REPORT

A LATE PLEISTOCENE MEGAFAUNA, KENAI PENINSULA, SOUTHCENTRAL ALASKA

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ABSTRACT

Models of eastern Beringia generally exclude the southwestern Kenai Peninsula in southcentral Alaska, yet fossils of extinct large vertebrates have been discovered on beaches and in stream floodplains. We report nine fossils of woolly mammoths, two steppe bison, and bones of an undetermined herbivore and an undetermined carnivore radiocarbon dated from 20,470 ^{14}C yrs BP to > 48,500 ^{14}C yrs BP. We propose that the fossils represent a middle Wisconsinan (marine-isotope stage 3 [MIS 3]) to late Wisconsinan (MIS 2) megafauna that persisted on the peninsula for at least 28,000 ^{14}C years before becoming locally extirpated after 20,470 ^{14}C years ago. Geographic distribution of the fossils indicates that all have been displaced from unknown sites of preservation close to or outside the nearby limits of the Naptowne glaciation.

Beginning in the late 1940s, residents of the Kenai Peninsula have reported the discovery of Pleistocene-age mammal fossils (Thorson et al. 1981:405). For decades, few people seriously considered that a mammal community had inhabited the peninsula during the Pleistocene (Klein 2008:15–18) because the region was intensely glaciated (Karlstrom 1964; Reger et al. 2007). However, the growing number of fossils encouraged us to document the known discovery localities, to radiocarbon date the fossils, and to relate their distribution to known glacial limits.

Since 2010, we have collaborated with Kenai Peninsula residents in a citizen-science program to document their fossil finds. Residents who discovered mammal fossils along beaches and creeks and retained them in personal collections were encouraged to contact us. We examined the fossils, documented the evidence, recorded field locations, and contacted experts in bone identification. To identify specimens or verify previous identifications, vertebrate paleontologist Patrick Druckenmiller, earth science curator at the University of Alaska Museum of the North, compared these fossils with the museum's extensive vertebrate fossil collection. Integral to the public outreach program were thirteen articles in Homer, Soldotna, Anchorage, and Fairbanks newspapers and five public lectures that increased public awareness of our developing investigation. The purpose of this paper is to publish this inventory and discuss the implications.

A chronology for the fauna was developed by radiocarbon (^{14}C) dating, using atomic mass-spectrometer (AMS) methods. Finite AMS radiocarbon ages were calibrated online with the Calib 7.0.1 program and IntCal13 and Marine13 calibration curves (Reimer et al. 2013). Infinite radiocarbon dates could not be calibrated. In Table 1 of this paper, we report our radiocarbon and calibrated ages.

STUDY AREA

The Kenai Peninsula protrudes into the North Pacific Ocean from southcentral Alaska (Fig. 1). Cook Inlet is a large, tide-flushed estuary that separates the Kenai Peninsula from the Alaska Range and Alaska Peninsula to the west and the Chugach Mountains to the north. The ice-capped Kenai Mountains, a segment of the extensive Chugach Mountains arc, form the eastern backbone of the peninsula. Between the Clam Gulch–Anchor Point lowland to the west and the Kenai Mountains to the east are the Caribou Hills, a glacier-scoured upland of late Tertiary sedimentary rocks that stands in relief up to ~800 m (Bradley et al. 1999).

Mapping by Karlstrom (1964) and Reger et al. (2007) and our interpretation of aerial photographs indicate that erosion features and deposits of the penultimate glaciation are present in the northwestern Kenai Mountains and in the upper Caribou Hills above and beyond features of the last major glaciation. In the Caribou Hills, erosion features and deposits of the penultimate glaciation reach an elevation of 810 m around the highest summit (Ptarmigan Head, 870 m asl), surrounding an ice-free area of about 3 km^2 (Fig. 2). Although the penultimate glaciation has not been dated on the Kenai Peninsula, cosmogenic-exposure ages indicate that correlative glacial deposits in east-central Alaska and in the central and western Alaska Range are early Wisconsinan (marine-isotope stage 4 [MIS 4]) in age: 45–60 kya (thousand years ago) (Briner et al. 2005); 54.6 ± 3.5 kya (Dortch et al. 2010); and 55.6 ± 8.9 kya (Matmon et al. 2010).

During the early phase of the last major (MIS 2, Naptowne) glaciation, which began about 32 kya, glaciers advancing eastward from the Alaska Peninsula near the

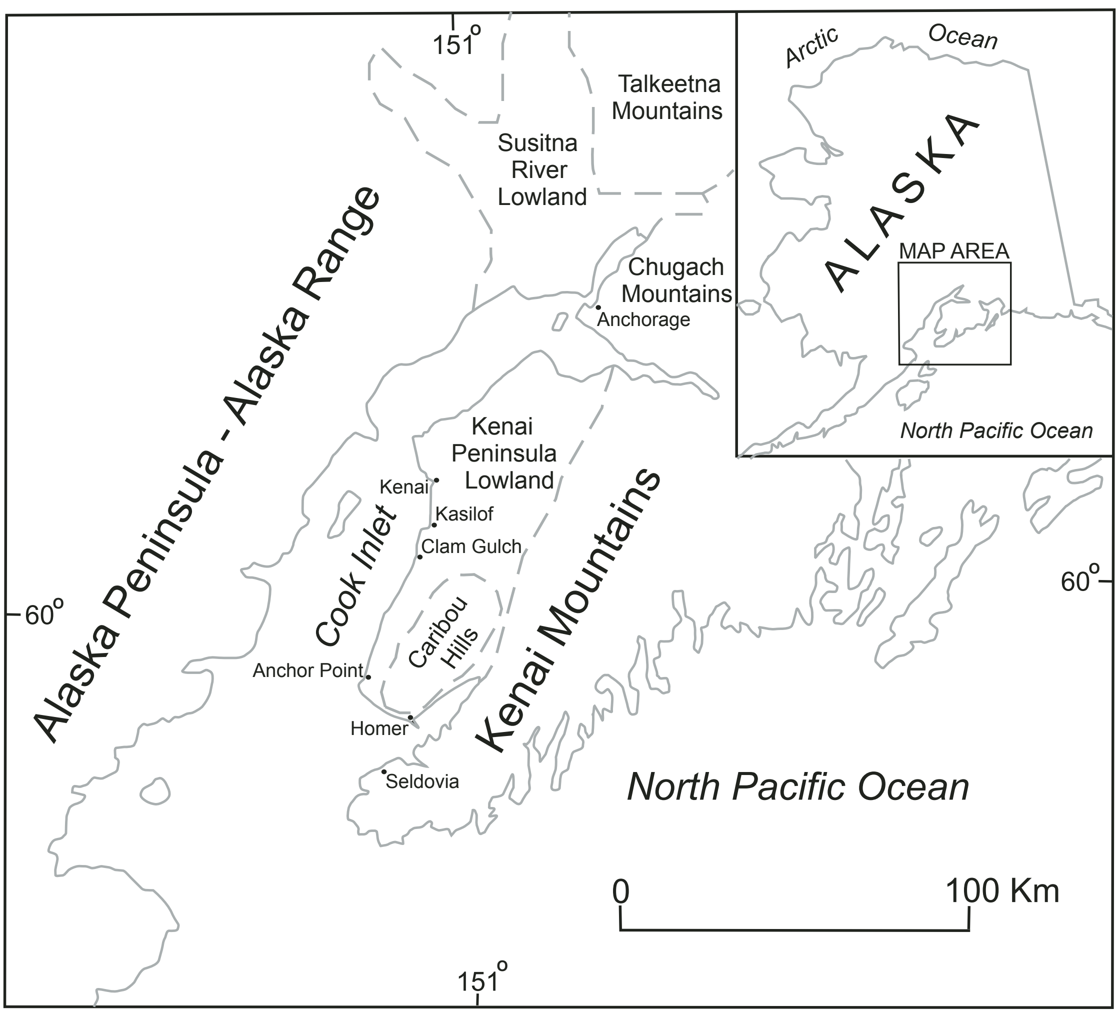

Figure 1. Major physiographic features and principal settlements in the vicinity of the Kenai Peninsula lowland.

southwestern Cook Inlet trough met with ice advancing westward from the southern Kenai Mountains, blocking the mouth of the trough (Reger et al. 2007). Because eustatic sea level was dropping at the time in response to expanding worldwide, land-based glaciation (Benn and Evans 1998), the ice barrier became grounded, forming a massive glacier dam that impounded an extensive, cold meltwater lake in the Cook Inlet basin (Karlstrom 1964). Vigorously expanding glaciers from the Alaska Range and Alaska Peninsula spread eastward relatively quickly across this lake and reached maximum positions on the western Kenai Peninsula, probably before less vigorous, shorter ice streams from the Kenai Mountains reached their maximum extents (Reger et al. 2007). During this period, the Caribou Hills were surrounded by glacial ice on the northern, eastern, and southern flanks and by a large, meltwater lake impounded between the Cook Inlet lowland ice sheet from the west side of Cook Inlet and the western flank of the Caribou Hills (Fig. 2). Between 19.0 and 28.0 kya, the extended glacier system became unstable, thinned, and began receding. This general recession was interrupted by successively less extensive readvances that culminated ~18.0 kya, ~16.5 kya, and ~15.0 kya (Reger et al. 2007). The Naptowne glaciation ended 11.0 kya.

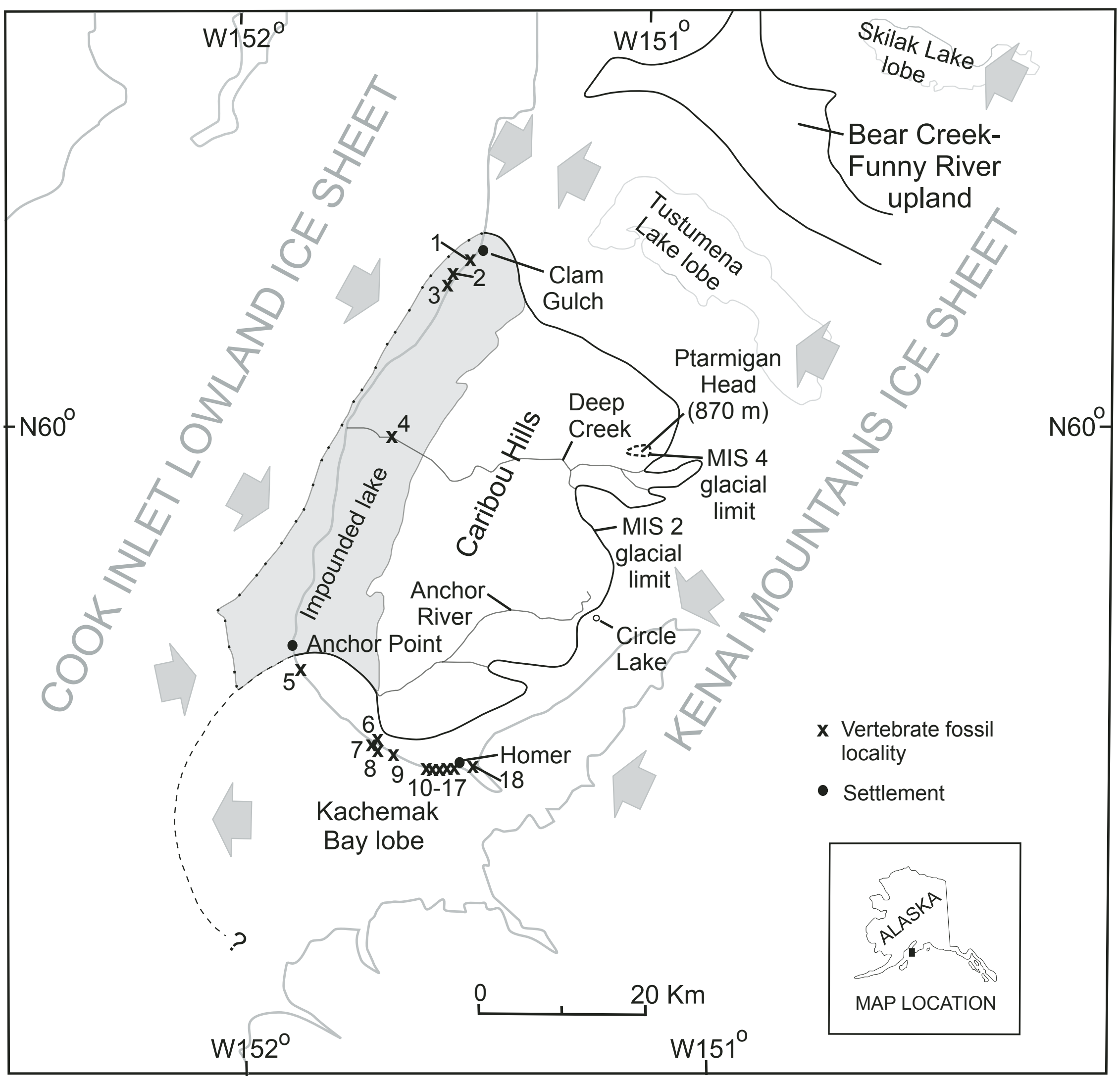

Figure 2. Localities (x) where retransported mammal fossils have been found on the southwestern Kenai Peninsula related to ice limits during the penultimate (MIS 4) and last major (MIS 2 Naptowne) glaciations. Locality numbers are keyed to Table 1. Ice limits are solid where based on definitive marginal features, dashed where approximately located, and dotted where inferred. Arrows indicate dominant glacier flow directions during the Naptowne glaciation.

The modern climate of the southwestern Kenai Peninsula is maritime along the coast, where annual precipitation ranges from ~63 cm at Homer to ~91 cm at Seldovia (Ager 2000). Average annual temperature is about 3°C along the southern inlet, and cloudy winters are rainy when relatively warm maritime air masses are present or snowy when cooler, continental air masses episodically move into the area. Farther north in the Cook Inlet trough, the average annual temperature is about 1°C at Kenai, and winters tend to be less cloudy and drier.

Lowland forests in the Kachemak Bay area are transitional between coastal and boreal forests (Ager 2000). Coastal rain forests are dominated by Sitka spruce and western hemlock with dense thickets of alders, devil's club, and other shrubs (Viereck and Little 1972). Upland forests are composed of white spruce, white spruce x Sitka spruce hybrids (Lutz spruce), scattered black spruce, Kenai birch, black cottonwood, balsam poplar, and quaking aspen with alder and willow thickets. Altitudinal treeline is located at ~370 to ~500 m asl (Ager 2000). Open muskegs are vegetated by scattered and stunted black spruce and by a variety of low shrubs, sedges, grasses, and mosses in poorly drained forested and alpine settings. Better-drained, upper alpine slopes in the Caribou Hills support sedges, grasses, and forbs, and low shrubs grow in drainages and sites protected from desiccating winter winds.

Draining the central and southern Caribou Hills are Deep Creek and Anchor River, respectively, each about 48 km long (Fig. 2). These waterways cut deeply through coastal bluffs to disgorge their sediment loads into Cook Inlet. Numerous debris flows occur along the bluffs between Homer and Clam Gulch.

FOSSIL INVENTORY

During the past fifty-six years, eighteen ice-age mammal fossils were reported collected in the southwestern Kenai Peninsula, including sixteen from the 80-km-long beach between Clam Gulch and Homer and two on creek floodplains (Fig. 2). Concentrations of vertebrate fossils were discovered along the beach up to 6 km south of Clam Gulch and within 10 km of Homer (Fig. 2). Some fossils are broken and abraded, indicating that they had been eroded from the sites of their initial preservation and transported to distant locations where they were found.

Woolly mammoth (*Mammuthus primigenius*) is represented by thirteen fossils, including eight molars, four tusk fragments,[1] and one astragalus. Molars, several of which are well preserved, represent 61.5% of the mammoth remains (Fig. 3). Particularly significant is the recovery of a 41-cm-long mammoth tusk section, dated at 31,740 ± 200 ^{14}C yrs BP (Beta-304499), on a floodplain gravel bar deposited during the massive November 2002 flood of Deep Creek, where the source of the tusk fragment is unequivocally identified as the Caribou Hills. Radiocarbon dating establishes the ages of the mammoth remains between 20,470 ± 90 ^{14}C yrs BP (Beta-345995) and > 48,500 ^{14}C yrs BP (UCIAMS-87255). One mammoth molar, dated > 43,500 ^{14}C yrs BP (Beta-327313), was donated to the Kasilof Regional Historical Association (acc. no. 13-255). The other fossils remain in private collections. The Δ^{13}C ratios for bone collagen in the woolly mammoth fossils range from –20.2 to –21.7‰ (n = 11) (Table 1).

Steppe bison (*Bison priscus*) is represented in our small collection by three horn cores, including a right horn core attached to a broken but unabraded partial skull that was found in lower Diamond Creek in 2012 (Fig. 2, locality 6; Fig. 4). That horn core provided an infinite radiocarbon age of > 43,500 ^{14}C yrs BP (Beta-331131). The 20-cm-long tip of a steppe bison horn core, which also dated > 43,500 ^{14}C yr BP (Beta-401969), was found in beach gravels near the mouth of Diamond Creek in January 2015. The Δ^{13}C ratios for bone collagen in these two fossils are –19.4 and –20.2‰, respectively (Table 1). One small, undated, partial horn core appeared to be contaminated (pers. comm. Chris Patrick, Beta Analytic, 14 January 2015). A fourth horn core was reported by R. B. Gray, who lived near Diamond Creek during the 1940s; Gray donated it to the University of Alaska Museum (acc. no. 373) (Thorson et al. 1981:405). Unfortunately, the record, location, and horn core have been missing for more than thirty years.

Two fossils have been dated but are not identified to species. A femur fragment from an ungulate was dated at 32,220 ± 240 ^{14}C yrs BP (Beta-361909) and has a Δ^{13}C ratio of –20.2‰ for bone collagen (Table 1). A medial rib fragment was dated > 46,100 ^{14}C yrs BP (UCIAMS-110721). The rib fragment has a stable-isotopic signature (Δ^{15}N = 11.8 ‰, Δ^{13}C = –16.2‰) (Table 1) for bone collagen that is consistent with a piscivorous carnivore, such as a bear or perhaps a seal or whale (pers. comm. John Southon to Edward Berg, 3 July 2012; Hilderbrand et al. 1996).

DISCUSSION

Comparison of fossil ages with the glacial chronology for the western Kenai Peninsula reveals that eleven of

Figure 3. Well-preserved occlusal surface of mammoth molar dating 40,080 ± 430 ^{14}C yrs BP (Beta-304497), which was found in 2008 on the beach near Homer (Table 1 and Fig. 2, locality 16). Scale in centimeters.

Figure 4. This 47-cm-long skull and right horn core from lower Diamond Creek provided an infinite radiocarbon age of > 43,500 ^{14}C yrs BP (Beta-331131) (Table 1 and Fig. 2, locality 6).

Table 1. AMS radiocarbon ages of ice-age mammal fossils found on the southwestern Kenai Peninsula, keyed to Figure 2. Analyses were conducted by Beta Analytic and University of California Irvine (UCIAMS). Finite ages calibrated using the Calib 7.0.1 and IntCal13 and Marine13 calibration curves (Reimer et al. 2013); calibrated ages are rounded to the nearest ten years and are reported as the median (50 percentile) age. Infinite calibrated ages are considered to be > 50,000 cal yrs BP.

Map locality	Reported latitude/ longitude	Species	Fossil element	$\Delta^{13}C$ ‰	Radiocarbon age ± 2σ (^{14}C yrs BP)	Calibrated median age (cal yrs BP)	Laboratory number
1	N 60° 12′47.3″ W 151° 25′ 12.9″	*Mammuthus primigenius*	molar				
2	N 60° 10′ 57.0″ W 151° 29′ 10.9″	*Mammuthus primigenius*	molar	–20.9	> 43,500	> 50,000	Beta-327313
3	N 60° 09′ 45.6″ W 151° 32′ 08.4″	*Mammuthus primigenius*	molar				
4	N 60° 16′ 02.0″ W 151° 37′ 17.6″	*Mammuthus primigenius*	tusk fragment	–21.1	31,740 ± 200	35,640	Beta-304499
5	N 59° 45′ 20.0″ W 151° 51′ 38.6″	*Mammuthus primigenius*	molar				
6	N 59° 40′ 16.2″ W 151° 42′ 10.5″	*Bison priscus*	horn core	–19.4	> 43,500	> 50,000	Beta-331131
7	N 59° 40′ 13.4″ W 151° 42′ 12.2″	*Mammuthus primigenius*	tusk fragment	–20.5	28,200 ± 420	32,150	UCIAMS-110723
8	N 59° 40′ 11.5″ W 151° 42′ 19.9″	*Bison priscus*	horn core	–20.2	> 43,500	> 50,000	Beta-401969
9	N 59° 39′ 32.2″ W 151° 41′ 50.7″	*Bison priscus*	horn core	–21.2	appeared contaminated		Beta-304498
10	N 59° 39′ 01.1″ W 151° 38′ 44.5″	*Unidentified ungulate*	femur articulation	–20.2	32,220 ± 240	36,110	Beta-361909
11	N 59° 38′ 45.1″ W 151° 37′ 03.4″	*Mammuthus primigenius*	tusk fragment	–20.8	27,040 ± 200	31,070	UCIAMS-87256
12	N 59° 38′ 37.1″ W 151° 35′ 29.5″	*Mammuthus primigenius*	molar	–21.7	> 46,100	> 50,000	UCIAMS110722
13	N 59° 38′ 36.5″ W 151° 35′ 23.9″	*Mammuthus primigenius*	molar				
14	N 59° 38′ 32.0″ W 151° 35′ 34.1″	*Unidentified carnivore*	rib fragment	–16.2	> 46,100	> 50,000	UCIAMS-110721
15	N 59° 38′ 31.0″ W 151° 34′ 31.6″	*Mammuthus primigenius*	molar	–20.4	39,620 ± 480	43,340	Beta-331132
16	N 59° 38′ 20.9″ W 151° 32′ 58.9″	*Mammuthus primigenius*	molar	–20.5	40,080 ± 430	43,700	Beta-304497
17	N 59° 38′ 13.0″ W 151° 32′ 18.4″	*Mammuthus primigenius*	astragalus	–21.5	> 48,500	> 50,000	UCIAMS-87255
18	N 59° 37′ 50.6″ W 151° 29′ 57.5″	*Mammuthus primigenius*	tusk fragment	–20.5	20,470 ± 90	24,660	Beta-345995

twelve dates cluster during the MIS 3 interstade[2] (Fig. 5). We suggest that large mammals were extirpated in the Caribou Hills during the MIS 4 glaciation, when glacial ice inundated all but about 3 km^2 of the highest summit (Ptarmigan Head).

The mid-Wisconsinan woolly mammoth and steppe bison fossils found on the southwestern Kenai Peninsula represent principal components of the megafauna that concurrently inhabited eastern Beringia (Froese et al. 2009; Gaglioti et al. 2011; Guthrie 1990, 2001; Harington 2011; Zazula and Kuhn 2014). Thorson et al. (1981) dated a proboscidean (cf. woolly mammoth) femur at 29,450 ± 610 ^{14}C yrs BP (Beta-1819) in the northwestern Copper River basin (Fig. 6, locality A). They proposed that large mammals migrated from the Beringian interior through principal passes in the Alaska Range after the retreat of MIS 4 glaciers and before the last major glaciation. Our results support the mid-Wisconsinan migration hypothesis and extend the length of the hypothetical migration at least 190 km to the southwestern Kenai Peninsula. No paleobotanical data exist to characterize the middle Wisconsinan vegetation on the Kenai Peninsula, and we are reluctant to speculate on it because the character of the mid-Wisconsinan flora varied in time and space across eastern Beringia (Anderson and Lozhkin 2001).

Our data indicate that woolly mammoths, steppe bison, and other members of the Beringian megafauna persisted on the Kenai Peninsula for > 28,100 ^{14}C yrs. A single date of 20,470 ± 90 ^{14}C yrs BP (Beta-345995) implies that woolly mammoths survived well into the Naptowne glaciation in the Caribou Hills. At that time, the 1,320-km^2 refugium was located ~165 km inland from the southern, ice-covered coast of the Kenai Peninsula (Mann and Peteet 1994) and was the largest and southwesternmost of four refugia along the western front of the Kenai Mountains (Reger et al. 2007). In the Bear Creek–Funny River upland refugium 25 km northeast of the Caribou Hills across the ice stream occupying the Tustumena Lake trough, > 310 km^2 of potential foraging terrain stood above the MIS 2 ice (Fig. 2).

Ager (2000) analyzed fossil pollen in a 467-cm core taken from Circle Lake at 418 m asl northeast of Homer, just inside the limit of the Naptowne glaciation (Fig. 2). Pollen data indicate that a basal herb tundra zone, dated

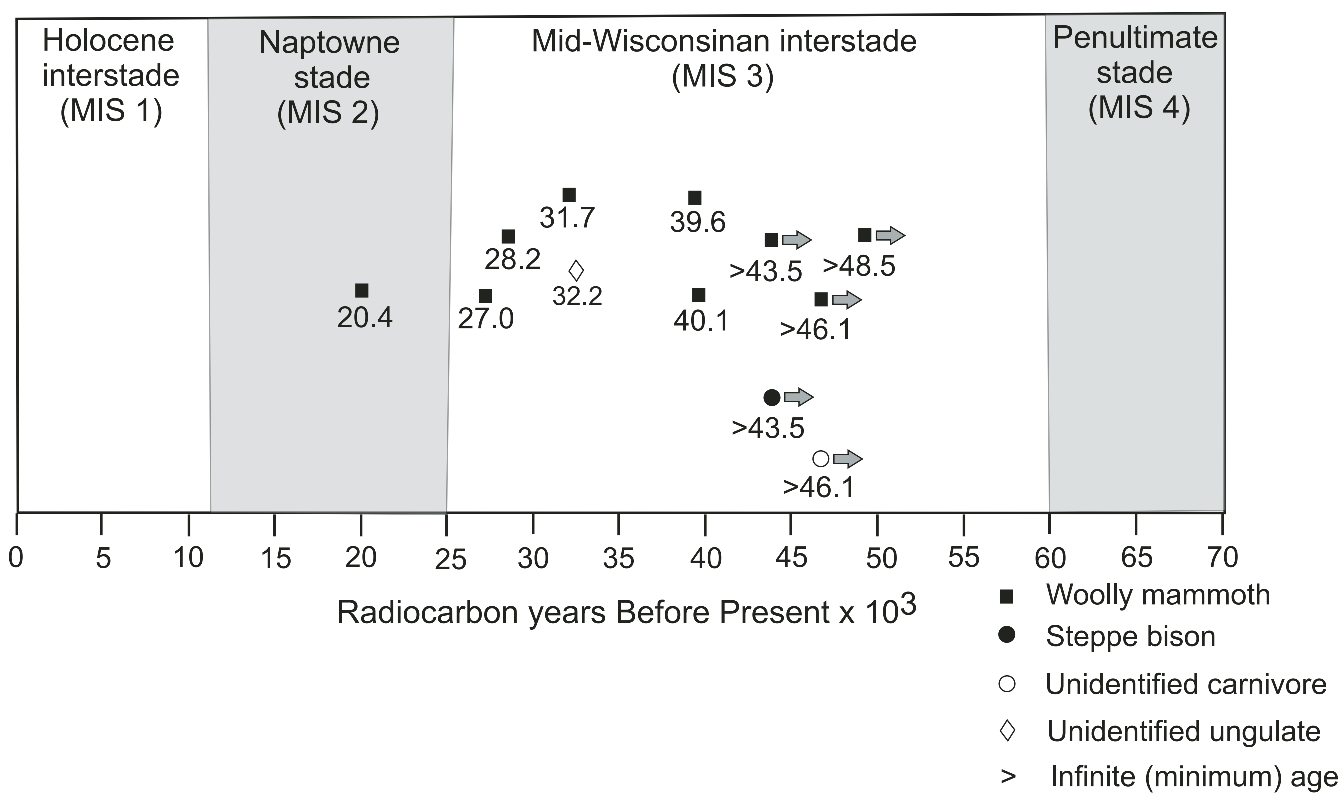

Figure 5. Radiocarbon ages of mammal fossils found on the Kenai Peninsula plotted against the late Pleistocene glacial chronology (Reger et al. 2007). Infinite ages represent the most recent times that the dated animals lived on the peninsula and are considered to be > 50,000 ^{14}C yrs BP.

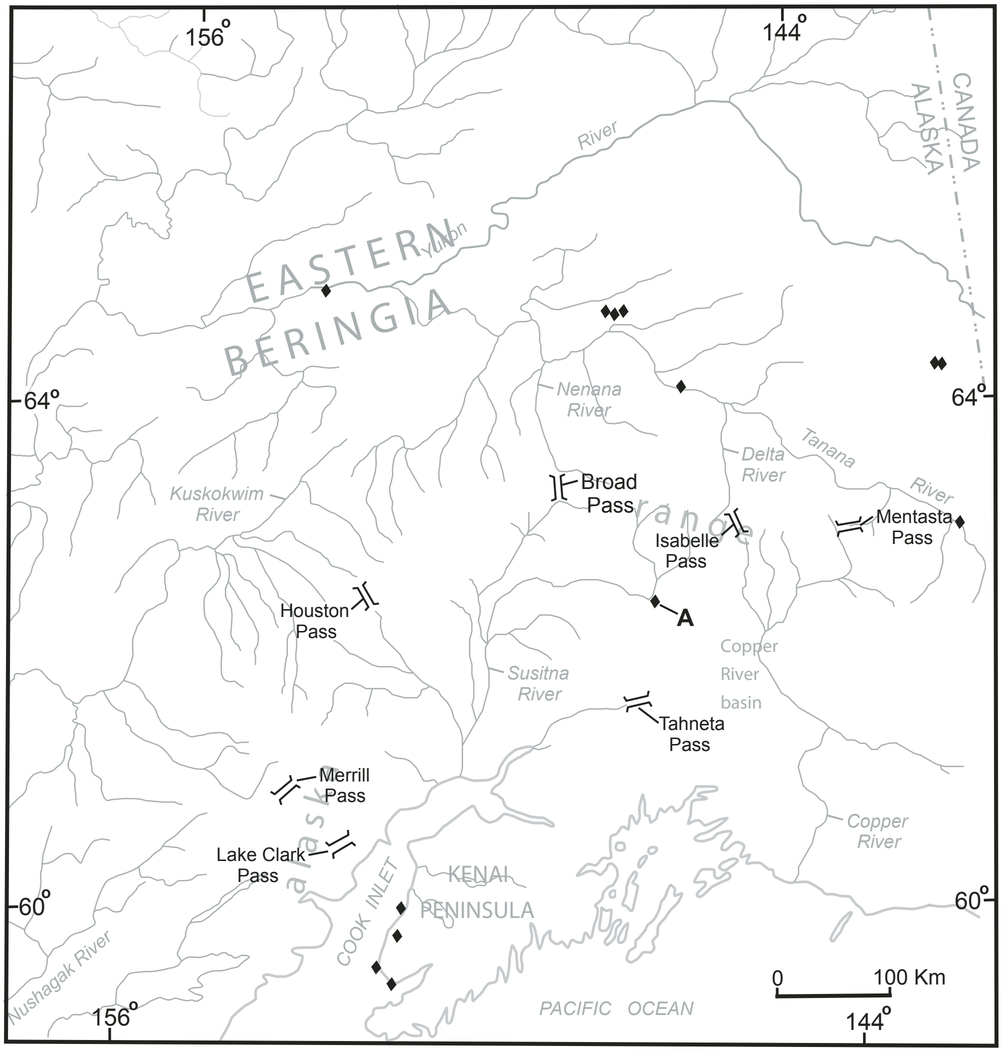

Figure 6. Alaska Range passes through which MIS 3 mammals could have accessed the Kenai Peninsula between the last major (MIS 2) and penultimate (MIS 4) glaciations. Known MIS 3 fossil localities (◆) are in eastern Beringia north of the Alaska Range and in the Kenai Peninsula and Copper River Basin south of the range (M. Guthrie 1988; R. D. Guthrie 1990; Matheus et al. 2003; Péwé 1975; Porter 1986, 1988; Reger et al. 2012; Thorson et al. 1981; Weber et al. 1981). Locality A is the site in the northwestern Copper River Basin where Thorson et al. (1981) recovered a woolly mammoth femur dated 29,450 ± 610 ^{14}C yrs BP (Beta-1819).

at 12,800 ± 300 ^{14}C yrs BP (W-5518), was dominated by an upland flora of willows, grasses, sedges, and wormwood with horsetails, ferns, and club moss growing in the moist lake margins. As local conditions became wetter about 9550 ± 300 ^{14}C yrs BP (W-5905), the upland herb tundra was replaced by a shrub (dwarf birch) herb tundra (Ager 2000). This palynological evidence implies that adequate forage for large Beringian grazing mammals could have existed in the upland refugia during the last major glaciation.

Mammoth were apparently extirpated from mainland Alaska 11–12 kya (Guthrie 2006; Mann et al. 2013; Zazula and Kuhn 2014), although they survived into the Holocene on St. Paul Island in the southern Bering Sea (Guthrie 2004; Veltre et al. 2008) and on Wrangel Island in the western Chukchi Sea (Vartanyan et al. 2008). On Wrangel Island the youngest steppe bison bone dates 9450 ± 100 ^{14}C yrs BP (LU-2801) (Vartanyan et al. 2008). Steppe bison persisted in Alaska and Yukon until ~400 years ago (Zazula and Kuhn 2014).

The distribution of the fossils and their preservation quality on the Kenai Peninsula demonstrate that they were not recovered in situ. Sites of initial preservation in mid-Wisconsinan sediments in the Anchor Point–Homer area must have been outside or just inside the nearby margins of the Naptowne glaciation, which would have deeply buried or destroyed them where the ice was thick (Fig. 2). Remains recovered near Clam Gulch were located inside the limits of the large meltwater lake that was impounded during the early stage of the Naptowne glaciation in the Clam Gulch–Anchor Point lowland between the ice front to the west and the Caribou Hills to the east (Reger et al. 2007).

Fossils carried along the beaches by beach drift or longshore currents would have been subjected to powerful storm waves and high abrasion rates, so unabraded mammoth molars found on the beach (Fig. 2) were probably transported under much less abrasive circumstances. Widespread debris-flow deposits on the Homer bench and along the northern shore of Kachemak Bay close to the sites of several fossil finds (Reger et al. 2007:95) indicate that fossils were transported downslope by debris flows from beyond the nearby limits of the Naptowne glaciation. Fossils recovered from stream floodplains would have been transported as part of the traction bed load of the stream and would have moved downstream with other large bed-load clasts only during floods. Those fossils would be affected by very high rates of abrasion, so the presence of a broken but unabraded partial steppe-bison skull and horn core (Fig. 4) in lower Diamond Creek indicates little transportation from the site of initial preservation.

The lack of stratigraphic context for the fossils, little paleoenvironmental data, and the absence of archaeological remains associated with the fossils leave us no basis for evaluating the peopling of North America along the southern coast of Alaska, as previously discussed by Dixon et al. (1997) and Al-Suwaidi et al. (2006). However, this paper provides considerable new information on the late Pleistocene Beringian megafauna in southcentral Alaska. The absence of woolly mammoth and steppe bison in the coast-oriented, late Pleistocene faunal assemblages reported in southeastern Alaska refugia (Heaton et al. 1996; Heaton and Grady 2003) and their presence in eastern Beringia imply a faunal link between the Kenai fossil assemblage and interior Beringia but not necessarily with coastal refugia in Southeast Alaska.

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NOTES

1. Because only the distinctive molars of woolly mammoth have been found on the Kenai Peninsula, we assume that the four nondefinitive fragments of proboscidean tusks also represent woolly mammoth and not American mastodon (*Mammut americanum*). Scattered molars of American mastodon have been recovered in interior and arctic Alaska (Mann et al. 2013; Péwé 1975) and in the Klondike (Froese et al. 2009; Harington 2011; Zazula and Kuhn 2014).

However, a suite of new radiocarbon dates demonstrates that the American mastodon died out in eastern Beringia during the penultimate (MIS 4) glaciation (Zazula et al. 2014).

2. Clague et al. (2004) defined the middle Wisconsinan interstade in northwestern North America as approximately equivalent to MIS 3 between 60 and 25 ^{14}C yrs BP.

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