% | | | | | 3 |
| 18 | 86.4% | 11.5% | .7% | | 1.4% | 433 |
| 19 | 74.6% | 20.2% | 1.2% | 2.8% | 1.2% | 248 |
| 20 | 60.0% | 32.0% | 4.0% | | 4.0% | 25 |
| 21 | 61.8% | 2.9% | 2.9% | 32.4% | | 34 |
| Total | 80.7% | 14.4% | 1.2% | 2.4% | 1.3% | 757 |

Table 6.14. Size distribution of KRF flake counts from square 1308NE1055, organized by general level number. Defined cultural components indicated by shading.

| | | Size Grade | | | | |
|---|---|---|---|---|---|---|
| AU | General Level | G2 | G3 | G4 | G5 | Total |
| Riverdale | 6 | | 20.0% | 80.0% | | 5 |
| | 7 | | | 16.7% | 83.3% | 6 |
| | 8 | | | 66.7% | 33.3% | 6 |
| | 9 | | | 25.0% | 75.0% | 12 |
| | 10 | | 6.3% | 18.8% | 75.0% | 32 |
| | 11 | | | 16.7% | 83.3% | 12 |
| | *Riverdale Total* | | *4.1%* | *27.4%* | *68.5%* | *73* |
| Pick City | 12 | | 33.3% | 33.3% | 33.3% | 3 |
| | 13 | | | 40.0% | 60.0% | 5 |
| | 14 | | | 16.7% | 83.3% | 6 |
| | 17 | | 33.3% | 66.7% | | 3 |
| | 18 | 1.2% | 13.4% | 27.7% | 57.7% | 433 |
| | 19 | 1.2% | 8.1% | 31.5% | 59.3% | 248 |
| | 20 | | 8.0% | 20.0% | 72.0% | 25 |
| | 21 | | | 50.0% | 50.0% | 34 |
| | *Pick City Total* | *1.1%* | *10.8%* | *29.9%* | *58.3%* | *757* |

other flake tools come from Pick City contexts above and below the lower component.

### Agate Basin Assemblage

This discussion is divided into two main parts. The first part considers the technological properties of the Agate Basin flaking debris and stone tool assemblages from several different perspectives. The presentation is divided into four subsections, beginning with an analysis of aggregate data on the flaking debris assemblage. This is followed by a consideration of the attributes of individual flakes in the coarse fraction (size grades 1 through 3). The third subsection describes the technological properties of the excavated stone tool assemblage as a whole. The first part concludes with a detailed examination of Agate Basin weaponry, combining data on specimens in the excavated assemblage with data on specimens in the surface collection.

The second main part of the analysis considers the spatial distribution of Agate Basin-age artifacts. The discussion first examines the distribution of the flaking debris assemblage. The presentation concludes with data and interpretations derived from a tool conjoin and flaking debris refit study.

#### Mass Analysis of the Flaking Debris Assemblage

An estimated 1,804 flakes are assigned to the Aggie Brown Member (table 6.2). Specimens in the "unclassified" group are omitted from the following analysis. To simplify the discussion, flakes made from rare raw material types are grouped in table 6.15. The "other fine" group includes various chalcedonies, cherts, and silicified woods that can be found throughout southwest North Dakota. The “other coarse” group is comprised of igneous, metamorphic, and other raw materials exhibiting limited or poor conchoidal fracture, all of which likely derive from local till deposits.

The Agate Basin flake aggregate from Beacon Island is too small for rigorous mass analysis, particularly given the potential pitfalls of this approach (Andrefsky 2004; but see Bradbury and Carr [2009] and Shott [2004]). However, in view of the data presented in chapter 3 showing that all of these specimens derive from a single brief occupation, it is reasonable to consider the significance of size grade distributions as measured both by artifact counts and weights.

The flake count data in table 6.15 are organized by collapsed raw material group and size grade. Two main patterns are evident in the size distributions of different raw material groups. First, several are represented mainly by small flakes, with the Swan River Chert fraction most heavily weighted toward the smallest size grade. A similar, though some less skewed pattern characterizes KRF and the “other fine” group. The differences between the Swan River Chert and KRF distributions may be due in part to sample size differences. Experimental data suggest that distributions skewed toward the smallest size classes commonly are produced by tool finishing and maintenance using pressure flaking techniques, including biface resharpening or end scraper production (Ahler 1989a). Resharpening with soft hammer percussion can also produce similar distributions.

Antelope Chert exhibits a rather different pattern. The numbers of size grade 4 and size grade 5 flakes are equivalent and a much larger proportion of the assemblage falls in the coarse fraction. In experimental assemblages, distributions skewed toward the larger size classes commonly are produced by technological operations incorporating hard hammer percussion. Soft hammer biface production can also produce distributions skewed toward medium and large flakes.

Flake count distributions commonly are biased toward the smallest size classes (Shott 2004). However, for the Beacon Island assemblage, flake weight data generally support the interpretations derived from count data (table 6.16 and figure 6.7). Weight data again suggest that tool finishing or maintenance by soft hammer percussion and pressure flaking were the dominant technological operations applied to Swan River Chert and KRF. The proportional distribution by weight of Antelope Chert flaking debris is strongly skewed toward the largest size classes, suggesting that flake production, using soft or hard hammer percussion, was the principal operation

Table 6.15. Size distribution of flake counts from Aggie Brown Member contexts in Area A, organized by collapsed raw material type.

| | Size Grade | | | | | |
|---|---|---|---|---|---|---|
| Collapsed Raw Material Group | G1 | G2 | G3 | G4 | G5 | Total |
| other fine | | 3.3% | 6.7% | 36.7% | 53.3% | 30 |
| other coarse | | 11.1% | | 27.8% | 61.1% | 18 |
| Swan River Chert | | | 8.2% | 20.5% | 71.2% | 73 |
| White River Group silicate | | | 100.0% | | | 2 |
| porcellanite | | | | 100.0% | | 3 |
| Knife River Flint | | .3% | 6.6% | 34.9% | 58.2% | 1496 |
| Antelope Chert | 1.2% | 5.5% | 11.0% | 41.7% | 40.5% | 163 |
| Total | 2 | 16 | 127 | 624 | 1016 | 1785 |

Table 6.16. Size distribution of flake weights from Aggie Brown Member contexts, organized by collapsed raw material type.

| | Size Grade | | | | | |
|---|---|---|---|---|---|---|
| Collapsed Raw Material Group | G1 | G2 | G3 | G4 | G5 | Total (g) |
| other fine | | 75.2% | 9.7% | 9.1% | 6.1% | 8.3 |
| other coarse | | 91.9% | | 2.7% | 5.4% | 5.6 |
| Swan River Chert | | | 53.9% | 13.8% | 32.3% | 4.3 |
| White River Group silicate | | | 100.0% | | | 1.1 |
| porcellanite | | | | 100.0% | | .2 |
| Knife River Flint | | 10.4% | 46.7% | 26.3% | 16.5% | 70.0 |
| Antelope Chert | 35.0% | 53.5% | 9.8% | 1.1% | .6% | 136.3 |
| Total (g) | 47.7 | 91.5 | 50.3 | 21.7 | 14.6 | 225.8 |

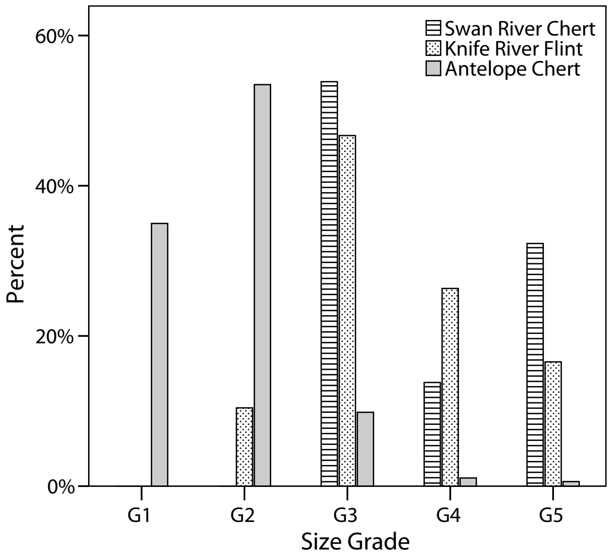


Figure 6.7. Weight distributions of the common flaking debris raw material types from Aggie Brown Member contexts.

applied to this material. Weight data on the "other fine" group are strongly influenced by a single size grade 2 flake and so are difficult to interpret.

Data on the proportion of size grade 4 flakes bearing cortex and on the ratio of small to large flakes provide additional insights not evident in the count and weight distribution data (Ahler 1986, 1989a, 1989b). Table 6.17 provides these data for the three most common material types in the assemblage. These mass analysis measures should be approached rather cautiously, primarily because the sample size is small, especially for Swan River Chert and Antelope Chert. (Recall that roughly 57 percent of the flakes in the Aggie Brown Member aggregate fall in the size grade 5 class [table 6.2], which are not reflected in the data in table 6.17). The ratio of smaller to larger flakes (G4:G1-G3 ratio) provides an indirect measure of the prevalence of pressure flaking. The percentage of size grade 4 flakes bearing cortex measures reduction stage: as reduction progresses, the proportion of flakes exhibiting cortex decreases.

The relatively low G4:G1-3 ratio for Swan River Chert suggests that percussion flaking was important, a finding somewhat at odds with the count and weight distributions discussed previously. Small sample size could be a factor in this. The ratio for Antelope Chert is even smaller, confirming the importance of percussion flaking for that material. The larger value for KRF suggests a mixture of percussion and pressure flaking.

The proportion of size grade 4 cortical flakes is relatively low for all three materials, indicating late-stage reduction. It should be said that cortex can be difficult to identify in small flakes of Swan River Chert, which often exhibits only moderate conchoidal fracture. The values for Antelope Chert and KRF are comparable and very low. This evidence for late-stage reduction in Antelope Chert stands in marked contrast with the weight distribution data and the G4:G1-G3 ration data that point to early-stage reduction, using hard-hammer percussion. Together, these findings suggest that two rather different technological procedures were applied to Antelope Chert: on the one hand, flake production from freehand cores or large bifaces and, on the other hand, tool resharpening and rejuvenation. It is relevant to note here that Antelope Chert cores (of rather poor quality) occur within the bonebed in the northwest block, but that the collection also includes 19 Antelope Chert projectile points, all of which are made from moderate to high-quality stone.

Just over one-sixth of the Agate Basin flake assemblage exhibits evidence of burning (table 6.18). However, the rate of burning varies considerably by toolstone type. More than a third of the Antelope Chert flakes are burned. Only one-sixth of the KRF flakes are burned, as are less than 3 percent of the Swan River Chert flakes.

Individual Flake Analysis

Just 144 specimens comprise the coarse-fraction flaking

Table 6.17. Mass analysis data.

| Raw Material Type | Percentage of G4 Cortical | G4:G1-3 Count Ratio |
|---|---|---|
| Swan River Chert | 13.3% | 2.5 |
| Knife River Flint | 4.0% | 5.1 |
| Antelope Chert | 4.4% | 2.3 |

Table 6.18. Proportion of burned flakes from Aggie Brown Member contexts, organized by material type.

| Raw Material Type | Burned | Total |
|---|---|---|
| Swan River Chert | 2.7% | 73 |
| chert/jasper | 50.0% | 6 |
| White River Group | | 2 |
| clear/gray chalcedony | 9.1% | 11 |
| yellow/brown chalcedony | | 6 |
| dark brown chalcedony | | 3 |
| porcellanite | 66.7% | 3 |
| Knife River Flint | 16.3% | 1496 |
| metaquartzite | | 5 |
| silicified wood | 50.0% | 4 |
| Antelope Chert | 34.4% | 163 |
| Total | 17.5% | 1772 |

debris assemblage (table 6.19). Nevertheless, attribute data on these items provide useful technological insights. Eight raw materials are represented in the coarse fraction. As is the case for the flaking debris aggregate as a whole, the most abundant raw materials are Swan River Chert, KRF, and Antelope Chert. The single metaquartzite flake likely comes from the large cobble tool found roughly 10 m west, which is described later in this chapter. The silcrete flake exhibits very poor conchoidal fracture and it may be a product of natural flaking.

The Swan River Chert fraction falls entirely within size grade 3, as does the majority of the KRF fraction. By contrast, just over half of the Antelope Chert fraction falls in the two larger size grades. Unsurprisingly, the mean dimensions of complete KRF flakes are significantly smaller than the mean dimensions of Antelope Chert flakes (table 6.20 and figure 6.8). (No complete Swan River Chert flakes are present in the collection). The majority of complete KRF flakes are rather small, with most measuring between 1 and 2 sq. cm in size.

In addition to these size differences, there are differences in the types of flakes made from different materials. Table 6.21 organizes data on size grade 3-sized specimens by raw material and flake type. The "indeterminate" class shown in this table consists mainly of flake fragments (Sullivan and Rozen 1985). For all three common raw materials at least a plurality of the specimens are "simple" flakes, exhibiting two or fewer dorsal flake scars. However, shatter is far more common in the Antelope Chert fraction. Pieces of shatter are more frequently produced by hard-hammer percussion than by other reduction techniques (Ahler 1989a). Note, though, that the proportion of complex flakes (those with three or more dorsal scars) is roughly the same in all three materials.

One bipolar flake is present in the KRF fraction. Bipolar flakes can be produced by a number of different reduction techniques, but are most commonly produced by bipolar percussion. Recall that four bipolar nodules made from KRF are present in the surface collection,

Table 6.19. Size distribution of coarse-fraction flake counts from Aggie Brown Member contexts, organized by raw material type.

| | Size Grade | | | |
|---|---|---|---|---|
| Raw Material Type | G1 | G2 | G3 | Total |
| Swan River Chert | | | 5 | 5 |
| White River Group | | | 2 | 2 |
| clear/gray chalcedony | | | 1 | 1 |
| Knife River Flint | | 4 | 101 | 105 |
| metaquartzite | | 1 | | 1 |
| silicified wood | | 1 | | 1 |
| Antelope Chert | 1 | 9 | 18 | 28 |
| silcrete | | 1 | | 1 |
| Total | 1 | 16 | 127 | 144 |

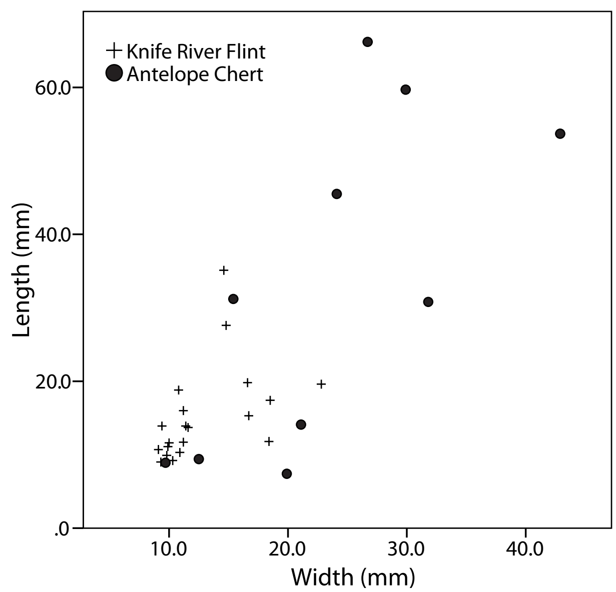


Figure 6.8. Sizes of complete KRF and Antelope Chert flakes.

Table 6.20. Metric data on complete KRF and Antelope Chert flakes from Aggie Brown Member contexts.

| Raw Material Type | | Length (mm) | Width (mm) | Area (sq. mm) |
|---|---|---|---|---|
| Knife River Flint | Mean | 15.32 | 12.87 | 163.41 |
| | N | 20 | 20 | 20 |
| | Std. Deviation | 6.547 | 3.878 | 101.482 |
| Antelope Chert | Mean | 32.69 | 23.40 | 711.32 |
| | N | 10 | 10 | 10 |
| | Std. Deviation | 22.502 | 9.958 | 637.248 |
| Total | Mean | 21.11 | 16.38 | 346.05 |
| | N | 30 | 30 | 30 |
| | Std. Deviation | 15.956 | 8.133 | 449.205 |

Table 6.21. Flake types from Aggie Brown Member contexts, organized by raw material type.

| | Flake Type | | | | | | |
|---|---|---|---|---|---|---|---|
| Raw Material Type | shatter | bipolar | biface thinning | simple | complex | indeterminate | Total |
| Swan River Chert | | | | 60.0% | 20.0% | 20.0% | 5 |
| Knife River Flint | 1.0% | 1.0% | 1.0% | 51.5% | 15.8% | 29.7% | 101 |
| Antelope Chert | 27.8% | | | 38.9% | 16.7% | 16.7% | 18 |
| Total | 6 | 1 | 1 | 62 | 20 | 34 | 124 |

one of which exhibits moderate patination (figure 6.4b). A tiny bipolar splinter is also present in the excavated tool assemblage, as is a possible bipolar anvil. Together these data suggest that bipolar reduction was a minor component of the Agate Basin technological repertoire.

Striking platform data augment the flake type data reportin table 6.21. Two variables—morphology and preparation method—were used to capture information about striking platforms. These two variables are clearly interrelated, but were coded separately to better partition objective data on platform shape from inferences about reduction stage and strategy. Table 6.22 provides data on platform morphology for size grade 3 flakes made from the three common material types. An equivalent fraction (about 13 percent) of the KRF and Antelope Chert flakes exhibit cortical platforms. However, apart from that commonality, the types of platforms differ between these two materials. Half of the Antelope Chert flakes have simple (flat), non-cortical platforms. By contrast, more than half of the KRF flakes have complex (mainly faceted) platforms. These same patterns also are expressed in the small collection of size grades 1 and 2 flakes (table 6.23).

Differences in the technological procedures applied to different materials are also reflected in platform preparation methods (table 6.24). Just one of the eight Antelope Chert flakes has a faceted platform, and none are ground, whereas more than half of the KRF flakes are faceted and five are ground. About 12 percent of the KRF flakes exhibit crushed platforms, another signal that the Agate Basin occupants of Area A made some use of bipolar reduction.

The individual flake data indicate that both core and biface reduction were applied to KRF, Swan River Chert, and Antelope Chert, but that core reduction was significantly more common in Antelope Chert. Bifacial reduction in KRF and Antelope Chert included both soft hammer thinning of larger bifaces and trimming or rejuvenation of smaller bifaces.

### Excavated Stone Tool Assemblage

A total of 90 stone tools are assigned to excavated Aggie Brown Member contexts (tables 6.4 and 6.6); this figure includes two specimens bearing evidence of two different

Table 6.22. Platform morphological type on size grade 3 flakes from Aggie Brown Member contexts, organized by raw material type.

| | Raw Material Type | | | |
|---|---|---|---|---|
| Platform Type | Swan River Chert | Knife River Flint | Antelope Chert | Total |
| cortical | 1 | 8 | 1 | 10 |
| simple | | 8 | 4 | 12 |
| complex | 2 | 36 | 1 | 39 |
| crushed | | 7 | 2 | 9 |
| Total | 3 | 59 | 8 | 70 |

Table 6.23. Platform morphological type in size grades 1 and 2 flakes from Aggie Brown Member contexts, organized by raw material type.

| | Raw Material Type | | |
|---|---|---|---|
| Platform Type | Knife River Flint | Antelope Chert | Total |
| cortical | 1 | 1 | 2 |
| simple | | 5 | 5 |
| complex | | 1 | 1 |
| Total | 1 | 7 | 8 |

Table 6.24. Platform preparation type on size grade 3 flakes from Aggie Brown Member contexts, organized by raw material type.

| | Raw Material Type | | | |
|---|---|---|---|---|
| Platform Preparation | Swan River Chert | Knife River Flint | Antelope Chert | Total |
| none | 1 | 13 | 4 | 18 |
| faceted | 2 | 32 | 1 | 35 |
| dorsal reduction | | 2 | 1 | 3 |
| ground | | 5 | | 5 |
| unknown | | 7 | 2 | 9 |
| Total | 3 | 59 | 8 | 70 |

manufacturing modes. Table 6.25 organizes data on the chipped stone component of the complete tool assemblage (85 tools or 94 percent of the combined chipped stone and groundstone collection) by raw material type and technological class. (One of the specimens exhibits evidence of two different manufacturing modes). A selection of these items is illustrated in figures 6.9, 6.10, 6.12, 6.13, and 6.15.

The largest part of the assemblage consists of 57 large patterned biface fragments made from four different raw materials. All but two of these are projectile points or point fragments, which are described in more detail in the next section. One of the unhafted biface fragments is burned; though it was finished, its original shape is not known. The other is very small and it is possible that it is a margin fragment of a projectile point. Both of these tools are made from KRF.

Unpatterned flake tools are the second most common tool type (figure 6.9). Five of the 12 KRF flake tools exhibit one or more extensively retouched margins, as do all of the Antelope Chert flake tools. These tools are technologically similar to flake tools recovered from the Agate Basin butchery locality at the Agate Basin site (Frison and Stanford 1982a:Figure 2.61, Figure 2.62; Stanford 1999:Figure 25). As Frison and Stanford (1982a:107) observe, a definite procedure was used to manufacture these tools, one that produces relatively broad, flat, and sturdy flakes that are suitable, with only minimal retouch, for a variety of butchery tasks. Platforms are preserved on three specimens from Beacon Island and in each case the flake blanks were struck from large bifacial cores.

One graving tool occurs in the excavated assemblage (figure 6.9e). Made on a KRF flake, this specimen features two graving tips, both of which exhibit use-wear traces. As noted previously, such tools commonly were used for incising or grooving bone or wood.

Two pieces of tested raw material (nodules exhibiting three or fewer small flake removals) and four cores are present in the collection. Both of the tested cobbles and two of the cores are made from platy, low-quality Antelope Chert (figure 6.10b). A much higher-quality Antelope Chert, presumably from a different and more distant source, was used to produce projectile points and retouched flake tools, suggesting that at least two different sources of this raw material were exploited. The two KRF cores are completely exhausted, weighing just 2.5 and 2.6 g, respectively.

The remaining six items in the chipped stone tool assemblage represent four technological classes. One

Table 6.25. Counts of chipped stone tools from Aggie Brown Member contexts, organized by raw material type.

| | Raw Material Type | | | | | |
|---|---|---|---|---|---|---|
| Technological Class | Swan River Chert | clear/gray chalcedony | Knife River Flint | metaquartzite | Antelope Chert | Total |
| small patterned biface | | | 1 | | | 1 |
| large patterned biface | 1 | 2 | 42 | | 12 | 57 |
| unpatterned biface | | | 2 | | | 2 |
| unpatterned flake tool | | | 12 | | 4 | 16 |
| core tool/chopper | | | | 1 | | 1 |
| tested raw material | | | | | 2 | 2 |
| core | | | 2 | | 2 | 4 |
| bipolar nodule | | | 1 | | | 1 |
| tabular plate tool | | | 1 | | | 1 |
| Total | 1 | 2 | 61 | 1 | 20 | 85 |

specimen is a large (933 g) metaquartzite cobble split longitudinally (figure 6.10a) (Ahler 2003b:95). A large flake was removed from the exterior face of the split cobble, forming a rough bifacial edge used for chopping. This specimen was later recycled for use as a groundstone tool, which is described later in this section. One size grade 4 specimen is classified as a small patterned biface. By definition, such tools are produced by pressure flaking. This particular item could represent the margin of a bifacially retouched flake tool, or it could represent a small bifacial cutting tool. The collection also includes a small (size grade 3) fragment of what very likely was an expedient unifacial or bifacial tool made from a platy piece of KRF. However, the working edge of the tool is not preserved and so nothing can be said about the morphology of function of this item.

The assemblage includes two unpatterned bifaces, both made from tabular pieces of KRF. One exhibits use-wear, indicating that it was broken during use or resharpening, rather than during manufacture. The other is too burned to determine when in the manufacturing trajectory it was discarded. Finally, the collection includes a single bipolar nodule. This item clearly was produced by bipolar percussion, but it is far too small to be classified as a core or as a wedge. Fragments such as this can be byproducts of a number of technological processes. It is also conceivable that this fragment was produced by an impact fracture.

Five groundstone tools are assigned to Aggie Brown contexts (table 6.26). One of these, a metaquartize

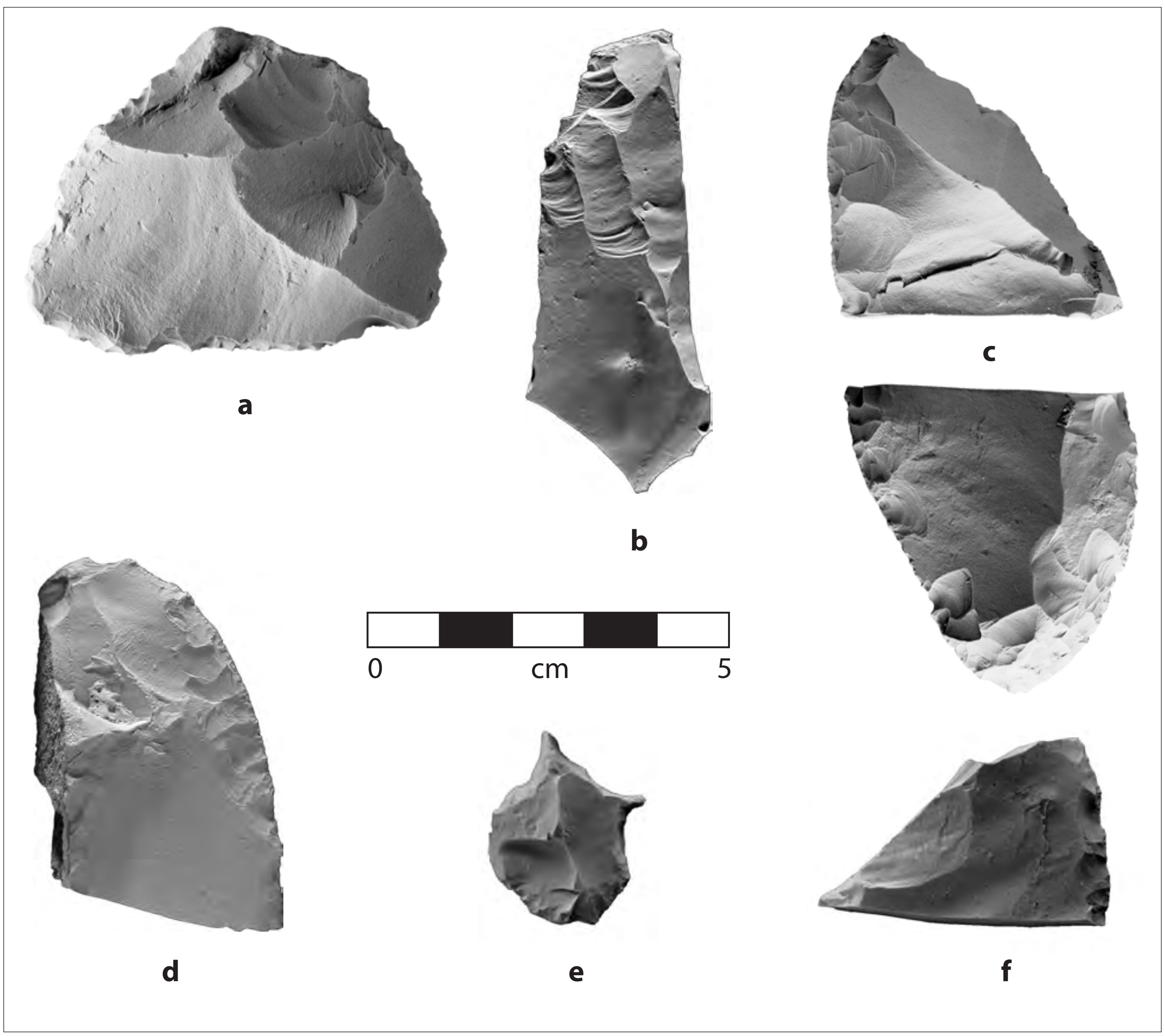


Figure 6.9. Agate Basin-age flake tools. a, b, d, f: Antelope Chert; c, e: KRF. b is unused. (b and d from Ahler [2003b:Figure 65]).

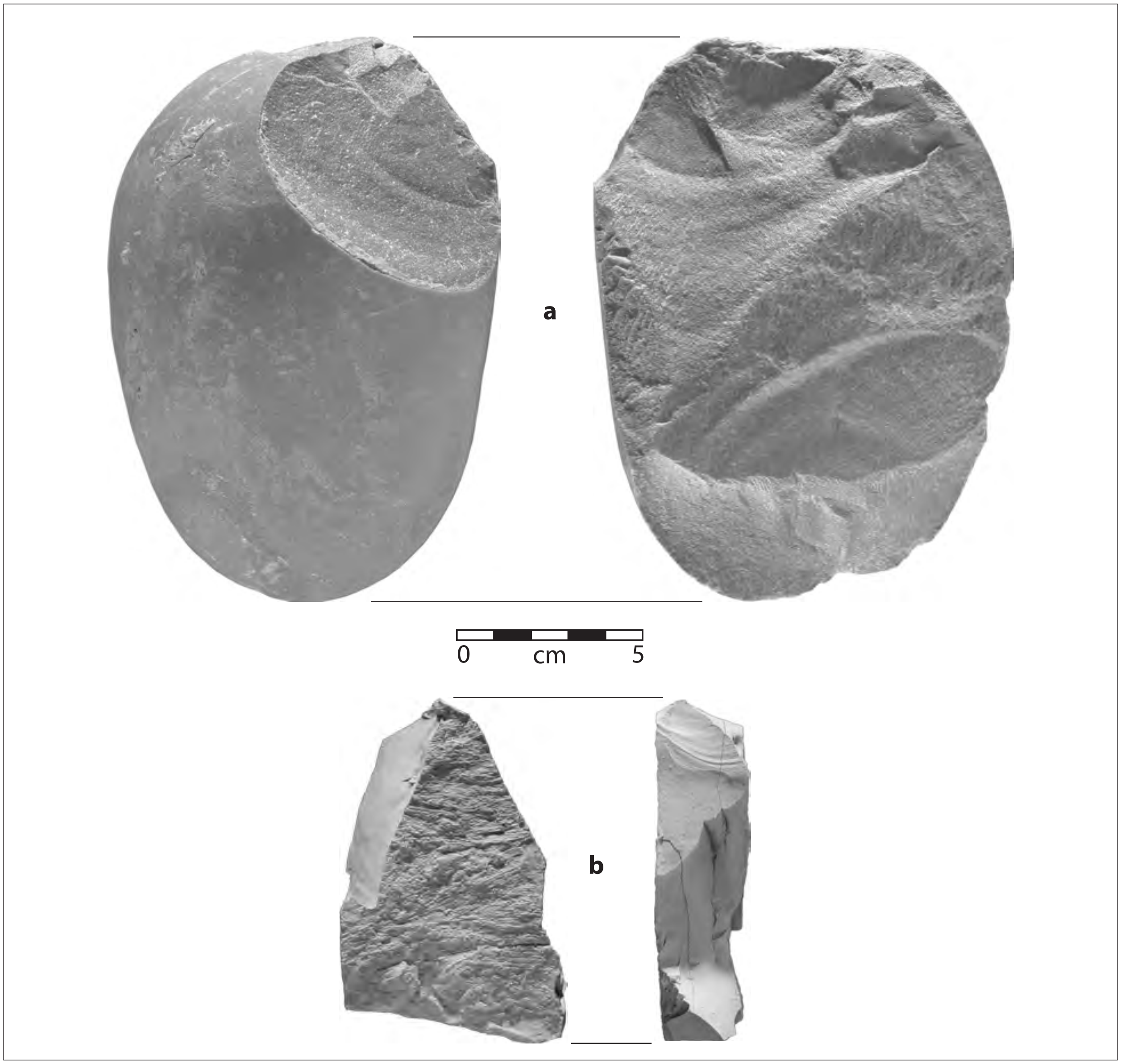


Figure 6.10. Agate Basin-age stone tools. a: metaquartzite cobble tool; b: Antelope Chert core (Ahler 2003b:Figure 65 and Figure 66).

hammerstone, represents the second use of the large, split cobble chopping tool described previously (figure 6.10a). The cortical surface of this tool exhibits a series of marks or scars likely resulting from impacts with bison bone (Ahler 2003b:95). Two other groundstone tools were found together, roughly 20 cm above the bonebed, in square 1279NE1111 in the northwest block. One of these is a complete granite abrading stone with a single ground

Table 6.26. Counts of groundstone tools from Aggie Brown Member contexts, organized by raw material type.

| Raw Material Type | bipolar anvil or hammer | hammerstone | hand-held abrading stone | Total |
|---|---|---|---|---|
| granitic | | | 2 | 2 |
| compact sandstone | 1 | | | 1 |
| metaquartzite | | 1 | | 1 |
| siltstone/mudstone/limestone | | | 1 | 1 |
| Total | 1 | 1 | 3 | 5 |

facet bearing moderately intensive surface smoothing. The second is a small cobble of compact sandstone or very poorly cemented quartzite, weighing 165 g, which exhibits pitting or battering on one face. This item could have been used to fracture bone; however its small size and the extent and location of the pitting suggests that it was more likely used as a bipolar anvil or hammerstone.

The remaining two groundstone items are more difficult to interpret. The larger of the two, a complete granitic cobble weighing 306 g, exhibits extensive, parallel striations or scratches on both faces. Most are parallel to the long axis of the cobble, though a few of the deeper scratches on one face run at an acute angle to the long axis. In several places shallow striations are also present on the edges of the tool. One end shows evidence of battering. The striations appear to post-date the battering. The other, much smaller groundstone tool, which weighs just 5 g, bears similar striations. In this case, they are most pronounced on the pebble's single flat side, though they also occur elsewhere. Similar striations occur on a few other pebbles and cobbles from Area A, possibly suggesting that they were produced by some natural process. However, striations are far more extensive, and more pronounced on the two specimens included in the stone tool aggregate than on the natural cobbles.

As was the case for the Pick City Member contexts discussed previously, pebbles and cobbles of various size and lithology occur within Aggie Brown Member contexts at Beacon Island. None of these bear obvious use-wear traces. Many are rather small—ranging in weight from roughly 25 to 75 g—and likely are simply naturally occurring pieces. However, others are quite large and several of these are directly associated with the bonebed (figure 6.11). Table 6.27 summarizes data on the largest such clasts. The cobble from square 1253NE1096 exhibits a few striations similar to those present on the abrading tools discussed previously. A few small smears of an unknown dark residue are also present on one face. It seems likely that one or more of these clasts were used in the butchery process, but lacking direct use-wear evidence it is difficult to say precisely how.

More than one-third of the Agate Basin chipped stone tool assemblage is burned (table 6.28). This includes nearly half of the large patterned bifaces and one-quarter of the flake tools. Overall, burning is more common in the tool assemblage than it is in the flaking debris assemblage.

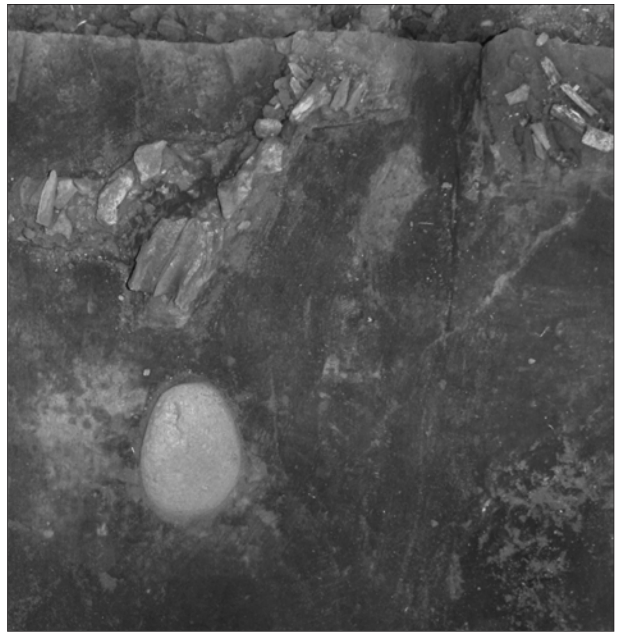

Figure 6.11. Large unmodified clast associated with Agate Basin bonebed in square 1281NE1108.

Agate Basin Projectile Points

This discussion of Agate Basin weaponry combines data on the 55 point fragments in the excavated assemblage with data on 19 specimens recovered from the surface in 2000 or 2001 that are described by Ahler (2003a) and Ahler and McGonigal (2001). Ahler's original analysis included 22 items; however, one of these comes from another nearby site (Gull Island) and two others (Specimens 6 and 22) are probably not projectile points, based on Ahler's unpublished notes and on Mitchell's subsequent analysis. Specimen 22 (Ahler 2003a:Figure 67:22 SRC) is short, thick, steep-edged, lacks lateral or basal grinding, and exhibits flaking patterns unlike the other specimens in the surface collection. For these

Table 6.27. Data on five large, unmodified clasts association with the Agate Basin bonebed.

| Raw Material | Weight (g) | Square | Standard Level | Context |
|---|---|---|---|---|
| metaquartzite | 1649.0 | 1281NE1108 | 22 | in bonebed |
| granite | 399.1 | 1276NE1119 | 23 | top of bonebed |
| limestone | 159.8 | 1280NE1112 | 21 | in bonebed |
| granite | 362.9 | 1280NE1119 | 21 | in bonebed |
| metaquartzite | 194.7 | 1253NE1096 | 22 | bottom of bonebed |

Table 6.28. Frequency of burned chipped stone tools from Aggie Brown Member contexts, organized by technological class.

| Technological Class | Burned | Total |
|---|---|---|
| small patterned biface | | 1 |
| large patterned biface | 49.1% | 57 |
| unpatterned biface | 50.0% | 2 |
| unpatterned flake tool | 25.0% | 16 |
| core/chopper | | 1 |
| tested raw material | | 2 |
| core | | 4 |
| bipolar nodule | | 1 |
| tabular plate tool | | 1 |
| Total | 37.6% | 85 |

Table 6.29. Raw material types represented in the Agate Basin projectile point collection, organized by analytic unit.

| | Analytic Unit | | |
|---|---|---|---|
| Raw Material Type | Excavated Collection | Surface Collection | Total |
| Swan River Chert | 1 | 2 | 3 |
| Sentinel Butte Flint (?) | 2 | | 2 |
| Porcellanite | | 2 | 2 |
| Knife River Flint | 40 | 8 | 48 |
| Antelope Chert | 12 | 7 | 19 |
| Total | 55 | 19 | 74 |

reasons it is excluded from the analysis. Specimen 6 (figure 6.15j; see also Ahler 2003a:Figure 67[6 POR]) is also technologically distinct. Though lenticular in cross-section, it has straight, converging blade margins. The ventral surface of the original flake blank is well preserved on one face. Scars on both faces indicate primarily comedial pressure flaking, rather than comedial to transmedial percussion thinning and shaping followed by pressure flaking to trim and straighten the blade margins, a pattern typical of Agate Basin technology. Specimen 6 exhibits 4 to 5 flake scars per centimeter of blade margin, compared to 2 to 3 scars per centimeter for most Agate Basin points. For these reasons, Specimen 6 is also excluded.

The presentation begins with a summary and discussion of basic nominal data, including raw material type, burning, heat treatment, cortex, patination, use phase, and so forth. It concludes with an examination of metric data on a subset of 32 specimens large enough for more detailed analysis.

With one exception, the same raw material types are represented in the excavated and surface collections (table 6.29). The exception is two items in the surface collection made from red porcellanite. Interestingly, just three porcellanite flakes, all made of the gray variety, are present in the Aggie Brown Member analytic unit, suggesting that porcellanite points brought to Beacon Island were not refurbished for later use. Antelope Chert is somewhat better represented in the surface collection than it is in the excavated collection and KRF is better represented in the excavated collection.

The two assemblages exhibit rather different fragmentation patterns. The excavated point assemblage is highly fragmented: 60 percent of the specimens fall into size grades 3, 4, or 5 (table 6.30). Comparable size grade data are not available for the specimens in the surface collection, but their mean length is 58 mm and their mean width is 23 mm; the narrowest is 17.3 mm wide, while the widest is 30.7 mm. These measurements indicate that virtually all the surface-collected specimens would fall into size grade 2.

Specimens in the two analytic units also represent different portions of points (table 6.31). Half of the items in the excavated assemblage are proximal fragments (bases and segments with ground edges), whereas just 25 percent of the items in the surface assemblage are. One-third of the specimens in the surface collection are complete or nearly so and one of these is pristine. By contrast, no complete points occur in the excavated assemblage and just 2 (4 percent) are unbroken; however, one of these was recycled for use as a knife (CN1929.03). Forty-five percent of the surface assemblage, and 46 percent of the excavated assemblage, consists of distal segments. However, in the excavated assemblage more of these are short blade fragments or margin fragments. In sum, then, the surface assemblage includes more

Table 6.30. Size distribution of Agate Basin projectile point fragments in the excavated collection.

| | Size Grade | | | | |
|---|---|---|---|---|---|
| Raw Material Type | G2 | G3 | G4 | G5 | Total |
| Swan River Chert | | 1 | | | 1.8% |
| Sentinel Butte Flint (?) | 2 | | | | 3.6% |
| Knife River Flint | 9 | 24 | 6 | 1 | 72.7% |
| Antelope Chert | 11 | 1 | | | 21.8% |
| Total | 40.0% | 47.3% | 10.9% | 1.8% | 55 |

Table 6.31. Completeness patterns in Agate Basin projectile points, organized by analytic unit.

| | Analytic Unit | | | |
|---|---|---|---|---|
| | Excavated | | Surface | |
| Completeness Class | N | % | N | % |
| complete | | | 2 | 11% |
| resharpened tip, complete base | 2 | 4% | 2 | 11% |
| missing tip only | | | 2 | 11% |
| basal fragment | 12 | 22% | 3 | 16% |
| segment with ground edge | 15 | 27% | 2 | 11% |
| distal segment or blade margin | 19 | 34% | 4 | 21% |
| distal fragment lacking base | 7 | 13% | 4 | 21% |
| Total | 55 | | 19 | |

complete points and fewer basal fragments, whereas the excavated assemblage includes more basal fragments and small blade margin fragments and fewer complete points.

The two collections exhibit different degrees of burning. Forty-nine percent of the specimens in the excavated assemblage are burned, though it should be said that this includes several cases in which burned fragments refit to form a single point, a topic taken up later in this section. By contrast, just one of the 20 specimens in the surface collection is definitively burned and one other is possibly burned.

One could chalk up these differences in fragmentation and burning to "collector bias." However, there is evidence that they are archaeologically meaningful. First, the intensive surface collection carried out in May 2002, just a year or two after the site was first identified and the projectile points were collected, failed to recover any inconspicuous point fragments that might have been passed over by artifact collectors—small margin pieces, burned medial segments, and so forth—in the same area. Second, the bone collected from the surface (see chapters 3 and 5) exhibits almost precisely the same fragmentation signature relative to the excavated bone as the surface point collection does to the excavated point collection. That is, the surface bone collection is less fragmented and includes a higher proportion of complete bones than the excavated bone collection. The precise spatial distribution of the surface-collected point assemblage is not known. However, bone fragments recovered from the surface in 2002 occur in a spatially restricted zone, mainly east of the northeast excavation block. Given the shared fracture patterns, it seems likely that the points came from the kill itself, located in the now-eroded area adjacent to the intact processing area, where they were lost in unbutchered bison carcasses represented by the relatively intact surface bone assemblage. By contrast, the excavated point collection, recovered from the carcass processing area, mostly represents small or badly damaged fragments that the hunters deemed unsuitable for reworking or recycling.

Data on the reasons for point discard fill out this picture (table 6.32). Just one specimen in the excavated assemblage has potential for further use as a projectile point. One other complete point was recycled into a knife. Nearly 40 percent were burned after they were deemed unsuitable for some other reason, though the specific grounds for discard cannot be determined from the recovered fragments. Most of the remainder (47 percent of the total) exhibit definite impact fractures or bend fractures likely produced by impact or by back pressure within the haft. Fractures commonly produced during manufacture, including perverse fractures or

Table 6.32. Reasons for projectile point discard in the excavated collection, organized by material type.

| | Raw Material Type | | | | |
|---|---|---|---|---|---|
| Reason for Discard | Swan River Chert | Sentinel Butte Flint (?) | Knife River Flint | Antelope Chert | Total |
| potential for further use | | | 1 | | 1 |
| bending fracture or end shock | | | 7 | 2 | 9 |
| material flaw | 1 | | | | 1 |
| impact fracture | | | 13 | 4 | 17 |
| thermal fracture | | 2 | 17 | 2 | 21 |
| lateral fracture | | | 2 | 3 | 5 |
| recycled | | | | 1 | 1 |
| Total | 1 | 2 | 40 | 12 | 55 |

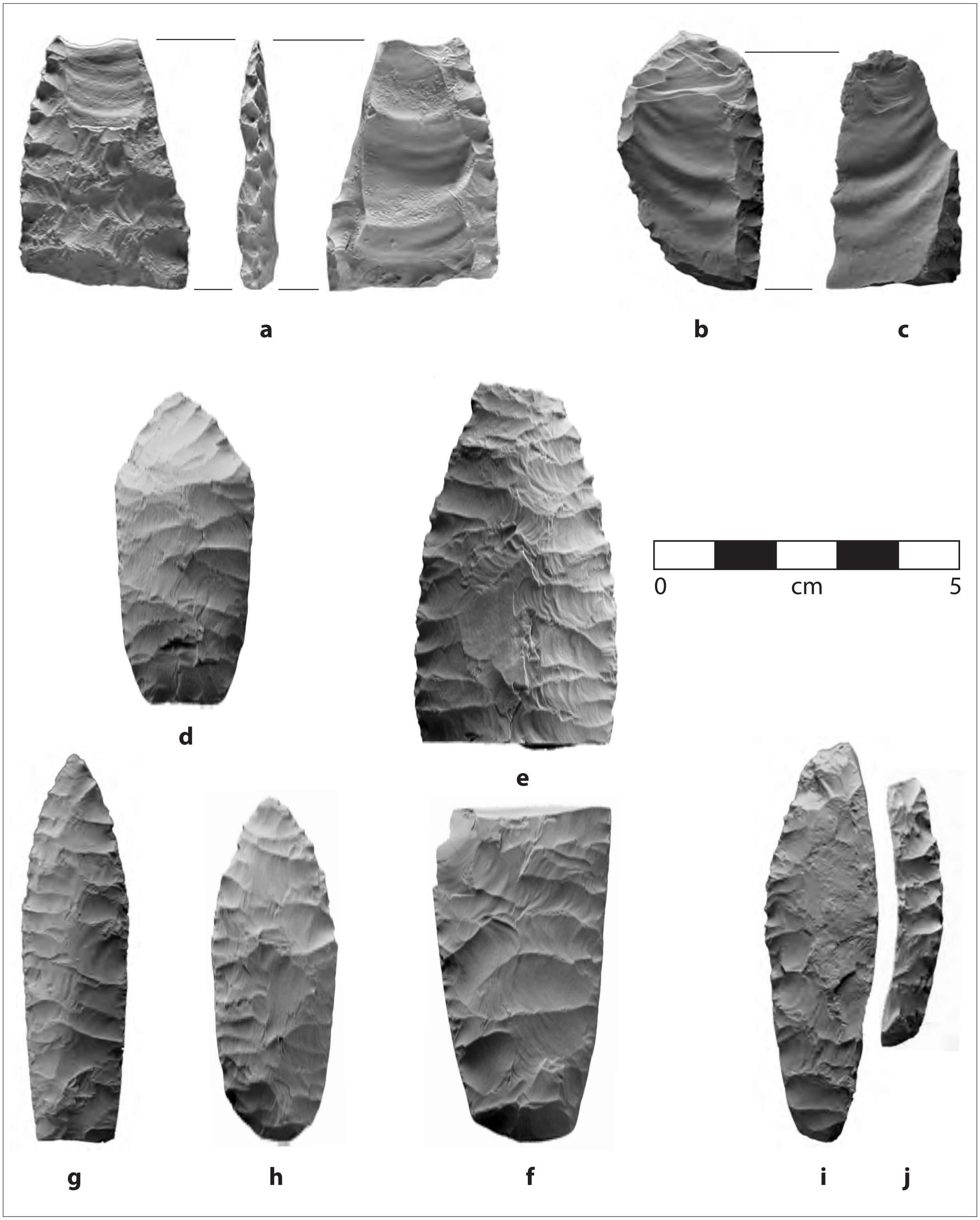


Figure 6.12. Projectile points from excavated contexts. a, b c, i, j: major impact fractures; d: recycled point; b, c, e, f, i, j: conjoinable fragments (a from Ahler [2003b:Figure 65]).

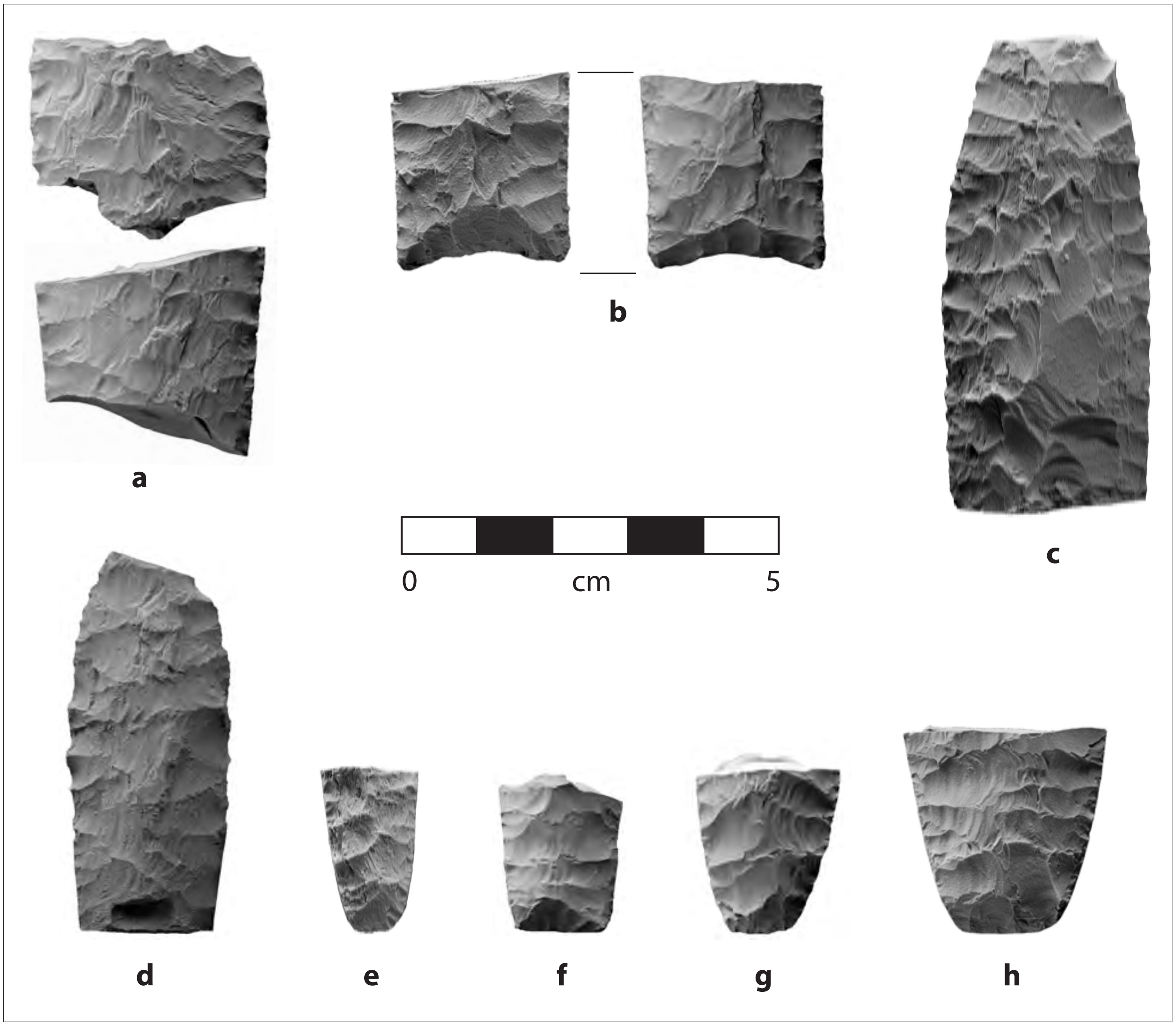


Figure 6.13. Projectile points from excavated contexts. a, c, d: Antelope Chert; b: Goshen point; e, g, h: unmodified basal fragments; f: reworked basal fragment.

outré-passe fractures, are conspicuously absent. Stacked step or hinge fractures, another reason a piece might be discarded during manufacture, are also absent.

Additional data on the nature of the impact fractures are available for the subset of 32 points or point fragments included in the detailed study (table 6.33). Ten of the 32

Table 6.33. Tally of impact-related fracture types in Agate Basin projectile points in the detailed study sample.

| | Analytic Unit | | |
|---|---|---|---|
| Impact Fracture Type | Excavated Collection | Surface Collection | Total |
| Absent | 5 | 5 | 10 |
| Bend | 5 | 5 | 11 |
| Bend and flute-like fracture | 4 | 1 | 5 |
| Major flute | 2 | 3 | 5 |
| Minor flute | | 1 | 1 |
| Burination | 1 | | 1 |
| Total | 17 | 15 | 32 |

do not exhibit impact fractures; however, the majority of surface specimens lacking impact fractures are complete or nearly so, while the majority of excavated specimens lacking impact fractures exhibit burning or some other type of damage. Virtually all of the remaining 22 points exhibit fractures sufficiently catastrophic to preclude further rejuvenation, ranging from buckle breaks at the top of the haft element to massive flutes on one or both faces, to marginal burination (figure 6.12a, b, c, i, j).

No unfinished points or production failures are present in the Beacon Island collection so little can be said about the techniques used to make them. However, a few completed specimens do preserve limited evidence of manufacture. Four points in the excavated assemblage exhibit remnant percussion flake scars on one face (figures 6.12e, 6.12h, and 6.13c), as do four points in the surface assemblage (figure 6.15b). In most cases the scars are rather flat and featureless, providing few clues about their orientation relative to the axes of the finished points. This could indicate that the points were constructed on large flake blanks; however, most of these scars likely were produced during initial bifacial shaping. One scar in particular (figure 6.13c) is certainly oriented perpendicular to the point's long axis, lending support to the latter interpretation. The biface from which it was produced must have been rather broad. Based on his study of unfinished specimens from the Hell Gap site, Bradley (2009a:265) suggests that Agate Basin flintknappers used "widely spaced full-face and to some extent controlled overshot flaking" during the middle stage of production to establish the point's characteristically flat longitudinal cross-section.

Another specimen preserves clearer evidence of original input blank form. One point in the excavated collection made from KRF preserves a relatively flat cortical surface that indicates it was made on a tabular piece of stone (figure 6.12i).

Heat treatment was rarely used in the production of Beacon Island points. Just one specimen exhibits unequivocal evidence of heat treatment—an Antelope Chert point in the excavated collection (figure 6.12d). A second Antelope Chert point in the excavated collection may have been made from treated stone. Two points in the surface collection also show possible evidence of heat treatment. One of these is made from Swan River Chert and the other is made from Antelope Chert. Untreated pieces of Swan River Chert sometimes can be difficult to flake in a manner sufficiently controlled to produce Agate Basin points and this may also be true of Antelope Chert (Phil Geib, personal communication, 2011). None of the KRF points exhibit any evidence of heat treatment. (Just 5 KRF flakes in the coarse-fraction assemblage exhibit possible evidence for heat treatment).

Marginal grinding is evident on all of the 32 points and point fragments in the detailed analysis subsample where a portion of the haft element is preserved. Just under 30 percent of the specimens in the subsample exhibit intensive grinding or polishing. This includes the three longest complete points in the collection, suggesting that more intensive grinding was applied during primary point manufacture that during rejuvenation. Basal dulling occurs on 11 of the 15 points with preserved bases. In every case grinding on the base is less intensive than on the margins.

The Beacon Island assemblage offers insights on the life histories of Agate Basin weapons. All researchers recognize that extensive reshaping or rejuvenation of broken point fragments is an important element of Agate Basin technology (Bradley 1982:195-197, 2009a:265, 2010:483; Frison and Stanford 1982a:131; Hill 1994; Peterson 1978). Indeed, Bradley (2009a:265) argues that Agate Basin weaponry was specifically designed to facilitate the serial rejuvenation of broken fragments.

This study uses Bradley's (1982:196) four criteria to identify reworked or rejuvenated points. Resharpened specimens may exhibit evidence of prior breaks; abrupt changes in plan or cross section shape; irregular flaking that truncates the comedial to transmedial flaking pattern common to the type; or some combination of these indicators. In addition, proximal ends could sometimes be snapped off by back pressure from the haft during impact (Frison and Stanford 1982a:105-107), and small pressure flakes often were subsequently removed from these breaks, producing a squared off or slightly concave base. Thus, unmodified points or point segments exhibit symmetrical transverse and longitudinal cross sections and careful comedial to transmedial, but not serial, percussion flaking finished with selective invasive or abrupt pressure flaking designed to produce straight, even margins.

Examples of each rejuvenation criterion can be seen on the points from Beacon Island. Thirty of the 55 fragments in the excavated assemblage exhibit some degree of reworking (table 6.34), as do seven of the 19 fragments in the surface assemblage. The figure for the excavated assemblage may underestimate the actual frequency of resharpening because reworking occurs more frequently on distal ends but base fragments make up a disproportionate share of that part of the collection. (Reworking location on complete points is discussed in the next section). Much of the reworking is essentially unifacial and sometimes is confined to just one blade margin. When reworking extended into the half element of the original point, the lateral margins were apparently re-ground, but not as intensively as the original haft element. In some cases this secondary grinding is asymmetrical, with dulling on one margin extending closer to the tip. With just two exceptions (figure 6.12d

Table 6.34. Reworking on Agate Basin points in the excavated collection, organized by completeness class.

| | Reworking | | |
|---|---|---|---|
| Completeness Class | Not reworked | Reworked | Total |
| resharpened tip, complete base | | 2 | 2 |
| basal fragment | 10 | 2 | 12 |
| segment with ground edge | 8 | 7 | 15 |
| distal segment or blade margin | 7 | 12 | 19 |
| distal fragment lacking base | | 7 | 7 |
| Total | 25 | 30 | 55 |

and 6.12h), fracture and resharpening patterns together indicate that points in the collection were rejuvenated before the kill at Beacon Island took place. Presumably, points recovered from the kill and rejuvenated on site were carried away to be used in the next kill.

Potentially informative between-site patterning exists in the frequency of reworked Agate Basin points. Figure 6.14 illustrates the frequencies of complete points showing evidence of rejuvenation in four Agate Basin-age assemblages (Bradley 1982:Table 3.9, 2009b; Slessman 2004:Table 10). All of the specimens in this sample are complete and therefore serviceable as weaponry, so they must either have been lost or inadvertently discarded. Several factors likely contribute to the differences illustrated in figure 6.14. Bradley (2009a:266) classifies the Agate Basin component at the Hell Gap site as a "weapon-refurbishing camp," whereas the other three components represent kill-butchery localities. Complete points left behind at Beacon Island, Frazier, and Agate Basin presumably were lost in unbutchered or minimally butchered carcasses. Thus, the total number of complete points from each of these sites might reflect the size of the kill or the intensity of carcass processing (Hofman 1999). (The estimated excavated portion of each site is roughly comparable). It is unclear why a substantial number of usable points would have been left behind at Hell Gap. Another, more interesting factor, though, is the likely systematic relationship of each site relative to episodes of primary point production. While rejuvenation took place at each site, the fact that a larger fraction of the recovered assemblage at Agate Basin consists of unreworked points suggests that the kill there occurred relatively soon after a major production effort. By contrast, Beacon Island and especially Frazier may have occurred later in the weaponry life cycle. These data suggest that primary point production occurred only intermittently. By contrast, secondary reworking seems to have occurred regularly and habitually.

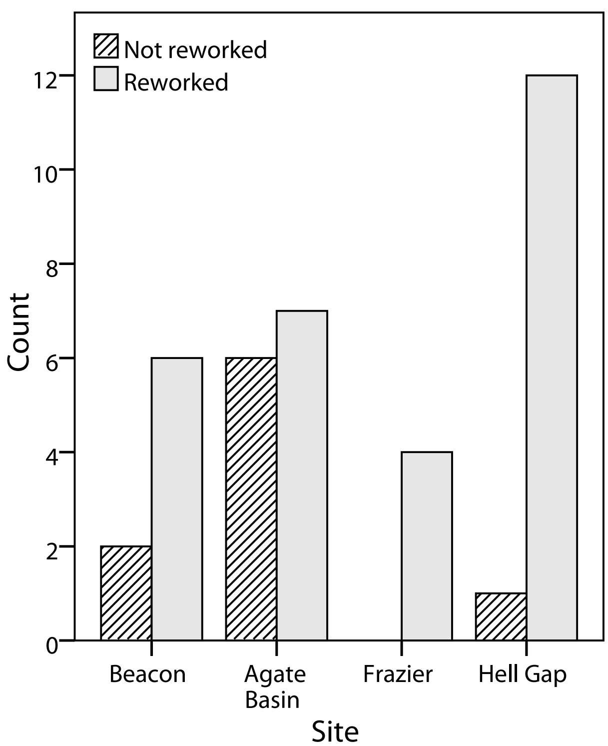


Figure 6.14. Frequency of reworked projectile points at four Agate Basin sites.

Frison and Stanford (1982a:131) argue that reworked Agate Basin projectile points seldom were used as knifes or other tools. Stanford (1999:315) notes some evidence for this type of secondary use among the "Agate Basin-like" points from the Packard site in northeastern Oklahoma, though he notes that the cultural and technological connections between the Packard assemblage and Agate Basin assemblages from the western Plains are unknown. Hill (1994:233) suggests that Agate Basin points from the Silver Mound site in Wisconsin were also recycled into multifunction tools.

The Beacon Island assemblage shows little evidence of such recycling, with just two projectile point fragments exhibiting technological evidence of secondary use. One of these is a basal fragment made from Antelope Chert (figure 6.12d). The very short blade was unifacially resharpened, producing a markedly obtuse front angle and asymmetrical transverse cross section. The other recycled fragment is an impact-fractured blade segment that was reused as an unhafted cutting or scraping tool. Some of the other reworked point segments could conceivably have

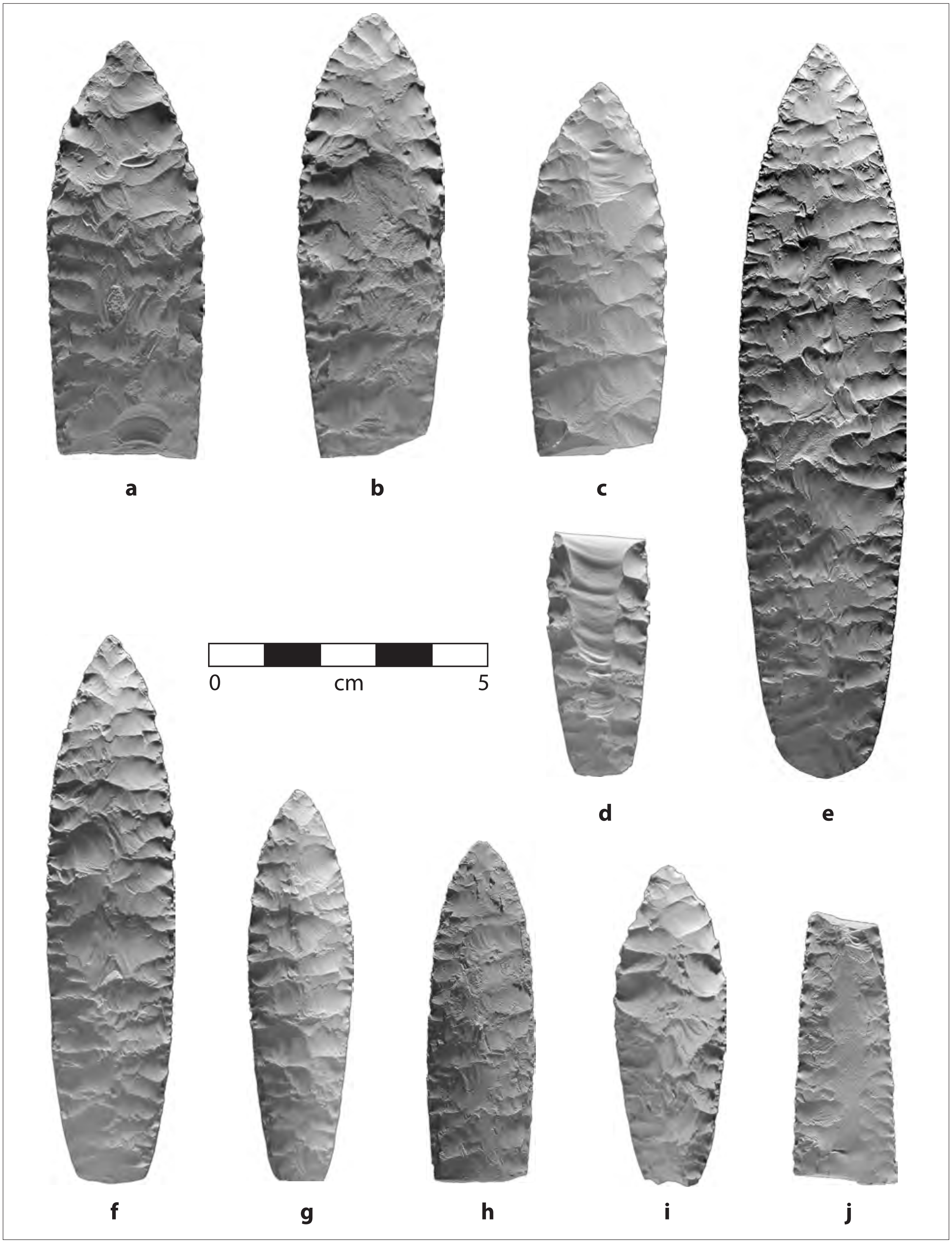


Figure 6.15. Agate Basin projectile points collected from the surface. a, c, g, h: Antelope Chert; b, d, e, f, i: KRF (from Ahler 2003a: Figure 67, Figure 68, Figure 69, Figure 70). Specimen j (BI-6) is excluded from the projectile point analysis because its morphology and flaking patterns are not consistent with Agate Basin technology; see page 137.

been put to secondary uses, but, as Frison and Stanford (1982a:131) observe for the Agate Basin assemblage, such recycling did not involve an effort to "to alter the morphology of the projectile points … into what would be considered more usable tool shapes."

All but one of the projectile points from Beacon Island are morphologically and technologically consistent with the points from the Hell Gap and Agate Basin sites that Bradley (1982, 2009a, 2010) describes in detail. The lone exception is the base of what can be called a Goshen point (figure 6.13b). This specimen is made from KRF and is relatively broad and flat. Its slightly concave base and excurvate margins give it a vaguely "eared" appearance. Rows of short, equally spaced pressure flakes were removed from the base on both faces. Lateral flaking is mainly comedial, with one flake scar diving toward the midline. Several flake scars on the opposite face end in step terminations shy of the midline. The point was finished with nearly continuous abrupt to invasive marginal retouching. Both margins and the base are lightly ground.

The term "Goshen" clearly is an apt description of this specimen's morphological and technological characteristics. It is remarkably similar to a point base recovered from the Alkali Creek site, located within the KRF primary source area, some 75 km south-southeast of Beacon Island (Ahler et al. 1995:231-234, Figure 55). It also is morphologically and metrically similar to many, but not all, of the specimens from the Mill Iron site, the best known Goshen assemblage (Bradley and Frison 1996). Visually and descriptively, the Beacon Island point is quite similar to Number 1582 from Mill Iron, which Bradley and Frison (1996:47, Figure 4.3[b]) describe as a "typical" example. It is also similar to several points from the Jim Pitts site (Sellet et al. 2009). However, as Sellet and others (2009) argue, points classified as Goshen exhibit significant technological and morphological variation.

Given its position in the bonebed there is no doubt that this point was among the weapons used in the kill. A number of explanations are possible for its co-occurrence with what otherwise is a "classic" Agate Basin assemblage, some of which are rather prosaic. It could, for instance, simply represent a found object that was reused by Agate Basin hunters. However, a more intriguing explanation is offered by Sellet and others (2009; see also Sellet 2001), who argue that multiple point types were produced concurrently on the Northern Plains between 10,500 and 10,000 $^{14}$C yr B.P. Thus, the Goshen point at Beacon Island may signal connections of one sort or another among contemporaneous but culturally distinct bison hunters.

Finally, data on differential patination in Agate Basin points from Beacon Island provide clues about post-depositional processes. Virtually all of the unburned points made from KRF in both the surface and excavated assemblages exhibit some degree of differential patination. A number of these artifacts are completely unpatinated on one face but exhibit pronounced patination on the other. This pattern is strongly correlated with the occurrence of adhering carbonate: in each case, the more heavily patinated face lacked carbonate encrustation, which had built up on the artifact's downward-facing side. Apparently, carbonate present in the site's sediment promoted patination, but the carbonate rind on the bottom of the artifacts isolated that face from contact with the intrastratal solutions responsible for chemical weathering. The consistent presence of carbonate encrustation on one face only suggests that post-depositional artifact movement was limited. It also suggests that most artifacts originally lay flat.

### *Agate Basin Point Size and Morphology*

One especially striking feature of the Beacon Island projectile points is their extreme size range coupled with their nearly perfect proportional scaling (Ahler 2003a:96). The largest complete, unreworked point in the collection (figure 6.15e) is four times as heavy and nearly twice as long as the smallest (figure 6.15g), yet both exhibit similar length-to-width ratios and outline shapes. Basal width data on point fragments suggest that the full size range was in fact even greater that this.

To better understand metric and morphological variability in Agate Basin points, data were compiled on a sample of 84 points and point fragments from four Agate Basin sites. The Beacon Island subsample includes 32 points from which one or more measurements could be taken (appendix H). Of these, 15 come from the surface collection and 17 come from the excavated collection. (Seven of the 17 excavated points incorporate two to four conjoinable fragments; additional information about these conjoined specimens is presented later in the chapter). The balance of the four-site sample comprises 33 complete points and point fragments from the Agate Basin site (Bradley 1982:Table 3.9); 13 complete points from the Hell Gap site (Bradley 2009b); and six complete points and point fragments from the Frazier site (Slessman 2004:Table 10).

Figure 6.16 illustrates the lengths and maximum widths of nine complete, unreworked points from Beacon Island, Hell Gap, and Agate Basin. Data on three incomplete points from the Agate Basin site, one of which has been reworked, are also included in this figure. These data show that in their original, unreworked form Agate Basin points in fact did not exhibit a single, invariant length-to-width ratio. Rather, there appear to be two distinct morphological modes. The first mode

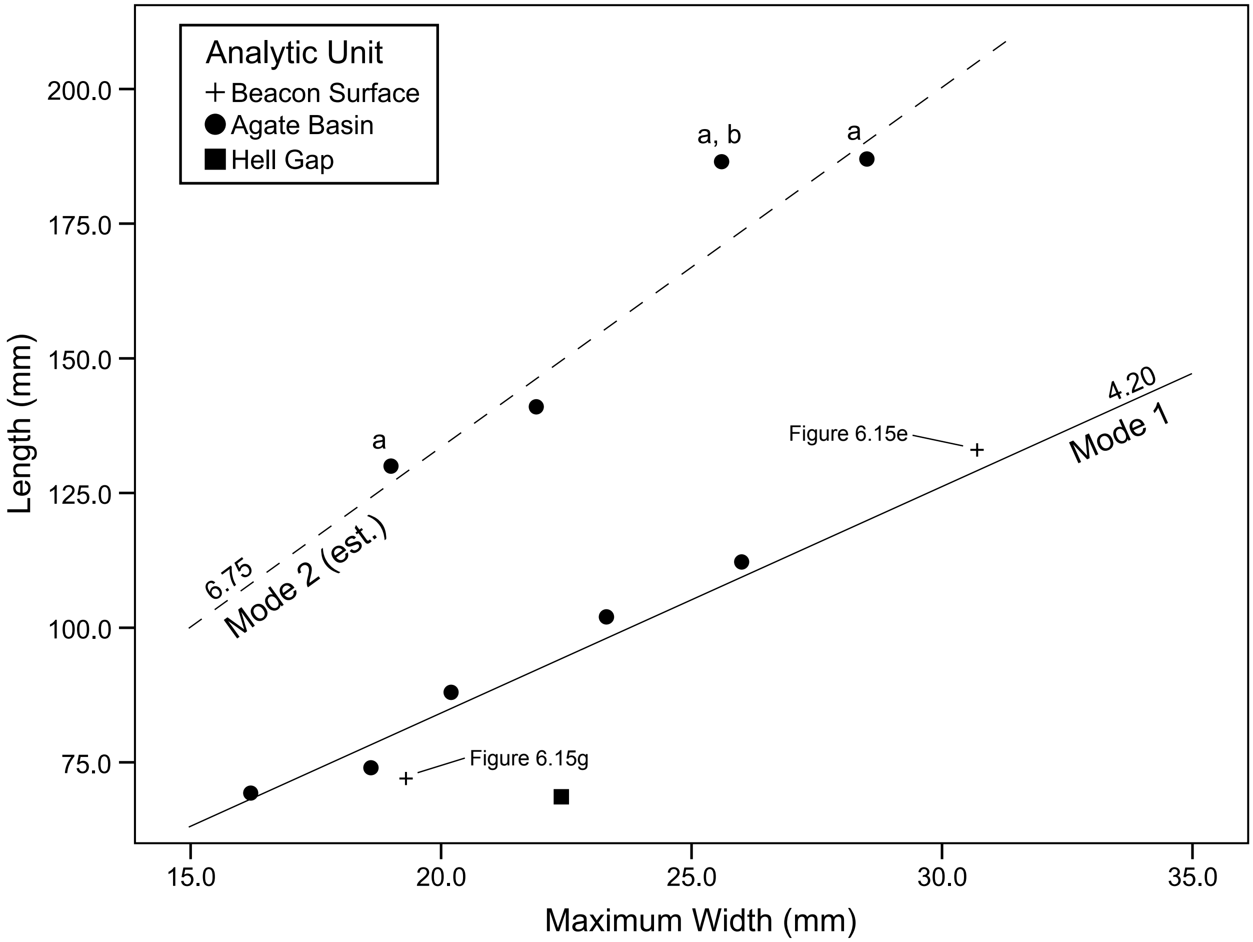


Figure 6.16. Lengths and maximum widths of nine complete and three incomplete Agate Basin points (a, incomplete; b, reworked).

is represented by five points from Agate Basin and two from Beacon Island, all of which exhibit a length-to-width ratio falling in a narrow range between 3.73 and 4.38 with a mean of 4.20. These points differ greatly in size, ranging from 72 mm to 133 mm long, but all exhibit essentially the same outline shape, at least as expressed by this ratio. This suggests that Agate Basin flintknappers scaled the standard-ratio points they made to the sizes of the available raw material nodules. It also suggests that the hafting method they used was sufficiently flexible to accommodate points of widely varying size.

The second mode is represented only by specimens from the Agate Basin site in eastern Wyoming, including one complete point and three broken points. The length-width ratio of the lone complete point is 6.44. The ratios of the incomplete points range from 6.56 to 7.28; originally they would have been somewhat greater. The ratio line representing this mode is estimated at 6.75 in figure 6.16. The fact that megapoints only occur at the Agate Basin site, much farther from the KRF source area than Beacon Island, may indicate that the techniques necessary to make them were not shared among all Agate Basin bands.

The single unreworked complete point from the Hell Gap site is shorter, wider, and thicker than the specimens from either Beacon Island or Agate Basin.

Interestingly, these two size modes are not reflected in the width-to-thickness ratios of the same specimens (figure 6.17). In fact, only the widest, thickest points exhibit a consistent ratio.

Additional evidence of variability in original size comes from the Beacon Island assemblage. Figure 6.18 illustrates the widths of 16 Beacon Island point bases. Seven of these exhibit some evidence for reworking; however, given the gently tapering shape of Agate Basin points, the reworked bases likely are only slightly wider than the original bases. In this sample, the narrowest unreworked base (6.8 mm) is just 40 percent as wide as the broadest (16.5 mm). The latter measurement comes from a complete point that falls close to the 4.2 length-

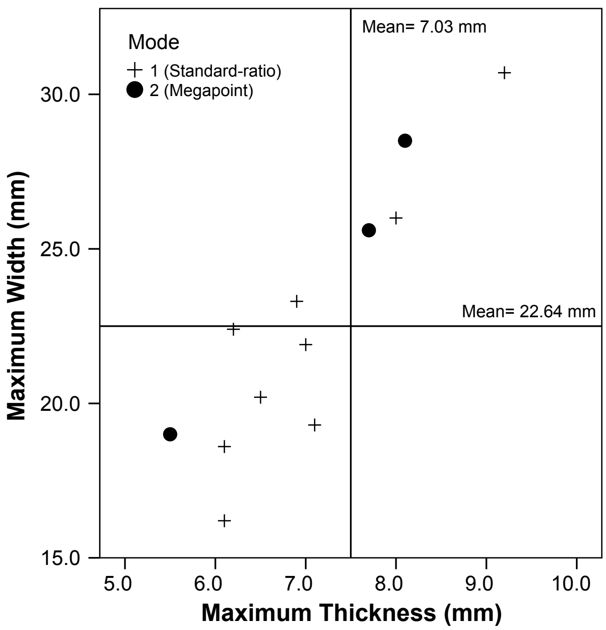


Figure 6.17. Maximum widths and thickness of nine complete and three incomplete Agate Basin points.

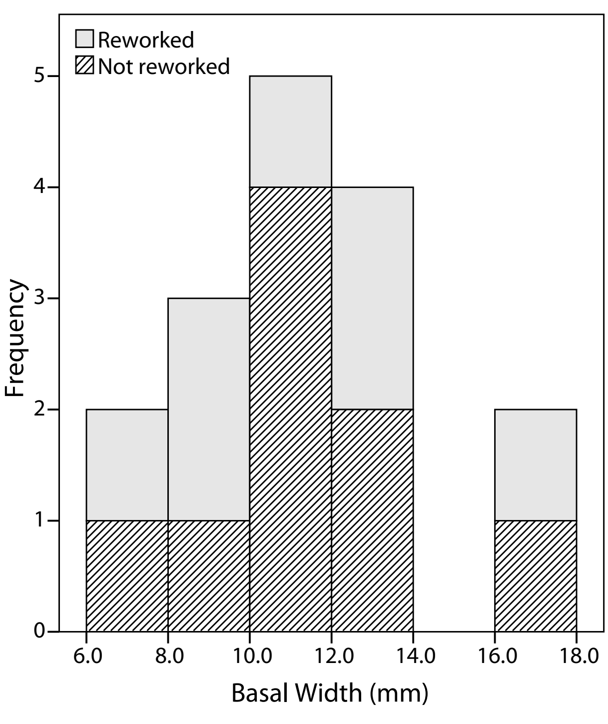


Figure 6.18. Basal widths of 16 Agate Basin points from Beacon Island.

to-width ratio line in figure 6.16. Assuming a uniform outline shape based on the 4.2 ratio, the narrowest base could have come from a complete point that in its original form was just 55 mm long.

In sum, these data suggest that Agate Basin points initially conformed to one of two basic morphological modes. A majority originally exhibited a consistent or standardized mean length-to-width ratio of about 4.2 but varied greatly in size, from a minimum of about 55 mm to a maximum in excess of about 135 mm. A minority exhibited length-to-width ratios between 6.4 and at least 7.3. All of these "megapoints" are long, though at present the sample is too small to determine whether they exhibit a uniform length-to-width ratio. The small point from Hell Gap, with a length-to-width ratio of just 3.06, does not conform to either mode. Unfinished points from the Silver Mound site in Wisconsin exhibit similarly low ratios (Hill 1994:Table 3), suggesting the possibility of a third morphological type.

The existence of at least two Agate Basin original point morphologies suggests that there may also have been at least two distinct use-life trajectories or rejuvenation strategies. Bradley (2010:483, Figure 9.21) argues that Agate Basin points were designed so that multiple broken segments, including tips, midsections, and bases, could be reworked into a series of shorter points. The example he illustrates is one of the megapoints from the Agate Basin site included in this study. By contrast, the generally shorter length of the standard-ratio points, especially those that were originally shorter that about 110 mm, likely precluded this strategy. Instead, broken tips and blades were reworked while the point was still in the haft, sometimes producing a relatively blunt point with an asymmetrical cross section.

Figure 6.19 illustrates the size and shape differences between reworked and unaltered points. The upper reference line represents the standard mean length-to-width ratio of seven complete, unmodified points (which, again, excludes the single complete megapoint from Agate Basin and the short point from Hell Gap). The lower reference line represents the mean ratio of 29 complete, but reworked, points from Beacon Island, Agate Basin, Frazier, and Hell Gap. The length-to-width ratios of the reworked points are less uniform than those of the standard-ratio points, suggesting that the resharpened specimens include both re-tipped standard-ratio points and reworked segments of megapoints. Several reworked specimens lie close to or even above the standard-ratio line and therefore likely represent rejuvenated segments of megapoints. However, most reworked points fall into an elongated cluster well below, but parallel to, the standard-ratio line, suggesting that the majority of reworked specimens originally exhibited the standard-ratio form.

This interpretation is bolstered by data on reworking location (figure 6.20). The majority of points exhibit reworking on the distal end, including the tip, blade, or tip and blade. This is the pattern one would expect

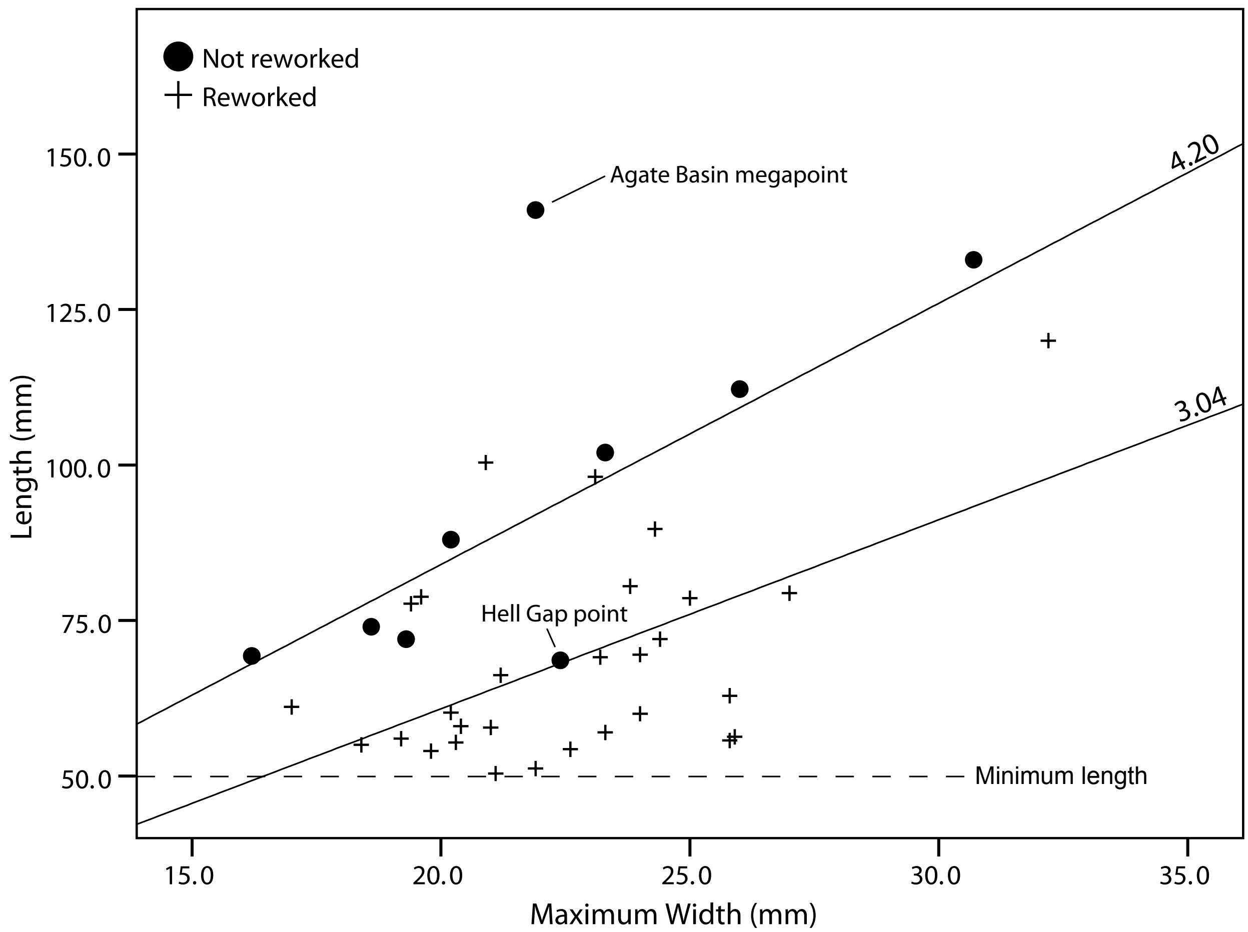


Figure 6.19. Lengths and maximum widths of reworked and unreworked complete Agate Basin points.

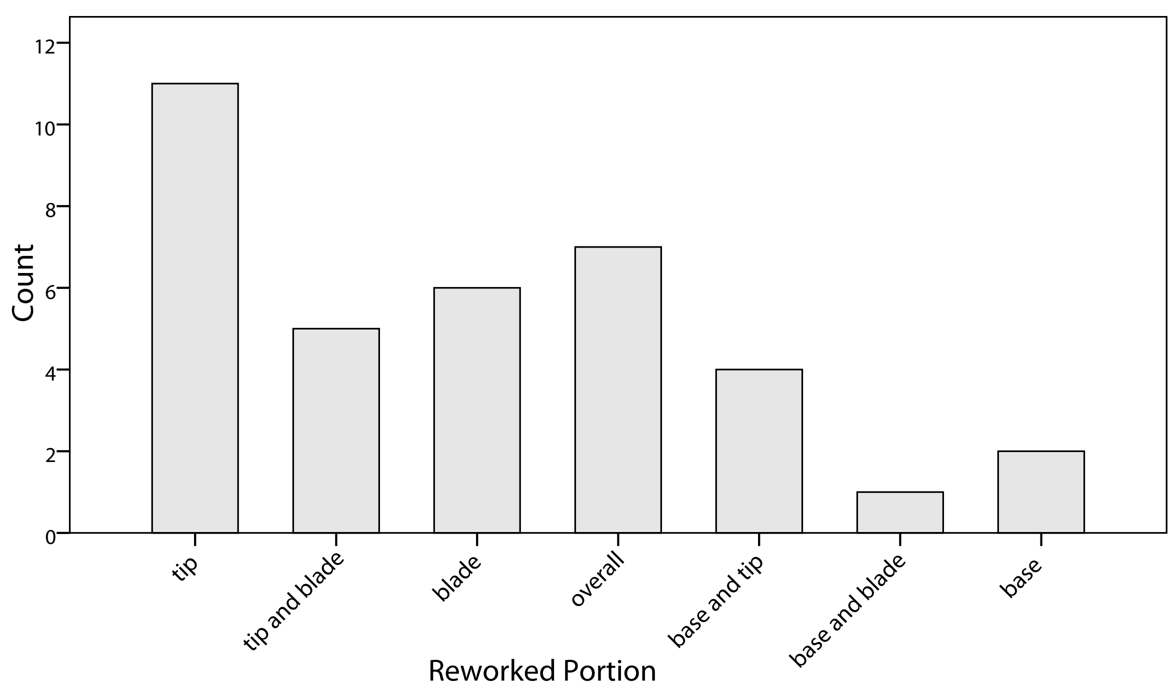


Figure 6.20. Location of reworked portion of 29 complete Agate Basin points.

to see if the majority of reworked points originally had the standard-ratio form. However, 39 percent of the points exhibit some evidence for reworking on the base, suggesting that they could represent segments of megapoints. It is relevant to note that, while the data collected for this study are not directly comparable to Peterson's (1978) data, they do support his conclusion that rejuvenated points were more commonly produced from bases than from tips or midsections.

The data shown in figure 6.19 also indicate that the minimum length Agate Basin flintknappers considered suitable for a serviceable point is around 50 to 55 mm. Bradley (2009a) suggests a similar minimum length, though he observes that serviceable specimens longer than 55 mm were abandoned at Hell Gap, which he finds difficult to square with the notion that there was a definite minimum suitable length. (Bradley notes that the Hell Gap assemblage includes a biface measuring just 39 mm long. However, this specimen lacks lateral or basal edge grinding and so is excluded here. The Beacon Island surface assemblage includes a similar biface lacking edge grinding that is estimated to have been 46.4 mm long (Specimen 22 [Ahler 2003a]); that specimen is also excluded from this analysis.)

## Spatial Patterning in the Agate Basin Assemblage

Two types of spatial data are considered here. The first part of the discussion examines the distribution of tools and flaking debris within the excavation blocks. The second part presents spatial data on the tool conjoin and flaking debris refit study.

### *Flaking Debris Distributions*

Figure 6.21 illustrates the distribution of the coarse-fraction flaking debris within the main excavation blocks. Flakes occur in many excavation units, but mostly are scattered around the perimeter of the butchery area, away from the densest concentrations of bone scrap (see figures 3.48, 3.49, and 3.50 for additional details). The largest number of flakes occurs in the southern end of the northwest block. Flakes made from Antelope Chert are concentrated on the north end of the northwest block (figure 6.22). A tested cobble and a core made from Antelope Chert also were recovered from these squares, and several more flakes and cobbles of this material were recovered from the surface a few m to the north. These data indicate that a flake production work area is preserved in this part of the site.

Somewhat different patterns are evident in the distribution of the fine-fraction flaking debris (figure 6.23). Compared with the coarse-fraction debris, a higher proportion of the size grades 4 and 5 flakes are associated with concentrations of highly fragmented bison bone. For instance, square 1277NE1119 contains over 11.2 kg of unidentified bone scrap, along with 45 size grades 4 and 5 flakes. Both of these figures represent the highest recorded anywhere in the northeast block. The same pattern is evident in the southwest corner of the northwest block, which also contains relatively large numbers of fine-fraction flakes associated with large amounts of bone scrap.

However, the largest concentrations of small flakes occur away from the main butchery areas. Four excavation units produced more than 70 fine-fraction flakes. These include the three westernmost units within the kettle basin (squares 1262NE1099, 1253NE1099, and 1272NE1100) and one unit on the south end of the northwest block (square 1278NE1112). The latter unit also produced the largest number of coarse-fraction flakes (figure 6.21). This suggests that a tool maintenance activity area is preserved in this part of the site. Fine-fraction flakes are also relatively abundant in the southwest part of the north block, suggesting that this activity area extends into the unexcavated area between the north and west blocks and south of the northwest block.

By contrast, only three larger flakes occur in just one of the three westernmost units (square 1263NE1099). Only 1.6 kg of bone was recovered from these three units. Many of the small flakes there are burned: 52 percent of the size grades 4 and 5 flakes from the three western units show evidence of thermal alteration, compared to just 18 percent of the fine-fraction assemblage as a whole. Almost 90 percent of the 114 small flakes from 1272NE1100 are burned. (Burning is less common in square 1272NE1112 in the northwest block, with only 3 of the 122 flakes from that unit showing evidence of thermal alteration.) These data suggest that yet another activity area, likely associated with one or more hearth features, exists west and south of the butchery area. Six tool fragments, all made from KRF, were recovered from these units. Square 1262NE1099 produced two flake tools, one of them burned. Square 1272NE1100 produced four projectile point fragments, all of them burned. These four fragments do not directly conjoin, but likely derive from a single Agate Basin point. While the dearth of excavation units in this part of the site limits what can be said about the tasks carried out there, the distinctive character of their modified stone assemblage suggests that it was something other than carcass processing. Given the prevalence of very small flakes, intensive weaponry refurbishing is likely.

### *Tool Conjoins and Flaking Debris Refits*

Laughlin and Kelly (2010) define a "refit" as a match between the ventral face of one flake and the dorsal

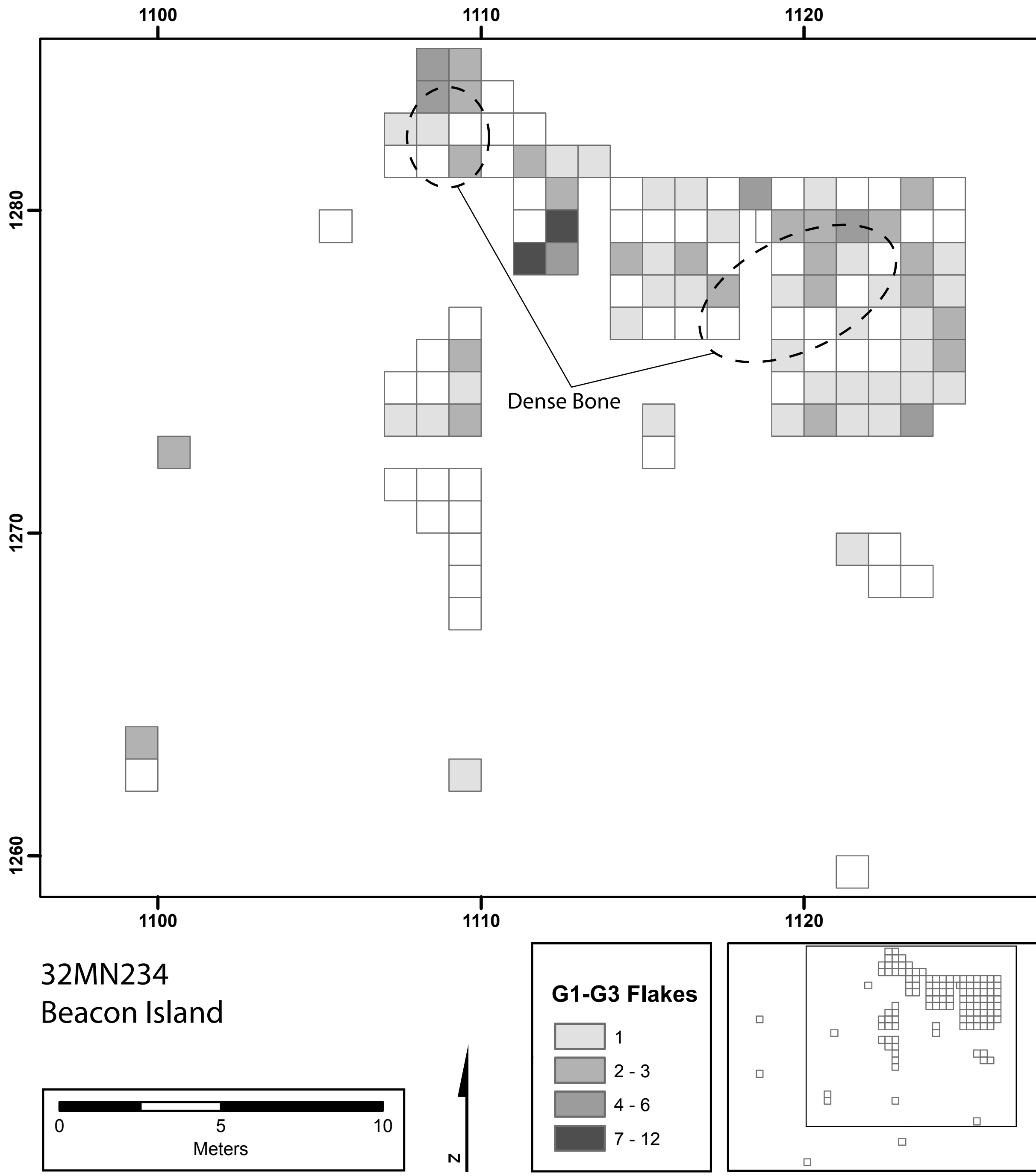


Figure 6.21. Distribution of coarse-fraction flaking debris.

face of another and a "conjoin" as a match between the distal end of one object and the proximal end of another. A total of 32 modified stone specimens in the Beacon Island assemblage refit or conjoin to form 13 composite items. The conjoined items include nine projectile points, one flake tool, one tested cobble, and one core. Two unmodified flakes also refit.

The nine composite projectile points are comprised of twenty-two fragments (table 6.35). Each of the composite points is made up of two to four fragments. Four other fragments do not directly refit but almost certainly represent a single artifact based on their provenience and condition. Thus, the 55 point fragments in the collection represent no more than 39 original points. Sixty-seven percent of these are made from KRF, while 28 percent are made from Antelope Chert.

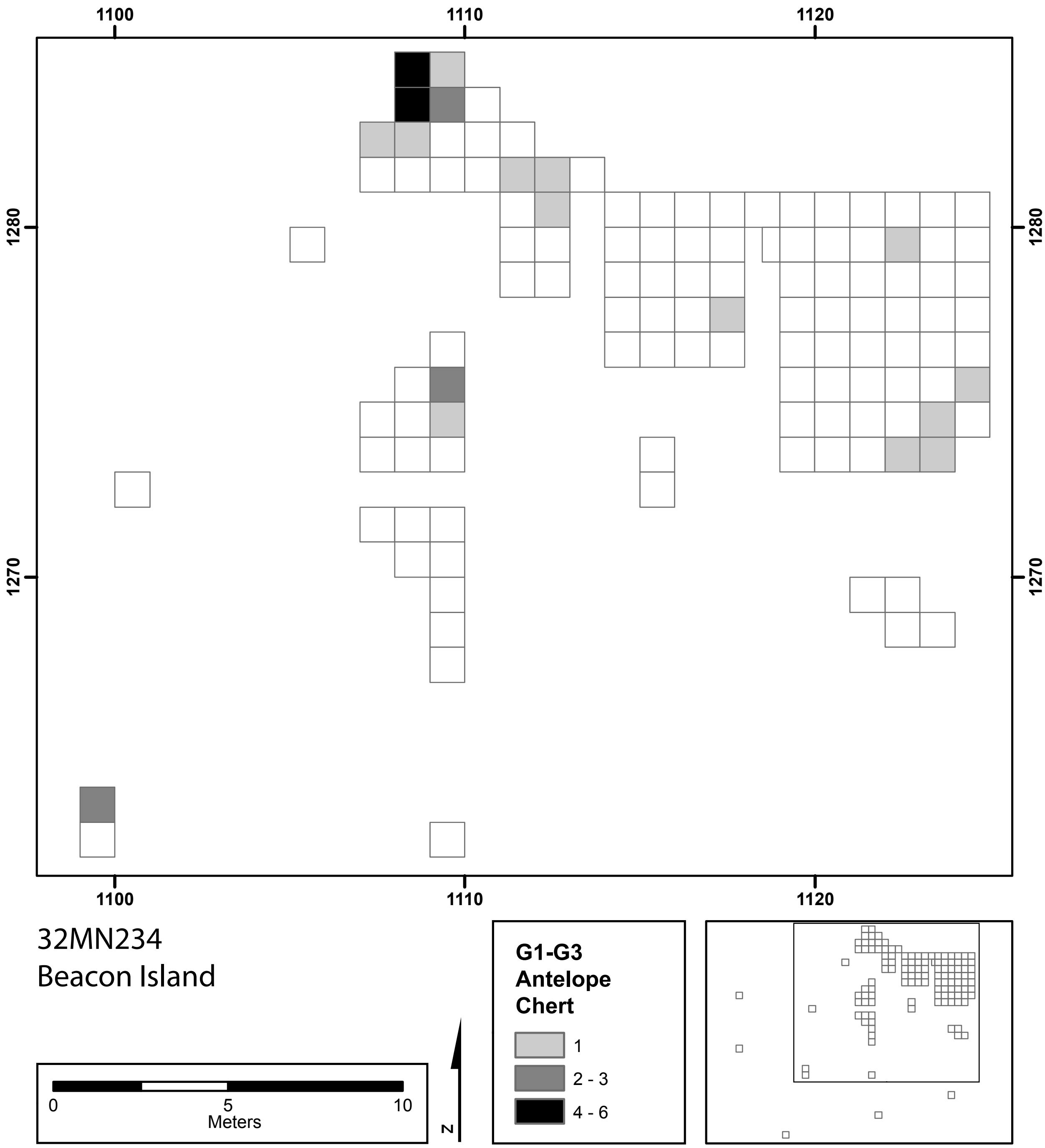


Figure 6.22. Distribution of Antelope Chert coarse-fraction flaking debris.

Figure 6.24 illustrates the locations of refitted and conjoined items from the northwest block. Figure 6.25 illustrates conjoins from the north and northeast blocks. In three cases, including two in the northwest block and one in the north block, conjoined projectile point fragments are represented by a single marker because the constituent items were recovered from waterscreened level lots. The single marker is positioned at the center of the excavation unit. In addition, two composite points recovered from the northeast block incorporate fragments recovered by both piece plotting and waterscreening. One of these includes three plotted items and one item recovered from a level lot. The other includes one plotted item and one waterscreened item. In both cases, the

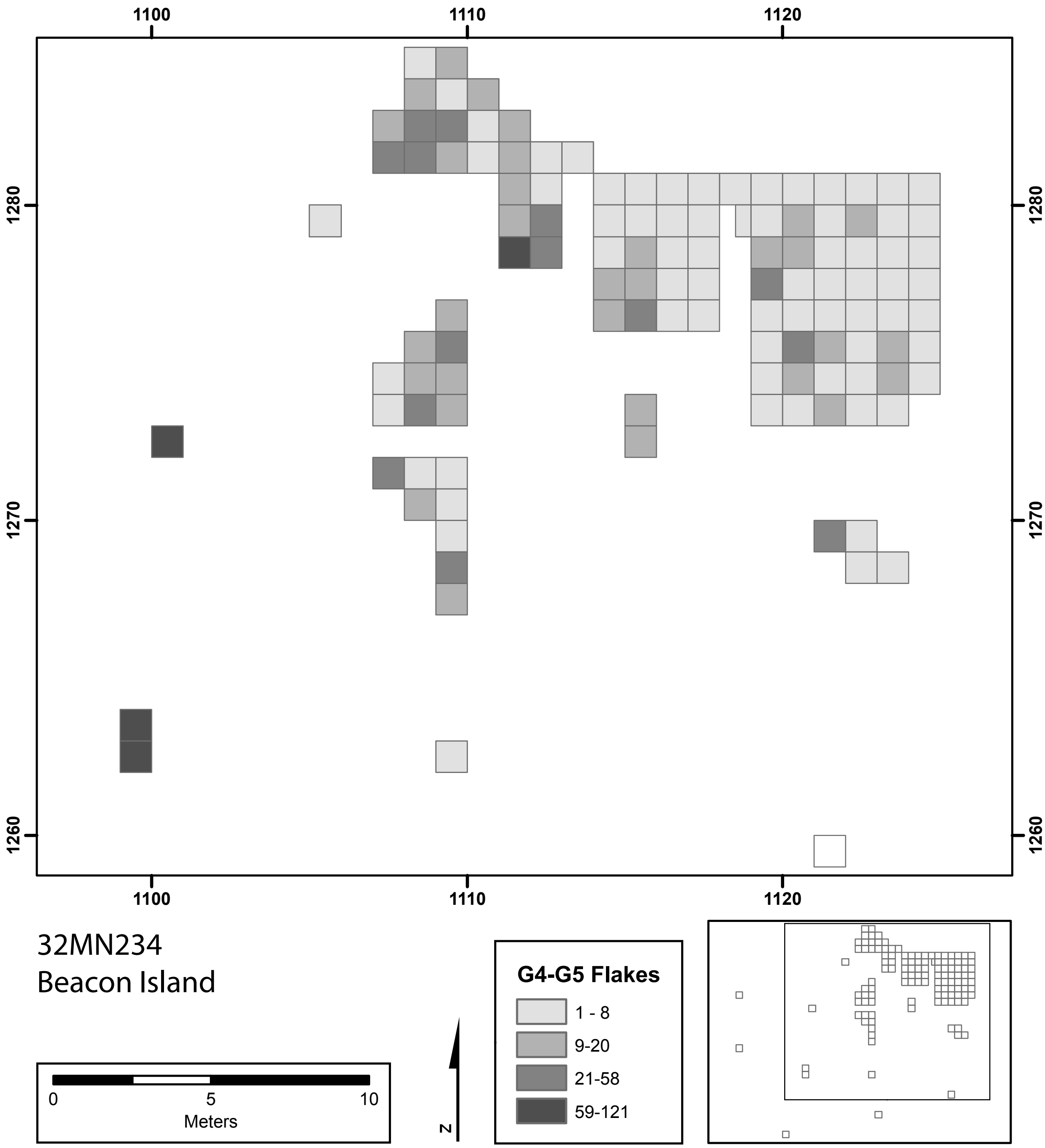


Figure 6.23. Distribution of fine-fraction flaking debris.

markers for the fragments recovered by waterscreening are positioned in the center of the excavation square. Note that the probable conjoin listed in table 6.35 comes from square 1272NE1100, an isolated 1 x 1 m unit west of the bonebed, and is not illustrated here.

Five composite items were recovered from the northwest block. This includes two projectile point fragments, one core, one tested cobble, and one flake refit. The projectile points are made from KRF and both are burned. The other items are made from Antelope Chert. Recall from the previous section that a scatter of Antelope Chert flaking debris also occurs in the northern part of the northwest block. The cluster of conjoined and refitted items illustrated in figure 6.24 therefore can

Table 6.35. Summary data on conjoinable projectile point fragments.

| | Number of Fragments | Estimated Number of Points | Raw Material Type: Swan River Chert | Sentinel Butte Flint (?) | Knife River Flint | Antelope Chert |
|---|---|---|---|---|---|---|
| Single item points | 29 | 29 | 1 | | 18 | 10 |
| Multiple item points | 26[a] | 10 | | 1 | 8 | 1 |
| Total | 55 | 39 | 1 | 1 | 26 | 11 |

[a] Includes four items that probably conjoin into a single point.

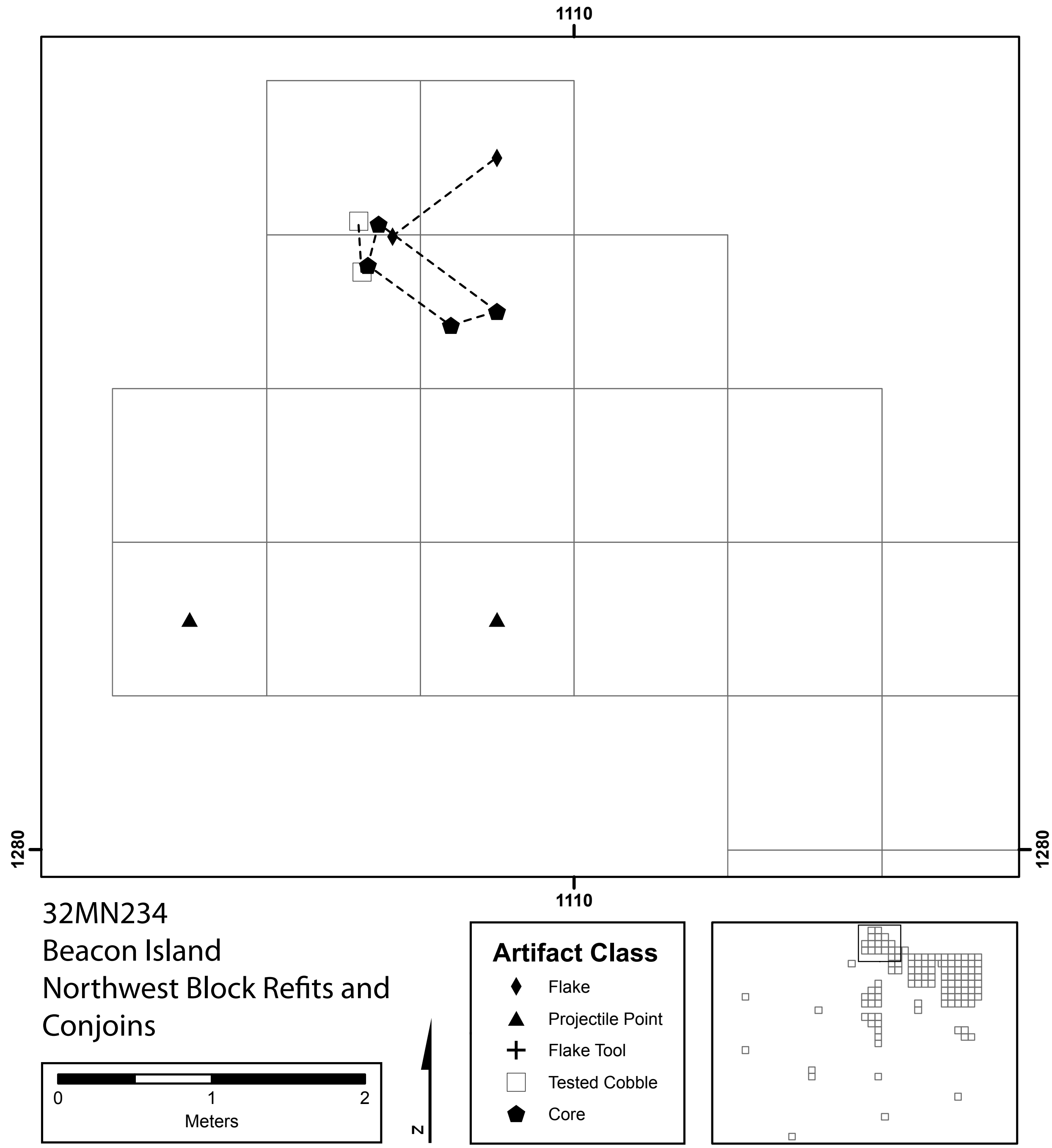


Figure 6.24. Flaking debris refits and stone tool conjoins in the northwest block.

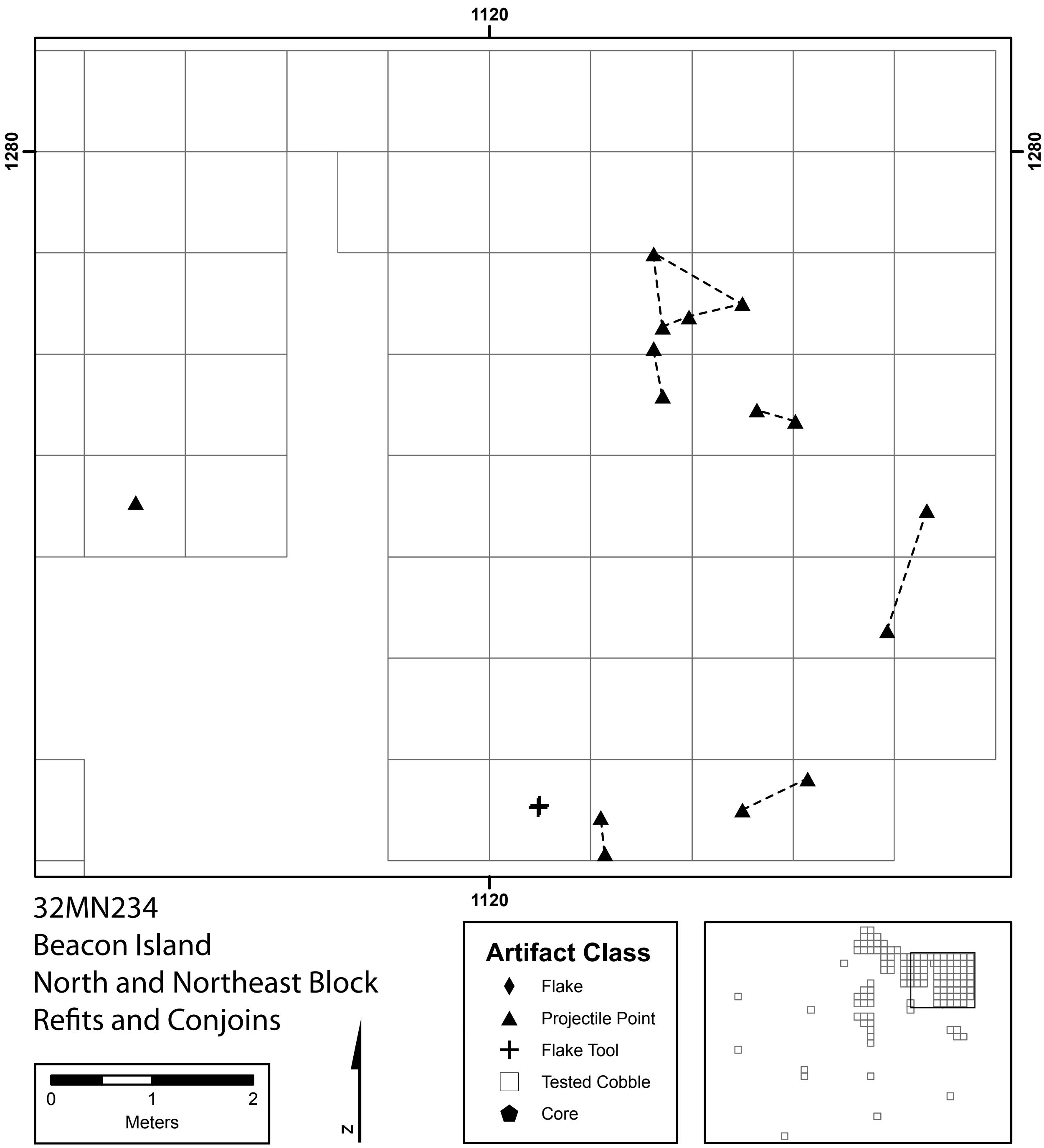


Figure 6.25. Stone tool conjoins in the north and northeast blocks.

be interpreted as a preserved activity area devoted to Antelope Chert flake production.

Eight composite items occur in the north and northeast blocks (figure 6.25). One is a large KRF retouched flake tool exhibiting intensive use-wear (figure 6.9c). The other seven are projectile points. The single projectile point conjoin from the north block (recovered by waterscreening) is made from a gray chalcedony that may come from Sentinel Butte. Five of the six projectile point conjoins from the northeast block are made from KRF. The sixth is made from Antelope Chert.

The mean distance between plotted matched specimens (which account for 13 of the 19 individual refits or conjoins) is 53.2 cm, with a range of 3 to 126 cm. By contrast, the distances between conjoined items at the Agate Basin site ranges from about 35 cm to 10.5 m (Frison and Stanford 1982a:Figure 2.77). The proximity of conjoined and refitted items at Beacon Island indicates that post-occupation lateral displacement of artifacts (and, presumably, faunal remains) was limited.

### Summary

Little can be said definitively about the Holocene components documented in Area A, given their overall low artifact density and the limited extent of the excavation units exposing them. Far and away the most significant of these is an early Holocene occupation exposed near the base of square 1308NE1055. The unusually high density of flaking debris in this lower component indicates rather intensive use of the area, but without additional data it is impossible to speculate on the nature of that use. The Holocene component overlying a portion of the Agate Basin component in the eastern kettle basin appears to represent a comparatively ephemeral use of the area.

Before summarizing data on the Agate Basin component it is relevant to call attention to several caveats. Recall from chapter 3 that circumstantial evidence suggests that around half of the occupation area may have been stripped away by both recent and ancient erosion. The eroded portion likely contained the kill location itself, east of the butchery area exposed in the excavation blocks. In addition, the butchery area almost certainly extended northward, perhaps as much as 10 or 15 m.

In addition, the flaking debris distribution suggests that several unexplored parts of the site may contain additional activity areas, including the southwest portion of the kettle basin, west of the west excavation block, as well as an area near the center of the basin between the west and north excavation blocks and adjacent to the hearth documented in 1272NE1115. If so, activities not represented in the existing collection could also have taken place in Area A concurrent with carcass processing.

Several lines of evidence indicate that the excavated deposits are relatively well preserved. The vertical and horizontal distributions of bison bone (discussed in chapters 3 and 5) suggest that post-occupation displacement was limited. These data are bolstered by the stone tool conjoin data that indicate only limited lateral movement of artifacts and, presumably, faunal remains. Some vertical movement of artifacts is evident, if one assumes that Antelope Chert was used only during the Agate Basin occupation of Area A (see chapters 3 and 4 for additional data). Concentrations of flaking debris in two parts of the northwest block, as well as the overall distribution of faunal remains, further suggest that activity areas at the site are relatively intact. The high frequency of marked differential patination in KRF projectile points suggests that these artifacts remained in position, with the patinated side facing upward, from the time they were lost or discarded. In sum, the Agate Basin-age deposits appear to represent a single occupation that was buried relatively rapidly and disturbed only minimally after burial and therefore preserve with some fidelity the original spatial structure of the occupation.

Both aggregate and individual flake data indicate that late-stage reduction primarily was applied to tools made from Swan River Chert and KRF. Weaponry rejuvenation, mainly by pressure flaking, as well as flake tool resharpening, is indicated. However, the presence of cortical platforms on some KRF flakes, and on one Swan River Chert flake, also indicate that these materials were used in core reduction, an interpretation corroborated by the presence of two exhausted KRF cores in the tool assemblage. The presence of one bipolar flake made from KRF may indicate limited bipolar reduction of that material. This interpretation is bolstered by the presence of several KRF bipolar nodules and a possible bipolar anvil exhibiting small-scale pitting on one broad face.

Antelope Chert was used in a somewhat different manner. Some late-stage reduction is indicated for Antelope Chert, but this material was used more commonly than KRF or Swan River Chert to produce larger flakes, mostly from irregular, tabular cores. These cores exhibit relatively poor conchoidal fracture, compared to the projectile points and large flake tools made from the same material, suggesting that they derive from a different quarry locality.

While it is possible that the large flakes used as butchery tools were produced at Beacon Island, several lines of evidence suggest instead that they were transported to the site. Quality differences in the flaking debris assemblage indicate that the Antelope Chert flake tools were not struck from the cores recovered from the butchery area. The excavation recovered very few larger pieces of KRF flaking debris, of the size one might expect to be produced during the reduction of cores or bifaces large enough to produce the flake tools. Several of the larger flake tools also exhibit macroscopic dorsal wear patterns suggestive of long-distance transport.

The technological and functional diversity of the Beacon Island stone tool assemblage is low compared to other Agate Basin kill-butchery localities. The Beacon Island collection is dominated by weaponry and butchery tools. The latter includes flake tools used for cutting and scraping, but also pounding and chopping tools and large clasts that may have been used to break bone. No patterned, hafted scraping tools are present in the collection. By contrast, end scrapers occur at both the Frazier site and the Agate Basin site (Frison and Stanford 1982a; Slessman 2004). Two graving tools were recovered from Area A at Beacon Island, one of which definitely is associated with the Agate Basin component. However, the Frazier assemblage includes 26 gravers and a number also occur at Agate Basin.

Unhafted large patterned bifaces, representing various reduction stages, occur at both Frazier and Agate Basin, but are nearly absent at Beacon Island. Many of the finished bifaces at Agate Basin have a distinctive asymmetrical outline shape (Frison and Stanford 1982a:Figure 2.72). The shapes of the two unhafted biface fragments from Beacon Island cannot be determined, though it is possible that the larger of the two might originally have had a similar form.

Finally, flake tools bearing distinctive notch-shaped working edges occur in the Frazier and Agate Basin assemblages, but not in the Beacon Island assemblage. While it is certainly possible that the minimally explored southwestern part of the eastern kettle basin at Beacon Island preserves evidence of activities other than bison butchery, it is relevant that the more-diverse toolkits at Agate Basin and Frazier were primarily recovered from within and immediately adjacent to the carcass processing area. In sum, the Beacon Island assemblage reflects a rather narrowly focused, and likely comparatively brief, occupation.

Because the weaponry from Beacon Island includes only finished specimens, the collection yields little data on Agate Basin point production techniques. At least one was manufactured on a thin, tabular piece of stone. Limited evidence, in the form of broad, relatively featureless flake scars on some points, lends support to Bradley's (2009a:265) view that the middle stage of point production involved "widely spaced full-face" percussion flaking designed to establish a flat longitudinal section. With a single exception—a point base that is technologically congruent with the "Goshen" type—the point assemblage conforms closely to Bradley's descriptions of the later stages of Agate Basin production technology. Remnant flake scars are shallow, comedial to transmedial, and evenly spaced, but not serial. The points were finished with selective invasive and abrupt marginal retouch. Lateral margins are ground or polished. Grinding on the base is comparatively light or absent. Heat treated stone seems only rarely to have been used.

Metric data on points from the Beacon Island and Agate Basin sites suggest that Agate Basin flintknappers produced weaponry according to at least two different morphological modes. The more common mode exhibits a relatively standard length-to-width ratio of about 4.2. The less common mode includes comparatively long points, with length-to-width ratios greater than about 6.4. It is likely that the life-histories of these megapoints differed from those of the more common standard-ratio points. As Bradley (2010) argues, megapoints might break into two or three sections, each of which easily could be reworked into a serviceable weapon. By contrast, reworking of standard-ratio points mainly involved re-tipping, perhaps while the base was still in the haft. In either case, rejuvenation of damaged weaponry was an integral aspect of Agate Basin technology, which was carried out habitually at both camps and kill-butchery sites. In fact, many of the point fragments recovered from Beacon Island were reworked sometime prior to the kill there.

A diversity of raw materials was used to make the Beacon Island projectile points, but all of them can be found in southwestern North Dakota, and virtually all occur within 75 km of the site. This pattern differs from that seen at the Frazier and Agate Basin sites. Figure 6.26 shows the proportions of different artifact classes made from local and non-local raw materials at three Agate Basin sites. At each site, local materials dominate the flaking debris assemblage. Small percentages of the non-weaponry tools at Agate Basin and Frazier were made from non-local materials. The most notable difference among the sites lies in the materials used to make projectile points. At Frazier the majority was made from Hartville Uplift chert, a non-local material there (Slessman 2004). In the Agate Basin sample analyzed by Carolyn Craig (1983), just under half were made from non-local materials, including KRF. At Beacon, one specimen may have been made from a non-local raw material (Sentinel Butte Flint); however, the identification of this material is uncertain. All of the others were made from locally available stone. Conspicuously absent are points or other tools made from Hartville Uplift cherts, White River Group silicates, or Morrison formation quartzite. In fact only the barest hint of long-distance travel or interaction is provided by the two small White River Group silicate specimens in the flaking debris assemblage. The diversity of local raw materials at Beacon Island suggests that the band responsible for the kill there was intimately familiar with the immediate region, but had only limited contacts with distant groups. If they traveled outside the region during a part of the year, they must have been resident in and around the Missouri River valley long enough to exhaust or discard any tools made from non-local sources.

## Conclusion

The interpretations developed in this chapter permit a reasonably clear picture of the Agate Basin use of Area A. The toolkit the hunters brought to Beacon Island included projectile points, many of which had been retrieved and refurbished from an earlier kill, along with a selection of large flake tools needed for butchery and cores needed for flake production. Several nodules of low-quality Antelope Chert likely were picked up just prior to the

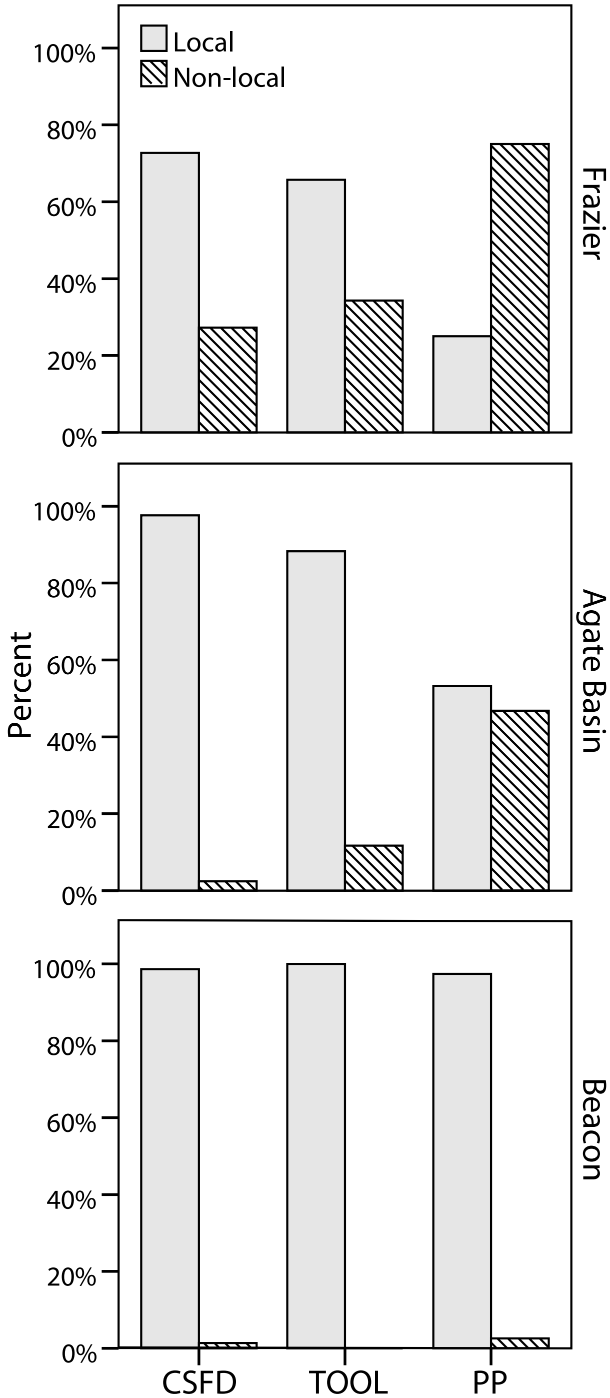


Figure 6.26. Proportions of flaking debris (CSFD), non-projectile tools (TOOL), and projectile points (PP) manufactured from local and non-local sources at three Agate Basin sites.

kill. Cobbles for breaking open bison long bones were obtained in the immediate vicinity.

The majority of the animals brought down in the kill were thoroughly butchered (see chapter 5). During processing, the group recovered and rejuvenated serviceable point fragments, leaving behind segments deemed unsuitable for further use as weaponry and points or fragments lost in minimally butchered carcasses. Several of the retouched flake tools brought to the kill were either broken or lost during butchery. The hunters produced additional flake tools, in the process exhausting several KRF cores. Several larger, lower-quality Antelope Chert cores used for expedient flake production were left behind when the group returned to their camp.

The hunters built a number of small fires adjacent to the butchery area (see chapter 3), but the evidence in hand suggests that they mostly limited their activities at Beacon Island to carcass processing and weaponry refurbishment. Evidence for biface production is entirely lacking. The overall low diversity of the tool kit indicates that they placed little or no emphasis on ancillary activities such as hide processing, bone ornament or tool manufacture, or woodworking. Instead, they focused their efforts narrowly on the immediate tasks at hand.

The diversity of local stone tool raw materials in the assemblage indicates that the hunters were well familiar with the local landscape, but that their contact with distant groups (or their direct experience of distant landscapes) was limited. With the exception of two flakes made from White River Group silicate, and one point possibly made from Sentinel Butte Flint, all of the flaking debris and stone tools recovered from Beacon Island are made from materials that occur naturally within a maximum of 90 km from the site. Productive sources of most of the materials are in fact readily available within a one- or two-day walk. Together, these data suggest that the Agate Basin occupation at Beacon Island represents one node of a local adaptation.

# 7

## Point Use-wear Analysis and Technological Structure

*Marvin Kay*

Nine Agate Basin points and point fragments and one Goshen point base excavated from Area A are described for microscopic evidence of tool use. The wear traces are consistent with the context of their discovery and include evidence of post-depositional soil movement, of hafting, and tool use. The points were used to kill and then dismember the bison; two point fragments were recycled. Overall, the Agate Basin point maintenance strategy allowed for both bifacial and unifacial blade sharpening, which conserved toolstone and increased the use life and potential utility of the points. In these respects, the overall Agate Basin technological structure is analogous to that described by Ahler and Geib (2000) for Folsom points. While there are obvious formal and other technological differences between Folsom and Agate Basin points, their model is a clue to variability in Agate Basin points found in the bison kill at Beacon Island. Processes by which these artifacts undoubtedly became incorporated into the deposit can be outlined chiefly as being lost in the kill's gore and post-depositional down slope movement within its shallow basin. On the one hand, the artifacts need not be regarded in principle as having no potential utility even when badly broken; while on the other hand, one might anticipate microscopic taphonomic evidence of soil movement on artifact surfaces. As will be shown in this chapter, insights into tool function, possible retention or recycling, plus taphonomic damage are evident from a microscopic analysis of use-wear on Beacon Island points. Taken together, the archaeological contexts of excavated finds and use-wear evidence are used here to model the technological structure of the point assemblage from Beacon Island.

The chapter begins with a description of use-wear findings to help the reader understand both strengths and weaknesses of the methods and the nature of wear traces. The discussion then turns to the results of the analysis, keyed to taphonomic evaluations and individual point types.

### The Sample

Ten bifacial points available for this study represent less than a third of the total number retrieved from Beacon Island. The ten are instructive of the entire point collection, however, because the others are with a couple of exceptions also extensively damaged and reworked (see Bradley 1982:196), and in the same general size range. The sample specimens are made either from Knife River Flint or Antelope Chert, two toolstone resources found in the nearby but not immediate vicinity and generally well suited for microwear examination. The sample came from the bonebed excavations (figure 7.1). Prior to this study they were evaluated for protein residues but none were identified (Girado 2009; see appendix B). The sample consists of nine Agate Basin points, of which only two are complete albeit reworked, and one Goshen point base. The unstudied remainder of the point collection is exclusively Agate Basin. Scale photographs of the largest specimen, which was obtained from the surface and was not examined for microscopic use-wear, are included in the assessment of Agate Basin point technology. It also is used to develop comparative measurements of total length, haft length, and width.

On typological grounds, one might wonder why or how a Goshen point was incorporated into the deposit. While anomalous at first glance, such a co-occurrence is not without precedence. From past analyses, I know of other instances. The Jim Pitts site in the Black Hills of South Dakota has both Agate Basin and Goshen points but differs from Beacon Island in that Agate Basin is distinctly in the minority there (Sellet, Donohue, and Hill 2009). Similarly, an Agate Basin point came from the vicinity of the Hudson-Meng bison kill, located in western Nebraska, that otherwise is dominated by Alberta points. I suspect an exclusively typological approach to point classification for Paleoinidan bison kills has its limitations. The main problem is that the typological approach doesn't seem to square with the social reality of northern High Plains communal bison hunters, who may not have been as consumed with irregularities in point styles. Alternatively, point style differences might as easily reflect the effects of reworking broken points into another form (Flenniken and Raymond 1986; Flenniken and Wilke 1989; Miller 1980). Regardless of which explanation is most likely, there is no reason to doubt the contextual integrity of the Goshen point at Beacon Island (chapters 3 and 6). However, for analytical purposes, it is described separately from the Agate Basin points.

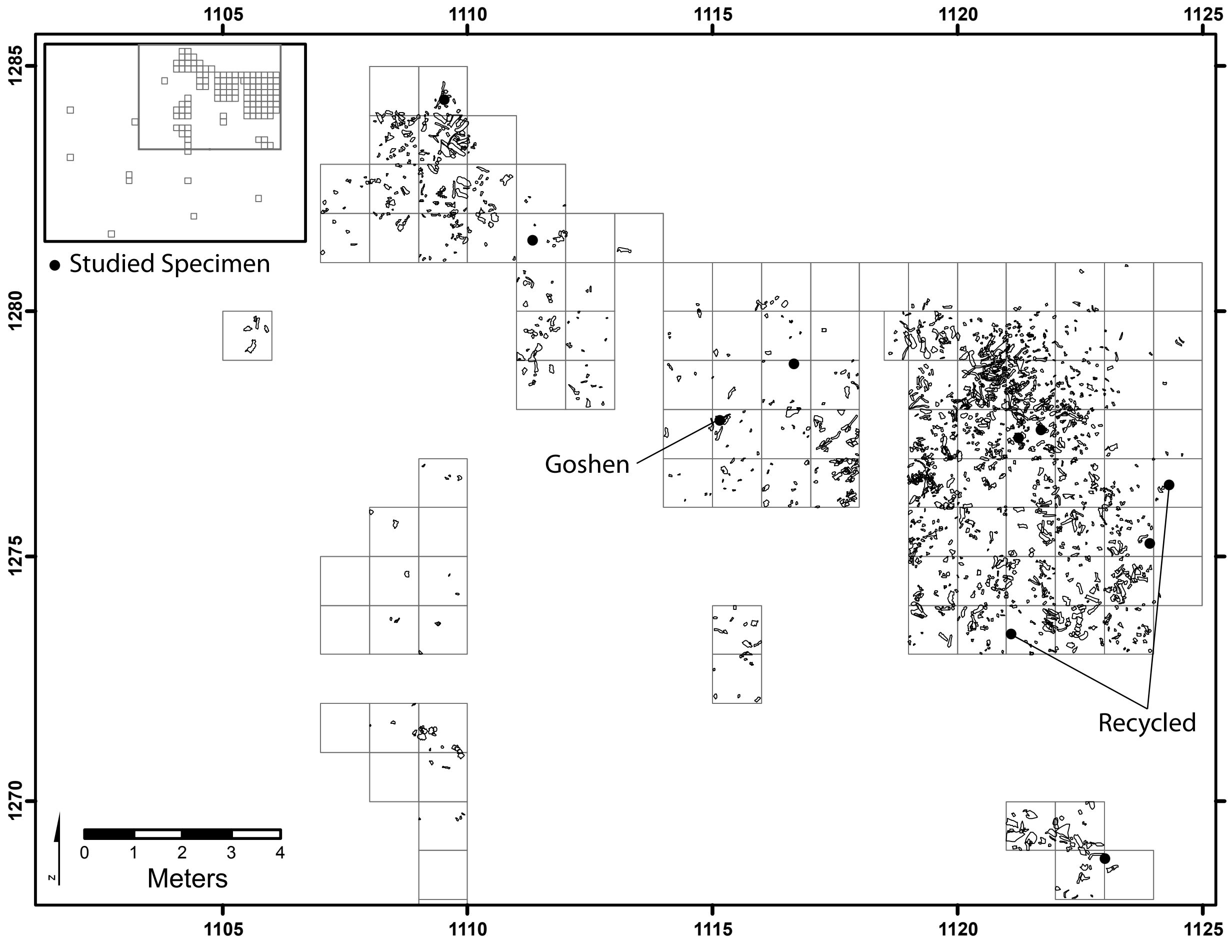


Figure 7.1. Distribution of the studied sample of excavated bifacial points.

## Methods

Use-wear studies rely on realistic experimentation with stone tool replicas to evaluate telltale signs of use on archaeologically obtained artifacts. These include the location of and orientation of discrete, abrasive or additive wear traces. For the Beacon Island site, the microscopic use-wear assessment follows procedures that bridge between traceological (Semenov 1964) and polish formation (Keeley 1980) approaches. These methods are discussed in detail elsewhere (Hardy et al. 2001; Kay 1996, 1998; Kay and Martens 2004). Most important are striations and associated traceological wear that often striate what are likely silica gel residues, or "microplates," on tool surfaces and edges. The microscopy uses a differential-interference binocular microscope with polarized light and Nomarski optics (Hoffman and Gross 1970) at magnifications of 100, 200, and 400 diameters. This microscope affords three-dimensional views with exceptional clarity of microtopography, the capability to enhance microscopic details, and the ability to improve resolution as magnification increases, all of which are essential to a use-wear evaluation. Artifact edges were also inspected with incident light microscopy at magnifications of 5 to 40 diameters to judge crushing and grinding that is relatively common. The analysis presented in this chapter addresses: (1) differentiation between taphonomic alterations and evidence of tool use or hafting; (2) determination of production stages of manufacture-use-recycling; and (3) for those artifacts employed as tools, tool function and likely contact material.

The artifacts were not subjected to further cleaning. Invasive cleaning would have destroyed obvious residues and organic microremains and would not have affected the accuracy and reliability of the microscopic evaluations. The microscopic evaluations systematically covered the edges and surfaces of the artifacts, and took note of edge cross-sectional shape and damage. Wear traces were photographed and their position and orientation on the artifact were recorded on the photographs. Observations about edge damage, tool edge placement and extent, and hafting indicators were also recorded on photographs, which were taken before the microscopic analysis began. Other details of the investigation were recorded on a standard form for each artifact.

Basal and lateral edge grinding was noted on an ordinal scale that, while not perfect, divides simple striking platform preparation from final edge dressing to facilitate hafting. As viewed microscopically, the principal grinding motion is parallel to the edge. This reduces the likelihood of edge failure and step fractures. Striking platform preparation is noted by weak or light grinding in which the edge is dulled slightly but sufficiently to give greater purchase to the indirect percussion removal of flakes. In contrast, moderate to heavy grinding results in a visual flattening and smoothing of the edge to dull the edge so that haft binding materials would not likely be altered or damaged. The extent of lateral edge grinding and the distribution of microscopic haft wear traces on artifact surfaces were used to identify the division between formal haft and blade element areas on the points.

Tool edge angles were measured with a magnification reticle protractor to the nearest five degrees from each artifact's profile. Other linear measurements were recorded with vernier calipers to the nearest 0.5 mm. Mass was measured to the nearest 0.001 g with a digital balance. Some of these data incidental but not essential to the analysis are presented in appendix J.

Photomicrographs were taken initially with a 4 X 5-inch camera with a Polaroid camera back and Polaroid Professional 55 black-and-white positive/negative film. As the analysis proceeded, however, this film stock was discontinued and in its stead, I switched to a digital color camera. Both types of photomicrographs are included in this report. Photomicrographs were digitally scanned and then manipulated with Adobe Photoshop.

Wear trace quantification and statistical evaluation are fundamentals of this analysis. Stone tool wear traces combine abrasion with additions to the tool edge and adjacent surfaces. Their expression depends on the duration and biochemical environments of tool use. Interaction of these variables can result in highly complex wear trace patterns and palimpsests not easily amenable to automated quantification. Thus, priority is given to delineating the sequence and underlying structure of use of stone tools, or what can be better understood as categorical differences among nominal variables, the rank ordering of ordinal variables, and the hierarchical modeling of functional relationships among stone tools (see Spaulding [1982] for a general discussion of these issues). Admittedly, this comes at the expense of a statistically more rigorous assessment of contact material from surface texture comparisons with experimental analogs (for examples of dental wear, see Scott and others [2006] and Ungar and others [2008]).

In its stead, tool edge microgeometry; striation density, placement, and orientation; and residue attributes all differentiate contact materials, although not perfectly. The most conservative approach is to simply regard these as indicators of relative hardness. On an ordinal scale of soft to hard, scraping soft materials tends to round tool edges while hard materials tend to break them or produce relatively angular to subangular cross-sections. A difference between soft plant and hide processing is the character of the polish that develops at and near a tool edge. Herbaceous plant polish tends to be bright, with a melted appearance. This also applies to a large degree for polish due to contact with harder wood too, but with fewer striations. Hide polish tends to have a dull or matt-like appearance and a rough texture, so it is generally easy to distinguish plant from hide work.

Experimental replicas of chipped stone projectile points and knives show unequivocal wear traces (Kay 1996) amenable to this analysis. Briefly stated, projectile point wear traces occur as the tool is used, originate at the tip (or distal end), are invasive, and tend to be oriented parallel to the long axis. Knife wear traces contrast in originating at the blade edges but can be equally invasive in butchering a carcass, so they often crosscut projectile point wear traces when both activities are evident. There may be secondary wear traces in the haft (proximal or basal end) element too due to projectile point penetration or use as a knife.

Having once developed a functional classification of stone tools and other elements of the technology, these technological classes can be evaluated statistically within sample collections. In this chapter, analysis of variance (ANOVA) of sample means for length, width, and thickness of technological types identified by the use-wear analysis is employed to reveal or to reject statistically important differences among them. Whenever identified, statistical differences emphatically support the argument that seemingly subtle differences in form and size differentiate tool function.

## A Note on Wear Traces

Beacon Island point wear traces are largely striated residues, or additive "microplating" features, that develop progressively with tool use (Kay 1996, 1998; see also Banks 2009) that can be either opaque or translucent. Microplating residues are impervious to ultrasonic cleaning with a strong base (KOH) or acid (HCL), occur on siliceous artifacts from varied depositional environments, and are preserved for at least 100,000 years. Experimentation demonstrates that microplating residues develop and harden coincident with tool use, are a biochemical byproduct of moisture and direct contact with a material worked by a stone tool, and in an elegant way express tool motion kinematics. In short, they are friction-related features of surface-to-surface contact. For illustrative purposes, schematic kinematic diagrams are employed to highlight striations and other microplating features. Microplates are likely to be silica gels. They exhibit flow characteristics of a viscous liquid, and desiccation cracks as they harden. Microplating in-fills striations, becomes striated whenever abrasive particles strike, and crystallizes as brilliant white translucent filaments on the trailing (i.e., opposite from the) border of contact with a worked or manipulated material, and thus opposite the direction(s) of movement of a tool stroke. They are also instructive of hand-holding the tool or complementary movement of the tool in its handle. Microplating features are ubiquitous on the artifacts and overprint other tool use-related abrasion and abrasive wear traces.

Microplates exhibit long-term stability and sensitivity to motion, and affect the microgeometry of a tool edge. Microplates bond to stone surfaces and edges as use continues. Experimental controls indicate hardening occurs coincident with use, or shortly thereafter. Unless deliberately removed, microplating so dulls an edge that it can no longer function. Microplates are among the more valuable wear traces; analysis of microplates can identify when a tool no longer had a usable edge as well as the steps taken just before discard of spent tools.

## Results

The nine Agate Basin points and the Goshen point base all have microscopic wear traces. These allow for unambiguous functional classification of the sample, and to a lesser degree insight into post-depositional taphonomic processes. Divided by point type, these results are presented in table 7.1 and described in the following sections.

### Taphonomic Pseudo-wear

Although not compromising functional evaluations of other wear traces, six Agate Basin specimens sustained damage consistent with experimentally produced soil movement. Soil movement abrades microtopographic high and low areas and shows flow characteristics. Flow features show directionally oriented striations, streaks, or pitting and abrasive particles (figure 7.2). In high energy cases, substantial alteration of the microtopography can include highly reflective wave-like and scalloped surface smoothing (figure 7.3). In contrast, actual use-wear traces occur on higher microtopography and are proportionally of lesser extent.

Generalized abrasion is common on both sides of the points and occurs on haft and blade elements of individual specimens, as opposed to being specific to the haft element alone. Were the latter the case, one could argue that this damage is haft wear (Rots 2010). That seems unlikely for Beacon Island, with two notable exceptions, described later, that are arguably haft wear. Three specimens (7 [CN7022], 8 [CN7099], and 9 [CN8311]) have associated metal streaks. This is likely excavation damage and is only partly responsible for the surface abrasion. The remaining specimen (10 [CN8570]) has no metal damage, which also is the case for the two plausible cases of haft wear. In all three of these cases, soil movement damage seems unrelated to the archaeological excavation. In sum, but a single example of soil movement is unambiguous in its bonebed association. It either relates directly to the kill or to post-depositional movement of the bison carcasses. Plant fossils that might be confused as striations are also present on the Antelope Chert specimens but proved no difficulty in the analysis. An example of these fossils is illustrated in appendix K. No pseudo-wear is on the Goshen point base.

Table 7.1. Summary of analytical results.

| Specimen | CN | Type | Raw Material | Completeness | Function[a] | Recycled | Comment |
|---|---|---|---|---|---|---|---|
| 4 | 1836.01 | Agate Basin | Knife River Flint | distal | ppt->knife | no | soil movement |
| 8 | 7099 | Agate Basin | Knife River Flint | distal | ppt->knife | no | soil movement |
| 1 | 8755 | Agate Basin | Antelope | medial | ppt->burin | burin | |
| 5 | 1651.01 | Agate Basin | Antelope | medial | ppt->knife | no | |
| 10 | 8570 | Agate Basin | Antelope | medial | ppt->knife | no | soil movement |
| 9 | 8311 | Agate Basin | Knife River Flint | other | ppt->knife | no | soil movement |
| 7 | 7022 | Agate Basin | Knife River Flint | proximal | ppt->knife | knife | soil movement |
| 6 | 1929.03 | Agate Basin | Antelope | whole | ppt->knife | no | soil movement |
| 2 | 8363 | Agate Basin | Knife River Flint | whole | ppt->knife | no | blood cells? |
| 3 | 9289 | Goshen | Knife River Flint | proximal | ppt | no | |

[a] "ppt->knife" indicates initial use as a projectile and secondary use as a knife; ppt—burin indicates initial use as a projectile and secondary use as a burin.

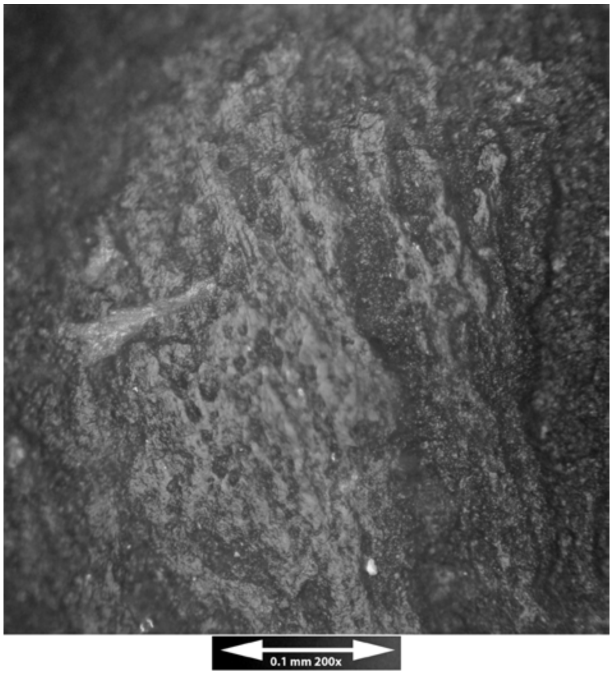


Figure 7.2. Generalized abrasion of microtopraphy on reverse face opposite metal damage on obverse face of Agate Basin point, specimen 8 (CN7099).

Agate Basin Wear Traces

Wear traces on the nine Agate Basin points are separable by discrete functional areas: namely, the blade and haft elements. Haft element wear corresponds in most instances to the maximum extent of lateral grinding of individual specimens. Blade element wear occurs on the edges and surfaces beyond the lateral grinding and ending at the tip. In addition, macroscopic evidence of tip impact breakage and scars correspond to microscopic wear traces. Other breakage of the points, especially where the blade element snapped off, does not have wear traces. Two notable exceptions, however, are ones in which broken points were apparently retrieved, recycled, and then discarded or lost. The other Agate Basin specimens seemingly were not retrieved from the kill, regardless of their size or completeness.

Haft wear traces are somewhat easier to address. The haft element of Specimen 4 (CN1836.01) has extensive abrasive planing of high microtopography but without the wave-like, scalloped smoothing (figure 7.4). This abrasive planing is on both sides and in a patch at the tip on the reverse side. Absent the tip patch, these wear traces conceivably could be haft wear, as could the extensive generalized abrasion with striations obliquely-oriented to the longitudinal axis (figure 7.5) on both faces

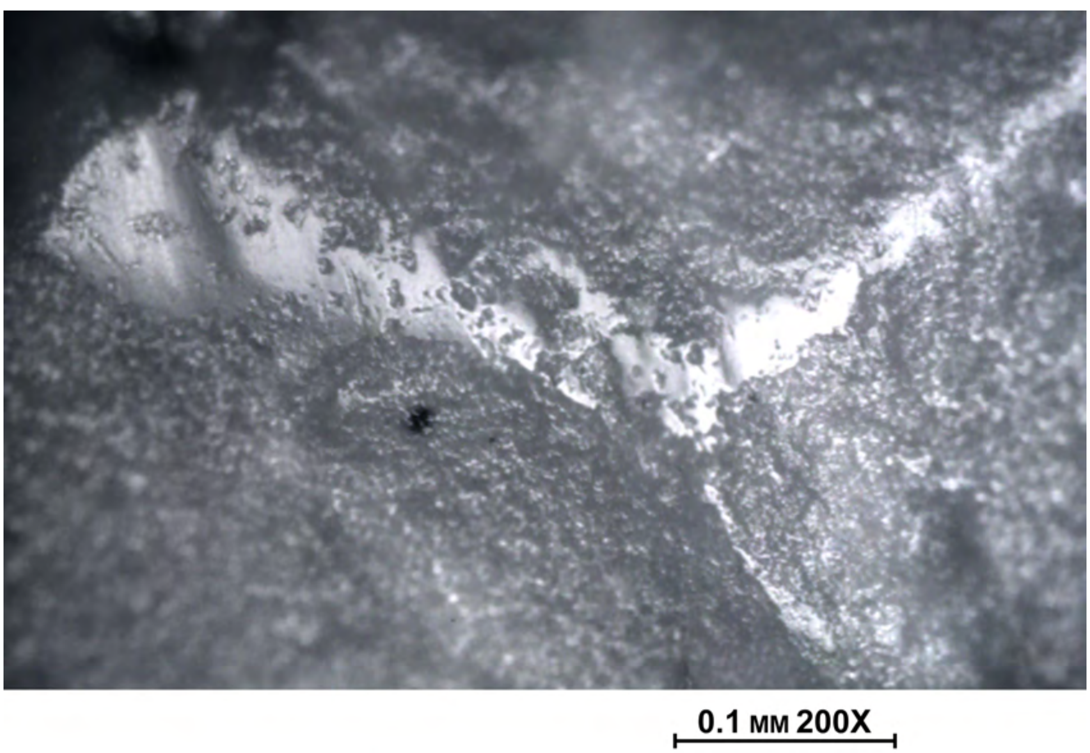


Figure 7.3. High energy soil movement abrasive effects on Gainey point (number: 11-5-593/53) from the Mueller-Keck site, Illinois.

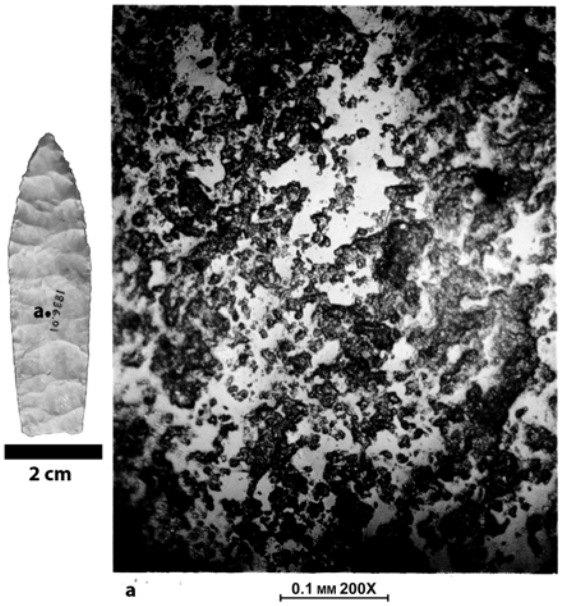


Figure 7.4. Oriented photomicrograph of abrasive planing on Agate Basin specimen 4 (CN1836.01). On this and all similar illustrations, the filled-in circle marks the location of the photomicrograph.

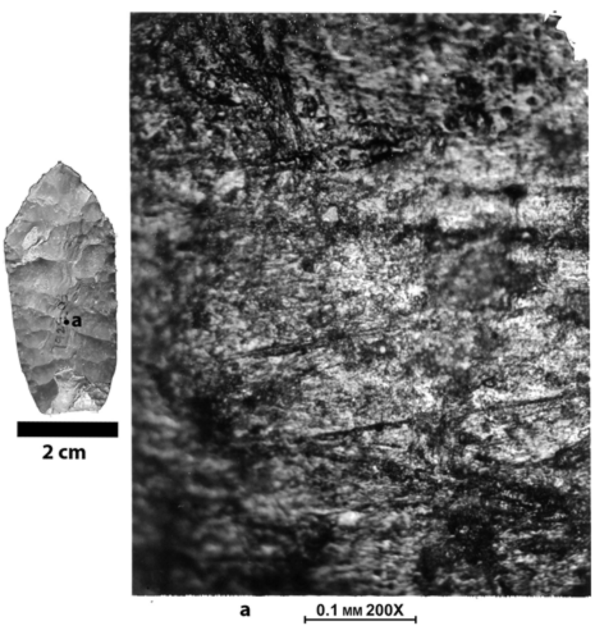


Figure 7.5. Oriented photomicrograph of extensive generalized abrasion on Agate Basin specimen 6 (CN1929.03).

of Specimen 6 (CN1929.03).

Beyond the examples of extensive abrasion just noted, the haft wear appears to have occurred due to slight movement of the specimen in its foreshaft as a byproduct of tool use; these wear areas are extensively microplated. The haft wear traces complement those of the blade element and often seem to define secondary effects of tool use. Two textbook examples are illustrated here (figures 7.6, 7.7, and 7.8).

In the first, note the cross-cutting striations and spherical abrasive particles at opposite ends of striations (figure 7.6) obliquely oriented to the longitudinal axis on the reverse face of Specimen 2 (CN8363). These indicate a back-and-forth movement within the haft at roughly a right angle to the longitudinal axis; compare also to figure 7.5. Interestingly, the microplated haft wear on the obverse face differs significantly in going from extensive generalized abrasion to abrasive planing (figure 7.7). This might be expected of direct surface-to-surface contact with a hard substrate such as bone, antler, or hard wood.

The stark contrasts in haft wear on this Agate Basin point could be accounted for in two ways. Attaching it to a foreshaft did not entail an enveloping resin, or mastic, that would have added greater stability. Had the point been glued to its handle, the striated microplating haft wear would not have occurred. A second factor inferred from and accounting for the wear traces is the reconstruction of the haft itself. Most plausible is for the point's obverse surface to have been in direct contact with a single projecting flat side of the foreshaft. The reverse side would have been wrapped or lashed to it probably with sinew and that encased too the projecting and extensively ground lateral edges. An additional detail is two "cellular" bodies adhering to the haft wear on the obverse face (see especially figure 7.7b). Exactly what these "cells" are is in doubt and they have not been further identified.

In the second, note the rounding of the flake scar arris, the curved striations bordering this arris, and, diagonal to them on the opposite side of the arris (or toward the tip), the crystallization filaments at the ends of the haft striations of Specimen 7 (CN7022) (figure 7.8). These kinematic elements indicate the point rocked slightly back-and-forth within the haft and presumably with impact was pushed back into the haft, creating the crystallization filaments on the trailing edge of the wear traces and opposite the primary direction of haft movement.

Even given the lack of wear trace evidence too for a haft resin or mastic, an inference is that this Beacon Island Agate Basin point contrasts in its hafting approach from that of Specimen 2. It does so in approximately the same way as three other Agate Basin points (Specimens 4, 6, and 9) and the Goshen point base from Beacon Island, and likely would apply equally well to the four mostly blade element Agate Basin specimens. The wear traces document about equal surface-to-surface contact of both faces with the foreshaft. The most logical explanation is a split ended foreshaft into which the point was inserted

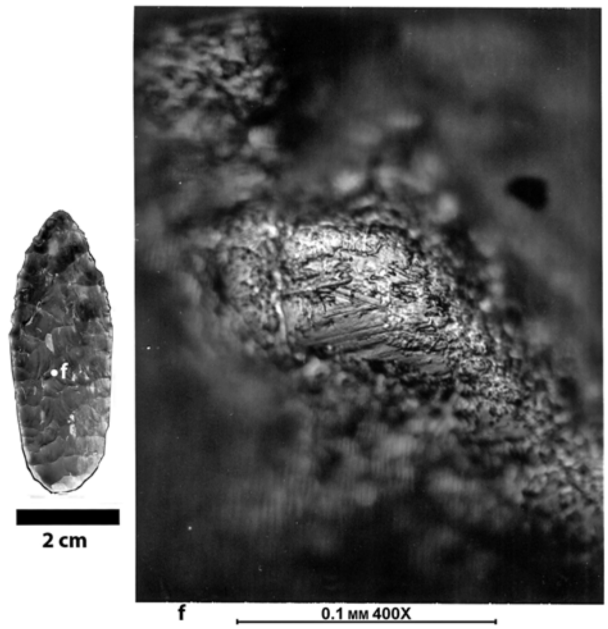


Figure 7.6. Oriented photomicrograph of striated microplating haft wear traces on the reverse face of specimen 2 (CN8363).

and then wrapped or lashed with sinew on the projecting and extensively ground lateral edges. This approach would have been also without the aid of an enveloping resin, or mastic, to better stabilize it.

Agate Basin blade element wear traces are of two functional kinds, those related directly to use as projectile points/knives and secondary recycling of broken points. The former instances apply to all but two of the points. Typically, there is a clear sequencing of tool usages beginning with deliberate employment as a projectile and then as a butcher knife. The net result is that the wear traces are invasive and preferentially located along the longitudinal axis on or about the midline (figure 7.9). They can be traced to both blade edges. The blade edges, however, are generally sharp and often were resharpened, which removed telltale wear traces. Insofar as this is a repetitive pattern, the sequential usage as a projectile point and then as a knife appears to have been anticipated and normal. Undoubtedly, Agate Basin point engineering design considered the likelihood of two sequential primary tool functions plus optional maintenance. As long as the maintenance costs to resharpen the tip and blade edges did not exceed a decline in primary performance, these points would have been—and in fact were—retained whenever possible at Beacon Island.

Recycling appears to have been a corollary to this overall pattern, one in which the cost to maintain the Agate Basin point did, in fact, exceed its intended primary performance. The two examples differ, however, in recycled tool function. Recycling appears simply to have taken advantage in an ad hoc fashion of an already available functional edge or edges without further retouching. In the first case (Specimen 7 [CN7022]), an

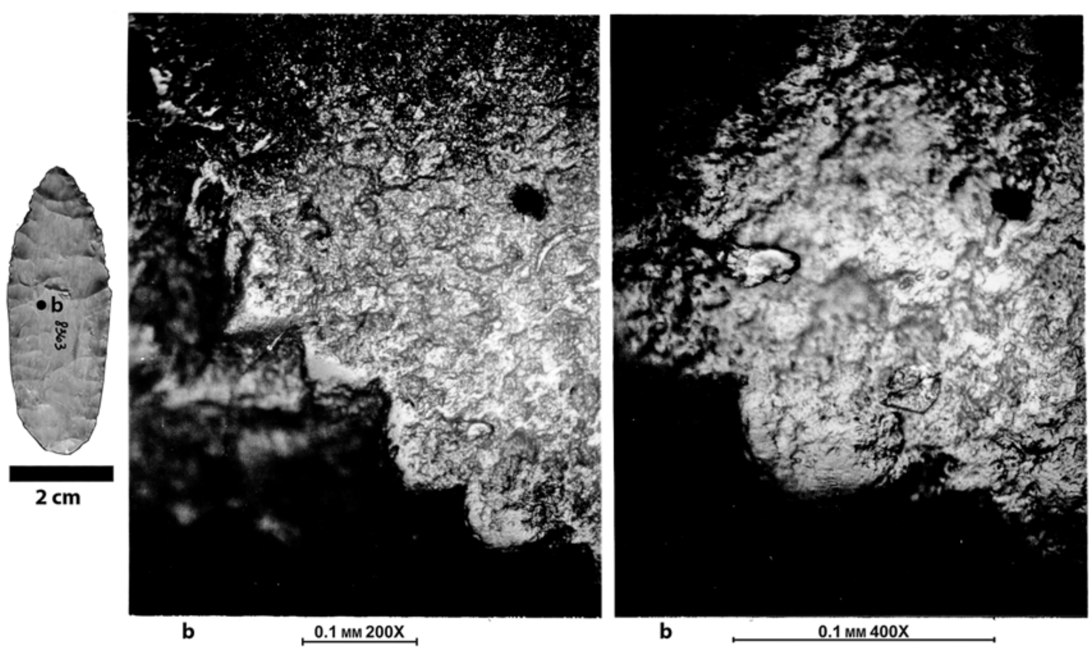


Figure 7.7. Oriented photomicrographs of haft wear abrasive planing on the obverse face of specimen 2 (CN8363). Note also the two “cellular” bodies adhering to the wear traces and best viewed at 400x. Compare with figure 7.6.

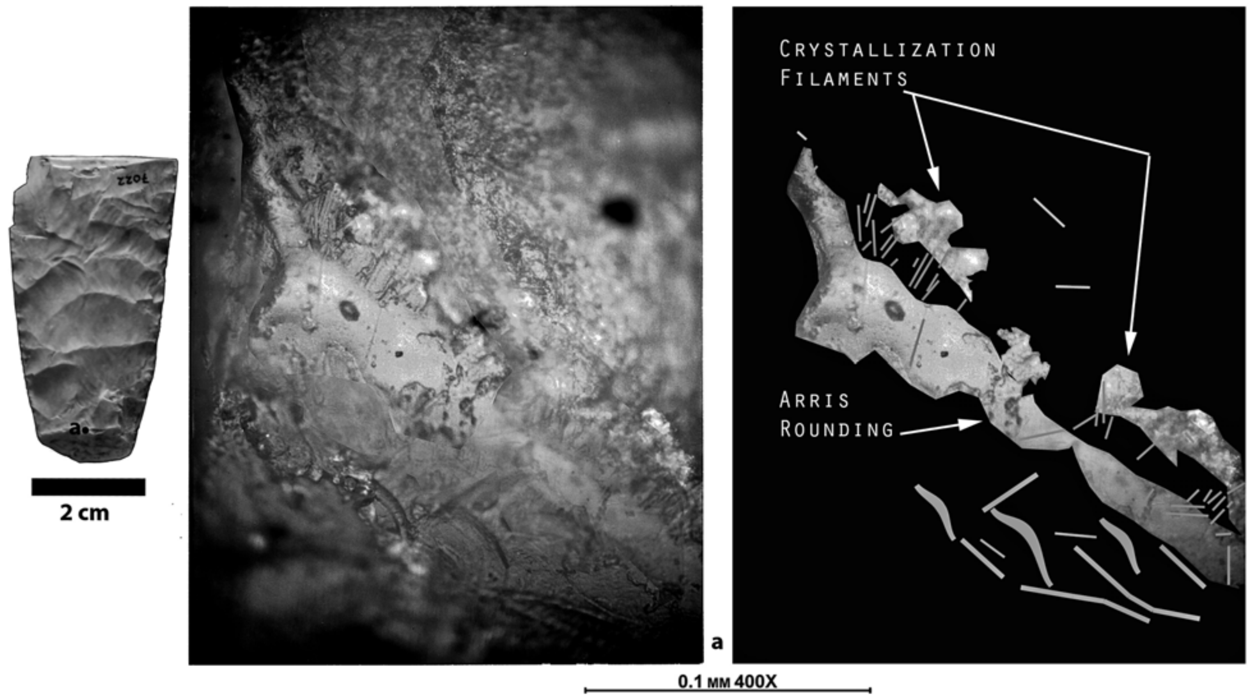


Figure 7.8. Oriented photomicrograph of striated microplated haft wear traces on obverse side of Agate Basin point, specimen 7 (CN7022) and (on the right) schematic kinematic diagram. Crystallization filaments are on the trailing edge of the microplating, and indicate a distal-to-proximal (tip-to-base) movement of the point in its haft element.

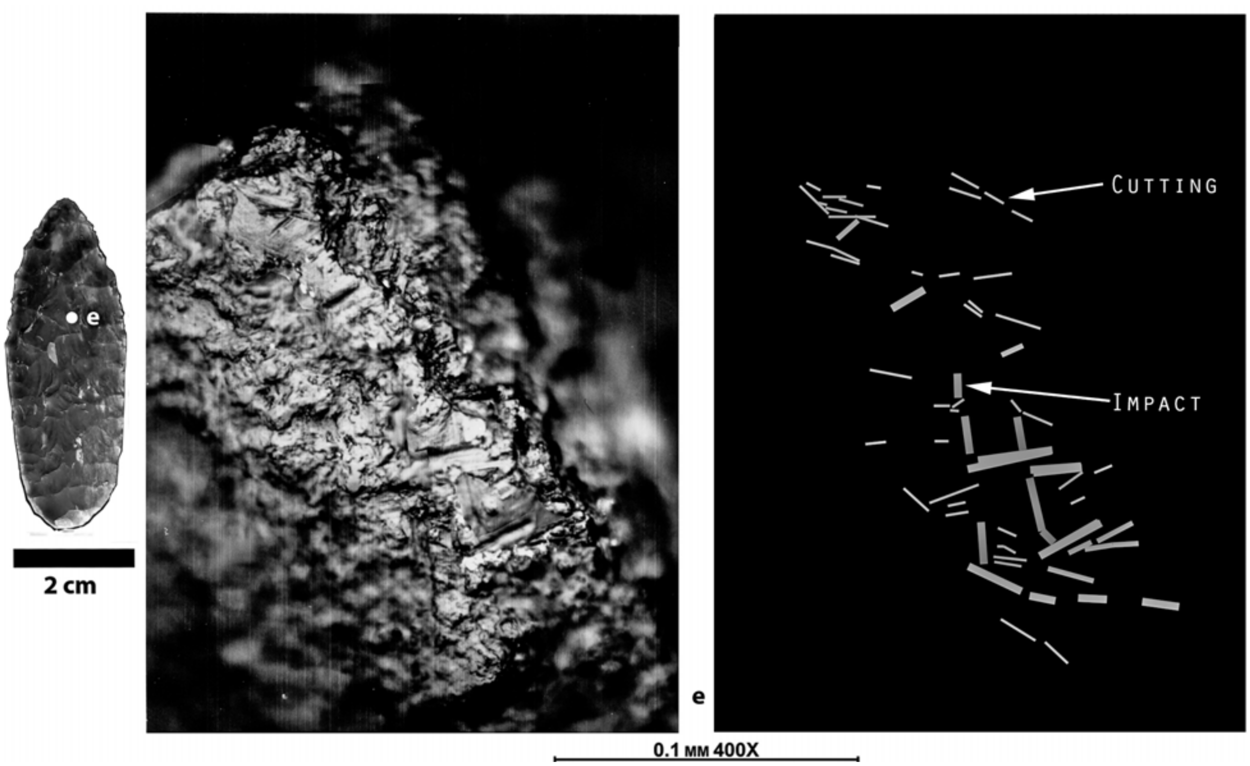


Figure 7.9. Oriented photomicrograph of blade element striated microplating wear traces on reverse side of Agate Basin point, specimen 2 (CN8363) and, on the right, schematic kinematic diagram of impact striations crosscut by cutting striations.

Agate Basin point base or proximal fragment appears to have been retrieved from the kill and later left or lost there. It has a near right angle snapped end near the haft-blade element juncture and an acutely angled perverse fracture off the snapped end on one edge on both faces. While the perverse fracture probably precluded further edge repair, it became the object of tool recycling as a knife. This probably was because the formerly dulled lateral edges, due to extensive grinding in initial haft preparation, now had a sharp edge on one side. The use-wear is invasive. On the reverse face, the knife wear traces originate at the fractured edge (figure 7.10) and have a microplating buildup. On the obverse face, the invasive cutting wear is accompanied by a band of crystallization filaments on the trailing edge of the striated microplating (figure 7.11). That puts it squarely at the edge fracture. Were the tool subjected to further repair, microplating of the edge likely would have been removed. That it was not is indicative of tool rejection or loss after recycling occurred.

The second case is that of an Agate Basin point midsection (Specimen 1 [CN8755]) that must have been dislodged from its foreshaft. It broke on impact roughly at the haft/blade element juncture and then again farther down in the haft, as judged by the extent of lateral edge grinding. The snapped ends form right to oblique angles. These were sharp and yet resistant to breakage, which comes close to the ideal for an obtusely angled tool edge, or edges, as described by Crabtree (1977). Use-wear is found on either snapped end, which at the microscopic level forms clearly damaged narrow microplated bands immediate adjacent to the breaks. Just above the haft-blade element juncture on the reverse side the wear traces are those of a burin, or chisel-like tool, used both to gouge and to slot a relatively hard material, most likely bison bone in this instance (figure 7.12). The opposite break on the obverse side has similar wear traces but is more likely related to slotting the same hard material (figure 7.13). The microplating buildup on both snapped ends is indicative of no additional repair to the obtusely angled edges, and likely of tool discard.

A final wear trace detail on the Agate Basin sample concerns digital color imagery (figure 7.14). This shows the same range of tool functions (projectile point/knife) as noted for other Agate Basin points from Beacon Island. In addition, there is clear evidence of striations in-filled by a red liquid, more-or-less by capillary action, together with red liquid smears and incorporation in microplating domes within individual layers. This indicates that the in-filling is directly associated with wear trace formation. Neither of the two other points (Specimen 8 [CN7099] and Specimen 9 [CN8311]) whose wear traces were subjected to digital color imagery, however, documented similar red liquid in-fillings. The question is: what is the red liquid?

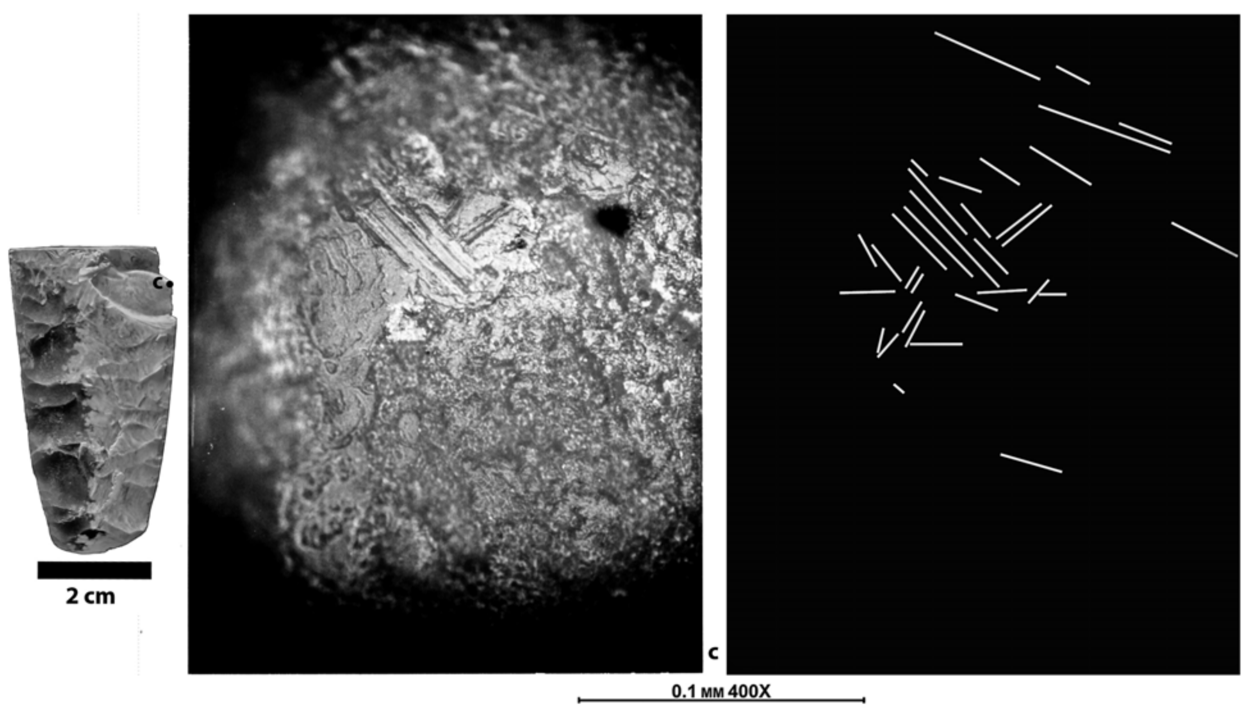


Figure 7.10. Oriented photomicrograph of haft element striated microplating wear traces on reverse side of Agate Basin point, specimen 7 (CN7022) and, on the right, schematic kinematic diagram of cutting striations adjacent to and originating at the fractured edge. See also figures 7.8 and 7.11.

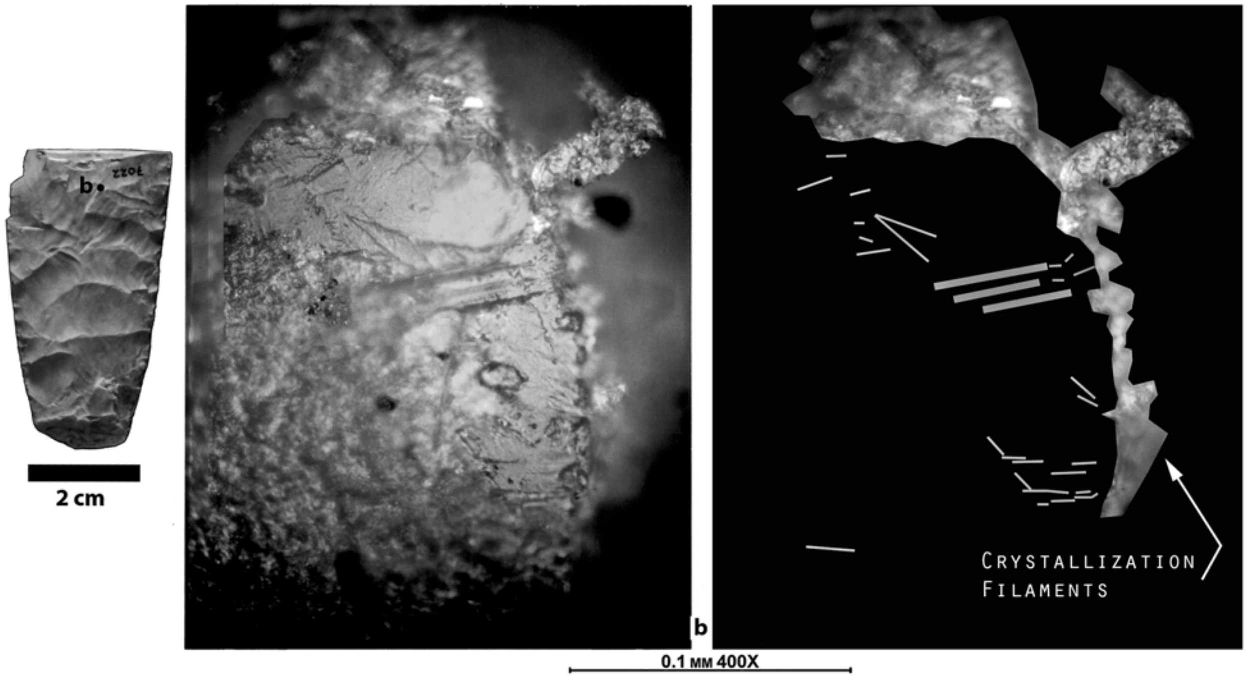


Figure 7.11. Oriented photomicrograph of haft element invasive, striated microplating wear traces on obverse side of Agate Basin point, specimen 7 (CN7022) and, on the right, schematic kinematic diagram of cutting striations accompanied by crystallization filaments on the trailing edge of the wear traces and opposite their point of origin. Note photomicrograph image is a stitched together photomosaic. See also Figures 7.8 and 7.10.

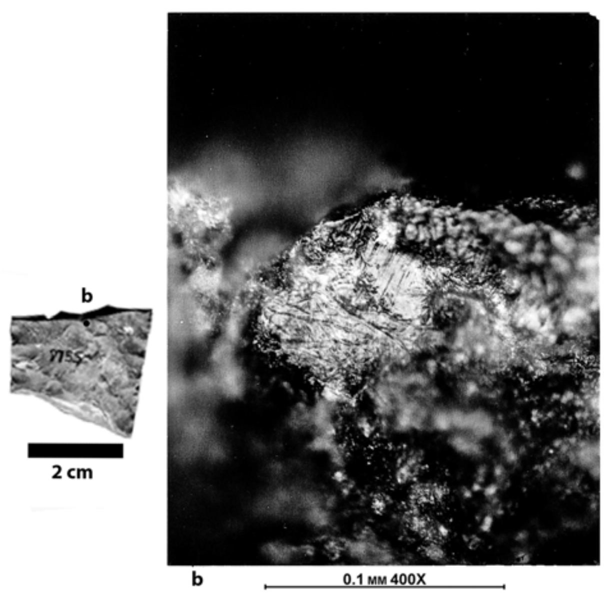


Figure 7.12. Oriented photomicrograph of striated microplating wear traces due to burin use of snapped end on reverse side of Agate Basin point, specimen 1 (CN8755).

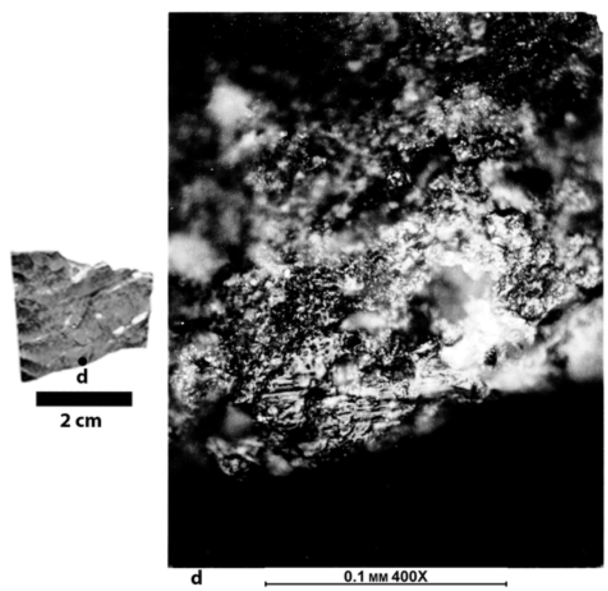


Figure 7.13. Oriented photomicrograph of striated microplating wear traces due to burin use of snapped end on obverse side of Agate Basin point, specimen 1 (CN8755).

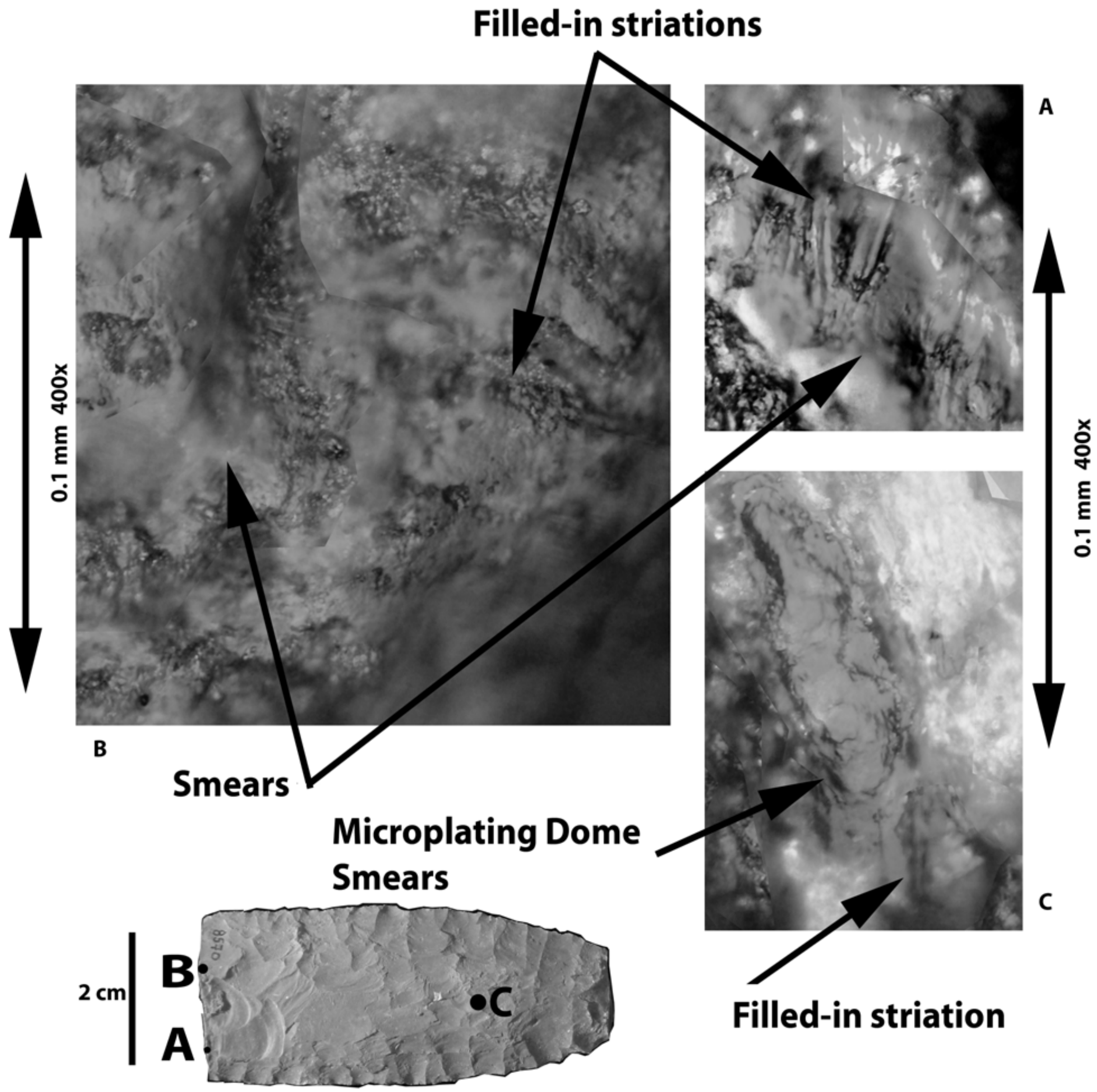


Figure 7.14. Oriented photomicrographs of striated microplating wear traces due to use as a projectile point and knife on obverse side of Agate Basin medial fragment, specimen 10 (CN8570). Note photomicrograph images A and B are stitched together photomosaics.

The obvious choice would seem to be a blood residue. This makes sense due to the color and bison kill context. Experimental butchery of a goat with stone tools showed similar blood smears but which on drying cracked into irregular polygons. There are no irregular polygon desiccation cracks on the Beacon Island tool. But it is unclear if irregular polygon desiccation cracks are normal and expectable with blood drying, or just peculiar to the goat butchery experiment.

Goshen Wear Traces

Haft wear is extensive on both faces of this point base but is best developed on the reverse surface (figure 7.15). These show secondary, striated microplating features of the blade element, arguably due to projectile point impact. A curious detail is that the lateral grinding common on the Agate Basin points is largely absent. The specimen is just slightly more than 2 mm shorter than the smallest

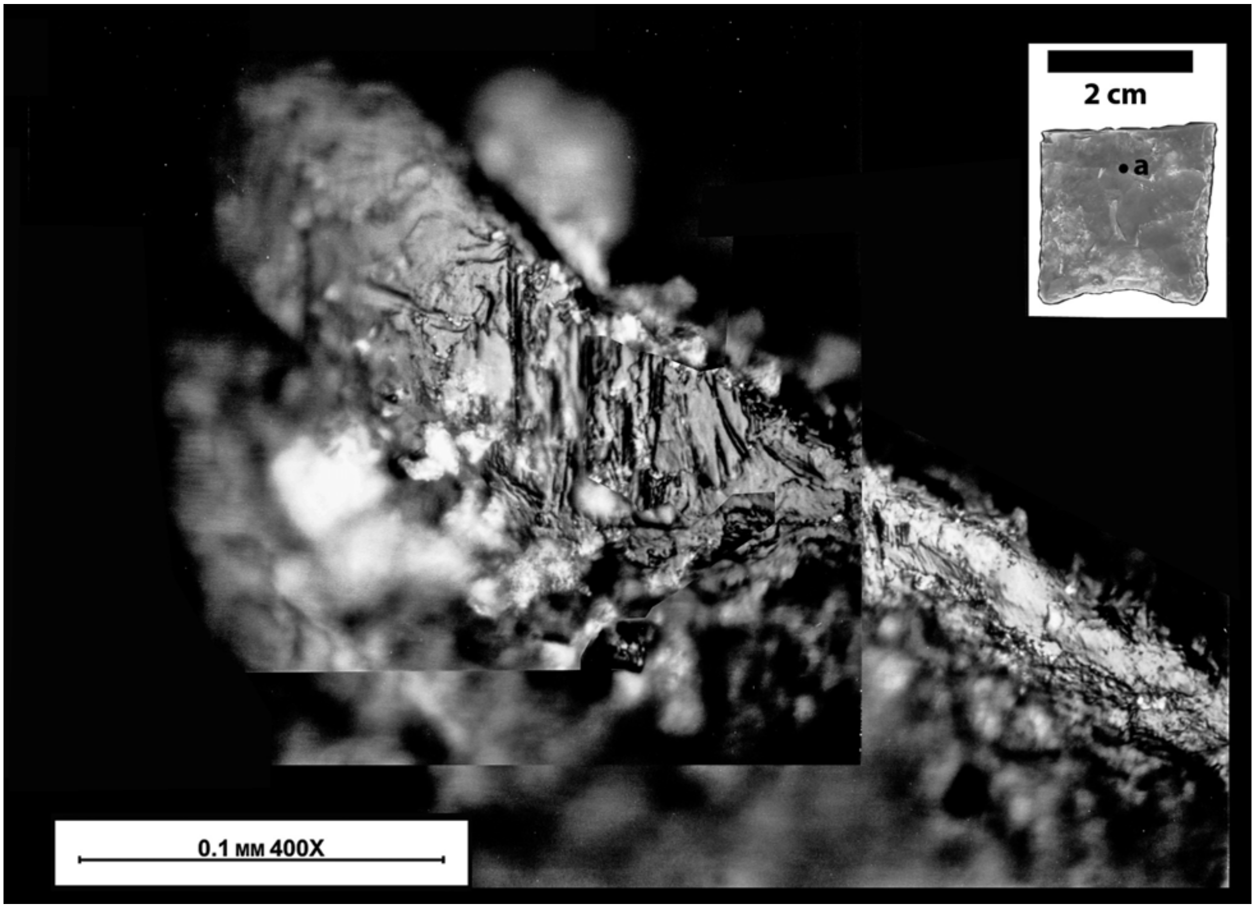


Figure 7.15. Oriented photomicrograph of striated microplating wear traces due to hafting and secondarily use as a projectile point and knife on reverse side of Goshen basal fragment, specimen 3 (CN9289). Note photomicrograph image is a stitched together photomosaic.

Agate Basin recycled tool. So it too would seem to have been in an acceptable size range for recycling. Moreover, it has a tough, obtusely angled snapped edge. Yet, no effort was made to recycle the snapped distal edge as an obtusely angled burin, consistent with some of the other snapped Agate Basin points. This Goshen base may have been lost in the kill.

### Technological Structure

One cannot overestimate the heuristic value of the recycled points from Beacon Island. The two include the shortest (27.35 mm in length) Agate Basin specimen in the sample and one (at 54.2 mm length) in between the lengths of the two analyzed complete points (table 7.2). The latter have sharp blade edges without any microplating buildup and, on these criteria, are judged as still serviceable. The recycled points represent emphatic, unequivocal evidence of continued use well after breakage occurred. The determinant factor appears to have been success in relocating broken Agate Basin points in the kill. The implication is, had they been retrieved, the Agate Basin specimens would have been subjected to continued use either as initially designed or recycled into a subsidiary function. The obvious preference, I think, was to continue to use the Agate Basin points as projectiles/knives at Beacon Island, as long as doing so adhered to appropriate engineering design principles and they could be found in the kill. Retrieving the specimens, however, was clearly a hit-or-miss process, apparently successful only in the two instances of point recycling (figure 7.1). Two questions remain: what was the minimum acceptable length for maintaining the points as projectiles? And what was behind the differences in blade element sharpening evident in the studied sample?

There is no significant difference in the mean lengths of points or point fragments in each of the completeness classes. The mean length of the two whole points, which on use-wear criteria described earlier were likely to have been still useable, is approximately the same as that of the other fragmentary specimens. However, the haft lengths of the two complete, reworked points included in this

Table 7.2. Metric and other attributes of the studied sample.

| Specimen | CN | Type | Weight (g) | Length (mm) | Width (mm) | Thickness (mm) | Haft Length (mm) | Completeness |
|---|---|---|---|---|---|---|---|---|
| 4 | 1836.01 | Agate Basin | 6.53 | 62.3 | 17 | 5.8 | | distal |
| 8 | 7099 | Agate Basin | 18.362 | 57.7 | 32.3 | 8.8 | | distal |
| 1[a] | 8755 | Agate Basin | 8.798 | 27.35 | 30.4 | 10 | | medial |
| 5 | 1651.01 | Agate Basin | 10.253 | 50.85 | 21.9 | 8 | 15 | medial |
| 10 | 8570 | Agate Basin | 18.207 | 62.5 | 27.65 | 8.3 | | medial |
| 9 | 8311 | Agate Basin | 10.736 | 63.85 | 17.7 | 8.3 | 28.1 | other |
| 7[a] | 7022 | Agate Basin | 14.916 | 54.2 | 28.65 | 8.25 | 49 | proximal |
| 6 | 1929.03 | Agate Basin | 9.417 | 50.35 | 22.3 | 8 | 37 | whole |
| 2 | 8363 | Agate Basin | 8.366 | 55.45 | 20.23 | 7 | 32.3 | whole |
| — | BI-4[b] | Agate Basin | 40.1 | 133.0 | 30.7 | 9.2 | 47 | whole |
| 3 | 9289 | Goshen | 4.03 | 25.2 | 24.1 | 4.65 | 19 | proximal |

[a] Recycled specimen.
[b] Data from Ahler (2003b:Table 27).

study (Specimen 2 and Specimen 6) are actually much shorter than the recycled Agate Basin base, Specimen 7. The haft length on the Agate Basin point that split longitudinally on impact, Specimen 9, is only slightly smaller, at 28.1 mm. This may represent empirically the lower boundary on acceptable haft lengths. So for practical purposes, a haft length of about 30 mm would have satisfied minimal engineering design criteria. This would have been met by all but one of the Agate Basin point fragments in the Beacon Island study sample.

The upper boundary on blade element length of approximately 86 mm is set arbitrarily by the largest point found at the bison kill. None of the points' total lengths comes close to this figure. Blade element lengths of the two analyzed complete points are respectively, 13.35 mm and 23.15 mm. Their mean of 18.25 mm can be taken as a first order approximation of a lower boundary for a functional blade element length at Beacon Island. Everything else being equal, one could sum the mean lengths for the haft and blade elements of the studied sample to approximate the minimum acceptable size of an Agate Basin point. This comes to 48.25 mm, less than the total length of all but the recycled Agate Basin medial fragment. If any of these artifacts had been retrieved, they could have been reworked into a functional projectile point, at least in theory.

To grasp what would have been required to refurbish the sample, and thereby to restore potential projectile point utility, we can scale the points by the juncture of their hafts and blade elements, once grouped by completeness and recycling (figure 7.16). The largest point found at Beacon Island (figure 7.16j) can be taken as maximum projectile point potential utility. The two complete but heavily reworked points (figure 7.16f,g) and the recycled elements (figure 7.16h,i) are examples of minimum potential utility as a projectile point or another tool type. Fragmentary blade elements (figure 7.16a-c) would have required further retouching of the tip and their proximal ends to create a new base. They would also have required additional—and extensive—lateral grinding. Although doubtful as a pragmatic matter, the longitudinally split point (figure 7.16d) would have needed total bifacial reworking of the snapped edge, allowing for remodeling of the tip and base too, including extensive lateral grinding on one side. In contrast, the point with a snapped base but having much of its haft element intact (figure 7.16e) would have needed reworking only of its basal, or proximal, end. That broken Agate Basin blade elements were less likely to be retrieved from a bison kill and refurbished than the haft elements seems more likely if not self-evident. The haft elements logically might have been secured still in their foreshafts, making retrieval easier, and they would have required far fewer steps to recreate and sharpen the blade element.

Agate Basin blade element sharpening at Beacon Island followed two strategies: a bifacial or unifacial one (figure 7.17). To switch to a unifacial approach from the bifacial one is possible, but it is impractical to switch back from a unifacial to a bifacial approach. The bifacial approach allows for about equal contact of the adjacent surfaces in knife use and greater flexibility in resharpening, but it costs proportionally more edge reduction than the unifacial one. The net result is a biconvex blade cross section. Bifacial Agate Basin blade edge angles at Beacon Island measure initially 40 degrees to 45 degrees and, after sharpening, upwards of 60 degrees, with one instance of 70 degrees. The unifacially sharpened blade edges have measured angles of 60 and 65 degrees, or well within the range of bifacial blade resharpening at Beacon Island. However, the cross sectional profile is more triangular, and creates an unequal contact of the adjacent surfaces. Preferentially, the flat side constitutes the leading surface

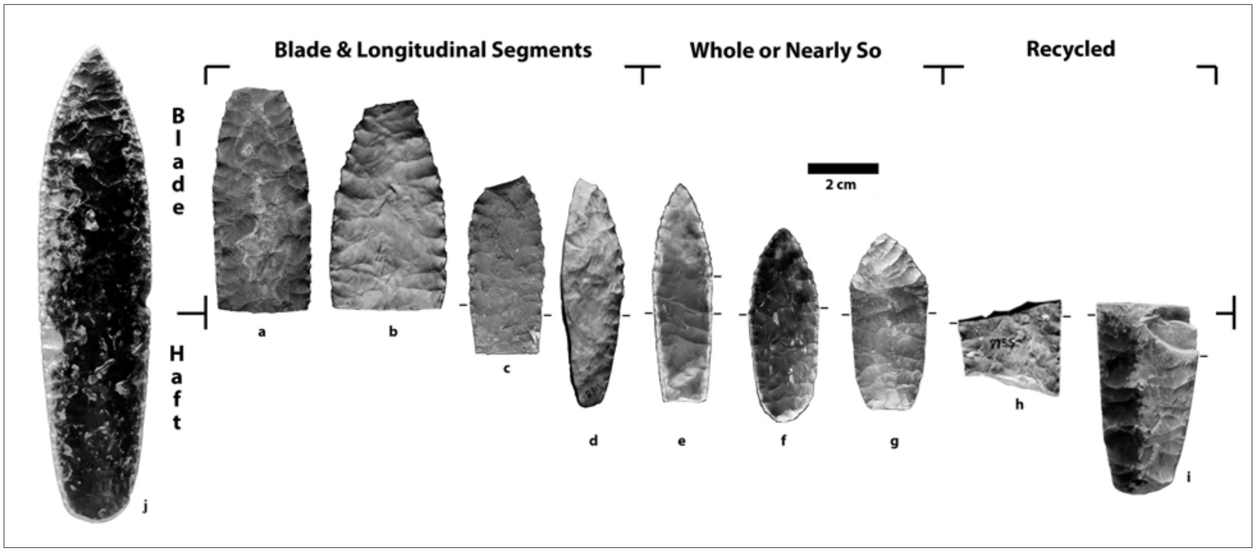


Figure 7.16. Beacon Island Agate Basin points in the analyzed sample (a-i) and from the uncontrolled surface collection (j). Those judged still serviceable include the whole or nearly so and the recycled points. Horizontal tick marks indicate extent of lateral grinding. (a, specimen 10; b, specimen 8; c, specimen 5; d, specimen 9; e, specimen 4; f, specimen 2; g, specimen 6; h, specimen 1; I, specimen 7; j, specimen BI-4; see table 7.2 for additional data).

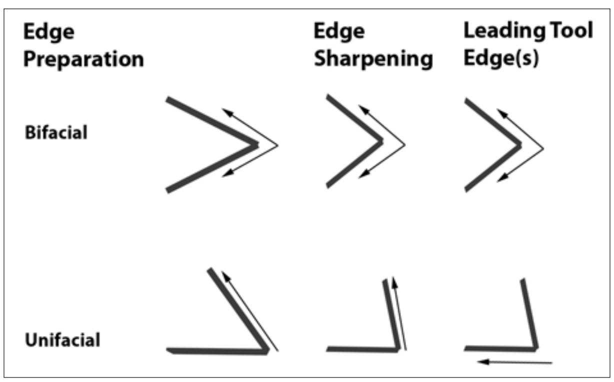


Figure 7.17. Alternative models of chipped stone tool edge preparation, sharpening, and use. Note the tool edge angle is the same in each column. The arrows indicate the primary direction of applied force (edge preparation and sharpening) or of tool surface contact with a worked material in use (leading edge).

in knife use. It represents a technological compromise in which a loss in cutting efficiency is balanced or offset by extending the use-life of a tool edge. All but one of the specimens in the studied sample took a simple bifacial resharpening approach. It was preferred at Beacon Island. The unifacial approach, however, is hardly inexplicable at Beacon Island. The one example is the most extensively reworked yet serviceable complete point (figure 7.16g) with the smallest blade element length. Going to the unificial approach, in this case, was the final option to extend the tool's use-life and it was successful.

# 8

## Paleoenvironmental Context: The Local Fauna Record

*Carl R. Falk and Holmes A. Semken, Jr.*

Archaeological, geophysical, and geomorphological investigations of late/terminal Pleistocene and early Holocene deposits at the Beacon Island site in 2002 and 2006 exposed an area of more than 100 square meters within a small kettle basin (chapter 3). A well-defined bonebed incorporating the butchered remains of extinct bison (*Bison antiquus*) and stone tools assignable to the Paleoindian-age Agate Basin complex were found near the base of the Aggie Brown Member of the Oahe Formation (chapter 2). Four radiocarbon samples on bone and charcoal yield a weighted mean age of 10,326±28 $^{14}$C yr B.P. and provide a radiocarbon age for the Agate Basin component and perhaps the inception of the Aggie Brown Member (see appendix A). The bison materials are considered in chapter 5. Additionally, the scattered remains of fish, amphibians, reptiles, birds and smaller mammals were recovered, primarily from excavated fill processed over fine-mesh screen. Micromammal specimens representing shrews, ground squirrels, pocket gophers, mice, and voles are particularly well represented. This chapter is concerned with the non-bison component of the vertebrate sample found within the Aggie Brown Member with particular attention to taphonomic pathways, broad temporal associations, and paleoecological implications of the identified remains. Vertebrate specimens from stratigraphic units lying above (Pick City, Riverdale and lakebed sediments) and below (Mallard Island and glacial till) the Aggie Brown Member are not considered here.

### Field Methods, Sample Selection and Laboratory Processing

A total of 127.5 1 x 1-meter units was excavated during eight field sessions in 2002 and 2006. Although methods varied somewhat by field session, generally specimens 5 cm or greater in maximum dimension were plotted and tentatively identified as the bonebed was exposed. Nearly all plotted pieces are the remains of bison (chapter 5) though a small number represent other animals. With few exceptions, excavated deposits were screened (chapter 3). During the initial May 2002 testing program, recovery procedures included use of both 1/4-inch dryscreening and 1/16-inch waterscreening while all excavated fill was waterscreened over 1/16-inch mesh during later fieldwork.

Sorting procedures for the May 2002 collection are described by Ahler, Timpson, and Crawford (2003:23) and the same general approach was used with the 2006 samples (chapter 4). Screened materials were size-graded over nested wire-mesh screens with standard screen openings. All bone was sorted and separately packaged from size grade 1 through 4 samples. However, the primary emphasis was on field-plotted (bison) specimens and identifiable pieces were not sorted from the coarse fraction (size grades 1 through 3) samples during the initial lab work. Potentially identifiable vertebrate specimens were, however, removed from size grade 4 samples and unsorted size grade 5 debris samples were checked for additional identifiable remains.

Following our preliminary examination of plotted specimens and identifiable elements from the fine fraction (size grades 4 and 5) samples, a decision was made to check previously sorted fine fraction screen residues from Aggie Brown levels for additional specimens and to sort the September 2002 coarse fraction samples for identifiable remains. The resort of fine fraction residues increased the total number of identifiable skeletal elements. Also, a number of identifiable elements were recovered from the September 2002 coarse fraction samples. The latter group included 20 pieces of bison bone (see chapter 5 for a discussion of these remains). Unfortunately, neither time nor funds were available to support a sort of the coarse fraction samples from the 2006 field investigation. However, inclusion of additional specimens from the larger size grades would be unlikely to alter the results of the present study, which focuses primarily on the sample of micromammals recovered from the size grades 4 and 5 fractions. Table 8.1 provides a synopsis of samples utilized for this study.

#### Specimen Identification

Identifications for fish, amphibian, reptile, bird, and some mammal specimens were provided by Falk. Micromammal cranial elements and dentition were identified by Semken. All identifications were completed using modern skeletons available to the authors, including

Table 8.1. Summary of plotted and screened Beacon Island samples included in this study.

| | | | General Level Samples | | | | |
|---|---|---|---|---|---|---|---|
| | | | Size Grade | | | | |
| Field Year | Sessions | Plotted Specimens | G1 | G2 | G3 | G4 | G5 |
| 2002 | 3-4 | Studied | Studied | Studied | Studied | Studied | Studied |
| 2006 | 5-8 | Studied | Not Sorted | Not Sorted | Not Sorted | Studied | Studied |

comparative materials curated by the Department of Geoscience, University of Iowa. Specimens were considered "identifiable" if the anatomical element or element group (e.g., rib, thoracic vertebra, proximal phalanx), side (left, right, axial), and portion (e.g., proximal, distal, cranial, caudal) could be established. Identifiable materials were sorted by taxonomic group and recorded by element and catalog lot. Additional data concerning specimen staining, burning, carnivore and/or rodent gnawing, and partial digestion were recorded as appropriate. Inventories were organized by taxon and summarized by number of identified specimens (NISP) and minimum number of individuals (MNI) following commonly accepted methods. A full record of identified remains was prepared for inclusion with permanent site files. Unless otherwise noted, taxonomic nomenclature follows the American Fisheries Society (1991) for fish, Kiesow (2006) for amphibian and reptiles, the American Ornithologist's Union (2011) for birds, and Baker and others (2003) for mammals.

As noted previously, staining (color) was characterized for each identified specimen. In practice, specimens were recorded as either dark or light in color. Some background to this decision is necessary. During the course of the initial sorting process both authors noted considerable color variation between specimens recovered from the Aggie Brown deposits, both within and between excavation levels. The range of colors appeared to be strongly bimodal with many specimens showing a dark gray to black, or near chocolate-brown color while others were markedly lighter in color. Caliche nodules were noted on many of the darkly stained specimens. Ahler, Geib and Timpson (2003:55) describe the Aggie Brown sediments as a "very dark grayish brown to black clayey silt," and early in the analysis it was supposed that the darkly colored specimens likely reflected post-depositional staining of bone matrix as a result of exposure to organic and/or inorganic components found in the Aggie Brown Member. In contrast to the darkly stained pieces, the lighter colored specimens varied from a near white or pale yellow, to very pale brown, or a light reddish brown. Generally, carbonate deposits were not found on the lighter-colored specimens. The implications of the observed color variations (degree of staining) are discussed later in the chapter.

## Identified Remains

Five-hundred-fifty specimens were identified from the combined September 2002 and 2006 samples. None of the identified pieces examined in this study show tool marks or other clear evidence of human alteration. Five specimens (noted in the following sections) show possible burning but the evidence is problematic at best. The identified total does not include materials recovered during the May 2002 test investigation. For comparative purposes, table 8.2 summarizes data on non-bison specimens from that investigation reported by Lee (2003a:104-112). Four specimens are from small volume samples screened over 1/16-inch mesh while the remaining piece is from general level deposits dry-screened over 1/4-inch mesh.

### Plotted Specimens

The field-plotted sample from Aggie Brown Member levels includes ten identifiable specimens (table 8.3). Six dark-stained leporid bones from a single plot are from the lower hind limb of a single individual. These specimens are tentatively identified as snowshoe hare

Table 8.2. Taxonomic and element identifications for specimens recovered during the May 2002 test excavations in Area A.

| Taxon | Element | Side | Sample |
|---|---|---|---|
| Rodentia (rodents) | tibia | ? | waterscreen |
| *Thomomys talpoides* (northern pocket gopher) | humerus | left | waterscreen |
| *Castor canadensis* (American beaver) | radius | left | waterscreen |
| *Cynomys ludovicanus* (black-tailed prairie dog) | atlas | axial | waterscreen |
| *Sylvilagus* sp. (cottontail) | humerus | ? | dry screen |

Table 8.3. Taxonomic and element identifications for select piece-plotted specimens from Area A, September 2002 and 2006 samples combined.

| Taxon | Element | Side | Remarks |
|---|---|---|---|
| Leporidae (hares and rabbits) | tibia | right | dark stain |
| Leporidae (hares and rabbits) | tibial tarsal | right | dark stain |
| Leporidae (hares and rabbits) | central tarsal | right | dark stain |
| Leporidae (hares and rabbits) | tarsal 4+5 | right | dark stain |
| Leporidae (hares and rabbits) | metatarsal 2 | right | dark stain |
| Leporidae (hares and rabbits) | metatarsal 3? | right | dark stain |
| *Spermophilus* cf. *S. tridecemlineatus* (13-lined ground squirrel) | cranium | axial | light stain |
| *Thomomys talpoides* (northern pocket gopher) | cranium | axial | light stain |
| *Thomomys talpoides* (northern pocket gopher) | mandible | right | light stain |
| Artiodactyla (even-toed ungulates) | 1st phalanx | unsided | carbonate |

(*Lepus americanus*) based on their intermediate size between modern cottontail (*Sylvilagus* sp.) and white-tailed jackrabbit (*Lepus townsendii*), both common to north-central North America. Preferred habitat for the snowshoe hare is hardwood or coniferous woodland with associated understory vegetation (Jones et al. 1983:110-111). Additional plotted materials include a thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) cranium, and two northern pocket gopher (*Thomomys talpoides*) pieces, a cranium and a right mandible. These three specimens are lightly stained. A partial first phalanx from an unidentified small artiodactyl completes the plotted sample. This bone is encrusted with a thick grey carbonate deposit.

Six additional specimens were categorized as non-bison in the field but are excluded from table 8.3. The authors regard these pieces—all likely representing indeterminate small and/or large artiodactyls—to be unidentifiable under the definition used in the present study. Included here are a fragmented rib, a rib or vertebral spine fragment, a possible vertebra fragment, and three long bone fragments.

Screened Samples

Nearly one thousand pieces of potentially identifiable bone were sorted from processed waterscreen samples. A total of 540 specimens was identified for the present analysis. The identified sample includes all fish, amphibian, reptile, and bird remains, as well as elements representing leporids, large rodents (beaver, muskrat), and a cervid. Identification of micromammal (shrew, ground squirrel, gopher, mouse and vole) remains is limited to cranial elements and isolated teeth. Micromammal postcranial elements (about 453 specimens) are not included in this study. Table 8.4 summarizes specimen counts and minimum number estimates, as well as specimen color classifications, for the identified materials. Brief narrative summaries organized by taxonomic class are provided in the next sections, followed by a more detailed discussion of identified micromammal remains.

*Fish*

One fish vertebra was recovered from Aggie Brown levels (table 8.4). The piece is unburned and light in color. This small specimen (with a of diameter 1.0 mm) is tentatively referred to the Family Hiodontidae (mooneyes) and is either goldeye (*Hiodon alosoides*) or mooneye (*H. tergisus*). Goldeye are regularly found in late prehistoric assemblages from village sites along the Missouri River (Falk 1997) and are locally common in the river system. In addition to the vertebra, four unidentified scale fragments were sorted from screened samples. The possibility that these specimens are from recent lake sediments cannot be discounted.

*Amphibian*

Ninety-six pieces of amphibian bone were recovered (table 8.4). Identified salamander remains include one humerus, one femur, and seven vertebrae. A single individual would account for the pieces recorded. The specimens are not identified beyond the order (Caudata) but compare well with the remains of tiger salamander (*Ambystoma tigrinum*). Wheeler and Wheeler (1966:31-35) record tiger salamander—the only salamander currently reported from the Missouri Plateau—from locations throughout much of North Dakota, including several records from the southern portion of Burke County, just north of Mountrail County. Colors range from near-white to a very pale brown; one specimen is a light gray brown.

The order Anura (toads and frogs) is represented by 87 specimens. Sixty-three of these, comprised primarily of vertebrae and fragmented limb elements, are identified

Table 8.4. Specimen counts (NISP) and minimum number of individual estimates (MNI) organized by taxon and specimen color classification from Area A, September 2002 and 2006 waterscreen samples combined.

| | Dark Stain | | Light Stain | | Total | |
|---|---|---|---|---|---|---|
| Taxon | NISP | MNI | NISP | MNI | NISP | MNI |
| Fish | | | | | | |
| *Hiodon* sp. (mooneye/goldeye) | | | 1 | 1 | 1 | 1 |
| *Subtotal* | | | *1* | *1* | *1* | *1* |
| Amphibians | | | | | | |
| Caudata (salamanders) | | | 9 | 1 | 9 | 1 |
| Anura (toads and frogs) | 13 | | 50 | | 63 | |
| Scaphiopodidae (spadefoots) | | | 7 | 2 | 7 | 2 |
| Bufonidae (toads) | | | 5 | 2 | 5 | 2 |
| Ranidae (true frogs) | 12 | 6 | | | 12 | 6 |
| *Subtotal* | *25* | *6* | *71* | *5* | *96* | *11* |
| Reptiles | | | | | | |
| Colubridae (columbrids) | 1 | 1 | 3 | 1 | 4 | 2 |
| *Thamnophis* sp. (garter and ribbon snakes) | 130 | 1 | | | 130 | 1 |
| *Subtotal* | *131* | *2* | *3* | *1* | *134* | *3* |
| Birds | | | | | | |
| Anatidae (waterfowl) | 2 | 1 | | | 2 | 1 |
| Passeriformes ( passerine or perching bird) | 6 | 2 | 6 | 3 | 12 | 5 |
| *Subtotal* | *8* | *3* | *6* | *3* | *14* | *6* |
| Mammals | | | | | | |
| *Sorex* sp. (long-tailed shrew) | | | 2 | 1 | 2 | 1 |
| Leporidae (hares and rabbits) | 46 | 2 | 1 | 1 | 47 | 3 |
| *Spermophilus tridecemlineatus* (13-lined ground squirrel) | | | 22 | 4 | 22 | 4 |
| *Thomomys* cf. *T. talpoides* (northern pocket gopher) | 1 | 1 | 33 | 4 | 34 | 5 |
| *Perognathus* sp. (pocket mouse) | 1 | 1 | 15 | 8 | 16 | 9 |
| *Castor canadensis* (American beaver) | 2 | 1 | | | 2 | 1 |
| *Peromyscus* sp. (deer/white-footed mouse) | 1 | 1 | 10 | 4 | 11 | 5 |
| *Phenacomys* cf. *P. ungava* (eastern heather vole) | 5 | 3 | | | 5 | 3 |
| *Myodes* sp. (red-backed vole) | 59 | 19 | | | 59 | 19 |
| *Microtus ochrogaster* (prairie vole) | 22 | 12 | 4 | 4 | 26 | 16 |
| *Microtus pennsylvanicus* (meadow vole) | 64 | 36 | 3 | 1 | 67 | 37 |
| *Ondatra zibethicus* (common muskrat) | 3 | 1 | | | 3 | 1 |
| *Odocoileus* sp. (deer) | | | 1 | 1 | 1 | 1 |
| *Subtotal* | *204* | *77* | *91* | *28* | *295* | *105* |
| Total | 368 | 88 | 172 | 38 | 540 | 126 |

as toad and/or frog. Thirteen specimens are darkly stained, while the remaining 50 pieces are pale brown to a light-reddish brown in color.

Seven elements (right humerus, left humerus, sacrum, three vertebrae, and left ilium) are referred to the family Scaphiopodidae, the spadefoots. Based on size differences noted for the humeri, at least two animals are represented. Each of these specimens compare well with modern examples of the Plains spadefoot (*Spea bombifrons*). The Plains spadefoot is generally found within open grasslands and is recorded for the southwestern portion of North Dakota (Wheeler and Wheeler 1966:36-37). The identified specimens are near-white to very pale brown in color.

Five elements (one sacrum, two left ilia, and two right ilia) are referred to the genus *Anaxyrus* (formerly *Bufo*) within the family Bufonidae (toads). These specimens are pale brown to reddish brown in color. A minimum of two individuals is represented. Woodhouse's toad (*A. woodhousii*), Great Plains toad (*A. cognatus*), Canadian toad (*A. hemiophrys*) and American toad (*A. americanus*) are presently found in North Dakota, though the American toad is apparently restricted to the eastern margin of the state (Wheeler and Wheeler 1966:39-44). The recovered ilia compare well with modern examples of the Great Plains toad but identification beyond the genus is not warranted given the small sample, limited comparative materials and argued difficulty in separating extant members of the genus based on characteristics of recovered ilia (see Bever 2005). In addition, Kiesow (2006:23) indicates that the American toad hybridizes with both Woodhouse's toad and the Great Plains toad in areas well east of the Missouri River where their ranges overlap.

Twelve specimens are referred to the family Ranidae (true frogs). Identified elements include six right ilia, four left ilia, one sacrum, and one urostyle. A minimum of six individuals is indicated based on the right ilium. The bones are stained dark gray to near black in color. These specimens represent comparatively small animals and nearly all are incomplete. For example, the identified ilia are all partial specimens with varying portions of the acetabulum, ilial shaft, ilial crest and blade present. Morphologically these specimens compare well with modern examples of the northern leopard frog (*Lithobates pipiens*) from north-central South Dakota but the incomplete character of identified pieces renders an assignment to the generic level somewhat problematic. Wheeler and Wheeler (1966:49-54) report two members of the family Ranidae in North Dakota, the (northern) leopard frog and the wood frog (*L. sylvatica*). The leopard frog is found statewide, including Mountrail County, and is strongly associated with aquatic habitats but also may be found some distance from water, particularly in the summer months. The wood frog is more limited in distribution with records centered on the eastern and northeastern parts of the state.

*Reptile*

A total of 134 snake bones was identified (table 8.4). One-hundred-thirty of these are from the same catalog lot and represent the partial remains of a single animal. Nearly all specimens show a brown to dark brown staining and carbonate deposits are noted on many vertebrae. Identified specimens include eight cranial elements (left dentary, right dentary, left surangular, left quadrate, left (?) pterygoid, left palatine, left (?) ectopterygoid, and sphenoid), along with 90 vertebrae and 32 ribs. The remains are referred to the genus *Thamnophis*. Members of this genus include the garter and ribbon snakes. Both the common or red-sided garter snake (*T. sirtalis*) and the Plains garter snake (*T. radix*) are known from Mountrail County (Wheeler and Wheeler 1966:70-73) and aquatic habitats are favored by both species.

The remaining four specimens are isolated finds. With a single exception (a fragmented vertebra stained gray to dark brown), the specimens are lightly stained with color variation ranging from yellow-tan to light brown. The latter pieces include two proximal rib fragments and one vertebra. All four specimens are referred to the family Colubridae (colubrids). Two individuals are represented based on size variation of identified vertebrae.

*Bird*

Fourteen pieces of bird bone were recovered from Aggie Brown deposits (table 8.4). Two specimens (left ulnar carpal and cervical vertebra) are referred to the family Anatidae (waterfowl). Both specimens compare well with large- to medium-sized ducks. The pieces are stained medium brown to dark gray brown.

The remaining 12 pieces represent relatively small birds and compare well with modern passerines. Six specimens (mandible fragment, left proximal humerus, right distal humerus, left proximal ulna, right distal ulna, and cervical vertebra fragment) are dark gray brown to black in color. Three of the darkly colored specimens appear to be burned, although burning is not certain. A minimum of two individuals is indicated by size variation in identified elements. The remaining pieces (mandible fragment, cervical vertebra, right scapula, right proximal humerus, left carpometacarpus, and left femur) are light yellow brown to near-white in color. The femur shows a recent mid-shaft break, revealing a distinct lining of medullary bone. Size variation suggests a minimum of three individuals is represented by lightly stained pieces.

*Mammal*

A total of 295 mammal specimens was identified for this study (table 8.4). The majority of these (NISP=242) are the cranial remains of various micromammals including shrew, ground squirrel, pocket gopher, mice, and voles. Micromammals are discussed in a separate section later. Identified mammals also include leporid, beaver, muskrat and small cervid remains.

The family Leporidae (hares and rabbits) is represented in the screened sample by 47 specimens; with one exception, all pieces show some variation of dark staining (table 8.4). Identified materials include an upper incisor fragment, maxilla fragment (without dentition), distal humerus, proximal femur fragment, complete fibular tarsal (calcaneum), proximal fibular tarsal fragment, complete central tarsal (navicular), complete second metatarsal, 5 partial metacarpals or metatarsals, and 34 phalanges. More specific identification of the leporid bones is difficult. Lee (2003a:111) reports a cottontail humerus from the May 2002 investigation (table 8.2), and several of the identified specimens (proximal femur, distal humerus, and two metapodials) presented in table 8.4 fall within the size range of modern cottontail elements. Then again, most specimens reported here are incomplete and may represent eastern cottontail

(*Sylvilagus floridanus*), Nuttall's cottontail (*S. nuttallii*), or (for smaller fragments) members of the genus *Lepus,* such as snowshoe hare and white-tailed jackrabbit.

Two elements (complete fibular tarsal and second metatarsal) are intermediate in size between available cottontail and white-tailed jackrabbit comparative specimens, suggesting they might be identified as snowshoe hare. The six piece-plotted specimens listed in table 8.3 are also tentatively identified as snowshoe hare, again based on size considerations. However, lacking diagnostic cranial materials (Jones et al. 1983:110), more systematic study of snowshoe and cottontail skeletal remains from the Northern Plains is necessary before size can be easily (if ever) used as a wholly reliable indicator for species identification in the region (Yang et al. 2005).

American beaver (*Castor canadensis*) is represented by two small cranial fragments (mastoid process and occipital condyle). The specimens are from the same catalog lot and likely from the same individual. Both pieces show a dark stain. A beaver radius was recovered in the May 2002 test (Lee 2003a:104). A second large rodent, the common muskrat (*Ondatra zibethicus*), is represented by three specimens. Identified pieces include a proximal femur, a complete right tibial tarsal (astragalus), and a partial left tibial tarsal. A minimum of one individual is indicated. All three are dark in color but two of these specimens (femur and right tibial tarsal) could be burned. Beaver and muskrat are strongly linked to aquatic habitats and require permanent water (Jones et al. 1983).

## Beacon Island Micromammals

In addition to the mammal remains discussed in the previous section, 242 micromammal cranial pieces were identified from the screened samples; these specimens form the basis for the following discussion. In an earlier paper (Falk and Semken 1997), we argued that micromammals recovered from archaeological contexts and shown to be largely contemporaneous with cultural deposits may prove useful as paleoecological indicators. We also noted that micromammal remains may be intrusive (see also Semken and Ahler 2003). Both scenarios appear likely for the Beacon Island local fauna and there appear to be at least two taphonomic pathways for micromammals recovered from the 10,300 $^{14}$C yr B.P. bison bonebed. The pathways are separated, largely on coloration, into the Dark and Light Faunules for interpretation. As discussed previously, the color distinctions are not absolute, but the color spectrum is strongly bimodal with only three intermediate specimens. These three items were assigned to the closest category. Specimens assigned to each of the two faunules are summarized in table 8.5.

Micromammal specimens assigned to the Dark Faunule generally exhibit a chocolate-brown color, usually with adhering carbonate nodules. Moreover, elements in the Dark Faunule invariably consist of either isolated molars or first lower molars in a horizontal ramus. When present, the rami are consistently broken between the alveoli for the second and third molars. This pattern represents an extreme reduction of the mandible when compared to the category "D" mandible breakage pattern presented by Andrews (1990:56) where the m3 region is preserved. The pocket gopher molar assigned to the Dark Faunule (table 8.5) is mottled yellow and chocolate (dominant), has a complex taphonomic history, and perhaps should not be included in either faunule.

In contrast, specimens assigned to the Light Faunule vary from yellow to light brown, with a continuous color spectrum between the two. Some Light Faunule specimens are mottled with differing color phases and only three approach a darker brown color. Carbonate nodules are not present on Light Faunule molars and partial ascending rami usually are present on the recovered mandibles. Only one Light Faunule mandible was complete. A long-tailed shrew (*Sorex* sp., but not *S. hoyi*,) mandible fragment assigned to the Light Faunule exhibits a unique slate grey color. This may reflect a different pathway into the site with respect to the two defined faunules. However, since there is much more color variation in the Light Faunule, the shrew is placed here; it certainly does not belong to the Dark Faunule group for interpretation. In any event, the presence or absence of long-tailed shrew in either faunule is ecologically neutral with respect to the rest of the identified species because the genus ranges nearly continent-wide today and occupies a variety of habitats.

We interpret the Dark Faunule elements as remains of regurgitated raptor pellets. Many of the dark-stained ranid, passerine, and leporids elements may have accumulated in a similar manner. Most of the Light Faunule remains probably accumulated later in time, perhaps with a different raptor and in conjunction with other pathways into the bonebed (e.g., burrowing or carnivore scat). Postcranial data are not presented here but we note that complete micromammal skeletons were not recovered from any excavation unit. However, a relatively complete garter or ribbon snake, the bones stained dark brown, was recovered from bonebed deposits.

The distinct taxonomic composition of the two faunules (table 8.5) also belies more than one period of accumulation. Ninety-eight percent of the 153 identified micromammal specimens in the Dark Faunule are voles with only three specimens being non-arvicoline: a deer mouse, a questionably colored northern pocket gopher, and a pocket mouse. The red-backed vole (38 percent of the NISP and 26 percent of the MNI) and eastern heather or Ungava vole (3 percent of the NISP, 4 percent of

Table 8.5. Specimen counts (NISP) and minimum number of individual estimates (MNI) for micromammal remains, organized by faunule, recovered from Aggie Brown Member contexts in Area A, September 2002 and 2006 waterscreen samples combined.

| Taxon | Element Counted | NISP | % NISP | MNI | % MNI |
|---|---|---|---|---|---|
| **Dark Faunule** | | | | | |
| *Sorex* sp. (long-tailed shrew) | - | 0 | 0 | 0 | 0 |
| *Spermophilus tridecemlineatus* (13-lined ground squirrel) | - | 0 | 0 | 0 | 0.0 |
| *Thomomys* cf. *T. talpoide*s (northern pocket gopher) | Lmx | 1 | 0.6 | 1 | 1.4 |
| *Perognathus* sp. (pocket mouse) | L | 1 | 0.6 | 1 | 1.4 |
| *Peromyscus* sp. (deer/white-footed mouse) | L mandible | 1 | 0.6 | 1 | 1.4 |
| *Phenacomys* cf. *P. ungava* (eastern heather vole) | Lm1 | 5 | 3.3 | 3 | 4.1 |
| *Myodes* sp. (red-backed vole) | Rm1 | 59 | 38.5 | 19 | 26.1 |
| *Microtus ochrogaster* (prairie vole) | Rm1 | 22 | 14.4 | 12 | 16.4 |
| *Microtus pennsylvanicus* (meadow vole) | Lm1 | 64 | 41.8 | 36 | 49.3 |
| Total | | 153 | 99.8 | 73 | 100.1 |
| **Light Faunule** | | | | | |
| *Sorex* sp. (long-tailed shrew) | LP4 | 2 | 2.2 | 1 | 3.8 |
| *Spermophilus tridecemlineatus* (13-lined ground squirrel) | RM1 | 22 | 24.7 | 4 | 15.4 |
| *Thomomys* cf. *T. talpoide*s (northern pocket gopher) | Rp4 | 33 | 37.5 | 4 | 15.4 |
| *Perognathus* sp. (pocket mouse) | L mandible | 15 | 16.8 | 8 | 30.8 |
| *Peromyscus* sp. (deer/white-footed mouse) | L mandible | 10 | 11.2 | 4 | 15.4 |
| *Phenacomys* cf. *P. ungava* (eastern heather vole) | - | 0 | 0 | 0 | 0 |
| *Myodes* sp. (red-backed vole) | - | 0 | 0 | 0 | 0 |
| *Microtus ochrogaster* (prairie vole) | Lm1 | 4 | 4.4 | 4 | 15.4 |
| *Microtus pennsylvanicus* (meadow vole) | R mandible | 3 | 3.2 | 1 | 3.8 |
| Total | | 89 | 100.0 | 26 | 100.0 |

the MNI) only are found in the Dark Faunule. Reverse proportions characterize the Light Faunule where only seven out of 89 specimens are arvicolines—four prairie voles and three meadow voles. This stands in marked contrast to the Dark Faunule where the meadow vole comprises 42 percent of the identified specimens and prairie voles comprise 12 percent. The remains of deer mouse, northern pocket gopher, and pocket mouse, with the addition of the 13-lined ground squirrel, comprise 92 percent of the Light Faunule specimens. The dominant taxon in the Light Faunule, the pocket gopher (38 percent of the NISP and 15 percent of the MNI), is represented by a single tooth (1 percent) in the Dark Faunule.

## Paleoecology

The most striking aspect of the two Beacon Island faunules, individually and collectively, is low species richness in a robust sample. With 242 identified specimens, only nine micromammal taxa are recorded for the Beacon Island local fauna with a maximum of seven present in either faunule. This low diversity indicates a very restricted, albeit distinct, environmental variation for each faunule.

Beacon Island micromammal paleoecology is interpreted here using two methods: (1) area of sympatry within North American ecoregions, and (2) relative abundance of species with respect to the center of their modern biogeographic distribution. While boundaries of ecoregions are somewhat subjective, the regions themselves are well defined (Omernik 2004). Collectively, the two approaches suggest distinct environmental sources for each of the two faunules represented in lower Aggie Brown Member sediment at Beacon Island. Habitat requirements of the Beacon Island micromammals are taken from Jones and others (1983), Banfield (1974), Bowles (1975), and Wilson and Ruff (1999).

### *Dark Faunule*

*Area of Sympatry*. There are two areas of sympatry for the Dark Faunule (figure 8.1). One is located in central Saskatchewan and the other on the prairie-montane interface in Wyoming and Montana. The Saskatchewan sympatry, located around Meadow Lake, is defined by pocket mouse (*Perognathus sp.) and prairie vole (Microtus ochrogaster) to* the north and the heather vole (*Phenacomys cf. P. ungava)* to the south. The base maps used here, those of Hall (1981), place the three species

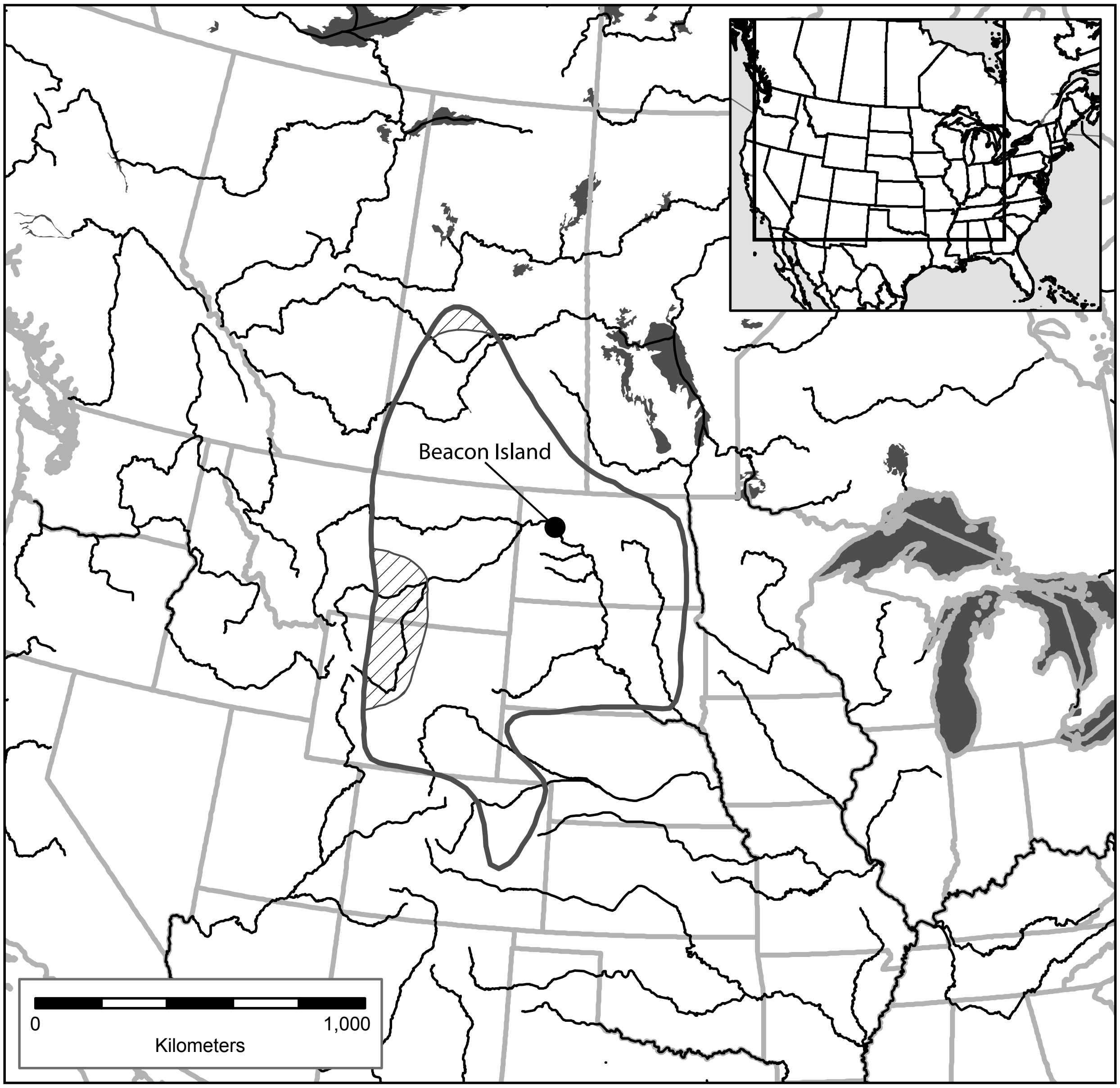


Figure 8.1 Area of sympatry for the Light and Dark Micromammal Faunules comprising the Beacon Island local fauna. The hatched area in Saskatchewan represents the area where all members of the Dark Micromammal Faunule presently co-exist. The hatched area in the Rockies is a function of superimposed life zones. Species from the Light Micromammal Faunule occupy the area inside of the heavy line, which also encompasses the dark sympatry.

as either sympatric, or nearly so, on the ecotone between the Mixed Grass Prairie, Aspen Parkland, and Boreal Transition ecoregions (Bailey 1995). Meadow Lake's town website describes itself as surrounded by an even mix of forest and prairie. As such, the Saskatchewan sympatry represents an analog local fauna in a modern area where all component species co-exist. Non-analog faunas, where ecotonal associations spread over broad geographic areas (i.e., hundreds of miles), characterize late-glacial local faunas (Graham 2005; Semken 1983, 1988; Semken et al. 2010). This is especially true for the Younger Dryas (10,000-11,000 $^{14}$C yr B.P.) in southeastern North America (Semken et al. 2010).

If the pocket mouse and pocket gopher were removed from the Dark Faunule species list (one specimen each or 2 percent of the NISP), the sympatry would expand to cover almost the entire boreal region of Canada. The boreal region, also described as sub-arctic (Bailey 1981), is in stark contrast to western North Dakota of today which is located in more temperate biological complexes.

Table 8.6. Selected climatic parameters representing Williston, North Dakota, and North Battleford, Saskatchewan (NOAA 2010), augmented by information taken from Thomas (1953) and Visher (1954).

| Variable | Williston, North Dakota | North Battleford, Saskatchewan |
|---|---|---|
| Temperature | | |
| Mean annual (°F) | 41 | 35 |
| January | | |
| Mean (°F) | 9 | 1 |
| Mean Low (°F) | -2 | -9 |
| Mean High (°F) | 20 | 10 |
| July | | |
| Mean (°F) | 71 | 64 |
| Mean Low (°F) | 77 | 52 |
| Mean High (°F) | 85 | 76 |
| Frost Free Days | 120 | 110 |
| Precipitation | | |
| Annual (inches) | 20 | 15 |
| Annual snowfall (inches) | 50 | 40 |

This point is illustrated by comparison of select climate data from weather stations in Williston, North Dakota, located just west of Beacon Island, and North Battleford, Saskatchewan, situated south of Meadow Lake (table 8.6) These data suggest cooler, shorter summers (fewer frost free days) and colder winters than at present in North Dakota were prevalent when the bonebed was deposited. Seasonal extremes are presented in table 8.6 because they are the limiting factors (January low vs. July high) for species distribution. The southern boundary of a northern species distribution frequently is based on summer highs and vice-versa for southern taxa. For Beacon Island during Agate Basin times, we envision a boreal steppe with stands of shrubby vegetation as described by Rhodes (1984) for the Craigmile local fauna (23,200 $^{14}$C yr B.P.) and similar to the ca. 14,800 $^{14}$C yr B.P. Waubonsie local fauna in which forest species had entered. Both are in southwestern Iowa. This is similar to the northernmost Great Plains Boreal Forest ecotone today but with shrubs instead of trees present on the landscape. This interpretation certainly is compatible with the more northern and western 10,300 $^{14}$C yr B.P. age of the Agate Basin component at Beacon Island because it is near the Pleistocene/Holocene Transition (PHT) and occurred within the Younger Dryas event. The presence of a widespread boreal grassland interpretation at the time is reinforced by the 9000 $^{14}$C yr B.P. micromammal horizon at the Clary Ranch Paleoindian site (May et al. 2008). This fauna is interpreted as a relict late-glacial association that survived the PHT in the protective confines of Ash Hollow in southwestern Nebraska.

The Wyoming/Montana sympatry (figure 8.1) is defined by the pocket mouse (*Perognathus* sp.) to the west, red-backed vole (*Myodes* sp., formerly *Clethrionomys*, Musser and Carleton 2005, Myers et al. 2008) to the north, and the Ungava vole (*Phenacomys* cf. *P. ungava*) to the east. This sympatry resides on the interface between Bailey's (1995) Great Plains Shortgrass Steppe and Middle Rocky Mountain ecoregions. Life zones in montane regions artificially juxtapose very different ecosystems at the scale on figure 8.1 and this sympatry undoubtedly is a function of the superposition of altitudinal life zones placing boreomontane species in close geographic proximity to shortgrass prairie inhabitants. This sympatry is almost certainly an artifact and is not interpreted.

*Relative Abundance of Species*. The relative abundance of species in the Dark Faunule (table 8.5) does not indicate a balanced ecological association. As noted above, 98 percent of the 153 identified specimens in the Dark Faunule are voles. Poor evenness is further exemplified by the meadow vole, which comprises 42 percent of the specimens and nearly 50 percent of the individuals in this faunule. The meadow vole is followed by the red-backed vole which is represented by 39 percent of the specimens and 26 percent of the individuals. The meadow vole is generally confined to meadow environs and its dominance in the Dark Faunule strongly suggests a prime meadow habitat. However, the red-backed vole and the Ungava vole are primarily browsers and require willow, birch, popular or other riparian woody vegetation. The relative scarcity of the Ungava vole (3 percent of the NISP and 4 percent of the MNI), a microtine browser, suggests that local woody vegetation may not have been well developed. The red-backed vole (39 percent of the NISP and 26 percent of the MNI) thrives in low woody thickets but will not tolerate desiccation. The low numbers of the Ungava voles may relate more to the general scarcity of this animal throughout its range today. Taken together, most of the recovered voles are compatible with meadows, bogs, and sedge marshes. A high water table undoubtedly was present and would be enhanced by the location of the site in a region of kettles. The only exception to this interpretation is the presence of the prairie vole (14 percent of the NISP and 16 percent of the MNI), suggesting some sampling of the Dark Faunule was from an upland prairie association. The rim of the kettle probably was suitable for this, as well as shrubby vegetation, but was not sufficiently dry to permit prairie ecotypes. Low topography in itself does not substantiate a primary cause for a high water table because the members of the Light Faunule also recovered from the same geomorphic feature, clearly represent an accumulation from a shortgrass prairie.

*Summary*. The Dark Faunule taxa, 98 percent of which by specimen count are voles likely collected by raptors, best reflect cool, mesic conditions with a high water table and a grassy substrate —either a meadow or a bog. These conditions are consistent with and support identification of Beacon Island as an example of a locality with a Younger Dryas-age "black mat" deposit, associated with cooler climates and higher water tables (Haynes 2008). Two taxa in the Dark Faunule, the red-backed and Ungava voles, also require low shrubby vegetation; dwarf birch is a favorite. However, if shrub stands were extensive, one would expect that the deer mouse would be represented by more than a single specimen.

*Light Faunule*

The Light Faunule, which also appears to be primarily raptor derived, was selected from a shortgrass prairie source and shows a dramatically opposite signature compared to taxa associated with the Dark Faunule. The Light Faunule taxa, 77 percent of which are shortgrass prairie ecotypes, are dominated by pocket mice, pocket gophers, or ground squirrel remains. A few prairie voles (4 percent of the NISP and the MNI) also are present. Two of the remaining taxa in the Light Faunule, a long-tailed shrew and a deer mouse (together amounting to 13 percent of the NISP and 19 percent of the MNI) are ecologically neutral because of the broad environmental parameters at this taxonomic level. They are compatible associates. Only the meadow vole (3 percent of the NISP) does not normally appear in prairie situations and may indicate meadow remnants, perhaps in the immediate or nearby kettles.

The area of sympatry (figure 8.1) for the Light Faunule, defined by the pocket mouse on the west and north and the northern pocket gopher to the south and east, is typical of the shortgrass prairie present in North Dakota today. In fact, the Beacon Island area is near the center of this sympatry.

The relative abundance of species in the Light Faunule indicates a strict source from a dry, upland shortgrass prairie characteristic of the modern Northern Great Plains of North America. The Light Faunule also is dominated by burrowing species (83 percent of the NISP and 77 percent of the MNI) that require a low water table for elaborate burrows, deep nest chambers, and large subterranean food caches. In the case of the northern pocket gopher, at least a meter of depth for nest chambers is required in North Dakota today. Deeper nest chambers are necessary for the thirteen-lined ground squirrel, which hibernates below the frost penetration. Only the meadow vole, represented by three specimens (3 percent of the NISP and 4 percent of the MNI)— a strict meadow dweller—is out of place with the presence of a ubiquitous shortgrass prairie at the time of accumulation.

## Conclusions

Screened matrix associated with the butchered remains of *Bison antiquus* recovered from the Aggie Brown Member of the Oahe Formation at Beacon Island yielded a robust vertebrate fauna represented by 295 identified mammal bones, including 242 micromammal cranial specimens. The identified sample also includes the remains of fish (NISP 1), amphibians (NISP 96), reptiles (NISP 134) and birds (NISP 14). Piece plotted specimens add an additional ten mammal bones, including three micromammal elements. Species richness is unusually low (nine micromammals) for a Northern Plains site that has been carefully waterscreened.

Micromammals from the Beacon Island local fauna can generally be divided into two distinct faunules based on coloration, the presence or absence of adhered carbonate nodules, and a distinctive pattern of mandibular breakage. Specimens from the Light Faunule are tan to yellow in color, do not have carbonate nodules adhered to the dentition, and the mandibles (where preserved) have a partial ascending ramus. All but one of seven identified taxa in the Light Faunule are shortgrass prairie residents. In contrast, specimens assigned to the Dark Faunule are dark brown in color, encrusted with carbonate nodules, and the mandibles (where preserved) are broken between the alveoli for the second and third molars. Component taxa are primarily arvicolines associated with cool, bog-like environments.

It is conceivable that the Light and Dark Faunules are contemporaneous, with members of the Dark Faunule occupying a microenvironment within the shallow kettle and with Light Faunule members residing on the rim of the basin and in the surrounding uplands. Under such a scenario, differing mandibular breakage patterns could be explained by harvesting by different raptors specializing in separate habitats. Unless there was a miniscule microenvironment, it is surprising that there are no more edge taxa, other than perhaps the red-backed (numerous) and Ungava voles. Also, the inventory of the Beacon Island local micromammal fauna is small (nine taxa) with a maximum of seven taxa for each distinct faunule. Low species richness is not unusual in Northern Plains archaeological sites, but sites that are intensively waterscreened over fine-mesh such as Beacon Island frequently produce at least 15 taxa (Semken and Falk 1987). Moreover, if the Beacon Island faunules accumulated contemporaneously, all specimens should exhibit similar preservation, with ubiquitous color variation and carbonate nodule distribution. Thus we consider the Dark and Light Faunules at Beacon Island to represent separate chronological entities. The Saskatchewan sympatry is still valid for all species if the faunules are combined.

The Dark Faunule reflects the presence of a marsh or bog-like environment and enhances the interpretation that Paleoindian-age black mats are the result of a high water table (Haynes 2008). The Light Faunule is representative of the shortgrass prairie that appeared across north central North America at the beginning of the Holocene.

# 9

## Paleoenvironmental Context: The Shell Record

*Paul R. Picha*

The Area A molluscan faunas are described and analyzed to derive paleoecological information about the physiographic and environmental setting at Beacon Island through time. Particular emphasis is devoted to the Agate Basin component and corresponding Aggie Brown Member sedimentary contexts. The chapter is divided into four parts. It begins with a review of molluscan proxy data used to reconstruct late Pleistocene/early Holocene environments in the Plains. The chapter then turns to a discussion of analytic methods used on the Area A assemblage and a summary of the Gastropoda (univalve snails) and Pelecypoda (freshwater bivalves) comprising the collection. The final section summarizes the results and provides interpretations of the ancient environment at Beacon Island.

A taxocene (Evans 1991) or habitat association (Cvancara 1983; Bickel 1977) model underlies the analytical and interpretative framework used here:

> The concepts of species, associations, and environments are still used as the basis for analysis because they have proved relevant throughout biology and ecology, but further interpretive detail needs to be acquired from the contexts of the assemblages. Context comprises species-species (internal) and species-other (external) associations [Evans 1991:75].

Sympatry analysis of the accompanying micromammalian assemblage from Area A, discussed in chapter 8, represents a similar methodological and theoretical orientation for addressing the paleoenvironmental questions at hand.

### Paleoenvironmental Molluscan Proxy Data

Molluscan datasets provide proxy information regarding past climates and local paleoenvironmental conditions and habitats with respect to species distributions in space and time (Dillon 2000; Evans 1991; Sparks 1971:395). For Paleoindian contexts in the Plains, molluscan datasets have been described and analyzed with emphasis directed at both univalve (gastropod) and bivalve (freshwater mussel) remains. Several authors report good to excellent shell preservation in sediment packages dating to the Paleoindian period. Ashworth and Cvancara (1983:Table I) note that ten, and perhaps up to 13, aquatic snail species have been reported from regional contexts thought to date between 12,000 and 10,000 $^{14}$C yr B.P. This section reviews the results of recent investigations that bear on an understanding of the Beacon Island shell assemblage.

For the Agate Basin site in eastern Wyoming, Evanoff (1982:357, Table 5.21) reports that "fossil nonmarine gastropods … indicate that moist vegetation-rich conditions existed during the Clovis and Folsom occupations." Both terrestrial and aquatic gastropod taxa are represented there, though the collection is heavily weighted toward the former class in both the Clovis and Folsom samples. The specific aquatic forms in the assemblage suggest the presence of intermittent aquatic habitats nearby. As Evanoff (1982:358) points out, "*Fossaria parva* is a semiaquatic snail, which often occurs with *Oxyloma* spp. *Aplexa hypnorum* typically inhabits intermittent water bodies." The terrestrial gastropod species in the assemblage also point to locally mesic conditions: "the less abundant snails *Catinella* spp., *Cionella lubrica*, *Euconulus fulvus*, and *Succinea* spp. typically occur in moist vegetation-rich habitats" (Evanoff 1982:358).

Shaw and others (1998) discuss molluscan remains (both bivalve and univalve) recovered from the Wilson-Leonard site in central Texas. Both terrestrial and aquatic snail species serve as indicators of specific microhabitats. For instance, *Gastrocopta armifera,* a terrestrial snail species, "is usually found in wooded habitats with significant amounts of leaf litter and downed wood" (Shaw et al. 1998:1569). Similarly, the presence of aquatic snail taxa may provide information about habitats. Shaw and others (1998:1569) note that "the occurrence of *Cincinnatia cincinnatiensis* and *Fossaria dalli [parva]* indicate the perennial occurrence of shallow, nonstagnant water."

Theler (2003:Figure 12.8) illustrates in schematic fashion gastropod taxa and microhabitats (or taxocenes) along a mesic-xeric environmental gradient for the Burnham Pleistocene pond locality in northeastern Oklahoma. Emergent aquatic vegetation in a ponded setting there is indicated by the occurrence of *Planorbella* sp., while drought tolerant snails (*Gastrocopta* sp.)

typically occur in xeric environments.

Meltzer and Theler (2006:188-189) report on archaeological and modern gastropod assemblages from the Folsom site in northeastern New Mexico. They observe that:

> The absence of freshwater gastropods [at the Folsom site] is in sharp contrast to, for example, the dozen or so Folsom-age localities along Blackwater Draw and at Clovis … wherein aquatic forms (e.g., members of the genus *Gyraulus* and *Stagnicola*) comprised the vast majority of the recovered snails. [The] terrestrial forms present at Folsom—such as *G. armifera*, *G. holzingeri*, *G. procera*, *E. fulvus*, *Hawaiia minuscule*, *V. cyclophorella*, *V. gracilicosta*, and *N. electrina*—were found at these sites, but were in the minority [Meltzer and Theler 2006:188-189].

Using data on the freshwater mussel shell assemblage from the Allen site, Warren (2007) proposes a series of hydrological changes in the site's riverine setting through the Holocene. Mussel shells illustrated by Warren (2007:Figure 4.2) reflect taphonomic traits such as weathering on valves concordant with their age. A single edge-modified valve is present in the Allen collection.

The best represented terrestrial snail forms at the Hell Gap site are *Vallonia gracilicosta* and *Zonitoides aboreus* (Nass and Mead 2009:Table 7.1). Aquatic taxa include *Fossaria cf. F. parva* and *Gyraulus circumstriatus*, indicative of a local, semi-permanent water source, "perhaps in the form of intermittent stream activity or periods when standing water was present at the site" (Nass and Mead 2009:100). However, the number of aquatic specimens in the assemblage is small.

## Methods

Two classes of unmodified shell remains occur in the Beacon Island assemblage: univalve snails or gastropods and freshwater bivalves. Shell remains were segregated for further study using the processing and sorting procedures described in chapter 4. Methods and reporting follow those used previously for other Paleoindian shell assemblages (Evanoff 1982; Nass and Mead 2009; Warren 2007). The Beacon Island shell assemblage is partitioned into six classes: (1) unidentifiable bivalves, (2) identifiable bivalves, (3) non-fossil gastropods, (4) modified shells, (5) fossil remains, and (6) pill/modern clams. Unidentified bivalve remains are fragments of mussel shell that lack taxonomically diagnostic landmarks such as the beak, hinge, or umbo, features which permit specimen classification at the level of genus or species (Cvancara 1983:Figure 1). Identifiable bivalve specimens are those that retain the taxonomic shell landmarks described above; these specimens may be partial or complete shells. Non-fossil gastropods comprise either freshwater or terrestrial snails exhibiting relatively thin shells; thicker-walled specimens with a "chalky" appearance are excluded from this class. Modified shells are specimens that exhibit evidence of human modification by shaping or use, or that have adhering ochre or pigment residue. No modified shells are present in the Beacon Island assemblage. Fossil shell remains include specimens with thick walls and a chalky structure and appearance. Fossil shells typically are larger in size than non-fossil snails and clams. Subfossil remains are included with the non-fossil gastropods. Pill Clams or sphaeriid clams are small bivalves that exhibit a porcellaneous rather than nacreous inner shell (Cvancara 1983:5-6). Sphaeriid clams were not recognized in the assemblage. Modern clams are bivalves that exhibit a vivid, unbleached periostracum and lustrous nacre coloration; some specimens in the Beacon Island assemblage exhibit attached tissues indicative of recent death.

Taxonomic identifications for freshwater bivalve shells were made using illustrated guides (Couch 1997; Cvancara 1983). Key shell traits and taxonomic landmarks used for classification purposes include: shell form or morphology, shell sculpture, aperture shape, and dextral or sinistral coiling (Cvancara 1983:2-8). Other references dealing with terrestrial and aquatic gastropods or univalve snails were consulted while conducting inspections and data collection (Bickel 1977; Burch 1962, 1982; Clarke 1981; Cvancara 1983). Gastropods received primary analytical attention, given their potential to answer paleoenvironmental questions about Beacon Island.

Determination of the context and affiliation of the gastropod remains is critical (Evans 1991). A conservative approach was used in this study, looking first at the collection as a whole and then targeting a select sample of provenience lots assigned to the Aggie Brown and Pick City members. These targeted samples contained the largest number of specimens (MNI), as well as the most diverse and representative assemblages (table 9.1). In the case of the Aggie Brown Member proveniences examined, dark sediment adhering in the recesses of shell apertures and concavities or darker gray staining on translucent to opaque shells suggests they are contemporaneous with the organic-rich sediments of the Aggie Brown Member. By contrast, many specimens from Pick City Member contexts exhibit adhering lighter-colored sediment (figure 9.1). Some indications of turbation processes acting on the site deposits are present, such as the presence in several level lots of modern freshwater mussels; this topic is discussed in more detail later in the chapter. As discussed in chapter

Table 9.1. Provenience data on sampled contexts.

| Catalog Number | Northing | Easting | Elevation | Analytic Unit | MNI |
|---|---|---|---|---|---|
| 1678 | 1269 | 1121 | 988.16-988.04 | Aggie Brown | 19 |
| 1772 | 1272 | 1115 | 988.22-988.10 | Pick City | 21 |
| 1779 | 1274 | 1121 | 988.07-987.97 | Aggie Brown | 26 |
| 1781 | 1272 | 1115 | 988.10-988.00 | Aggie Brown | 27 |
| 7021 | 1276 | 1124 | 988.06-987.95 | Aggie Brown | 86 |
| 7521 | 1277 | 1122 | 988.02-987.89 | Aggie Brown | 81 |
| 7228 | 1278 | 1122 | 988.02-987.88 | Aggie Brown | 80 |
| 7781 | 1273 | 1123 | 988.09-988.00 | Aggie Brown | 244 |
| 7995 | 1275 | 1120 | 988.08-988.00 | Aggie Brown | 101 |

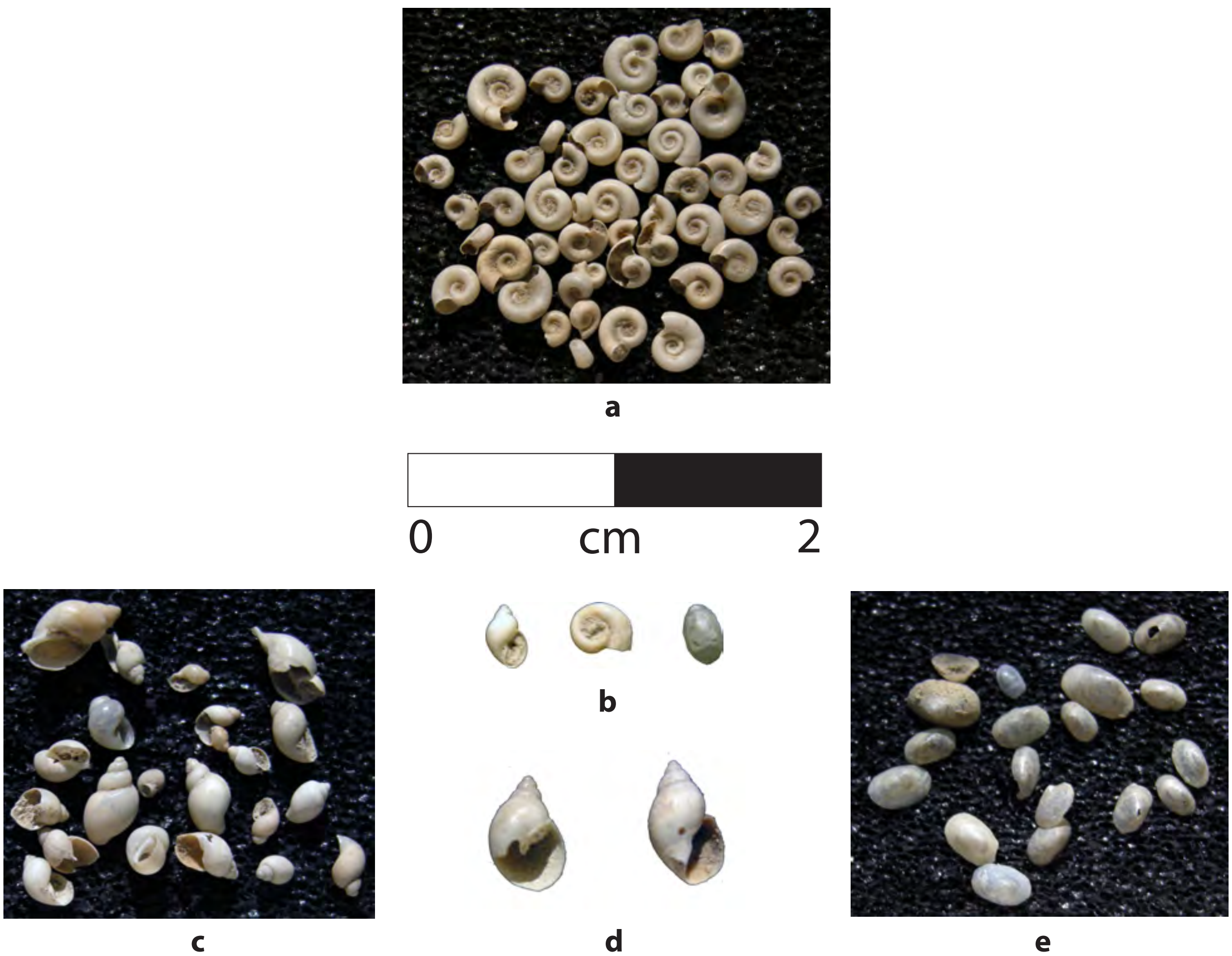


Figure 9.1. Gastropods from Pick City Member contexts in Area A. a: planispiral gastropods; b: conispiral, planispiral, and cap-shaped snails; c, d: conispiral gastropods; e: cap-shaped snails. Note the light-colored sediment adhering to many of the shells.

3, two different recovery methods were used at Beacon Island: dryscreening through 1/4-inch hardware cloth and waterscreening through 1/16-inch window screen. Because a significant fraction of the shell assemblage falls in the size grades 4 and 5 fractions, which only are captured by fine-mesh screening, this analysis excludes samples recovered by dryscreening during the May 2002 field session.

## Gastropod Data from Beacon Island

Gastropods dominate the shell assemblage from Area A. Shell preservation appears to be good, with gastropod remains occurring consistently throughout the excavated deposits. However, sample sizes of recovered shells are not large and the number of specimens varies considerably among provenience lots. Shell fragments occur in some samples, with unidentifiable whorl scrap being more common than complete valves. As noted in the previous section, the occurrence of staining (mostly gray) or adhering dark sediment confirms the contemporaneity of a portion of the shell aggregate with the Aggie Brown.

Minimum number of individual values (MNI) for provenience lots processed with fine-screen recovery range from 1 to 244. Conispiral, planispiral, and cap-shaped shell forms are present (figure 9.2; table 9.2). Six aquatic taxa definitely are represented and three others possibly are represented (table 9.3). Planispiral snails occur most frequently (table 9.2). Common genera include *Planorbula* sp. Rare genera include *Gyraulis* sp., *Helisoma* sp., and *Amnicola* sp. Conispiral snails include *Fossaria* sp. (common), *Stagnicola* sp. (rare), and *Valvata* sp. (rare). Patelliform or cap-shaped snails are the least abundant form overall and include *Ferrisia* sp. (common). Significantly, Cvancara (1983:66) notes that *Fossaria decampi* "is known only as a fossil in [North Dakota] from sediments older than about 9,600 years."

The only terrestrial gastropod specimen and taxon recognized in the Beacon Island shell aggregate is *Discus cronkhitei*, a radial-ribbed form, which prefers "moist woodland habitat" (Bickel 1977:18) (table 9.4). It occurs in an Aggie Brown Member context (figure 9.2a).

## Gastropod Ecology

Interpreting these data requires an understanding of species environmental preferences, which are outlined in this section.

### Aquatic Gastropods

Aquatic gastropods inhabit various riparian environments, such as shallow backwaters of the Missouri River system and its tributaries, where flowing or ponded water occurs, with corresponding vegetation communities on different substrates (Theler 2003:Figure 12.8). Snail lifespans are typically short—one to two years—although some may live as long as decade. Several distinctive forms of aquatic conispiral, planispiral, and cap-shaped (patelliform) shells occur in North Dakota. *Valvata tricarinata* is a conispiral snail that Clarke (1981:52) notes is "rare in ponds." The planispiral *Armiger crista* "lives among dense vegetation in eutrophic ponds and slow-moving streams" according to Clarke (1981:184).

Cvancara (1983:Figure 18) proposes a *Helisoma trivolvis-Lymnaea stagnalis* association in North Dakota for permanent lake or pond habitats that includes five gastropod species: two conispiral aquatic snails (*Physa gyrina* and *Valvata tricarinata)* and three planispiral aquatic snails (*Helisoma ancep*s, *Helisoma trivolvis*, *Gyraulis parvus*). Among the most distinctive is *Valvata tricarinata* (Say) with its prominent carinae (Cvancara 1983:61, Figure 5). Cvancara (1983:61, Figure 18) also groups seven gastropod species that live in intermittent lake or pond habitats. Species making up this *Aplexa hypnorum-Gyraulis circumstriatus* association include three conispiral aquatic snails (*Aplexa hypnorum*, *Stagnicola caperata*, *Physa jennessi*), and four planispiral aquatic snails (*Promenetus umbilicatellus*, *Promenetus exacuous*, *Armiger crista*, *Gyraulus circumstriatus*).

Two additional aquatic snail species are relevant to this discussion. *Planorbula campestris* is a planispiral snail. Cvancara (1983:79) indicates that in North Dakota this species "was collected alive only from an intermittent marsh … [and] … empty shells were also taken from an intermittent pond." Similarly, *Planorbula armingera* has been reported elsewhere to be characteristic of stagnant bodies of water. However, based on the cluster analysis that derived the habitat associations, *P. campestris* and

Table 9.2. Summary of gastropod forms from Area A.

| Catalog Number | Analytic Unit | Conispiral | Planispiral | Cap-shaped | MNI |
|---|---|---|---|---|---|
| 1678 | Aggie Brown | 3 | 14 | 2 | 19 |
| 1772 | Pick City | 1 | 19 | 1 | 21 |
| 1779 | Aggie Brown | 5 | 15 | 6 | 26 |
| 1781 | Aggie Brown | | 27 | | 27 |
| 7021 | Aggie Brown | 20 | 61 | 5 | 86 |
| 7521 | Aggie Brown | 22 | 51 | 8 | 81 |
| 7228 | Aggie Brown | 23 | 50 | 7 | 80 |
| 7781 | Aggie Brown | 67 | 168 | 9 | 244 |
| 7995 | Aggie Brown | 24 | 51 | 26 | 101 |


Figure 9.2. Gastropods from Aggie Brown Member contexts in Area A. a: planispiral gastropods; b: cap-shaped snails; c: planispiral gastropods; d: conispiral and planispiral gastropods; e: conispiral gastropods; f: conispiral gastropods. Note the dark staining and adhering dark sediment on many specimens.

Table 9.3. Summary of aquatic gastropod taxa identified from Area A. (Based on Cvancara [1983] and Ashworth and Cvancara [1983]).

| Species | Form | Occurrence | Reference |
|---|---|---|---|
| *F. obrussa* | Conispiral | Yes | Cvancara 1983:Plate 4 |
| *F. decampi* | Conispiral | ? | Cvancara 1983:66 |
| *C. cincinnatienus* | Conispiral | ? | Cvancara 1983:Plate 4 |
| *P. gyrina* | Conispiral | No | Cvancara 1983:Plate 4 |
| *P. jennessi* | Conispiral | No | Cvancara 1983:Plate 4 |
| *P. integra* | Conispiral | No | Cvancara 1983:Plate 4 |
| *A. hypnorum* | Conispiral | No | Cvancara 1983:Plate 4 |
| *C. decisum* | Conispiral | ? | Cvancara 1983:Plate 4 |
| *L. stagnalis* | Conispiral | No | Cvancara 1983:Plate 4 |
| *V. tricarinata* | Conispiral | No | Cvancara 1983:Plate 4 |
| *V. sincera* | Conispiral | Yes? | Clark 1981:46-47 |
| *P. lacustris* | Conispiral | No | Cvancara 1983:Plate 4 |
| *A. limosa* | Conispiral | Yes | Cvancara 1983:Plate 4 |
| *S. elodes* | Conispiral | Yes | Cvancara 1983:Plate 4 |
| *S. caperata* | Conispiral | ? | Cvancara 1983:Plate 4 |
| *H. trivolvis* | Planispiral | Yes? | Cvancara 1983:Plate 5 |
| *H. anceps* | Planispiral | Yes? | Cvancara 1983:Plate 5 |
| *A. crista* | Planispiral | No | Cvancara 1983:Plate 5 |
| *G. circumstriatus* | Planispiral | ? | Cvancara 1983:Plate 5 |
| *G. parvus* | Planispiral | Yes | Cvancara 1983:Plate 5 |
| *P. armigera* | Planispiral | ? | Cvancara 1983:Plate 6 |
| *P. campestris* | Planispiral | Yes | Cvancara 1983:Plate 6 |
| *P. umbilicatellus* | Planispiral | No | Cvancara 1983:Plate 6 |
| *P. exacuous* | Planispiral | No | Cvancara 1983:Plate 6 |
| *F. rivularis* | Cap-shaped | ? | Cvancara 1983:Plate 6 |
| *F. parallela* | Cap-shaped | Yes | McAndrews *et al.* 1967 |

Table 9.4. Summary of terrestrial gastropod taxa identified from Area A. (Based on Bickel 1977 and Ashworth and Cvancara 1983).

| Species | Form/Family | Occurrence | Reference |
|---|---|---|---|
| *G. armifera* | Pupillidae | No | Bickel 1977:Figure 1 |
| *G. holzingeri* | Pupillidae | No | Bickel 1977:Figure 5 |
| *P. blandi* | Pupillidae | No | Bickel 1977:Figure 2 |
| *V. binneyana* | Pupillidae | No | Bickel 1977:Figure 3 |
| *V. ovate* | Pupillidae | No | Bickel 1977:Figure 4 |
| *V. excentria* | Valloniidae | No | Bickel 1977:Figure 11 |
| *V. gracilicosta* | Valloniidae | No | Bickel 1977:Figure 9 |
| *C. lubrica* | Cionellidae | No | Bickel 1977:Figure 6 |
| *H. minuscula* | Zonitidae | No | Bickel 1977:Figure 15 |
| *Z. arboreus* | Zonitidae | No | Bickel 1977:Figure 13 |
| *E. fulvus* | Zonitidae | No | Bickel 1977:Figure 8 |
| *R. binneyana* | Zonitidae | No | Bickel 1977:Figure 16 |
| *V. limpida* | Zonitidae | No | Bickel 1977:Figure 12 |
| *C. avara* | Succineidae | ? | Bickel 1977:Figure 7 |
| *D. cronkhitei* | Endodontidae | Yes | Bickel 1977:Figure 18 |
| *D. laeve* | Limacidae | No | Bickel 1977:Figure 19 |

*P. armingera* were not included with a proposed habitat cluster by Cvancara (1983:Figure 18), due to their infrequent modern occurrence.

Ashworth and Cvancara (1983:152, Table I) suggest "that three aquatic snails, *Valvata sincera*, *Fossaria decampi*, and *Helisoma campanulatum*, may have become regionally extinct in North Dakota about 9,000 B.P." The first two of these genera (*Fossaria* and *Valvata*) are identified in the Area A shell samples.

Cvancara (1983:117) also reports on pill clams and aquatic gastropods from collection stations along the Little Knife River drainage. Three gastropod genera are identified: *Probythinella lacustris*, *Helisoma anceps*, and *Physa gyrina*. In relative frequencies, these are ranked from uncommon to abundant.

## Limpet-like or Cap-shaped Shell

An aquatic limpet-like or cap-shaped (patelliform) univalve, *Ferrissia rivularis,* occurs in North Dakota. Cvancara (1983: Plate 6:11, 70-71) indicates that it is a small stream species that prefers a firm substrate such as gravel. In settings lacking this firm substrate, it is found attached to bivalve mussels. Another species, *Ferrissia parallela*, has been reported in fossil assemblages from a Missouri Coteau pothole lake (Cvancara 1983:70-71; McAndrews *et al.* 1967:Table H-2).

Cap-shaped shells are present in many Aggie Brown proveniences at Beacon Island. The specimens that occur in Aggie Brown contexts are identified as *Ferrissia parallela*, where the shell apex is located posterior to the shell mid-line. *Ferrissia* sp. shells have been recorded at other Plains Paleoindian sites.

## Terrestrial Gastropods

Terrestrial gastropod population diversity and distributions within various habitats are governed by moisture and corresponding cover vegetation. Bickel (1977:Figures 1-19) illustrates terrestrial snail species derived from his survey of southwestern North Dakota. Ten species of land snails are recorded from 14 sample locations in McKenzie County (Bickel 1977:Table 1). Among the distinctive terrestrial snails are the pupillid forms, such as *Gastrocopta* spp., *Pupilla* spp., and *Vertigo* spp., that are recognizable by their shell form and aperture architecture.

Burch (1962:67) indicates that, in general, conispiral terrestrial forms of the Family Succineidae "are nearly always found close to bodies of water, along stream banks, at the edges of ponds or lakes, and in or near marshes."

No pupillaform (Pupilladae) gastropods were recognized in the Area A assemblage. These distinctive terrestrial forms, often represented by *Gastrocopta* and *Vertigo* spp. in snail samples, are common to xeric settings in western North Dakota and throughout the Northern Plains.

Lastly, in their summary of molluscan ecology Ashworth and Cvancara (1983:Table I) report that only four land snail taxa (*Catinella*, *Oxyloma*?, *Discus*, and *Helicodiscus*? spp.) are known from contexts thought to date between 12,000 and 10,000 $^{14}$C yr B.P.

Discussion

Ubiquity provides one means of addressing the species-species context outlined by Evans (1991) (table 9.5). Patelliform *Ferrissia* sp. shell is common throughout Area A. Other common taxa include *Fossaria* sp. and *Planorbula* sp. This suite of aquatic snails is indicative of a nearby intermittent water body or of a semi-permanent pond or water-filled depression within a larger kettle basin landscape (Nass and Mead 2009).

The taxocene approach of Evans (1991) and association groupings of Cvancara (1983) and Bickel (1977) also support the inference of a "wet-ground" microhabitat at Beacon Island during the deposition of the Aggie Brown Member, as indicated by an aquatic species association most characteristic of a proximate intermittent pond or standing water.

Two lines of negative evidence corroborate this interpretation, though they should be viewed with some caution, given the potential biasing effects of field recovery methods (Baerreis 1980; Jaehnig 1971; Nass and Mead 2009:99). First, certain aquatic species that prefer permanently wet microhabitats, such as pill clams (*Pisidium* and *Sphaerium* spp.) or sinistral forms of the Physidae (*Aplexa*, *Physa*) spp. were not observed in the Area A assemblage. The pill clams in particular are durable and exhibit a characteristic form (Cvancara 1983:Plate 3), and so likely would have been recovered and recognized if present. Second, the general paucity of terrestrial snail taxa, and the absence of certain forms (e.g., Pupillids) that are stress tolerant, argues against locally xeric conditions in Area A during the deposition of the Aggie Brown Member.

**Bivalve Shell**

Freshwater mussel shell is present in the Area A shell aggregate. A total of 19 provenience lots produced identified or unidentified bivalve shell in size grades 1 through 5 (figure 9.3). Together these specimens weigh 4.4 g. Recovered pieces include a size grade 2 ligament-hinge segment, a size grade 4 ventral edge-margin fragment, and several size grade 3 medial portions. One identified specimen (a juvenile size grade 4 *Pyganodon grandis* valve) occurs in CN1928. A pair of juvenile size grade 4 *Lampsilis siliquoidea* valves was recovered in CN7081. A second set of paired juvenile size grade 4 *Lampsilis siliquoidea* valves was recovered in CN7351.

Given their lustrous and uneroded appearance, these bivalve shell remains are associated with modern lakebed sediment. Backlund (2000) documents similar modern bivalve populations on the Missouri River flats at the confluence of Medicine Knoll Creek along Lake Sharpe (Big Bend Reservoir) in South Dakota. Similarly, Emerson (1993:241-243; see also Ahler 1994:135) reports that the mussel and aquatic gastropod shells recovered at the Folsom site 32DU955A at Lake Ilo were of recent origin and associated with "historic lake sediment." At Lake Ilo, *Pyganodon grandis* mussels were exposed in sandy silt beach deposits during a recent reservoir drawdown in 2008 (figure 9.4). A similar scenario accounts for the fragmented mussel shells in the modern beach-lag sediments and near-surface contexts at Beacon Island. Warren (2007:Figure 4.2) illustrates bivalve specimens from the Allen site, but these exhibit an eroded and non-lustrous appearance that is consistent with their reported Paleoindian/Archaic age.

Pioneering malacological surveys were undertaken by Cvancara (1983) that provide valuable biological baseline data concerning molluscan composition and density. Cvancara (1983:34-38,117) sampled locations along Little Knife River in 1967 and reports occurrences of two common freshwater bivalve species in the drainage near the confluence with Lake Sakakawea. These include *Pyganodon* (=*Anodonta*) *grandis* (Say) or "giant floater," and *Anodontoides ferussacianus* (Lea, 1834) or "cylindrical paper shell." The *Pyganodon grandis-Lasmigona complanata* association forms the basis of

Table 9.5. Summary of gastropod taxa identified in the Area A shell aggregate.

| Species | Ubiquity | Habitat | Form |
|---|---|---|---|
| *Fossaria obrussa* | Common | Aquatic | Conispiral |
| *Valvata sincera* | Rare | Aquatic | Conispiral |
| *Amnicola limosa* | Rare | Aquatic | Conispiral |
| *Stagnicola elodes* | Rare | Aquatic | Conispiral |
| *Helisoma trivolvis* | Rare | Aquatic | Planispiral |
| *Helisoma anceps* | Rare | Aquatic | Planispiral |
| *Gyraulis parvus* | Rare | Aquatic | Planispiral |
| *Planorbula campestris* | Common | Aquatic | Planispiral |
| *Ferrissia parallela* | Common | Aquatic | Cap-shaped |
| *Discus cronkhitei* | Rare | Terrestrial | Endodontidae |

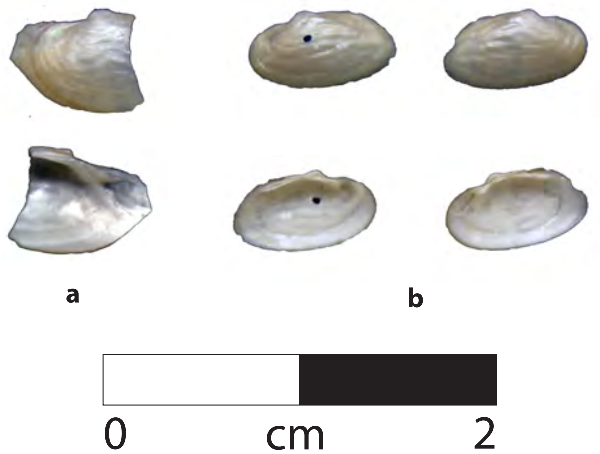


Figure 9.3. Bivalve shell from Area A. a: juvenile *Pyganodon grandis* valve (CN 1928); b: juvenile *Lampsilis siliquoidea* valves (CN 7081). Note the vivid luster of the nacre and the vivid coloroation of the periostracum in all three specimens.

Figure 9.4. *Pyganodon grandis* valves in near-shore lakebed sediments at Lake Ilo National Wildlife Refuge, Dunn County, North Dakota, following drawdown of the small man-made reservoir.

small, permanent-stream aquatic habitat as these species are the most common and abundant in the Missouri River basin in west-central North Dakota.

### Summary and Conclusions

The shell aggregate from Area A at Beacon Island includes gastropod (univalve) and bivalve remains. This analysis of the recovered shell assemblage is directed toward taxa identification and construction of corresponding taxocene or habitat associations that complement other paleoenvironmental proxy data for the site.

The gastropod assemblage reflects an intermittent or semi-permanent, pond-edge habitat (or at least a setting with proximal standing water), such as a kettle basin landform that held water intermittently during Agate Basin times and during the formation of the Aggie Brown Member. Further, the results of this investigation are in accord with the environmental scenario that Haynes (2008:6520) has proposed. Haynes argues that the lithostratigraphic units he describes as "black mats" occur in "eolian silt or fine sand (loess) where the black organic horizons reflect more mesic conditions than either before or after." The gastropods identified at Beacon Island comprise almost entirely aquatic taxa. Only one terrestrial taxon is definitely represented, and that species, *Discus cronkhitei*, is a mesic environment indicator. The suite of identified aquatic and terrestrial gastropod taxa at Beacon Island is in accord with other regional Paleoindian molluscan proxy data reported to date (Evanoff 1982; Meltzer and Theler 2006; Nass and Mead 2009).

The freshwater mussels recovered from the excavations are interpreted as entirely recent in origin and associated with recent lakebed sediment. Two common bivalve species (*Pyganodon grandis* and *Lampsilis siliquoidea*) were identified in the collections. No unmodified or modified bivalve shell remains can be definitively associated with the Agate Basin component in Area A.

The taxocene (wet-ground) or habitat association scenario (mesic environment in proximity to standing water in an intermittent pond-edge setting within the larger kettle basin) presented here would be strengthened by the collection and analysis of controlled molluscan column samples from other parts of the site (Jaehnig 1971; Nass and Mead 2009:99). In closing, Evans offers the following observations regarding molluscan datasets and their relation to paleoenvironmental studies:

> More generally, there are two directions of research needed. One is the accumulation of more data from autochthonous contexts, an amassing of recurrent associations both species-species and species-external, so building on the taxocenes proposed here. The other is a deeper appraisal of the ecology of chalk-grassland and wet-ground habitats and the ecology of their molluscan faunas and taxocene—both modern and subfossil [Evans 1991:87-88].

# 10

## Paleoenvironmental Context: The Stable Carbon Isotope and Phytolith Record

*Laura R. Murphy and Rolfe D. Mandel*

This chapter presents the results of a combined isotopic and microbotanical analysis of buried soils in Area A. Two components of the soils were analyzed to infer changes in vegetation through time and during human occupation at the site: stable carbon isotopes of soil organic matter, and plant phytoliths. Understanding the paleoenvironmental context of Beacon Island, including the composition of former plant communities, is crucial to understanding the relationships between landscape evolution, climatic fluctuations, and human activities at the site.

Few paleoenvironmental indicators exist for the grasslands of the Northern Plains, and even fewer extend to the late Pleistocene (Beaudoin 1993; Cyr et al. 2011). Proxies used for late-Quaternary paleoenvironmental reconstruction in the region include lithostratigraphy and pedostratigraphy (Clayton et al. 1976), pollen (Yansa 2006), stable nitrogen and carbon isotopes of bison collagen (Leyden and Oetelaar 2001), microscopic charcoal (Boyd 2002), opal phytoliths (Fredlund and Tieszen 1997; Boyd 2002, 2005; Cyr et al. 2011), and stable carbon isotopes of soil organic matter (Cyr et al. 2011). In a recent study, Mason and others (2008) conducted a quantitative analysis of loess accumulation and soil formation to assess the timing, abruptness, and nature of climate change in the Northern Plains during the Pleistocene–Holocene transition. Valero-Garcés and others (1997) demonstrate the effectiveness of comprehensive multi-proxy analyses in the Northern Plains that include stratigraphy, pollen, diatoms, and isotope geochemistry.

The episode of human occupation represented by the Agate Basin component at Beacon Island coincides with the Younger Dryas Chronozone (YDC) (ca. 11,000-10,000 $^{14}$C yr B.P.), a period of cooler climate compared to the preceding Bølling/Allerød interstadial (Alley 2007; Alley et al. 1993; Broecker et al. 1989; Mayewski et al. 1993). Although the YDC is often described as a cool, dry period (Alley 2007), precipitation and run-off patterns varied, both on a continental and sub-continental scale (Meltzer and Holliday 2010). Several studies indicate that the Northern Plains experienced cool, moist conditions during the time of the YDC. For example, Artz (1995, 2000) suggests that a cool, moist climate supported a grassland community in the Northern Plains during the late Wisconsin and early Holocene, prior to the onset of the Altithermal (around 8000 $^{14}$C yr B.P.). Valero-Garcés and others' (1997) record from Moon Lake, North Dakota shows that climate was cool and moist with high effective moisture between 11,700 and 9500 $^{14}$C yr B.P. Also, according to Mason and others (2008), the Leonard Paleosol, which typically dates to around 10,000-8000 $^{14}$C yr B.P., formed at a time with high effective moisture in the Northern Plains.

Ahler, Timpson, and Crawford (2003:21) suggest that during the time of Agate Basin occupation at the Beacon Island site (roughly 10,300 $^{14}$C yr B.P.) the plant community there probably was a mesic $C_3$ grassland suitable for bison herds. One of the primary objectives of this paleoenvironmental investigation is to confirm or refute this hypothesis.

### Modern Climate and Vegetation

With the exception of the southwest corner of the state, North Dakota is in Thornthwaite's (1948) Dry Subhumid ($C_1$) climatic region. The $C_1$ climate is characterized by hot, dry summers and cold, dry winters. Most of the precipitation occurs in spring and early summer. The mean annual precipitation at nearby New Town, North Dakota is 38.35 cm (15.1 in) (High Plains Regional Climate Center 2011). The average daily maximum and minimum temperature in January is 8.5º C (16.7º F) and -19.6º C (-3.3º F), respectively. The average daily maximum and minimum temperature in July is 28.3º C (83.0º F) and 13.3º C (56.0º F), respectively.

The Plains is dominated by tall-grass, mixed-grass, and short-grass prairies (figure 10.1) comprised of the three major Poaceae (grass) subfamilies: Chloridoideae, Panicoideae, and Pooideae. The climate of the Northern Plains, including the area around Beacon Island, largely supports $C_3$ grasses of the Pooideae subfamily (Rovner 2001; Cyr et al. 2011). Native species of the Poaceae family found in Mountrail County, North Dakota today include Pooideae varieties of wheatgrass (*Agropyron*), wild rye (*Elymus*), fescue (*Festuca*), needlegrass (*Hesperostipa*, e.g. *Stipa*), brome (*Bromus*), and bluegrass (*Poa*) (USDA NRCS 2011). A smaller proportion of the plant community is made up of $C_4$ Chloridoideae and

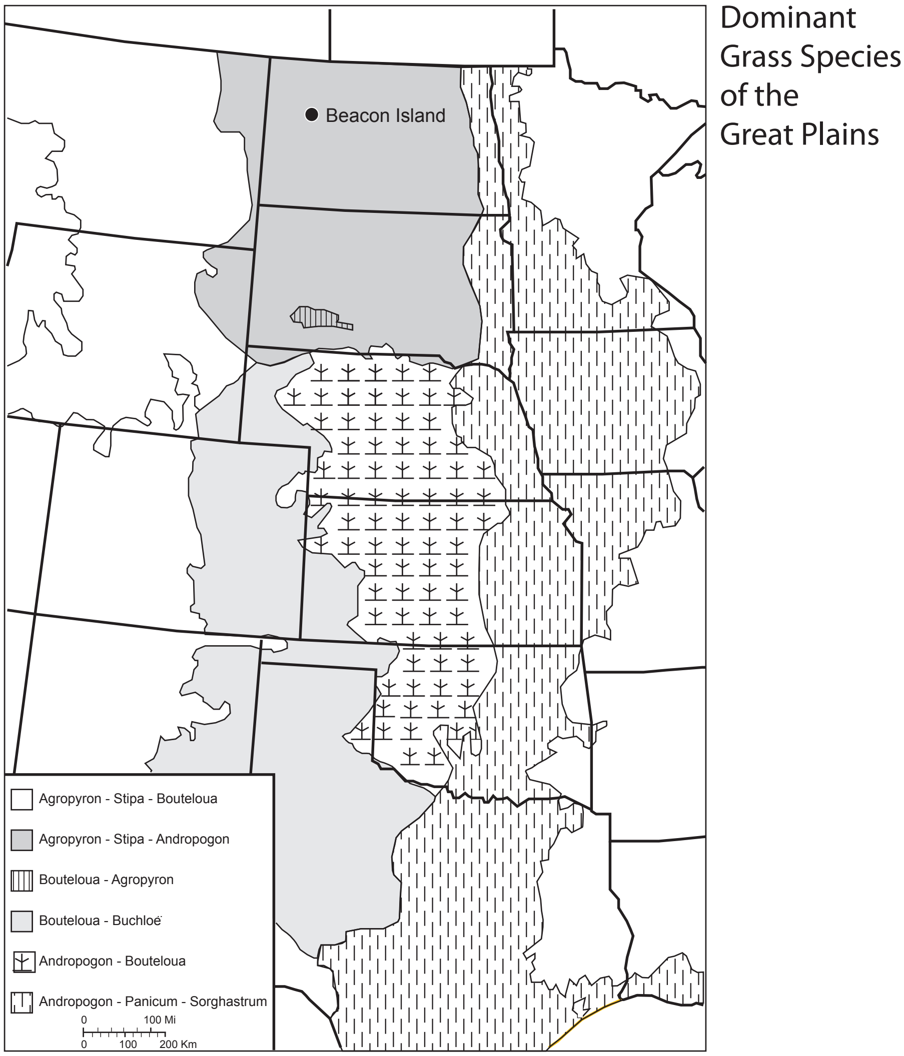


Figure 10.1. Generalized vegetation map showing the location of the Beacon Island site within the Agropyron-Stipa-Andropogon (Panicoid-Pooid) grassland (adapted from Fredlund and Tieszen [1994] and Küchler [1975]).

Panicoideae varieties, including bluestem (*Andropogon*), grama (*Bouteloua*), and three-awn (*Aristida*).

## Background

### Stable Carbon Isotopes

Stable carbon isotope analysis of organic carbon in soils has been successfully used in many paleoenvironmental studies (Ambrose and Sikes 1991; Dorale et al. 2010; Fredlund and Tieszen 1997; Guillet et al. 1988; Kelly et al. 1991, 1993; Krishnamurthy et al. 1982; Mandel 2006; Nordt 1993, 2001; Nordt et al. 1994, 2008; Schwartz 1988; Schwartz et al. 1986). To understand the theory behind this analytical technique, the ecology of $C_3$ and $C_4$ plants must be considered. During photosynthesis, $C_4$ plants discriminate less against $^{13}CO_2$ than $C_3$ plants (O'Leary 1981; Vogel 1980). This difference in carbon isotope fractionation results in a characteristic carbon isotope ratio in plant tissue that serves as an indicator for the occurrence of $C_3$ and $C_4$ photosynthesis (Nordt 1993:52). The $\delta^{13}C$ values, or the difference between the $^{13}C/^{12}C$ ratio and a known standard, are expressed in parts per thousand (‰). Boutton (1991a) demonstrates that the $\delta^{13}$ C value of $C_3$ plant species range from -32 to -20 ‰, with a mean of -27 ‰, whereas the $\delta^{13}C$ values of $C_4$ plant species range from -17 to -9 ‰, with a mean of -13 ‰. Values between -22‰ and -17‰ represent a mixed plant community consisting of both $C_3$ and $C_4$ grasses. Thus, $C_3$ and $C_4$ plant species have distinct, non-overlapping $\delta^{13}C$ values and differ from each other by approximately 14 ‰ (Boutton 1991b).

Nearly all trees, shrubs, forbs, and cool-season grasses are $C_3$ species. Hence, forests and most other temperate plant communities are dominated by $C_3$ species. Plants with the $C_4$ photosynthetic pathway are common in warm, semiarid environments with high light intensity, such as grasslands, savannas, deserts, and salt marshes. Studies have shown that the proportions of $C_4$ species and $C_4$ biomass in a given plant community are strongly related to temperature (Boutton et al. 1980; Terri and Stowe 1976; Tieszen et al. 1979). These relationships are invaluable in paleoecological studies when the relative proportions of $C_3$ vs. $C_4$ species can be reconstructed (Nordt et al. 1994).

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

### Phytoliths

Phytoliths, or "plant stones," are rigid, microscopic silica bodies deposited in cell walls, cell interiors, and intracellular spaces (Piperno 2006). Phytoliths are abundant in grasses, are deposited directly into the soil, are resistant to decay, and exhibit morphological differences among the dominant $C_3$ and $C_4$ grass subfamilies (i.e. Chloridoideae, Panicoideae, and Pooideae). Thus, phytolith analysis in the grass-dominated Plains is an important paleoenvironmental proxy in a region where pollen is not typically preserved (Piperno 2006).

Changes in phytolith assemblages throughout a soil profile may suggest shifts in local environment from warm and dry to warm and moist or cool and moist. Chloridoids are $C_4$ short-grasses such as grama grass (*Bouteloua* spp.) and buffalo grass (*Buchloë dactyloides*). Chloridoids are adapted to warm and dry climates, and have a diagnostic "saddle" shaped, short-cell phytolith. Panicoids are $C_4$ tall-grasses such as switchgrass (*Panicum*), Indian grass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*) that are adapted to warm and moist climates. Panicoid short-cell morphotypes include cross-shapes and bilobates. Pooids are $C_3$ cool-season grasses that include a variety of genera such as bluegrass (*Poa*), wheatgrass (*Agropyron*), wild rye (*Elymus*), and needlegrass (*Stipa*). Pooids produce a variety of unique morphotypes that are classified as trapeziforms (Madella, Alexandre and Ball 2005), including the *Stipa*-type lobate trapeziform identified by Fredlund and Tieszen (1994). $C_3$ trees and shrubs (i.e., those in the Dicotyledonae class) are under-represented in the phytolith record, but their presence can be inferred from stable carbon isotope data.

Phytolith preservation in soils and sediments is impacted by bioturbation, translocation, presence of iron and aluminum oxides, erosion, fire, wind, herbivory, anthropogenic activity, soil texture and pH, rates of deposition, and exposure to water (Fredlund and Tieszen 1997; Grave and Kealhofer 1999; Piperno 2006; Murphy 2008). Also, while grasses actively collect soluble silica, other plants, such as $C_3$ trees and shrubs, do so passively and may produce phytoliths irregularly depending on local climate and soil conditions (Bozarth 1992).

### Multiple Proxies

Multi-proxy analyses should be employed to corroborate each line of evidence used to reconstruct paleoenvironments. For example, stable carbon isotope values determined on pedogenic carbon offer a direct comparison to the recovered phytoliths. Changes in the relative proportions of $C_3$ vs. $C_4$ species inferred from the $\delta^{13}C$ values can be compared to the phytolith data, and inferences can be made about the input of carbon from $C_3$ trees and shrubs that are under-represented in the phytolith record (Fredlund and Tieszen 1997; Piperno 2006). Also, phytolith differentiation among the major grass subfamilies allows a more-refined assessment of the stable carbon isotope data. Because warm and moist and warm and dry $C_4$ grasses can be differentiated based on phytolith morphotypes, more precise paleoenvironmental assessments can be made compared to the broad trends in stable carbon isotope values alone.

## Methods

In Area A, 29 soil samples from Profile 1 and 29 samples from Profile 2, each weighing approximately 200 g, were collected mostly at 5 cm intervals, except where stratigraphic breaks occur. Eight bulk soil samples were collected by soil horizon from Profile 3. Samples were processed for stable carbon isotope analysis at the Kansas Geological Survey. The isotope samples were dried in an oven at 50ºC, and homogenized with a ceramic mortar and pestle. Samples were pre-treated by adding 20 ml of 0.5 N hydrochloric acid solution to 1 g of soil to remove calcium carbonate. After the reaction was complete, 30 ml of distilled water were added to each sample and centrifuged at 4000 RPMs for five minutes and decanted. The process was repeated to ensure chlorine removal. Decalcified samples were dried at 50º C, pulverized using a synthetic ruby mortal and pestle, and transferred to vials.

Prepared isotope samples from Profile 2 were sent to the Stable-Isotope Biogeochemistry Laboratory at McMaster University where they were combusted using a Costech element analyzer coupled with a Thermo-Finnigan DeltaPlus XP isotope ratio mass spectrometer. Nine National Institute of Standards and Technology (NIST) standards and three internal standards with known $^{13}C/^{12}C$ ratios were used, which were calibrated against the NIST NBS 21 standard. The precision of reported $\delta^{13}C$ values are based on a linear correction of observed values versus expected values of the standards. A linear fit of 0.999 is used to correct all data.

Prepared isotope samples from Profiles 1 and 3 were analyzed at the Keck Paleoenvironmental and Environmental Stable Isotope Laboratory (KPESIL), University of Kansas. Raw $\delta^{13}C$ values were obtained via high-temperature combustion with a Costech ECS4010 elemental combustion system in conjunction with a ThermoFinnigan MAT253 isotope ratio mass spectrometer at KPESIL. International standards used to calibrate $\delta^{13}C$ values were NIST USGS-24 (graphite) No. 8541, IAEA-600 (caffeine), and NIST ANU (sucrose) No. 8542. A pre-calibrated internal standard (DORM-2 dogfish muscle; National Research Council of Canada) was used in the $\delta^{13}C$ calibration curve, as well as for percent carbon (%C) determination. The precision of reported $\delta^{13}C$ values is based on a linear correction of observed values versus expected values of the standards. Typical standard calibration curves yield an $R^2$ of 0.9994 or greater.

A subset of eight soil samples from Profile 2 at Area A were processed for phytoliths using a modified procedure described by Piperno (2006). Seventy-five milliliters of sodium pyrophosphate were added to each sample to disperse clays. The samples were then centrifuged at low speeds (1,500-2,000 RPMs) and decanted; this process was repeated until the supernatant was clear.

Several samples contained large quantities of very fine organic material and charcoal that remained in suspension. The organic material was removed with a pipette after the first five centrifugations and transferred to 250 ml centrifuge bottles. The bottles were centrifuged at 2,500 RPMs for 15 minutes, decanted, and centrifuged again at 2,500 RPMs for 5 minutes and decanted. The remaining organic materials were then transferred back to the original samples.

After oxidation with hydrogen peroxide, 3 lycopodium spore tablets, each containing 18,585 spores, were added to each sample to calculate phytolith concentrations using the method developed by Bozarth (1992). Phytolith isolation and thin section mounting followed methods used for plant materials published by Piperno (2006). Samples were mounted on 25 x 75 x 1 mm microscope slides in standard Type A immersion oil. A standard petrographic microscope was used to analyze each slide at 40x and 100x magnification. Phytoliths were tallied by transect until at least 200 cells were counted for each slide. Phytolith concentrations (phytoliths per gram of treated sediment) were calculated with the following formula:

([number of observed phytoliths] x [number of lycopodium spores introduced] / [number of observed lycopodium spores]) / [original sample weight].

Recovered phytoliths representing identifiable subfamilies and genera were compared to a phytolith reference collection at the University of Kansas.

A digital pH meter was used to determine soil pH in Profile 2, where the eight phytolith samples were collected. Because silica generally goes into solution at pH 8.5, it is important to determine soil alkalinity.

## Results

### Stable Carbon Isotope Ratios

The $\delta^{13}C$ values determined on organic carbon from soils at the Beacon Island site range from -25.4 to -22.6‰, indicating a strong $C_3$ signature for the entire period of record (figures 10.2, 10.3, and 10.4). The lightest value, -25.4‰, occurs in the mixing zone between the Mallard Island and Aggie Brown members, which is where the Agate Basin cultural component is located in the stratigraphic sequence. The heaviest value, -22.6‰, occurs in the Pick City Member. The difference between the maximum and minimum $\delta^{13}C$ value is -2.8‰.

Identifying the point at which changes in the $\delta^{13}C$ values reflect actual changes in vegetation composition ($C_3$ vs. $C_4$) is difficult (Cyr et al. 2011). According to Krull and Skjemstad (2003), changes between 1 and 3‰ are related to inherent soil processes, whereas differences exceeding 3‰ result from changes in the contribution of $C_3$ and $C_4$ vegetation. Ehleringer et al. (2000), however, noted that changes as slight as 1‰ may be caused by environmental stress. A 1‰ to 3‰ shift in the $\delta^{13}C$ values may reflect increased fractionation against $^{12}C$ by $C_3$ plants due to changes in respiration rates during drought, but may also represent small increases in $C_4$ plants within a $C_3$-dominated community.

Two distinct $\delta^{13}C$ excursions occur in Profiles 1 and 2: one at the boundary between the Mallard Island and Aggie Brown members, and the other at the boundary between the Aggie Brown and Pick City members (figures 10.2 and 10.3). In Profile 1, the $\delta^{13}C$ values determined on samples from the Mallard Island Member remain fairly consistent, ranging from -24.1‰ to -24.0‰. However, the $\delta^{13}C$ value abruptly shifts from -23.7‰ at the top of

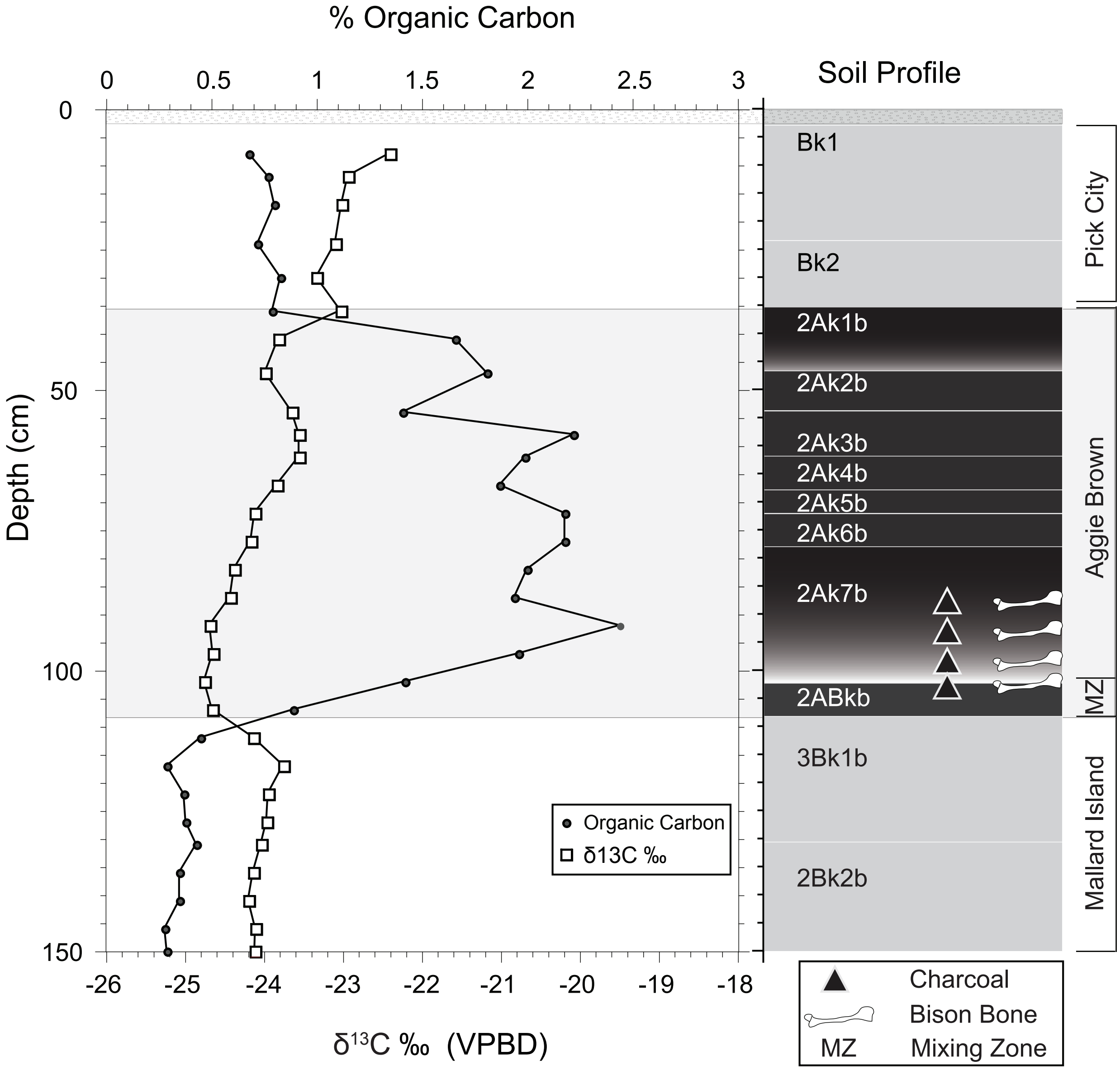


Figure 10.2. Diagram of Profile 1 in Area A showing stable carbon isotope values, organic carbon content, and the soil stratigraphy.

the Mallard Island Member to -24.8‰ in the mixing zone at the bottom of the Aggie Brown Member. Similarly, in Profile 2 there is little fluctuation within the Mallard Island Member, with $\delta^{13}C$ values ranging between -24.5‰ and -24.1‰, but a distinct shift from -24.2‰ to -25.4‰ occurs across the boundary between the Mallard Island Member and the mixing zone at the bottom of the Aggie Brown Member.

In the three profiles there is a general trend of higher $\delta^{13}C$ values (less negative) up through the Aggie Brown Member until the top 40 cm of that stratigraphic unit is reached, where a slight shift to lower $\delta^{13}C$ values (more negative) occurs. Based on radiocarbon ages determined on soil organic matter in Profile 2, this shift began around 8700 $^{14}C$ yr B.P. and ended shortly before 8000 $^{14}C$ yr B.P. (figure 10.3). The shift to lower $\delta^{13}C$ values may represent a slight cooling event.

The second distinct $\delta^{13}C$ excursion in the profiles occurs at the boundary separating the Aggie Brown and Pick City members. In Profile 1, the $\delta^{13}C$ value shifts from -23.8‰ to -23.0‰ in the top 5 cm of the Aggie Brown Member, and there is a trend towards higher $\delta^{13}C$ values near the top of the Pick City Member, where it reaches -22.4‰ (figure 10.2). A similar pattern was recorded in Profile 2, where the $\delta^{13}C$ value shifts from -24.0‰ to -23.1‰ in the top 5 cm of the Aggie Brown Member,

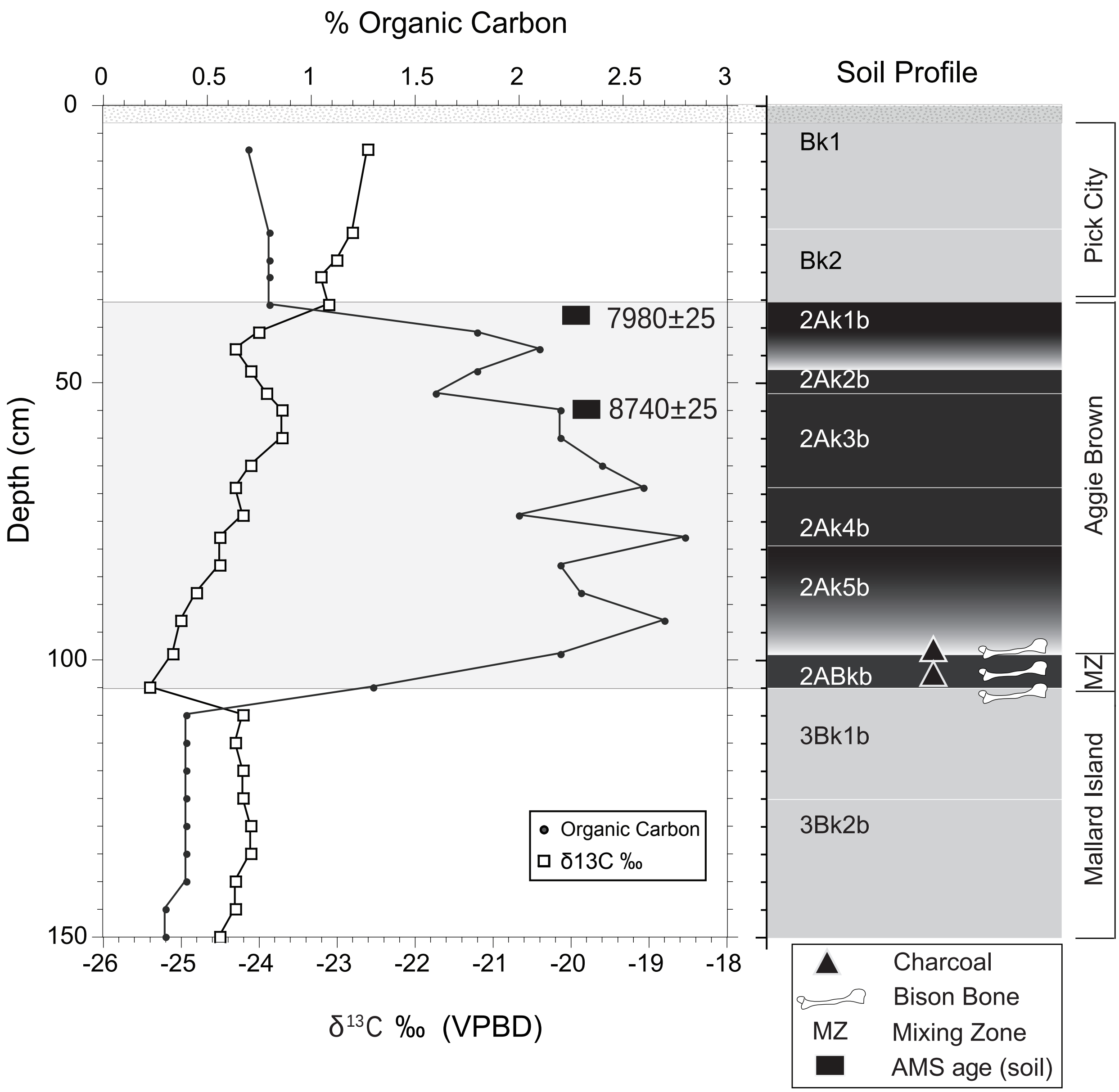


Figure 10.3. Diagram of Profile 2 in Area A showing stable carbon isotope values, organic carbon content, and the soil stratigraphy.

and trends upward in the Pick City Member to -22.6‰ (figure 10.3).

Assuming that small changes in the $\delta^{13}C$ values reflect actual changes in vegetation community, the stable carbon isotope record at Beacon Island indicates that $C_4$ grasses were minor components of the plant community and that the amount of $C_4$ grasses fluctuated slightly during the terminal Pleistocene and early through middle Holocene. Given that the most $^{13}C$ enriched soil samples are from the Agate Basin component at the bottom of the Aggie Brown Member, it is likely that the coolest and perhaps wettest period at the site occurred at 10,300 $^{14}C$ yr B.P. This may explain the presence of water in the kettle basin at that time, which attracted both bison and people. The distinct shift towards higher $\delta^{13}C$ values in the upper 10 cm of the Aggie Brown Member and continuing into the Pick City Member, along with the accompanying shift from pond sedimentation (Aggie Brown Member) to loess deposition (Pick City Member) (see chapter 2), point to a warming and drying trend that began around 8000 $^{14}C$ yr B.P. and continued into the early and middle Holocene. This interpretation is supported by the phytolith data, which are presented in the following discussion.

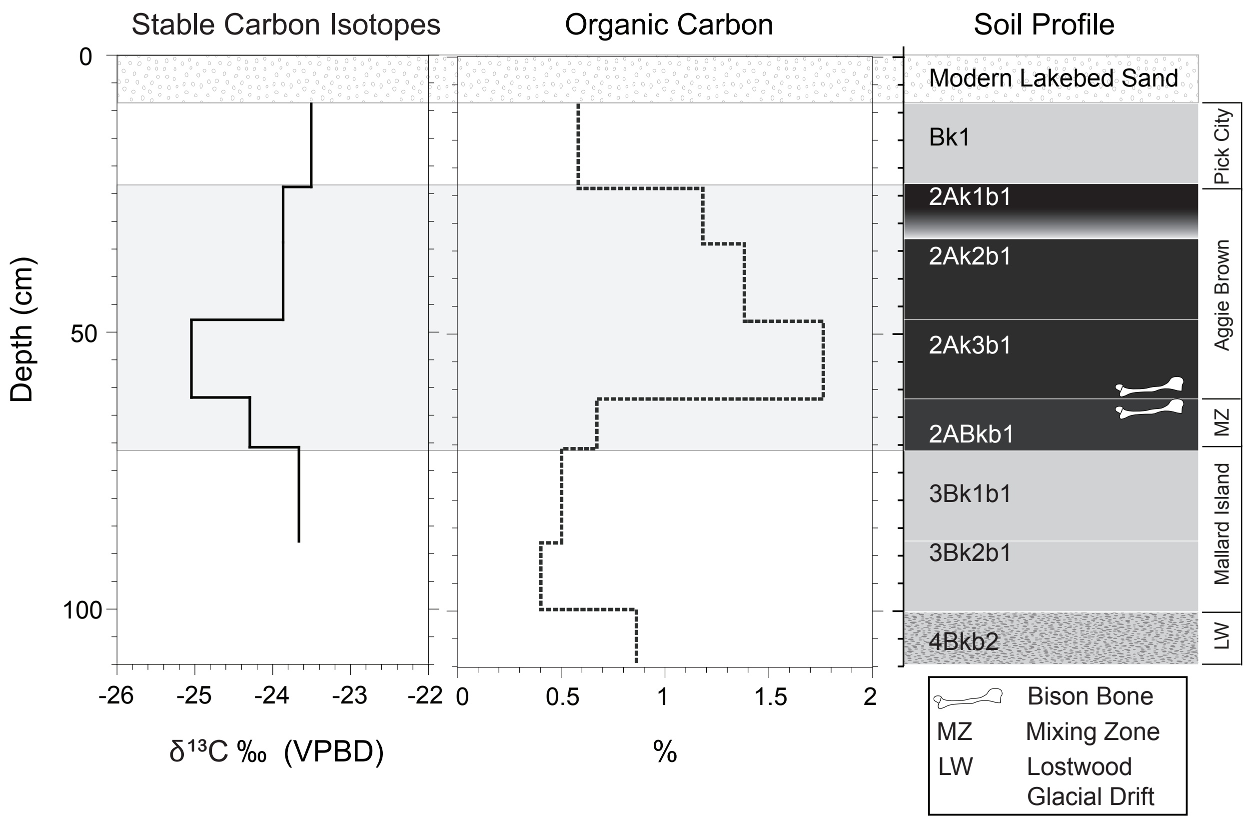


Figure 10.4. Diagram of Profile 3 in Area A showing stable carbon isotope values by soil horizon, organic carbon content by soil horizon, and the soil stratigraphy.

Phytoliths and Microscopic Charcoal

Results of opal phytolith analysis from Profile 2 are reported in figure 10.5. $C_3$ grasses of the Pooideae family dominated the phytolith assemblage. Short-cell phytolith morphologies were similar to the reference collection morphologies of Western wheatgrass (*Agropyron smithii*) and Canada wildrye (*Elymus canadensis*), which are typical $C_3$ pooids, and to green needlegrass (*Stipa viridula),* Porcupine grass (*Stipa spartea*), and wavy-sided (sinuate) *Stipa,* which are drought-resistant pooids. To detect changes in aridity, the percentage of general Pooid-type short cells can be compared to the percentage of the more drought-resistant *Stipa*-type short cells. A significant shift from pooids to drought-resistant species occurred across the boundary between the Agate Basin cultural horizon and overlying Ak5b horizon (figure 10.5). The shift in assemblage is from 96 percent pooids and 4 percent drought-resistant *Stipa*-types in the Agate Basin horizon, to 44 percent pooids and 56 percent drought-resistant *Stipa*-types in the Ak5b horizon. Phytolith assemblages from the top and bottom of the 2Ak1b and from the 2Ak4b horizons are typical of a stable plant community, with each sample consisting of approximately 60 percent pooids and 40 percent drought-resistant *Stipa*-types. A small number of $C_4$ grasses from the Chloridoideae family appear in the two samples from the 2Ak1b horizon at the transition from the Aggie Brown Member to the Pick City Member.

Soil samples from the Bk2 horizon in the Pick City Member and the 3Bk1b and 3Bk2b horizons in the Mallard Island Member failed to yield phytoliths. The absence of phytoliths in some of the samples may be related to soil pH. The pH values in Profile 2 range from 8.2 to 8.8, with the highest value, 8.8, in the Bk2 horizon (Pick City Member). High alkalinity may have caused silica comprising the phytoliths to go into solution, which may explain the absence of phytoliths in the Bk2 horizon. However, the soil sample from the 2Ak1b horizon (Aggie Brown Member) had good phytolith preservation and high phytolith concentrations despite a pH of 8.7, while soil samples from the 3Bk1b and 3Bk2b horizons, which lacked phytoliths, had relatively low pH values (8.3 and 8.4, respectively). Hence, it is likely that factors other than pH affect phytolith preservation at Beacon Island.

The particulate microscopic charcoal concentration is highest in the 2Ak4b horizon in the Aggie Brown Member, with 124,000 particles per gram of treated

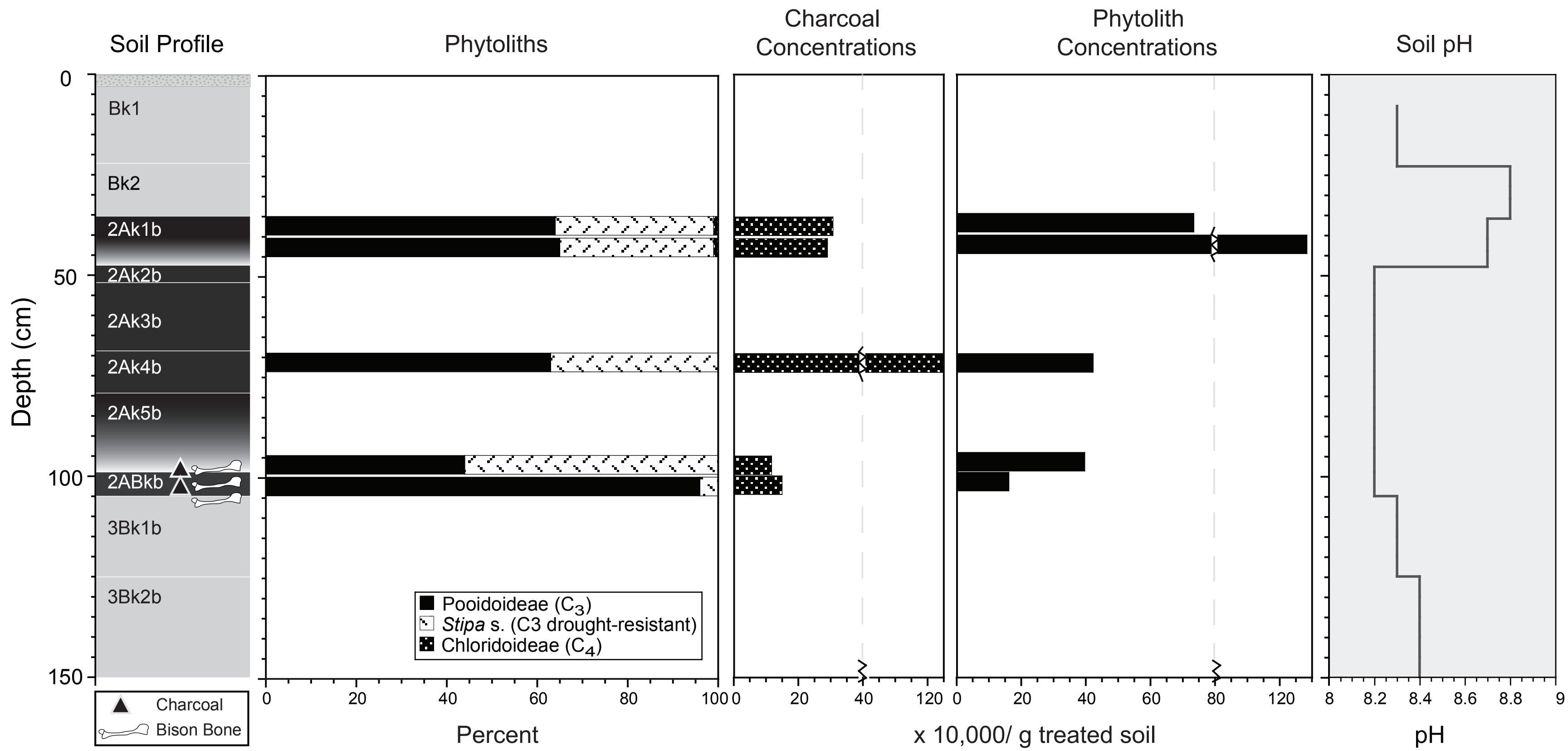


Figure 10.5. Diagram of Profile 2 in Area A showing the phytolith assemblage, charcoal and phytolith concentrations, soil pH, and the soil stratigraphy.

soil. Charcoal concentrations in the 2Ak1b horizon were 31,000 and 29,000 particles per gram of treated soil. The 2ABkb horizon (mixing zone) had the lowest charcoal concentrations, with 12,000 and 15,000 particles per gram of treated soil. Charcoal was not observed in the Pick City or Mallard Island Members.

## Discussion and Conclusions

The results of phytolith and stable carbon isotope analyses support Ahler, Timpson, and Crawford's (2003) hypothesis that during the time of the Agate Basin bison kill at the Beacon Island site (about 10,300 $^{14}$C yr B.P.) the plant community was a mesic $C_3$ grassland. Overall, it is likely that the site's Agate Basin occupants did not experience climatic conditions drastically different from modern conditions, though the occupation likely coincided with the coolest and perhaps the wettest episode for the period of record at the site. Today, analogs of the kettle lake and associated grass assemblage likely present during Agate Basin times at Beacon Island occur in northwestern North Dakota. These findings also support previous paleoenvironmental studies indicating that a cool-season $C_3$-dominated prairie existed in the Northern Plains during the Pleistocene-Holocene transition. Soon after about 10,300 $^{14}$C yr B.P., gradual warming and/or drying occurred at Beacon Island, as indicated by an increase in drought-resistant *Stipa*-type short cells immediately above the Agate Basin component. By around 8000 $^{14}$C yr B.P., warm-season $C_4$ chloridoids appear at the site and there is a trend towards higher (less negative) $\delta^{13}$C values from the bottom to the top of the Pick City Member. Hence, the climate became progressively warmer and probably drier from around 8000 $^{14}$C yr B.P. through the middle Holocene.

This study demonstrates that there are many complex factors affecting phytolith preservation, and that charcoal preservation is subject to similar factors. Also gleaned from the study is the importance of separating cool-season grasses from cool-season drought resistant *Stipa* species in phytolith assemblages, a tool that has been largely ignored in the literature. Drought-resistant grasses provide a more precise indication of increasing aridity, and recognition of drought-resistant grass species in the phytolith record can help detect regional environmental changes. However, micro-environments, such as the area around a kettle lake, can be highly variable, and phytolith assemblages may be drastically different only meters apart. Thus, at Beacon Island multi-proxy analyses provide a means for comparing and more fully interpreting the paleoenvironmental record.

In sum, paleoenvironmental information was gleaned from soils at the Beacon Island site. Two components of the soils, phytoliths and stable carbon isotopes of soil organic matter, were analyzed to infer changes in vegetation through time and during human occupation at the site. The stable carbon isotope data revealed a slight shift to cooler and wetter conditions at around 10,300 $^{14}$C yr B.P., the period of Agate Basin occupation at the site. Based on the isotope and phytolith data, gradual warming and drying occurred after that time, though it appears to have been interrupted by a slight cooling episode that began around 8700 $^{14}$C yr B.P. and ended soon before 8000 $^{14}$C yr B.P. Despite the general warming and drying trend, a relatively stable plant community of $C_3$ grasses existed at the site from the terminal Pleistocene through the middle Holocene. No major turnover in the grassland photosynthetic pathway was detected as evidence for the onset of the warm and dry middle-Holocene Altithermal.

# 11

## Other Material Classes

*Mark D. Mitchell*

This chapter presents data on several rare artifact classes and on other materials not subjected to intensive study. This includes specimens directly associated with the Agate Basin occupation of Area A, including bone ornaments and tools, ochre or pigment nodules, and burned rocks, as well as items occurring naturally within the Oahe Formation or introduced by the site's post-Agate Basin occupants. Specimens collected from the surface are omitted from the tallies presented in this chapter; however, excavated specimens assigned to the Surface/Lakebed analytic unit are included.

### Bone Tools and Ornaments

Apart from specimens exhibiting butchery marks, just nine pieces of bone recovered from Aggie Brown Member contexts show evidence of modification or use-wear (table 11.1). Two of these are expedient tools with smoothed, blunt ends (CN1951.11 and CN7210). Both are burned. Four other specimens consist of small long bone or flat bone fragments that exhibit polishing, striations, and rounded edges. One of these (CN7415) could be a fragment of a split-rib spatulate tool. Another (CN1641) may be a small, bi-pointed awl; this specimen is lightly burned on one end.

The remaining three items are nearly identical beads (table 11.2 and figure 11.1). Two are complete and the third is broken into two fragments. All three come from the southwest corner of the northeast excavation block, roughly 5 m northeast of the small hearth feature documented in 1272NE1115, on the southern edge of the main butchery area.

They likely were manufactured from small- to medium-sized mammal long bone shaft sections. Cancellous tissue is visible on the interior surface of the broken specimen (CN9010). Both complete beads exhibit short, smooth grooves on their exteriors representing a foramen or canal.

All three beads are barrel-shaped in longitudinal cross-section. In lateral cross-section they are slightly polygonal rather than circular. One in particular exhibits slight facets on the exterior (CN9151). However, the

Table 11.1. Provenience and other data on modified bone pieces from Area A.

| CN | Recovery Method | Northing | Easting | SL | Elevation | Element | Burning | Type/Modification |
|---|---|---|---|---|---|---|---|---|
| 1641 | WS | 1283 | 1108 | 20 | 988.10-988.00 | LB[a] | Yes | Use-wear/expedient tool |
| 1951.11 | PL | 1273.03 | 1115.68 | 28 | 987.22 | RB | Yes | Expedient tool |
| 7210 | PL | 1279.41 | 1121.53 | 21 | 987.94 | UN[a] | Yes | Expedient tool |
| 7415 | WS | 1275 | 1122 | 22 | 987.90-987.84 | FB[a] | No | Use-wear/tool (?) |
| 7562 | PL | 1278.84 | 1122.54 | 20/21 | 987.97 | LB | No | Use-wear (?) |
| 8418 | WS | 1276 | 1120 | 23 | 987.80-987.67 | FB[a] | No | Use-wear (?) |
| 8684 | PL | 1273.54 | 1120.27 | 23 | 987.68 | UN[a] | No | Bead |
| 9010 | WS | 1273 | 1119 | 24 | 987.71-987.58 | LB[a] | No | Bead |
| 9151 | WS | 1275 | 1119 | 25 | 987.60-987.50 | UN[a] | No | Bead |

[a] Specimen not including in faunal analysis.

Table 11.2. Metric data on three bone beads recovered from Area A.

| | | Exterior Diameter at Midline | | Interior Diameter | | | |
|---|---|---|---|---|---|---|---|
| CN | Length (mm) | Maximum (mm) | Minimum (mm) | Maximum (mm) | Minimum (mm) | Weight (g) | Comment |
| 8684 | 8.58 | 8.66 | 8.05 | 5.58 | 4.33 | 0.38 | Complete |
| 9010 | 8.14 | 7.87 | 7.50 | 4.38 | 4.09 | 0.34 | Two pieces |
| 9151 | 8.52 | 8.71 | 7.69 | 4.53 | 3.66 | 0.47 | Complete |

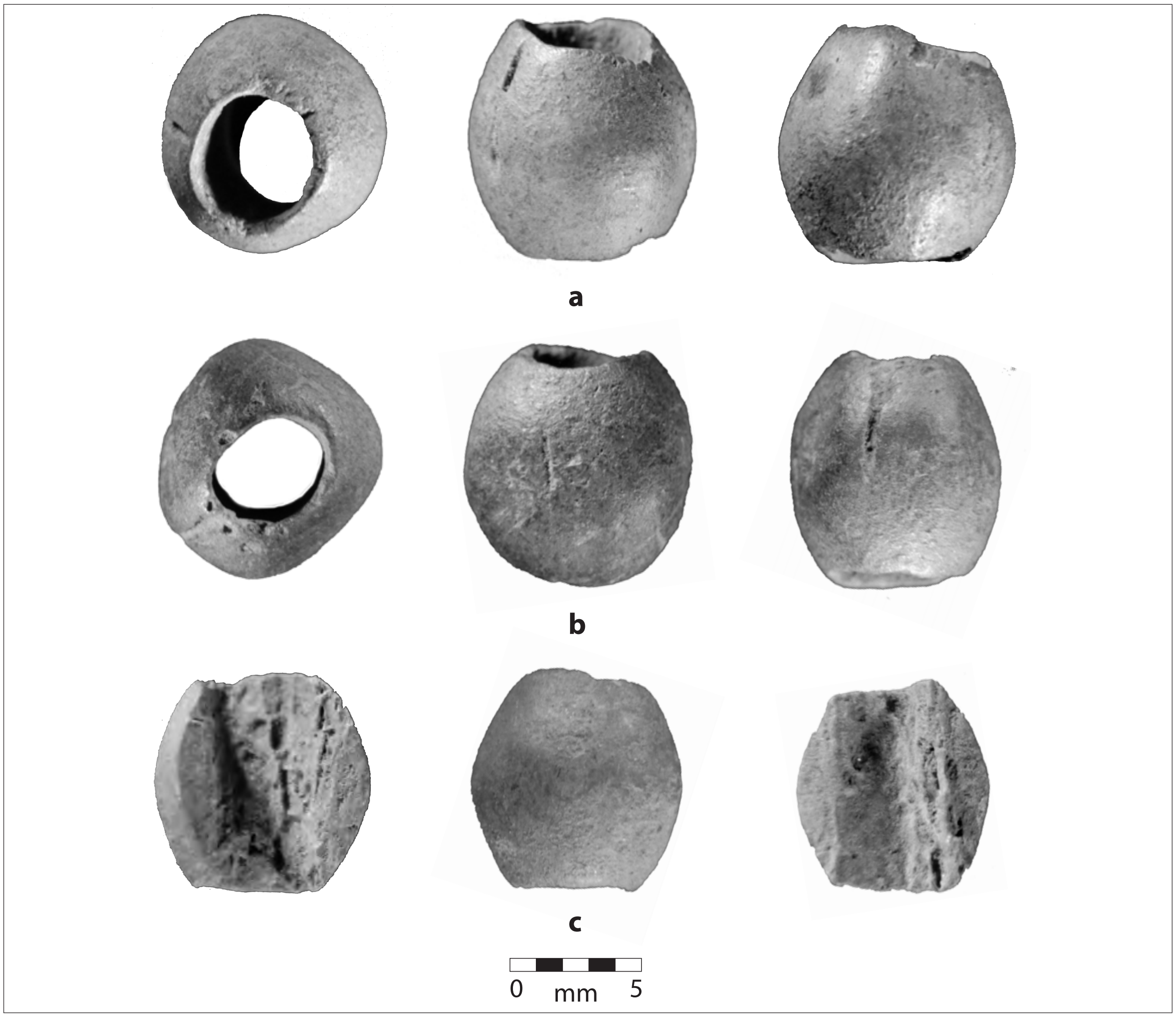


Figure 11.1. Photographs of three bone beads from the Agate Basin occupation in Area A. a: CN8684; b: CN9151; c: CN9010.

surfaces of all three have been carefully smoothed. The interiors are straight-sided and somewhat oblong. The interior and exterior surfaces meet at an acute angle, accentuating the beads' barrel shape. It seems highly likely that all three originally belonged to a single string, which came apart during the Agate Basin occupation. No bead manufacturing debris, or stone tools likely to have been used for bead manufacture, were recovered from Area A.

## Ochre or Pigment

Three types of pigment occur in the deposits investigated in Area A: red ochre or hematite ($Fe_2O_3$); yellow ochre or limonite ($Fe_2O_3 \cdot H_2O$); and other pigments ranging in color from white to pink to orange. All specimens consist of soft, chalky lumps. Some exhibit ground facets or smoothed surfaces. A small number of specimens of uncertain composition or function are included in the "other pigment" group.

Table 11.3 presents counts of pigment nodules sorted from general level samples. Specimens were sorted from the size grades 1 through 4 fractions of all general level samples recovered during all field sessions (chapter 4). However, the general level samples recovered in May 2002 have not been quantified and so table 11.3 only includes counts of specimens recovered during September 2002 and 2006 (field sessions 3 through 9 [see table 3.1]). Table 11.4 provides weight data on these specimens. Table 11.5 shows their size grade distribution. A disproportionate share of specimens assigned to the "other pigment" group fall in the smallest size grade.

Table 11.3. Counts of ochre or pigment nodules sorted from general level lots, organized by analytic unit.

| | Pigment Type | | | |
|---|---|---|---|---|
| Analytic Unit | hematite | limonite | other | Total |
| Surface/Lakebed | | 1 | 1 | 2 |
| Riverdale | | 2 | 5 | 7 |
| Pick City | 7 | 9 | 8 | 24 |
| Aggie Brown | 36 | 29 | 50 | 115 |
| Mallard Island | 1 | 3 | 3 | 7 |
| Total | 44 | 44 | 67 | 155 |

Table 11.5. Size distribution by counts of ochre or pigment nodules sorted from general level lots, organized by analytic unit.

| | Size Grade | | | |
|---|---|---|---|---|
| Pigment Type | G3 | G4 | G5 | Total |
| other | 6.0% | 35.8% | 58.2% | 67 |
| limonite | 11.4% | 81.8% | 6.8% | 44 |
| hematite | 20.5% | 68.2% | 11.4% | 44 |
| Total | 18 | 90 | 47 | 155 |

The significance of this difference is not clear. However, pigment specimens were not systematically sorted from all size grade 5 fractions and so this distribution may reflect an unrecognized sample bias.

Four pigment nodules were recovered by piece-plotting. These include three pieces of limonite (weighing 11.9, 27.6, and 98.2 g) and one piece of hematite (weighing 0.1 g).

Table 11.4. Weights of ochre or pigment nodules sorted from general level lots, organized by analytic unit.

| | Pigment Type | | | |
|---|---|---|---|---|
| Analytic Unit | hematite | limonite | other | Total (g) |
| Surface/Lakebed | | .40 | .03 | .43 |
| Riverdale | | .10 | .06 | .16 |
| Pick City | 1.13 | .33 | .21 | 1.67 |
| Aggie Brown | 5.90 | 2.21 | 2.56 | 10.67 |
| Mallard Island | .03 | .10 | .06 | .19 |
| Total (g) | 7.06 | 3.14 | 2.92 | 13.12 |

Pigment nodules are unevenly distributed within the area of Agate Basin occupation. Figure 11.2 shows the number of ochre or pigment specimens sorted from general level lots assigned to the Aggie Brown Member analytic unit from each excavation square. The distribution illustrated in figure 11.2 includes a total of 101 pieces of pigment, or 88 percent of the 115 pieces assigned to the Aggie Brown Member. The largest concentration occurs along the south edge of the northeast block. These squares lie a few meters south of a major concentration of butchered bison bone (figure 5.6) and 3 to 8 meters east of the hearth feature documented in square 1272NE1115 (figure 3.45). The three bone beads illustrated in figure 11.1 also were recovered from this area. Other pigment concentrations occur on the west edge of the northwest block and on the north end of the west block.

| | 1107 | 1108 | 1109 | 1110 | 1111 | 1112 | 1113 | 1114 | 1115 | 1116 | 1117 | 1118 | 1119 | 1120 | 1121 | 1122 | 1123 | 1124 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1283 | | 6 | | | | | | | | | | | | | | | | |
| 1282 | | 2 | 2 | | 0/A | | | | | | | | | | | | | |
| 1281 | | 3 | 3 | | 1 | | | | | | | | | | | | | |
| 1280 | | | | | 1 | 2 | | 1 | | 1 | | | | | | | 1 | 1 |
| 1279 | | | | | | | | | 1 | 1 | 2 | | | 1 | | | 1 | |
| 1278 | | | | | | | | | | | 2 | | 8 | | 2 | | 0/B | 1 |
| 1277 | | | | | | | | | | | | | | | 1 | | | |
| 1276 | | | 4 | | | | | 1 | | | | | | | | | | |
| 1275 | | 7 | | | | | | | | | | | 2 | 1 | 2 | 3 | | |
| 1274 | | 1 | | | | | | | | | | | 1 | 6/C | 10 | 4 | 1 | 2 |
| 1273 | | | | | | | | | | | | | 3 | 3 | 2 | 1 | 5/D | |

Figure 11.2. Distribution of ochre or pigment nodules in the main excavation blocks. Shading depicts excavated units; slashes indicate units excavated in May 2002, for which data on pigment samples are not available. Numbers represent counts of pigment nodules sorted from all size grade fractions of general level lots. Letters denote piece-plotted nodules (A: limonite, 98.2g; B: limonite, 27.6 g; C: hematite, 0.1 g; D: limonite, 11.9 g).

## Natural Rock

Pebbles and cobbles of natural, unmodified stone were sorted from the size grades 1 through 3 fractions from all general level lots (table 11.6). Natural rock also was sorted from size grade 4 fractions from general level lots recovered in May and September 2002 (field sessions 2 through 4 [tables 3.1 and 4.1]); however, data on these samples are excluded from table 11.6. This tally also excludes data on six large cobbles, two assigned to Pick City Member contexts and four assigned to Aggie Brown Member contexts, that may represent manuports used in the butchery process (see chapter 6). The largest proportion of size grade 1 natural clasts occurs in Mallard Island contexts, while the smallest occurs in Riverdale contexts. Pick City and Aggie Brown contexts exhibit roughly similar clast weight distributions. However, the overall weight density of natural clasts varies among analytic units (table 11.7). The data in table 11.7 exclude general level lots from the deep sondage into Mallard Island Member sediment in square 1273NE1119, which produced a total of roughly 10 kg of rock in just 441 liters of excavated volume, or 22.76 kg/cu. m, by far the highest density of natural rock encountered anywhere in the Area A excavations. The density by weight of natural rock in Pick City Member contexts is less than half that of Aggie Brown Member contexts and just over one-eighth that of Mallard Island Member contexts.

## Burned Rock

As is the case for natural rock, pieces of fire-cracked rock were sorted from coarse fraction (size grades 1 through 3) samples from all general level lots (table 11.8). Burned rock was also sorted from size grade 4 fractions from general level lots recovered in May and September 2002

Table 11.6. Size distribution and weight of natural rock recovered by dryscreening, waterscreening, and piece-plotting, organized by analytic unit.

| | Size Grade | | | |
|---|---|---|---|---|
| Analytic Unit | G1 | G2 | G3 | Total (g) |
| Surface/Lakebed | 23.7% | 34.0% | 42.3% | 5,841 |
| Riverdale | 2.6% | 19.3% | 78.1% | 1,355 |
| Pick City | 11.2% | 30.3% | 58.6% | 8,122 |
| Aggie Brown | 8.9% | 34.5% | 56.6% | 110,004 |
| Mallard Island | 31.1% | 45.3% | 23.6% | 20,697 |
| Total (g) | 18,514 | 52,035 | 75,469 | 146,018 |

Table 11.7. Weight density of natural rock in coarse fraction samples in selected analytic units.

| Analytic Unit | Weight (kg) | Volume (cu. m) | Density (kg/cu. m) |
|---|---|---|---|
| Pick City | 8.122 | 7.764 | 1.05 |
| Aggie Brown | 110.004 | 38.660 | 2.85 |
| Mallard Island[a] | 10.659 | 1.381 | 7.82 |
| Total | 128.785 | 47.805 | 2.69 |

[a] Excluding samples from SL 26-29 in square 1273NE1119; see text.

Table 11.8. Size grade distribution of burned rock by weight, organized by analytic unit. Includes specimens sorted from general level lots and specimens recovered by piece-plotting.

| | Size Grade | | | |
|---|---|---|---|---|
| Analytic Unit | G1 | G2 | G3 | Total (g) |
| Surface/Lakebed | | 1.5 | 36.3 | 37.8 |
| Riverdale | 36.8 | 35.0 | 12.7 | 84.5 |
| Pick City | | 29.2 | 26.6 | 55.8 |
| Aggie Brown | 1426.9 | 300.9 | 146.4 | 1874.2 |
| Mallard Island | 105.3 | 140.0 | 72.1 | 317.4 |
| Indeterminate | 207.0 | 13.0 | | 220.0 |
| Total (g) | 1776.0 | 519.6 | 294.1 | 2589.7 |

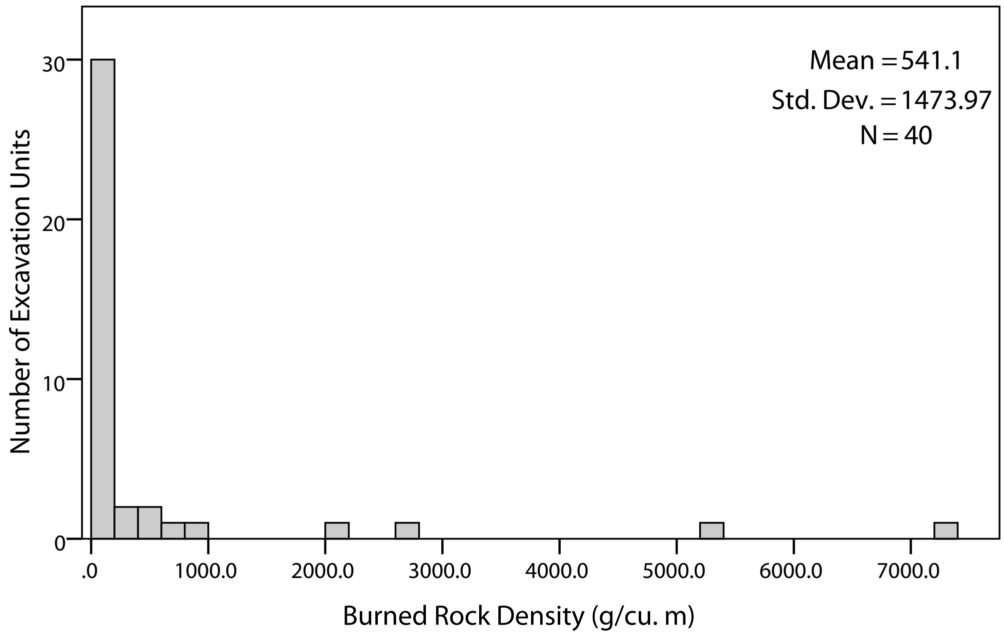


Figure 11.3. Histogram of burned rock density (g/cu. m) in Aggie Brown Member contexts from 40 excavation units.

(field sessions 2 through 4 [tables 3.1 and 4.1]). However, the May 2002 samples have not been weighed. Data on size grade 4 fractions from September 2002 general level lots (totaling just 2.23 g) are also excluded from table 11.8.

Nearly three-quarters of the burned rock by weight occurs in Aggie Brown Member contexts, and most of this occurs in the size grade 1 fraction. However, this distribution is strongly affected by a small number of especially large pieces. Figure 11.3 illustrates the density of burned rocks, in g/cu. m, in Aggie Brown Member contexts in 40 excavation units. In 30 of the 40 squares, the density of burned rocks is less than 200g/cu. m, while one square exhibits a density between 7,200 and 7,400 g/cu. m. Figure 11.4 shows the distribution, by weight, of burned rocks assigned to Aggie Brown Member contexts. Chapter 3 provides additional discussion on the distribution of burned rock.

## Pottery

Three native earthenware ceramic sherds were sorted from general level lots. All three lots are assigned to Aggie Brown Member contexts; however, they all occur in the upper part of the Aggie, in locations where overlying Pick City Member sediment has been stripped away.

The largest of the three sherds (CN7701) is a size grade 2 neck (zone 2) fragment, with a maximum thickness of 9.2 mm. The interior surface is gray and exhibits shallow parallel striations produced by scraping. The exterior is plain and buff colored. Temper particles are exposed on the exterior surface and the sherd's broken edges are slightly smoothed. The second specimen (CN9627) is a size grade 2 body sherd with similar surface characteristics and a maximum thickness of 7.2 mm. The exterior surface preserves a single, very faint cord mark. The broken margins of the specimen are quite rounded, suggesting significant post-depositional transport. These two specimens were recovered from units approximately 9 m apart. The third specimen (CN1779) is a size grade 4 fragment from the interior of a vessel wall.

The cultural or temporal affiliation of these specimens is unknown, though the cord-marked surface of the body sherd suggests a date before about A. D. 1200 (Ahler and Swenson 1993). The two size grade 2 specimens may derive from a single vessel.

## Wood Charcoal

Charcoal samples were sorted from size grades 1 through 3 fractions of general level lots recovered during September 2002 and 2006 (field sessions 3 through 9 [tables 3.1 and 4.1]) and from size grade 4 fractions recovered in 2006 (field sessions 5 through 9). The collection includes a total of 132 samples, including 79 sorted from general level lots, 2 sorted from bulk sediment lots, and 51 piece-plotted specimens (recovered during all field sessions) (table 11.9). Three piece-plotted samples recovered in May 2002 were submitted for AMS radiocarbon dating; the results of the assays are presented in appendix A.

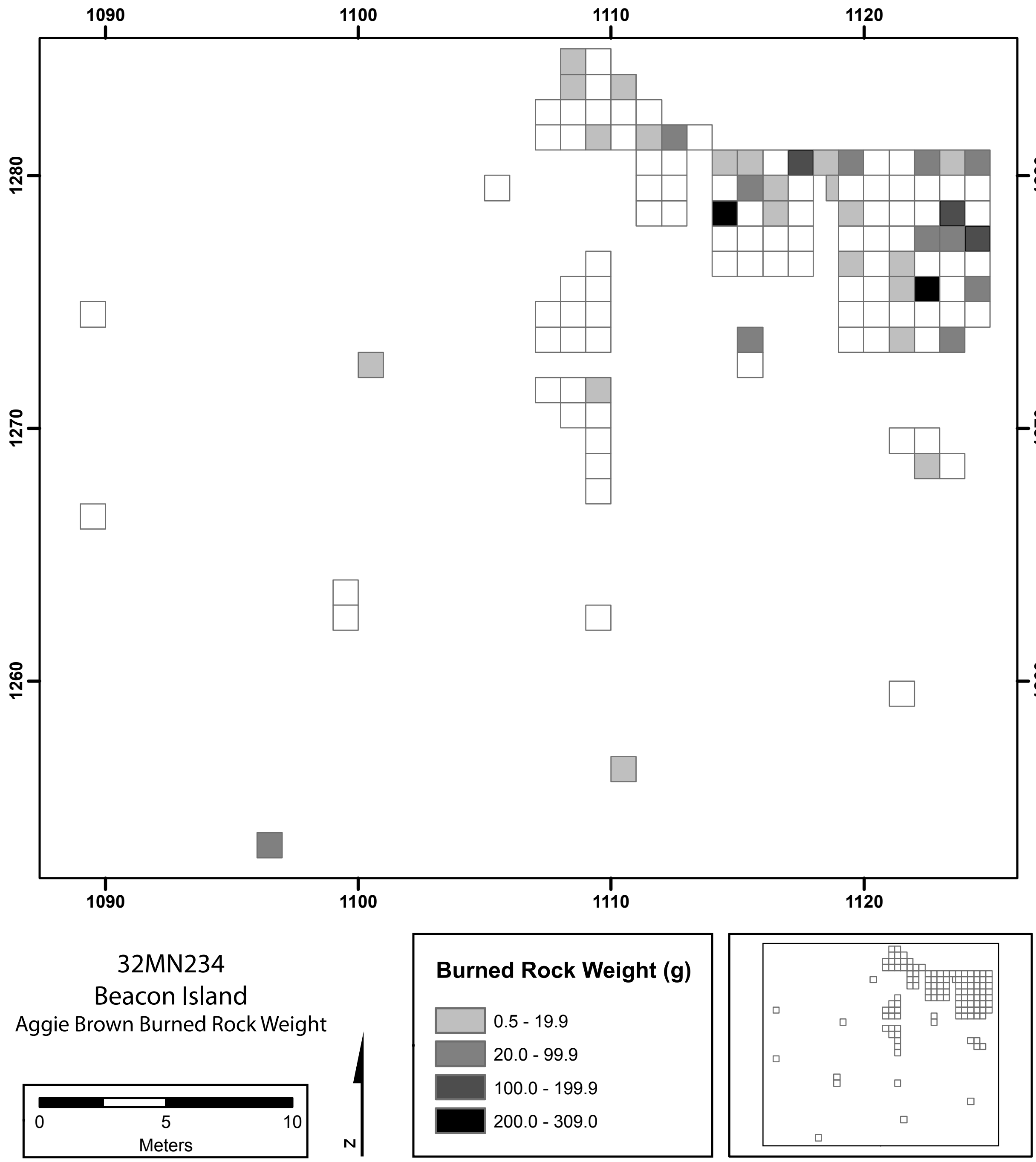


Figure 11.4. Distribution of burned rock recovered from Aggie Brown Member contexts.

Table 11.9. Counts of charcoal samples organized by analytic unit and sample type.

| | Sample Type | | | |
|---|---|---|---|---|
| Analytic Unit | General Level | Piece Plot | Bulk Sediment | Total |
| Surface/Lakebed | 3 | | | 3 |
| Aggie Brown | 75 | 51 | 2 | 128 |
| Mallard Island | 1 | | | 1 |
| Total | 79 | 51 | 2 | 132 |

## Historic Artifacts

Historic artifacts were sorted from size grades 1 through 4 fractions of all general level lots. A total of 29 items were identified (table 11.10). This tally does not include specimens obviously derived from the excavation itself, including paint chips from wheelbarrows and nails, fruit labels, and pieces of paper and plastic; these items are retained in the collection but were not quantified. The recent artifacts tallied in table 11.10 include fence staples, nails, coins, strips of weathered cloth, shotgun pellets, bottle caps, zipper parts, shards of clear glass, and pieces of aluminum foil. Just under half derive from general level lots assigned to Aggie Brown Member contexts. Most of these were recovered from near-surface contexts. A few items come from deeper parts of the excavation; these may have been transported downward by burrowing animals or blown in during the course of the excavation.

## Unsorted Residue

Size grade 5 fractions of all general level lots yielded a remainder of unsorted materials, as did size grade 4 fractions from lots recovered in 2006 (field sessions 5 through 9 [tables 3.1 and 4.1]). Table 11.11 provides count and weight data on unsorted residue samples, which consist primarily of pieces of natural rock and non-identifiable bone fragments.

Table 11.11 Summary count and weight data for unsorted residue samples, organized by analytic unit.

| | Number of Samples | | |
|---|---|---|---|
| Analytic Unit | G4 | G5 | Weight (g) |
| Surface/Lakebed | 1 | 14 | 2039 |
| Riverdale | | 16 | 1049 |
| Pick City | 54 | 93 | 9229 |
| Aggie Brown | 308 | 464 | 192032 |
| Mallard Island | 6 | 17 | 14274 |
| Total (N) | 369 | 604 | 218623 |

## Other Materials

A small number of other miscellaneous items were sorted from all size grade fractions of all general level samples. These items include seeds, fossils, crystals, eggshells, and pieces of ash, burned earth, and charred, fused organic material. The vast majority of these specimens come from the size grades 4 and 5 fractions. The collection also includes 23 bulk sediment samples taken for pollen, phytolith, flotation, and blood residue analyses.

Table 11.10. Counts of recent historic items, organized by analytic unit and material class.

| | | Size Grade | | | | |
|---|---|---|---|---|---|---|
| Analytic Unit | Material Class | G2 | G3 | G4 | G5 | Total |
| Surface/Lakebed | Other | 1 | 1 | 6 | | 8 |
| Pick City | Glass | | 1 | | | 1 |
| Aggie Brown | Metal | | 2 | | 3 | 5 |
| | Other | 3 | 4 | 6 | 2 | 15 |
| Total | | 4 | 8 | 12 | 5 | 29 |

# 12

## Summary and Conclusions

*Mark D. Mitchell, Jennifer Borresen Lee, Rolfe D. Mandel, Carl R. Falk, Marvin Kay, Laura R. Murphy, and Paul R. Picha*

This concluding chapter sums up the major findings of the field investigation and lab analyses, organized according to the research themes and questions posed in chapter 1. The discussion concludes with comparisons among the three excavated Agate Basin kill-butchery sites.

### Site Setting and Paleoenvironment

During Agate Basin times, the landscape around the confluence of the Little Knife and Missouri rivers featured a series of shallow, intermittent wetlands filling small kettle basins or irregular depressions in lodgement till (figure 12.1). The Agate Basin bonebed occurs in one such pothole, which likely was separated by a low sill from a somewhat deeper sub-basin immediately to the west. The original rim of the basin was not exposed during excavation and may no longer be preserved. However, the distribution of till to the north and east indicates that the basin was no more than a few meters deep at the time of the kill. The grade of the north and east slopes of the basin, from which the majority of faunal remains and artifacts were recovered, varies from 5 to 10 percent. The floor of the basin is just 50 or 60 cm below the highest preserved remnant of the bonebed. The presence of a hearth on the floor of the basin indicates that the pothole was dry during the occupation. However, stratigraphic and other data indicate that the floors of nearby basins were lower and so may have held water at the time.

The Agate Basin occupation occurred early in a period of relative landscape stability marked by a well-developed paleosol, known regionally as the Leonard, that formed during the Younger-Dryas stadial. At Beacon Island, the inception of the Leonard coincided with a shift from eolian deposition, represented by the slightly sandy loess of the Mallard Island Member of the Oahe Formation, to the primarily paludal deposits of the Aggie Brown Member, a shift indicative of a wetter climate. Paludal deposition typically occurs in marshy environments, where water is shallow and where grasses, rushes, and sedges dominate the vegetation community. Molluscan data indicate that the basin containing the bonebed intermittently held water following the occupation. The habitat requirements of the identified gastropod taxa, which consist mostly of aquatic forms, point to the presence of locally dense, pond-edge vegetation. The taxa comprising the "dark faunule" identified in the micromammal study similarly point to a marshy or bog-like environment during and after Agate Basin times. Beaver and muskrat bones are present in the excavated assemblage, indicating the persistent presence of standing water nearby.

Outside the basin, the local plant community at the time of the occupation was a mesic, cool-season ($C_3$) grassland. While the environment likely did not differ too dramatically from modern conditions, stable carbon isotope and phytolith data indicate that the occupation coincided with the coolest and perhaps the wettest episode recorded in the sampled deposits. Data on likely micromammal habitat suggest that this boreal grassland may have been punctuated by stands of shrubby vegetation, perhaps including dwarf birch.

Following the occupation, paludal deposits continued aggrading in the kettle basin, deeply burying the bonebed. However, sedimentation was slow, allowing soil development to keep up with deposition. The resulting cumulization process produced an overthickened A horizon typical of Younger-Dryas-age paleosols in the Plains. The cumulic A horizon of the Leonard at Beacon Island is multi-storied, indicating that brief periods of landscape stability were punctuated by episodes of sedimentation, a pattern reflecting alternating wet and dry climatic cycles.

Build-up of the Aggie Brown Member slowed around 8700 $^{14}$C yr B.P. and ceased around 8000 $^{14}$C yr B.P. A loess deposit, known as the Pick City Member of the Oahe Formation, began accumulating soon after this time, likely marking the initiation of the Altithermal climatic episode. Stable carbon isotope and phytolith data also point to a warmer and probably drier climate after 8000 $^{14}$C yr B.P., indicated by the appearance of warm-season $C_4$ chloridoids at the site and by higher $\delta^{13}$C values.

While the Agate Basin component is the best-documented use of Area A, it represents just one of many successive uses of what clearly was a highly productive landscape. Pre-Agate Basin use is attested by the presence of Folsom projectile point fragments. Evidence for Holocene use of Area A comes from a series of isolated test units north and west of the Agate Basin bonebed. The most intensive of these is an early Holocene occupation

Figure 12.1. A modern analog for the Agate Basin landscape, located in Ward County, North Dakota, 90 km east of Beacon Island .

exposed in a single excavation unit some 50 m west of the bonebed. Intermittent, less-intensive occupation later in the Holocene is indicated by artifacts and features recovered from the Pick City Member overlying the southwestern part of the Agate Basin component and by projectile points recovered from the surface.

## Site Taphonomy

Intact Agate Basin-age deposits at Beacon Island are confined to a remnant of Aggie Brown Member sediment covering roughly 800 sq. m. To the north and east, the cultural deposit is bordered by a lag surface formed in glacial till. When the site was first identified, bison bones and Agate Basin points were recovered from this eroded surface, indicating that the site originally covered a larger area; the distribution of bone fragments and of artifacts made from Antelope Chert, a likely index material for the Agate Basin occupation, suggests that it may once have covered roughly 1,600 sq. m. Thus, at least 50 percent of the original occupation surface may have been lost to erosion. However, the distribution of excavated faunal remains suggests that most of the carcass processing area was exposed during the course of the excavation.

At least two major episodes of surface erosion affected the deposits. Recent wave action, exacerbated by cyclical fluctuations in the pool elevation of Lake Sakakawea, has stripped away nearly all Oahe Formation sediment north and east of bonebed, depositing artifacts and other materials in at least two east-west strand lines. Some of these artifacts likely derive from the Agate Basin component; however, a substantial fraction undoubtedly is younger. Given the presence of two Folsom point fragments in the surface collection, some of these items could also derive from other Paleoindian components. Surface erosion occurring between about 1,000 and 5,000 years ago also stripped away Aggie Brown Member sediment on the western edge of the basin. In this area, mid- to late-Holocene Riverdale Member sediment lies unconformably on late-Pleistocene Mallard Island Member sediment.

Aggie Brown Member sediment buried the bonebed relatively rapidly. Loess eroding from the rim of the basin accumulated first on the slopes of the basin as sheetwash, then on the floor as paludal sediment, covering and isolating the bonebed from intensive post-occupation disturbance. This process likely transported smaller items short distances, as evidenced by the light scatter of bone pieces overlying the hearth located near the center of the pothole. However, the fact that the vast majority of the bone is located on the slope rather than on the floor of the pothole suggests that lateral movement was limited.

Burrowing by small mammal species is the most significant post-depositional disturbance process affecting the vertical distribution of artifacts and bones. Krotovina of multiple ages were observed in most excavation units. Trailing by large animals, along with cycles of desiccation and sediment cracking, may also have affected the vertical distribution of faunal remains and artifacts. However, at least some of the observed large animal trails likely pre-date the occupation. Trailing would only have transported specimens downward, into culturally sterile Mallard Island Member sediment. No stone tools and just 24 pieces of flaking debris were recovered from Mallard Island contexts.

The bone deposit is notably compact, with most specimens occurring in just one or two excavation levels in each unit. In a small number of cases, artifacts that definitely or probably derived from the Agate Basin occupation were recovered from more recent lithostratigraphic units. One Agate Basin projectile point fragment was recovered from the base of the early-Holocene Pick City Member and two were recovered from modern lakebed sediment directly overlying the bonebed. Three stone tools and two flakes made from Antelope Chert were recovered from Pick City Member contexts. The maximum vertical separation between the most distant of these translocated items and the Agate Basin bonebed is 40 cm. However, there is little chance that the defined Agate Basin assemblage includes items derived from more recent occupations. This is so mostly because the Agate Basin cultural layer is relative thin and well-defined and occurs at the base of the Aggie Brown Member. Where the Pick City-Aggie Brown contact is preserved, two to seven sterile excavation levels separate the Agate Basin component from overlying components. In addition, the procedures used to define analytic units were designed specifically to minimize the possibility of mixing.

The inferences that the Agate Basin occupation was buried rapidly and subsequently disturbed only minimally are supported by data on the faunal remains and stone artifacts. Data on lithic conjoins and refits indicate that lateral movement was limited. A total of 32 modified stone specimens in the collection refit or conjoin to form 13 composite items, including nine projectile points, one flake tool, one tested cobble, one core, and one unmodified flake. The mean distance between plotted matched specimens is 53.2 cm, with a range of 3 to 126 cm. By comparison, the distances between conjoined items at the Agate Basin site ranges from about 35 cm to 10.5 m (Frison and Stanford 1982a:Figure 2.77). Moreover, the conjoined core, tested cobble, and flake at Beacon Island are all made from Antelope Chert and are clustered together in the northwest corner of the northwest excavation block, along with a concentration of Antelope Chert flaking debris. The close association of these items suggests that a core reduction activity area is preserved there. In addition, the strong differential patination exhibited by most stone tools made from KRF suggests that they were not turned over and therefore that a low-energy process was responsible for lateral movement of artifacts and other materials.

Bison bone data further bolster these interpretations. A degree of density-mediated attrition is evident in the bone assemblage and a portion of the bison archaeofauna exhibits tooth pits and rodent gnawing. However, few of the bones exhibit the kind of surface splintering and exfoliation caused by prolonged surface exposure. Some instances of differential weathering were observed, again suggesting that tumbling transport of larger items was limited. Patterns of carbonate deposition suggest that the current fragility of the bone is due largely to ancient post-burial inundation of the kettle basin, rather than to recent inundation by Lake Sakakawea.

In sum, data on the depositional environment, on lithic refits and conjoins, on bone preservation, and on the vertical distribution of artifacts and faunal remains indicate that the integrity of the Agate Basin cultural deposits is good. It is therefore reasonable to assume that the excavated remains exhibit a definite, if not altogether perfect, relationship to the spatial structure of the occupation.

## Chronology, Occupation Duration, and Seasonality

The bonebed at Beacon Island is the most precisely dated Agate Basin occupation. Four of five radiocarbon assays from the site, two on charcoal and two on bone, produced statistically equivalent ages. The weighted mean age of these four assays is 10,326±28 $^{14}$C yr B.P. A fifth assay on charcoal produced a non-contemporaneous, slightly younger age of 9,911±105 $^{14}$C yr B.P. Owing to a broad plateau on the radiocarbon calibration curve, the four-date mean age corresponds to a two-sigma calibrated date range discontinuously spanning 371 calendar years, from 10,431 cal B.C. to 10,060 cal B.C. (12,380 cal B.P. to 12,009 cal B.P.) (figure 12.2) (Bronk Ramsey 2010; Reimer et al. 2009). Haynes (2009:45) reports a similar age for the Agate Basin complex at the Hell Gap site (10,260±95 $^{14}$C yr B.P.). New dates on curated charcoal samples from the Frazier site suggest that the Agate Basin occupation there may be slightly more recent (Lee et al. 2011). While the overall span of the Agate Basin complex is uncertain, owing in part to the magnitude of the radiocarbon calibration plateau, the age of the

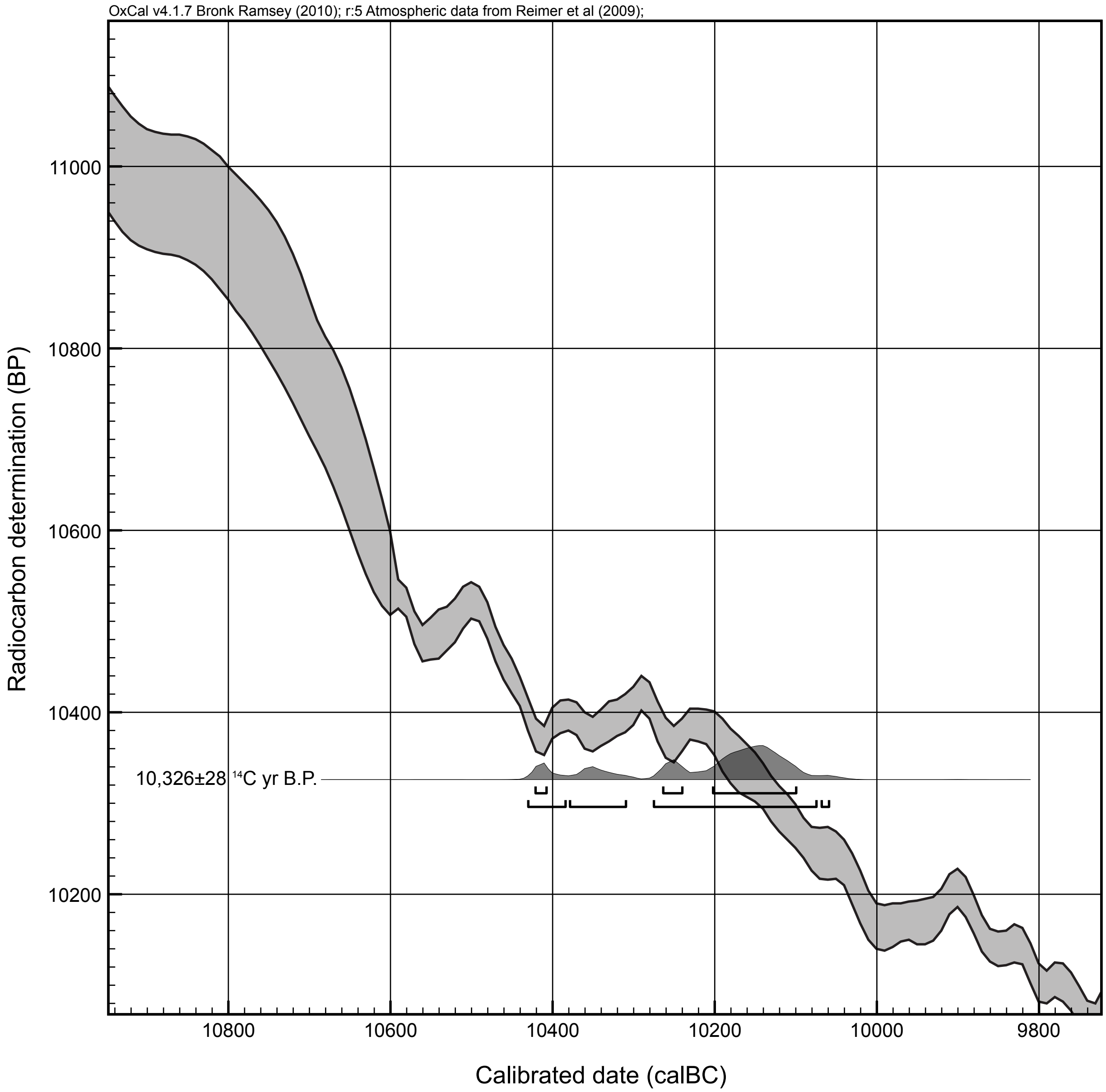


Figure 12.2. A section of the IntCal09 radiocarbon calibration curve showing the calibrated date distribution of the weighted mean age of four contemporaneous assays from Beacon Island.

Beacon Island occupation falls near the middle of the 10,500-10,000 $^{14}C$ yr B.P. range originally suggested by Irwin-Williams and others (1973) for the occupation at the Hell Gap site. Stratigraphic data from Beacon Island suggest that the kill there occurred a century or so after the inception of the local climatic effects of the Younger Dryas stadial (appendix A).

Several lines of evidence indicate that the Agate Basin bonebed at Beacon Island represents a single, short-term occupation. On average, the bonebed is just 5 to 10 cm thick; the standard deviation of plotted bone elevations concatenated by excavation unit is 0.0385±0.0138 m, which yields a one-sigma mean bonebed thickness of 7.7±2.8 cm or a median thickness of 7.1 cm. Microtopographic variations, along with local variations in the extent of post-occupation disturbance, explain the somewhat thicker deposits observed in a few excavation units. No internal stratigraphy was seen during excavation and no gaps or discontinuities exist in the vertical distribution of bones. The bonebed occurs on a single surface conforming to the original topography of the basin, as modeled by elevation data on the contact between the Aggie Brown Member and the Mallard Island Member of the Oahe Formation, located immediately below the bonebed. The tight cluster of radiocarbon dates—taken on both bison bone and charcoal—lends further support to the conclusion that the site represents a single occupation. Interpretations summarized in the next section further suggest that Agate Basin hunters lingered only briefly at Beacon Island.

Bison tooth eruption and wear data indicate that the kill at Beacon Island took place in early to mid-winter (N+0.6-N+0.7 years, or 31 to 36 weeks after calving). Dentition data also show that the target herd included yearlings as well as animals more than six years old. Metric data on calcanea and metapodials indicate that both bulls and cows were present. The unexpectedly high male-to-female ratio suggests that bones from larger males were preferentially left behind or not processed on-site for marrow. In the nineteenth century, both native and European hunters practiced a similar selection against mature bulls during the early to mid-winter, owing to their leanness and the undesirability of their meat relative to cows during that season (Brink 2008).

## Archaeological Content, Site Function, and Activity Areas

Analysis of artifacts and faunal remains recovered from Aggie Brown Member deposits in Area A supply data on the range of activities taking place there and on Agate Basin butchery practices and lithic technology (figure 12.3).

### Activity Set and Site Type

The dominant feature of the Agate Basin component at Beacon Island is an extensive, jumbled mass of butchered bison bone representing a carcass processing locale. Several lines of evidence suggest that the kill itself took place immediately east of the butchery area, on the rim of the kettle basin. Skeletal element profiles showing the differential occurrence of low-utility elements in the assemblage indicates that the kill location was nearby. The distinctive fragmentation signature of the projectile point assemblage collected from the surface, relative to that of the excavated assemblage, supports the inference that the kill occurred immediately adjacent to the butchery area. Complete points and distal segments are more common in the surface collection, while bases and highly fragmented pieces are more common in the excavated collection derived from the processing area, suggesting that the surface collection is made up mostly of specimens lost in unbutchered or minimally butchered carcasses. A similar contrast exists between the surface-collected bone and the excavated bone. Finally, the distribution of small bone pieces on the surface further suggests that the kill took place 10 to 15 m east of the processing area. However, no specific data on the manner of the kill were gathered during the field investigation.

One definite hearth was documented several meters south of the butchery area. Data suggesting the presence of another hearth, buried beneath a mass of bone, come from the northeastern part of the butchery area. Charcoal and burned flaking debris, along with a small number of burned and calcined bone pieces, are scattered throughout the excavation blocks, pointing to the presence of other hearths nearby. In particular, concentrations of burned, fine-fraction flaking debris in two isolated excavation squares on the west side of the kettle basin supply good evidence that additional hearth features are present there. Similar, though somewhat larger, hearths occur adjacent to the butchery areas in the upper Hell Gap level of Area 3 at the Agate Basin site (Frison 1982c) and on the west side of the Frazier site (Slessman 2004).

The likely presence of multiple hearth features raises the possibility that the Agate Basin occupation of Beacon Island can also be characterized as a camp location, where gearing-up and non-butchery-related activities took place. However, the diversity of the excavated stone tool assemblage is remarkably low. The majority of the excavated assemblage consists of projectile point fragments too small or damaged to be reworked successfully into usable weapons. Most of the remainder is made up of butchery tools, including large flake tools for cutting and scraping as well as cobbles for breaking open long bones. No patterned, hafted scraping tools occur in the collection. Just two graving tools were recovered from Area A, only one of which is definitely associated with the Agate Basin component. No notched flakes occur in the Beacon Island assemblage.

Though the Beacon Island hunters struck flakes from several cores, presumably to produce butchery tools needed to augment those transported to the site, both mass analysis and individual flake analysis of the flaking debris assemblage point to tool rejuvenation or maintenance rather than production. Evidence for primary biface manufacture is entirely lacking. Though one cannot discount completely the possibility that the minimally explored southwestern quadrant of the kettle basin contains evidence of other activities, the data at hand suggest that the site's occupants focused their efforts narrowly on carcass processing and weaponry refurbishing and therefore that the Agate Basin occupation at Beacon Island is properly characterized as a kill-butchery locality.

The low diversity of the toolkit and the evidence for stone tool maintenance but not production, combined with data on butchery practices discussed later in the chapter, further suggests that the kill at Beacon Island represents one node of a logistical hunting strategy, through which the most able-bodied members of the group supplied

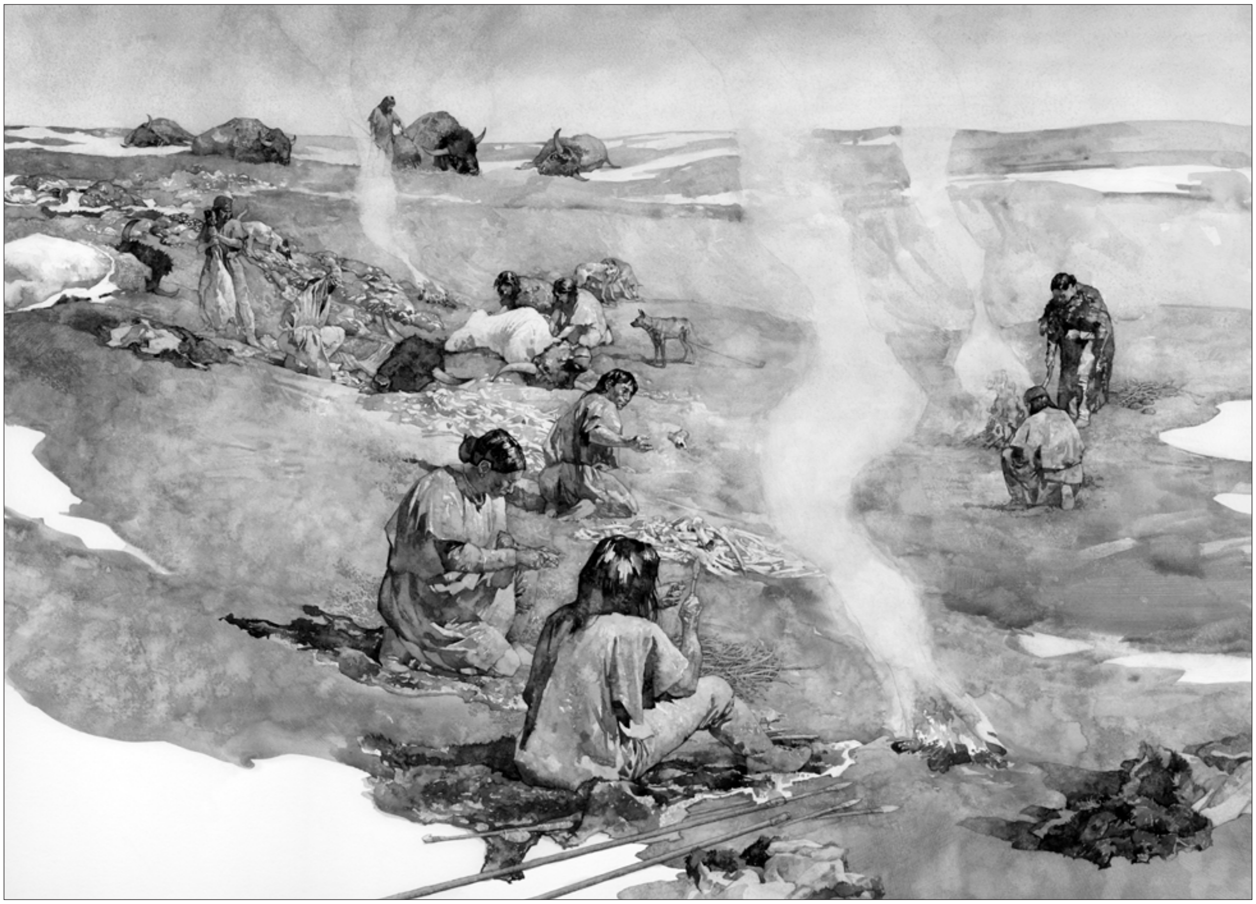

Figure 12.3. Artist's reconstruction of the Agate Basin occupation at Beacon Island. Artwork by Greg Harlin.

meat and other animal products to the remainder of the band camped elsewhere. In the nineteenth century, Indian groups lived during the winter in major river and stream valleys, where fuelwood was plentiful. Marrow and meat stored as pemmican could have facilitated such seasonal sedentism (Sellet 2006).

*Activity Areas*

Distributions of butchered bone, stone tools, and flaking debris point to the presence of discrete activity areas at Beacon Island. Fractured bone is piled into several relatively discrete masses. The largest of these occurs in the northeast excavation block. A somewhat smaller pile occurs in the northwest block. In a few cases, bone accumulated in several small depressions in the basin; however, it is not clear whether these depressions occurred naturally or were excavated or modified in some way by the hunters. The larger pieces of bone making up these piles, which mostly were recovered by piece-plotting, exhibit a different distribution than smaller bone scraps recovered by waterscreening. This difference may reflect discard patterns of processed bone, though post-occupational processes may be partly responsible.

A contrasting pattern is evident in the distribution of stone tools and flaking debris. Some tools and flakes occur within the large piles of butchered bone. Very few are associated with concentrations of small bone scrap. However, the majority of tools and flakes are located around the perimeter of the mass of bone, in areas where carcasses were dismembered, projectile points were recovered and rejuvenated, and flake tools were resharpened.

Two other aspects of the lithic artifact distribution point to the existence of discrete activity areas. One is the concentration of flakes and cores made from Antelope Chert in the northwest block mentioned previously. The fact that eight of these items refit or conjoin to form three composite artifacts—a core, a tested cobble, and a flake—suggests that a core reduction activity area is preserved there.

The second aspect is the uneven distribution of fine-fraction (size grades 4 and 5) flaking debris. Of the 121.5 excavation squares in which Aggie Brown Member sediment was exposed, just six squares produced 45 or more fine-fraction flakes. Together, these six units produced nearly one-third of entire Agate Basin-age fine-fraction assemblage. Three of these six units are located in the southwest quadrant of the kettle basin. Two more are adjacent in the southwest corner of the northwest block. Moreover, the three isolated units in the southwest part of the kettle basin together produced three-quarters of the burned fine-fraction flakes recovered during the excavation. Given the large number of small, burned flakes from these units, coupled with the fact that they are not directly associated with bison remains, it seems probable that intensive, hearth-centered weapon refurbishing took place in this part of the site. The same may also be true of the southern part of the northwest block.

In sum, these data suggest that the Agate Basin occupation at Beacon Island, though brief, was organized spatially, with different activities occurring sequentially or simultaneously in different parts of the kettle basin.

### Butchery Practices

Agate Basin hunters killed a minimum of 29 bison at Beacon Island, based on right astragali recovered from the excavation blocks. The MNI increases to 31 if right astragali in the controlled surface collection are included. If right first ribs in the uncontrolled surface collection analyzed by Karpinski (2002) are counted, then the MNI is 33. Skeletal element profiles and utility indices show that the hunters selectively extracted roughly half of the available limbs for transport to a secondary processing locale. The transported limbs were removed as complete units, though the butchery method commonly involved disarticulating the calcaneus and astragalus, leaving behind the latter, along with the metatarsal. The moderate-to-large correlation between percent minimum number of animal units (percent MAU) and the total products utility model suggests that transported packages were designed to provide both meat and fat. In addition, the jumbled but piled distribution of the recovered specimens, coupled with the paucity of articulated elements, points to intensive on-site butchery of the non-transported fraction of the kill. The high frequency of spirally fractured long bones suggests on-site consumption of bone marrow during carcass processing.

### Agate Basin Lithic Technology

The limited evidence for primary stone tool manufacturing at Beacon Island restricts what can be said about the range of Agate Basin technological practices. However, flaking debris and stone tool data together permit a number of generalizations about how different raw materials were used and about the life-histories of Agate Basin weapons.

A portion of the complete KRF and Swan River Chert flakes in the collection exhibit cortical or simple platforms, indicating that these materials were used in core reduction; in fact, the stone tool collection includes two exhausted KRF cores. However, the bulk of the aggregate and individual flake data indicate that the predominant technological operation applied to these materials was pressure flaking, presumably to rejuvenate projectile points and resharpen flake tools. By contrast, Antelope Chert was used somewhat differently. Some late-stage reduction of this material is indicated, but Antelope Chert was used more frequently than KRF or Swan River Chert to produce larger flakes suitable for butchery tools.

The Antelope Chert cores and tested cobbles in the assemblage exhibit relatively poor conchoidal fracture, compared to the Antelope Chert nodules used to produce the butchery tools (and projectile points) in the collection. This suggests either that the Antelope Chert butchery tools discarded at Beacon Island were manufactured elsewhere or that the cores from which they were struck were systematically curated when the hunters moved on. The lack of larger flakes of higher-quality Antelope Chert in the assemblage supports the former interpretation, as does the occurrence of macroscopic transport wear on the dorsal surfaces of some of the flake tools.

Most of the retouched flake tools in the Beacon Island assemblage are similar in size and morphology to butchery tools recovered from the Area 2 Agate Basin component at the Agate Basin site. As Frison and Stanford (1982a) argue, such tools were manufactured according to a definite procedure, one that produces relatively broad, flat, and sturdy flakes suitable for heavy butchery tasks. Platforms are preserved on three of the Beacon Island specimens, and in each case they were struck from large bifacial cores.

Some evidence suggests that bipolar technology was a component of the Agate Basin technological repertoire. One small KRF bipolar nodule or splinter, too small to be classified as a core, occurs in the Beacon Island tool assemblage. Such fragments can be produced by a number of technological processes and it also is possible that this particular example is a byproduct of an impact fracture. However, another somewhat larger bipolar nodule, made from KRF exhibiting moderate patination, occurs in the controlled surface collection (Ahler 2003b). One definite bipolar flake made from KRF occurs in the excavated flaking debris assemblage and the tool inventory also includes a cobble exhibiting battering and pitting on one broad face. Together, these data suggest that Agate Basin hunters made limited use of bipolar percussion.

#### *Weaponry Technology*

No unfinished projectile points or production failures occur in the Beacon Island assemblage. However, close inspection of flaking patterns provides some data on Agate Basin weaponry technology. Eight points in the combined surface and excavated assemblage preserve percussion flake scars on one face. All of the flake scars are relatively flat and featureless, providing few clues to their orientation relative to the axes of the finished points. However, several scars appear to be oriented perpendicular to the long axis. This lends support to Bradley's (2009a:265) hypothesis that Agate Basin flintknappers used "widely spaced full-face, and to some extent controlled overshot flaking" during the middle stage of production to establish the type's characteristically flat longitudinal cross-section. A KRF point in the excavated assemblage preserves a relatively flat cortical surface, clearly indicating that it was made on a tabular piece of stone. Overall, the technological properties of the Agate Basin points from Beacon Island conform closely to those Bradley (1982, 2009a) describes for the Agate Basin and Hell Gap assemblages. Remnant flake scars are shallow, comedial to transmedial, and evenly spaced but not serial. The points were finished with selective invasive and abrupt marginal retouch. Lateral margins are ground or polished. Grinding on the base is comparatively light or absent.

Heat treatment was rarely used in the production of the Beacon Island weaponry assemblage. Just one specimen, made from Antelope Chert, exhibits clear evidence of heat treatment. A second Antelope Chert point in the excavated collection may have been made from treated stone. Two other points in the surface collection also show possible evidence of heat treatment. One of these is made from Swan River Chert and the other is made from Antelope Chert. None of the KRF points exhibit any evidence of heat treatment.

Metric data on 32 complete points or large point fragments from Beacon Island, along with comparable data on 52 points from the Agate Basin, Frazier, and Hell Gap sites, suggest that in their original form Agate Basin points fell into one of at least two morphological classes. The majority of complete, unreworked points exhibit a standardized length-to-width ratio of about 4.2 but vary greatly in size, from a minimum of roughly 55 mm to a maximum of roughly 135 mm long. The second class, which occurs only at the Agate Basin site in eastern Wyoming, exhibits length-to-width ratios between 6.4 and at least 7.3. All of these megapoints are long, though the current sample is too small to gauge whether they exhibited consistent proportions; however, the available data suggest that they did not. The one complete, unmodified point from Hell Gap (Bradley 2009b) conforms to neither morphological class, as do several from the Silver Mound site (Hill 1994). This suggests the existence of a third morphological type.

Data from Beacon Island confirms the signal importance Agate Basin hunters put on weaponry retrieval and rejuvenation. Thirty of the 55 point fragments in the excavated assemblage exhibit some degree of reworking, as do seven of the 20 in the surface assemblage. The figure for the excavated assemblage may underestimate the actual frequency of resharpening because reworking typically occurs more frequently on distal ends but base fragments make up a disproportionate share of that part of the collection. Flaking debris data clearly show that point fragments were recovered during butchery and rejuvenated on-site. However, many of the fragments left behind that exhibit catastrophic impact fractures also exhibit evidence of reworking, indicating that they were refurbished prior to the kill at Beacon Island. Combined with observations on the differing frequencies of unmodified points in other Agate Basin assemblages, these data show that rejuvenation was a habitual component of Agate Basin weaponry technology, but that primary point production occurred only intermittently.

The existence of at least two Agate Basin original point morphologies suggests that there may also have been at least two distinct use-life trajectories or rejuventation strategies. Bradley (2010:483, Figure 9.21) argues that the weapons here described as megapoints were designed so that multiple broken segments, including tips, midsections, and bases, could be reworked into a series of shorter points. The smaller sizes of the standard-ratio-style points likely precluded this strategy. Instead, broken tips and blades were reworked, sometimes producing a relatively blunt point with an asymmetrical cross section. This interpretation is supported by data on reworking location. The majority of the multi-site sample of complete points exhibits reworking on the distal end, including the tip, blade, or tip and blade. This is the pattern one would expect to see if most reworked points originally had the standard-ratio form. However, nearly 40 percent of the points in the sample exhibit some evidence for some reworking on the base, suggesting that they could represent segments of megapoints.

Much of the reworking is essentially unifacial and sometimes is confined only to one blade margin. When reworking extended into the haft element of the original point, the lateral margins were re-ground, but not as intensively as the original haft element. In some cases this secondary grinding is asymmetrical, with dulling on one margin extending closer to the tip.

Frison and Stanford (1982a) argue that reworked Agate Basin projectile points seldom were used as knives or other tools. From a purely morphological and technological standpoint this is certainly true of the Beacon Island assemblage as well. The tip of one Antelope Chert point in the excavated assemblage exhibits markedly asymmetrical flaking that likely precluded its use as an effective weapon. Another segment of an impact fractured point was flaked and re-used as a butchery tool. However, use-wear data on a sample of projectile points suggests that many were used for ancillary tasks, even if they were not reshaped. Similarly, Bamforth and Becker (2009) identify use-wear indicative of bone- or antler-working on the base of an Agate Basin point from Hell Gap. It is not clear, though, whether this auxiliary use took place before hafting or after the specimen was deemed unsuitable as a weapon.

*The Transported Toolkit*

Together, technological data on the stone tool and flaking debris assemblages can be extrapolated to identify the kinds of tools Agate Basin hunters brought with them to Beacon Island. Weapons no doubt made up the bulk of the transported toolkit, many of which had been retrieved and refurbished from an earlier kill. The hunters also brought a selection of large flake tools needed for butchery as well as cores needed for flake production. Several nodules of lower-quality Antelope Chert likely were picked up just prior to the kill, possibly from outcrops of the Bullion Creek formation along the Missouri or White Earth rivers to the west. Cobbles for breaking open bison long bones were obtained in the immediate vicinity.

The majority of the animals brought down in the kill were thoroughly butchered. During processing, the group recovered and rejuvenated serviceable point fragments, leaving behind segments deemed unsuitable for further use as weaponry or fragments lost in minimally butchered carcasses. Several of the retouched flake tools brought to the kill were either broken or lost during butchery. The hunters produced additional flake tools, in the process exhausting several KRF cores. The lower-quality Antelope Chert cores used for expedient flake production were left behind when the group returned to camp. However, the overall paucity of cores and serviceable tools discarded at Beacon Island suggests that the hunters made an effort to find and curate usable items.

## Agate Basin Mobility

The kinds of lithic raw materials in the Beacon Island assemblage offer a relatively clear view of the hunter's movements prior to the kill there. Apart from two size-grade-3 flakes of White River Group Silicate (just over 1 percent of the coarse-fraction flakes recovered from Aggie Brown Member contexts), all of the Beacon Island flaking debris is made from locally available toolstone. One of the projectile points may be made from Sentinel Butte Flint, which occurs naturally some 160 km from Beacon Island, but all of the other tools are made from toolstone available within one or two day's walk.

Knife River Flint—the highest-quality and most-abundant locally available toolstone—dominates the Beacon Island assemblage. However, a wide range of other locally available materials also is present in the collection. In fact, the only raw materials available in western North Dakota that commonly occur in pieces large enough to manufacture Agate Basin points that are not present in the Beacon Island assemblage are smooth gray Tongue River silicified sediment (TRSS) and Rainy Buttes silicified wood. The smooth gray TRSS source area is located well to the south and east, in central and southwestern North Dakota. Rainy Buttes is known to occur in just one locality, roughly 180 km south of Beacon Island.

In sum, then, the assemblage reflects procurement stops at many different local lithic sources. This suggests that the hunters who made the kill at Beacon Island were intimately familiar with the local landscape and stopped regularly at numerous quarry localities as they moved from kill to kill or when they shifted camp locations. The lack of exotic items in the assemblage further suggests that, even if they had periodic access to stone from distant sources, either through trade or direct acquisition, they nevertheless had spent enough time in the local area to exhaust their supply of imported materials. Thus, even if their residence in and around the Missouri River valley was seasonal, they nevertheless were moving through an area they knew well.

## Agate Basin Cultural Relationships

Because Beacon Island is a briefly occupied, single-function site it provides only a limited view on broader Agate Basin cultural relationships. However, aspects of the assemblage offer hints about the social connections among Paleoindian bands of the time.

Notwithstanding the local character of the raw material types represented, both lithic technology and faunal assemblage data point to at least episodic contacts between the Beacon Island band and other Agate Basin bands. The technological practices expressed in the weaponry assemblage, as well as in other tools, indicate participation in a common technological tradition, one that could only have been maintained through periodic interaction. The technological details are simply too congruent to conclude that the Beacon Island band had no contact with the wider Agate Basin world. Similarities between the butchery and carcass transport practices expressed in the Beacon Island bison remains and those expressed at other sites similarly point to shared adaptive strategies. In particular, the details of hindlimb processing methods at Beacon Island and Frazier are suggestive of a common butchery tradition. Given the lack of imported toolstone at Beacon Island, it seems likely that encounters among Agate Basin bands occurred somewhere other than the Missouri River valley.

Accompanying the classic Agate Basin points in the Beacon Island assemblage is one that morphologically and technologically can aptly be labeled "Goshen." This specimen is made from KRF and is remarkably similar to a point base recovered from the Alkali Creek site, located within the KRF primary source area, some 75 km south-southeast of Beacon Island (Ahler et al. 1995). It also is morphologically and metrically similar to many, but not all, of the specimens from the Mill Iron site, the best known Goshen assemblage (Bradley and Frison 1996). Given its position in the bonebed there is no doubt that this point was among the weapons used in the Beacon Island kill. A variety of mundane explanations could account for its presence there: for instance, it could simply be a found object, picked up and rehafted by the Beacon Island band. However, it seems at least as likely that it represents some type of contact with a contemporaneous, but culturally distinct, group. The Beacon Island band could have acquired it through trade, perhaps during a seasonal aggregation of smaller bands. Alternatively, it could be indicative of some form of inter-band migration. In any case, its co-occurrence with Agate Basin points at Beacon Island lends support to Sellet's (2001; Sellet et al. 2009) view that multiple Paleoindian point types were produced concurrently on the Northern Plains between 10,500 and 10,000 $^{14}$C yr B.P.

**Pattern and Variety in Agate Basin Archaeology**

Both similarities and differences exist among the three excavated Agate Basin kill-butchery components. Table 12.1 presents basic data on these sites. Summary indices calculated from these data are given in table 12.2.

Several caveats are in order before considering these data. First, the reported figures partly reflect recovery methods. For instance, at Frazier the field crew screened excavated sediment during the testing phase of the project in 1965 but not during the larger block excavations in 1966 and 1967 (Slessman 2004:34-35). Small bone fragments likely were discarded (Borresen 2002). By contrast, at Beacon Island all chipped stone and bone specimens larger than 1/16 inch were recovered. Table 12.1 only reports the coarse fraction flaking debris from Beacon Island, but does include 13 tool fragments falling in size grades 4 or 5, seven of which are projectile point fragments. Second, curation and cataloging practices also affect the values in table 12.1. Craig (1983) tallies 76 projectile points or point fragments from the Area 2 Agate Basin component at the Agate Basin site, but only 46 of them are associated with specific provenience information. Frison and Stanford (1982a:Figure 2.77) illustrate the locations of 62 specimens within the excavation block, suggesting that some plot data have been misplaced.

Faunal data reveal the most prominent similarities among the three sites. In each case, a relatively large number of bison were killed within, or immediately adjacent to, the excavated portions of the site and the

Table 12.1. Selected data on excavated Agate Basin kill-butchery components.

| Site | Season | Excavated Area (sq. m) | Bison MNI | Flaking Debris[a] | Total Chipped Stone Tools | Projectile Points and Fragments | Complete Points |
|---|---|---|---|---|---|---|---|
| Agate Basin[b] | Early to mid-winter | 123 | 53 | 1,478 | 191 | 76 | 25 |
| Frazier[c] | Late winter-early spring | 288 | 44 | 942 | 219 | 8 | 4 |
| Beacon Island[d] | Early to mid-winter | 121.5[e] | 29 | 144 | 85 | 55 | 2 |

[a] Larger than 1/4 inch.
[b] Agate Basin component in Area 2; modified stone data from Craig (1983:Appendices G, H, and M) (Hill's [2008:Table 3.15] tally only includes specimens retaining unit-specific provenience data); bison MNI data from Hill (2008).
[c] Modified stone data from Slessman (2004); bison MNI data from Borresen (2002).
[d] Excludes artifacts and faunal remains collected from the surface.
[e] Excludes 6 sq. m opened in Area A that failed to expose Agate Basin-age deposits.

Table 12.2. Calculated indices for excavated Agate Basin kill-butchery assemblages.

| Site | Carcass Density (MNI/sq. m) | All Tools:MNI | Percent Complete Points | Tools:Points | All Tools:Flakes |
|---|---|---|---|---|---|
| Agate Basin | 0.43 | 3.6 | 32.9 | 2.5 | 0.13 |
| Frazier | 0.15 | 4.9 | 50.0 | 27.4 | 0.23 |
| Beacon Island | 0.24 | 2.9 | 3.6 | 1.5 | 0.59 |

carcasses were dismembered for transport to a secondary processing locality. Forelimb and hindlimb element profiles of the Agate Basin site assemblage indicate abandonment of low-utility, lower limb elements. At Beacon Island and Frazier, forelimbs appear to have been transported off-site as complete units, but hindlimbs were disarticulated at the hock, with the tibia and calcaneous being transported off-site while the astragalus and metatarsal were abandoned and, in the case of the latter, processed on-site for their marrow. Axial skeleton representation is comparable in all three assemblages, although upper vertebrae are better-represented in the Beacon Island assemblage. Utility indices suggest that at all three sites the hunters sought to maximize both meat and marrow content of the transported packages. Similar packages were brought to Hell Gap, a campsite. However, the overall lack of functional diversity among excavated Agate Basin components limits an appraisal of the range of Agate Basin subsistence practices. Hill (2008:101) argues that large-scale bison kills mostly were "unplanned events resulting from fortuitous circumstances."

The occupations at both Beacon Island and Frazier exhibit clear spatial structure. In both cases, primary carcass dismemberment was segregated from other tasks, including weapon refurbishment, which mostly were carried out in hearth-centered activity areas. This pattern is less evident at Agate Basin. At that site, major carcass parts were stacked in piles, but the bulk of the tool assemblage was recovered from within the bonebed (Frison and Stanford 1982a:Figure 2.44, Figure 2.77).

The degree to which the hunters processed the non-transported fraction of the kill varied among the three sites. At Beacon Island, the near absence of articulated elements in the jumbled mass of bone suggests that the majority of the animals were butchered, with a portion of the meat consumed on-site. At Agate Basin, the largest bone pile includes "several articulated units," though much of the bonebed is made up of disarticulated parts (Frison and Stanford 1982a:76). The number of articulated segments at Frazier is unclear (Borresen 2002:48), though the situation there may have been comparable to that at Agate Basin. However, carcass density values for the three sites vary only slightly, particularly compared to values for other Paleoindian bison kills (table 12.2) (Hofman 1999:Table 3).

Long-bone breakage data more clearly reveal differences in processing intensity. Spiral fractures are twice as common at Beacon Island at they are at Agate Basin, and two and one-half times as common as they are at Frazier. Metatarsals and metacarpals were targeted at Agate Basin but at Frazier and Beacon Island the hunters opened major limb bones for their marrow. At Beacon nearly half of the tibia and more than one-third of the humeri and femora exhibit green breaks. Metapodials also were exploited, but to a lesser extent. The view that the Beacon Island band intensively processed their kill is corroborated by the extremely low percentage of complete projectile points in the excavated Beacon Island assemblage, indicating that the hunters scoured the butchered carcasses for serviceable points and point fragments (table 12.2) (Hofman 1999:Table 3). Together, these data bolster Byers's (2009:151) conclusion that Agate Basin groups routinely exploited within-bone fat. The fact that marrow extraction occurred both at the Hell Gap campsite and at Beacon Island further suggests that marrow fat—perhaps processed into pemmican—was a key component of the Agate Basin diet.

All three sites are cold-season occupations. Agate Basin and Beacon Island were occupied in early to mid-winter, while the occupation at Frazier occurred at the end of the winter. The lack of documented warm-season occupations makes it impossible to assess whether bison hunting was a year-round activity or whether it was confined to certain seasons.

At Beacon Island, the hunters stopped only long enough to butcher the animals they brought down, prepare and pack a portion of the meat for transport, extract bone marrow, and re-tool for the next kill. The Agate Basin and Frazier tool assemblages indicate that a range of ancillary tasks also took place at those sites, concurrent with, or subsequent to, carcass processing. For instance, 26 graving tools occur at Frazier, along with a number of patterned end scrapers and large patterned bifaces representing various reduction stages (Slessman 2004). At Agate Basin, the hunters produced bifaces and used gravers, scrapers, and notch tools for a variety of tasks (Frison and Stanford 1982a). It is significant that at both of these sites artifacts representing a range of activities were recovered from within or immediately adjacent to the mass of butchered bone. By contrast, only one graver occurs at Beacon Island and end scrapers and notch tools are entirely absent. The summary indices presented in table 12.2 show that Beacon Island contains the fewest tools, normalized for the size of the kill, and that a greater share of those tools consist of projectile point fragments. The Beacon Island assemblage also contains the fewest flakes as a proportion of the tool assemblage. These data further indicate that the occupation at Beacon Island was briefer, and functionally more focused, than were the occupations at either Frazier or Agate Basin.

The clear evidence for logistical mobility at Beacon Island adds to the picture of Agate Basin subsistence organization. Hill (2008:102) makes the case that group mobility varied by season, arguing that "cold-season residential hubs were provisioned by hunters operating in a strict logistical mode, [while] warm-season provisioning may have involved serial mobility of residential consumer populations." The evidence from Beacon Island corroborates Hill's view, though the degree to which large-scale bison hunting figured in this remains unknown.

Patterns of stone tool raw material use at Beacon Island provide a counterpoint to previous interpretations of Agate Basin mobility. While episodic contact with other Agate Basin bands, or culturally distinct Paleoindian groups, seem likely, it is clear that the Beacon Island band was intimately familiar with the local landscape drained by the tributaries of the Missouri River in western North Dakota. The co-occurrence of numerous locally available materials, including Antelope Chert, a toolstone poorly represented in regional assemblages, coupled with the virtual absence of imported materials, indicates that the Beacon Island band occupied a relatively restricted range, at least during the cold season. The fact that Agate Basin occupations to the south in Wyoming and Colorado also occurred in the cold season, but differ in their reliance on imported toolstone, suggests that variability existed in Agate Basin band territory size and mobility strategies (Bamforth 2002; Sellet 2006).

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# Appendix A

## Radiocarbon Dating

*Stanley A. Ahler, Thomas W. Stafford, Herbert Haas, and L. Anthony Zalucha*

[*Editor's Note: The following text is a reprint of Ahler and others (2003). The dating results have been re-calibrated using the IntCal09 calibration dataset (Reimer et al. 2009).*]

We were fortunate that a number of items were recovered during excavations that were suitable for radiocarbon dating using AMS techniques that require only miniscule amounts of dateable material. Thomas Stafford of Stafford Research Laboratories, Inc. has developed specific procedures for isolating and dating the most suitable components of animal protein or collagen that may be preserved in bone of considerable antiquity. Information about Stafford's laboratory, methods, and results may be found on the web site *www.staffordlabs.com*. Having a large amount of *Bison antiquus* bone available in the excavated collection from Area A, we turned to Stafford to obtain the most reliable possible dates from the bone materials. Given the presumed antiquity of the bones in question as well as elements we knew to be present in the assemblage, Stafford recommended the following elements in order of decreasing suitability and likelihood for preservation of dateable organic matter: petrosals, astragali, teeth, and phalanges. On this advice we submitted one each of the first three elements. Chemical pretests indicated that suitable organic material was not preserved in the submitted petrosal bone, but did occur in the astragalus and tooth. Consequently, organic materials from these two elements were extracted at Stafford Research Laboratories and prepared for AMS dating conducted at the Center for Accelerator Mass Spectrometry, Lawrence Liverpool National Laboratory at Berkeley, California.

Owing to the attention and keen eyesight of Phil Geib, a substantial number of very small fragments of charred wood were observed and individually collected in the field for purposes of AMS dating. While the bone samples noted above could not be more directly associated with the Agate Basin bison kill event, the temporal link between the charcoal and the Agate Basin component is less direct and is based on contextual association. All of the collected charcoal samples occurred at the interface between the black Aggie Brown Member and the immediately underlying yellowish brown Mallard Island Member sediment. Most of the collected samples were taken from medium to dark brown sediment that was intermediate in color between the main bodies of these two units. All of the collected charcoal came from Units 2 and 4 near the center of the kettle basin, where bone occurred not in a bed but as dispersed, relatively small fragments. Most of the observed bone pieces were in the black sediment of the Aggie Brown Member, very near the basal margin of that unit, but nonetheless in most cases 2 to 4 cm above the elevation of the majority of the plotted and collected charcoal specimens. No charcoal was observed in pure Mallard Island sediments, where it would have been even more visible. We considered it likely that much of the collected charcoal was directly associated with Agate Basin activities at the site, having found its way into slightly deeper contexts through minor processes of vertical turbation such as people or animals walking on the wet, soft floor of the basin during or shortly after the kill event. Another factor arguing in favor of an Agate Basin association for the charcoal with the consistent presence of calcined bone within the bonebed deposit as well as the occurrence of heat-altered Agate Basin points and other artifacts in the assemblage. We considered it probable that yet larger numbers of charcoal pieces existed but were invisible within the black sediment containing the bone remains, and that we had therefore collected only the stratigraphically lowest specimens that happened to lie in slightly lighter colored surrounding matrix. In sum, we considered the collected charcoal to provide, at the minimum, good paleoclimatic and geologic dating information by its precise stratigraphic position in the lowest part of the Aggie Brown Member sediments, and quite probably, good potential for additional dates on the Agate Basin component itself.

The excavated sample contains 19 plotted charcoal pieces, all from the Aggie Brown/Mallard Island interface. Eleven of the largest specimens were sent to L. Anthony Zalucha for microscopic study and identification of wood species prior to destructive analysis in the AMS dating process. The results of Zalucha's analysis are summarized in table A-1. Three specimens were identified as *Salix* spp. (willow), four specimens were identified as a diffuse-porous angiosperm that could

Table A-1. Results of taxonomic analysis of selected wood charcoal specimens from Area A.

| Catalog No. | Unit | North Coordinate | East Coordinate | Elevation (m) | Taxonomic Identification |
|---|---|---|---|---|---|
| 1364 | 2 | 1269.67 | 1109.23 | 987.30 | diffuse-porous angiosperm; possibly *Salix* spp., but very uncertain |
| 1367 | 2 | 1269.14 | 1109.81 | 987.30 | diffuse-porous angiosperm; possibly *Salix* spp., but very uncertain |
| 1399 | 4 | 1274.41 | 1109.41 | 987.38 | unidentified angiosperm; very poor preservation, little visible structure |
| 1400 | 4 | 1274.41 | 1109.51 | 987.40 | unidentifiable; very poorly preserved |
| 1407 | 2 | 1269.75 | 1109.71 | 987.26 | *Salix* spp., willow |
| 1410 | 2 | 1269.65 | 1109.23 | 987.29 | diffuse-porous angiosperm; possibly *Salix* spp., but very uncertain |
| 1412 | 2 | 1269.70 | 1109.59 | 987.27 | unidentifiable; very poorly preserved |
| 1413 | 2 | 1269.22 | 1109.73 | 987.28 | *Salix* spp., willow |
| 1416 | 2 | 1269.29 | 1109.54 | 987.23 | *Salix* spp., willow |
| 1418 | 2 | 1269.94 | 1109.71 | 987.22 | unidentifiable; very poorly preserved |
| 1419 | 2 | 1269.94 | 1109.71 | 987.22 | diffuse-porous angiosperm; possibly *Salix* spp., but very uncertain |

possibly be willow, and the remaining four specimens were unidentifiable due to extremely poor preservation. The identification of willow is fully compatible with the discovery context in the floor of a small enclosed wetland where a highly organic A horizon was developing. Some and perhaps all of the charcoal could have originated in willow that was growing in or on the immediate margin of the basin, or perhaps in or on the margin of the larger kettle basin a short distance to the west of the kill location (see Timpson 2003).

Following the wood identification, three charred wood specimens were selected for AMS radiocarbon analysis. These specimens were sent to Herbert Haas of RC Consultants, Inc. of Las Vegas, Nevada, who conducted sample pretreatment and target preparation prior to their submittal for dating under the direction of Georges Bonani at the ETH-Hoenggerberg AMS facility in Zurich, Switzerland.

Table A-2 provides detailed provenience and identification information for the five samples that were radiocarbon dated by AMS techniques. Table A-3 provides results of the radiocarbon analysis reported by Stafford and Haas. The results are extremely gratifying from the perspective of internal consistency and offer a significant advance in our understanding of the age of Agate Basin archaeology. The two bone samples that provide an ideal association between a relatively short-lived organic material and the targeted cultural event vary from each other by only 25 years, with central tendencies that lie well with each 45-year standard deviation value. Two of the three dates on charcoal (ETH-26779 and 26780) are also extremely similar to the two bone dates, with all four of these dates overlapping well at one standard deviation. The fifth date in the series (ETH-26781, on charcoal) is clearly an outlier from the other four, not overlapping with any of the others at one standard deviation. Unlike the bone remains, there is no reason to expect all of the charcoal within the basin to be the same age and exclusively associated with the Agate Basin activities, so it is feasible to consider the last date in the series to be unassociated with the Agate Basin kill event but nonetheless associated with the accumulation of the Aggie Brown sediment unit within the basin. The first four dates in the series pass the test of contemporaneity using methods provided in program OxCal 4.1.7 (Bronk Ramsey 2010; Reimer et al. 2009) (T'=0.6 where significant $X^2$ = 7.81 at p=.05) and can therefore be averaged. The weighted mean of these four dates is 10,326±28 $^{14}$C yr B.P.

The calibrated calendrical ages of the four dates

Table A-2. Details about materials in dated radiocarbon samples and their specific contexts within Area A.

| Catalog No. | Sample Description | Weight | Unit | North Coordinate | East Coordinate | Elevation (m) |
|---|---|---|---|---|---|---|
| 1329 | astragalus, right, complete; *Bison antiquus* | 115.4 g | 11 | 1283.60 | 1109.60 | 988.00 |
| 1467 | tooth, upper M1/M2 (adult), left, no roots; *Bison antiquus* | 50.8 g | 7 | 1277.52 | 1117.96 | 987.58 |
| 1399 | charred wood; unidentified angiosperm | < 0.1 g | 4 | 1274.41 | 1109.41 | 987.38 |
| 1413 | charred wood; *Salix* spp., willow | < 0.1 g | 2 | 1269.22 | 1109.73 | 987.28 |
| 1416 | charred wood; *Salix* spp., willow | < 0.1 g | 2 | 1269.29 | 1109.54 | 987.23 |

Table A-3. Results of AMS radiocarbon analyses for samples from Area A.

| Catalog No. | Material | Lab Number | $^{14}C$ Age | Calendrical Age at 1 σ (68.2% probability) | δ $^{13}C/^{12}C$ |
|---|---|---|---|---|---|
| 1329 | astragalus | SR-6231, CAMS-90966 | 10,330 ± 45 B.P. | 12,375-12,049 cal B.P. | - |
| 1467 | tooth | SR-6232, CAMS-90967 | 10,305 ± 45 B.P. | 12,370-11,989 cal B.P. | - |
| 1399 | charred wood | ETH-26779 | 10,338 ± 82 B.P. | 12,384-12,046 cal B.P. | -20.7 ± 1.2 |
| 1413 | charred wood | ETH-26780 | 10,371 ± 80 B.P. | 12,390-12,095 cal B.P. | -27.3 ± 1.2 |
| 1416 | charred wood | ETH-26781 | 9,911 ± 105 B.P. | 11,602-11,218 cal B.P. | -24.5 ± 1.2 |

(generated in OxCAL Version 4.1.7 [Bronk Ramsey 2010]) are quite broad, ranging from 295 to 381 calendar years at one sigma and 389 to 700 years at two sigma, owing to a combination of the flatness of the calibration curve in this time range as well as imprecision in the curve for samples more than 11,900 years in calendar age. The calendar age of the weighted average is 12,371-12,049 cal B.P. at one sigma and 12,380-12,009 cal B.P. at two sigma.

Not only do the radiocarbon dates pinpoint the radiocarbon age of the Agate Basin component more accurately than has been possible in previous attempts to date this cultural complex (see Stanford 1999), they also provide a relatively precise date for beginning development of the Aggie Brown Member sediment unit on Beacon Island. Because of the context of the samples, within an enclosed basin likely subject to occasional flooding, we expect prevailing sedimentary processes at the locus to have been dominated by relatively continuous aggredation or buildup of sediment from windblown sources as well as from in-wash from higher ground surrounding the basin. Given these factors and the mean date, it seems reasonable to suggest that the Aggie Brown Member began to develop at this location no more than 100 years before the mean radiocarbon date, or perhaps between 10,450 and 10,350 B.P. This provides an important timeline for the start of a significant climatic event reflected by the formation of the Leonard paleosol that is synonymous with the Aggie Brown sediment unit (see Clayton et al. 1976).

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# Appendix B

## Protein Residue Analysis of Seven Artifacts

*Amy Girado*

*[Editor's Note: The following text is a reprint of Girado (2009).]*

### Introduction

The use of chemical and molecular biological techniques in the analysis of archaeological materials can provide significant new information for the interpretation of their use. The identification of organic residue from lithic and ceramics artifacts, coprolites and soils have provided archaeologists with specific data regarding prehistoric exploitation of animals and plants. Although ancient protein residues may not be preserved in their original form, linear epitopes are generally conserved which can be identified by immunological methods (Abbas et al. 1994).

Immunological methods have been used to identify plant and animal residues on flaked and ground stone lithic artifacts (Allen et al. 1995; Gerlach et al. 1996; Henrikson et al. 1998; Hyland et al. 1990; Kooyman et al. 1992; Newman 1990, 1995; Petraglia et al. 1996; Shanks et al.1999; Yohe et al. 1991) and in Chumash paint pigment (Scott et al. 1996). Plant remains on artifacts also been identified through chemical (opal phytoliths), and morphological (use-wear), studies (Hardy and Garufi 1998; Jahren et al. 1997, Sobolik 1996). Plant and animal residues on ceramic artifacts have been identified through the use of gas-liquid chromatography, high performance liquid chromatography and mass spectrometry (Bonfield and Heron 1995; Evershed et al. 1992; Evershed and Tuross, 1996; Heron et al. 1991, Patrick et al. 1985). Serological methods have been used to determine blood groups in skeletal and soft tissue remains (Heglar 1972; Lee et al. 1989) and in the detection of hemoglobin from 4500-year-old bones (Ascenzi et al. 1985). Human leukocyte antigen (HLA) and deoxyribonucleic acid (DNA) determinations made on human and animal skeletal and soft tissue remains have demonstrated genetic relationships and molecular evolutionary distances (Hänni et al. 1995; Hansen and Gurtler 1983; Lowenstein 1985, 1986; Pääbo 1985, 1986, 1989; Pääbo et al. 1989). Successful identification of residues on stone tools, dated between 35-60,000 B.P., has been made by DNA analysis (Hardy et al. 1997), while recently, residues on surgical implements from the American Civil War were identified by immunological and DNA analysis (Newman et al. 1998). A recent study demonstrated the viability of identifiable immunoglobulin G in 1.6 million-year-old fossil bones from Venta Micena, Spain, (Torres et al. 2002). Horse exploitation was identified by immunological analysis of residues retained on Clovis points dated to ca. 11,200 B.P. (Kooyman et al. 2001).

The use of forensic techniques in the investigation of archaeological materials is appropriate as both disciplines deal with residues that have undergone changes, either deliberate or natural. Criminals habitually endeavor to remove bloodstains by such means as laundering, scrubbing with bleach, etc. yet; such degraded samples are still identified by immunological methods (Lee and De Forest 1976; Milgrom and Campbell 1970; Shinomiya et al. 1978, among others). Similarly it has been shown that immunological methods can be successfully applied to ancient human cremations (Cattaneo et al. 1992). Forensic wildlife laboratories use immunological techniques in their investigation of hunting violations and illegal trade, often from contaminated evidence (Bartlett and Davidson 1992; Guglich et al. 1993; Mardini 1984; McClymont et al. 1982). Immunological methods are also used to test the purity of food products such as canned luncheon meat and sausage, products which have undergone considerable degradation (Ashoor et al. 1988; Berger et al. 1988; King 1984). Thus the age and degradation of protein does not preclude detection (Gaensslen 1983:225).

### Materials and Methods

The method of analysis used in this study of archaeological residues is cross-over immunoelectrophoresis (CIEP). Prior to the introduction of DNA fingerprinting this test was used by forensic laboratories to identify trace residues from crime scenes. Minor adaptations to the original method were made following procedures used by the Royal Canadian Mounted Police Serology Laboratory, Ottawa (1983). The solution used to remove possible residues is five percent ammonium hydroxide which is the most effective extractant for old and denatured proteins without interfering with subsequent testing (Dorrill and Whitehead 1979; Kind and Cleevely 1969). Artifacts are placed in shallow plastic dishes and 0.5 ml of five percent ammonia solution applied directly to each. Initial disaggregation is carried out by floating the dish and contents in an ultrasonic cleaning bath for five minutes. Extraction is continued by placing the dish and contents on a rotating mixer for thirty minutes. For large ground stone items, such as metates, stone bowls, etc., the ammonium hydroxide is applied directly to the worked surface, agitated periodically with a sterile orangewood stick, and allowed to sit for one half hour. The resulting solution is drawn off, placed in a numbered, sterile plastic vial and stored at -20ºC prior to testing. In the case of soil samples, one gram is placed in a vial and 0.5 ml of 1 M Tris buffer solution ($H_2NC[CH_2OH]_3$) is used instead of ammonium hydroxide. The vial is placed in a rotating mixer overnight. The resulting solution is drawn off, placed in a numbered, vial and stored at -20ºC prior to testing.

A series of paired wells is punched into an agarose gel. Approximately 2 µl. of antiserum is placed into one well and the same amount of the unknown sample extract is placed in the other. An electric current is then passed through the gel. The antiserum and unknown sample migrate through the gel and come into contact. If there is protein in the unknown which corresponds with the antiserum, an antigen-antibody reaction occurs and the protein precipitates out in a specific pattern. The precipitant is detected when the gel is pressed, dried and stained. Control positives are run simultaneously with all the unknown samples. Sterile equipment and techniques are used throughout the analysis.

## The Samples

Seven flaked stone artifacts and one soil sample from archaeological site 32MN234, Area A of the Beacon Island site, North Dakota, were submitted for immunological analysis by PaleoCultural Research Group, of Arvada, Colorado. Residues were removed from the artifacts as discussed above. The residues were tested against a suite of animal antisera relevant to the study area (table B-1). Animal antisera provided by Cappel Research and Sigma-Aldrich, and plant antisera produced at the University of Calgary, provide family level identification only. The relationship of antisera to some of the possible species identified is shown in table B-2.

Table B-1. Antisera used in analysis.

| Animal Antiserum | Source |
|---|---|
| Bear | Cappel Research |
| Bovine | Cappel Research |
| Camel | Cappel Research |
| Cat | Sigma-Aldrich |
| Chicken | Cappel Research |
| Deer | Cappel Research |
| Dog | Cappel Research |
| Elephant | Cappel Research |
| Guinea-Pig | Lampire Biomedical |
| Horse | Sigma-Aldrich |
| Rabbit | Cappel Research |
| Rat | Cappel Research |
| Sheep | Cappel Research |
| Swine | Cappel Research |
| Tadpole Shrimp | Cappel Research |
| Trout/Salmon | Cappel Research |

Table B-2. Possible species identified.

| Antiserum to: | Reacts with: |
|---|---|
| Bear | black, grizzly, etc. |
| Bovine | bison, cow, musk ox |
| Camel | all camelids (New & Old world) |
| Cat | bobcat, cougar, lynx, etc. |
| Chicken | quail, grouse, & other gallinaceous fowl |
| Deer | Deer, elk, moose |
| Dog | Coyote, dog, wolf |
| Elephantidae | Elephant, mammoth |
| Guinea-Pig | Beaver, marmot, porcupine, squirrel |
| Horse | Horse, donkey, kiang, etc. |
| Rabbit | Rabbit, hare, pika |
| Rat | All rat & mouse species |
| Sheep | Bighorn & other sheep |
| Swine | Pig, possibly javelina |
| Trout | Trout and salmon species |

## Results

No positive reactions were registered (table B-3). The absence of identifiable proteins on the artifacts may be due to poor preservation of protein, insufficient protein, or that they were not in contact with any of the organisms included in the available antisera.

Table B-3. Results.

| LAS No. | Catalog Number | Artifact | Results |
|---|---|---|---|
| 1 | 7022 | Biface fragment | Negative |
| 2 | 7099 | Biface fragment | Negative |
| 3 | 8311 | Biface fragment | Negative |
| 4 | 8471 | Biface fragment | Negative |
| 5 | 8570 | Biface fragment | Negative |
| 6 | 8914 | Flake | Negative |
| 7 | 11025 | Flake | Negative |
| 8s | 7327 | Sediment | Negative |

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# Appendix C

## Modified Stone Coding Format

*Mark D. Mitchell*

The modified stone aggregate was first partitioned into two classes: chipped stone flaking debris and stone tools. A tool is defined as any intentionally shaped object, an item exhibiting use-wear, or a remnant nodule of raw material from which flakes were removed. Intentionally shaped objects range in complexity from simple flakes with retouched edges to items produced by flaking, pecking, grinding, or some combination of these techniques. Flaking debris, by contrast, consists of detached pieces discarded during lithic reduction and therefore lacking evidence of use or modification other than that produced by transport, trampling, or other post-depositional factors.

The Beacon Island analysis focuses on the assemblage's technological, rather than functional, properties. Technological analysis of flaking debris focuses on flake size distributions and on the details of striking platform type and preparation. Two datasets were collected on the flaking debris aggregate. A basic suite of variables were coded for all sizes of flaking debris (size grades 1 through 5), including size grade, raw material type, presence of cortex, patination intensity, burning, counts, and weights (table C-1). This basic dataset was collected to assess raw material procurement patterns, differences in the ways different raw materials were used, the presence and distribution of intra-site activities areas, and post-depositional alteration to the assemblage.

To gather additional data on the technological procedures used to produce and modify Agate Basin-age stone tools in Area A, an individual-flake analysis was applied to the coarse-fraction (size grades 1 through 3) flake aggregate recovered from Aggie Brown Member contexts. In addition to the variables coded for the complete flaking debris assemblage, this phase of the analysis also considered heat treatment, flake type, and striking platform morphology and preparation method (table C-2).

Data on 18 variables were collected on the stone tool assemblage (table C-3). The most important production variable in the system used here is technological class. A tool's technological class is defined primarily by the dominant method used to manufacture it and secondarily by the initial form of the raw material blank. Each class is defined by a sequence of production techniques.

Determinations about manufacturing stage and technological trajectory depend in part on the concept of "patternedness." Patterned tools exhibit bilateral symmetry. By contrast, unpatterned tools generally are asymmetrical, with their form dictated mainly by the shape of the original input blank. Use-wear traces, though not rigorously quantified, provide additional information about whether the production process was complete when an artifact was lost or discarded. Variables designed to capture supplementary technological data include "use phase," "reason for rejection," "original input blank," and "heat treatment." Data also were collected on three other dimensions of stone tool variation, including raw material use, artifact life-history, and post-depositional alteration.

Additional discussion on the analytic methods applied to the Beacon Island collection can be found in Ahler (2002), Ahler, Kellet, and Crawford (2003), Ahler, Root, and Feiler (1994), Ahler and Toom (1993), and Root and others (1999).

Table C-1. Variables and attribute codes applied to chipped stone flaking debris in all size grades.

| | |
|---|---|
| **CATNO** | **catalog number** |
| **SIZE** | **size grade (1, 2, 3, 4, or 5)** |
| **RAWM** | **raw material type** |
| 1 | smooth gray Tongue River silicified sediment |
| 2 | coarse Tongue River silicified sediment |
| 3 | coarse red Tongue River silicified sediment |
| 4 | solid quartzite (fine-grained orthoquartzite) |
| 5 | Swan River chert (porous quartzite) |
| 6.0 | miscellaneous jasper/chert |
| 6.5 | dendritic yellow |
| 6.6 | dendritic red |
| 6.7 | dendritic other (green, etc.) |
| 7 | White River Group silicates |
| 8 | clear/gray chalcedony (not silicified wood) |
| 9 | yellow/light brown chalcedony (not silicified wood) |
| 10 | dark brown chalcedony (non-KRF, non-silicified wood) |
| 11 | plate chalcedony |

Table C-1. Variables and attribute codes applied to chipped stone flaking debris in all size grades (continued).

| | |
|---|---|
| 12 | burned chalcedony (not further identifiable) |
| 13 | basaltic material |
| 14 | other unclassifiable |
| 15 | Bijou Hills silicified sediment |
| 16 | milk or vein quartz |
| 17 | porcellanite |
| 18 | obsidian \ |
| 19 | granitic material |
| 20 | coarse porous sandstone |
| 21 | compact sandstone |
| 22 | fossil or concretion |
| 23 | clinker |
| 24 | catlinite |
| 25 | hematite (red ochre) |
| 26 | limonite (yellow ochre) |
| 27 | gypsum |
| 28 | Knife River Flint |
| 29 | Rainy Buttes silicified wood |
| 30 | tough gray-green chert |
| 31 | blonde French flint |
| 32 | Thames River (Dover) flint |
| 33 | light yellow pigment stone |
| 34 | historic period glass |
| 35 | metaquartzite (not type 4) |
| 36 | scoria |
| 37 | siltstone/limestone/mudstone |
| 38 | steatite |
| 40 | non-volcanic natural glass |
| 41 | opal |
| 42 | felspar |
| 50 | Charlie Creek chert |
| 51 | Miocene flint (Sentinel Butte flint) |
| 52 | obvious silicified wood |
| 53 | moss agate |
| 54 | Antelope Chert |
| 55 | gray silcrete (non-Tongue River types) |
| 56 | Scenic chalcedony |
| 57 | Hartville Uplift chert |
| 58 | Yellowstone agate |
| 59 | Turtle Valley orthoquartzite |
| 69 | Schmidtt chert |
| 70 | shist |
| **BURN** | **burning or heat treatment** |
| 0 | not burned |
| 2 | heat altered |
| **CORT** | **cortex** |
| 0 | absent |
| 1 | present |
| **PATI** | **patination intensity (coded for KRF only)** |
| 0 | absent |
| 1 | light |
| 2 | moderate |
| 3 | pronounced |
| 9 | not applicable or burned, if KRF |
| **COUNT** | **count of flakes with common coding** |
| **WEIGH** | **combined weight this data case, to 0.1 g** |

Table C-2. Variables and attribute codes applied to coarse fraction flaking debris (size grades 1 through 3) from Aggie Brown Member contexts.

| | |
|---|---|
| **CATNO** | **catalog number** |
| **SIZE** | **size grade (1, 2, or 3)** |
| **RAWM** | **raw material type (see table C-1 for attributes)** |
| **HEAT** | **heat treatment (coded for KRF only)** |
| 0 | no heat treatment |
| 1 | possible heat treatment |
| 2 | definite heat treatment |
| 9 | not applicable or burned, if KRF |
| **BURN** | **burning** |
| 0 | not burned |
| 1 | burned |
| **CORT** | **cortex** |
| 0 | absent |
| 1 | present |
| **PATI** | **patination intensity (coded for KRF only)** |
| 0 | absent |
| 1 | light |
| 2 | moderate |
| 3 | pronounced |
| 9 | not applicable or burned, if KRF |
| **SRT** | **Sullivan and Rozen class** |
| 1 | complete flake |
| 2 | broken flake |
| 3 | flake fragment |
| 4 | debris |
| **LENG** | **measured on complete flakes only, to 0.1 mm** |
| **WIDTH** | **measured on complete flakes only, to 0.1 mm** |
| **TYPE** | **flake type** |
| 1 | shatter |
| 2 | bipolar flake |
| 3 | percussion bifacial thinning flake |
| 4 | blade |
| 5 | simple flake |
| 6 | complex flake |
| 7 | bifacial pressure flake |
| 8 | linear flake |
| 10 | radial break flake |
| 11 | unifacial retouch flake |
| 99 | indeterminate |
| **PTYPE** | **platform type** |
| 1 | cortical |
| 2 | simple |

Table C-2. Variables and attribute codes applied to coarse fraction flaking debris (size grades 1 through 3) from Aggie Brown Member contexts (continued).

| | |
|---|---|
| 3 | complex |
| 4 | crushed |
| blank | not observable |
| **PPREP** | **platform preparation** |
| 1 | none |
| 2 | faceted |
| 3 | dorsally reduced |
| 4 | ground |
| 9 | indeterminate |
| blank | not observable |
| **WEIGH** | **specimen weight, to 0.1 g** |

Table C-3. Variables and attribute codes applied to stone tools.

| | |
|---|---|
| **CATNO** | **catalog number** |
| **SIZE** | **size grade (1, 2, 3, 4, or 5)** |
| **SEQ** | **sequence number for waterscreen samples** |
| **RAWM** | **raw material type (see table C-1 for attributes)** |
| **TECH** | **technological class** |
| 1 | patterned small thin biface |
| 2 | patterned large thin biface |
| 3 | unpatterned small to medium biface |
| 4 | patterned steeply beveled flake tool |
| 5 | unpatterned flake tool, retouched or use-modified |
| 6 | large, thick bifacial core-tool |
| 7 | nonbipolar core and core-tool |
| 8 | bipolar core and core-tool |
| 9 | unpatterned pecked or ground tool |
| 10 | patterned pecked or ground tool |
| 11 | radial break tool |
| 12 | retouched tabular piece or plate |
| **BLANK** | **original input blank** |
| 1 | tabular cobble/pebble (>10 mm thick; w/th ratio >2.5) |
| 2 | thin plate (thickness < 10 mm) |
| 3 | subrounded, rounded, spherical cobble or pebble |
| 4 | blocky/angular cobble or pebble (thickness >10 mm; w/th ratio < 2.5) |
| 5 | split cobble |
| 6 | other nonbipolar flake, with no platform present or with unprepared platform present |
| 7 | bifacial thinning flake |
| 8 | bipolar flake |
| 9 | blade or bladelet |
| 10 | shatter |
| 11 | indeterminate |
| 12 | other nonbipolar flake from prepared core; platform ground and/or dorsally reduced |
| 13 | finished patterned biface used as blank |
| 14 | unfinished patterned biface used as blank |
| 15 | unpatterned flake tool or ret. tabular piece used as blank |
| 16 | patterned flake tool used as blank |
| 17 | simple flake |
| 18 | complex flake |
| 19 | non-bipolar core or core fragment |
| 20 | bipolar core |
| 21 | fire-cracked rock |
| 22 | unpatterned biface |
| 23 | complex/patterned ground stone tool |
| **USE** | **use-phase class** |
| 1 | unfinished, usable (unbroken) |
| 2 | unfinished, unusable (broken or rejected) |
| 3 | finished, usable (unbroken; includes usable cores) |
| 4 | finished, unusable (broken, burnt, exhausted, rejected; includes exhausted cores) |
| **REJECT** | **reason for rejection, failure, discard** |
| 1 | has potential for further work or use |
| 2 | bending fracture or end shock |
| 3 | perverse fracture |
| 4 | material flaw or poor quality stone |
| 5 | outré-passé fracture |
| 6 | compound hinge/step occurrence |
| 7 | impact fracture |
| 8 | small size or exhaustion |
| 9 | indeterminate |
| 10 | heat or thermal fracture |
| 11 | lateral break |
| 12 | broken by radial fracture |
| 13 | crescentic chunk from tool margin |
| 14 | channel flake or fragment |
| 15 | recycled into another form or use, by bipolar process |
| 16 | burination spall |
| 17 | resharpening flake coded as a tool; no further use possible |
| 18 | recycled into another form or use, by non-bipolar process |
| **RESH** | **resharpening** |
| 0 | absent |
| 1 | present |
| **RECY** | **recycling** |
| 0 | absent |
| 1 | recycled into different function |
| **FUNC** | **functional class** |
| 0 | unknown function |
| 1 | projectile point |
| 2 | perforator, drill |
| 3 | light duty bilateral cutting tool |
| 4 | transverse-edged cutting tool |
| 5 | basal scraper/grinder |

Table C-3. Variables and attribute codes applied to stone tools (continued).

| | |
|---|---|
| 6 | light duty transverse scraper used on soft material |
| 7 | bilateral, heavy duty 1 bifacial cutting tool |
| 8 | expedient, general purpose cutting tool |
| 9 | heavy duty 3 ripping, sawing, tearing tool |
| 10 | heavy duty 1 asymmetrical or unilateral bifacial cutting tool |
| 11 | stone saw |
| 12 | bifacial cutting tool used on hard material |
| 13 | lateral scraper used on soft material |
| 14 | heavy duty chopping, pounding tool |
| 15 | generalized patterned bifacial cutting tool |
| 16 | transverse scraper used on abrasive material |
| 17 | transverse scraper used on hard material |
| 18 | denticulated flake or edge modified tool |
| 19 | slotting or grooving tool |
| 20 | generalized transverse scraping tool |
| 21 | core |
| 22 | utilized flake used to saw or slice hard material |
| 23 | retouched or utilized flake used on variable material |
| 24 | whetstone |
| 25 | core/punch/wedge/chisel |
| 26 | punch/wedge/chisel |
| 27 | steep-edged heavy duty scraping/adzing tool |
| 28 | bipolar anvil or hammer |
| 29 | hammerstone or pounder |
| 30 | graving or incising tool |
| 31 | tested raw material |
| 32 | woodworking ax |
| 33 | simple hand-held abrading tool |
| 34 | simple hand-held grooved abrading tool |
| 35 | complex hand-held grinding/crushing tool |
| 36 | complex anvil used in grinding/crushing |
| 37 | simple burnishing tool |
| 38 | unaltered fossil or concretion |
| 39 | altered or modified fossil or concretion |
| 40 | unmodified manuport |
| 41 | pounding/grinding tool |
| 42 | edge ground saw (not used on stone) |
| 43 | gunflint |
| 44 | bifacial tools of generalized or unknown specific function |
| 45 | spokeshave |
| 46 | large core-tool of uncertain function |
| 47 | nonutilitarian item of uncertain specific function |
| 48 | complex grooved abrasive grinding tool (shaft smoother) |
| 49 | reamer |
| 50 | smoking pipe |
| 51 | pendant or bead |
| 52 | pigment source |
| 53 | edge or corner ground tool |
| 54 | generalized flake tool |
| 55 | digging tool |
| 56 | practice pieces and miscellaneous chipped stone tool |
| 57 | striker flake |
| 58 | notched flake |
| 59 | edge ground flake |
| 60 | patterned disc or tablet |
| 61 | rolled flake |
| 62 | ochre-stained flake or stone |
| 63 | perforated stone hammer |
| 64 | clinker cylinder or cone |
| 65 | donut-shaped stone |
| 66 | flake ridge plane used on resistant material |
| 67 | snap break plane used on resistant material |
| 68 | point-concentrated wear on radial break or pie-shaped tool |
| 69 | hinge edge tool |
| 70 | isolated polish tool |
| 71 | wood working adz |
| 72 | lance tip or symbolic weapon tip |
| 73 | net weight |
| 74 | chipped marble-like object |
| 99 | unknown due to fracture |
| **COMP** | **tool completeness** |
| 1 | complete |
| 2 | nearly complete |
| 3 | distal end |
| 4 | proximal end |
| 5 | medial fragment or segment |
| 6 | indeterminate end |
| 7 | margin fragment |
| 9 | other fragment |
| **COMP2** | **projectile point completeness** |
| 1 | complete |
| 2 | resharpened tip, complete base |
| 3 | missing tip |
| 4 | basal fragment |
| 5 | fragment with ground edge |
| 6 | distal segment |
| 7 | distal part lacking base |
| 9 | not applicable or indeterminate |
| **BURN** | **burning** |
| 0 | not burned |
| 1 | burned |
| **HEAT** | **heat treatment (coded for KRF only)** |
| 0 | no heat treatment |
| 1 | possible heat treatment |
| 2 | definite heat treatment |
| 9 | not applicable or burned, if KRF |
| **CORT** | **cortex** |
| 0 | absent |

Table C-3. Variables and attribute codes applied to stone tools (continued).

| | |
|---|---|
| 1 | present |
| **PATI** | **patination intensity (coded for KRF only)** |
| 0 | absent |
| 1 | light |
| 2 | moderate |
| 3 | pronounced |
| 9 | not applicable or burned, if KRF |
| **WEIGH** | **specimen weight, to 0.1 g** |

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# Appendix D

## Faunal Analysis Coding Format

*Jennifer Borresen Lee and Stacey D. Bennett*

Table D-1 lists the variables and attributes coded in the analysis of piece-plotted bison remains recovered from Area A during September 2002 and 2006. To facilitate comparison with other bison bonebed studies, the remains were analyzed using a coding system established by Todd (1987:121-122) and subsequently modified by Hill (2001). Characteristics recorded for each identifiable specimen include element, portion, segment, side, fusion, diagnostic landmarks, breakage, and burning. Lee (2003) notes that the surfaces of many of the bones recovered during the May 2002 testing program are poorly preserved or difficult to observe owing to carbonate build-up. Accordingly, surface modification data were not collected on the material excavated in September 2002 and in 2006. The presence or absence of spiral or green fractures on long bone fragments was noted, but the frequencies of other fracture types were not tabulated.

The current study added to and modified several of Hill's (2001) element landmarks in order to simplify the quantification process. Modifications to Hill's landmarks include the addition of Landmark 3 Side and Landmark 4 Side for the cervical, thoracic, and lumbar vertebrae and Landmark 16 for the radius. Landmark 3 Side and Landmark 4 Side refer to the cranial and caudal articular processes, respectively, and were added because individual (i.e., right or left) articular processes are far more frequent than specimens preserving both processes. Landmark 16 (the styloid process of the ulna) was added to the radius because the distal ulna fuses to the radius and is therefore often present on distal radius fragments. The addition of this landmark simplifies quantification of MNE for the radius, ulna, and radius-ulna (RDU) specimens.

Table D-1. Faunal analysis variables and attributes.

| | |
|---|---|
| **ELEMENT CODES** | |
| | Cranium/Teeth |
| CRN | cranium |
| DPUN | indeterminate deciduous premolar |
| HS | horn sheath |
| HY | stylohyoid |
| MR | mandible |
| MUN | indeterminate molar |
| PUN | indeterminate premolar |
| TFR | indeterminate tooth fragment |
| | Axial |
| AT | atlas vertebra |
| AX | axis vertebra |
| CA | caudal vertebra |
| CE | cervical vertebra |
| CS | costal cartilage |
| LM | lumbar vertebra |
| MN | manubrium |
| RB | rib |
| SA | sacral vertebra |
| SAC | sacrum |
| SN | sternal element |
| TH | thoracic vertebra |
| VT | indeterminate vertebra |
| | Appendicular (Forelimb) |
| CP | indeterminate carpal |
| CPA | accessory carpal |
| CPF | 4th carpal |
| CPI | intermediate carpal |
| CPR | radial carpal |
| CPS | fused 2nd and 3rd carpal |
| CPU | ulnar carpal |
| HM | humerus |
| MC | metacarpal |
| MCF | 5th metacarpal |
| RD | radius |
| RDU | radius-ulna |
| SC | scapula |
| UL | ulna |
| | Appendicular (Hindlimb) |
| AS | astragalus |
| CL | calcaneus |
| FM | femur |
| LTM | lateral malleolus |
| IM | innominate |
| MT | metatarsal |
| MTS | 2nd metatarsal |
| PT | patella |
| PV | complete pelvis |
| TA | tibia |

| | |
|---|---|
| TR | indeterminate tarsal |
| TRC | fused central and 4th tarsal |
| TRF | 1st tarsal |
| TRS | fused 2nd and 3rd tarsal |

Other Appendicular

| | |
|---|---|
| DEW | accessory phalanx |
| MP | indeterminate metapodial |
| PH | indeterminate phalanx |
| PHF | 1st phalanx |
| PHS | 2nd phalanx |
| PHT | 3rd phalanx |
| SE | indeterminate sesamoid |
| SED | distal sesamoid |
| SEP | proximal sesamoid |

Fragments

| | |
|---|---|
| CB | indeterminate cancellous bone |
| FB | indeterminate flat bone |
| LB | indeterminate long bone |
| UN | unidentified fragment |

**PORTION CODES**

Long Bone

| | |
|---|---|
| BL | blade of scapula or rib |
| CDL | condyle |
| CO | complete |
| DDS | distal diaphysis |
| DF | diaphysis |
| DFD | DS + DSE |
| DFP | DF + PRE |
| DPR | proximal diaphysis |
| DS | distal end |
| DSE | distal epiphysis |
| DSH | distal, articular end plus > ½ shaft |
| DSS | distal, articular end plus < ½ shaft |
| EP | epiphysis |
| FK | flake, <½ circumference of shaft |
| HE | head |
| IFC | impact cone |
| IFK | impact flake |
| PR | proximal end |
| PRE | proximal epiphysis |
| PRS | proximal, articular end plus > ½ shaft |
| PSH | proximal, articular end plus < ½ shaft |
| SH | long bone shaft |
| US | unspecified |

Cranium

| | |
|---|---|
| BRC | braincase |
| BSL | basilar |
| DP2-4 | deciduous maxillary premolar |
| EN | tooth enamel |
| FN | frontal |
| HC | horn core |
| HS | horn sheath |
| INV | incisive |
| JUG | jugal process |
| LC | lacrimal |
| M1-3 | maxillary molar # |
| MUN | indeterminate maxillary molar |
| MX | maxilla |
| NSL | nasal |
| OCC | occipital |
| PAL | palatine |
| PAR | parietal |
| PET | petrosal |
| P2-4 | maxillar premolar # |
| PUN | indeterminate maxillary premolar |
| SKO | other combination |
| SR | skull roof (FN + HC) |
| TMP | temporal |
| TW | tooth row |
| ZYG | zygomatic |

Mandible

| | |
|---|---|
| ANG | angle |
| BDR | distal border |
| CP | condylar process |
| CRD | coronoid process |
| DAM | DRM + RAM |
| DIC | deciduous incisor |
| DP2-4 | deciduous mandibular premolar |
| DRM | dentary ramus |
| EN | tooth enamel |
| HRM | horizontal ramus |
| IC | incisor |
| P2-4 | mandibular premolar # |
| M1-3 | mandibular molar # |
| MUN | indeterminate mandibular molar |
| PUN | indeterminate mandibular premolar |
| RAM | ascending ramus |
| SYM | symphysis |
| TW | tooth row |

Stylohyoid

| | |
|---|---|
| ANG | angle |
| BOD | body |

Vertebra

| | |
|---|---|
| AEP | anterior epiphysis |
| AP | articular process |
| CN | centrum |
| CAN | CN + AP |
| CNN | CN + neural arch |
| CNS | CN + dorsal spine |
| CNW | atlas, CN + wings |
| CNT | CN + TSP |
| DSP | dorsal spinous process |
| NAS | neural arch + spine |
| PEP | posterior epiphysis |
| TSP | transverse spinous process |

<u>Scapula</u>

| | |
|---|---|
| CRB | cranial border |
| CBD | caudal border |
| GN | glenoid |
| GNB | GN + blade fragment |
| GS | GN + spine |

<u>Ulna</u>

| | |
|---|---|
| ANC | trochlear notch portion |
| OLC | olecranon portion |
| SH | shaft |

<u>Innominate</u>

| | |
|---|---|
| AC | acetabulum |
| ACL | AC + IL |
| ACP | AC + PB |
| ACS | AC + IS |
| IL | ilium |
| ILC | ilium (cranial) |
| ILD | ilium (caudal) |
| IS | ischium |
| ISC | ischium (cranial) |
| ISD | ischium (caudal) |
| PB | pubis |
| PBS | pubis symphysis |
| VPT | ventral pubic tubercle |

**SEGMENT CODES**

| | |
|---|---|
| AL | anterolateral |
| AM | anteromedial |
| CD | caudal (posterior) |
| CDL | condyle |
| CO | complete |
| CR | cranial (anterior) |
| DR | dorsal |
| DS | distal |
| EN | tooth enamel |
| EX | exterior |
| FO | fore |
| FR | fragment |
| HB | split rib blade |
| HD | hind |
| HE | head |
| IN | interior |
| LT | lateral |
| ME | medial |
| PL | posterolateral |
| PM | posteromedial |
| PR | proximal |
| SP | spine |
| TW | tooth row |
| VN | ventral |
| US | unspecified |
| # | vertebra/rib/tooth |

**SIDE CODES**

| | |
|---|---|
| A | axial |
| L | left |
| N | not sided |
| R | right |

**EPIPHYSEAL FUSION CODES**

| | |
|---|---|
| 0 | unfused |
| 1 | partially fused |
| 2 | fused, line visible |
| 3 | complete fusion |
| 4 | broken, indeterminate |
| 5 | not applicable (e.g., proximal metapodial, tooth) |

**BISON ELEMENT LANDMARKS**

**<u>Axial</u>**

<u>MR (mandible)</u>

| | |
|---|---|
| L1 | coronoid process |
| L2 | articular condyle |
| L3 | mandibular foramen |
| L4 | angle |
| L5 | M3 |
| L6 | M2 |
| L7 | M1 |
| L8 | P4 |
| L9 | P3 |
| L10 | P2 |
| L11 | lower border |
| L12 | diastema |
| L13 | mental foramen |
| L14 | symphysis |
| L15 | incisor (n= ) |

<u>HY (hyoid)</u>

| | |
|---|---|
| L1 | angle |
| L2 | body |

<u>AT (atlas)</u>

| | |
|---|---|
| L1 | ventral tuber |
| L2 | dorsal tuber |
| L3 | right cranial artic.surf |
| L4 | left cranial artic.surf |
| L5 | right intervertebral facet |
| L6 | left intervertebral facet |
| L7 | right caudal artic facet |
| L8 | left caudal artic.facet |

<u>AX (axis)</u>

| | |
|---|---|
| L1 | dorsal spine |
| L2 | dens (cranial artic.surf) |
| L3 | right caudal artic.surf |
| L4 | left caudal artic.surf |
| L5 | right transverse process |
| L6 | left transverse process |
| L7 | centrum |

<u>CE 3-7 (cervical vertebrae 3-7)</u>

| | |
|---|---|
| L1 | dorsal spine |
| L2 | cranial artic processes (coded by side) |
| L3 | caudal artic processes (coded by side) |
| L4 | transverse processes (coded by side) |

| | |
|---|---|
| L5 | centrum |
| | TH 1-14 (thoracic vertebrae 1-14) |
| L1 | dorsal spine |
| L2 | cranial artic processes (coded by side) |
| L3 | caudal artic processes (coded by side) |
| L4 | transverse processes (coded by side) |
| L5 | centrum |
| | LM 1-5 (lumbar vertebrae 1-5) |
| L1 | dorsal spine |
| L2 | cranial artic processes (coded by side) |
| L3 | caudal artic processes (coded by side) |
| L4 | transverse processes (coded by side) |
| L5 | centrum |
| | SA (sacrum) |
| L1 | segment I |
| L2 | segment II |
| L3 | segment III |
| L4 | segment IV |
| L5 | segment V |
| L6 | right wing |
| L7 | left wing |
| | RB (rib) |
| L1 | head |
| L2 | tubercle |
| L3 | proximal blade |
| | **Forelimb** |
| | SC (scapula) |
| L1 | prox superior border |
| L2 | prox inferior border |
| L3 | nutrient foramen |
| L4 | spine |
| L5 | acromion |
| L6 | distal superior border |
| L7 | distal inferior border |
| L8 | neck |
| L9 | coracoid process |
| L10 | glenoid cavity |
| | HM (humerus) |
| L1 | lateral tuberosity |
| L2 | medial tuberosity |
| L3 | head |
| L4 | neck |
| L5 | deltiod tuberosity |
| L6 | teres major tuberosity |
| L7 | posterolateral foramen |
| L8 | prox olecranon fossa |
| L9 | coronoid fossa |
| L10 | lateral epicondyle |
| L11 | medial epicondyle |
| L12 | lateral condyle |
| L13 | medial condyle |
| | RD (radius) |
| L1 | lateral glenoid cavity |

| | |
|---|---|
| L2 | medial glenoid cavity |
| L3 | prox posterior shaft |
| L4 | radial tuberosity |
| L5 | posterolateral foramen |
| L6 | midposterior shaft |
| L7 | midanterior shaft |
| L8 | distal posterior shaft |
| L9 | distal anterior shaft |
| L10 | CPR facet |
| L11 | CPI facet |
| L16 | styloid process of the ulna (coded for RDU) |
| | UL (ulna) |
| L1 | proximal epiphysis |
| L2 | olecranon process |
| L3 | anconeal process |
| L4 | articular facets |
| L5 | proximal shaft |
| L6 | midshaft |
| L7 | styloid process |
| | MC (metacarpal) |
| L1 | CPS facet |
| L2 | CPF facet |
| L3 | anterior shaft |
| L4 | posterior shaft |
| L5 | anterior foramen |
| L6 | posterior foramen |
| L7 | medial condyle |
| L8 | lateral condyle |
| | **Hindlimb** |
| | IM (innominate) |
| L1 | ilium blade |
| L2 | ilium shaft |
| L3 | ilio-ischial border |
| L4 | acetabulum |
| L5 | ischium shaft |
| L6 | ischium tuberosity |
| L7 | pubis shaft |
| L8 | pubic symphysis |
| | FM (femur) |
| L1 | head |
| L2 | greater trochanter |
| L3 | minor trochanter |
| L4 | anterior shaft |
| L5 | linea aspera |
| L6 | posterolateral foramen |
| L7 | supracondyloid fossa |
| L8 | proximal trochlea |
| L9 | medial condyle |
| L10 | lateral condyle |
| | TA (tibia) |
| L1 | tibial tuberosity |
| L2 | medial condyle |
| L3 | lateral condyle |

| | |
|---|---|
| L4 | anterior crest |
| L5 | posterolat foramen |
| L6 | prox posterior shaft |
| L7 | distal posterior shaft |
| L8 | distal anterior shaft |
| L9 | medial groove |
| L10 | lateral groove |
| L11 | LTM facet |
| | CL (calcaneus) |
| L1 | proximal epiphysis |
| L2 | proximal shaft |
| L3 | sustentaculum |
| L4 | talus facet |
| L5 | LTM facet |
| L6 | TRC facet |
| | MT (metatarsal) |
| L1 | TRC facet |
| L2 | TRS facet |
| L3 | anterior shaft |
| L4 | posterior shaft |
| L5 | anterior foramen |
| L6 | posterior foramen |
| L7 | medial condyle |
| L8 | lateral condyle |
| | PHF, PHS, PHT (phalanx 1-3) |
| L1 | proximal |
| L2 | medial |
| L3 | distal |
| **SURFACE MODIFICATION CODES** | |
| | Spiral Fracture |
| 0 | absent or indeterminate |
| 1 | spiral |
| | Burning |
| 0 | none |
| 1 | carbonized |
| 2 | calcined |
| | Comment |
| 0 | no comment |
| 1 | comment on butchery marks, rodent gnawing, refits, unusual features, etc. |

Table D-2. Metapodial measurement descriptions.

| Measurement | Description |
|---|---|
| M1 | Maximum length |
| M2 | Transverse width |
| M3 | Transverse width at center of shaft |
| M4 | Transverse width of the distal end |
| M5 | Anterior-posterior width at center of shaft |
| M6 | Anterior-posterior width of proximal end |
| M7 | Anterior-posterior width of proximal end |
| M8 | Anterior-posterior width of distal end |
| M9 | Minimum anterior-posterior width of shaft |
| M10 | Minimum lateral width of shaft |
| M11 | Rotational length |
| M12 | Foramen to articular surface length, anterior |
| M13 | Foramen to articular surface length, posterior |

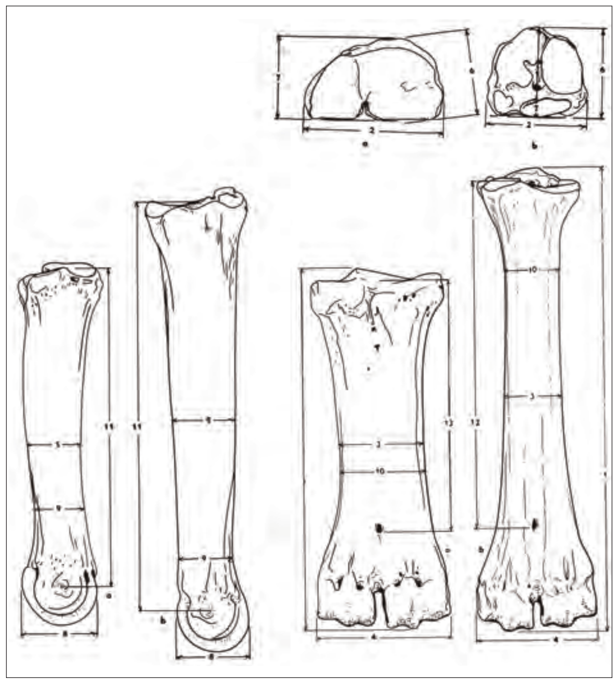

Figure D-1. Metapodial measurements.

### Metapodial Measurements

Metacarpals and metatarsals were measured following the method Bedord (1974, 1978) applied to the Casper site bison assemblage. The Beacon Island study utilized Bedord's numbering system, measurement descriptions, and inferences (table D-2 and figure D-1). Thirteen individual measurements were collected to the nearest millimeter (mm) by a single analyst using digital sliding calipers, a ruler, and an osteometric board.

### Calcaneous Measurements

Calcanea were measured using Hill's (1996:232) variables applied to the Mill Iron site assemblage. Descriptions of the 11 variables are provided in table D-3.

### Dentition Measurements

The Beacon Island dentition study uses the analytic methods developed by Todd and others (1996) and Reher and Frison (1980). Measurements of individual teeth were confined to identifiable mandibular molars and followed the terminology and definitions outlined in the Mill Iron study (Todd et al. 1996). Molar measurements include: metaconid height (M), entoconid height (E), mesial width at the occlusal surface (MS), distal width at the occlusal surface (DS), length of occlusal surfaces (L), and distance from ectostylid to the occlusal surface (EC) (Todd et al. 1996:147-148) (figure D-2).

Table D-3. Calcanea measurement descriptions.

| Measurement | Description |
|---|---|
| CL1 | Greatest length |
| CL2 | Greatest breadth proximal end |
| CL3 | Greatest depth of proximal end |
| CL4 | Greatest breadth |
| CL5 | Greatest depth |
| CL6 | Distal width |
| CL7 | Greatest length of naviculocuboid facet |
| CL8 | Greatest length of talus facet |
| CL9 | Greatest length of shaft |
| CL10 | Greatest length (unfused epiphysis) |
| CL11 | Greatest length of shaft (unfused epiphysis) |

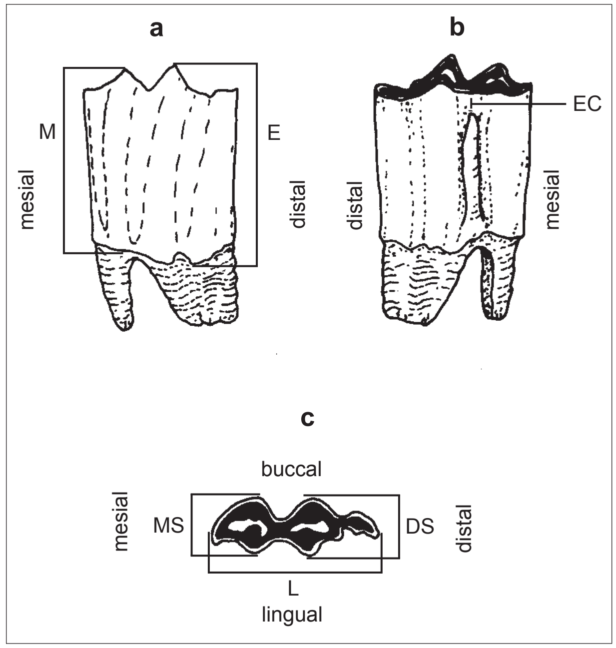


Figure D-2. Tooth measurements (Todd et al. 1996:Figure 8.2).

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Todd, Lawerence C., David J. Rapson, and Jack L. Hofman

1996 Dentition Studies of the Mill Iron and Other Early Paleoindian Bison Bonebed Sites. In *The Mill Iron Site*, edited by George C. Frison, pp. 145-175. University of New Mexico Press, Albuquerque.

# Appendix E

Beacon Island Technical Report Bibliography

Table E-1. Summary of technical publications describing fieldwork at the Beacon Island site.

| Reference | PCRG Contribution No. | Field Year | Site Area(s) | Major Field Activities |
|---|---|---|---|---|
| Haberman and Schneider 1975 | n/a | 1974 | n/a | Survey, testing |
| Timpson and Ahler 2002 | 47 | 2001 | n/a | Aerial photo interpretation |
| Ahler et al. 2002 | 48 | 2002 | A, B, F, T | Survey, coring, surface collection, testing |
| Ahler, Crawford, and Timpson 2002 | 49 | 2002 | A | Mapping, testing, mitigation |
| Ahler, ed. 2003 | 54 | 2002 | A, B, F, T | Survey, coring, surface collection, testing |
| Ahler et al. 2006 | 75 | 2006 | A | Mitigation, data recovery |
| Ahler et al. 2006 | 76 | 2006 | A | Mitigation, data recovery |
| Spurr, Nickel, and Ahler 2007 | 77 | 2006 | A | Remote sensing, coring, testing |
| Mitchell, ed. 2011 | 86 | 2002, 2006 | A, P | Mitigation, data recovery |


Ahler, Stanley A. (editor)
2003 *Resurvey and Test Excavations at Beacon Island in Lake Sakakawea, Mountrail County, North Dakota*. Research Contribution No. 54. Paleocultural Research Group, Flagstaff, Arizona. Submitted to the State Historical Society of North Dakota, Bismarck.

Ahler, Stanley A., George T. Crawford, and Michael E. Timpson
2002 *Fieldwork Report Regarding Test Excavations During September 2002 at an Agate Basin Cultural Component in Area A within the Beacon Island Site, 32MN234, Lake Sakakawea, North Dakota*. Research Contribution No. 49. Paleocultural Research Group, Flagstaff, Arizona. Submitted to the U. S. Army Corps of Engineers, Omaha District, Omaha, Nebraska.

Ahler, Stanley A., George Crawford, Michael E. Timpson, and Phil R. Geib
2002 *Preliminary Report on Field Investigations During May 2002 at the Beacon Island Site, 32MN234, Lake Sakakawea, Mountrail County, North Dakota*. Research Contribution No. 48. Submitted to the State Historical Society of North Dakota, Bismarck, and the U.S. Army Corps of Engineers, Omaha District, Omaha, Nebraska.

Ahler, Stanley A., Fern E. Swenson, Frédéric Sellet, Kimberly Spurr, Stacey Madden, Rolfe D. Mandel, and Stance Hurst
2006 *Final Report on Pre-Field Planning and Fieldwork Under the Save America's Treasures Grant Program for Area A at the Beacon Island Site (32MN234), North Dakota*. Research Contribution No. 76. Paleocultural Research Group, Flagstaff, Arizona. Submitted to the State Historical Society of North Dakota, Bismarck.

Ahler, Stanley A., Fern E. Swenson, Kimberly Spurr, Rolfe D. Mandel, Stacey Madden, Frédéric Sellet, Stance Hurst, and George Crawford
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Haberman, Thomas W., and Fred Schneider
1975 *1974 Archaeological Surveys of Portions of the Garrison Reservoir Shoreline, North Dakota*. University of North Dakota, Grand Forks. Submitted to the U. S. Department of the Interior, National Park Service, Lincoln, Nebraska.

Mitchell, Mark D. (editor)
2011 *Agate Basin Archaeology at Beacon Island, North Dakota*. Research Contribution No. 86. Paleocultural Research Group, Broomfield, Colorado. Submitted to the State Historical Society of North Dakota, Bismarck, and the National Park Service, Historic Preservation Grants Division, Washington, D. C.

Spurr, Kimberly, Robert K. Nickel, and Stanley A. Ahler
2007 *Remote Sensing Investigations in 2006 at Area A of Beacon Island, Lake Sakakawea, Mountrail County, North Dakota*. Research Contribution No. 77. Paleocultural Research Group, Flagstaff, Arizona. Submitted to the State Historical Society of North Dakota, Bismarck.

Timpson, Michael E., and Stanley A. Ahler
2002 *Geomorphic Analysis of Beacon Island, Site 32MN234, Mountrail County, North Dakota*. Research Contribution No. 47. Paleocultural Research Group, Flagstaff, Arizona. submitted to the State Historical Society of North Dakota, Bismarck.

# Appendix F

Field Crew Rosters, 2001-2006

Table F-1. Summary of SHSND and PCRG field sessions in Area A, 2001-2006.

| Year | Session Number | Session Name | Date(s) | Goals |
|---|---|---|---|---|
| 2001 | 1 | | 6/24 | Project planning |
| 2002 | 2 | May | 5/17-5/27 | Testing |
| | 3 | September Session 1 | 9/6-9/13 | Testing, data recovery |
| | 4 | September Session 2 | 9/18-9/26 | Testing, data recovery |
| 2006 | 5 | Remote Sensing | 6/13-6/24 | Testing |
| | 6 | Session 1 | 6/26-7/4 | Data recovery |
| | 7 | Session 2 | 7/10-7/18 | Data recovery |
| | 8 | Session 3 | 7/24-8/1 | Data recovery |
| | 9 | Session 4 | 8/7-8/15 | Data recovery |

Table F-2. Roster of field crew members, SHSND and PCRG field investigations in Area A, 2001-2006.

| Name | Position | Session Number |
|---|---|---|
| Ahler, Stanley | Field Director | 1, 2, 3, 4 |
| Badorek, Chad | Field Technician | 2 |
| Bennett, Stacey | Field Technician | 5, 6, 7, 8, 9 |
| Bjorum, Erika | Field Technician | 4 |
| Boynton, William | Field Technician | 8 |
| Brady, Perry | Monitor (Three Affiliated Tribes) | 8 |
| Burns, Jeffery | Field Technician | 8, 9 |
| Campbell, Christina | Field Technician | 6, 7, 8, 9 |
| Campbell, Rich | Field Technician | 8 |
| Chantreau, Yoann | Field Technician | 9 |
| Christi, Ryan | Field Technician | 4 |
| Clifford, Mike | Field Technician | 7, 8, 9 |
| Clymor, Amy | Field Technician | 3, 4 |
| Condon, Peter | Field Technician | 2 |
| Craig, John | Field Technician | 2, 9 |
| Crawford, George | Assistant Field Supervisor, Field Technician | 2, 3, 4, 5, 6, 7, 8, 9 |
| Crevier, Larry D. II | Field Technician | 6 |
| Eckberg, David | Field Technician | 6 |
| Ellis, Josh | Field Technician | 9 |
| Frohlich, Michael | Technology Specialist (SHSND) | 8, 9 |
| Gardner, Robert | Field Technician | 6,7 |
| Geib, Phil | Field Technician | 2 |
| Hewes, Dan R. | Field Technician | 6 |
| High Elk, Roberta | Field Technician | 4 |
| Huber, George | Historic Site Maintenance (SHSND) | 5, 7 |
| Huntsinger, Matt | Field Technician | 8 |

| Name | Position | Session Number |
|---|---|---|
| Hurst, Stance | Field Director, Assistant Field Supervisor, Faunal Specialist | 5, 6, 7, 8, 9 |
| Jastrzembski, J.A. | Field Technician | 6 |
| Jensen, Dave | Field Technician | 2 |
| Jensen, Lloyd | Construction Supervisor (SHSND) | 5 |
| Johnson, Craig | Field Technician | 9 |
| Karellas, Peter | Field Technician | 8 |
| Kossel, Christine | Field Technician | 5, 8, 9 |
| Kraus, Mary Jo | Field Technician | 3, 4 |
| Krause, Michael | Field Technician | 6 |
| Krause, Richard | Field Technician | 6 |
| Kristmann, Dan | Field Technician | 8 |
| Kulevsky, Andrea | Field Technician | 3, 4 |
| Leake, Juliana | Field Technician | 7 |
| Lee, Craig | Field Technician | 2 |
| Lee, Jennie B. | Faunal Specialist, Field Technician | 2, 3, 4, 9 |
| Malone, Lucas | Field Technician | 3 |
| Mandel, Rolfe | Geomorphologist | 8 |
| Meidinger, Brett | Field Technician | 3, 4 |
| Morgan, Brooke | Field Technician | 8 |
| Naudinot, Nicolas | Field Technician | 9 |
| Nickel, Kay | Remote Sensing Specialist | 5 |
| Nickel, Robert | Remote Sensing Specialist | 5 |
| Otto, Rebecca | Archaeologist (USACE) | 3 |
| Owens, Don | Field Technician | 2, 3, 4 |
| Pedersen, Carol | Field Technician | 7 |
| Pedersen, Michael | Field Technician | 7 |
| Picha, Paul | Chief Archaeologist (SHSND) | 2, 4, 8, 9 |
| Porter, Laurinda | Field Technician | 8 |
| Potter, Alan | Field Technician | 4 |
| Purcell, Dave | Field Technician | 2 |
| Reed, Timothy | Research Archaeologist (SHSND) | 2, 3, 4, 8, 9 |
| Rightnour, Jerry | Field Technician | 7 |
| Ross, Robert | Field Technician | 3, 4 |
| Sellet, Frédéric | Field Director | 5, 6, 7, 8 |
| Slaughter, Stephanie | Field Technician | 4 |
| Smith, Nicholas | Field Technician | 8 |
| Smith, R. J. | Field Technician | 8, 9 |
| Spurr, Kimberly | Field Director | 2, 5, 6, 7 |
| Stine, Ed | Field Technician | 3, 4 |
| Sublett, Virginia | Field Technician | 8 |
| Sunwall, Lane | Field Technician | 8 |
| Swan, Thaddeus | Field Technician | 8 |
| Swenson, Fern | Director of Historic Preservation (SHSND) | 3, 4, 7, 8, 9 |
| Thompson, Kerry | Field Technician | 2 |
| Threet, Todd N. | Field Technician | 7 |
| Timbrook, Mark | Field School Director (Minot State University) | 6 |
| Timpson, Michael | Field Technician | 4 |
| Van Pelt, Kristin | Field Technician | 8, 9 |
| Vicha, John | Field Technician | 5 |
| Wencel, Marie | Field Technician | 8 |
| Wurtz, Doug | Field Technician | 8 |
| Zachmann, Carl | Field Technician | 8 |

# Appendix G

## Supplementary Provenience System Data

Horizontal and vertical control for all excavation, mapping, and surface collection at Beacon Island was based on a standard northing and easting grid system. A master site datum was established on the uneroded part of the island and marked by a wooden stake. This datum was assigned an arbitrary position of 1000NE1000, Z1000.000. Major subdatums were set at 1280NE1100, Z988.192 (Station 3388) and 1261NE1100, Z988.595 (Station 3389). Both were marked with steel reinforcing rods set flush with the modern ground surface. In 2006, these subdatums initially were removed to facilitate the magnetic gradiometry survey. After the geophysical investigation was complete a new rebar subdatum was established at 1282NE1128, Z988.064 (Station 4000), immediately east of the main bonebed. This subdatum was used to collect the bulk of the position data recorded in 2006. Backsights were reestablished close to the original locations of the major subdatums set in 2002, at 1280NE1100, Z988.187 and 1261NE1100, Z988.575. Toward the end of the 2006 sessions, a second temporary datum point was set at 1289NE1109, Z987.989 (Station 4230). Grid north is aligned to magnetic north, as observed on a hand-held compass. In May 2002, magnetic north was 9 degrees, 25 minutes east of true north. Excavation squares are designated by the nominal positions of their southwest corners.

Two excavation level numbering systems were used. During the 2002 sessions, level numbers were assigned independently for each excavation unit, with the surface-most level designated level 1, regardless of absolute elevation or thickness. Subsequent level numbers were assigned sequentially with increasing depth. In 2006, a site-wide, elevation-based system was used. In this system, level 1 designates excavation increments with a beginning elevation falling between 989.999 and 989.900, level 2 designates increments with a beginning elevation between 989.899 and 989.800, and so forth. In this report, excavation levels tied to this system are called "standard levels," (SL) to differentiate them from the general levels (GL) used in 2002. Where an excavation increment is roughly equally divided between two standard levels both the upper and lower level numbers are given. Table G-1 gives the upper and lower elevations of each standard level. These differences in

Table G-1. Top and bottom elevations of standard levels.

| Level Number | Top Elevation (m) | Bottom Elevation (m) |
|---|---|---|
| 1 | 989.999 | 989.900 |
| 2 | 989.899 | 989.800 |
| 3 | 989.799 | 989.700 |
| 4 | 989.699 | 989.600 |
| 5 | 989.599 | 989.500 |
| 6 | 989.499 | 989.400 |
| 7 | 989.399 | 989.300 |
| 8 | 989.299 | 989.200 |
| 9 | 989.199 | 989.100 |
| 10 | 989.099 | 989.000 |
| 11 | 988.999 | 988.900 |
| 12 | 988.899 | 988.800 |
| 13 | 988.799 | 988.700 |
| 14 | 988.699 | 988.600 |
| 15 | 988.599 | 988.500 |
| 16 | 988.499 | 988.400 |
| 17 | 988.399 | 988.300 |
| 18 | 988.299 | 988.200 |
| 19 | 988.199 | 988.100 |
| 20 | 988.099 | 988.000 |
| 21 | 987.999 | 987.900 |
| 22 | 987.899 | 987.800 |
| 23 | 988.799 | 987.700 |
| 24 | 987.699 | 987.600 |
| 25 | 987.599 | 987.500 |
| 26 | 987.499 | 987.400 |
| 27 | 987.399 | 987.300 |
| 28 | 987.299 | 987.200 |
| 29 | 987.199 | 987.100 |
| 30 | 987.099 | 987.000 |
| 31 | 986.999 | 986.900 |
| 32 | 986.899 | 986.800 |
| 33 | 986.799 | 986.700 |
| 34 | 986.699 | 986.600 |
| 35 | 986.599 | 986.500 |
| 36 | 986.499 | 986.400 |
| 37 | 986.399 | 986.300 |
| 38 | 986.299 | 986.200 |
| 39 | 986.199 | 986.100 |
| 40 | 986.099 | 986.000 |
| 41 | 985.999 | 985.900 |

Table G-1. Top and bottom elevations of standard levels (continued).

| Level Number | Top Elevation (m) | Bottom Elevation (m) |
|---|---|---|
| 42 | 985.899 | 985.800 |
| 43 | 985.799 | 985.700 |
| 44 | 985.699 | 985.600 |

level numbering do not affect interpretations of measured profiles or plot depths because a single coordinate system was used during all phases of the project.

In 2002, an on-site, provenience- and recovery-based field catalog was maintained. Catalog numbers were assigned as new excavation levels were begun, or as piece-plotted specimens were collected. During the May session, separate catalog numbers were assigned to each plotted item. During the September sessions, a multi-plot system was used, in which a single catalog number was assigned to all the plots from each level and individual specimens were assigned separate letter designations, beginning with "A." When the field catalogs for each major phase of the project were combined in the lab, these alphanumeric designations were converted to decimal equivalents. Table G-2 provides a concordance between multi-plot letters and corresponding numerical values.

The field catalog kept in 2006 was similar to that used in May 2002. However, to minimize the potential for damage during waterscreening, separate lot numbers were assigned to bone fragments from each level falling below the minimum plot size. Provenience data associated with these "general level recovery" lots are the same as those associated with the waterscreen lots from the same unit and level. During the analysis phase of the project, the contents of corresponding general level recovery and waterscreen samples were combined and the general level recovery catalog numbers were retired.

Table G-2. Concordance between lab-assigned decimal equivalents and multi-plot letters assigned during September 2002 field sessions.

| Multi-plot Letter | Assigned Decimal Value |
|---|---|
| A | .01 |
| B | .02 |
| C | .03 |
| D | .04 |
| E | .05 |
| F | .06 |
| G | .07 |
| H | .08 |
| I | .09 |

Table G-2. Concordance between lab-assigned decimal equivalents and multi-plot letters assigned during September 2002 field sessions. (continued).

| Multi-plot Letter | Assigned Decimal Value |
|---|---|
| J | .10 |
| K | .11 |
| L | .12 |
| M | .13 |
| N | .14 |
| O | .15 |
| P | .16 |
| Q | .17 |
| R | .18 |
| S | .19 |
| T | .20 |
| U | .21 |
| V | .22 |
| W | .23 |
| X | .24 |
| Y | .25 |
| Z | .26 |
| AA | .27 |
| BB | .28 |
| CC | .29 |
| DD | .30 |
| EE | .31 |
| FF | .32 |
| GG | .33 |
| HH | .34 |
| II | .35 |
| JJ | .36 |
| KK | .37 |
| LL | .38 |
| MM | .39 |
| NN | .40 |
| OO | .41 |
| PP | .42 |
| QQ | .43 |
| RR | .44 |
| SS | .45 |
| TT | .46 |
| UU | .47 |
| VV | .48 |
| WW | .49 |
| XX | .50 |
| YY | .51 |
| ZZ | .52 |
| AAA | .53 |
| BBB | .54 |
| CCC | .55 |
| DDD | .56 |
| EEE | .57 |
| FFF | .58 |

Table G-2. Concordance between lab-assigned decimal equivalents and multi-plot letters assigned during September 2002 field sessions. (continued).

| Multi-plot Letter | Assigned Decimal Value |
|---|---|
| GGG | .59 |
| HHH | .60 |
| III | .61 |
| JJJ | .62 |

# Appendix H

## Projectile Point Data

*Mark D. Mitchell*

The metric and other data tallied in table H-1 come from a sample of 32 projectile points from Beacon Island sufficiently complete to take one or more measurements. Of these, 15 come from the surface collection and 17 come from the excavated collection. Seven of the 17 excavated points incorporate two to four conjoinable fragments; see chapter 6 for additional information about these conjoined specimens. A list of the variables and attribute codes applied to the sample is given in table H-2.

Table H-1. Metric and other data on projectile points from Area A, 32MN234.

| | | | | | | | | | Resharpening | |
|---|---|---|---|---|---|---|---|---|---|---|
| Catalog Number | Analytic Unit | Raw Material | Part | Length 1 (mm) | Length 2 (mm) | Width 1 (mm) | Width 2 (mm) | Thickness (mm) | Occurrence | Location |
| 7022[a] | 1 | 28 | 1 | 120.0 | 111.1 | 32.2 | 32.2 | 9.0 | 1 | 5 |
| 7230[a] | 1 | 28 | 7 | | 48.6 | 17.0 | 17.0 | 7.2 | 1 | 6 |
| 9989 | 1 | 8 | 4 | | 43.6 | | 18.6 | | 1 | 5 |
| 8755[a] | 1 | 54 | 5 | | 46.4 | 30.8 | 30.8 | 10.2 | 0 | |
| 8311[a] | 1 | 28 | 2 | 72.0 | 63.9 | 24.4 | 24.2 | 7.8 | 1 | 5 |
| 7780[a] | 1 | 28 | 7 | | 41.3 | 24.9 | 24.9 | 7.0 | 0 | |
| 7523[a] | 1 | 28 | 4 | | 36.4 | | 17.1 | | 0 | |
| 1929.03 | 1 | 54 | 2 | | 50.1 | | 22.3 | | 1 | 6 |
| 8363 | 1 | 28 | 2 | 55.4 | 55.4 | 20.3 | 20.3 | 7.1 | 1 | 6 |
| 1836.01 | 1 | 28 | 7 | | 61.9 | 17.0 | 17.0 | 5.9 | 1 | 6 |
| 8570 | 1 | 54 | 6 | | 62.2 | 27.6 | 27.6 | 8.4 | 1 | 6 |
| 1293 | 1 | 54 | 6 | | 41.5 | 28.6 | 28.6 | | 1 | 6 |
| 1651.01 | 1 | 54 | 7 | | 50.4 | 21.6 | 21.6 | 7.9 | 1 | 6 |
| 9986 | 1 | 28 | 4 | | 23.7 | | 18.6 | | 0 | |
| 9989[a] | 1 | 28 | 4 | | 26.7 | | 26.3 | | 0 | |
| 1068 | 1 | 54 | 4 | | 21.0 | | 12.5 | | 0 | |
| 9289[b] | 1 | 28 | 4 | | 25.3 | | 23.6 | | 0 | |
| 1 | 2 | 28 | 2 | 98.1 | 98.1 | 23.1 | 23.1 | 8.3 | 1 | 6 |
| 2 | 2 | 5 | 5 | | 51.5 | 25.6 | 25.6 | 8.4 | 1 | 1 |
| 3 | 2 | 28 | 5 | | 56.2 | 22.2 | 22.2 | 6.2 | 1 | 1 |
| 4 | 2 | 28 | 1 | 133.0 | 133.0 | 30.7 | 30.7 | 9.2 | 0 | |
| 7 | 2 | 54 | 1 | 72.0 | 70.2 | 19.3 | 19.3 | 7.1 | 0 | |
| 8 | 2 | 54 | 4 | | 27.0 | | 22.0 | | 0 | |
| 9 | 2 | 54 | 7 | | 63.2 | 19.8 | 19.8 | 7.2 | 0 | |
| 11 | 2 | 28 | 7 | | 79.8 | 26.3 | 26.3 | 8.3 | 1 | 6 |
| 12 | 2 | 54 | 7 | | 81.7 | 29.7 | 29.7 | 9.1 | 1 | 6 |
| 13 | 2 | 54 | 7 | | 74.6 | 28.2 | 28.2 | 10.6 | 1 | 1 |
| 14 | 2 | 28 | 7 | | 67.3 | 25.1 | 25.1 | 8.6 | 1 | 1 |

Table H-1. Metric and other data on projectile points from Area A, 32MN234 (continued).

| Catalog Number | Analytic Unit | Raw Material | Part | Length 1 (mm) | Length 2 (mm) | Width 1 (mm) | Width 2 (mm) | Thickness (mm) | Resharpening Occurrence | Resharpening Location |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 2 | 28 | 2 | 58.0 | 57.2 | 20.4 | 20.4 | 7.0 | 1 | 6 |
| 17 | 2 | 5 | 4 | | 35.8 | 22.3 | 22.3 | 8.8 | 1 | 7 |
| 19 | 2 | 54 | 2 | 56.0 | 52.8 | 19.2 | 19.2 | 7.6 | 1 | 5 |
| 20 | 2 | 28 | 2 | | 44.0 | 18.6 | 18.6 | 6.0 | 1 | 5 |

[a] Includes two or more conjoined items.
[b] Goshen point base.

Table H-2. Variable and attribute codes applied to Agate Basin projectile points in table H-1.

| | |
|---|---|
| **Analytic Unit** | |
| 1 | Aggie Brown Member |
| 2 | Uncontrolled surface collection |
| **Raw Material** | |
| 5 | Swan River Chert |
| 8 | Clear/gray chalcedony |
| 28 | Knife River Flint |
| 54 | Antelope Chert |
| **Part** | |
| 1 | Complete |
| 2 | Resharpened tip, complete base |
| 3 | Missing tip |
| 4 | Basal fragment |
| 5 | Fragment with ground edge |
| 6 | Distal or margin segment |
| 7 | Distal part lacking base and tip |
| **Length 1** | |
| Maximum original length, to 0.1 mm | |
| **Length 2** | |
| Maximum extant length, to 0.1 mm | |
| **Width 1** | |
| Maximum original width, to 0.1 mm | |
| **Width 2** | |
| Maximum extant width, to 0.1 mm | |
| **Thickness** | |
| Maximum thickness, to 0.1 mm | |
| **Resharpening Occurrence** | |
| 0 | Not reworked |
| 1 | Reworked |
| **Resharpening Location** | |
| 1 | Tip |
| 2 | Base |
| 3 | Base and tip |
| 4 | Blade |
| 5 | Overall |
| 6 | Tip and blade |
| 7 | Base and blade |

# Appendix I

## GIS Data Layers

*Kenneth L. Kvamme and Jo Ann Kvamme*

### Vector Layers

Vector layers occur in four possible formats and each vector file is linked with a data table that holds multiple fields of data about each element in the file. As traditionally defined in GIS, vector layers represent conventional map elements that may be characterized by points, lines, or polygons. All three of these types are utilized to represent elements of the Beacon Island data (tables I-1, I-2, and I-3). A fourth type of vector layer is also included, which is known as a TIN model, or "triangulated irregular network" (table I-4). It is through the TIN model that vector layers can represent surfaces. Each elevation point recorded in the field represents the vertex of a triangle and every three points that make up a triangle define the surface of a plane. Technically, each triangle represents a polygon that encloses an area, but TIN models occupy a special category because collectively, the hundreds or thousands of triangles represent a surface as opposed to the discrete objects of a traditional polygon shapefile. Several TIN models occur in the database, although they were employed primarily as intermediate steps in the creation of raster digital elevation models (DEM).

### Raster Layers

Raster layers occur in a gridded structure composed of cells holding measurements or counts. The cells are organized in a two-dimensional matrix composed of rows and columns. Rasters may also represent pictorial or image data, such as a JPEG or TIFF file, where the cells hold image brightness information, or they may represent surfaces where the cells hold measurements of some continuous phenomenon as it varies over space,

Table I-1. Polygon layers.

| Layer Name | Content |
|---|---|
| Excavations | The locus of each excavation unit, containing data on the year excavated, work session, and searchable coordinates. |
| Fauna | Fauna data with complete recorded data about each bone element in 21 fields. |
| Feature | The area of the single archaeological feature, a basin hearth . |
| Raster-mask | Polygons representing various blocks of excavated and non-excavated areas. |
| Stone—Polygon | All pieces of modified stone greater than 5 cm. |

Table I-2. Line layers.

| Layer Name | Content |
|---|---|
| Contourleonard5cm | 5-cm contours representing the top of the Leonard paleosol, computed from raster dem-leonard. |
| Contourmallard5cm | 5-cm contours representing the top of the Mallard Island Member, computed from raster dem-mallard. |
| Contoursurface5cm | 5-cm contours representing the modern ground surface, computed from raster dem-surface. |
| Mallardtop2cm-SPL | 2-cm elevation contours representing the top of the Mallard Island depositional unit, computed from spline interpolation in raster Mallardtopspl. |
| Mallardtop2cm-TIN | 2-cm elevation contours representing the top of the Mallard Island depositional unit, computed from the tin file Mallardtin. |
| Surface-contours | 5-cm contours digitized from drawn contour map in raster Basemap. |

Table I-3. Point layers.

| Layer Name | Content |
|---|---|
| Elev-leonard-top | Elevation data taken on top of Leonard paleosol. |
| Elev-mallard-top | Elevation data taken on top of Mallard Island Member. |
| Elev-surface | Modern surface elevations. |
| Faunal-points | Center points of all plotted bones, including bone represented in the polygon layer. |
| Mallard-top-elev-constrained | Elevation data taken on top of Mallard Island member from selected excavation units. |
| Plotted-stone | Center points of all plotted stone. |

such as an altitude. Many of the Beacon Island primary datasets occurred in a raster format, such as the bonebed photo imagery taken for each excavation unit as well as the resulting image composites. Several additional raster layers were generated for the Beacon Island database. Ten primary layers derived from photos or drawings from which most of the data were generated are listed in table I-5. Table I-6 lists 25 secondary layers derived analytically or from data held in Microsoft Excel files. For the most part, this second group holds counts or weights of items (such as lithics or bones) per excavation square. Layer names are given along with the dimensions of the raster (columns x rows) and the spatial resolution (in meters) of each cell.

Table I-4. TIN layers.

| Layer Name | Content |
|---|---|
| Beacon-tin | TIN model generated from line layer Surface-contours. |
| Mallardtin | TIN model generated from point layer Mallard-top-elev-constrained. |
| Tin-leonard | TIN model generated from point layer Elev-leonard-top. |
| Tin-mallard | TIN model generated from point layer Elev-mallard-top. |
| Tin-surface | TIN model generated from point layer Elev-surface. |

Table I-5. Primary layers from photographic images.

| Layer Name | Pixel Size and Resolution | Layer Content |
|---|---|---|
| Basemap | 2,177 x 1,753; 0.002 m | Resampled color basemap showing surface elevation contours and excavation units. |
| Mosaic1 | 10,000 x 9,001; 0.002 m | Composite image, bonebed slice 1. |
| Mosaic2 | 10,000 x 9,001; 0.002 m | Composite image, bonebed slice 2. |
| Mosaic3 | 10,000 x 9,001; 0.002 m | Composite image, bonebed slice 3. |
| Mosaic4 | 10,000 x 9,001; 0.002 m | Composite image, bonebed slice 4. |
| Mitchell | 4,653 x 3,574; 0.002 m | Registered scan segment of bonebed drawing from photomosaics. |
| Ovs | 6,665 x 4,981; 0.002 m | Registered scan segment of bonebed drawing from photomosaics. |
| tds49 | 4,276 x 6,681; 0.002 m | Registered scan segment of bonebed drawing from photomosaics. |
| tds88 | 1,786 x 2,120; 0.002 m. | Registered scan segment of bonebed drawing from photomosaics |
| tds89 | 3,726 x 3,708; 0.002 m | Registered scan segment of bonebed drawing from photomosaics . |

Table I-6. Secondary layers derived analytically from Microsoft Excel files.

| Layer Name | Pixel Size and Resolution | Layer Content |
|---|---|---|
| Allg1-g3 | 36 x 32; 1 m | Flaking debris in size grades 1 through 3, per excavation square. |
| Allg4 | 36 x 32; 1 m | Flaking debris in size grade 4, per excavation square. |
| Allg4-g5 | 36 x 32; 1 m | Flaking debris in size grades 4 and 5, per excavation square. |
| Allg5 | 36 x 32; 1 m | Flaking debris in size grade 5, per excavation square. |
| Beacon-dem | 501 x 411; 0.1 m | DEM created from TIN model Beacon-tin. |
| Beacon-dem2 | 501 x 411; 0.1 m | Same as Beacon-dem but with 1 m subtracted from excavated cells. |
| Bonebed-thick | 36 x 32; 1 m | Computed showing bonebed thickness over excavation area. |
| Bone-wt-g1 | 36 x 32; 1 m | Weight of size grade 1 bone, per excavation square. |
| Bone-wt-g2 | 36 x 32; 1 m | Weight of bone size grade 2 bone, per excavation square. |
| Bone-wt-g3 | 36 x 32; 1 m | Weight of bone size grade 3 bone, per excavation square. |
| Bonewt-mask | 36 x 32; 1 m | Excavated cells are coded with “1.” |
| Bone-wt-total | 36 x 32; 1 m | Total bone weight per excavation square. |
| Dem-leonard | 71 x 63; 0.5 m | Raster generated from TIN Tin-leonard. |
| Dem-mallard | 71 x 63; 0.5 m | Raster generated from TIN Tin-mallard. |
| Dem-shade | 501 x 411; .1 m | Hillshade algorithm applied to Beacon-dem2. |
| Dem-surface | 339 x 221; 0.5 m | Raster generated from TIN Tin-surface with Excavations substracted. |
| Excavations | 501 x 411; 0.1 m | Raster holding “-1” in excavated cells by subtraction from Dem-surface. |
| Fcrstrat2new | 36 x 32; 1 m | Weight of burned rock in all size grades, per excavation square. |
| G1-g3rawm28 | 36 x 32; 1 m | Knife River Flint flaking debris in size grades 1 through 3, per excavation square. |
| G1-g3rawm54 | 36 x 32; 1 m | Antelope Chert flaking debris in size grades 1 through 3, per excavation square. |

Table I-6. Secondary layers derived analytically from Microsoft Excel files (continued).

| Layer Name | Pixel Size and Resolution | Layer Content |
|---|---|---|
| G4-g5burned | 36 x 32; 1 m | Burned flaking debris in size grades 4 and 5, per excavation square. |
| G4-g5rawm28 | 36 x 32; 1 m | Knife River Flint flaking debris in size grades 4 and 5, per excavation square. |
| G4-g5rawm54 | 36 x 32; 1 m | Antelope Chert flaking debris in size grades 4 and 5, per excavation square. |
| Mallardtopspl | 77 x 69; 0.25 m | Elevation surface of top of Mallard Island Member from spline interpolation of point file Mallard-top-elev-constrained. |
| Raster-mask | 72 x 64; 0.5 m | Binary mask indicating excavated (1) versus unexcavated (0) cells. |

# Appendix J

## Ancillary Use-wear Data

*Marvin Kay*

Table J-1. Edge angle and completeness data on the sample of artifacts included in the use-wear study. Edge angle measurement locations are showing in figure J-1.

| Specimen | CN | Type | Completeness | Angle 1 | Angle 2 | Angle 3 | Angle 4 | Angle 5 | Angle 6 |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 1836.01 | Agate Basin | distal | 55 | 60 | 60 | 55 | | |
| 8 | 7099 | Agate Basin | distal | 50 | 55 | | | | |
| 1 | 8755 | Agate Basin | medial | | | 65 | 65 | 100 | 110 |
| 5 | 1651.01 | Agate Basin | medial | 60 | 65 | 65 | 70 | | |
| 10 | 8570 | Agate Basin | medial | 45 | 40 | | | | |
| 9 | 8311 | Agate Basin | other | 70 | | 65 | | | |
| 7 | 7022 | Agate Basin | proximal | | | 45 | 55 | | |
| 6 | 1929.03 | Agate Basin | whole | 60 | 65 | 65 | 60 | | |
| 2 | 8363 | Agate Basin | whole | 50 | 55 | 65 | 65 | | |
| 3 | 9289 | Goshen | proximal | | | 60 | 65 | | |

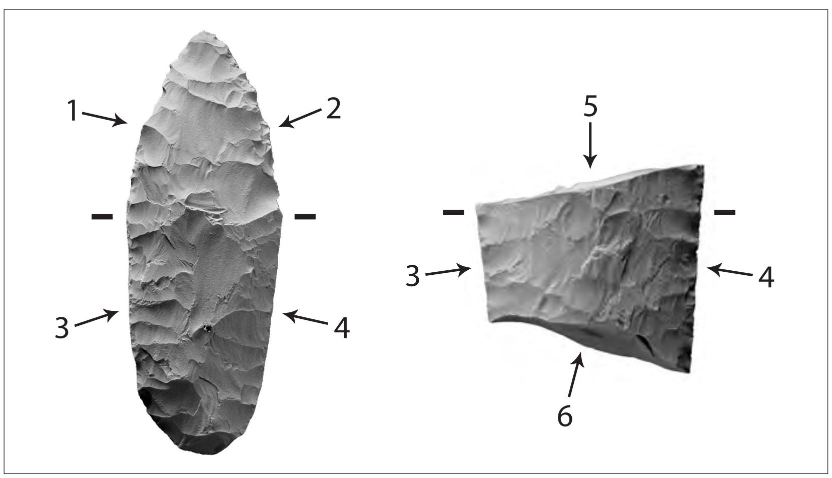


Figure J-1. Diagram showing edge angle measurement locations. Marginal tick marks denote the extent of lateral edge grinding.