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Serpentine Hot Springs, Alaska: results of excavations and implications for the age and significance of northern fluted points

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ABSTRACT

The dispersal of *Homo sapiens* across the New World is one of the greatest chapters in the history of our species; however, major questions about this late Pleistocene diaspora remain unanswered. Two contentious issues are the timing of colonization of the Bering Land Bridge and origin of Clovis, which at 13,000 calendar years ago is the earliest unequivocal complex of archaeological sites in temperate North America, known by its specialized fluted spear points. One hypothesis is that fluting technology emerged in Beringia and from there was carried southbound, with fluted points becoming the diagnostic "calling card" of early Paleoindians spreading across the Western Hemisphere. Fluted points have long been known from Alaska, yet until now they have never been found in a datable geologic context, making their relationship to Clovis a mystery. Here we show that a new archaeological site at Serpentine Hot Springs, Bering Land Bridge National Preserve, Alaska, contains fluted points in a stratified geologic deposit dating to no earlier than 12,400 calendar years ago. Our results suggest that Alaska's fluted-point complex is too young to be ancestral to Clovis, and that it instead represents either a south-to-north dispersal of early Americans or transmission of fluting technology from temperate North America. These results suggest that the peopling of the Americas and development of Paleoindian technology were much more complex than traditional models predict.

1. Introduction

The source of Clovis, the earliest well-recognized and widespread complex of archaeological sites known in the Americas (Goebel et al., 2008), has long puzzled archaeologists. Although fluted points diagnostic of Clovis occur in numerous sites dating to ~13,000 calendar years ago (cal BP) across a large part of temperate North America (Haynes, 2002; Meltzer, 2009; Waters and Stafford, 2007), their origin remains unknown. Doubts concerning the earliest radiocarbon-dated Clovis occupations prevent definite identification of a starting point for the dispersal of Clovis technology (Beck and Jones, 2010; Fiedel and Morrow, 2012; Hamilton and Buchanan, 2007), and an obvious precursor to Clovis has yet to be defined—in either temperate North America or Alaska—despite many proposals (Hoffecker et al., 1993; Kunz and Reanier, 1994; Stanford and Bradley, 2012; Waters et al., 2011).

One avenue of Clovis-origins research has been the search for fluted points in Beringia, the area that today constitutes northwestern-most Canada, Alaska, northeastern-most Russia, and the now-submerged shelves of the Bering and Chukchi seas (Hoffecker and Elias, 2007). The first fluted point from Alaska was found in 1947 (Solecki, 1950), and since then they have turned up at more than 20 archaeological sites, mostly in northern Alaska (Clark, 1983, 1984, 1991; Dixon, 1993; Dumond, 1980). Nowhere in Beringia, however, have fluted points been found in reliably radiocarbon (^{14}C) dated contexts (Bever, 2006b). At some sites, for example

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Putu/Bedwell and Batza Téna, fluted points were from very shallow contexts without clear hearth features (Alexander, 1987; Clark and McFayden Clark, 1994), so that ^{14}C dates could not be unequivocally tied to artifacts (Bever, 2006a; Reanier, 1995), while at other sites, like Healy Lake and even the Uptar site in the Magadan region, northeast Russia (Cook, 1996; King and Slobodin, 1996), artifacts originally proposed to be fluted points upon closer scrutiny were later dismissed as points with invasive basal trimming or severe impact scarring (Reanier, 1995; Waguespack, 2007). As a result, archaeologists have not been able to ascertain whether Alaskan fluted points were older than, the same age as, or younger than Clovis, such that the historical relationship between these fluted-point industries could not be judged.

Three alternative hypotheses were developed to explain the relationship between Alaskan and temperate North American fluted points (Bever, 2006a, 2006b; Clark, 1984; Dixon, 1993; Dumond, 1980; Kunz et al., 2003; Morlan, 1977; Reanier, 1995): Alaskan fluted points represent (1) an antecedent Clovis population that dispersed southward from Beringia at the end of the Pleistocene; (2) a post-Clovis, late Paleoindian northward migration of people or transmission of technology from temperate North America to the Arctic; or (3) a non-Paleoindian, locally developed mid-Holocene phenomenon. The second, late Paleoindian northward-spread hypothesis is not a new one (see the early projections of MacNeish, 1956, 1963; Willey, 1966; Wormington, 1957), and it has found support in the recovery of similar fluted-point technology at Charlie Lake Cave, British Columbia, dating to about 12,500 cal BP, as well as secure dating of other (typically non-fluted) “Northern Paleoindian” bifacial technologies at Arctic sites like Mesa and Engigstciak (Cinq-Mars et al., 1991; Hoffecker and Elias, 2007; Kunz and Reanier, 1994). The lack of firmly dated fluted-point sites in the far north, however, continues to stymie Beringian archaeologists’ efforts for confirmation of the northward-spread hypothesis.

A new archaeological site in Bering Land Bridge National Preserve (Seward Peninsula, western Alaska) provides the first empirical evidence needed to resolve the place of Alaskan fluted points in the origins-of-Clovis debate. This archaeological site, numbered BEN-192 in official records and informally called the Serpentine fluted-point site, is located about 2 km north of Serpentine Hot Springs and 150 km north of the city of Nome (65°52′N, 164°43′W) (Fig. 1). National Park Service archaeologists Chris Young and Bob Gal discovered the site in 2005 when they recovered a basal fragment of a fluted point from the ground surface (Young and Gilbert-Young, 2007). Their initial test excavation confirmed that stone flakes occurred in a buried context loosely associated with wood charcoal ^{14}C dated to about 12,000 cal BP. Our team returned to Serpentine for three field seasons in 2009–2011 to conduct a comprehensive field study and excavation. We recovered four fluted points in a stratigraphic context associated with charcoal- and bone-rich features repeatedly dated through accelerator ^{14}C methods to less than 12,400 cal BP, the very end of the Pleistocene and more than 500 years younger than the time of Clovis in temperate North America. Here we report the preliminary findings of the site’s excavation—its context, age, and artifact assemblages—focusing attention on the sample of eight fluted-point fragments recovered.

2. The Serpentine fluted-point site

2.1. Site setting

The Serpentine fluted-point site is situated upon a southeast-facing granite bedrock ridge overlooking the tundra of a broad upland valley, ~145 m in elevation. It is 9 km northwest of the continental divide, about 50 km southwest of the Chukchi Sea shore. The vista from the site includes a small unnamed creek immediately

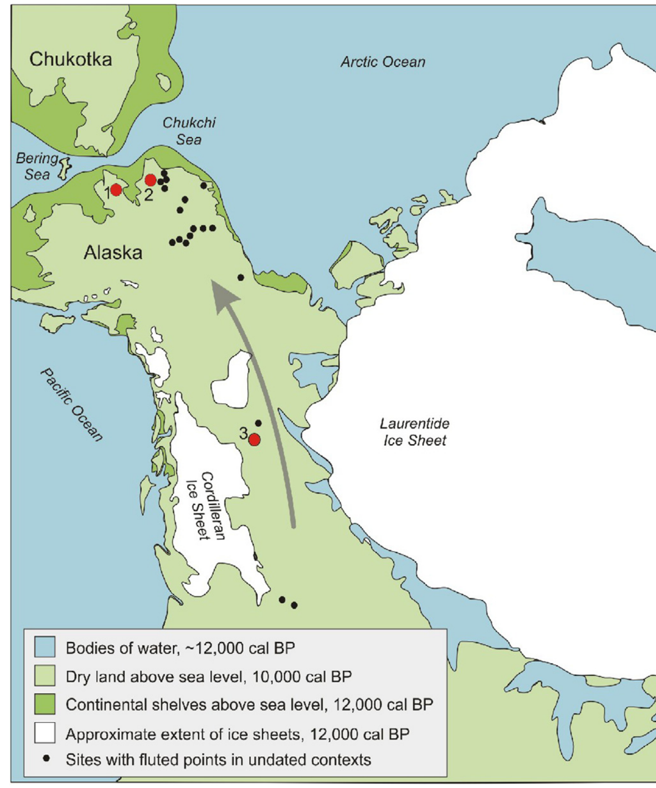

Fig. 1. Paleogeography of northwestern North America about 12,000 cal BP, showing limits of Canadian ice sheets, flooding of central Bering Land Bridge, locations of important archaeological sites described in text (1, Serpentine Hot Springs; 2, Raven Bluff; 3, Charlie Lake Cave), and inferred dispersal of fluted-point makers (or diffusion of fluted-point technologies) from western Canada to northwestern Alaska.

below the granite ridge, its confluence with Hot Springs Creek about 1 km to the south, and Serpentine Hot Springs itself, 2 km southeast (Fig. 2). Shrub-tundra vegetation on the site is dominated by shrub birch (*Betula glandulosa*) and blueberry (*Vaccinium* sp.); stands of willow (*Salix* sp.) also occur along nearby creek floodplains.

Surface survey identified two concentrations of artifacts, the north and south loci (Fig. 3). The north locus contained 115 artifacts lying on exposed surface blowouts. Among these artifacts were two fluted-point fragments. In this area of the site there was little chance for retrieval of artifacts from a buried context. The south locus, however, was minimally deflated and had small blowouts restricted to the bluff edge. On the modern surface there were few artifacts recovered; one was the original 2005 fluted-point find. Bedrock in this area was mantled by a matrix of loose, excavatable sediment, protected from deflation by shrub-tundra vegetation. Excavations focused on this part of the site, and we dug a 34-m^2 area near where Young and Gilbert-Young (2007) reported the discovery of the first fluted point.

2.2. Excavation methodology and analytical protocols

Archaeological block excavations at the Serpentine site covered an area of 33 square meters (plus a 1 square-meter test pit). Excavations followed standard procedures, with sediments being removed by hand trowel and dry-screened through 1/8-inch mesh. Regular samples of sediment were also wet-screened, again through 1/8-inch mesh. Artifacts, bone fragments, and charcoal samples recovered *in situ* were three-point provenienced (x, y, and z coordinates) using a Sokkia total-station theodolite, while materials recovered from the screen were provenienced to 50-cm^2 horizontal

Fig. 2. View of the Serpentine fluted-point site (BEN-192), looking southeast, toward Serpentine Hot Springs.

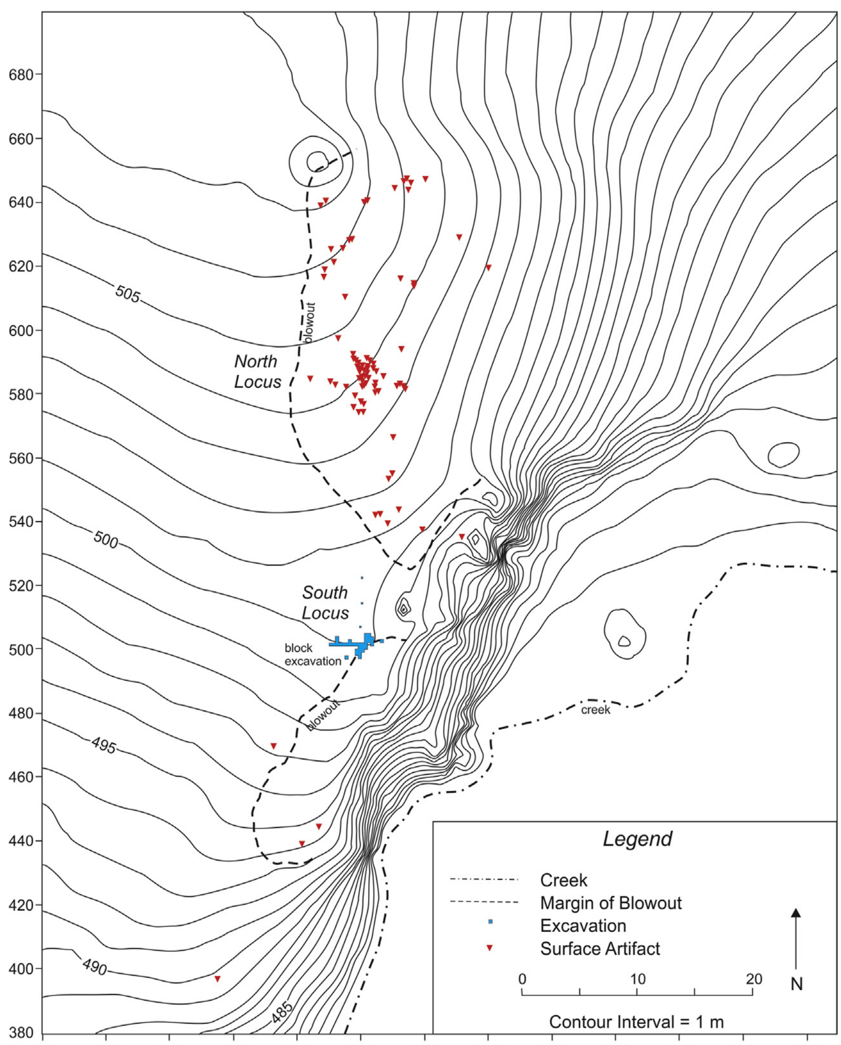

Fig. 3. Topographic map of the Serpentine fluted-point site (BEN-192), showing locations of surface finds and excavation units.

quadrant and 5-cm vertical level within recognized stratigraphic layers. Strike and dip of larger-sized artifacts ($n = 62$) were also measured. Sediment descriptions and profiles were completed in the field, with standard sedimentary (granulometric and chemical) analyses being conducted at the soil-characterization laboratory, Texas A&M University.

Micromorphological samples of sediment were collected and prepared by removing oriented blocks of material from excavation faces (by driving plastic conduit boxes into exposures), air-drying the samples, impregnating them with epoxy, and preparing them into 2-×-3-inch thin sections. Micromorphological analyses were accomplished using an Olympus BX-51 research microscope with both polarized light and UV fluorescence at Baylor University.

Charcoal samples were identified taxonomically, using the plant reference collection and library maintained at the Desert Research Institute, Reno. Radiocarbon analyses were based entirely on samples of charcoal from excavations. Sample preparation (including physically separating datable material from rootlets and other modern contaminants, and pretreating them with hydrochloric acid and sodium hydroxide to remove carbonates, humic acids and fulvic acids) occurred at Stafford Research Laboratories, Inc., and accelerator radiocarbon analyses following standard techniques were conducted at the AMS facility, University of California Irvine (Waters and Stafford, 2007).

Faunal remains were not well-preserved, so analyses of these materials were limited to counting and weighing samples, taxonomically identifying better-preserved bone and tooth fragments using diagnostic morphological features, and scoring evidence of burning (following Stiner et al., 1995) and other taphonomic processes. Stone-artifact analyses presented here followed an analytical protocol developed for early-period archaeological assemblages from northwest North America and northeast Asia (Goebel, 2007; Graf, 2010), useful for characterizing lithic technologies as well as variability in tool forms. Nonmetric variables analyzed were macroscopic, being visible with the naked eye or small magnifying lens, while metric variables were analyzed using digital calipers, scales, and goniometer. Quantitative data were tabulated with SPSS, and artifact-distribution maps were prepared with Surfer mapping software.

2.3. Stratigraphy and site formation

Quaternary sediments at the south locus of the Serpentine fluted-point site have a maximum thickness of 70 cm and rest directly on Cretaceous granite (the Oonatut complex) (Hudson, 1979). These sediments are separated into three units, labeled 1 to 3, from oldest to youngest (Fig. 4). Unit 1 is grussy, clayey silt, unit 2 is clayey silt to silt, and unit 3 is grussy, sandy silt capped by a shrub-tundra vegetation mat (O horizon). Units 1 and 3 are colluvial deposits that represent a mixture of reworked windblown silts and sands mixed with gruss particles. Unit 2, however, is aeolian loess minimally affected by colluvial processes. All three deposits display cryogenic features resulting from ice-lens formation and solifluction; in the northeastern area of the excavation, overturned solifluction lobes are common. Rodent burrows are present, too, but rare. Despite these disturbances, the three geological units are distinguishable across the site and not obviously intermixed (Fig. S1). Archaeological integrity between units is intact as well, with artifacts being most abundant in unit 2 (Fig. 4). In areas where unit 2 becomes thin and pinches out, artifacts lie on or near the unconformity between units 1 and 3. Besides this, only a few artifacts are found in unit 3, typically in its upper portion and associated O horizon. No artifacts occur in unit 1. Unit 2 represents the main cultural occupation of the site, while the few materials from upper unit 3 appear to represent a much later ephemeral occupation.

Micromorphological analysis of the Serpentine sediment packages focused on soil-forming conditions, post-depositional processes, and the degree to which cryoturbation affected stratigraphy. Unit 1 shows a curious mixture of pedogenic features suggesting formation under two different sets of environmental conditions. It contains evidence of moderate cryoturbation in the form of frost-shattered grains and lenticular pores, suggesting the presence of ice in the soil and moderate cryoturbation (Fig. 5f); however, redox mottles in the soil suggest variable drainage and periodic perching of water on an impermeable surface, such as the permafrost table (Fig. 5f) (Vepraskas, 1992). Unit 2 shows pedogenic features suggesting paleosol formation during warmer, perhaps ice-less conditions. Wet, well-drained (and thus relatively ice-free) conditions are indicated by extensive chemical weathering of this unit. Fe-oxides and disseminated iron-organic-matter complexates comprise the groundmass, and feldspars show varying degrees of hydrolysis and sericitization (Fig. 5b–c). Biotite grains are both chemically altered and delaminated, also suggesting hydrolysis reactions (Fig. 5d). Illuviated clay-coating pores indicate a freely drained soil environment that was chemically active enough to promote formation of pedogenic clays from primary feldspars (Fig. 5d). The presence of frost-shattered grains (Fig. 5e) indicates

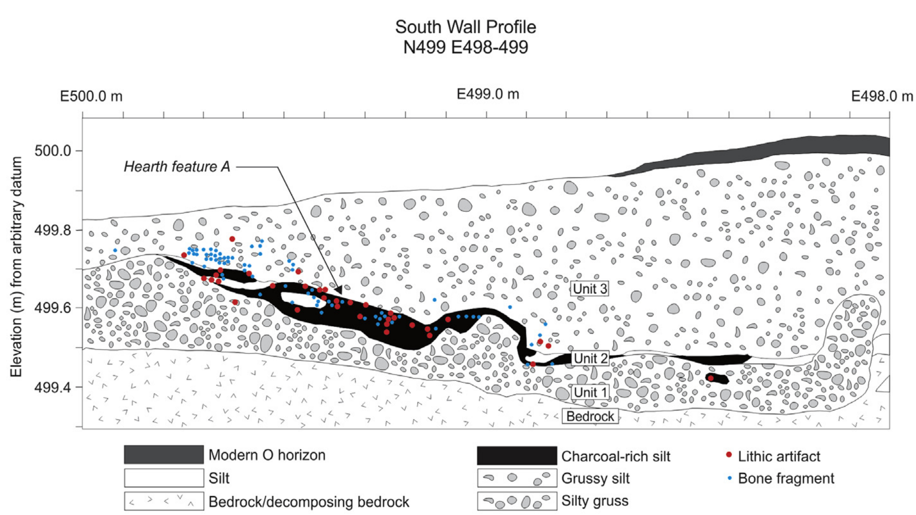

Fig. 4. Representative stratigraphic section from the Serpentine fluted-point site, exposed in 2010, showing hearth feature A in profile (in unit 2).

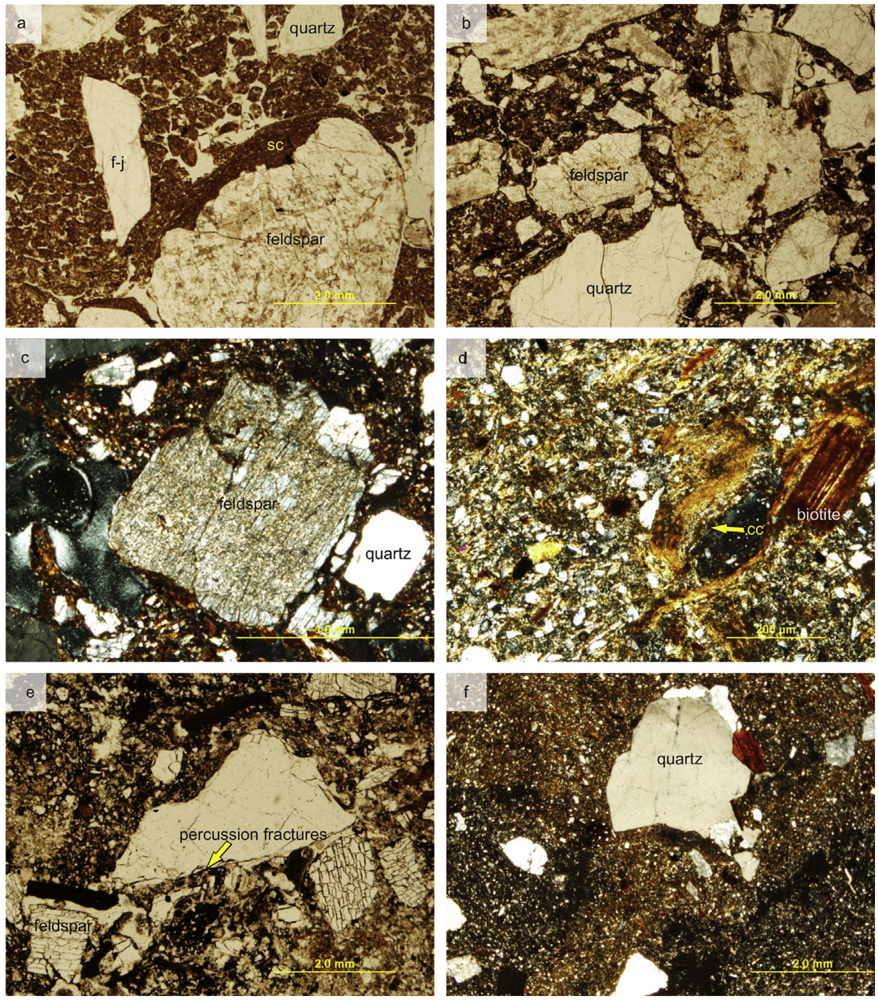

Fig. 5. Photomicrographs of the sediment package at Serpentine Hot Springs. (a) Cryoturbated, soliflucted material in unit 3, including frost-jacked grains (f–j), silt-capped grains (sc), and granular microaggregates. (b) Fe-oxides and complexated organic matter and Fe-oxides in unit 2 groundmass. (c) Hydrolysis and sericitization of feldspar grains along cleavage planes in unit 2. (d) Illuviated clay (cc) lining pores and de-laminated and chemically altered biotite in unit 2. (e) Frost-shattered grains and microdebitage in unit 2. (f) Redox mottles and lenticular pores in unit 1 (images a, b, e, and f were taken with plane-polarized light; images c and d were taken with cross-polarized light).

some degree of frost action during the formation of this unit, but their weak nature suggests that stratigraphic and, by extension, archaeological integrity of unit 2 is intact. Microdebitage is observed in this unit, recognized by their sharp, angular edges with percussion fractures (Fig. 5e). Unit 3 shows the most significant evidence for cryogenic disturbance. Both the macro- and micro-structure of the unit have been affected by freeze–thaw processes, as evidenced by frost-shattered and frost-jacked skeletal grains as well as granular microaggregates (Fig. 5a) (Bockheim, 2012). The grain features suggest that modern freeze–thaw and associated physical-weathering processes are the primary means of soil formation in this unit, and the granular microstructure indicates some degree of solifluction affecting this unit (Van Vliet-Lanoë et al., 2004).

Evidence of cryoturbation was also observed through analysis of strike and dip of large-sized artifacts (>1.5 cm^2 in surface area) recovered *in situ* in excavations. Resulting strike measurements were randomly distributed in all directions, with nearly every 20° directional increment being represented around a 360° circle. Dip measurements were also variable, with every 10° increment being represented between horizontal (0°) and vertical (90°); however, 25 (40%) artifacts had plunges of less than 25°, again suggesting that the cultural component was not completely deformed by freeze–thaw processes.

2.4. Dating

Twenty-five new radiocarbon dates provide chronological control on the deposits at the Serpentine site (Fig. 6a–b) (Table 1). All of these are dates on wood charcoal collected during excavations. The charcoal samples were identified as birch (*Betula* sp., presumably shrub birch), willow (*Salix* sp.), and Ericaceae, all of which occur in the vicinity of the site today—shrub birch and Ericaceae (e.g., blueberry) on the site and willow along the stream below the cliff in front of the site.

Sample UCIAMS-90967 (12,760 ± 50 ^{14}C BP, 14,950–15,418 cal BP) originated from an isolated sample of charcoal recovered from a soil pit in the north locus of the site. This sample came from stratigraphic unit 1 and provides a lower-limiting age for the cultural component in unit 2 of the south locus.

The remaining 24 charcoal samples came from stratigraphic unit 2 in the main block excavation, from concentrations of charcoal labeled features A-E (Fig. 6a–b). Five dates on charcoal provide chronological control for Feature A, together suggesting an age of about 12,000–12,400 cal BP for this charcoal concentration. A sixth date, UCIAMS-90964, was run on humic acids from sample UCIAMS-90963 to test for degree of humic-acid contamination. (This date should not be used to interpret the age of unit 2, despite

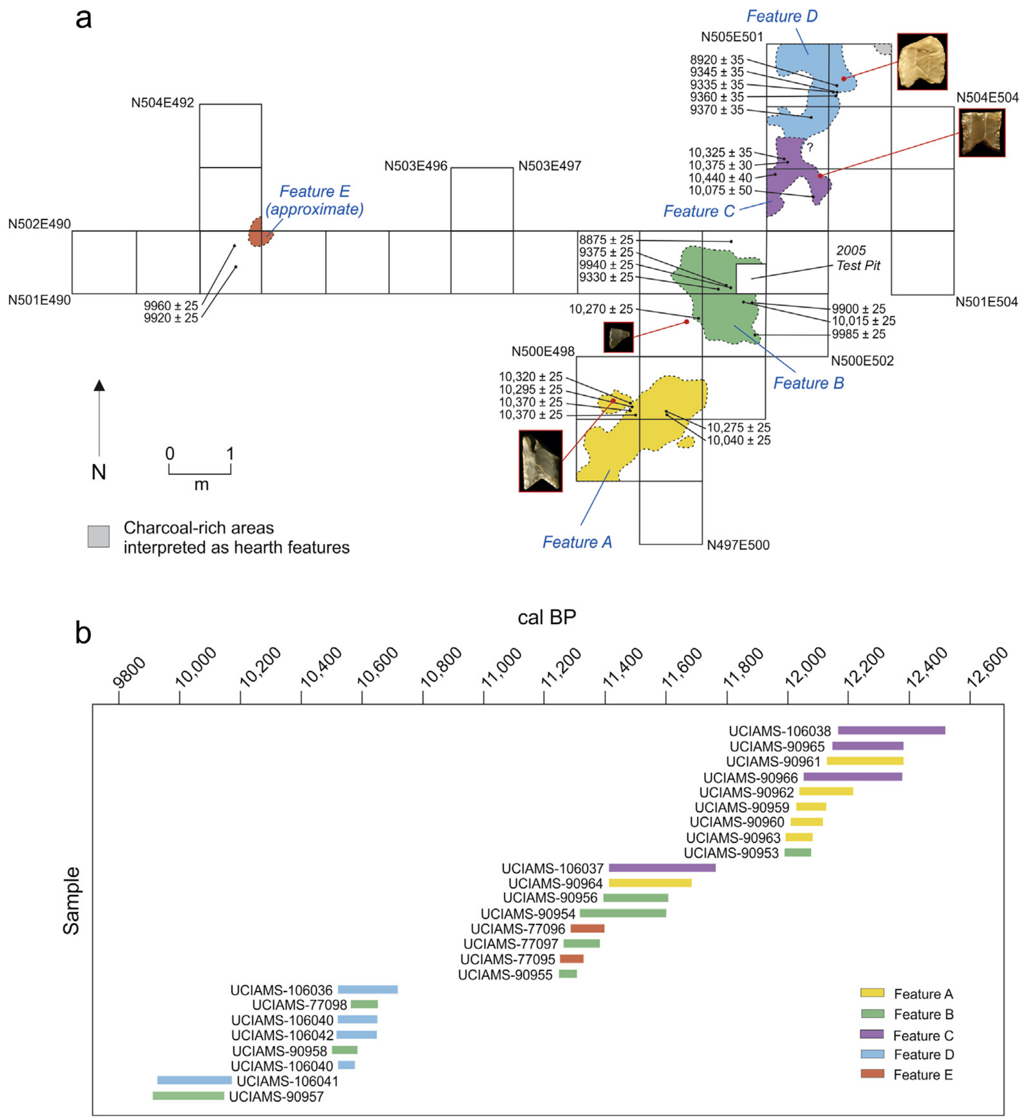

Fig. 6. Spatial context and temporal distribution of radiocarbon-dated charcoal samples from the Serpentine excavation (a, map of 2009–2011 block excavation at Serpentine, showing five discernible hearth features and provenience of radiocarbon-dated charcoal samples (in ^{14}C BP) and fluted points found *in situ*; b, calibrated radiocarbon dates, organized by hearth feature.

concordance with its dated pair.) Feature B yielded seven dates that span from about 9900 to 12,000 cal BP. These dates, however, cluster into two groups, five between 11,200 and 12,200 cal BP, and two between 10,500 and 10,600 cal BP. The Feature B dates are supplemented by four dates previously reported by Young and Gilbert-Young (2007) for this feature: 9480 ± 40, 10,060 ± 40, 10,250 ± 60, and 10,250 ± 60 ^{14}C BP, together ranging from about 10,600 to 12,400 cal BP. Feature C yielded four samples dating in excess of 11,400 cal BP, and three of these fall between 12,000 and 12,500 cal BP. The five dates for Feature D are all younger than 10,700 cal BP, and four of these fall between 10,500 and 10,700 cal BP. Feature E, finally, is associated with a pair of dates suggesting an age of 10,250–11,400 cal BP.

By accepting all of the dates, the obvious interpretation is that unit 2 (and the archaeological material contained within it) was deposited between 9900 and 12,400 cal BP and represents sporadic, very slow deposition of wind-blown silt on the Serpentine ridge top. The question remains, however, whether any or all of the dated samples are the product of intentional burning by humans. A 2500-year span of occupation seems exceptionally long given that individual fluted-point fragments were associated with four of the five features (A–D), and not surprisingly, when considering the dates by taxon, some interesting patterns emerge. The six *Salix* dates span just 12,000–12,500 cal BP, while the eight *Betula* and four Ericaceae dates span 9900–12,000 cal BP, indicating a discrepancy between willow dates and low-growing shrub dates (birch and presumably blueberry). Perhaps the willow charcoal represents wood intentionally burned by humans, while the small-shrub charcoal represents natural wood resulting from later tundra fires and root burn. Ethnographic accounts indicate that Arctic peoples preferred willow when driftwood was unavailable along the northwestern Alaska coast (Stefansson, 1919; cited in Alix, in press), and charcoal from other early archaeological sites in northwestern (i.e., Onion Portage, Tuluaq Hill, and Nat Pass) and central Alaska (i.e., Owl Ridge and Upward Sun River) suggest an early human preference for burning of willow, while shrub-birch charcoal is rare and Ericaceae charcoal is seemingly absent (Alix, in press; Anderson, 1970; Graf and Bigelow, 2011; Potter et al., 2011; Rasic, 2011). Obviously early Beringians preferred to burn willow in their hearths, and this may be an indication that the

Table 1
New radiocarbon dates from the Serpentine fluted-point site (BEN-192).

Sample number	Age, ^{14}C BP	Age, cal BP (1 σ range)	Material dated
Soil pit, north locus			
UCIAMS-90967	12,760 ± 50	14,950–15,418	charcoal[a]
Excavation, south locus			
Feature A			
UCIAMS-90959	10,295 ± 25	12,030–12,120	cf. *Salix* sp. charcoal
UCIAMS-90960	10,290 ± 25	12,010–12,109	cf. *Salix* sp. charcoal
UCIAMS-90961	10,370 ± 25	12,132–12,379	cf. *Salix* sp. charcoal
UCIAMS-90962	10,320 ± 25	12,045–12,210	cf. *Salix* sp. charcoal
UCIAMS-90963	10,275 ± 25	11,998–12,083	cf. *Salix* sp. charcoal
UCIAMS-90964[b]	10,040 ± 25	11,405–11,690	humic acids
Feature B			
UCIAMS-77097	9940 ± 25	11,267–11,385	charcoal[a]
UCIAMS-77098	9375 ± 25	10,567–10,655	charcoal[a]
UCIAMS-90953	10,270 ± 25	11,993–12,078	*Betula* sp. charcoal
UCIAMS-90954	9985 ± 25	11,321–11,598	cf. Ericaceae charcoal
UCIAMS-90955	9900 ± 25	11,247–11,305	*Betula* sp. charcoal
UCIAMS-90956	10,015 ± 25	11,398–11,603	cf. Ericaceae charcoal
UCIAMS-90957	8875 ± 25	9914–10,147	cf. Ericaceae charcoal
UCIAMS-90958	9930 ± 25	11,250–11,390	*Betula* sp. charcoal
Feature C			
UCIAMS-90965	10,375 ± 30	12,142–12,379	charcoal[a]
UCIAMS-90966	10,325 ± 35	12,046–12,372	charcoal[a]
UCIAMS-106037	10,075 ± 50	11,408–11,763	cf. Ericaceae charcoal
UCIAMS-106038	10,440 ± 40	12,169–12,521	cf. *Salix* sp. charcoal
Feature D			
UCIAMS-106036	9370 ± 35	10,524–10,658	*Betula* sp. charcoal
UCIAMS-106039	9335 ± 35	10,501–10,587	*Betula* sp. charcoal
UCIAMS-106040	9360 ± 35	10,520–10,651	*Betula* sp. charcoal
UCIAMS-106041	8920 ± 35	9937–10,178	*Betula* sp. charcoal
UCIAMS-106042	9345 ± 35	10,510–10,645	*Betula* sp. charcoal
Feature E			
UCIAMS-77095	9920 ± 25	11,256–11,325	charcoal[a]
UCIAMS-77096	9960 ± 25	11,285–11,396	charcoal[a]

[a] Sample too small for identification.
[b] Split sample from UCIAMS-90963, test for contamination, rejected as date for feature.

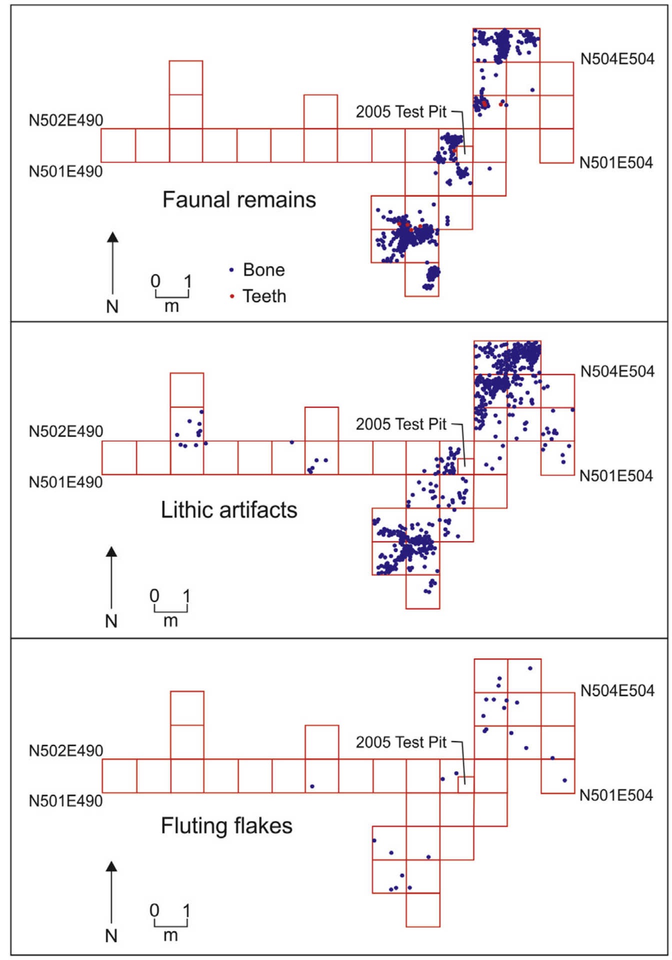

Fig. 7. Map of 2009–2011 block excavation, showing distributions of faunal remains and lithic artifacts recovered *in situ*.

willow dates from Serpentine reflect the real age of the associated fluted points.

With these observations in mind, we conclude that the fluted points from Serpentine certainly date to between 9900 and 12,400 cal BP (confirming earlier ^{14}C dates reported by Young and Gilbert-Young (2007)), but that they could date more specifically to 12,000–12,400 cal BP, the repeated age of the willow charcoal in the site's features. AMS dating of bone or tooth fragments from the same features is needed to test this hypothesis, as is continued dating of willow charcoal, especially from features B, D, and E.

2.5. Features and faunal remains

Despite the complexities of site geology and chronology, the buried cultural component in stratum 2 was stratigraphically intact and excavatable. We precisely mapped >2000 lithic artifacts, small bits of bone and teeth, and charcoal (Fig. 7). As noted above, these were distributed horizontally into four adjacent charcoal-rich features (labeled A–D) in the eastern area of the excavation, as well as a fifth possible feature (E) separated from the rest in the western end of the excavation. Although deformed by solifluction and cryoturbation and not lined with stones, the charcoal features' perimeters could be traced, and they overlapped spatially with distributions of carbonized bone fragments. Features C and D, however, were not easily distinguished from each other; hence their common border was set arbitrarily, with their separation being based on clustering of carbonized faunal remains encountered in the excavation (Fig. 7). Although these five features could represent natural burning events, we hesitate to interpret them as such because charcoal was not uniformly distributed across the site, despite unit 2's obvious occurrence throughout the excavation (Fig. S1). Moreover, as shown in Fig. 7, lithic artifacts and faunal remains were clearly concentrated in and around the charcoal features and relatively rare away from them. Four of the charcoal-rich areas (A–D) also yielded individual associated fluted-point fragments.

Additional evidence of burning comes from the lithic and faunal assemblages. The fluted-point base from Feature A was heat-spalled after discard (Movie S1), and occasional debitage pieces show signs of heat alteration (e.g., pot-lidding). Bone was highly fragmented, with >1000 pieces being less than 15 mm^2 in size, often a characteristic of burned bone assemblages (Costamagno et al., 2005; Stiner et al., 1995). Despite fragmentation, a few specimens were identified to be remains of small ungulates (caribou/deer-sized), and one bone was from a small hare-sized animal. Almost all of the bone was burnt black and carbonized all the way through the compact bone (i.e., Stiner et al.'s (1995) burning code 3) (Fig. 8), suggesting that bone fragmentation was chiefly due to burning (Clark and Ligouis, 2010; Marquer et al., 2012; Stiner et al., 1995). Few of the bones were calcined, and the high proportion of carbonized to calcined bone could be the result of low-temperature burning (e.g., Crass et al., 2011; Théry-Parisot, 2002; Théry-Parisot and Costamagno, 2005) that occurred through natural fires soon after human occupation of the site. This ratio, however, could also be the result of high-temperature burning of bone for fuel. Costamagno et al. (2005) have found

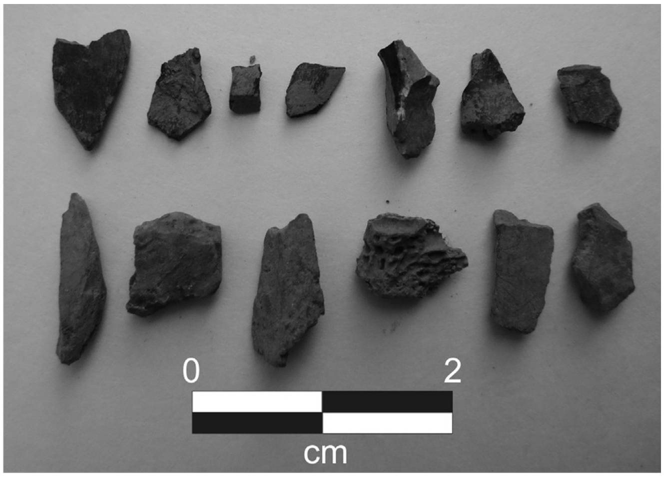

Fig. 8. Carbonized bone fragments from Serpentine fluted-point site excavations.

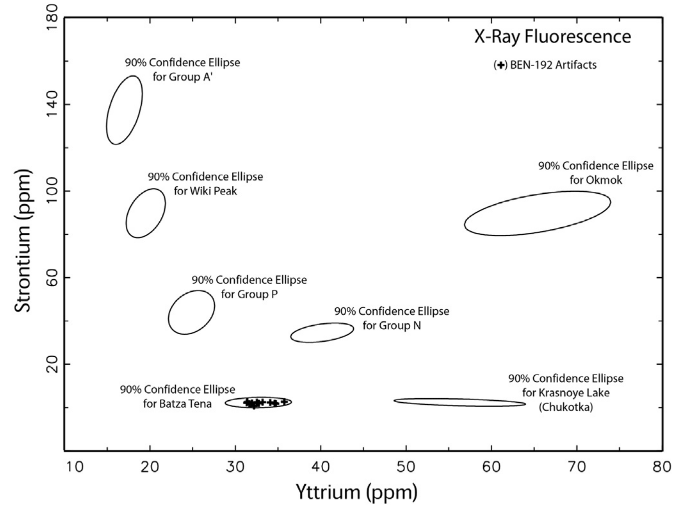

Fig. 9. Bivariate plot of yttrium and strontium concentrations (in ppm), projecting data generated for artifacts from BEN-192 (black crosses) against 90% confidence ellipses for relevant Alaskan and Russian obsidian reference groups.

that although experimental high-temperature, bone-fueled fires produce large quantities of calcined bone fragments, these readily disintegrate upon cooling, so that in Upper Paleolithic contexts features with sparse wood charcoal and concentrated carbonized bone fragments could have resulted from intentional burning of bone as fuel (Costamagno et al., 2005). In the alternatingly frozen and wet sediments at Serpentine, the concentrations of fragmented, carbonized bone, charcoal, and lithic debris (some with signs of heat alteration) could similarly represent cultural features resulting chiefly from such behavior. Again, continued dating coupled with careful taphonomic analyses may resolve this problem (Movie S1).

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.jas.2013.05.027.

2.6. Lithic artifact assemblage

Here we summarize the excavated lithic assemblage. It includes 1481 debitage pieces and 31 tools. Among the debitage, cherts and chalcedonies (95.1%) dominate, while quartzite (2.2%), obsidian (1.3%), diabase (1.0%), and quartz (0.9%) are rare. Sources of raw materials are not well-known, but the cherts and chalcedonies may have originated far from Serpentine, in the western Brooks Range ~250–300 km northeast, while obsidian debitage, according to X-ray fluorescence analysis, originated from Batza Téna, 450 km east (Fig. 9; Table S1). Debitage consists primarily of biface-thinning flakes and retouch chips (together 89.9% of the classifiable assemblage), while core-reduction (2.2%) and cortical (0.9%) flakes are much less common. Among the biface-reduction debitage there are 31 fluting (or "channel") flakes (Fig. 10l–n), providing evidence that biface fluting occurred at Serpentine. Six bladelet fragments, 19 microblade fragments, and one platform tablet from a conical-shaped bladelet/microblade core (Fig. 10i) were also recovered from the excavation; however, only four of these (three bladelets and one microblade fragment) came from the hearth areas that produced the fluted points, while the remainder (including three bladelets, 18 microblade fragments, and the core tablet) came from isolated feature E in the western area of the excavation or upper unit 3, the latter representing a significantly younger ephemeral occupation.

Excavated tools consist of nine bifacial-point fragments, 15 biface fragments, and seven flake tools, all on cherts and chalcedonies. Four of the bifacial points are fragments of fluted points (Fig. 10e–h), while the others include two unfluted fragments with tongue-shaped bases and three non-diagnostic fragments, a basal corner and two tips. One of the tip fragments (Fig. 10k) has a constricted hinge similar to those commonly found in Folsom and other post-Clovis fluting industries of temperate North America (Crabtree, 1966; Wilmsen and Roberts, 1978). [A similarly constricted-hinged point tip was also recovered from the surface of the north locus (Fig. 10j).] The 15 biface fragments are small and undiagnostic, except that all show signs of being from finished or late-stage bifaces. Flake tools include one multi-spurred graver, one double side scraper, and five marginally retouched pieces (three flakes, one bladelet, and one flute flake).

In sum, the excavated assemblage of debitage and tools indicates that technological activities at Serpentine focused on finishing, fluting, and resharpening of bifacial points potentially transported great distances to the site, while local raw-material procurement, core reduction and early-stage-biface production rarely occurred. This was a short-term lookout camp occupied by small groups of mobile hunters who made repeat visits during a ~2000-year time span or less. They typically discarded broken bifacial points on site, but on at least one occasion they alternately discarded bladelets and microblades, some from a conical core.

3. Serpentine's fluted points

Eight fragments of fluted points have been recovered in the Serpentine Hot Springs area, seven at the main site (BEN-192) and an eighth at nearby BEN-170. Four of the BEN-192 points came from the south-locus excavation.

The four fluted-point fragments from the excavation are basal fragments on four different kinds of cherts/chalcedonies (Fig. 10e–h). They have multiple flute scars on both faces, typically three, sometimes two. The points are relatively small, averaging just 21.86 mm wide at the base and 5.61 mm thick (Table 2). Lateral margins are straight to slightly expanding toward the tip, and bases are deeply concave and V-shaped. Lateral and basal margins were finely trimmed after fluting, sometimes edge-ground. One of the points (Fig. 10e) spalled facially along a natural vein in the rock, likely from exposure to high heat; it was adjacent to one of the hearth features. Another point (Fig. 10h) was damaged at its tip and both basal corners, likely from impact against a hard material while in the haft; this point was

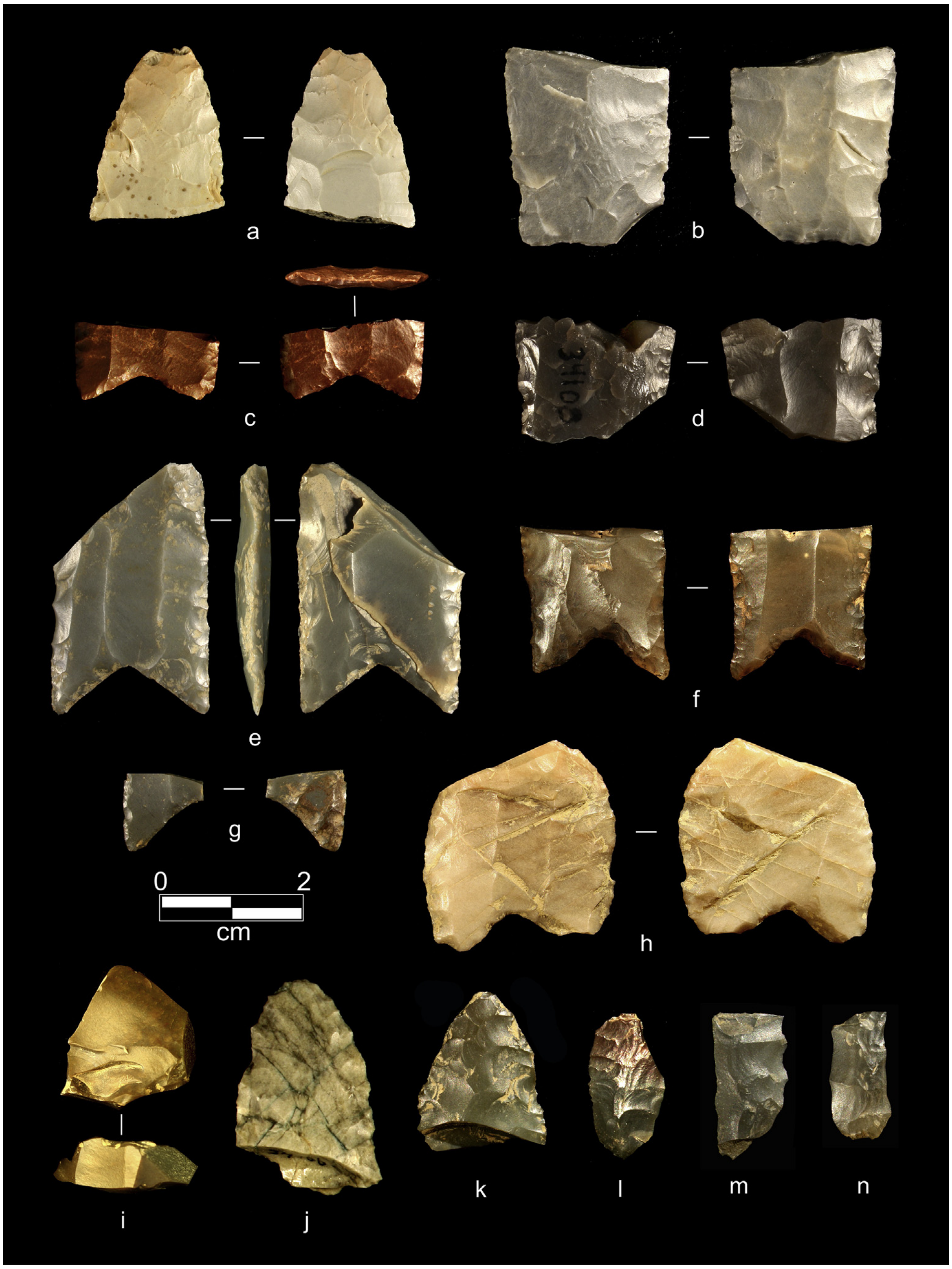

Fig. 10. Fluted points and associated lithic materials from Serpentine Hot Springs (a–h, fragments of fluted points; i, core tablet from conical bladelet/microblade core; j–k, biface tips with narrowed lip indicative of instrument-assisted fluting; l–n, fluting, or "channel", flakes). Artifacts e-h and k-n are from the excavation at the south locus of BEN-192; b–d and j are surface finds from BEN-192; c is the original 2005 fluted-point find; a is a surface find from BEN-170. Accession numbers for the fluted points (corresponding to Table 2) are: a, BELA-30561; b, BELA-34172; c, BELA-30104; d, BELA-34108; e, BELA-38789; f, BELA-50298; g, BELA-34230; h, BELA-49913.

resharpened to extend its use-life. Arises of flute scars often show abrasion from hafting, providing further evidence that the points were used as weapon tips.

Three additional fluted points were recovered from the surface of BEN-192. These include the original fluted-point base with multiple flutes discovered in 2005 (Young and Gilbert-Young, 2007) (Fig. 10c), as well as two additional fragments recovered during the 2009 field season. One of these is a midsection of a multiple-fluted point on chalcedony (Fig. 10d), while the other is a basal fragment on chert (Fig. 10b). The basal fragment has a single major flute and remnants of two minor guide flutes on its obverse face, while its reverse face was not fluted at all. Impact damage on this point suggests that it did not break during manufacture but instead was intentionally prepared to serve as a unifacially fluted point.

Besides the seven fluted-point fragments recovered from BEN-192, we recovered a tip fragment of a fluted point from the surface of a nearby site, BEN-170, located about 500 m south of BEN-192. This point is made on tan-gray chert, has evidence of a single flute on one face, and shows signs of having been exposed to high heat (it has a "potlid" and reddish tint near its tip) (Fig. 10a). Few other finds were recovered nearby this artifact, and we consider it to represent an isolate.

The eight fluted-point fragments recovered from the Serpentine Hot Springs area constitute one of the densest concentrations of

Table 2
Contextual, technological, morphological, and metric characteristics of fluted points from Serpentine Hot Springs.

Artifact No.	Provenience	Raw material	No. of flutes	Break	Basal shape	Width (mm)	Basal width (mm)	Thickness (mm)
BELA-30104	BEN-192; surface, south locus	Maroon chert	3/3	Typical hinge	V-shaped, concave	–	18.3	≥3.6
BELA-34108	BEN-192; surface, north locus	Gray-brown chalcedony	3/≥1	Snapped on both ends	–	≥22.5	–	≥6.5
BELA-34172	BEN-192; surface, north locus	Gray chert	1/0	Impact fracture	Straight	≥23.3	21.1	≥7.1
BELA-34230	BEN-192; excavation, N500E499	Green-gray chert	≥2/≥1	Transverse and longitudinal snaps	Deeply concave	–	–	≥2.7
BELA-38789	BEN-192; excavation, N499E498	Gray chert	3/3	Snap, along natural vein	V-shaped, deeply concave	≥24.7	22.5	≥6.0
BELA-49913	BEN-192; excavation, N504E502	Tan-gray chert	3/3	Impact fracture, partially along natural vein	V-shaped, deeply concave	≥20.6	19.8	≥4.6
BELA-50298	BEN-192; excavation, N502E501	Brown chalcedony	3/2	Impact fracture	V-shaped, deeply concave	≥27.4	23.3	≥6.0
BELA-30561	BEN-170; surface	Tan-gray chert	≥1/0?	Snap, from heating?	–	≥18.6	–	≥2.7

fluted points so far recovered from a single place in Alaska. As a group, the Serpentine points are small, narrow, multiple-fluted (although two fragments appear fluted just on one face), and have deeply concave, typically V-shaped bases. Like late Paleoindian fluted points from temperate North America (e.g., Goodyear, 2010), the Serpentine points' bases are too narrow and deeply concave to have been fluted through direct hammer percussion; rather, fluting likely occurred with a narrow punch or pressure flaker. Lateral retouching scars evident on the faces of the points extend no farther than biface midlines, while overshot/overface flaking, a hallmark of Clovis biface technology (Bradley et al., 2010; Smallwood, 2010), was not employed. In these respects—small size, multiple fluting, deeply concave bases, and to-the-midline flaking—the Serpentine points are distinct from Clovis. Instead, they seem morphologically and technologically more similar to late Paleoindian fluted points from temperate North America (e.g., Eren et al., 2011; Frison and Bradley, 1980; MacDonald, 1966).

4. Discussion

Given the evidence recovered thus far from the Serpentine fluted-point site excavations, we make the following conclusions about the site and its contents. First, its main cultural component occurs in a deposit of wind-blown silt that was sealed across the south locus of the site by 15–40 cm of grussy silt colluvial in origin. Second, although cryogenically disturbed and in places deflated, this cultural component remains intact and excavatable. Third, archaeological materials recovered from this component include numerous lithic artifacts and small fragments of carbonized bone and wood charcoal. Fourth, the concentrated associations of carbonized bone, charcoal, and occasional heat-altered lithic artifacts suggest the presence of five hearth remnants. Fifth, charcoal recovered from these features indicates the main cultural occupation occurred during the interval of 9900 and 12,400 cal BP; however, if only dates on willow charcoal, possibly the most suitable as a fuel source for humans, are considered, the span of occupation can be inferred to date to 12,000–12,400 cal BP. Sixth, individual fluted-point fragments have been recovered in or adjacent to four of the hearth features; these points are relatively small, multiple-fluted, and deeply concave-based, and they appear to have been fluted with the assistance of a punch. Seventh, technological activities on the site focused on resharpening and refurbishing of bifaces and finished bifacial points transported from elsewhere. Eighth, a few microblades and bladelets are present in the assemblage, but most of them are from around a fifth feature (Feature E) spatially segregated from features with fluted points, or in above-lying, much younger deposits (in or just below the modern O horizon).

Our results are consistent with similar finds from northwestern North America. At Raven Bluff in the nearby Brooks Range of northwestern Alaska, a fluted point similar to the Serpentine points was recently recovered in association with caribou remains and charcoal dated to about 12,000 cal BP (McCaa, 2009/2010). Research continues there, so details are not yet reported. At Charlie Lake Cave, central British Columbia, a multiple-fluted bifacial point was recovered from deposits with bison remains and dating to 12,500 cal BP (Driver, 1996, 1999; Fladmark et al., 1988). Moreover, at Engigstciak, northern Yukon (Canada), a possible fluted-point fragment was reportedly found in association with bison bones (MacNeish, 1956) subsequently ^{14}C dated to about 10,700–11,600 cal BP (Cinq-Mars et al., 1991), and at Mesa, northern Alaska, a "bipolarly" fluted biface appears to have been associated with hearth charcoal ^{14}C dated to about 12,000 cal BP (Kunz and Reanier, 1995; Kunz et al., 2003). Together with the numerous fluted points from undated contexts across the region, these finds indicate the presence of a late Paleoindian fluted-point complex that existed in northwestern North America at the very end of the Pleistocene.

Despite having data from just a handful of dated fluted-point sites from the far north, the contextual, chronological, and technological details recovered from Serpentine Hot Springs are still useful for interpreting the place of northern fluted points in the late Pleistocene peopling of the Americas. Certainly, Serpentine's fluted points are too young to be antecedent to Clovis, and they seemingly are too old to be a non-Paleoindian, mid-Holocene complex. The 9900–12,400-cal-BP ^{14}C ages and technological aspects of the Serpentine points indicate they represent a terminal Pleistocene/earliest Holocene, late Paleoindian, instrument-assisted fluting industry that likely spread from western Canada. With the evidence presently at hand, however, we cannot confidently determine whether the Serpentine points represent the diffusion of technology or dispersal of humans. On the one hand, the loose association of fluted points and microblades in the Serpentine excavation suggest that northern fluted points represent the transmission of a sophisticated projectile technology into Alaska through existing "Paleoarctic" populations. On the other hand, most of the metrically defined microblades (<5 mm in width) from the excavation were horizontally or stratigraphically separated from the fluted points, and the sole diagnostic technological artifact related to microblade production, a platform-rejuvenation tablet, came from a small conical core, not a narrow-faced wedge-shaped or end (*tortsovyi*) microblade core more diagnostic of the Paleoarctic tradition. We anticipate that continued spatial analysis of the Serpentine materials will help clarify this issue of the association of fluting and microblade technologies, as will excavations at other fluted-point sites in northwest Alaska (e.g., Raven Bluff).

The northward dispersal/diffusion hypothesis finds precedence in genetic models of both bison and humans. At the end of the Pleistocene in western Canada, the northern Plains clade of bison dispersed northward into the emerging ice-free corridor between the Laurentide and Cordilleran ice sheets, coming into contact with Beringian bison about 12,000–12,500 cal BP (Shapiro et al., 2004). Possibly western Canadian fluted-point makers followed these northward-dispersing bison herds to the southeastern edge of Beringia, whence they continued to disperse (or their technology continued to diffuse) into northern Yukon and Alaska, reaching the Bering Strait by 12,000 cal BP. High-resolution mitochondrial-DNA sequencing data from modern Native Americans and northeast Asians, although not well-defined chronologically, also indicate human migrations (or at least significant gene flow) from interior northwest North America to the Bering Strait and beyond. American sub-haplogroup A2a, for example, has been traced from the Dogrib of interior western Canada to several interior northeast Siberian groups (Tamm et al., 2007). Whatever the mechanism of transmission of fluted-point technology into the north, obviously the peopling of Beringia was a much more complicated process than the traditional, unidirectional Bering land bridge theory for Native American origins allows.

The late Paleoindian age of northern fluted points also helps explain their presence across northern Alaska but not neighboring Chukotka. By the time of the fluted-point occupation at Serpentine Hot Springs <12,400 cal BP, the Bering land bridge was becoming completely flooded forming the Bering Strait, effectively separating America from Asia (Elias et al., 1996; Keigwin et al., 2006). Fluting technology simply arrived too late in eastern Beringia to be transmitted terrestrially into western Beringia. Serpentine may represent the northwestern-most outpost of late Paleoindians in the Americas.

What of Clovis origins? The fluted-point industry at Serpentine is clearly too young to be relevant, and if we dare assume that the similarly shaped and manufactured fluted points from numerous other localities across northern Alaska are also <12,500 cal BP, then all are irrelevant to Clovis origins. Despite this, the discoveries at Serpentine Hot Springs are significant in our search for evidence of the first Americans in Beringia. After decades of looking, with Serpentine we have the first unequivocal evidence of Pleistocene humans in the central Bering Land Bridge region, despite it dating to the very end of the Pleistocene, as the land bridge itself was rapidly flooding (Elias et al., 1996). Systematic geomorphologically based surveys in the uplands of the land bridge, on both the Alaskan and Chukotkan sides, as well as underwater exploration of the now-submerged shelves of the Bering and Chukchi seas, must occur to determine whether the progenitors of Clovis indeed passed through this American gateway thousands of years earlier.

Our work with the Serpentine materials continues. Although excavations are complete, we are still engaged in careful lithic, faunal, paleobotanical, spatial, and sedimentological analyses. Through these studies we hope to achieve greater chronological control over the site's fluted-point component, better understand the site's context and formation, confirm whether the site's features are indeed cultural hearths, clarify the association of fluted points and microblades, and interpret technological and morphometric relationships between Serpentine's fluted points and those from other sites in Alaska, subarctic Canada, and temperate North America.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2013.05.027.

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