THE EROADAWAY SITE: LITHIC TECHNOLOGICAL VARIABILITY AT A LATE GLACIAL SUBALPINE CAMP IN THE CENTRAL ALASKA RANGE

Charles E. Holmes
Department of Anthropology, University of Alaska Fairbanks, P.O. Box 92118, Anchorage, AK 99509; charles.holmes@alaska.edu

Joshua D. Reuther
University of Alaska Museum of the North and Department of Anthropology, University of Alaska Fairbanks, 1962 Yukon Drive, Fairbanks, AK 99775; jreuther@alaska.edu

Jacob S. Adams
Department of Anthropology, Washington State University, College Hall 150, PO Box 644910, Pullman, WA 99164-4910; jacobsadams@gmail.com

Peter M. Bowers
University of Alaska Museum of the North, University of Alaska Fairbanks, 1962 Yukon Drive, Fairbanks, AK 99775; petebowers959@gmail.com

Allison Little
4609 NE 105th Ave., Portland, OR 97220; little.allie@gmail.com

ABSTRACT

Eroadaway represents a Late Glacial campsite, circa 12,600 cal BP, in the subalpine zone of the central Alaska Range. Reassessment of radiocarbon dates indicates that the age of the site is nearly 2800 years older than originally reported and places the reassessed age of the Eroadaway occupation in the Younger Dryas chronozone (12,900 to 11,700 cal BP). Eroadaway is viewed as a short-duration seasonal hunting camp where the maintenance and production of bifacial tools were the dominant activities. The site's distinctive thin bifacial projectile point technology is analyzed in terms of production technique and subsistence strategy, and a projectile point hafting model based on the Eroadaway points is proposed.

The Eroadaway site, discovered in 1985, is an important Late Glacial site in the Nenana Valley of the central Alaska Range of interior Alaska. Several Late Glacial and early Holocene sites are situated in the Nenana Valley and surrounding area, including the Carlo Creek (Bowers 1980), Dry Creek (Powers et al. 2017), Moose Creek (Pearson 1999), Walker Road (Goebel et al. 1996), Teklanika (Coffman and Potter 2011), and Bull River (Wygal 2010) sites. This region provided critical habitat for important subsistence resources, including bison, caribou, sheep, and elk (wapiti), for late Pleistocene and early Holocene hunter-gatherers (Bowers 1980; Guthrie 2017). Eroadaway affords a look at a site with a limited range of behavior, whereas occupations at most other early sites in the Nenana Valley likely were of longer duration with a broader range of activities.

Eroadaway has been an enigma in early eastern Beringian cultural chronology. It has been featured in several researchers' cultural-historical schemes for the Late Glacial and early Holocene (16,000 to 9,000 cal BP) time periods in Alaska (e.g., Bever 2001a; Dixon 1999, 2013; Goebel and Buvit 2011; Graf and Bigelow 2011; Heidenreich 2014; Potter 2011). However, within these studies references to the Eroadaway site have been limited to brief descriptions of the site and its age and a preliminary artifact analysis from a paper presented at the Alaska Anthropological Association conference 30 years ago (Holmes 1988). Eroadaway was originally interpreted as an early Holocene transition between Denali complex and Northern Archaic tradition on the basis of biface technology and a single radiocarbon date.

The recovery of artifacts at Eroadaway must be understood as a salvage of cultural material from a disturbed context. Only a few hours over the course of a few days in 1985 and again in 1987 were devoted to data recovery. This work was incidental to travel via the Parks Highway between Anchorage and Fairbanks for other commitments. The excavations took place August 20, 1987. The artifacts were not three-point plotted but were screened through one-eighth-inch mesh and recorded by subunits within each excavation block. Bulk samples from cultural features were collected for expediency and examined later.

More recently, we have reexamined the artifact assemblage and the age assessments of Feature 1 and 2 hearths. The age of the hearths places the main component between 12,750 and 12,570 cal BP and within the Late Glacial period (16,000 and 11,600 cal BP), nearly 2,800 years older than the original radiocarbon date reported. This age also places it within the Younger Dryas chronozone (12,900 to 11,600 cal BP; Steffensen et al. 2008; Viau et al. 2008), one of very few sites in interior Alaska that date to this period (Graf and Bigelow 2011; Potter 2011; Wygal 2011).

Here, we present the results of this reanalysis and argue that the Eroadaway site represents a brief short-term hunting camp where a limited array of activities occurred, primarily late-stage biface reduction, projectile point manufacture, and retooling efforts. Eroadaway documents an almost complete bifacial reduction and projectile point production sequence, from preform to finished point, with mistakes along the way. Several other studies on projectile point production sequences have been conducted in Alaska, but they primarily concentrate on Late Glacial and early Holocene sites in northern Alaska, such as the Sluiceway, Mesa, and northern fluted point complexes (Bever 2001b; Goebel et al. 2013; Rasic 2011). Research in early interior Alaska projectile point reduction sequences is sparse, with much of the research in this region concentrated on either study of raw material availability and/or constraints and stylistic traits (Graf and Goebel 2009; Potter 2005; Reuther et al. 2011). These studies have mostly focused on sites that have longer durations in occupation and a wider array of behavior marked by multiple episodes of tool production, maintenance, and discard (Heidenreich 2014). These studies on projectile point manufacture focus solely on either the debitage of biface manufacture or the final expended and discarded bifaces at the end of their complex use life.

We also discuss potential reasons why the people at Eroadaway chose to make and use thinner points over thicker, more robust projectile forms, in the context of simple technological investment models (e.g., Bettinger 2009; Bettinger et al. 2016). This framework allows us to explore costs and benefits between two technological systems and assess whether one technology benefits over another; for Eroadaway, thin, delicate projectile points are compared to thicker, more durable projectile points. This study provides a window into Late Glacial lithic technological variability in projectile production in interior Alaska. This variability is not solely marked by limitations in cultural group stylistic values (Graf and Goebel 2009; Hoffecker 2011) but is also influenced by situational factors such as seasonal hunting strategies, behavior of subsistence resources, differential access to higher-quality raw materials, and group mobility (Odess and Rasic 2007; Potter 2007; Rasic 2011).

SITE SETTING AND ENVIRONMENT

The Eroadaway site is situated on a broad terrace of a coarse gravel outwash plain in the Nenana Valley in the southern foothills of the central Alaska Range (Fig. 1). The terrace stands about 77 m above the Nenana River and around 640 m above sea level. At least four younger terraces lie between the Eroadaway terrace and the Nenana River. Several kettle lakes and ponds are scattered across and below the Eroadaway terrace outwash plain.

This region of the Nenana Valley, near the Yanert Fork, is favorable habitat for economically important game animals, such as Dall sheep, caribou, and moose, and was exploited in ethnographic times by both Tanana and Ahtna groups (Kari and Fall 2003). Faunal evidence from the archaeological record at Carlo Creek Component 1 and at Dry Creek Component 2 shows that caribou, Dall sheep, bison, wapiti, and ground squirrel were available during the period 12,500–11,200 cal BP (Bowers 1980; Powers et al. 2017).

The geomorphic history of the central Alaska Range landscape is primarily influenced by tectonics and glacial activity (Thorson 1986; Wahrhaftig 1958). The bedrock in the study area are east-west-trending Precambrian to Tertiary groups consisting of schist, phyllite, gneiss,

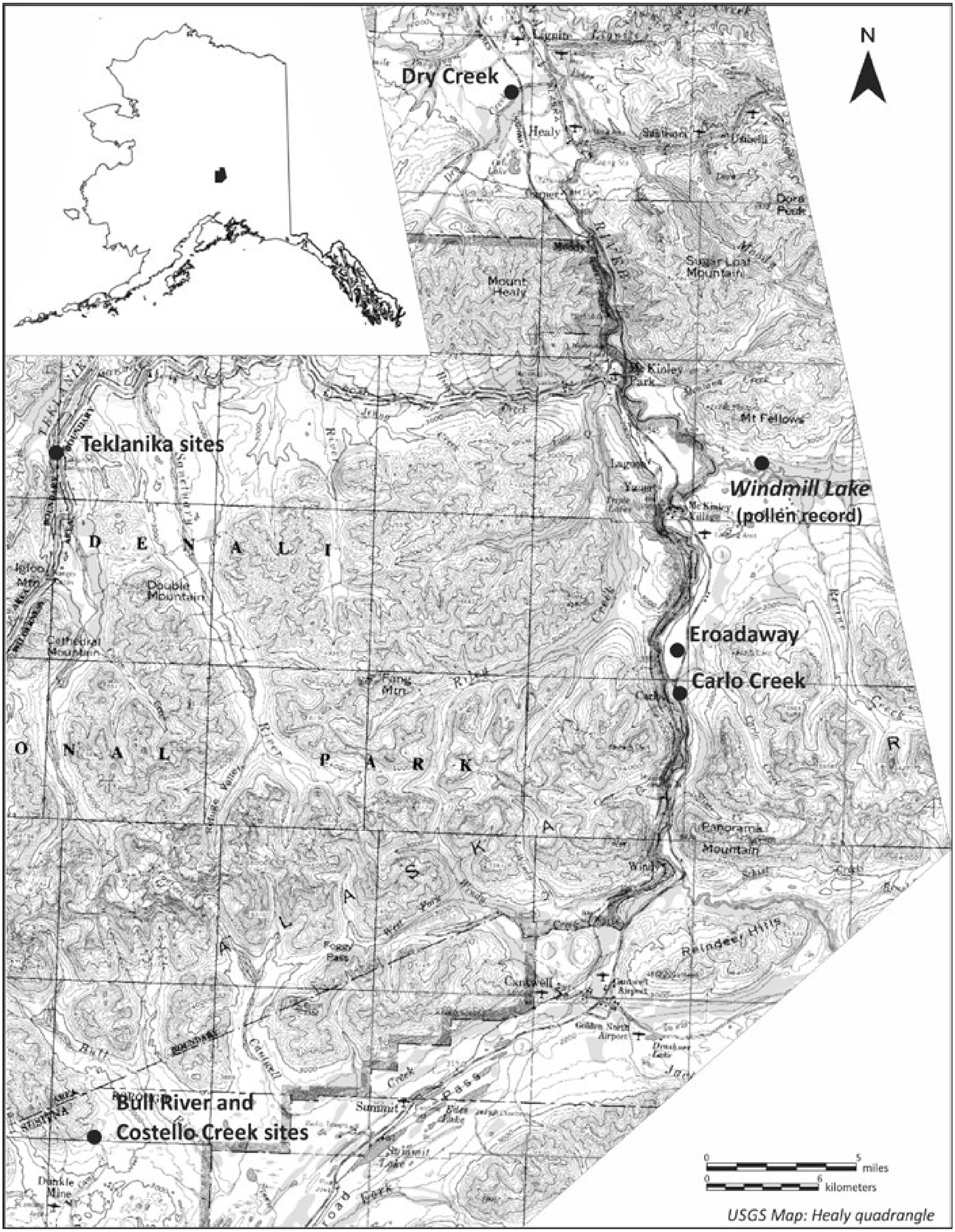


Figure 1. Location of the Eroadaway archaeological site in relation to other sites in the central Alaska Range.

chert, argillite, hornfels, limestone, conglomerate, slate, shale, and coal. Low-grade metamorphic rocks were subsequently formed by the intrusion and alteration of basic lava flows (Wahrhaftig 1958). The Paleocene-age sedimentary Cantwell Formation, the major formation underlying the study area, was deposited in a large continental basin and consists of metamorphosed conglomerate, sandstone, siltstone, shale, coaly shale, coal, and argillite (Wolfe and Wahrhaftig 1970). The upper portion of this formation contains a number of volcanic flows and tuffs (Wolfe and Wahrhaftig 1970).

The gravel and cobble terrace where Eroadaway is situated originated from glaciofluvial outwash of glaciers in the Alaska Range. The "Carlo re-advance" (Wahrhaftig 1958:53), the most recent glacial advance in the Nenana Valley, was over by ~16,000 cal BP (Dortch et al. 2010). The Carlo re-advance end moraine lies immediately west and north of the site. This region appears to have been sufficiently clear of ice and multibraided outwash channels by 14,000 cal BP to permit a suitable environment for humans and the terrestrial resources to thrive and move north and south through the Alaska Range, by way of the Nenana Valley, Broad Pass, and Susitna drainages (Wygal and Goebel 2012).

The Eroadaway terrace has been dissected on several sides by secondary drainages, and its top has broad and gentle rolling topography. Eroadaway's immediate setting is rather indistinguishable from the rest of the terrace, although the site area does occupy a slightly raised area that would likely have been important to provide a dry campsite. The major soils are Typic Historthels and Typic Haplogelods (Clark and Duffy 2006). The local vegetation is characterized as black spruce/bog blueberry, Labrador tea, scrub birch woodland.

A high-resolution pollen record from Windmill Lake, located about 10 km north of Eroadaway, documents regional vegetation changes over the past 14,000 cal BP years (Bigelow 1997; Bigelow and Edwards 2001). The Windmill Lake record provides a superb analogue for the paleoenvironmental setting due to similar elevations and positions of the site and the lake, thus allowing us to set the behavioral record of the Eroadaway site within the context of the environment. The pollen record is divided into four main vegetation zones (Bigelow and Edwards 2001): (1) full and Late Glacial herb zone (zone WL-1; >16,000–13,400 cal BP); (2) a *Betula* zone spanning the end of the Late Glacial to early Holocene (zone WL-2; 13,400–9,400 cal BP); (3) a *Picea-Alnus* zone dating to the mid-Holocene (zone WL-3; 9,400–7,340 cal BP); and (4) a late Holocene zone that contains many of the elements of the modern boreal forest (zone WL-4; 7,340 cal BP to present).

Of particular interest to the occupation at Eroadaway is pollen zone WL-2, which is separated into two subzones, WL-2a and WL-2b (Bigelow 1997). Zone WL-2a documents the nearly ubiquitous birch (*Betula* sp.) rise and reduced amounts of *Salix*, *Artemisia*, Cyperaceae, and Poaceae, which occurs slightly later here (13,550–10,950 cal BP) than in other pollen records from lower elevation sites in central Alaska (Bigelow and Powers 2001). The *Betula* pollen identified in zone WL-2a is assumed to be shrub or dwarf birch (*B. gladulosa* or *B. nana*). Bigelow and Edwards (2001) note a short period of increased *Artemisia* and Poaceae, dating to 12,500–11,900 cal BP, which may represent a return to cooler, drier conditions coincident with the Younger Dryas stadial.

These increases in xerophytic vegetation were subtle, implying that the effect of Younger Dryas climate change in the Alaska Range was relatively small. However, the effects are highly variable across Alaska (Kokorowski et al. 2008), and the impact on human occupations in interior regions remains ambiguous. Eroadaway is one of only a handful of sites that date within the Younger Dryas chronozone where it has been suggested a depopulation episode led to low visibility in the archaeological record (Potter 2011; Wygal 2011).

HISTORY OF RESEARCH AT ERODAWAY

At the time of discovery, in June 1985, it seemed unlikely that the site could contain contextual material or have much potential to yield important information. The site consisted of a few flakes and several biface fragments on the surface in a severely disturbed context (Holmes 1988). The site had been disturbed by the removal of the vegetation and upper surface of the soil during an aborted road-building episode during construction of the Denali Highway in the 1950s. Further damage resulted from the road serving as a bypass route for heavy equipment during construction of the Parks Highway in the early 1970s, hence the name "Eroadaway." Recent use of this area as a camping ground was apparent (Fig. 2).

In 1987, Holmes returned to Eroadaway with a small crew to salvage what remained of the site. The area was much the same as in 1985 but with increased usage from recent camping. More flakes and a couple of tiny burned

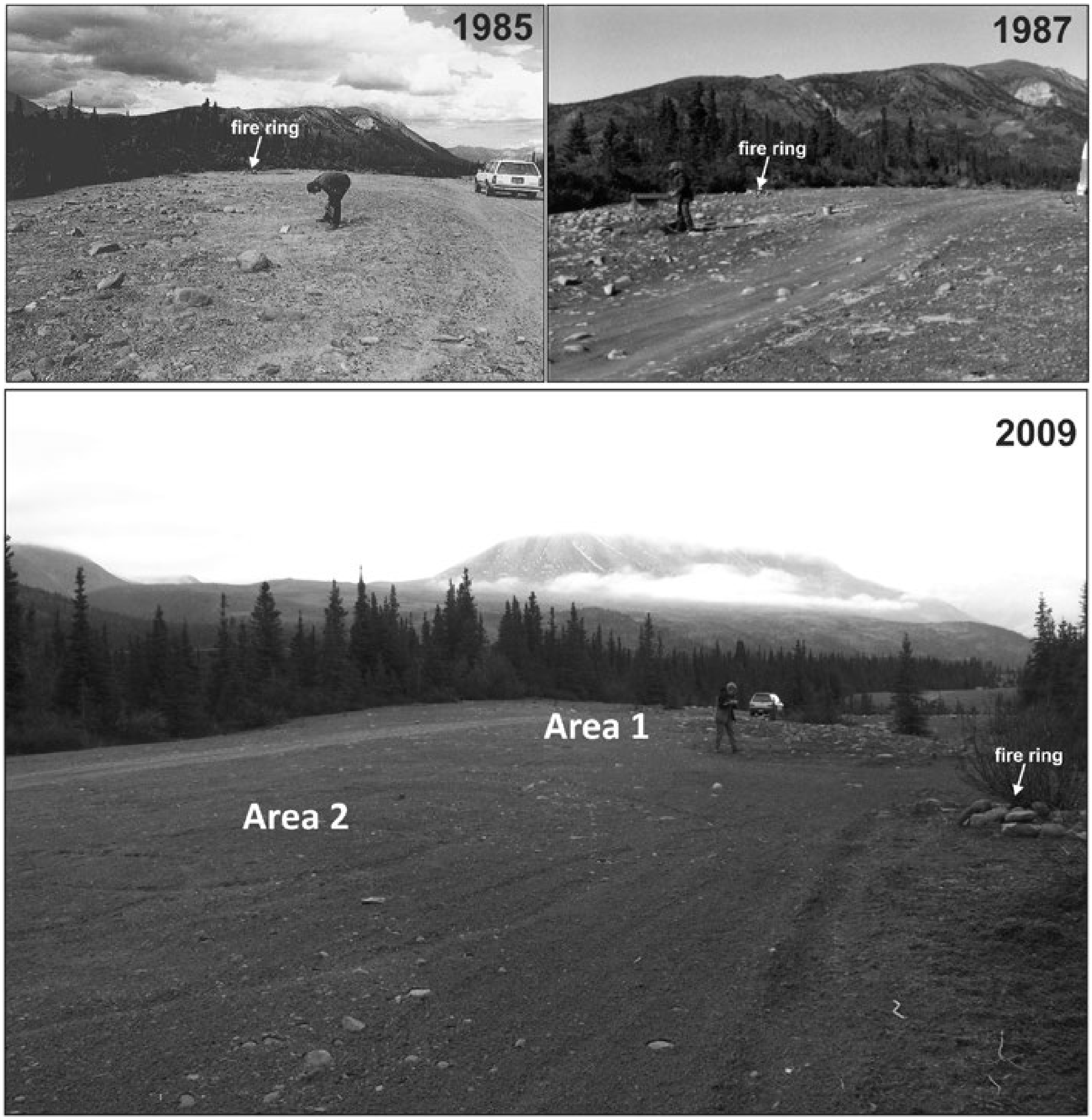


Figure 2. Historical photographs show the disturbed surface at the time of discovery in 1985 and later in 1987. The site looked very much the same in 2009, with exposed sediment and unsorted pebbles, cobbles, and boulders scattered about. The modern campfire ring noted in 1985 remains in the same position. Note the complete lack of vegetation growing in the area that was disturbed in the 1970s.

bone fragments were exposed on the surface of the aborted roadbed. Further investigation determined that, as unlikely as it seemed, partially intact portions of the site persisted (Holmes 1988). The surface scatter of artifacts indicated that additional cultural material might be present within a thin layer (10–15 cm thick) of undisturbed aeolian silt (loess) that caps terrace deposits.

A metric grid baseline was established in the center of the roadway, oriented north with excavation focused over two spatially discrete artifact concentrations (Areas 1 and 2) associated with charcoal fragments and more than 1,000 highly fragmented burned bone pieces (Fig. 3). Many of the bones were too fragmented to identify the species, but most relate to medium to large mammals based on wall thickness and tooth enamel fragments (cf. ungulate); however, two bones were identified as either small mammal or bird (Justin Hays, Northern Land Use Research, pers. comm., 2010). It was apparent that some exposed cultural material had been moved about, but artifact clusters were still distinguishable in both areas, and the disturbance had not completely removed the underlying silt matrix.

The investigation showed that artifact concentrations were focused around two hearths, designated Features 1 and 2. The hearths were located 15 m apart on the west side of the roadway. Sediment was collected with trowels and shovels, then sieved through one-eighth-inch screen mesh. In addition, bulk samples collected from both hearths were processed in the laboratory to recover organic material for radiocarbon dating. Almost 1,800 lithic artifacts that included 47 bifaces (including biface fragments) and 22 modified flakes (scrapers or knives) were collected in 1985 and 1987. The intact stratigraphy at the features shows about 13 cm of aeolian silt over outwash alluvium.

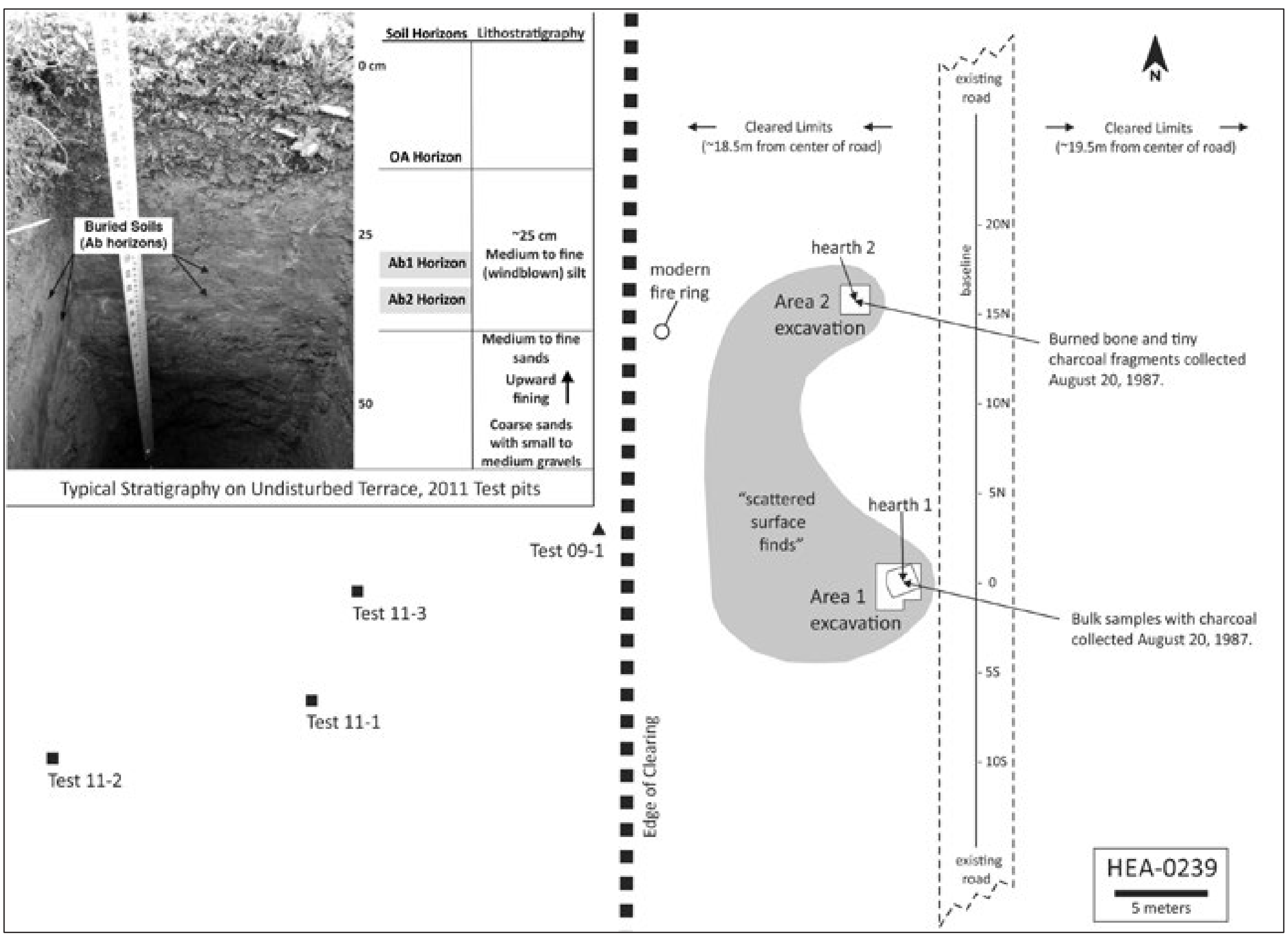


Figure 3. Generalized stratigraphy for geotests in undisturbed areas west of the Eroadaway site. The map shows the site grid, excavation units, location of Areas 1 and 2 concentrations, and where exposed artifacts were scattered across the surface.

The hearths appeared as oval-shaped dark stains, about 1 m in diameter, exposed at the erosional surface with evidence of oxidation. There was no indication of paleosols present within the excavation areas.

In 1987, the bulk samples were sieved in the laboratory to the 2 mm screen size. Charcoal samples from within the features' matrices were identified as fragments of cf. *Betula* sp. (birch) and Betulaceae (birch or alder [*Alnus* sp.]) shrubs, while other samples recovered from the Area 1 surface contexts of the Feature 1 hearth included *Betula* sp. and *Salix* sp. shrub fragments (Alix 2008) and a charred spruce needle (Holmes 1988). Three grams of birch and willow charcoal fragments from one of the Feature 1 bulk samples were combined to obtain a liquid scintillation radiometric age. Additional charcoal bits and tiny burned bone and teeth fragments were recovered from the other bulk samples from both hearth areas but not in sufficient amounts for standard radiometric assay. These small charcoal fragments were saved for the possibility of species identification and future dating by accelerator mass spectrometry (AMS). The single standard radiometric date of 8640 ± 170 RCYBP (WSU-3683; 9,300–10,180 cal BP; median probability: 9690 cal BP) was obtained from the 3 g sample of mixed charcoal from the Feature 1 hearth (Holmes 1988). It was on the basis of this date, along with the presence of distinctive bifacial technology and the absence of microblade technology, that the Eroadaway assemblage was originally interpreted as an early Holocene transition between the Paleoarctic (Denali complex) and Northern Archaic traditions (Holmes 1988).

In 2008 and 2010, we were able to obtain AMS dates on the curated charcoal samples directly associated with the hearth matrices of both features (Table 1). A single Betulaceae charcoal fragment from Feature 1 dated to 10,860 ± 40 RCYBP (Beta-245155; 12,690–12,800 cal BP: median probability: 12,740 cal BP), while a small charred piece of a birch shrub from Feature 2 dated to 10,570 ± 50 RCYBP (Beta-368365; 12,420–12,670 cal BP: median probability: 12,550 cal BP). The radiocarbon dates for the hearths in Area 1 and 2 appear slightly dissimilar, and their median probability ages are differentiated by 190 years. However, they differ by only 35 years between their combined maximum and minimum ranges, and for reasons discussed below we suggest that the two hearths were likely occupied contemporaneously. The AMS dating of these small charcoal fragments from Features 1 and 2 has allowed us to estimate the "true" age for the Eroadaway assemblage at 12,550 to 12,750 cal BP (based on median probabilities), nearly 2,800 years older than the 1988 date.

We also dated a charred piece of birch shrub from the Area 1 east matrix that was a mixture of the upper surface of the Feature 1 hearth and possibly disturbed sediments of the road surface. This sample dated to 190 ± 40 RCYBP (Beta-240740; 0–300 cal BP: median probability: 180 cal BP), essentially modern.

Table 1. Radiocarbon dates for the Eroadaway site.

Laboratory identification	Sample no.	Uncalibrated RCYBP ± 1s	Calibrated Age 2s median probability	Material	d^{13}C value	Notes
			Rejected Ages			
WSU-3683		8640 ± 170	9310 (9690) 10,180	Charcoal (cf. *Betula* sp. & cf. *Salix* sp.)	Not reported	~30 mg of charcoal fragments from Feature 1 bulk sample (1987)
Beta-240740	UA87-097-0046	190 ± 40	0 (180) 300	Charcoal (cf. **Betula** sp.)	–23.3%	~1 mg of charcoal twig from Area 1 east
			Accepted Ages			
Beta-245155	UA87-097-0080	10,890 ± 40	12,700 (12,750) 12,820	Charcoal (Betulaceae: *Betula* sp. or *Alnus* sp.)	–27.0%	~1 mg of charcoal twig from Feature 1 hearth, NW expansion
Beta-368365	HEA-0239: FEAT 2	10,570 ± 50	12,420 (12,550) 12,670	Charcoal (cf. *Betula* sp.)	–25.4%	~1 mg of charcoal twig from Feature 2 hearth
Pooled mean of accepted ages for component		10,760 ± 30	12,570 (12,660) 12,750			

Conventional radiocarbon dates were calibrated and median probabilities calculated using Calib v7.1 software (Stuiver et al. 2018) and the IntCal13 terrestrial calibration model (Reimer et al. 2013).

The 9690 cal BP age from the 1980s was affected by a number of potential problems with bulk samples: individual charcoal fragments may be from plants that lived for hundreds of years (old wood factor) or only a decade or less; thus, charcoal from different time periods can be mixed together. Also, bulk samples may contain larger amounts of younger soil-derived contaminants (e.g., fulvic and humic acids and humins) that can be more difficult to remove during pretreatment, such as likely occurred with bulk samples dated from Component 1 at the nearby Carlo Creek site in the 1970s (Bowers and Reuther 2008). AMS dating of an individual piece of charcoal can avoid the mixture of materials from different time periods and decrease the chance for younger soil-derived contaminants to skew a date from its true age. The original bulk sample for Feature 1, taken in 1987, appears to have contained a mixture of modern charcoal from the disturbed upper sediments of the hearth and ~12,600-year-old charcoal from the actual hearth matrix, and possibly younger soil-derived contaminants. A single fragment of modern charcoal could have skewed the outcome (Taylor and Bar-Yosef 2016); only 4 mg (13%) of the original 30 mg sample would have been enough to skew toward 2,800 years younger than its true age (Fig. 4).

GEOTESTING

In 2009, 2011, and 2012, we revisited Eroadaway as part of the Eroadaway-Carlo Creek Geoarchaeological Project to reevaluate the potential for intact cultural deposits and to gather information on the sediments and soils across the terrace. Seven tests (five 50 cm^2 and two 100 x 50 cm) were excavated across the terrace. Four tests were placed along the western edge of the abandoned road right-of-way and immediately adjacent to the known distribution of cultural materials and features in Areas 1 and 2 (Figs. 3 and 5). Berms of sediments were formed during highway construction and pushed up along the eastern and western sides of the road, marking the visible extent of highway construction.

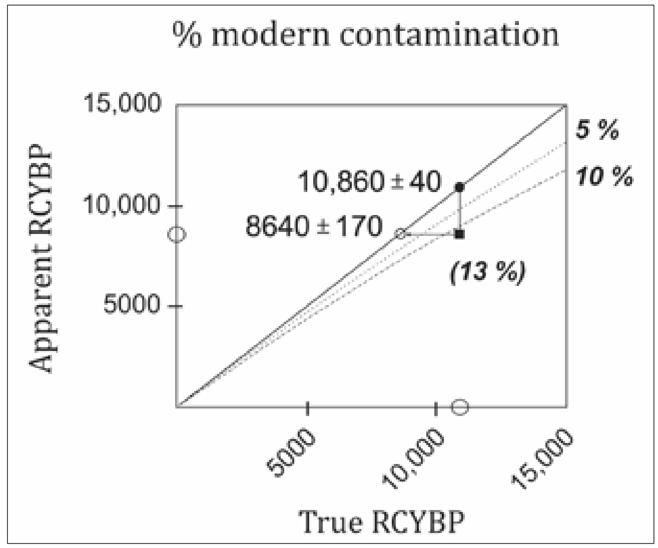
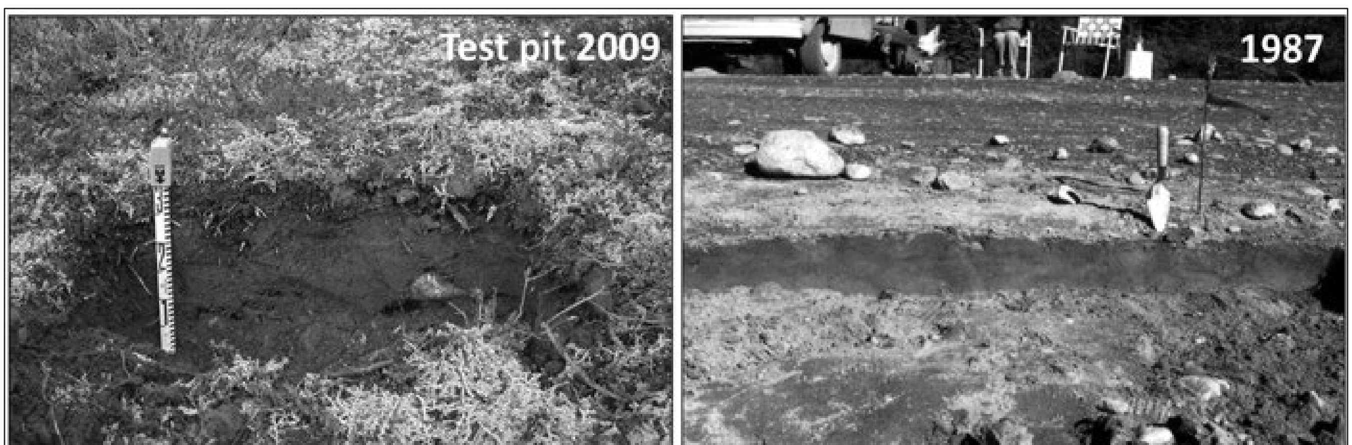


Figure 4. Effect of modern carbon contamination on radiocarbon determinations. A mixture of 13% modern carbon changes the true age by more than 2,000 years.



Test pit (09-1) is located in the undisturbed area close to the western edge of the disturbed road clearing. The undisturbed silt here is about 25cm thick overlying glacial till.

East wall profile of excavation Area 1 showing 13-15 cm thick intact silt over glacial till. About 10-15cm of the upper silt matrix had been scraped away. The adjacent surface had been scraped down exposing the till.

Figure 5. Geotest pit 09-1 compared to Area 1 east wall excavation profile.

To the west, outside the disturbed areas, more than 70 cm of unconsolidated sand and silt deposits cap glaciofluvial outwash. More than 40 cm of alluvial sands and gravels overlie outwash gravels and cobbles and show a general sequence of upward fining in particle sizes that indicates a transition from higher-velocity riverbed sediments to lower-velocity flood deposition. Aeolian fine sand and silt (loess) covers the alluvium. A buried soil 8 cm thick (very dark brown loam, Ab2 horizon) is present in the lower aeolian deposits near the contact with alluvium (Fig. 3). A period of landform stability and soil development appears to have occurred shortly after the transition from alluvial to aeolian deposition. A second buried soil 5 cm thick (very dark gray silt loam, Ab1 horizon) was separated from the lower Ab2 horizon by at least 5 cm of loess that shows little alteration from pedogenesis or turbation. A surficial soil 19 cm thick (very dark brown loam, OA horizon) is segregated from the Ab1 horizon by 5 cm of unaltered loess (Fig. 3). We have yet to reliably date the buried soils; therefore, the relationship of these buried soils to the main occupation context remains unclear.

ARTIFACT ASSEMBLAGE

More than 1760 artifacts were recovered from the 1985 surface collection and the 1987 Areas 1 and 2 excavations at Eroadaway. The surface collections were recovered in discrete clusters within the vicinity of two hearths (Features 1 and 2) that define the excavation areas. A 2 x 2 m unit (expanded S and W) was excavated around the hearth in Area 1, and another 2 x 2 m unit was excavated around the second hearth in Area 2 (Fig. 3). While we recognize that the disturbance at the surface may have created a mixture of occupations or palimpsest, the raw materials and their use are similar across the surface collections and those represented from the excavations. As will be discussed later, there is reason to interpret the site as a single short-term event.

The total assemblage consists of six types of raw materials: argillite, basalt, chalcedony, chert, rhyolite, and slate. Chert represents 54.46% of all lithics at the site, followed by basalt at 41.54%. Argillite, chalcedony, rhyolite, and slate comprise the remaining 4%. Chert and basalt colorations range across several hues of gray, from very dark gray, dark gray, dark greenish-gray, greenish-gray, to light gray. Rhyolite coloration varies from dark gray, gray, to greenish-gray and brown, pale brown, to reddish brown. In our analyses below, we have chosen not to separate these further into categories based on perceived differences in coloration, because most of the color variation within these classes is slight and we cannot assume that color is an indicator of differences in source materials.

A total of 21 waste flakes show evidence of exposure to heat; however, 18 of those (85.71%) were found on the surface and could have been exposed to modern campfires and natural burns.

Based on the debitage variables listed below, basalt and chert are considered local because of their abundance and the presence of cortex (2.6% basalt debitage and 2.8% chert debitage). Argillite and rhyolite appear to be local as well, although they may represent a different procurement strategy than basalt and chert. The single piece of slate is insufficient to correctly determine its locality. Chalcedony is rare and considered nonlocal. "Local" is defined as being within a day's walk, or about 20 km, following Surovell (2009:78).

BIFACES

In total, there are 41 bifaces and biface fragments in the Eroadaway collection, after all the refits are taken into account: 18 from Area 1, three from Area 2, and 17 from the 1985 surface collections, along with three refits between fragments from Area 1, Area 2, and the surface (Tables 2 and 3). In this context, there are a total of 10 biface fragments that refit across the sites: one refit between Area 1 and surface artifacts, two refits between artifacts from Area 2 and the surface, and one refit within both Areas 1 and 2. Basalt (43.9%) and chert (41.46%) comprise the largest percentage of biface raw materials, while chalcedony (7.32%), rhyolite (2.44%), and slate (4.88%) make up the rest. Eight complete bifaces comprise 19.51% of the total biface assemblage.

Many researchers (e.g., Callahan 1979; Whittaker 1994) have discussed the process of biface manufacture from start to finish based on experimental knapping. This can be highly advantageous for recognizing different stages of biface manufacture at an archaeological site and making inferences about how people organized their technology depending on situational factors (Nelson 1991). The Eroadaway bifaces (Figs. 6–9) show a range of mid- to late- stages in the reduction thinning and shaping sequence (cf. Andrefsky 2005) and have been grouped into three stages.

Table 2. Biface artifacts tabulated by individual specimen.

UAMN catalog number	Area	Outline shape	Base form	Max. length	Max. width	Max. thickness	Basal width	Basal thickness	Weight (g)	Max. W/T ratio	Max. T/L ratio	Basal W/T
Complete												
87-97-0025; 87-97-0039 (refits)	Area 1	Lanceolate to asymmetrical	Concave	52.3	23.7	3.0	21.5	2.5	4.6	7.9	0.1	8.6
87-97-0079; 85-145-0010 (refits)	Area 1 and Surface	Lanceolate	Concave	56.6	23.7	4.1	21.4	2.7	6.6	5.8	0.1	7.9
87-97-0053; 87-97-0060 (refits)	Area 2	Lanceolate	Concave	54.2	31.1	5.2	24.0	4.4	7.3	6.0	0.1	5.5
87-97-0061; 85-145-0002 (refits)	Area 2 and Surface	Lanceolate	Concave	54.0	19.7	4.4	19.3	2.7	4.6	4.5	0.1	7.1
87-97-0065; 85-145-0007 (refits)	Area 2 and Surface	Triangular	Concave	25.6	15.7	3.8	14.5	2.3	1.6	4.1	0.1	6.3
UA85-145-0001	Surface	Lanceolate	Straight	76.5	23.1	5.9	20.0	3.4	10.1	3.9	0.1	5.9
UA85-145-0014	Surface	Asymmetrical	Concave	48.0	26.2	5.4	22.2	4.8	8.0	4.9	0.1	4.6
UA85-145-0005	Surface	Lanceolate	Concave	46.3	19.3	4.3	18.6	2.3	4.0	4.5	0.1	8.1
Point bases												
87-97-0001	Area 1	Lanceolate	Concave	–	–	–	21.6	3.3	4.4	–	–	6.5
87-97-0032	Area 1	Squared	Straight	–	–	–	28.9	3.7	9.6	–	–	7.8
87-97-0033	Area 1	Lanceolate	Convex	–	–	–	29.9	3.9	5.2	–	–	7.7
87-97-0034	Area 1	Asymmetrical	Convex	–	–	–	26.7	3.4	4.6	–	–	7.9
87-97-0036	Area 1	Lanceolate	Convex	–	–	–	18.3	2.8	3.1	–	–	6.5
85-145-3	Surface	Lanceolate	Straight	–	–	–	16.0	2.2	3.6	–	–	7.3
85-145-4	Surface	Lanceolate	Convex	–	–	–	22.9	3.5	9.0	–	–	6.5
85-145-1	Surface	Lanceolate	Straight	–	–	–	20.0	3.4	10.1	–	–	5.9
85-145-6	Surface	Triangular	Straight	–	–	–	19.3	2.1	2.9	–	–	9.2
Averages ± STDEV				51.69 ± 14.02	22.81 ± 4.69	4.52 ± 0.94	21.48 ± 4.13	3.14 ± 0.79	5.84 ± 2.71	5.19 ± 1.32	0.09 ± 0.03	7.02 ± 1.20

Table 3. Biface artifacts tabulated by attributes, raw material, and area.

	Area 1	Area 2	Surface	Area 1 and surface	Area 2 and surface	Total	Total %
Condition							
Base fragment	4	0	1	0	0	5	12.20
Tip fragment	6	1	2	0	0	9	21.95
Medial fragment	4	1	2	0	0	7	17.07
Tip and medial fragments	0	0	1	0	0	1	2.44
Base and medial fragment	1	0	4	0	0	5	12.20
Complete	0	0	2	0	0	2	4.88
Complete refits	1	1	0	1	2	5	12.20
Other fragment	2	0	5	0	0	7	17.07
Total	18	3	17	1	2	41	100
Material type							
Chert	7	2	8	0	0	17	41.46
Basalt	10	1	5	1	1	18	43.90
Rhyolite	0	0	1	0	0	1	2.44
Chalcedony	1	0	1	0	1	3	7.32
Slate	0	0	2	0	0	2	4.88
Total	18	3	17	1	2	41	100
Breakage							
Transverse bending fractures	14	3	11	1	1	30	75
Perverse fractures	0	0	1	0	0	1	2.5
Impact fracture (burination & fluting)	0	0	2	0	1	3	7.5
Outrepassé	1	0	0	0	0	1	2.5
Other	1	0	4	0	0	5	12.5
Total	16	3	18	1	2	40	100

Stage 1 bifaces are the largest and thickest of all Eroadaway bifaces (Fig. 6). These bifaces may be considered early stages of manufacture and may also have served as bifacial cores. Stage 1 bifaces are represented by just four fragmented pieces, less than 10% of the total biface population, and are only found in the collections of Areas 1 and 2. These bifaces show that large flakes were removed across each face, and two large *outrepassé* flakes (Andrefsky 2005) are also represented in the collection. Stage 2 bifaces are larger and thicker than Stage 3 specimens and are in an intermediate stage of production (Fig. 7). Stage 3 bifaces are those in a late or final stage of implement formation and often show evidence of use (Fig. 8). These bifaces are generally shorter and thinner than the other Eroadaway bifaces.

A total of 17 complete, base, and medial biface fragments (41.5%) of the population and all Stages 2 and 3 show a similar morphology, with the dominant shape being lanceolate (n = 11; 64.71%). Other shapes include triangular (n = 2, 11.76%), asymmetrical (n = 2, 11.76%), lanceolate to asymmetrical (n = 1, 5.88%), and square (n = 1, 5.88%). The majority of these bifaces have concave bases (n = 8, 47.06%), with the remainder having convex bases (n = 4, 23.53%) and straight bases (n = 5, 29.41%). The Stage 3 late-stage or finished bifaces tend to have shallow concave or straight bases.

There are 11 utilized bifaces (26.83%), presumed damaged and/or repaired after use in hunting and discarded at camp (Rots et al. 2006), and 30 bifaces (73.17%) with no evidence of utilization. This suggests that bifaces were being manufactured at the site and many were broken during manufacture and discarded immediately. The bifaces exhibit characteristics of soft hammer and/or pressure flaking in the final stages of production. Notably, the bifaces at Eroadaway are very thin, and 30 have transverse fractures across the medial section of the blade, indicative of breakage during manufacture as a result of the fragility of their thinness (Crabtree 1972; Whittaker 1994). Ten

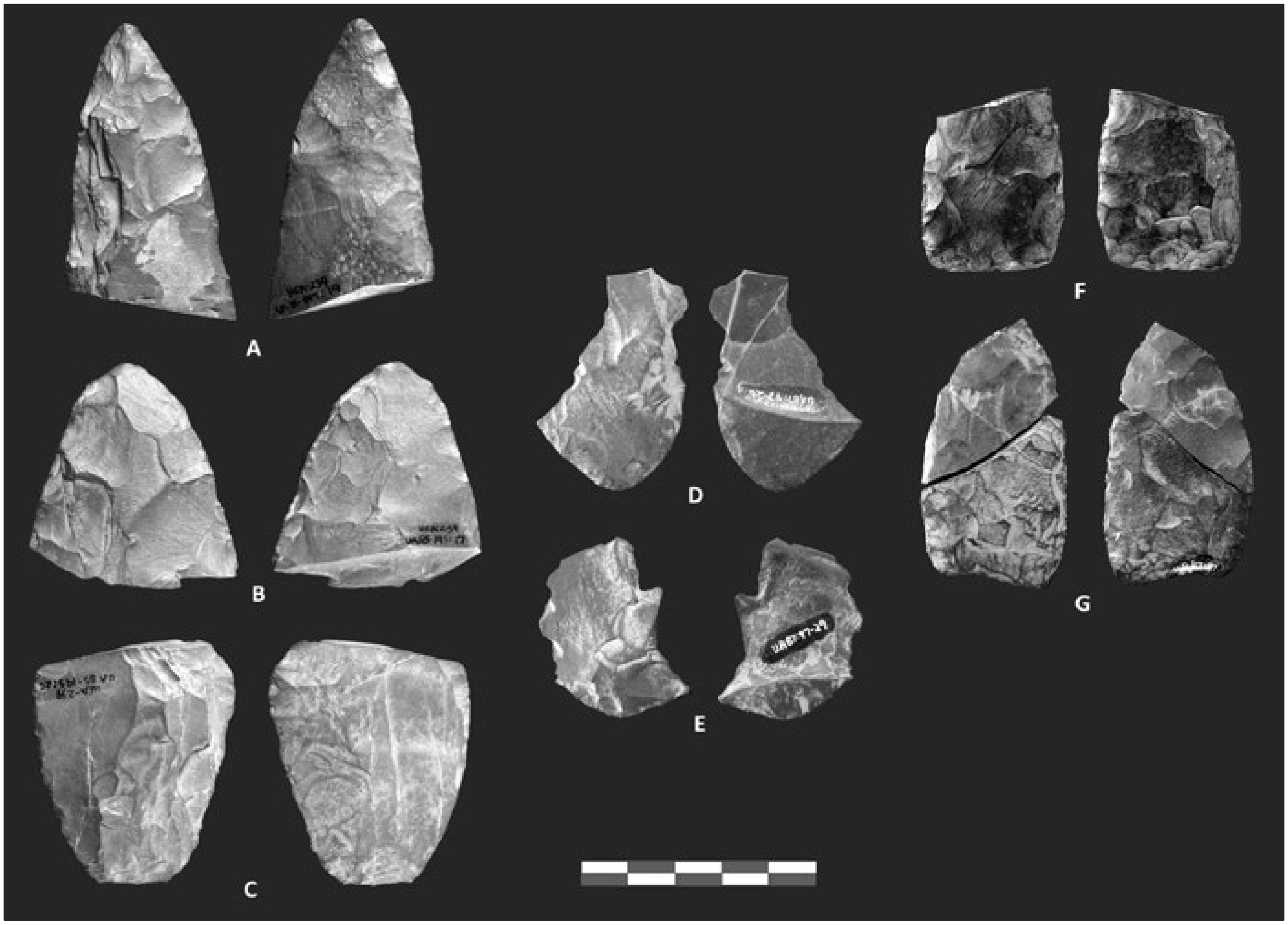


Figure 6. Eroadaway bifaces in early production stage. A–C, F, and G are preform bifaces with transverse breaks; B exhibits end shock or perverse fracture; D is overshot; and E has pronounced lip in biface thinning.

basalt bifaces retain recognizable ventral surfaces, suggesting bifacial reduction began on flake preforms rather than bifacial prepared preforms. This is further supported by the debitage analysis that follows. Only three bifaces display burination or fluting impact fractures, indicative of their likely use as projectiles and subsequent discard after the fact (Whittaker 1994).

The delicateness of the Eroadaway bifaces can be seen in width-to-thickness (W/T) ratios and the thickness-to-length (T/L) ratios (Callahan 1979; Cheshier and Kelly 2006) as compared to biface projectiles from other sites. Complete Eroadaway bifaces have overall W/T ratios between 3.92 and 7.9, with a mean of 5.19, while Eroadaway projectile point bases have higher W/T ratios, between 9.19 and 4.63, with a mean of 7.02. For complete Eroadaway points, T/W ratios are between 0.06 and 0.15, with a mean of 0.09, and fall within the longest and thinnest point categories established by Cheshier and Kelly (2006).

Non-Eroadaway projectile point W/T ratios were compiled from published reports (Baker 2009a; Pearson 1999; Powers et al. 2017; Rasic 2000); data shared by John Cook, Ted Goebel, Michael Bever, and Stephan Heidenreich; and measurements taken on collections at the University of Alaska Museum of the North. The robust forms, like Sluiceway and Mesa, are at the large end of the scale, with W/T ratios of 2 to 3, and Paleoindian Clovis/Folsom and Agate Basin fall between W/T ratio 3 and 4. The Nenana and Chindadn forms, along with northern fluted forms, are mostly between W/T ratios of 5 and 6 at the far end of the curve. The assemblages that most closely resemble Eroadaway are Moose Creek Component I (W/T ratio 6.7), Dry Creek Component I (W/T ratio 6.0), Swan Point CZ3 (W/T ratio 5.7), Jay Creek Ridge (5.8), and northern fluted points (W/T ratio 5.7).

Macroscopic evidence of slight hafting wear (polish, scarring, striations, grinding; Rots et al. 2006) was found only on the few bifaces that were discarded after use, as

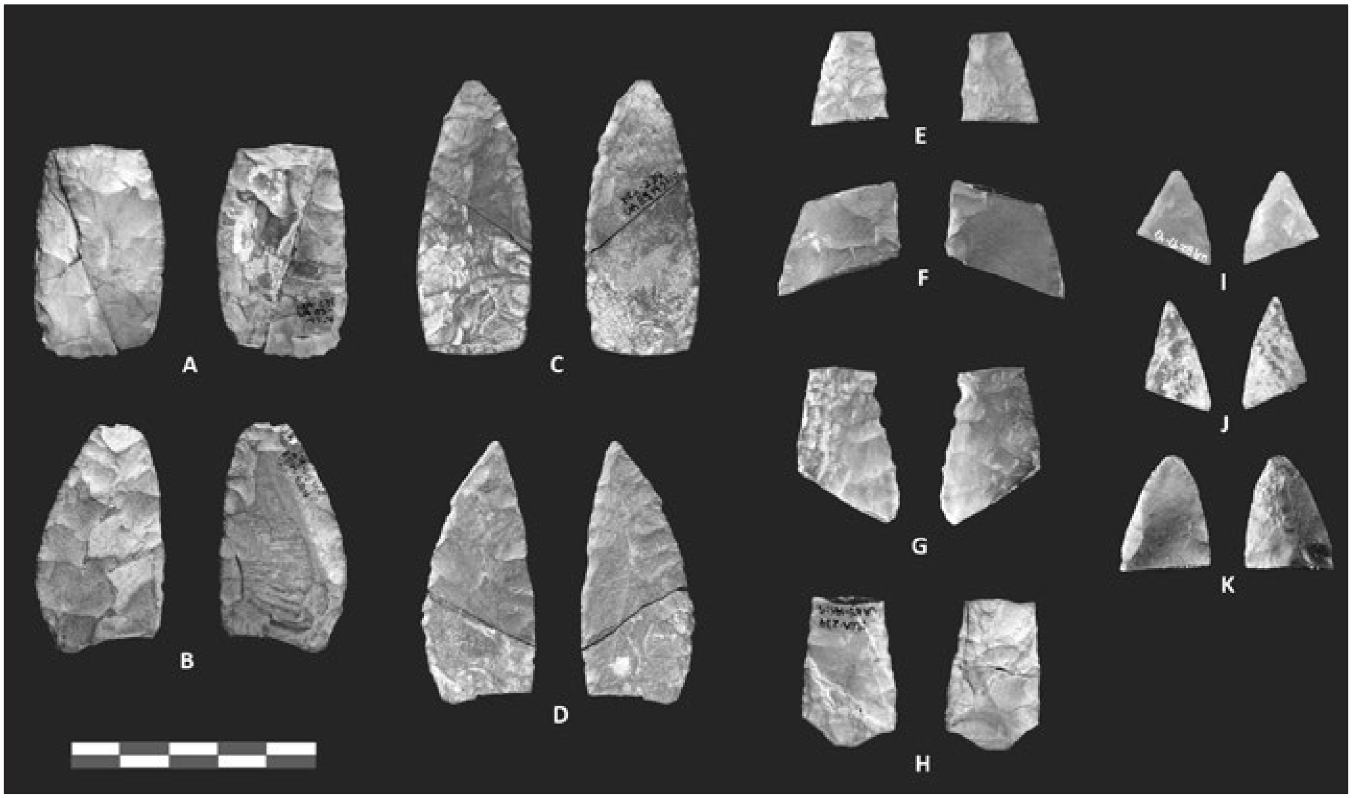


Figure 7. Eroadaway bifaces in secondary production stage. A–D have transverse fractures; E–H are midsections with transverse fractures; I–K are tip sections with transverse fracture.

opposed to those broken directly during their manufacture at the site. No evidence of resin or any glue-like material was noted on the hafted tools. Although the utilized chalcedony bifaces discarded at Eroadaway may have been fabricated at a different location (indicated by the absence of chalcedony debitage), it is likely the same individuals were responsible for biface manufacture at the Eroadaway campsite as well. The tip fragments found suggest that these unusable pieces of stone were transported to the site. It is a possibility that, in a short-term seasonal hunting camp with evidence of medium to large mammal bone in the hearth, some tips of projectile points were traveling back to the site inside prey meat (Keeley 1982:803). Or the tips may have broken during the manufacturing process at the camp but resulted in finished bifaces in perhaps a shorter form than originally planned.

FLAKE TOOLS

There are a total of 22 flake tools, consisting of modified flakes and scrapers, in the Eroadaway assemblage. Four of the flake tools were recovered from Area 1, four from Area 2, and 14 from the surface in 1985. In the collection, there are 16 modified flakes; of these, eight (50%) have been finely flaked across one or more of the margins, and eight (50%) show evidence of irregular chipping and minor serration without purposeful retouch. There are a total of six scrapers; three scrapers are made on flakes, three are made on unifaces, and one is a large planar scraper.

The six scrapers are made on basalt and chert materials. The planar scraper is basalt, the unifacial scrapers are one each of chert and basalt, and the remaining three are chert. By macroscopic observation, the average length of the utilized edge on scrapers is 52.3 mm, with the smallest edge measuring 31.7 mm and the longest measuring 104.6 mm. The average edge angle measures 33.5 degrees, with the most obtuse angle measuring 56 degrees and the most acute measuring 5.5 degrees.

The modified flakes consist of six basalt, eight chert, one argillite, and one chalcedony. The average length of the utilized edge on modified flakes is 24 mm, with the smallest edge measuring 11.3 mm and the longest measuring 52.9 mm. The average edge angle measures 35.2 degrees, with the most obtuse measuring 60 degrees and the most acute edge measuring 22 degrees. The low diversity of flake tools, especially considering the ratio of bifaces to

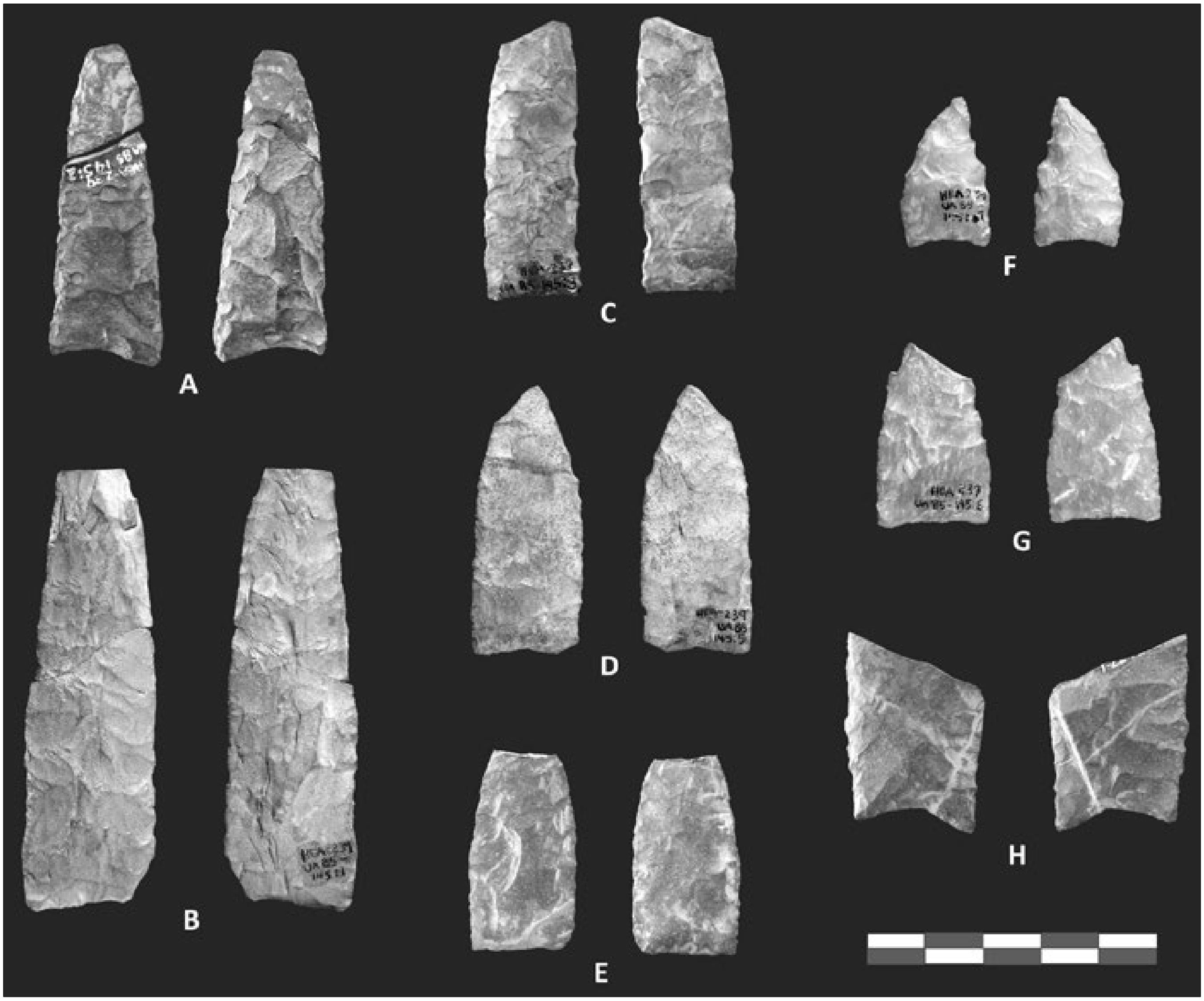


Figure 8. Eroadaway bifaces in late-stage production and biface fragments following use. A–E late-stage bifaces with tip loss and transverse fracture; F–G exhibit use (impact damage) and resharpening; H has a transverse fracture that may have resulted from use or a knapping error.

flake tools (43:22), speaks to the specialized function of the site for biface manufacture.

DEBITAGE

An examination of debitage at an archaeological site can provide unique insight into hunter-gatherer behavior and the way in which their technological system was organized. We approach this study following Morrow (1997) in regard to utilizing multiple types of analyses to examine debitage assemblages (e.g., Bradbury 1998; Root 1997). Because of the presence of bifaces in various stages of production, we approached the debitage with analysis techniques that examine reduction stages.

We observed the completeness and platform characteristics of flakes, presence of cortex and scar counts on dorsal surfaces, and size designations in regard to reduction stages (Andrefsky 2005; Little 2013; Prentiss 1998, 2001; Sullivan 1987; Sullivan and Rozen 1985). To further analyze the debitage assemblage, a technological analysis was employed to group debitage into categories based on attributes (e.g., bifacial thinning flake; Andrefsky 2005) to reflect the type of technological outcome achieved throughout the reduction process.

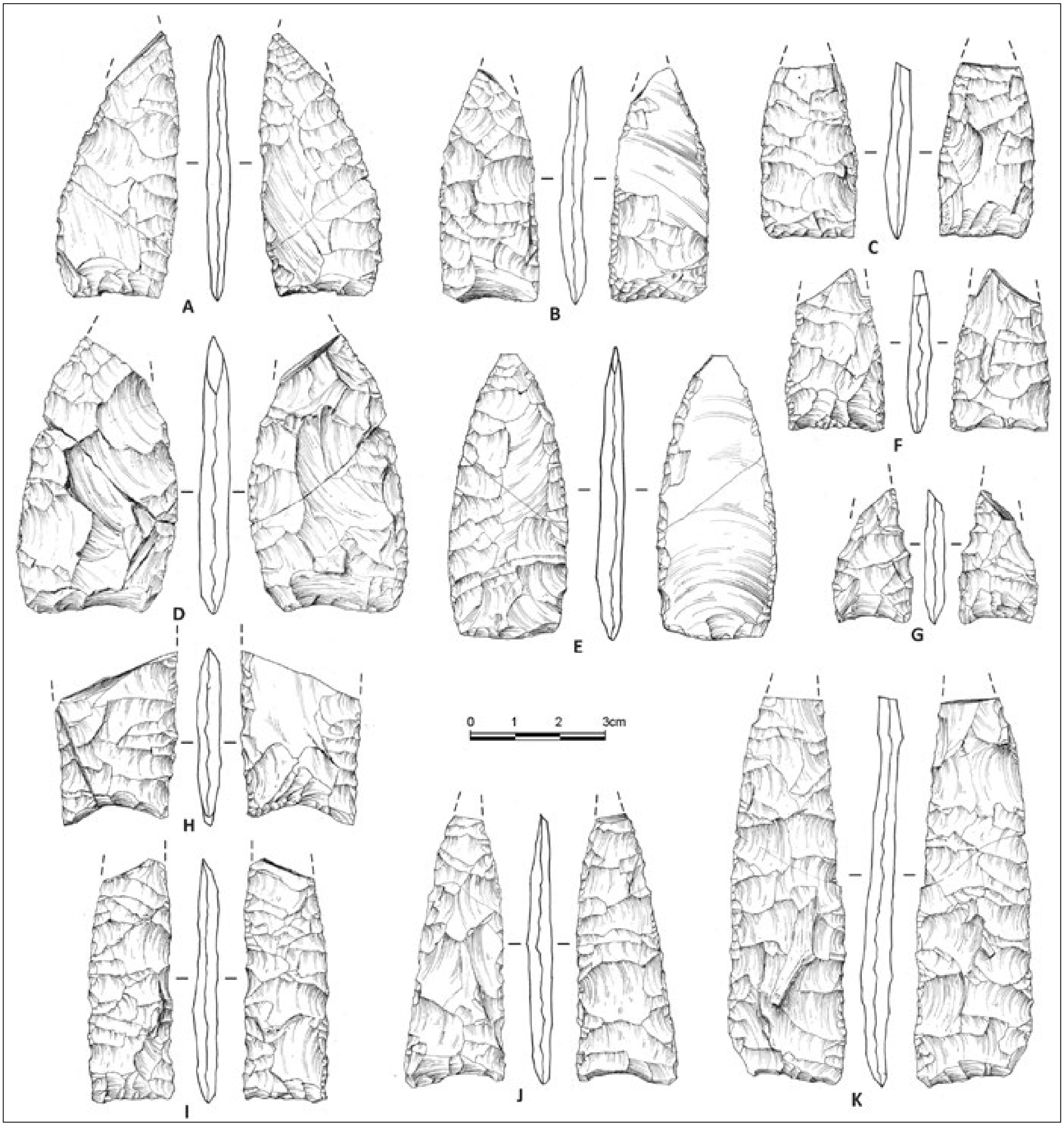


Figure 9. Eroadaway biface artifacts in various stages of production, use, and discard (compare with Figures 6–8): D is early stage; A and E are secondary stage; B, C, I–K late stage; F–H completed forms discarded after use damage.

Table 4. Lithic debitage tabulated by raw material, classification, and area clusters.

	Argillite		Basalt		Chalcedony		Chert		Rhyolite		Slate			
Count	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**Total**	**Total %**
Area 1	15	1.36	572	52.00	1	0.09	502	45.64	9	0.82	1	0.09	1100	65.79
Area 2	4	1.53	151	57.85	0	0.00	102	39.08	4	1.53	0	0.00	261	15.61
Surface	16	5.14	193	62.06	0	0.00	95	30.55	7	2.25	0	0.00	311	18.60
Total	35	2.09	916	54.78	1	0.06	699	41.81	20	1.20	1	0.06	1672	100
Weight (g)	**g**	%	**g**	%	**g**	%	**g**	%	**g**	%	**g**	%	**Total**	**Total %**
Area 1	3.25	0.89	206.18	56.40	16.50	4.51	127.73	34.94	11.06	3.03	0.82	0.22	365.54	39.33
Area 2	1.19	0.82	105.39	72.49	0.00	0.00	37.26	25.63	1.55	1.07	0.00	0.00	145.38	15.64
Surface	66.59	15.91	222.39	53.13	0.00	0.00	71.63	17.11	57.95	13.85	0.00	0.00	418.56	45.03
Total	71.03	7.64	533.96	57.45	16.50	1.78	236.62	25.46	70.56	7.59	0.82	0.09	929.48	100
MSRT*	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**Total**	**Total %**
Broken	10	28.57	214	23.36	0	0	163	23.32	3	15	0	0	390	23.33
Complete	14	40.00	176	19.21	1	100	194	27.75	8	40	0	0	393	23.50
Fragment	10	28.57	435	47.49	0	0	318	45.49	4	20	0	0	767	45.87
Shatter	1	2.86	74	8.08	0	0	12	1.72	5	25	0	0	92	5.50
Split	0	0.00	17	1.86	0	0	12	1.72	0	0	1	100	30	1.79
Total	35	2.09	916	54.78	1	0.06	699	41.81	20	1.20	1	0.06	1672	100
Platform type	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**Total**	**Total %**
Complex	0	0	25	6.16	1	100	30	8.15	1	9.09	0	0	57	7.04
Complex, lipped	2	8.33	59	14.53	0	0	63	17.12	2	18.18	0	0	126	15.56
Simple, lipped	10	41.67	120	29.56	0	0	104	28.26	7	63.64	0	0	241	29.75
Simple	11	45.83	164	40.39	0	0	146	39.67	0	0.00	0	0	321	39.63
Other	1	4.17	33	8.13	0	0	24	6.52	1	9.09	0	0	59	7.28
Other, lipped	0	0	5	1.23	0	0	1	0.27	0	0.00	0	0	6	0.74
Total	24	2.96	406	50.12	1	0.12	368	45.43	11	1.36	0	0	810	100
Cortical coverage	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**Total**	**Total %**
Present	2		19	2.07	1	100	9	1.29	1	5	0	0	32	1.91
Absent	33		897	97.93	0	0	690	98.71	19	95	1	100	1640	98.09
Total	35	2.09	916	54.78	1	0.06	699	41.81	20	1.20	1	0.06	5.71	100
Dorsal counts	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**94.29**	**Total %**
0	0	0	5	0.55	0	0	1	0.14	0	0	0	0	6	0.36
1	7	20	273	29.80	0	0	169	24.18	3	15	0	0	452	27.03
2	13	37.14	350	38.21	0	0	282	40.34	7	35	0	0	652	39.00
3	8	22.86	152	16.59	0	0	166	23.75	3	15	0	0	329	19.68
4	4	11.43	39	4.26	1	100	40	5.72	1	5	0	0	85	5.08
>4	2	5.71	24	2.62	0	0	29	4.15	1	5	0	0	56	3.35
N/A	1	2.86	73	7.97	0	0	12	1.72	5	25	1	100	92	5.50
Total	**35**	**2.09**	**916**	**54.78**	**1**	**0.06**	**699**	**41.81**	**20**	**1.20**	**1**	**0.06**	**1672**	**100**
Size class	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	*n* =	%	**Total**	**Total %**
Small	16	45.71	771	84.17	0	0	632	90.41	14	70	0	0	1433	85.71
Medium	19	54.29	144	15.72	1	100	67	9.59	5	25	1	100	237	14.17
Large	0	0	0	0	0	0	0	0	1	5	0	0	1	0.06
Very large	0	0	1	0	0	0	0	0	0	0	0	0	1	0.06
Total	**35**	**2.09**	**916**	**54.78**	**1**	**0.06**	**699**	**41.81**	**20**	**1.20**	**1**	**0.06**	**1672**	**100**

*Modified Sullivan and Rozen typology; Prentis 1998, 2001.

At Eroadaway, the debitage assemblage consists of 1672 flakes: 1100 from Area 1, 261 from Area 2, and 311 located on the surface (Table 4). Basalt and chert are the highest percentage of materials occurring by counts and weights across all of the areas. Argillite chalcedony, rhyolite, and slate occur in much lower percentages. Thus, we focus mainly on basalt and chert for our discussion. We have combined each of the areas' debitage assemblages for our analysis because they show similarities in material composition and flake characteristics.

Complete flakes comprise just 23% of the entire debitage assemblage, with basalt and chert displaying 19% and 27% completeness, respectively. Broken, split, and fragmented flakes comprise 71% of the entire assemblage, with 73% of basalt and 70% of chert flakes being broken, split, and fragmented.

Complex platforms comprise 23% of the platform types, with 21% of basalt and 25% of chert flake platforms being complex types. The assemblage also shows a high percentage (45%) of lipped platforms on complete or proximal-medial flakes. Basalt and chert flakes show between 44% and 45% percent of lipped platforms.

Size class designations are based on Prentiss (2001): small (0.64 to 4 cm^2), medium (4 to 16 cm^2), large (16 to 64 cm^2), and extra-large (> 64 cm^2). Nearly all of Eroadaway debitage (99%) falls into the medium and small size categories, with the vast majority (85%) being smaller flakes. Both chert and basalt flakes follow this trend in size.

Dorsal scar count has been shown to reflect the stage of reduction, with fewer dorsal scars occurring in the earliest stages and more in the later stages (e.g., MacDonald 1995; Magne 1989; Shott 1994). Flakes with dorsal scar counts of three or greater represent 28% of the entire debitage assemblage. Chert flakes (33%) display a slightly higher amount than basalt flakes (23%) with dorsal scar counts of three or greater. Also, less than 2% of the dorsal surfaces on the debitage assemblage have cortical surfaces.

The characteristics of this debitage assemblage indicate that soft-hammer reduction and tool production were occurring at the Eroadaway site, results congruent with the high percentage of bifaces in the tool assemblage. The debitage assemblage has a high number of broken flakes and flake fragments, an indication of tool production, rather than core production, occurring at the site (Prentiss 2001). The relatively high number of lipped platforms likely represents the use of soft-hammer reduction techniques.

The high percentages of medium- and smaller-sized flakes, flakes with dorsal scar counts of three or greater, and lack of cortical demonstrate that late-stage reduction of materials took place at Eroadaway. The slightly higher percentage of chert flakes with more dorsal scar counts, as compared to basalt, may indicate chert was being brought to the site and/or reduced differently. It may be that chert was being carried to the site as prepared bifacial cores while basalt was transported as flake blanks.

If we define bifacial thinning flakes by the presence of complex and lipped platforms (Andrefsky 2005), then we can say that, at a minimum, 23% of the assemblage relates to biface thinning. But if we include the majority of the flakes that have three or greater dorsal scars as bifacial thinning flakes, then 28% of the debitage can be considered to relate to biface thinning. Given that 99% of the assemblage is small to medium flakes, sizes that usually reflect the later stages of medium core and biface reduction (Prentiss 2001), the percentage of bifacial thinning flakes is likely underestimated in the Eroadaway assemblage. Overall, the uniform debitage assemblage indicates biface manufacture at the site, a conclusion supported by the presence of many bifaces broken during manufacture.

DISCUSSION

The Eroadaway artifact assemblage consists of a narrow range of tools in two tight clusters on a rather featureless landform. Rasic (2011) considers sites that have "one or a few small artifact clusters" less likely to be mixed. While the radiocarbon dates for the hearths in Area 1 and 2 appear dissimilar (Table 1), when calibrated they only differ by 35 years. *Betula nana* sp. can have a lifespan of 100–300 years (Greve Alsos et al. 2002; Jónsson 2004), but other Betulaceae species (e.g., alder and scrub birch) are shorter lived (Safford et al. 1990). Some of the disparity in the radiocarbon ages is likely attributable to differences, i.e., "the old wood effect," in the life histories of woody species being used for fuel (Schiffer 1986), as noted in other Late Glacial sites in Alaska (Kunz et al. 2003). The presence of birch (*Betula* sp.) as fuel in hearths 1 and 2 agrees with the pollen record at Windmill Lake for the Younger Dryas period. This shrub species remains prominent throughout the region, from its regional expansion around 14,000 cal BP and into the early Holocene, until its decline around 9,000 cal BP as the spruce forests (*Picea* sp.) expanded (Bigelow and Edwards 2001; Bigelow and Powers 2001).

The site functioned as a task-specific biface production and projectile point maintenance camp with little time for accumulation of waste, e.g., game processing (cf. Lanoë et al. 2017). The meager amount of bone material associated with the hearths indicates short-term use to cook small mammals, birds, and minor amounts of medium to large mammals. In contrast, other sites in the region are described as temporary hunting lookout locales with low tool frequency (Bowers 1980; Pearson 1999; Wygal 2010), or camps that were used with more periodicity or for a longer duration and have a mixture of activities and tool types (Powers et al. 2017).

Eroadaway provides an exceptional data set that includes thin, delicate points manufactured from a limited set of raw materials: basalt, chert, and chalcedony.

Raw material for tool production was likely obtained nearby in streams because the terrace gravel would have been covered with a thin layer of silt and unavailable. Also, tool blanks would have been roughed out away from the site, as indicated by the lack of primary cortex reduction flakes in the artifact assemblage. It is apparent from the assemblage that these thin points often broke during manufacture; however, it is reasonable to assume that finished points were carried away. Also, impact fractures on two of the bifaces (Fig. 8: F, G) indicate that used projectiles were discarded during this activity. This was a place where the whole systemic process of projectile manufacture and replacement was done.

Why would people 12,600 years ago manufacture long, delicate points rather than thicker, more durable points? A central theme for researchers studying lithic data (Andrefsky 2006; Kelly 1988; Nelson 1991) has been how hunter-gatherers organize their technology on the landscape (Torrence 1983, 2001), and artifact design has been explored using informal treatments (e.g., Bleed 1986; Doelman and Cochrane 2012; Hayden et al. 1996) and formal mathematical models (Beck and Jones 2015; Bright et al. 2002; Surovell 2009; Ugan et al. 2003). Variables central to simple technological investment models (Bettinger 2009; Bettinger et al. 2016) are procurement time, manufacture time, and return rates. *Procurement time* is the total amount of time expended to procure resources needed to manufacture a certain technology. *Manufacture time* represents the amount of time required to produce the technology. *Return rates* reflect the rate at which a resource is acquired using the technology (Bettinger 2009). Although we cannot assign actual numbers to such a model, these concepts can be used as heuristic tools to guide research and explore data. Thus, we can consider goals, decision variables, trade-offs (cost-benefit analysis), and constraints that allow for a clearer comparison of two technologies (Bird and O'Connell 2006). Here, we consider potential reasons why people at Eroadaway chose to make and use thinner points over thicker, more robust projectile forms. We compare procurement time, manufacture time, and return rates of thin points found at the Eroadaway site with a variety of points found elsewhere. In this case, we make the argument that the haft element would have been the key factor influencing the manufacture of thin projectile points to buffer against the risk of haft breakage and allow for a more lethal killing implement than a thicker counterpart. We do not explore all aspects of the model but apply its basic principles to examine the projectile point assemblage of the site.

Because most of the materials used to manufacture Eroadaway projectile points appear to consist of local raw materials, and although we haven't determined their specific geographic origin, we assume that procurement time is relatively short because of the availability of materials nearby the site (within 20 km). The time required to make projectiles has been of particular interest in the archaeological literature with replication studies by expert flintknappers (cf. Flenniken 1984; Johnson et al. 1978). The general consensus among flintknappers is that the manufacture of projectile points is not an overly time-consuming process, usually taking between 10 and 30 minutes (Keeley 1982; Rots 2008). The manufacture of a thin, delicate point may take a little longer due to the care in trimming the point and the susceptibility to breakage that occurs with thin points. As long as good raw material is available, biface projectiles can be produced without excessive time investment.

On the other hand, the hafting element (foreshaft) of a projectile can be thought of as costlier to manufacture than lithic projectile points. Hunter-gatherers would have spent more time investing in the haft element as opposed to the projectile point (Oswalt 1973). This is evidenced extensively in the ethnographic record worldwide, by hafts being passed down generationally, with continued use even exceeding five generations in some contexts (Gould 1980; Keeley 1982; Lee 1979; Rots and Williamson 2004).

A question, then, is: What are the differences in the manufacture of hafting mechanisms used for thin points versus thick points? Based on experimental evidence, Cheshier and Kelly (2006) tested the effect of thickness to length in regard to durability for projectile technology and found that points with a high T/L ratio (> 0.121) were more durable than those with lower ratios (< 0.121). As noted above, the T/L ratios for Eroadaway complete points fall below this lower ratio threshold. Odell and Cowan (1986), upon testing projectile point durability, concluded that long and narrow points were less durable than short and wide points, showing that the greater amount of mass associated with a projectile point makes it more resistant to breakage. It has been suggested that "long, thin points might be made more durable by lengthening the haft element, binding more of the point and providing it with more support" (Cheshier and Kelly 2006:362). Literature regarding hafting is minimal in regard to stone tools; this is because organic haft elements would have been highly curated and are rarely preserved in the archaeological record. However, Keeley (1982) provides an in-depth overview of hafting strategies for wedge, wrapped, and mastic methods that were probably used in combination with one another.

When comparing the width-to-thickness ratios of the Eroadaway site points to a variety of Late Glacial points found elsewhere in Alaska, and in the continental United States, the Eroadaway points are on the far end of the thinner point spectrum. In this context, we posit a hypothetical projectile system for Eroadaway points that employs the basic physical characteristics inherent in antler (Fig. 10). Antler, especially caribou and to a lesser extent wapiti, is strong and elastic and can be worked with stone tools, especially after softening by immersion in water or urine (Grønnow 2017; Guthrie 1983; Hough 1898; Osipowicz 2007). The fracture toughness of rehydrated antler is twice that of bone, one of the toughest biological materials known (Chen et al. 2009; Launey et al. 2010). In our model, antler foreshafts are designed to protect thin bifacial points by securing them midway on the biface, as suggested for hafting Folsom points (Ahler and Geib 2002); to detach from the shaft upon impact with prey and help preserve the shaft; and, if a biface point breaks, to be rearmed and reused. Also, Eroadaway bifaces have sharp edges that could interfere with binding to a foreshaft. This method ensures that the sharp edges on the biface are exposed to benefit in penetration of prey. This is in contrast to traits common to Paleoindian points that exhibit short hafting lengths and lateral edge and basal grinding, such as found on Agate Basin and Mesa points (Kunz and Reanier 1995; Kunz et al. 2003) and a feature on Denali lanceolate points (Coffman and Potter 2011; Potter et al. 2014). However, the material properties of antler would allow biface hafting without wrapping by sealing or friction gripping the biface in place after drying. Baker's experiments (2009b:13) showed "an antler foreshaft would shrink tight around a point if it was inserted into the foreshaft when it was wet and then allowed to dry. No additional masking or lashing was necessary to tightly secure the point."

The goal of using a projectile is to achieve penetration and efficiently dispatch a food resource. This requires a technology that can be maintained and will provide a high rate of return. A projectile must penetrate the tough hide of large animals to facilitate bleeding and organ piercing and would need to penetrate a depth of 20 cm to achieve fatal wounds in large ungulates (Friis-Hansen 1990; Guthrie 1983). While thinner points may obtain deeper penetration and be better for actual killing, they lack the overall durability that thicker points provide. It is well known that stone points, by nature brittle, are highly susceptible to breakage (Ellis 1997). Multiple studies show that projectile points of all sizes, when propelled, have a very short use life—no more than two or three throws or hits (Cheshier and Kelly 2006; Odell and Cowan 1986; Titmus and Woods 1986). Hypothetically, the thin points would have been more lethal but may have broken in more contexts, while the thicker points would not have achieved the deep penetration but may have lasted for subsequent uses. On the other hand, Englebrecht (2015) examined projectile points where low thickness-to-length ratios make the points less durable and concluded that thinner points would fragment easily and cause a larger wound cavity.

In the Eroadaway case, we assert that the osseous foreshaft haft element would have been the key factor influencing the manufacture of thin projectile points to buffer against the risk of haft breakage and allow for a more efficient killing implement than a thicker counterpart. When a projectile is launched, it needs to have a durable haft that holds up to the compressive forces that a projectile goes through upon impact (Hughes 1998). We know hafts were designed for repeated use and required more time to craft than the knapping of lithic projectiles. Therefore, instead of making lithic projectiles durable, and possibly compromising the haft, they could have been made thin to break and relieve pressure to the haft element. In their experiments, Cheshier and Kelly (2006:362) point out

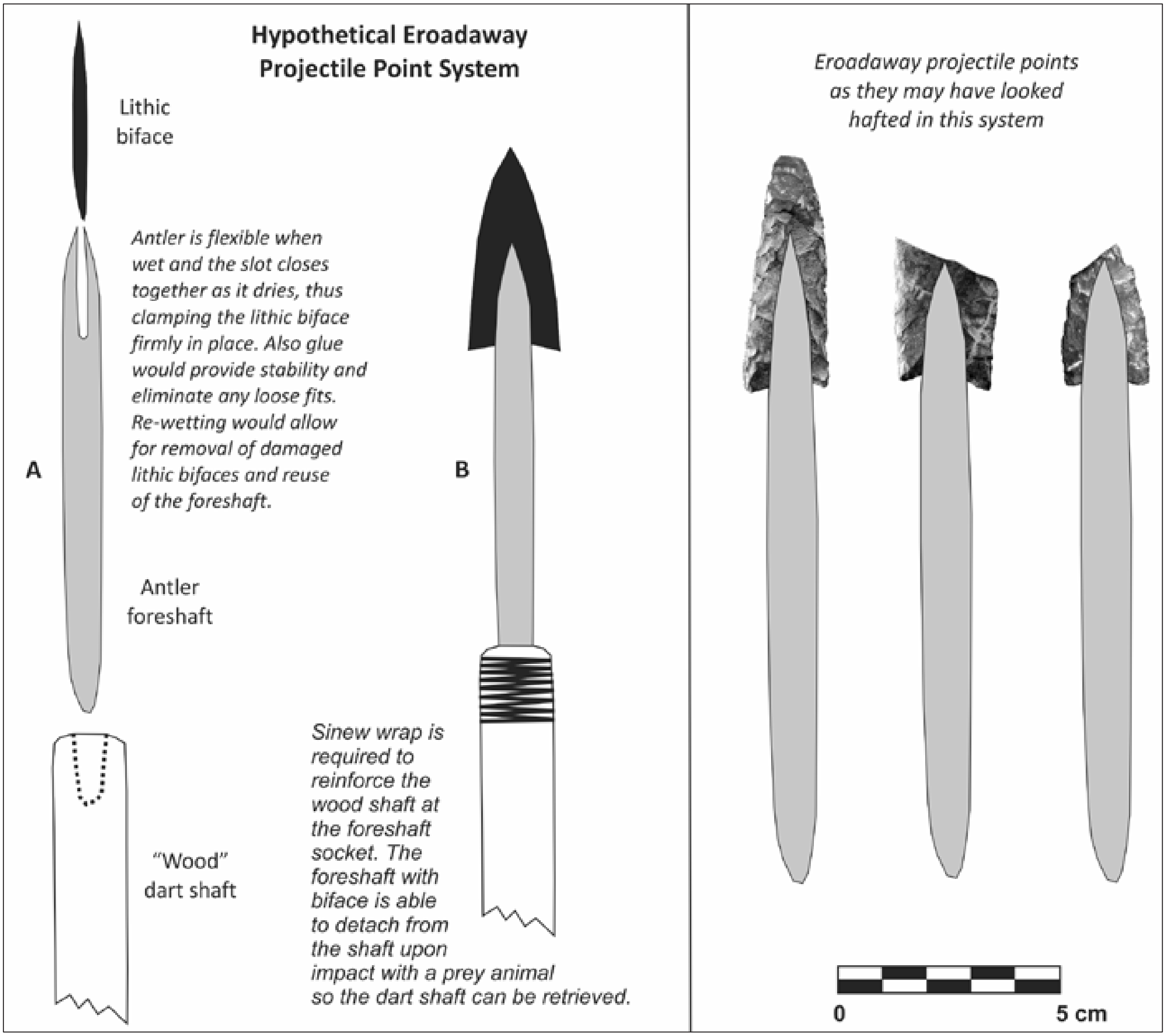


Figure 10. Hypothetical Eroadaway projectile point system: a composite weapon composed of wood shaft, antler foreshaft, and lithic point.

that "projectile point durability might have been an undesirable characteristic . . . a point intended to break might absorb the impact's force and hence protect the more time-consuming haft elements from shock and breakage." The Eroadaway data reflect this: thinner points, broken near the tip, would have been used to achieve penetration and bleeding and take stress off the haft element, which requires a greater time investment to replace or repair. Despite the fact that these points may have tended to break at a greater rate during manufacture than thicker points, this appears to have been the preferred technology implemented by the Eroadaway hunters.

Whether breakage of thin bifaces versus more durable thick bifaces is an advantage or not is debatable and requires more experimental study (sensu Fauvelle et al. 2012). As noted above, even though the thicker, more durable points may allow for a few more uses, the risk associated with the breakage of the haft and the time spent in its manufacture would make thin projectiles the more efficient of the two when taking the haft element into account.

The biface projectile forms are about the only potentially diagnostic tool we have to compare with other known archaeological entities for this time period; that is, if thinner lanceolate forms can be construed as diagnostic of particular cultural groups. The absence of microblade technology is significant and can be interpreted as either not part of the material culture or as being related to specific hunting or seasonal activities that did not require microblades. While similarities can be found in early Nenana and Tanana valleys assemblages (e.g., Dry Creek, Moose Creek, Broken Mammoth, and Swan Point) to the north of Eroadaway, the differences suggest that we may need to look elsewhere as well. Further investigation is warranted at sites similar in age, such as those south of Cantwell tested by Wygal (2010). It is possible that the Eroadaway hunters may have made a hunting expedition into the Alaska Range from the south, e.g., from the Broad Pass and upper Susitna River basin.

CONCLUSION

A small hunting group camped in the narrow valley near the Nenana River in the central Alaska Range during the Late Glacial. The revised dates for Eroadaway place the occupation during the early part of the Younger Dryas chronozone (12,900 to 11,700 cal BP) and possibly the coldest period during this chronozone (Steffensen et al. 2008; Viau et al. 2008). Vegetation changes in this region occurred at the end of the Younger Dryas (12,250 to 11,750 cal BP; Bigelow and Powers 2001) rather than during the cold snap at the beginning, when the site was occupied.

The behaviors expressed in the Eroadaway archaeological data are interpreted as a short-term campsite with an emphasis on bifacial tool production and retooling of projectile points to the near exclusion of other tools. The dominance of small flakes indicates that tool production and bifacial reduction was a major activity: specifically, to produce biface projectile points and to repair and discard broken pieces, a conclusion supported by the volume of broken bifaces recovered. In most cases, the finished form was a thin lanceolate biface with a straight or shallow concave base with very light smoothing on the basal edges or none at all. There was a high frequency of manufacturing failures associated with this activity.

Technological investment of manufacturing thin points compared to thick points indicates that thinner projectile points, as seen at Eroadaway, would have been highly effective in penetration to induce bleeding of animals and advantageous for preserving the haft element of the weapon system, as suggested by our "projectile point system" model. Not only is the haft element costlier to produce but a thinner point system might require more preparation (e.g., longer soaking and drying) as well in producing the haft system to support it. There may be more investment in the haft but less investment in producing thin bifacial projectiles over making thicker forms.

ACKNOWLEDGEMENTS

We thank our colleagues and friends who helped retrieve the artifacts from oblivion. Chuck Mobley, Joan Dale, and Dave McMahan applied their knowledge and experience to this effort. John Cook (Healy Lake), Ted Goebel (Walker Road), Stephan Heidenreich (Moose Creek), and Michael Bever (Mesa) graciously provided biface measurements. Claire Alix and Dave McMahan performed the charcoal identification, Eric Carlson illustrated the Eroadaway artifacts, and Justin Hays identified the animal and bird bones. Jason Rogers and a Northern Land Use Research Alaska crew helped to map and test some of the site area in 2012.

NOTES

Supplemental material is located online at https://www.alaskaanthropology.org/ under Publications. The artifact analysis, including all descriptive and metric data, is in Microsoft Excel files, and a gallery of photographs is available.

REFERENCES

Alix, Claire

2008 Eroadaway Site Charcoal Identifications. Northern Land Use Research, Inc., January 17, 2008. UAMN Accessions #UA87-097 on file at the University of Alaska Museum of the North, Fairbanks.

Ahler, Stanley A., and Phil R. Geib

2002 Why the Folsom Point Was Fluted: Implications from a Particular Technofunctional Explanation. In *Folsom Technology and Lifeways*, edited by John E. Clark and Michael B. Collins, pp. 371–390. Special Publication No. 4. Lithic Technology. University of Tulsa, OK.

Andrefsky, William, Jr.

2005 *Lithics: Macroscopic Approaches to Analysis*. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

2006 Experimental and Archaeological Verification of an Index of Retouch for Hafted Bifaces. *American Antiquity* 71(4):743–759.

Baker, Tony
2009a I Forgot to Remember to Forget: 1st Peoples in the New World (PDF version). Online at http://www.ele.net/forgot/forgotten.htm
2009b The Antler Foreshaft—The Original Shrink Wrapped Package (PDF version). Online at http://www.ele.net/antler/foreshaft.htm

Beck, Charlotte, and George T. Jones
2015 A Case of Extinction in Paleoindian Archaeology. In *Lithic Technological Systems and Evolutionary Theory*, edited by Nathan Goodale and William Andrefsky, Jr., pp 83–99. Cambridge University Press, New York.

Bettinger, Robert L.
2009 *Hunter-Gatherer Foraging*: *Five Simple Models*. Werner Publications, New York.

Bettinger, Robert L., Bruce Winterhalder, and Richard McElreath
2016 A Simple Model of Technological Intensification. *Journal of Archaeological Science* 33(4):538–545.

Bever, Michael R.
2001a An Overview of Alaskan Late Pleistocene Archaeology: Historical Themes and Current Perspectives. *Journal of World Prehistory* 15(2):125–191.
2001b Stone Tool Technology and the Mesa Complex: Developing a Framework of Alaskan Paleoindian Prehistory. *Arctic Anthropology* 38(2):98–118.

Bigelow, Nancy H.
1997 *Late Quaternary Vegetation and Lake Level Changes in Central Alaska*. PhD dissertation, Department of Anthropology, University of Alaska Fairbanks, Fairbanks.

Bigelow, Nancy H., and Mary E. Edwards
2001 A 14,000 Yr Paleoenvironmental Record from Windmill Lake, Central Alaska: Late Glacial and Holocene Vegetation in the Alaska Range. *Quaternary Science Reviews* 20(1–3):203–215.

Bigelow, Nancy H., and W. Roger Powers
2001 Climate, Vegetation, and Archaeology 14,000–9000 Cal Yr BP in Central Alaska. *Arctic Anthropology* 38(2):171–195.

Bird, Douglas, and James O'Connell
2006 Behavioral Ecology and Archaeology. *Journal of Archaeological Research* 14(2):143–188.

Bleed, Peter
1986 The Optimal Design of Hunting Weapons: Maintainability or Reliability. *American Antiquity* 51(4):737–747.

Bowers, P. M.
1980 *The Carlo Creek Site: Geology and Archaeology of an Early Holocene Site in the Central Alaska Range.* Occasional Paper No. 27, Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks.

Bowers, Peter M., and Joshua D. Reuther
2008 AMS Re-dating of the Carlo Creek Site, Nenana Valley, Central Alaska. *Current Research in the Pleistocene* 25:58–61.

Bradbury, A. P.
1998 The Examination of Lithic Artifacts from an Early Archaic Assemblage: Strengthening Inferences through Multiple Lines of Evidence. *Midcontinental Journal of Archaeology* 23:263–288.

Bright, Jason, Andrew Ugan, and Lori Hunskar
2002 The Effect of Handling Time on Subsistence Technology. *World Archaeology* 34(1):164–181.

Callahan, Errett
1979 The Basics of Biface Knapping in the Eastern Fluted Point Tradition. A Manual for Flintknappers and Lithic Analysts. *Archaeology of Eastern North America* 7(1):1–180.

Chen P.-Y., A. G. Stokes, and J. McKittrick
2009 Comparison of the Structure and Mechanical Properties of Bovine Femur Bone and Antler of the North American Elk (*Cervus elaphus canadensis*). *Acta Biomaterialia* 5(2):693–706.

Cheshier, Joseph, and Robert L. Kelly
2006 Projectile Point Shape and Durability: The Effect of Thickness: Length. *American Antiquity* 71(2):353–363.

Clark, Mark H., and Michael S. Duffy
2006 Soil Survey of Denali National Park Area, Alaska. NPS TIC #D-389. U.S. Department of Agriculture, Natural Resources Conservation Service and U.S. Department of the Interior, National Park Service, Inventory and Monitoring Program.

Coffman, Samuel C., and Ben A. Potter
2011 Recent Excavations at Teklanika West: A Late Pleistocene Multicomponent Site in Denali National Park and Preserve, Central Alaska. *Current Research in the Pleistocene* 28:29–32.

Crabtree, Don E.
1972 *An Introduction to Flintworking*. Occasional Papers of the Idaho State University Museum, no. 28.

Dixon, E. James
1999 *Bones, Boats and Bison: Archeology and the First Colonization of Western North America*. University of New Mexico Press, Albuquerque.
2013 *Arrows and Atl Atls: A Guide to the Archaeology of Beringia*. Shared Beringian Heritage Program, National Park Service, U.S. Government Printing Office, Washington, DC.

Doelman, Trudy, and Grant W. G. Cochrane
2012 Design Theory and the Australian Tula Adze. *Asian Perspectives* 51(2):251–277.

Dortch, Jason M., Lewis A. Owen, Marc W. Caffee, Dewen Li, and Thomas V. Lowell
2010 Beryllium-10 Surface Exposure Dating of Glacial Successions in the Central Alaska Range. *Journal of Quaternary Science* 25(8):1259–1269.

Ellis, Christopher J.
1997 Factors Influencing the Use of Stone Projectile Tips: An Ethnographic Perspective. In *Projectile Technology: Interdisciplinary Contributions to Archaeology,* edited by Heidi Knecht, pp. 37–74. Plenum Press, New York.

Englebrecht, William
2015 Interpreting Broken Arrow Points. *American Antiquity* 80(4):760–766.

Fauvelle, Mikael, Erin Smith, Sean Brown, and Mathew Des Lauriers
2012 Asphaltum Hafting and Projectile Point Durability: An Experimental Comparison of Three Hafting Methods. *Journal of Archaeological Science* 39(8):2802–2809.

Flenniken, J. Jeffery
1984 The Past, Present, and Future of Flintknapping: An Anthropological Perspective. *Annual Review of Anthropology* 13(1):187–203.

Friis-Hansen, Jan
1990 Mesolithic Cutting Arrows: Functional Analysis of Arrows Used in the Hunting of Large Game. *Antiquity* 64(244):494–504.

Goebel, Ted, and Ian Buvit
2011 Introducing the Archaeological Record of Beringia. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblages Variability in Late Pleistocene/Early Holocene Beringia*, edited by T. Goebel and Ian Buvit, pp. 1–30. Texas A&M University Press, College Station.

Goebel, Ted., Heather L. Smith, Lyndsay DiPietro, Michael R. Waters, Bryan Hockett, Kelly E. Graf, Robert Gal, Sergie B. Slobodin, Robert J. Speakman, Steven G. Driese, and David Rhode
2013 Serpentine Hot Springs, Alaska: Results of Excavations and Implications for the Age and Significance of Northern Fluted Points. *Journal of Archaeological Science* 40(12):4222–4233.

Goebel, Ted, W. Roger Powers, Nancy H. Bigelow, and Andrew S. Higgs
1996 Walker Road. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F. H. West, pp. 356–363. University of Chicago Press, Chicago.

Gould, Richard
1980 *Living Archaeology*. Cambridge University Press, Cambridge.

Graf, Kelly E., and Nancy H. Bigelow
2011 Human Responses to Climate during the Younger Dryas Chronozone in Central Alaska. *Quaternary International* 242(2):434–451.

Graf, Kelly E., and Ted Goebel
2009 Upper Paleolithic Toolstone Procurement and Selection across Beringia. In *Lithic Materials and Paleolithic Societies*, edited by B. Adams and B. S. Blades, pp. 54–77. Wiley-Blackwell, West Sussex, UK.

Greve Alsos, Inger, Torstein Engelskjøn, and Christian Brochmann
2002 Conservation Genetics and Population History of *Betula nana, Vaccinium uliginosum*, and *Campanula rotundifolia* in the Arctic Archipelago of Svalbard. *Arctic, Antarctic, and Alpine Research* 4(34):408–418.

Grønnow, Bjarne
2017 *The Frozen Saqqaq Sites of Disko Bay, West Greenland—Qeqertasussuk and Qajaa (2400–900 BC): Studies of Saqqaq Material Culture in an Eastern Arctic Perspective*. Monographs on Greenland vol. 356. Museum Tusculanum Press, Copenhagen.

Guthrie, R. Dale
1983 Osseous Projectile Points: Biological Considerations Affecting Raw Material Selection and Design among Paleolithic and Paleoindian Peoples. In *Animals and Archaeology*, vol. 1, *Hunters and Their Prey*, edited by J. Clutton-Brock and C. Grigson, pp. 273–294. BAR International Series 163, British Archaeological Reports, Oxford.
2017 Chapter 6: Paleoecology of the Dry Creek Site and Its Implications for Early Hunters. In *Dry Creek: Archaeology and Paleoecology of a Late Pleistocene*

Alaskan Hunting Camp, edited by Ted Goebel, pp. 153–192. Texas A&M Press, College Station.

Hayden, Brian, Nora Franco, and Jim Spafford
1996 Evaluating Lithic Strategies and Design Criteria. In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. Odell, pp. 9–49. Plenum Press, New York.

Heidenreich, S. M.
2014 Lithic Technologies, Functional Variability, and Settlement Systems in Late Pleistocene Beringia: New Perspectives on a Colonization Process. Unpublished PhD dissertation. University of Erlangen, Nuremberg. Online at https://opus4.kobv.de/opus4-fau/frontdoor/index/index/docId/5208

Hoffecker, John F.
2011 Assemblage Variability in Beringia: The Mesa Factor. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblages Variability in Late Pleistocene/Early Holocene Beringia*, edited by T. Goebel and Ian Buvit, pp. 165–178. Texas A&M University Press, College Station.

Holmes, Charles E.
1988 A Post Paleo-Arctic Site in the Alaska Range. Presented at the 15th Annual Meeting of the Alaska Anthropology Association, March 25–26, 1988, Fairbanks.

Hough, Walter
1898 The Lamps of the Eskimo. *Report of the U.S. National Museum for the Year Ending June 30, 1896*. U.S. Government Printing Office, Washington, DC.

Hughes, Susan S.
1998 Getting to the Point: Evolutionary Change in Prehistoric Weaponry. *Journal of Archaeological Method and Theory* 5(4):345–408.

Johnson, L. Lewis, Jeffery A. Behm, François Bordes, Daniel Cahen, Don E. Crabtree, Dena F. Dincauze, Conran A. Hay, Brian Hayden, Thomas R. Hester, Paul R. Katz, Ruthann Knudson, Francis P. McManamon, S. C. Malik, Hansjürgen Müller-Beck, Mark H. Newcomer, K. Paddayya, Patricia Price-Beggerly, Anthony J. Ranere, H. D. Sankalia, and Payson D. Sheets
1978 A History of Flint-Knapping Experimentation, 1838–1976 [Comments and Reply]. *Current Anthropology* 19(2):337–372.

Jónsson, Thorbergur Hjalti
2004 Stature of Sub-arctic Birch in Relation to Growth Rate, Lifespan and Tree Form. Online at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4242221

Kari, James, and James A. Fall (editors)
2003 *Shem Pete's Alaska: The Territory of the Upper Cook Inlet Dena'ina*, revised 2nd ed. University of Alaska Press, Fairbanks.

Keeley, Lawrence H.
1982 Hafting and Retooling: Effects on the Archaeological Record. *American Antiquity* 47(4):798–809.

Kelly, Robert L.
1988 The Three Sides of a Biface. *American Antiquity* 53(4):717–734.

Kokorowski, H. D., P. M. Anderson, C. J. Mock, and A. V. Lozhkin
2008 A Re-evaluation and Spatial Analysis for a Younger Dryas Climatic Reversal in Beringia. *Quaternary Science Reviews* 27(17–18):1710–1722.

Kunz, Michael L., and Richard E. Reanier
1995 The Mesa Site: A Paleoindian Hunting Lookout in Arctic Alaska. *Arctic Anthropology* 32(1):5–30.

Kunz, M., M. Bever, and C. Adkins
2003 *The Mesa Site: Paleoindians Above the Arctic Circle*. BLM-Alaska Open File Report 86. Alaska State Office, U.S. Department of the Interior, Bureau of Land Management, Anchorage.

Lanoë, François B., Joshua D. Reuther, and Charles E. Holmes
2017 Task-Specific Sites and Paleoindian Landscape Use in the Shaw Creek Flats, Alaska. *Journal of Archaeological Method and Theory* 1–21. Online at https://doi.org/10.1007/s10816-017-9360-0

Launey, M. E., P.-Y. Chen, J. McKittrick, and R. O. Ritchie
2010 Mechanistic aspects of the fracture toughness of elk antler bone. *Acta Biomaterialia* 6(4):1505–1514.

Lee, Richard
1979 *The !Kung San*. Cambridge University Press, Cambridge.

Lyman, R. Lee, and Michael J. O'Brien
2000 Measuring and Explaining Change in Artifact Variation with Clade-Diversity Diagrams. *Journal of Anthropological Archaeology* 19(1):39–74.

Little, Allison A.
2013 Lithic Analysis at the Mead Site, Central Alaska. Unpublished master's thesis, Department of Anthropology, University of Alaska Fairbanks.

MacDonald, Douglas H.
1995 Mobility and Raw Material Use at the Hunting Camp Spring Site (35WA96), Blue Mountains, Oregon. *North American Archaeologist* 16(4):343–361.

Magne, Martin P.
1989 Lithic Reduction Stages and Assemblage Formation Processes. In *Experiments in Lithic Technology*, edited by D. S. Amick and R. P. Mauldin, pp. 15–31. BAR International Series, Oxford.

Morrow, Toby A.
1997 A Chip Off the Old Block: Alternative Approaches to Debitage Analysis. *Lithic Technology* 22(1):51–69.

Nelson, Margaret C.
1991 The Study of Technological Organization. In *Archaeological Method and Theory 3,* edited by Michael B. Schiffer, pp. 57–100. Academic Press, New York.

Odell, George, and Frank Cowan
1986 Experiments with Spears and Arrows on Animal Targets. *Journal of Field Archaeology* 13(2):194–212.

Odess, Daniel, and Jeffery T. Rasic
2007 Toolkit Composition and Assemblage Variability: The Implications of Nogahabara I, Northern Alaska. *American Antiquity* 72(4):691–717.

Osipowicz, Grzegorz
2007 Bone and Antler: Softening Techniques in Prehistory of the North Eastern part of the Polish Lowlands in the Light of Experimental Archaeology and Micro Trace Analysis. *EuroREA: Journal for (Re)construction and Experiment in Archaeology* 4:1–22.

Oswalt, Wendell H.
1973 *Habitat and Technology: The Evolution of Hunting*. Holt, Rinehart and Winston, New York.

Pearson, Georges A.
1999 Early Occupations and Cultural Sequence at Moose Creek: A Late Pleistocene Site in Central Alaska. *Arctic* 52(4):332–345.

Potter, Ben A.
2005 Site Structure and Organization in Central Alaska: Archaeological Investigations at Gerstle River. PhD dissertation, Department of Anthropology, University of Alaska Fairbanks.
2007 Models of faunal processing and economy in early Holocene interior Alaska. *Environmental Archaeology* 12(1):181–204.
2011 Late Pleistocene and Early Holocene Assemblage Variability in Central Alaska. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblages Variability in Late Pleistocene/Early Holocene Beringia*, edited by T. Goebel and Ian Buvit, pp. 215–233. Texas A&M University Press, College Station.

Potter, Ben A., Joel D. Irish, Joshua D. Reuther, and Holly J. McKinney
2014 New Insights into Eastern Beringian Mortuary Behavior: A Terminal Pleistocene Double Infant Burial at Upward Sun River. *Proceeding of the National Academy of Sciences* 111(48):17060–17065.

Powers, W. Roger, R. Dale Guthrie, and John F. Hoffecker
2017 Part I: The Dry Creek Report. In *Dry Creek: Archaeology and Paleoecology of a Late Pleistocene Alaskan Hunting Camp,* edited by Ted Goebel, pp. 1–214. Texas A&M Press, College Station.

Prentiss, William C.
1998 The Reliability and Validity of a Lithic Debitage Typology: Implications for Archaeological Interpretation. *American Antiquity* 63(4):635–650.
2001 Reliability and Validity of a "Distinctive Assemblage" Typology: Integrating Flake Size and Completeness. In *Lithic Debitage: Context, Form, Meaning*, edited by William Andrefsky Jr., pp. 147–172. University of Utah Press, Salt Lake City.

Rasic, Jeffery T.
2000 Prehistoric Lithic Technology at the Tuluaq Hill Site, Northwest Alaska. Unpublished M.A. thesis, Department of Anthropology, Washington State University, Pullman.
2011 Functional Variability in the Late Pleistocene Archaeological Record of Eastern Beringia: A Model of Late Pleistocene Land Use and Technology from Northwest Alaska. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 128–164. Texas A&M Press, College Station.

Reimer P. J., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E. Buck, H. Cheng, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, H. Haflidason, I. Hajdas, C. Hatté, T. J. Heaton, D. L. Hoffmann, A. G. Hogg, K. A. Hughen, K. F. Kaiser, B. Kromer, S. W. Manning, M. Niu, R. W. Reimer, D. A. Richards, E. M. Scott, J. R. Southon, R. A. Staff, C. S. M. Turney, and J. van der Plicht.
2013 IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4):1869–1887.

Reuther, Joshua D., Natasha Slobodina, Jeff Rasic, John P. Cook, and Robert J. Speakman
2011 Gaining Momentum: Late Pleistocene and Early Holocene Archaeological Obsidian Source Studies in Interior and Northern Eastern Beringia. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 270–286. Texas A&M Press, College Station.

Root, Mathew J.
1997 Production for Exchange at the Knife River Flint Quarries, North Dakota. *Lithic Technology* 22(1):33–50.

Rots, Veerle
2008 Hafting and Raw Materials from Animals: Guide to the Identification of Hafting Traces on Stone Tools. *Anthropozoologica* 43(1):43–66.

Rots, Veerle, and B. S. Williamson
2004 Microwear and Residue Analyses in Perspective: The Contribution of Ethnoarchaeological Evidence. *Journal of Archaeological Science* 31(9):1287–1299.

Rots, V., L. Pirnay, Ph. Pirson, and O. Baudoux
2006 Blind tests shed light on possibilities and limitations for identifying stone tool prehension and hafting. *Journal of Archaeological Science* 33(7):935–952.

Safford, L. O., J. C. Bjorkbom, and J. C. Zasada
1990 *Betula papyrifera* Marsh. Paper birch. In *Silvics of North America,* vol. 2, *Hardwoods. Agriculture Handbook 654*, Russell M. Burns and B. H. Honkala, technical coordinators, pp. 158–171. U.S. Department of Agriculture, Forest Service, Washington, DC.

Schiffer, Michael B.
1986 Radiocarbon and the "Old Wood" Problem: The Case of the Hohokam Chronology. *Journal of Archaeological Science* 13(1):13–30.

Shott, Michael J.
1994 Size and Form in the Analysis of Flake Debris: Review and Recent Approaches. *Journal of Archaeological Method and Theory* 1(1):69–110.

Steffensen, Jorgen Peder, Katrine K. Anderson, Matthias Bigler, Henrik B. Clausen, Dorthe Dahl-Jensen, Hubertus Fischer, Kumiko Goto-Azuma, Margareta Hansson, Sigfús J. Johnsen, Jean Jouzel, Valérie Masson-Delmotte, Trevor Popp, Sune O. Rasmussen, Regine Röthlisberger, Urs Ruth, Bernhard Stauffer, Marie-Louise Siggaard-Andersen, Árny E. Sveinbjörnsdóttir, Anders Svensson, and James W. C. White
2008 High-Resolution Greenland Ice Core Data Show Abrupt Climate Change Happens in a Few Years. *Science* 321(5889):680–684.

Stuiver, M., P. J. Reimer, and R. W. Reimer
2018 CALIB 7.1 [WWW program] at http://calib.org

Sullivan, Alan P.
1987 Probing the Sources of Variability: A Regional Case Study near Homolovi Ruins, Arizona. *North American Archaeologist* 8(1):41–71.

Sullivan, Alan P., and Kenneth Rozen
1985 Debitage Analysis and Archaeological Interpretation. *American Antiquity* 50(4):755–779.

Surovell, Todd Alexander
2009 *Toward a Behavioral Ecology of Lithic Technology Cases from Paleoindian Archaeology.* University of Arizona Press, Tucson.

Taylor R. E., and Ofer Bar-Yosef
2016 Radiocarbon *Dating: An Archaeological Perspective,* 2nd ed. Routledge, Taylor and Francis Group, London.

Thorson, R. M.
1986 Late Cenozoic Glaciation of the Northern Nenana River Valley. In *Glaciation in Alaska: The Geologic Record,* edited by T. D. Hamilton, K. M. Reed, and R. M. Thorson, pp. 171–192. Alaska Geological Society, Anchorage.

Titmus, Gene L., and James C. Woods
1986 An Experimental Study of Projectile Point Fracture Patterns. *Journal of California and Great Basin Anthropology* 8(1):37–49.

Torrence, Robin
1983 Time Budgeting and Hunter-Gatherer Technology. In *Hunter-Gatherer Economy in Prehistory: A European Perspective*, edited by G. Bailey, pp. 11–22. Cambrdige University Press, Cambridge.
2001 Hunter-Gatherer Technology: Macro- and Microscale Approaches. In *Hunter-Gatherers: An Interdisciplinary Perspective*, edited by Catherine Panter-Brick, Robert H. Layton, and Peter Rowley-Conwy, pp. 73–98. Cambridge University Press, Cambridge.

Ugan, Andrew, Jason Bright, and Alan Rogers
2003 When Is Technology Worth the Trouble? *Journal of Archaeological Science* 30(10):1315–1329.

Viau, A. E., K. Gajewski, M. C. Sawada, and J. Bunbury
2008 Low- and High-frequency Climate Variability in Eastern Beringia During the Past 25,000 Years. *Canadian Journal of Earth Sciences* 45(11):1435–1453.

Wahrhaftig, Clyde
1958 Quaternary and Engineering Geology in the Central Part of the Alaska Range. *U.S. Geological Survey Professional Paper 293*. U.S. Geological Survey, U.S. Government Printing Office, Washington, DC.

Whittaker, John C.
1994 *Flintknapping: Making and Understanding Stone Tools.* University of Texas Press, Austin.

Wolfe, J. A., and Clyde Wahrhaftig
1970 The Cantwell Formation of the Central Alaska Range. In *Changes in Stratigraphic Nomenclature by the U.S. Geological Survey, 1968*, edited by G. V. Cohee, R. G. Bates, and W. B. Wright, pp. A41–A46. U.S. Geological Survey Bulletin 1296-A. U.S. Government Printing Office, Washington, DC.

Wygal, Brian T.
2010 Prehistoric Upland Tool Production. *Alaska Journal of Anthropology* 8(1):107–119.
2011 The Microblade/Non-microblade Dichotomy: Climatic Implications, Toolkit Variability, and the Role of Tiny Tools in Eastern Beringia. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblages Variability in Late Pleistocene/Early Holocene Beringia*, edited by T. Goebel and Ian Buvit, pp. 234–254. Texas A&M University Press, College Station.

Wygal, B. T., and T. Goebel
2012 Early Prehistoric Archaeology of the Middle Susitna Valley, Alaska. *Arctic Anthropology* 49(1):45–67.