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The northern fluted point complex: technological and morphological evidence of adaptation and risk in the late Pleistocene-early Holocene Arctic

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Abstract Analyses of fluted point technology and Paleoindian technological risk have contributed to our understanding of human adaptation across North America in the late Pleistocene and early Holocene. However, poor chronological control has dissuaded similar studies of fluted points found in Alaska and northern Yukon and our understanding of their adaptive role in early arctic adaptations remains unclear. Two new archeological sites have provided reliable radiocarbon data and for the first time, a comprehensive analysis of northern fluted points is possible. Here, technological and morphological analyses of northern fluted points are presented, including variables statistically evaluated and compared to a collection of fluted Folsom artifacts serving as a reference. Variation in tool shape was measured using geometric morphometrics, and a new approach to landmark placement designed to characterize basal morphology and allow the analysis to include tool fragments is presented. Results confirm that northern fluted points represent a cohesive technological strategy and are used to formulate hypotheses suggesting its service as a risk-management system promoting ease-of-replacement-after-failure to offset transport costs and reduce risk during long-distance travel.

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Introduction

The hallmark archeological signature of Paleoindians, the first human cultures to spread throughout and occupy North America, is the proximally fluted lanceolate projectile point. Earliest examples are found south of the late Pleistocene ice sheets in archeological sites dating to as early as 13,200 calendar years before present (cal BP[1]) (Waters and Stafford 2007) and possibly earlier (Haynes et al. 2007). Early fluted point forms of the mid-continent were highly standardized, both morphologically and technologically, forming homogenous types throughout the Paleoindian era (approximately 13,200 to 9000 cal BP). Despite archeological evidence of more than 3000 years of extensive use, many researchers consider fluted point production to have been a technological risk, citing high rates of production failure in both archeological and experimental contexts (Flenniken 1978; Gryba 1988; Judge 1973; Sellet 2004; Sollberger 1985; Winfrey 1990; but see Ellis and Payne 1995) and high potential for such failure to waste valuable lithic supplies carried by highly mobile peoples (Torrence 1989). Various hypotheses have been developed to understand why Paleoindian groups prioritized production of fluted points, including ease of hafting (Judge 1973; Wilmsen 1974; Wilmsen and Roberts 1978), improved penetration and lethality (Crabtree 1966), increased durability (Hutchings 1997), and predictive failure (Bleed 1986) (see also Ahler and Geib 2000). Analyses of fluted point

[1] Oxcal v4.2.2 Bronk Ramsey (2013); r:5 Atmospheric data from Reimer et al. (2009).

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technology and Paleoindian technological risk have been further used to interpret mobility patterns and planning depth to better understand Paleoindian adaptive behavior across mid-continental North America (Bamforth and Bleed 1997; Binford 1977, 1980; Bousman 1993; Brantingham 2006; Ellis 2008; Kelly and Todd 1988; Rasic 2011; Sellet 2013; Shott 1986; Torrence 1989).

Much attention has been devoted to fluted point research in the mid-continent; in contrast, fluted points in northern Alaska and the northern Yukon have been understudied. Hence, we have little understanding of the adaptive role these weapon tips played among late Pleistocene-early Holocene human groups living in the far North's highly variable and extreme climates, let alone an appreciation of technological risk in this context. Although fluted points have been known from arctic North America for over 50 years, almost all have been found in questionable stratigraphic and surface contexts equivocally associated with chronometric evidence, so that they could not be confidently ascribed to the Paleoindian era. However, excavations at two new sites in northwest Alaska, Serpentine Hot Springs and Raven Bluff, have provided reliable evidence that fluted points were used at these sites between 12,400 and 12,000 cal BP (Goebel et al. 2013; Hedman 2010; Smith et al. 2013). The evidence recovered from these sites serves as a benchmark to establish the chronological context for the greater collection of northern fluted points, allowing us to define their cohesiveness as a technocomplex and contribute to our understanding of the technological risk assumed by North America's early inhabitants.

The goal of this paper is to determine whether the technology and morphology of northern fluted points found in Alaska and northern Yukon (Fig. 1) represent a homogenous technological adaptation meant to reduce technological risk in the late Pleistocene-early Holocene Arctic. To this end, a combination of technological and morphological analyses of northern fluted points is reported, with variables statistically evaluated and compared to a collection of Folsom artifacts that serve as a reference for a known technologically cohesive fluted point complex that dates to a similar time frame as the fluted point assemblages from Serpentine and Raven Bluff and is found in mid-continental North America (Frison and Bradley 1981, 1982).

Background: fluted point research in the Arctic

The historic difficulty of finding northern fluted point sites in dateable contexts is a consequence of northern Alaskan and Yukon environments, their past depositional histories, and contemporary sampling biases. Sites frequently consist of surface or shallowly buried palimpsests that resulted from a lack of windblown-sediment deposition or, in the case of prominent landforms and exposed settings, periodic or even permanent deflation (Clark and Clark 1993; Desrosiers 2007). Conversely, in buried contexts, moisture caused episodic solifluction throughout the Holocene, often resulting in mixed stratigraphy (Mann et al. 2002). Additionally, recurring forest fires often led to the incorporation of natural charcoal into archeological components, or a re-setting of obsidian-hydration rims on artifacts (Clark and Clark 1993). Compounding this is the remoteness of northern Alaska and Yukon, making access to these areas challenging and expensive. As a result, fluted point sites are often found during government-sponsored geological surveys or in conjunction with road or oil-pipeline construction projects. Frozen ground and snow cover allow for only short field seasons, and during summer months, the growing season is accelerated by 24 h of sunlight, quickly limiting ground visibility with thick tundra and boreal vegetation (Dixon 1993; Mann et al. 2002).

Fig. 1 Fluted points from Alaska and the northern Yukon included in the analysis. Serpentine Hot Springs: **a** BELA-38788/89, **b** BELA-50298, **c** BELA-49913, **d** BELA-30104, **e** BELA-34172, **f** BELA-34108, **g** BELA-39071 (BEN-170), **h** BELA-34230; Raven Bluff: **i** UA2010-100-001, **j** UA2009-136-121; Putu: **k** UA70-84-74, **l** UA70-84-73; Upper Noatak: **m** NOAT 23286, **n** NOAT 2588; Caribou Mountain South: **o** UA2006-084-0001; Teshekpuk Lake: **p** UA78-224-9, **q** UA78-224-1; Red Star Creek: **r** GAAR4063; Girls Hill: **s** UA74-027-6485, **t** UA74-027-1256, **u** UA74-027-0228; Hank's Hill **v** UA76-203-0001; Island Site: **w** UA71-83-564, **x** UA71-083-0373; Tinayguk River: **y** GAAR4072; Itkillik Lake: **z** UA76-307-0001; Lisburne: **aa** UA78-080-0633; Kikavichic Ridge: **bb** 70K-A4-1; Kipmik Lake: **cc** GAAR-4120; Batza Téna: **dd** RKIg-31:60, **ee** RKIg-47:13, **ff** RKIg-29:16, **gg** RKIg-43:1, **hh** RKIg-31:120, **ii** RKIg-30:321, **jj** RKIg-30:42, **kk** RKIg-10:36, **ll** RKIg-31:15, **mm** RKIg-01:49, **nn** RKIg-31:119, **oo** RKIg-30:254, **pp** RKIg-30:160, **qq** RKIg-30:323

The first Alaskan fluted point was found in 1947 on the surface of a high ridge during an expedition sponsored by the US Geological Survey (Thompson 1948). The ridge overlooked the Utukok River and had no other cultural remains (Solecki 1950). Two more fluted points were soon found along the Kugururok river; they, too, were discovered in surface contexts on a mountain pass of the Brooks Range (Solecki 1951). Other early fluted point surface finds included a distal tip from Anaktuvuk Pass in association with artifacts assigned to the late Holocene Denbigh flint complex (Solecki 1951; Solecki and Hackman 1951) and a basal fragment on a hill near the confluence of the Utukok River and Driftwood Creek, in association with what were thought to be fluted point blanks, channel flakes, and a large "blade industry", which Humphrey (1966:587) organized into the "Driftwood Creek Complex".

In the 1970s, an archeological survey along the proposed Trans-Alaska Pipeline led to the discovery of the first buried fluted point sites (Cook 1971; Hoffecker et al. 1993; Reanier 1995). The first of these was the Putu site, where a fluted point base was recovered on the surface of a high knoll overlooking the Sagavanirktok River valley. In 1973, Alexander (1987)


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conducted excavations at Putu, revealing a buried assemblage with a second fluted point base, non-fluted lanceolate points, unifacial scrapers on blades, gravers, burins, utilized flakes, cores, and more than 7000 pieces of debitage. Radiocarbon dates associated with the fluted point zone ranged from 12,751 to 6718 cal BP, suggesting that the cultural horizons were mixed (Alexander 1987; Bever 2006; Hamilton and Goebel 1999). Reanier (1994, 1996) returned to Putu in 1993 and obtained a radiocarbon date of 10,158–9631 cal BP, but this could not be associated with the fluted points. Soon thereafter, Holmes (1971) discovered the Island site on a knoll overlooking the Bonanza Creek valley. Shallow deposits produced multiple artifacts including six lanceolate projectile-point bases, two of which were fluted, but no associated dateable material (Holmes 1971; Reanier 1995). Similarly, at Girls Hill, located along the Jim River in the southern foothills of the Brooks Range, Gal (1976) found multiple fluted points in two localities, along with artifacts representing an array of time periods and no reliable chronological control (Dumond 1980).

At about the same time as the pipeline surveys, more than 18 fluted points, preforms, and manufacturing rejects were recovered from the Batza Téna obsidian source at the head of the Koyukuk Lowlands near Hughes (Clark and Clark 1980, 1983, 1993). Clark and crew discovered these at ten localities in either surface or shallowly buried contexts along with debitage and artifacts that ranged from late Pleistocene to historic in age, obviously in mixed palimpsests that could not be radiocarbon dated (Clark 1972; Clark and Clark 1993). Obsidian-hydration analysis also failed to provide usable chronological information (Hamilton and Goebel 1999).

Other more recently discovered undated finds include several fluted points from surface exposures near Teshekpuk Lake and Iteriak Creek in the National Petroleum Reserve (Davis et al. 1981) and the mid-section of a fluted point in a buried context at the Lisburne site (Bowers 1982). Like earlier finds, the ages of these points could not be established. In the early 1990s, Gal found three more fluted points on the surface near the Kugururok, Nimiuktuk, and Koyukuk rivers (Reanier 1995).

Fluted points have been found in the northern Yukon Territory as well. These include single-fluted basal fragments from the surface of Kikavichik Ridge, which overlooks the Old Crow plain (Irving and Cinq-Mars 1974) and the nearby Dog Creek site (Esdale et al. 2001). Dateable material could not be confidently associated with the fluted fragments at either site. At the Engigstciak site, located along the Firth River, a lanceolate point with a flute on one face was reported, but radiocarbon dates from the site were not clearly tied to the point (Cinq-Mars et al. 1991; MacNeish 1956), and the artifact no longer exists in the collection at the Canadian Museum of History.

Thus, despite 50 years of searching by the turn of the last century, no fluted point site had been found in the Arctic that could be dated, and poor contextual evidence made defining a complex of archeological assemblages impossible. There were, however, several unifying characteristics of northern fluted point sites. First, they were repeatedly found on promontory settings providing commanding views of watersheds and mountain passes (Ackerman 2001). Second, geographically, they were restricted to northern Alaska, ranging from near the Chukchi Sea coast to the Yukon Territory (Smith et al. 2013). Third, of course, they all came from problematic contexts.

This all changed in 2005, when Gal and crew discovered a fluted point base near Serpentine Hot Springs on the Seward Peninsula, Bering Land Bridge National Preserve. Initial testing led to the discovery of a channel flake associated with four radiocarbon dates on charcoal ranging from 12,376 to 11,353 cal BP (Young and Gilbert-Young 2007). A team led by Goebel returned in 2009–2011 to conduct block excavations, uncovering a buried fluted point assemblage associated with charcoal-rich features that contained hundreds of pieces of burned and calcined bone, identified as ungulate, likely caribou (Goebel et al. 2013). Radiocarbon (AMS) dating of charcoal produced a series of dates ranging from 12,400 to 9900 cal BP, and when considering only willow charcoal (ethnographically preferred as firewood instead of shrub birch or Ericaceae (Stefansson 1919; cited in Alix 2013), an age of 12,400–12,000 cal BP was inferred for the cultural deposit. Four fluted point bases were recovered in situ in association with the dated features, and two fluted point bases and a midsection were found in eroded blowouts nearby the buried component (Goebel et al. 2013). A fluted distal fragment was also recovered from the surface of a knoll, designated as BEN-170, approximately 1.5 km south of the Serpentine fluted point site.

A second significant fluted point discovery was made in 2007 at the Raven Bluff site, located along the Kivalina River in the western foothills of the Brooks Range (Hedman 2010). Eight radiocarbon dates between 12,131 and 11,102 cal BP from a buried cultural layer bracket a fluted point and associated materials that include faunal remains of primarily caribou (Smith et al. 2013), replicating the Serpentine finds. Analyses of archeological materials are in progress, but they include both a fluted point and a fluted point preform.

With the evidence from Serpentine and Raven Bluff, we now know that northern fluted points are late Paleoindian in age, dating to the end of the Younger Dryas and beginning of the Holocene. During this time, human groups in the Arctic contended with dynamic seasonal extremes, a mosaic of ecological settings exaggerated by variable terrain and proximity to retreating mountain glaciers, rising sea levels, and thinly dispersed resources with intermittent availability (Abbott et al. 2010; Anderson and Brubaker 1994; Bever 2012; Edwards et al. 2000; Elias et al. 2000; Lie and Paasche

2006; Mann et al. 2001; Oswald et al. 2003; see also Graf and Bigelow 2011). The Serpentine site represents a specialized field camp where weapons maintenance and hunting took place (Goebel et al. 2013). Local raw materials make up less than 4 % of the assemblage, and the remainder includes non-local, high-quality toolstones that originated hundreds of kilometers away. Some of the lithic materials from Raven Bluff are made on similar raw materials, which are available locally (i.e. the Kivalina River valley surrounding Raven Bluff) (Hedman 2010).

Despite the encouraging information learned from Serpentine and Raven Bluff, we still do not know if all of the fluted points found in northern Alaska and Yukon form part of a cohesive technological complex and whether they can be ascribed the same age range. We also do not understand the role fluted points played in late Pleistocene-early Holocene human adaptations in the Arctic, i.e., why early northern Alaskans fluted some of their lanceolate projectile points, especially given the high risk potentially involved in the fluting strategy.

Theoretical background

Technological risk

A promising avenue of inquiry regarding fluted projectile point use in the late-Pleistocene Arctic is assessment of risk and risk-management (Ahler and Geib 2000; Amick 1996; Bamforth and Bleed 1997; Binford 1977; Ellis and Payne 1995; Sellet 2004; Torrence 1989, 2001). Discussions of risk in hunter-gatherer research generally concern the possibility of groups encountering unpredictable problems (often in, but not limited to, subsistence pursuits) and degree of negative outcomes, which serve as a measure of "cost" (Bamforth and Bleed 1997; Torrence 1989). Bamforth and Bleed (1997) point out that heuristically, risk and risk management can be translated into concepts of "predictability" and "reliability" (Bamforth 1988; Hayden 1981; Lee 1968; Wilmsen 1973), with predictability serving as a key variable in group planning depth and mobility scheduling ("gearing up" or "tool maintenance/retooling/reloading" strategies), social relationships, and food storage (Binford 1977; Bousman 1993; Jodry 1999; Sellet 2004, 2013; Smith and Boyd 1990; Torrence 1989; Wiessner 1982). Reliability in technology reduces risk of tool failure, especially when such failure would accrue high costs in terms of tool breakage at times when repair or replacement is difficult or a subsistence opportunity is lost (Bamforth and Bleed 1997).

But what makes a tool reliable? Bleed (1986) suggests it is the ability to forecast or manipulate a tool's use-life by designing it to have high stress limits and, ultimately, guard against failure, i.e., breakage. Ahler and Geib (2000) suggest, however, that a maintainable tool is simultaneously reliable because it facilitates anticipated failure rates, fracture management, and rejuvenation protocol so that the tool can be *reliably* returned to functionality in the event of failure (see also Odell 2001). The production cost of both maintainable and reliable tools is the same, requiring similar raw-material reduction, transport, and time expenditures, but production and rejuvenation schedules vary. Ultimately, the ability to control this schedule is a form of risk-management. Early in tool production, risk can be reduced by making optimal technological choices that can be determined if factors are known, for example, prey type, encounter strategy, terrain type, armature type, and the distance from a raw-material source that a tool is intended to be used and/or repaired. Therefore, the question is, was fluting an optimal choice given specific factors experienced by Paleoindian groups?

Risk in high-latitude environments

The most significant characteristic experienced by high-latitude hunter and gatherers is seasonality, and during the late Pleistocene and early Holocene in Alaska and northern Yukon, seasonality was compounded, on a large scale, by environmental alteration (Kaufman and Manley 2004; Lie and Paasche 2006; Mann et al. 2001). The post-LGM retreat of glacial ice in the Brooks Range, coupled with rising sea levels along the arctic coast and in the Bering, Beaufort, and Chukchi seas, led to fluctuations in the amount of effective moisture on the landscape, in turn affecting soil stability (Abbott et al. 2010; Elias et al. 2000; Guthrie 2001; Lie and Paasche 2006; Mann et al. 2001; Meyer et al. 2010; see also Graf and Bigelow 2011). As a result, Alaska and northern Yukon consisted of a fluctuating mosaic of vegetative zones causing resources to be highly dispersed spatially and seasonally and to fluctuate in availability (Anderson and Brubaker 1994; Edwards et al. 2000; Hoffecker 2002; Oswald et al. 2003). Adaptive challenges in high-latitude, pre-boreal, cold environments involved reduced availability and variability of plant foods and woody resources and higher caloric demands for humans, emphasizing a dependence on typically mobile animal resources for protein, fat, building materials, clothing, and fuel (Hoffecker 2002; Oswalt 1976; Rhode et al. 2003). Solutions to these environmental challenges involved increased foraging mobility and more complex and efficient tools to manage the risk created by the lack of less optimal, or lower-ranked, alternative resources to provide basic human necessities: heat, clothing, shelter, and food (Hoffecker 2002; Oswalt 1976; Torrence 1983). While potentially generalists, early arctic and sub-arctic fluted point makers appear to have been limited to a narrow ecological niche (Gillam et al. 2007; Waguespack and Surovell 2003), making a failed kill detrimental on multiple levels and recovery after tool failure challenging between such temporally and spatially dispersed resources.

Technological choice in the late Pleistocene-early Holocene Arctic

During the terminal Pleistocene and earliest Holocene of Alaska and northern Yukon, contemporaneous groups used variable complex weapon systems that involved slotted osseous and microblade technologies as well as lithic bifacial technology. The different technological schemes and risk-management strategies possibly resulted from different cultural groups, but other factors of variability may have included the arrangement of prey type, encounter strategy, terrain type, and raw-material availability experienced by different groups or during different seasons, as well as successive adaptive responses to alteration in resource distribution resulting from climate change (Dixon 1985; Dumond 2001; Goebel et al. 1991; Hoffecker 2001; Holmes 2001; Kunz et al. 2003; Potter 2011; Powers and Hoffecker 1989; Rasic 2011; Wygal 2011).

In northern Alaska and Yukon, regionally associated with northern fluted point localities, there are two bifacial projectile-point industries characterized by non-fluted lanceolate varieties known as Mesa and Sluiceway. Research conducted by Bever (2000) and Rasic (2008) provided the first comprehensive studies of these complexes. Bever noted that Mesa sites were often located near sources of high-quality raw materials and contained abundant evidence of bifacial core production but simultaneously a high degree of tool maintenance in the form of lateral edge rejuvenation. From this evidence, he inferred high residential mobility and logistical gearing-up strategies to combat unpredictability of faunal resources during encounter hunting (see also Bever 2008). This tactic reflects a replace-before-failure, or reliable, strategy of risk-management that may have ensured adequate performance when failure-to-procure costs were high (Bamforth and Bleed 1997; Kuhn 1989; Torrence 2001). Likewise, Rasic (2008) found that Sluiceway sites were often located near sources of high-quality toolstone, but they functioned as places of gearing-up for intercept hunting, with weapons maintenance often consisting of resharpening. According to Rasic (2008), risk-management strategies associated with the Sluiceway complex included communal involvement in intercept hunting, the production and transport of preforms, and, again, complementary to Mesa, a reliable tool design.

Late Pleistocene-early Holocene hunters at Serpentine focused maintenance efforts on fluting and resharpening projectile points hundreds of kilometers away from sources of high-quality knappable materials (Goebel et al. 2013). At Raven Bluff and Batza Téna, sources for quality toolstone were nearby and behaviors there included preform manufacture, demonstrating, similar to Mesa and Sluiceway, primary production occurring close to a raw material source coupled with long-distance movement and maintenance (Smith et al. 2013). Since fluting is a method of basal thinning, classically considered to have been a high-risk endeavor, with evident failure rates during production ranging from 30 to 50 % in both experimentation (Flenniken 1978; Gryba 1988; Sollberger 1985; Winfrey 1990) and archeological contexts (Judge 1973; Sellet 2004; Winfrey 1990; but see Ellis and Payne 1995), it appears incongruous for fluting to have taken place at Serpentine. Management solutions for such technological risk have hypothetically involved easy access to raw materials, existence of specialist producers, lowered transport costs, or risky production taking place only at the very beginning or end of a recycling system (Bamforth and Bleed 1997; Sellet 2004). At Serpentine, easy access to raw materials and risky production only at the beginning or end of a recycling system was not observed, suggesting potential for alternative solutions or consideration of risk.

The sample of known fluted points from Alaska and Yukon, combined with the assemblage-level evidence from Serpentine, presents a unique opportunity to investigate risk involved in using fluting technology in the late Pleistocene and earliest Holocene Arctic by evaluating evidence for the above-mentioned risk management solutions in northern fluted point technology, morphology, and provenance at a regional scale. Set within a technological organization context, the analysis presented here considers whether extreme effectiveness, maintainability, and transportability incorporated into the Alaskan fluted point production system may have outweighed anticipated failure rates and transport costs (Ahler and Geib 2000; Bleed 1986; Guthrie 1983). Alternatively, it is possible that modern perceptions of risk from fluting failure are ill-conceived, as we project situational bias in the form of our own difficulties in fluting experiments, or misinterpret archeological evidence regarding the actual impact of fluting failure on technological costs (Ahler and Geib 2000; Crabtree 1966; Ellis and Payne 1995). With this in mind, the hypothesis tested here is twofold: (1) northern fluted points comprise a cohesive point form, technologically representing a single reduction strategy that was (2) used to create a maintainable tool that minimized risk of tool-failure far from raw-material sources in the late Pleistocene-early Holocene Arctic.

Materials and methods

Technological and morphological analyses were performed on 51 fluted artifacts from 17 Alaskan and Yukon sites, consisting of basal, medial, distal, and corner fragments, as well as whole fluted points (Table 1 (a), Fig. 2). Nineteen of the 51 fluted points/fragments were suitable for geometric morphometric shape analysis. Data from 46 Folsom points

Table 1 Artifacts included in the analysis

Site	Artifact	Fragment type
a. Northern fluted		
Serpentine fluted point site	BELA-34166	Distal
Serpentine fluted point site	BELA-30104	Proximal
Serpentine fluted point site	BELA-34172	Proximal
Serpentine fluted point site	BELA-38788/89[a]	Proximal
Serpentine fluted point site	BELA-34108	Medial
Serpentine fluted point site	BELA-50298[a]	Proximal
Serpentine fluted point site	BELA-49913[a]	Proximal
Serpentine fluted point site	BELA-34230	Corner
BEN-170	BELA-34561	Distal
Batza Téna	RkIg-43:1	Proximal
Batza Téna	RkIg-29:16[a]	Proximal
Batza Téna	RkIg-10:36	Proximal
Batza Téna	RkIg-01:49	Medial
Batza Téna	RkIg-47:13	Proximal
Batza Téna	RkIg-31:120[a]	Proximal
Batza Téna	RkIg-31:15[a]	Proximal
Batza Téna	RkIg-31:60[a]	Whole
Batza Téna	RkIg-31:119	Medial
Batza Téna	RkIg-30:42	Proximal
Batza Téna	RkIg-30:160	Lateral margin
Batza Téna	RkIg-30:254	Lateral margin
Batza Téna	RkIg-30-321	Proximal
Batza Téna	RkIg-30:323	Corner
Batza Téna	RkIg-30:247	Distal
Girls Hill	UA74-027-0228[a]	Proximal
Girls Hill	UA74-027-1256	Whole
Girls Hill	UA74-027-6485[a]	Whole
Hank's Hill	UA76-203-0001	Proximal
Lisburne	UA78-080-0633	Medial
Teshekpuk Lake	UA78-224-1[a]	Proximal
Teshekpuk Lake	UA78-224-9[a]	Corner
Itkillik Lake	UA76-307-0001	Distal
Caribou Mountain South	UA2006-084-0001	Proximal
Raven Bluff	UA2009-136-121[a]	Proximal
Raven Bluff	UA2010-100-001	Proximal
Raven Bluff	UA2010-100-002	Medial
Raven Bluff	US2010-100-003	Distal
Putu	UA70-84-74[a]	Proximal
Putu	UA70-84-73[a]	Proximal
Kipmik Lake	GAAR-4120	Lateral
Red Star Creek	GAAR4063[a]	Distal
Tinayguk River	GAAR4072	Proximal
Island site	UA71-083-0373	Whole
Island site	UA71–83-564	Proximal
Upper Noatak	NOAT 23286[a]	Proximal
Upper Noatak	NOAT 2588	Proximal

Table 1 (continued)

Site	Artifact	Fragment type
Driftwood Creek (Utukok River)	391806[a]	Proximal
Driftwood Creek (Utukok River)	423535[a]	Whole
Driftwood Creek (Utukok River)	423534[a]	Proximal
Driftwood Creek (Utukok River)	"#A"	Proximal
Kikavichic Ridge[c]	70K-A4-1	Proximal
b. Folsom		
Agate Basin	OA093[a]	Proximal
Agate Basin	Refits 96506, 96508, 96509, OA285	Proximal
Agate Basin	96507[a]	Whole
Agate Basin	OA085	Whole
Agate Basin	OA059[a]	Whole
Agate Basin	OA112[a]	Whole
Agate Basin	96,533	Proximal
Agate Basin	OA175	Proximal
Agate Basin	refits 96544, OA016	Distal
Agate Basin	OA020	Proximal
Hanson	Refit 95290, 9528[a]	Proximal
Hanson	Refit 95267, 95268	Proximal
Hanson	95424[a]	Proximal
Hanson	refit 95461, 95450[a]	Proximal
Hanson	95456[a]	Proximal
Hanson	95478	Proximal
Barger Gulch	LJ490-17-126[a]	Proximal
Barger Gulch	No number[a]	Proximal
Barger Gulch	LI490-5-387[a]	Proximal
Barger Gulch	No number[a]	Proximal
Barger Gulch	No number[a]	Proximal
Barger Gulch	Refit LI490-3-167, LJ490-14-67[a]	Proximal
Barger Gulch	Li490-4-44[a]	Proximal
Barger Gulch	LJ487-3-2[a]	Proximal
Barger Gulch	LJ490-24-472	Proximal
Barger Gulch	LJ488-3-68[a]	Proximal
Barger Gulch	LJ490-24-334	Proximal
Barger Gulch	LI490-4-343[a]	Proximal
Barger Gulch	LI491-2-82[a]	Proximal
Barger Gulch	LJ490-23-169[a]	Proximal
Krmpotich	48SW9826-13[a]	Proximal
Krmpotich	48SW9826-4[a]	Proximal
Krmpotich	48SW9826-6[a]	Proximal
Krmpotich	48SW9826-7	Proximal
Krmpotich	48SW9826-1	Proximal
Krmpotich	Refit 48SW9826-3, 48SW9826-2[a]	Proximal
Krmpotich	A576745[a]	Proximal

Table 1 (continued)

Site	Artifact	Fragment type
Hell Gap	A6258[a]	Proximal
Hell Gap	47195[a]	Proximal
Hell Gap	47192[a]	Proximal
Hell Gap	46606	Proximal
Hell Gap	47196[a]	Proximal
Hell Gap	47193[a]	Proximal
Hell Gap	46530[a]	Proximal
Hell Gap	UWI-342	Proximal
Hell Gap	46531	Distal
Lindenmeier	440281[b]	Proximal
Lindenmeier	440420[b]	Whole
Lindenmeier	441017[b]	Proximal
Lindenmeier	441560[b]	Proximal
Lindenmeier	442795[b]	Whole
Lindenmeier	442839[b]	Proximal
Lindenmeier	443437[b]	Proximal
Lindenmeier	443844[b]	Proximal
Lindenmeier	A576741[b]	Whole
Lindenmeier	A576742[b]	Whole
Lindenmeier	A576743[b]	Whole
Lindenmeier	440777[b]	Whole

[a] Artifact also used in geometric morphometric analysis

[b] Artifact only used in geometric morphometric analysis

[c] Site located in northern Yukon, Canada

from seven archeological sites were included in the technological and morphological analyses, and data from 43 Folsom points were used in the geometric morphometric analyses to facilitate comparison to a known highly standardized technological complex. While a variety of homogeneous point assemblages could be used for comparison, we chose to use Folsom, in particular, because this complex (1) occurs archeologically within a geographic area of similar size to that of the northern fluted point sites, (2) dates to a post-Clovis Paleoindian time frame like Serpentine and Raven Bluff, and most importantly, (3) is characterized by a similar technology: fluting. This technological trait may represent either adaptation to similar ecological pressures or a phylogenetic signal of a widely dispersed Paleoindian technology. Ultimately, the common use of fluting to facilitate basal thinning in Folsom and northern fluted points provides the potential for overlap in morphology, technology, and shape, and increases our level of scrutiny in determining whether northern fluted points represent the development of a separate and cohesive technology (see Collard et al. 2010; Frison 1991; Frison and Bradley 1981, 1982) (Table 1 (b), Fig. 2). Due to variable breakage patterns, no specimen was eligible for all analytical procedures, but each contributed to the analysis in some way.

Data acquisition

Nominal technological attributes and count data included raw-material type, presence/absence of fluting, number of flute scars per face, fluting sequence, flake-scar pattern, frequency of marginal retouch after fluting, edge abrasion or grinding (identified as slight reduction of mass and asperities at margins), breakage pattern/fracture type, and cross-section shape (following Adams 2002; Ahler and Geib 2000; Andrefsky 2005, 2009; Gryba 2006; Inizan et al. 1999; Jennings 2013; Miller and Smallwood 2012; Titmus and Woods 1986). Two-dimensional high-resolution digital photographs of each artifact in planview were also taken with a Nikon D5100, for use in geometric morphometric shape analysis.

A variety of metric attributes and ratios were recorded for each specimen to infer manufacturing technique, artifact function, and point typology. These included maximum length, width, and thickness, width and thickness at 5-mm intervals from the proximal edge (FPE), basal concavity depth, maximum fluted-area width, edge angle, and width of dominant flute in 5-mm intervals FPE (Andrefsky 2005; Beck and Jones 2007; Bamforth and Bleed 1997; Hamilton and Goebel 1999; Morrow 1995; Morrow and Morrow 1999; O'Brien et al. 2001). The dominant flute was defined as the most unobstructed channel flake scar on each face, which usually represented the last flute removed and often the medial flute.

To evaluate whether northern fluted point technology served to minimize risk in the late Pleistocene-early Holocene Arctic, the qualities of reliability and maintainability were determined by assessing point function and patterns of rejuvenation and resharpening. Fluted point function was observed, specifically, by assessing fracture type, variation in fragment metrics, and hafting evidence in terms of edge-grinding (abrasion) and cross-section shape. Patterns of rejuvenation and resharpening were evaluated by identifying patterns of flute and flake scar removal according to fragment type and variation in basal concavity shape and depth. General characteristics of site type were also considered during evaluation of potential risk factors and risk-management solutions.

Statistical analyses

Frequencies of qualitative data (e.g. raw-material type, fluting presence and number of flutes, cross-section shape, presence of edge abrasion, presence of marginal retouch after fluting, breakage pattern), and quantitative data (e.g. average edge angle per fragment type) were used to assess trends in technology used to create northern fluted points. To test the hypothesis that northern fluted points represent a cohesive and standardized technological complex, this analysis also considered the coefficient of variation (CV) of a series of metric

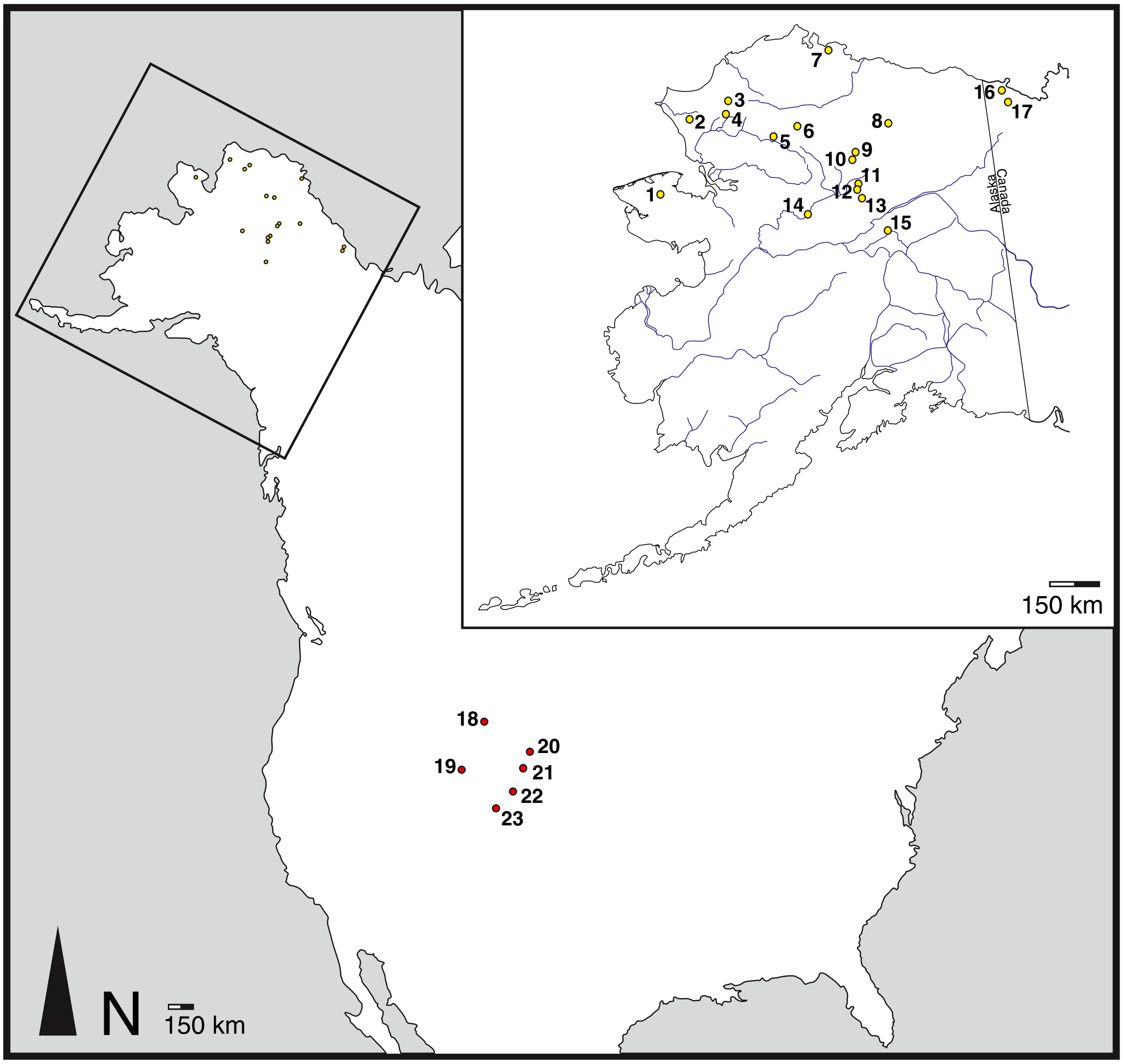


Fig. 2 Map showing the location of northern fluted point and Folsom sites mentioned in text. *1* Serpentine Hot Springs (BEN-192 and BEN-170), *2* Raven Bluff, *3* Driftwood Creek (Utukok River), *4* Upper Noatak, *5* Kipmik Lake, *6* Lisburne, *7* Teshekpuk Lake, *8* Putu, *9* Redstar Creek, *10* Tinayguk River, *11* Girls Hill, *12* The Island, *13* Caribou Mountain South, *14* Batza Téna, *15* Hank's Hill, *16* Engigstciak, *17* Kikavichik Ridge, *18* Hanson, *19* Krmpotich, *20* Agate Basin, *21* Hell Gap, *22* Lindenmeier, *23* Barger Gulch

variables, including fragment length, width, and thickness, both overall and in 5-mm increments, basal concavity depth, pooled standard deviation of dominant flute width in 5-mm increments, and ratio of basal concavity depth to basal width. As a unit of measure, CV can efficiently evaluate standardization of artifact morphology between samples of unequal and small sizes (Eerkens 1998, 2000; Eerkens and Bettinger 2001; Okumura and Araujo 2014), and when taken at uniform locations on artifacts, CV can inform on whether specimens were created to adhere to strict morphological or metric parameters. We acknowledge that the fluted points in this study entered the material record in late stages of their use-lives; however, despite the alteration in their original morphology, or "Frison effect" (see Jelinek 1976:22, Jelinek 1977), we assume that tools were reduced using a sequence of deliberate retouch so that throughout use-life, tools continued to meet certain functional criteria, e.g. fitting a pre-made hafting mechanism, making their morphology at time of discard still meaningful. Moreover, while tool form in discarded context will differ from that of its systematic context, this study aims to understand the meaning of homogeneity in discarded forms. Given that CVs report distributions around means, they can be compared on an attribute-by-attribute basis and assessed for magnitude in a comparative framework, in this case between northern and Folsom fluted points.

The D'AD statistic was used to test for differences in relative magnitude of variance among groups, i.e., whether CVs differed significantly among *k* populations (Feltz and Miller 1996). In particular, D'AD statistics helped determine whether measured variables in northern fluted points were more or less homogeneous than those in Folsom points and whether raw-material variability impacted tool morphology within and between groups (following Eerkens and Bettinger 2001). If specific tool dimensions of northern fluted points are not generally more variable than Folsom, we predict that, like Folsom, northern points were manufactured to meet specific morphological parameters, supporting the hypothesis of a technologically and morphologically homogenous northern fluted point complex.

Regression analysis was used to identify correlations between basal concavity depth and fragment width, thickness, and average fluted-area width for both northern and Folsom fluted points. Kruskal-Wallis analysis was used to identify morphological patterns in point width and thickness measured in 5-mm increments and thickness of proximal and distal fragments.

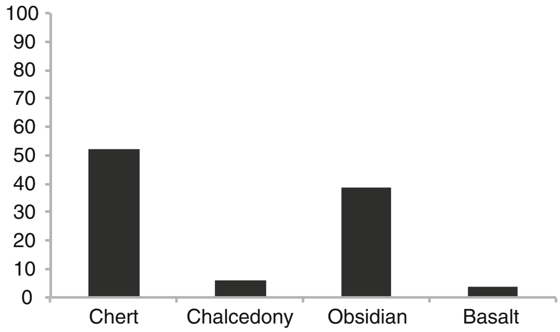
Geometric morphometric analyses and isolating basal morphology

Geometric morphometric shape analysis was used to assess morphological variation in fluted point basal fragments from sites across northern Alaska in comparison with Folsom point fragments. The use of only basal fragments posed a new challenge to outline evaluation using a landmark-based approach to tool shape. Previous analyses of outline shape using landmarks have often been limited to whole artifacts with three major landmarks—the distal tip and two basal corners—which served as homologous landmarks in Procrustes superimposition to align specimens horizontally along the X-axis in a Cartesian coordinate system (Buchanan 2006; Buchanan and Collard 2007, 2010; Buchanan et al. 2011; Gonzalez-Jose and Charlin 2012; Smith 2010; Smith et al. 2014; Thulman 2012). Procrustes superimposition rotates, aligns, and centers each configuration of an artifact's landmark data in a common coordinate system to facilitate geometric analysis and remove nuisance variation that results from differences in artifact orientation, location, and scale in the original photographs or scans (Bookstein 1991; Rohlf and Slice 1990; Zelditch et al. 2004).

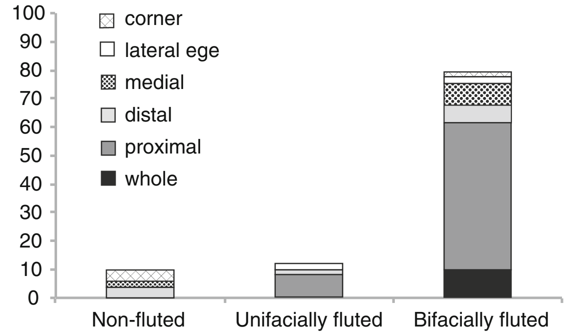
Without the distal tip to serve as the third full-rank landmark to align the conformations along their long axis, basal fragments must instead be aligned along their length by a different means. We accomplished this by digitizing tools, positioned horizontally with basal margin to the left in digital photographs, using tpsDig2 (v. 2.12) to place a constellation of semi-landmarks along each artifact's perimeter (Rohlf 2008a). Semi-landmarks along the distal breaks were then deleted to form a uniformly straight edge at the distal end. To produce horizontal alignment of the broken outlines, we performed a sequential balancing procedure as follows. First, a regression line was fitted to the semi-landmarks assigned to the top lateral margin. The semi-landmark constellations were then rotated to the regression angle to achieve a more horizontal position. The regression angles of the top and bottom lateral margins were then calculated and the outline was rotated to the average angle. We found that two rotations were enough to produce homogeneous slopes for the lateral edges, so that further iterations of rotation made only vanishingly small differences in final outline orientations. To standardize the length of the top and bottom lateral edges, the outlines were restricted to 13 mm FPE, and points in excess of this were deleted. Finally, landmark constellations were reduced to a suite of 120 type II semi-landmarks that consisted of outlines made of 30 equidistant type II semi-landmarks assigned to each lateral margin, and 60 equidistant type II semi-landmarks assigned to the basal margin. The resulting semi-landmark density was more than sufficiently saturated to capture tool shape differences. The excess of shape information was reduced by calculating principal components and discarding null and minor vectors. Five principal components (PCs) were found to summarize 93.36 % of total variation in the Alaska/Yukon points, six PCs summarized 95.33 % in the Folsom points, and seven PCs summarized 95.90 % in the combined northern and Folsom point dataset.

Fig. 3 Frequency diagrams of qualitative data. **a** Frequency (%) of fluted point raw material (n = 61). **b** Frequency of unifacially and bifacially fluted points. **c** Frequency (%) of the number of flutes (n = 85 faces) on fluted point faces. **d** Frequency (%) of flute removal sequences (n = 81 faces). **e** Frequency (%) of lateral (gray, n = 45) and basal (black, n = 37) margin retouch after fluting. **f** Frequency (%) of edge grinding (n = 51). **g** Frequency (%) of cross-section shape (n = 47). **h** Frequency of fracture type (n = 47)

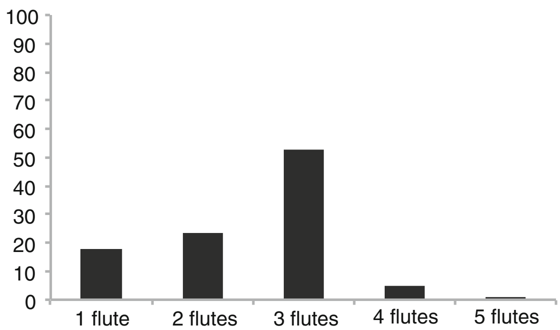
A landmark-based approach was desired in this analysis because it allowed the analyst to define the location of each landmark in a manner comparable across all artifacts in the sample and therefore, to capture the geometry of fragment shape similarly for all tools. For example, although no mechanically meaningful positions were identifiable along the lateral margin of projectile points in this sample, important variability in lateral margin shape was recorded by placing a uniform number of equidistant landmarks between the topologically proximal- and distal-most points on the lateral margins of each artifact. The location and number of each landmark were discrete in that each represents a location that explains shape at a relative percentage of the standardized length of the margin from the uniform topological position on each specimen (e.g. point no. 10 counting toward the distal end represents 33.33 % of the lateral margin) and corresponds to a point at the same location (33.33 % of the lateral margin) on all comparative specimens resulting in equal spatial and proportional intervals. This method was preferred to sliding semi-



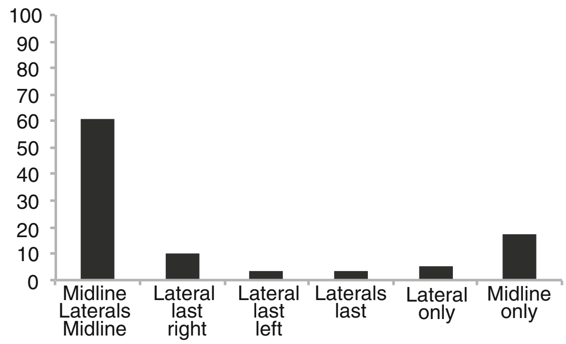
a Frequency (%) of fluted-point raw material (n=51).



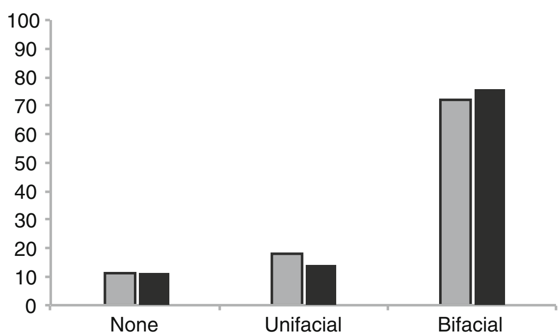
b Frequency (%) of unifacially and bifacially fluted points.



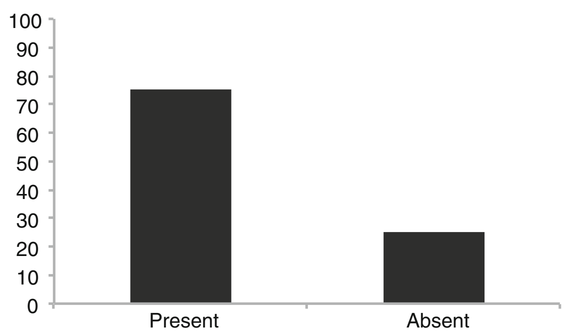
c Frequency (%) of number of flutes on (n=85) fluted-point faces.



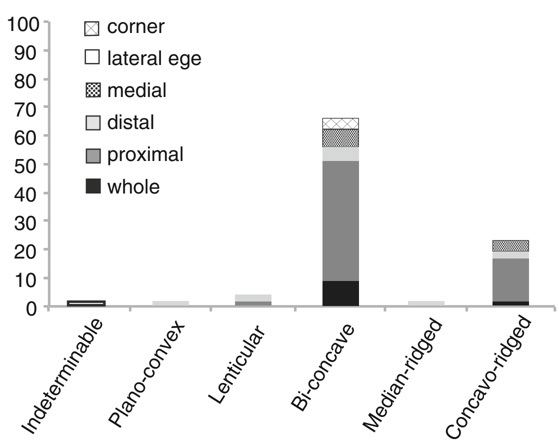
d Frequency (%) of flute removal sequences (n=81 faces).



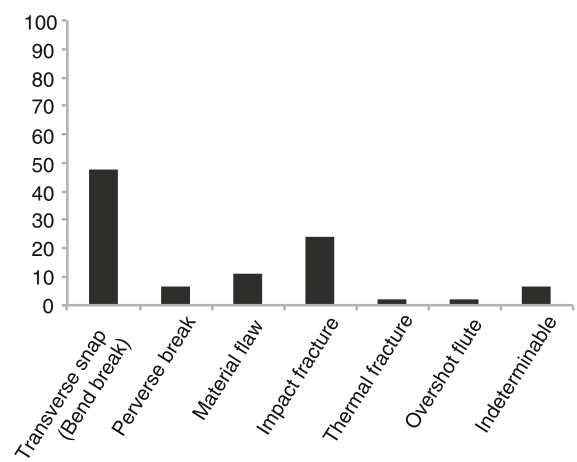
e Frequency (%) of lateral (gray, n=45) and basal (black, n=37) margin retouch after fluting.



f Frequency (%) of edge grinding (n=51).



g Frequency (%) of cross-section shape (n=47).



h Frequency (%) of fracture type (n=47).

landmarks, where landmark positions are adjusted to match the positions of corresponding landmarks on a reference specimen, which in the case of a curve, may result in landmark-placement error (Adams et al. 2004). This analysis took specific advantage of the proportionally equidistant placement of semi-landmarks to describe the curve of an artifact's margin.

Generalized least-squares Procrustes superimposition (generalized Procrustes analysis) was conducted in tpsRelw (v. 1.45, Rohlf 2008b) to superimpose the constellations of corresponding semi-landmarks (Rohlf and Slice 1990), translating each semi-landmark constellation to the same centroid location, scaling each constellation to the same centroid size, and iteratively rotating each constellation until the summed squared distances between the semi-landmarks and mean semi-landmark position was minimized (Bookstein 1991; Mitteroecker et al. 2013; Rohlf 1999). Superimposed semi-landmark constellations (Procrustes shape coordinates) were subjected to principal component (PC) analysis, and resulting PC scores summarizing 93–96 % of total variation were used to represent shape of the basal fragments (Adams et al. 2004, 2013; Bookstein 1991; Mitteroecker et al. 2013). Centroid size, the square root of the summed squared distances between all semi-landmarks to their common centroid, served as an unbiased size variable (Bookstein 1991) in analyses of shape and form (e.g. Smith et al. 2014).

Principal components of shape variation were also used to visualize shape characteristics that represent the major factors of variability in the sample of northern fluted and Folsom-point basal fragments and the combined samples of northern fluted and Folsom point fragments. Multivariate analysis of variance (MANOVA) was used to test models of morphological homogeneity by testing variation in shape and form among artifacts organized by Folsom sites and northern regions (with solitary contexts of northern fluted point finds being consolidated into four regions: Seward Peninsula, western Brooks Range, central Brooks Range, and the coastal plain), complexes (consisting of the proposed northern fluted complex and Folsom complex), and Folsom sites/northern regions nested within complex to test for within site/region structuring in shape variation. As is common in biological morphometrics, shape analysis used size as a covariate to characterize and statistically control for linear allometry, whereas form analysis included both size and shape as dependent variables (e.g. de Ruiter et al. 2013; Ruehl and DeWitt 2007). Statistical analyses were conducted using JMP software version 10 (SAS Inst. Inc., Cary, NC), and effect strengths (η_p^2) were calculated from JMP output (E & H matrices).

Results

Non-metric results

Frequency diagrams of observational data are provided in Fig. 3a–h. The northern sample is dominated by chert and obsidian, although there are three artifacts made from chalcedony and two from basalt (Fig. 3a). Overall, the northern fluted point sample is made of only high-quality, fine-grained raw materials. Forty-six of fifty point fragments are fluted on at least one face, and the four lacking flutes on one side include a reworked lateral fragment, one distal fragment, and two corner fragments (Fig. 3b). If complete, all of these could have been fluted bifacially. Among the northern fluted point specimens, 53 % of faces had three adjacent flute-removal scars, followed by 24 % with two adjacent flute-removal scars (Fig. 3c). Seventeen percent of flute faces have a single flute scar down the midline of the long axis. It should be noted that five of the nine single-fluted artifacts are distal and medial fragments. Sequence of flute-scar removals was observable on 81 artifact faces, and in over 60 % a primary medial (along the midline of the long axis) flute was removed first, followed by two lateral flutes and then a final medial flute was removed, and in 22 % a lateral flute was removed at the end of the flute-removal sequence (Fig. 3d).

Eighty-seven percent of northern fluted point fragments have evidence of some degree of marginal retouch after fluting (Fig. 3e). No marginal retouch after fluting was recorded on seven fragments, four of which are distal fragments, and one is a "preform" found at the Raven Bluff site. Eighty percent of fragments have marginal grinding in the proximal area suggesting preparation for hafting (Fig. 3f).

Cross-section shape demonstrates two major types of face preparation: bi-concave, resulting from channel flakes removed from both artifact faces, identified predominantly on basal fragments, and medial ridges remaining on one or both artifact faces creating shapes such as concavo-ridged, median-ridged, and lenticular, identified predominantly on distal fragments and whole points (Fig. 3g). The difference in cross-section shape between the base and the blade portion of the northern artifacts was a noticeable pattern. However, three basal fragments from Girls Hill (UA-74-27-228), Batza Téna (RkIg-31:15), and the Upper Noatak River (Noat 2588) have lenticular to median-ridged cross-sections, flute-removals from only one face, and relatively shallow basal concavities, which are atypical of the remaining 26 proximal fragments included in the cross-section shape analysis.

Breakage patterns were also observed on all non-corner fragments (Fig. 3h). Almost 50 % of the collection broke as a result of a transverse snap or bend-break fracture, followed by 24 % that have evidence of impact fractures. Only 11 % broke along planes of raw-material impurities, and 9 % consist of one thermally fractured artifact, one distal fragment that was detached by a hinge fracture from a failed fluting attempt, and three artifacts with indeterminable fractures.

Univariate metric results

Comparing distributions of width and thickness

A subsample (n = 29) of proximal fragments was used to observe variability in tool dimensions of northern fluted points (Table 2). There was little variation in maximum thickness and width measurements, with notably less dispersion around mean thickness and mean width (thickness CV = 17.15 %, width CV = 10.95 %) than mean length (CV = 31.97 %). Measurements of maximum length included both fragmented and whole points and, as a presumably more random factor, were compared to maximum width and thickness to demonstrate the difference in variance that may occur between morphological measurements fitting specific parameters and those resulting from variable breakage at time of discard. A similar pattern is apparent in the CVs generated for these measurements in the Folsom sample (n = 44). When considering basal fragments only, variability around mean fragment length decreased slightly in both samples. According to the D'AD statistic, CVs generated for fragment length in northern and Folsom points differed significantly, suggesting that variability around mean fragment length was greater in Folsom relative to northern points (p = 0.03). This may suggest a distinct breakage pattern due to hafting differences between the two assemblages; however, the difference in CVs generated for fragment length in northern and Folsom points was no longer significant when only chert artifacts were considered (p = 0.12).

Width and thickness were measured in 5-mm increments FPE, requiring a reduction in the sample as the analysis progressed to 25 mm FPE. Variability around mean width at 0 mm FPE in the northern sample (effectively the base of the point) was 37.21 %, indicating significantly more variation than in the Folsom sample (8.63 %). In the Folsom sample, variation around mean width between 5 and 20 FPE ranged from 8.74 to 11.26 % and remained fairly constant to 25 mm FPE (14.81 %). Relative standard deviations around the mean remained low, from 5 to 20 mm FPE in the northern sample as

Table 2 Relative variability in tool dimensions measured on northern fluted and Folsom complex points and point fragments

Variable	NFC[a] CV	Folsom CV	NFC mean	Folsom mean	NFC std dev	Folsom std dev	NFC n=	Folsom n=	D'AD *p* value
Thickness (max)	17.15	16.92	4.79	4.72	0.82	0.80	23	43	0.96
Width (max)	10.95	15.95	22.78	23.85	2.49	3.81	23	43	0.06
Length (max)	31.97	50.60	23.00	37.28	7.35	18.86	25	44	0.05
Length (bases only)	31.63	50.12	24.40	34.52	7.72	17.30	30	39	0.03
Basal width	37.21	8.63	18.31	18.36	6.81	1.58	19	38	0.00
Width 5 mm FPE	11.34	8.74	21.30	19.75	2.41	1.73	25	40	0.16
Width 10 mm FPE	9.84	9.10	21.80	21.15	2.15	1.93	24	42	0.67
Width 15 mm FPE	12.52	9.71	22.17	22.31	2.78	2.17	20	38	0.19
Width 20 mm FPE	17.01	11.26	21.19	23.29	3.60	2.62	17	29	0.06
Width 25 mm FPE	31.01	14.81	17.88	23.56	5.54	3.48	9	22	0.01
Basal thickness	20.62	18.35	1.49	1.36	0.31	0.24	25	39	0.39
Thickness 5 mm FPE	18.70	15.33	3.39	2.74	0.63	0.42	27	40	0.29
Thickness 10 mm FPE	15.08	12.16	4.39	3.77	0.66	0.46	27	40	0.24
Thickness 15 mm FPE	15.84	11.16	4.80	4.28	0.76	0.48	24	36	0.07
Thickness 20 mm FPE	15.81	12.43	5.16	4.47	0.82	0.55	18	27	0.24
Thickness 25 mm FPE	21.28	10.06	5.21	4.64	1.11	0.47	13	21	0.00
Basal concavity depth	39.90	41.05	4.39	4.13	1.75	1.70	29	40	0.87
Basal depth/Basal width	25.96	36.16	0.23	0.22	0.06	0.08	22	36	0.14
Pooled std. dev. of dominant flute	27.41	22.48	1.05	1.10	0.29	0.25	29	29	0.33
Edge angle 5 mm FPE	16.46	19.39	63.62	57.91	10.47	11.23	73	91	0.31
Edge angle 10 mm FPE	17.49	21.31	61.64	58.09	10.78	12.38	74	92	0.23
Edge angle 15 mm FPE	19.72	20.61	62.16	57.53	12.26	11.86	65	87	0.78
Edge angle 20 mm FPE	20.42	21.88	63.36	56.23	12.94	12.30	47	61	0.68
Edge angle 25 mm FPE	24.09	22.26	57.52	56.88	13.86	12.66	27	48	0.65

[a] Northern fluted point complex

well (11.34 %, $n = 25$; 9.84 %, $n = 24$; 12.52 %, $n = 20$; 17.01 %, $n = 17$, respectively), but at 25-mm FPE variation in width increased (31.01 %), being driven primarily by the whole points from Tinayguk River and Batza Téna (RkIg-47:13), the blade edges of which begin to contract between 20 and 25 mm from the base. This is a departure from the uniformity on the Folsom sample that remained after 20 mm FPE ($p = 0.01$). Therefore, basal width is more variable around the mean in the northern sample than in the Folsom sample. Moreover, measurements in width begin to vary in the northern sample after 20 mm FPE, whereas in the Folsom sample, variation around mean width remained constant from 5 to 25 mm FPE.

Thickness at base (0 mm FPE) was measured on 64 fragments (those with at least one corner remaining) (Table 2), but two were broken just beyond 15 mm FPE and could not be included in the 20 and 25 mm analyses. Variation in thicknesses FPE was relatively low among all points from 0 to 20 mm FPE, only fluctuating between 11.16 and 18.70 % of the mean. In the northern sample, however, variation around mean thickness significantly increased by 25 mm FPE, while it remained constant in Folsom ($p = 0.00$). Therefore, in the northern fluted points, basal thickness FPE was metrically uniform from the base to 20 mm FPE but variation increased by 25 mm FPE, whereas in the Folsom sample, variation around mean thickness was constant from the base to 25 mm FPE.

Kruskal-Wallis tests were used to identify whether the uniform patterns of width and thickness increased, decreased, or remained constant among northern fluted points. Results demonstrated no significant difference in width among 5-mm intervals ($X^2 = 7.43$, $p = 0.19$) suggesting that widths remained relatively uniform for the first 20 mm FPE (Fig. 4). Thickness, however, steadily increased from 5 to 20 mm FPE, demonstrating a gradient increase ($X^2 = 88.69$, $p < 0.0001$) (Fig. 5a). Thus, northern points have straight lateral margins in planview, and their profile shape is similar to a wedge with a very acute angle. Kruskal-Wallis analysis also found a significant difference in thickness between proximal and distal fragments ($X^2 = 13.27$, $p = 0.0041$) (Fig. 5b). Not only are points consistent in profile shape, they uniformly increase in thickness from the base at a constant rate, reflecting a 20-mm long wedge-shaped profile, with distal fragments being significantly thicker than basal fragments in the northern fluted point sample.

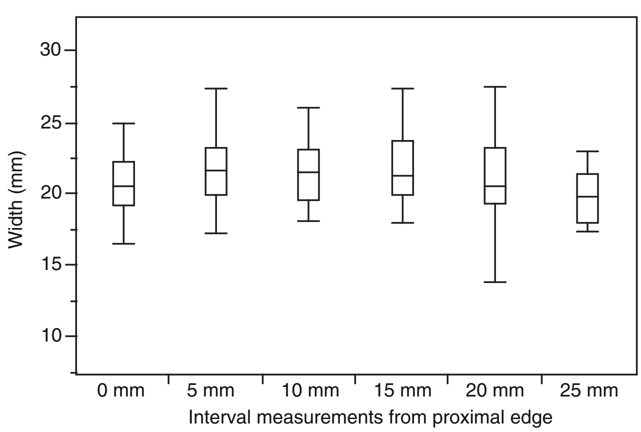


Fig. 4 Box plot showing results of Kruskal-Wallis analysis of width measured on northern fluted points from 5 to 25 mm ($X^2 = 7.43$, $p = 0.19$)

Basal concavity depth

Basal concavity depth was fairly variable around the mean (39.90 %, $n = 29$); however, this variation dropped 15 % when considered relative to width (25.96 %, $n = 22$) (see Table 2). Folsom basal concavity depths were similarly variable (41.05 %), and still highly variable even when indexed against basal width (36.16 %) (Table 2). There were moderate correlations between basal concavity depth and maximum width and average fluted-area width in the northern fluted point sample, but no such correlations in the Folsom sample (see Fig. 6a, b). This may indicate a greater degree of control of basal concavity design in the northern sample.

Channel-scar metrics

To compare uniformity in flute metrics, standard deviations of dominant flute widths measured in 5-mm intervals on each point face in the northern fluted sample were pooled and generated a CV of 27.41 % ($n = 29$), which is relatively greater than measures of width and thickness intervals, as well as CVs of pooled fluted-interval widths for Folsom points (22.48 %, $n = 29$) (Table 2). Similarly, no correlation was found in flute widths between faces of proximal fragments for either the northern sample ($r^2 = 0.04$, $p = 0.35$) or the Folsom sample ($r^2 = 0.01$, $p = 0.63$) (Fig. 6c). The width of the entire fluted area on each artifact face, however, did correlate with maximum basal fragment width in the northern sample ($R^2 = 0.54$, $p < 0.0001$), suggesting that the points were thinned across the entire face. This correlation was not present in the Folsom sample ($R^2 = 0.00$, $p < 0.89$) (Fig. 6d).

Edge angle

Edge angle measured on both edges in 5-mm intervals between 5 and 20 mm FPE on 35 northern-fluted basal fragments averaged 63.70°. On 20 specimens long enough for measurement at 25 mm FPE, average edge angle decreased to 57.52° (Table 2). This difference in edge angle is uniform throughout the sample providing evidence of lowered edge angles in the distal portions. Conversely, edge angle measured in 5-mm intervals between 5 and 20 mm FPE on 46 Folsom points averaged 57.44°, and did not fluctuate greatly at 25 mm FPE (average 56.88°). This suggests that northern fluted

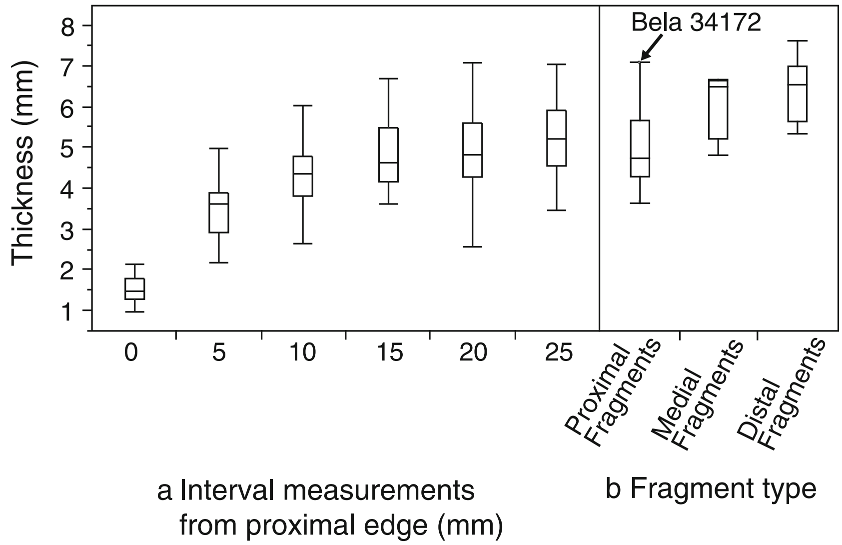


Fig. 5 Box plot showing results of Kruskal-Wallis analysis of thickness measured on northern fluted points. **a** Variation in thickness from 5 to 25 mm ($X^2 = 88.69$, $p = <0.0001$). **b** Variation in mean thickness between proximal and distal fragments ($X^2 = 13.27$, $p = 0.0041$). Artifact BELA-34172 represents the fragment from Serpentine with only a single flute on one face

points' edge angles were greater between 0 and 20 mm FPE than the distal portions beyond 20 mm FPE.

Comparing CV using the D'AD statistic

Results of the D'AD tests conducted on measures of CV between groups were able to demonstrate that northern and Folsom points are roughly equivalent in degree of variation, suggesting that, despite limitations in production possibly caused by variability in raw-material packages (see Jelinek 1976), both samples were manufactured to specific parameters that resulted in a suite of characteristic metric attributes, or, as exhausted or late-use-life forms, were reduced according to a method of refurbishment resulting in homogenous discarded forms. The northern sample demonstrated more variation in basal width, width at 25 mm FPE, and thickness at 25 mm FPE, and less variation in fragment length than Folsom, which may have ultimately resulted from differing hafting or maintenance strategies. Specific tool dimensions of northern fluted points were also not significantly more variable than Folsom when only chert artifacts were considered to test for raw-material impact on between-group variability (Table 3). The pattern observed in the D'AD tests conducted on the complete datasets remained the same for thickness at 25 mm FPE and

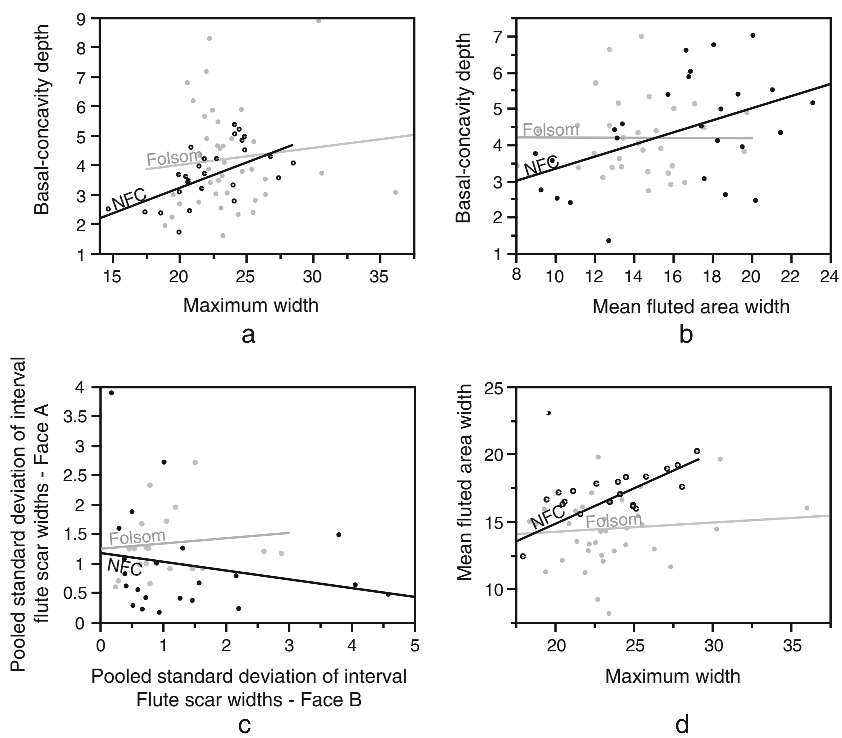


Fig. 6 Results of regression analysis describing relationships between (*gray* = northern fluted points and *black* = Folsom points). **a** Basal concavity depth and maximum width (NFC, $r^2 = 0.24$, $p = 0.0089$; Folsom, $r^2 = 0.01$, $p = 0.48$). **b** Basal concavity depth and average fluted area width (NFC, $r^2 = 0.21$, $p = 0.019$; Folsom, $r^2 = 0.00$, $p = 0.98$). **c** Correlation between pooled standard deviations of three width measurements per dominant flute on each face (NFC, $r^2 = 0.04$, $p = 0.35$; Folsom, $r^2 = 0.01$, $p = 0.68$). **d** Correlation between mean flute area width and maximum width (NFC, $r^2 = 0.54$, $p = <0.0001$; Folsom, $r^2 = 0.00$, $p = 0.63$)

Table 3 Relative variability in tool dimensions measured on chert artifacts in the northern fluted and Folsom complex point samples

Variable	NFC[a]	Folsom	NFC	Folsom	NFC	Folsom	NFC	Folsom	D'AD *p*-values	
	CV	CV	Mean	Mean	Std. Dev.	Std. Dev.	number	number	Between	Within NFC[b]
Thickness (max)	17.87	17.22	5.10	4.73	0.91	0.81	18	41	0.84	0.86
Width (max)	9.73	16.23	22.08	23.75	2.15	3.86	19	41	0.03	0.61
Length (max)	38.41	51.66	27.65	36.50	10.61	18.86	19	42	0.25	0.45
Length (bases only)	31.97	50.87	25.22	33.50	8.06	17.04	15	37	0.12	0.97
Basal Width	57.8	8.72	16.07	18.36	9.29	1.60	9	37	0.00	0.18
Width 5 mm FPE	10.82	8.96	21.45	19.73	2.32	1.77	13	38	0.41	0.86
Width 10 mm FPE	9.72	9.31	22.00	21.12	2.14	1.97	14	40	0.85	0.96
Width 15 mm FPE	11.42	9.97	21.76	22.27	2.48	2.22	11	36	0.59	0.74
Width 20 mm FPE	15.13	11.47	20.79	23.27	3.15	2.67	11	28	0.27	0.70
Width 25 mm FPE	26.78	15.49	18.37	23.41	4.92	3.63	6	20	0.08	0.74
Basal Thickness	17.52	18.59	1.49	1.36	0.26	0.25	14	38	0.79	0.50
Thickness 5 mm FPE	23.66	15.17	3.16	2.76	0.75	0.42	14	38	0.04	0.31
Thickness 10 mm FPE	16.69	11.70	4.43	3.80	0.74	0.44	14	38	0.09	0.66
Thickness 15 mm FPE	15.58	11.33	5.02	4.29	0.78	0.49	13	34	0.17	0.94
Thickness 20 mm FPE	17.27	12.42	5.24	4.50	0.91	0.60	11	25	0.31	0.76
Thickness 25 mm FPE	20.77	10.26	5.29	4.67	1.10	0.48	9	19	0.01	0.94
Basal concavity depth	46.63	41.46	4.32	4.09	2.01	1.70	15	39	0.65	0.56
Basal depth/Basal width	27.38	36.16	0.23	0.22	0.06	0.08	9	36	0.33	1.00
Pooled std dev of dominant flute	24.13	23.28	0.99	1.08	0.24	0.25	14	17	0.87	0.62
Edge angle 5 mm FPE	15.94	19.18	62.04	58.20	10.28	11.16	55	89	0.26	0.96
Edge angle 10 mm FPE	17.93	21.34	61.40	58.17	11.10	12.42	57	90	0.19	0.80
Edge angle 15 mm FPE	20.56	20.69	62.59	57.47	12.87	11.89	49	85	0.96	0.77
Edge angle 20 mm FPE	20.38	21.78	63.74	56.36	12.99	12.28	38	59	0.70	0.99
Edge angle 25 mm FPE	22.79	21.81	57.40	56.85	13.08	12.40	25	46	0.17	0.79

[a] Northern fluted point complex

[b] D'AD *p*-values used to test within group variability comparing CVs generated for the complete NFC dataset and only the chert specimens in the NFC dataset

basal width when only chert artifacts were compared. Variation in width at 25 mm FPE and fragment length was no longer significantly different between the Folsom and northern samples when only chert artifacts were considered; however, overall, raw-material type does not appear to impact variability between groups. It should be noted that, while Folsom was dominated by chert artifacts (> 95 %), chert artifacts made up only 51 % of the northern fluted point collection. D'AD tests comparing measures of CV generated for the complete northern-fluted dataset and the chert-only sample confirmed that raw-material type does not impact variability within groups (see Table 3).

Additional variables, such as basal concavity depth, demonstrate a degree of flexibility in base shape, which was more pronounced in Folsom and less dependent on width, suggesting higher standard of uniformity in the northern points. Technological flexibility in flutes, however, was greater in the production of uniform flute scars in the northern sample, which, given a correlation with maximum width, appears to demonstrate a different goal of fluting in the north: to thin the tools across the entire face.

Multivariate shape analysis results

Northern fluted PC analysis

The first five principal components were found to explain 93.36 % of variance in the northern-fluted point dataset ($n = 19$) (Table 4 (a)). Figure 7a illustrates shape characteristics expressed at the positive and negative ends of the PC axes. Each dimension of shape (each PC) in the Alaskan dataset describes a deep basal concavity that is predominantly V-shaped with triangular basal corners. Lateral margins are straight in almost every dimension as well, except for the PC2 axis that describes instances of basal lateral margins that are relatively more rounded (−PC2) or slightly more flaring (+PC2). A degree of asymmetry is expressed in each PC, too, which is appropriate given the fragmentary nature of the

Table 4 Percentages of variance explained for each principal component discussed in the text and cumulative variance explained for all PCAs

PC	Individual % variance explained	Cumulative % variance explained
a. NFC		
1	54.69	54.69
2	20.69	75.38
3	7.73	83.10
4	6.52	89.62
5	3.74	93.36
b. Folsom		
1	61.95	61.95
2	13.84	75.79
3	8.25	84.04
4	5.15	89.20
5	4.85	94.05
6	1.15	95.20
c. Combined NFC and Folsom		
1	54.14	54.14
2	16.87	71.01
3	11.70	82.72
4	5.00	87.71
5	4.88	92.59
6	1.91	94.50
7	1.31	95.81

dataset. This asymmetry likely explains a degree of variance in the sample.

Folsom PC analysis

The first six PCs explained 95.33 % of shape variance in the Folsom sample (Table 4 (b)). The "Folsomoid" basal concavity shape is angular, with fairly straight interior edges, pronounced basal ears, and straight lateral margins that contract toward the proximal end (see O'Brien et al. 2001:1127). These shape characteristics are represented along every PC axis illustrated in Fig. 7b. Negative loadings of PC2 and PC4 and positive loadings of PC3, PC5, and PC6 describe a small curve along the apex of the basal concavity, which represents remnants of the characteristic Folsom "nipple" platform (Crabtree 1966; Frison 1991).

Combination PC analysis

Substantial variation in basal shape was present in the combined sample of northern and Folsom fluted points. The first seven PCs explained more than 95.90 % of variance in basal shape (Table 4 (c)). Shape characteristics specific to each collection are identifiable in the series of seven PCs generated for the combined sample (Fig. 8a), with actual PC loadings for each complex charted at the bottom of the Fig. 8b. The first PC describes variance in basal concavity depth, with Folsomoid basal concavity shape being expressed predominantly in the positive loadings of PC1 and PC3, and to a lesser extent in the

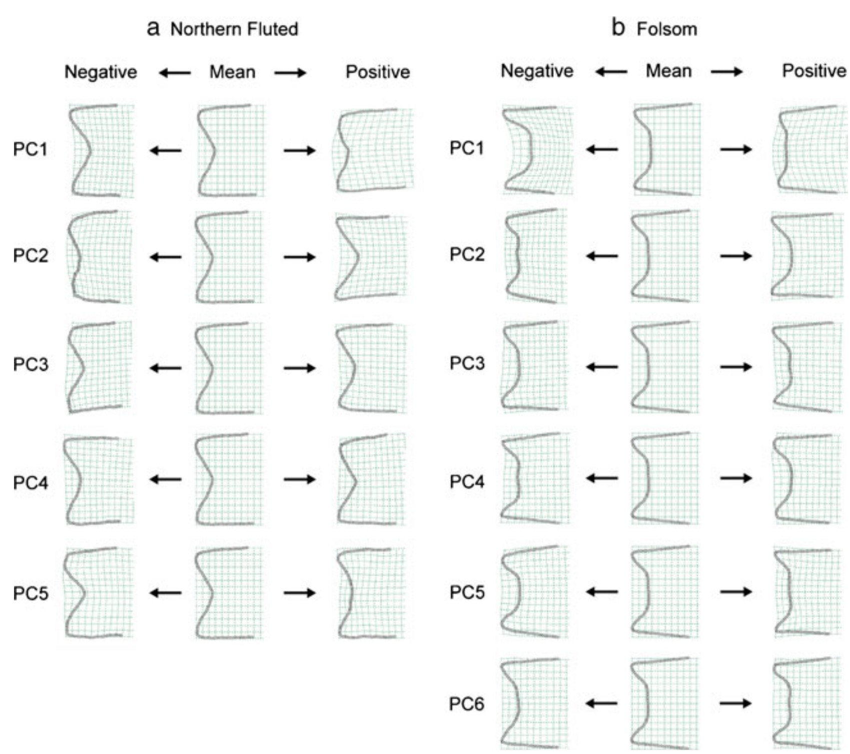


Fig. 7 Illustrations of shape variables expressed at positive and negative ends of each principal component axis explaining **a** 93.36 % of variance in the northern fluted point sample ($n = 19$) and **b** 95.33 % of variance in the sample of Folsom ($n = 43$) fluted points

negative loading of PC4 and PC5 and positive loadings of PC6 and PC7. These PCs feature Folsom-point characteristics such as angular basal concavity shape, pronounced basal ears, straight lateral margins, and the classically described fluting platform at the apex of the basal concavity. Northern shape characteristics are primarily expressed on negative PC1 and PC3 and less so on positive PC4 and PC5 and negative PC6 and PC7.

Analysis of variance

Models were organized by tool complex (northern fluted and Folsom), northern regions and Folsom sites nested in tool complex, and centroid size (Table 5). Tests of both shape and form found strong shape differences between northern-fluted and Folsom points organized by tool complex with a combined sample size of 62 specimens. Such variation in shape between typology and respective geography suggests that they indeed represent two cohesive complexes, with the range of variation within the northern fluted points being comparable to that of the chronologically and technologically well-defined Folsom complex (NFC Shape $p = 0.88$, $\eta_p^2 = 0.37$, Form $p = 0.885$, $\eta_p^2 = 0.38$; Folsom shape $p = 0.10$, $\eta_p^2 = 0.27$, Form $p = 0.046$, $\eta_p^2 = 0.31$). Size was found to also describe differences between northern-fluted and Folsom points, which was expected given that Folsom points are, overall, larger than northern-fluted points. A weak structural signature within Folsom was also apparent when considering artifact Form at a significance level of 0.05, driven by variation in artifact size, a pattern not present with the northern fluted point sample. However, the weak signature of within-Folsom structure may have been driven, in part, by a sample size twice that of the northern-fluted points.

The northern points, therefore, represent a morphologically homogeneous group separated in shape space from Folsom points. A visualization of the statistical separation of data clouds is provided in Fig. 9. Form and shape differentiation is given as multivariate least-squares means and their 95 % confidence ellipses in canonical space (among group axes of variation standardized to the within group variation). Larger confidence ellipses observed in the northern sample is likely due to smaller sample size for the NFC group; a trend also observed in the CVs generated for basal width, width at 25 mm FPE, and thickness at 25 FPE.

Discussion

Defining northern-fluted points

Morphology

Homogeneity in haft-area metrics was indicated by low variability around mean width and thickness for the first 20 mm FPE, with mean width staying constant and mean thickness increasing uniformly. Results of MANOVA conducted on geometric morphometric data found no significant variation in fluted point basal morphology between regions in Alaska, suggesting that the northern-fluted points in this dataset meet a uniform morphological standard. Moreover, shape variables described by PC axes did not demonstrate a broad range of variability within the data set. Each PC generated for the northern-fluted point sample describes the deep V-shaped basal concavity that varies slightly from a more angular to a more

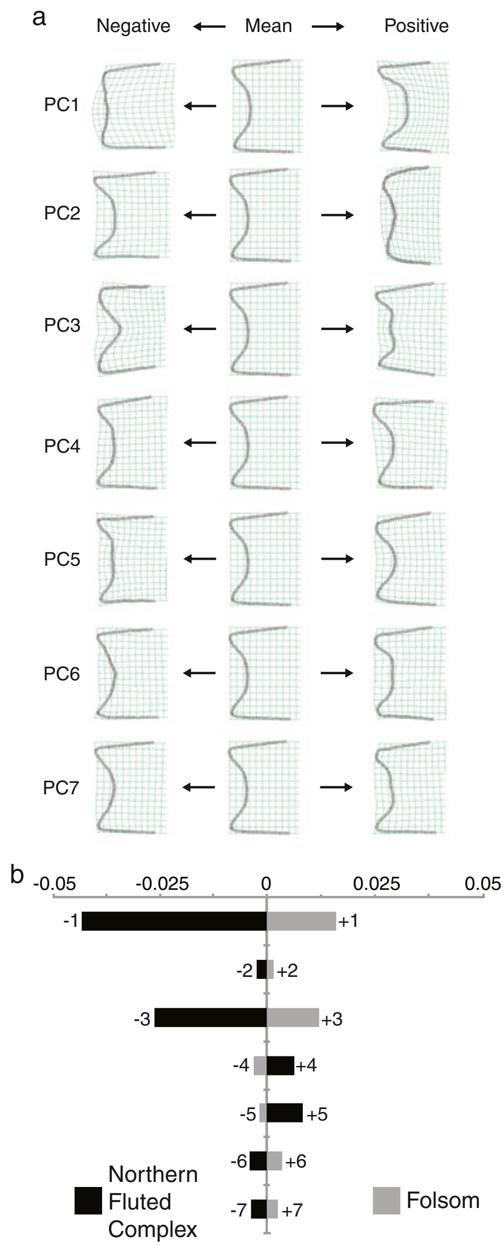


Fig. 8 Principal component analytical results. **a** Illustrations of the first seven principal components which explain 95.81 % of variance in the data set considering both northern (n = 19) and Folsom (n = 43) fluted points. **b** Least squares means of principal component loadings for northern fluted (*black*) and Folsom (*gray*) datasets

Table 5 MANOVA results for shape and form for the combined northern fluted points and Folsom complex points generated using geometric morphometrics

Model	Shape				Form			
Effect	*F*	df_n/df_d	*P*	η_p^2	*F*	df_n/df_d	*P*	η_p^2
Complex	13.8	7/45	<0.0001	0.68	16.4	8/45	<0.0001	0.75
Region [complex]	1.34	56/247.60	0.068	0.23	1.33	64/266.05	0.06	0.24
Size	46.2	7/45	<0.0001	0.88				

curved apex, straight lateral margins, and triangular basal corners. Likewise, MANOVA found that when comparing basal-outline shape, the northern fluted point series is separated in shape space from artifacts representing the Folsom complex, suggesting that the fluted points found across northern Alaska and Yukon form a morphologically homogenous projectile-point type.

Technology

Despite this study's focus on finished points and point fragments and not associated debitage or early-stage biface assemblages, much information regarding northern raw-material preference, pre-fluting and flute production, and morphological state at terminal use-life was indicated by the materials in the dataset. In the production of northern-fluted points, raw-material choice was limited to high-quality, fine-grained toolstone; and, despite a single proximal fragment from Serpentine fluted on only one face, it appears that all northern-fluted points were meant to have multiple flute scars on each face in the proximal area. Channel-scar metrics found significant variation in width along the dominant channel flake, suggesting some laxness on the part of the producer in terms flute uniformity. However, the width of the entire fluted area significantly correlated with fragment width, suggesting that multiple flutes served to thin the entire face. Outside edges of lateral channel scars were over-flaked by marginal thinning, creating an average edge angle of 63.70° between 5 and 20 mm FPE, and were then edge ground. At 25 mm FPE, average edge angle decreased to 57.52°**,** likely representing the edge angle imposed prior to fluting and completion of the manufacturing process or the differently shaped edges of the base and blade portions.

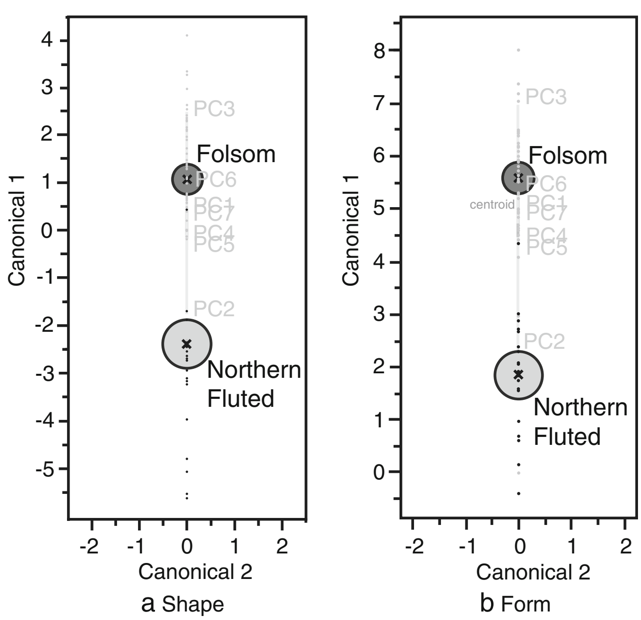


Fig. 9 Canonical centroid plot for **a** shape and **b** form showing separation of the northern fluted point sample from the Folsom complex

Despite these apparent regularities in northern fluted point production and form, there are some irregularities as well. One the one hand, dominant flute scar widths and basal concavity depths differed among points. On the other hand, the total fluted area was more regularly controlled, and mean basal concavity depth was scaled to point width, with wider points having deeper basal concavities. Moreover, the basal margin became more concave as channel flakes and marginal-retouch flakes were removed from the proximal edge, and marginal retouch followed to complete the inverted V-shape. The variation present in flute-scar width and basal concavity depth suggests allowance for flexibility during production or reworking, possibly attesting to less risk while fluting than previous hypotheses have noted, and even allowing for knappers at different skill levels to effectively flute faces of the proximal area and finalize a normative basal shape with pressure retouch (but see Ellis and Payne 1995).

Overall, fluting was used to thin the base, which facilitated the gradient increase in thickness. The Kruskall-Wallis test also found a significant difference in thickness between proximal and distal fragments. Blade portions of the fluted points were flaked to the longitudinal midline to produce a median-ridged to lenticular cross-section. This medial ridge was likely present on preforms as well, prior to fluting, and potentially used to guide the first flute removal. The lateral arises that remain after the first flute's removal could have been used to guide subsequent lateral flute removals.

Function

The presence of marginal grinding and fluting provides important evidence that northern-fluted points were prepared for hafting to another technological element, such as a fore shaft. Distal damage, resulting from impact, is present on two of seven distal fragments from the sample, which attests to their use as projectile tips. Nearly 75 % of basal fragments have transverse snaps, or bend breaks, a fracture type noted to occur in high frequencies in fluted point collections from the North American High Plains and northeastern USA and found, experimentally, to result from heavy impact (Collins 1993; Frison 1989). Without question, northern-fluted points functioned as hafted projectiles that impacted targets at high velocities.

The northern-fluted point complex as an adaptation to the late Pleistocene-early Holocene Arctic

The homogeneity in morphological and technological features documented here supports the hypothesis that northern fluted points form a cohesive complex, or point type, technologically representing a single manufacturing and reduction strategy. Results of this analysis have identified patterns of northern fluted point form, technology, and function, which may suggest whether they served as a component of a reliable or maintainable system to facilitate risk-management solutions. This can be further explored by considering the potential effect of northern fluted point technological and morphological characteristics.

Why flute?

Projectile-point bases can be thinned in a variety of ways, and hypotheses addressing why many Paleoindians technologically preferred to flute include weight reduction, enhanced bleeding, more cutting-edge exposure (Crabtree 1966), potential for thicker, more durable, hafting material (Hutchings 1997), and Bleed's (1986) suggestion that fluting promoted predicted failure to increase maintainability (see Ahler and Geib 2000). Further, Judge (1973) suggested that fluting facilitated interchangeability of projectile points within a still-usable foreshaft, and Wilmsen (1974; Wilmsen and Roberts 1978) suggested that the texture of a fluted surface increased friction and bonding, thus serving to secure the point in the absence of adhesive materials. The multiple and parallel flute scars on northern fluted points may have provided increased texture and stabilization of the point within a haft.

Fluting also facilitated the low-gradient increase in thickness FPE, providing northern fluted points with a long wedge in profile, which may have served as another mechanical advantage in terms of stability within a haft. Although other non-fluted forms of lanceolate projectile points (e.g. Sluiceway) in northern Alaska possess this wedge-like quality, they have an overall shorter, high-angle wedge, making them laterally unstable in a split-shaft and, therefore, requiring greater efforts in binding (Fig. 10). The ability to stabilize a projectile tip with help from the mechanics of the fluted point itself likely decreased the amount of time and supplies required to bind and maintain a point within a haft (Keeley 1982; Wadley et al. 2009; see also Weedman 2006).

Fig. 10 Photograph showing the wedge-like quality of northern fluted (*left*) and sluiceway (*right*) projectile-point profiles and the difference in wedge angle

Why a deep basal concavity?

Flenniken (1978) noted that most of his experimental projectile points failed beyond repair when one of the corners snapped, causing the points to become loose within the haft. In addition, Odell and Cowan (1986) found that symmetry in point positioning within the haft was key to successful penetration through the hide of prey animals. Deep basal concavities like those seen on the northern fluted points facilitate the presence of pronounced proximal corners to stabilize a point laterally, thereby increasing symmetry in the hafting element.

Characteristics of the Alaskan sample of fluted basal fragments (fragment length approximately 20 mm FPE and the high incidence of transverse snaps, or bend breaks, increased variation in mean thickness, width, and edge angle between 20 and 25 mm FPE) are similar to characteristics identified by Collins (1993), who found that most basal fragments of Angostura points were 20 mm long, suffered from bend-break fractures, and had basal-flaking patterns suggestive of reworking the proximal ends of distal fragments, not resharpening of blades still in a haft. This evidence suggested to Collins that these points were possibly designed to break at approximately 20 mm FPE to facilitate the rehafting of a considerable amount of material remaining on distal fragments (see also Musil 1988). Among the northern sample, it is also possible that once a corner broke during use, hunters snapped broken bases on purpose to fashion new corners and flutes on distal fragments (see Ellis 2004).

Why variable flaking patterns?

Blades on northern fluted points were median-ridged to diamond-shaped in cross-section, a durable shape for a projectile point (Cheshier and Kelly 2006). This form would have facilitated preservation of raw material in the distal portion after breaking from a more fragile base. The presence of the medial ridge would also serve to guide new flute removals from a fresh snap. Cheshier and Kelly (2006) suggest that point durability increases as more of the point is protected within the haft (e.g. Folsom), however, metric patterns in the Northern sample demonstrate a preference for a short hafting element, approximately 20 mm long, implying that blade durability, not basal durability, may have been a desired quality. This strategy would have allowed point-makers to control how much usable material remained after failure (see Ahler and Geib 2000). One caveat, of course, is that distal fragments would have had to be retrieved from the carcass or procurement site before rebasing. It is possible that the high number of channel flakes recovered at Serpentine (Goebel et al. 2013), seemingly removed during an intermediate stage of a recycling system, were detached from distal fragments serving as point blanks.

Mobility, land use, and risk management solutions

Northern fluted points have rarely been found associated with single-component high artifact densities and evidence of “gearing up” activities (Smith et al. 2013). Fluted point sites were often in overlook settings and at distances from raw-material sources. The functional advantage of this projectile-point design, therefore, potentially allowed for maximum portability and maintainability in terms of ease of removal and replacement, lowering transport costs in terms of risk-management by not requiring high investment in maintenance time and supplies (Bousman 2005; Eerkens 1998; Judge 1973; Torrence 1989).

Many studies have pointed out that risk increased with distance from raw-material sources (e.g. Bamforth 1986; Bleed 2002), but risk of not having adequate lithic material on hand when needed may have been coupled with not having organic supplies and time to repair, or recreate, hafting elements (see Cheshier and Kelly 2006). A maintainable northern fluted point system may have offset high costs involved with long-distance travel. Northern fluted point locales are geographically widespread across northern Alaska and Yukon and, often, not near Brooks Range sources for toolstone. In an embedded procurement system as groups traveled between locations intended for intercept hunting or toolstone acquisition, i.e., predictable resources, opportunities for encounter hunting would arise, i.e., unpredictable resources. The maintainable fluted point system would have provided portable yet effective hunting tools to reduce risk during unpredictable events, after which tool maintenance would have been more costly because access to raw materials was decreased.

Higher expenditures of hafting effort were required when using a point base with a high-angle wedge in profile and without basal corners, which (1) decreased the point’s own ability to contribute to stabilization within the haft while (2) increasing the point’s potential to resist breakage. In this scenario, risk increased as groups became less able to expend time and materials *if* the hafted area required repair (see Bousman 1993; Kuhn 1994). One way to reduce risk if basal damage occurred was to ensure that it *would* occur, if rebasing protocol was meant to quickly create an effective refurbished weapon. The multitude of channel flakes removed from northern fluted points, evidence of fluting far away from sources of lithic materials at intermediate stages of a recycling system, and lack of uniformity in channel flake metrics together suggest that fluting may not have been such a high-risk task as commonly thought. Instead, fluting had potential to provide security, serving as a reliable method of weapon maintenance by minimizing time and energy expenditures in haft maintenance and rebasing, resharpening, and reinsertion into the haft (following Boldurian et al. 1986; Ellis 2008). Blade resharpening, however, likely still occurred on northern fluted points; but, unlike with some Paleoindian technologies, this may have been a rejuvenation procedure used sparingly.

Conclusions

The analyses presented here support the hypothesis that Alaskan and northern Yukon fluted points represent a cohesive technological strategy and can be termed the Northern fluted point complex associated with the Paleoindian era dates from Serpentine and Raven Bluff. It is furthermore hypothesized that fluted point use in the north reflects a risk management strategy promoting ease-of-replacement-after-failure, which may have ensured that effective tools could be quickly recovered when high mobility meant maintenance costs were high (Bamforth and Bleed 1997; Kuhn 1989; Torrence 2001).

This assessment is supported by significant homogeneity in fluted point technology and basal fragment morphology which conveys an overall artifact “style,” in the sense of Wiessner (1985) and Rick (1996). However, functionality appears to have played a significantly influential role in the form of northern fluted points (Meltzer 2003; Sackett 1982; but see Betttinger et al. 2003). Northern fluted points were a projectile weapon system, the fluting of which thinned the proximal end to a low-angle wedge and created a basal cavity with prominent corners which served not only to laterally stabilize the point within the haft, but could also break at a specified length, preserving the distal portion for rebasing facilitated by removing flutes to re-thin the base. Thus, this technology was effective, maintainable, and transportable—the result of a production and maintenance system that specifically offset transport costs and reduced risk during long-distance travel.

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