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Late Pleistocene colonization of North America from Northeast Asia: New insights from large-scale paleogeographic reconstructions

E. James Dixon*

Maxwell Museum of Anthropology, Department of Anthropology, University of New Mexico, MSC01 1050, Albuquerque, NM 87131-0001, United States

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ABSTRACT

Advances in large-scale paleogeographic reconstruction define physical and environmental constraints relevant to understanding the timing and character of the first colonization of the Americas during the late Pleistocene. Diachronic mapping shows continental glaciers coalesced in central Canada during the Last Glacial Maximum (LGM) 20,000–14,000 years ago while unglaciated refugia existed along the Northwest Coast. The Bering Land Bridge connected Asia and North America until about 10,000 years ago when the two continents were separated by rising sea level. This visual analysis from large-scale synthesis of recent geological and environmental research establishes timelines for biotically viable colonization corridors connecting eastern Beringia to southern North America and provides insights into probable Paleoindian origins and subsistence strategies.

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1. Introduction

Geologic and biotic events constrained the routes and timing of colonization of the Americas from northeast Asia. Researchers have defined two competing theories about the first movement of people from Asia to the Americas: an interior mid-continental route through a Late Wisconsin deglaciation corridor in central western Canada versus a maritime route along the Northwest Coast of North America. Paleoenvironmental and geologic data are summarized and used to evaluate the viability of each route at selected periods of time during the late Pleistocene.

Large-scale paleogeographic reconstructions have been produced as a series of six maps of North America and Beringia (Fig. 2A–F). The maps integrate current data about changing sea level and glaciation over vast areas for the very late Pleistocene (18,000–12,500 cal BP). These reconstructions are based on Geographic Information System (GIS) analyses and digital elevation modeling (DEM) compiled by Ehlers and Gibbard (2004) and Manley (2002).

The data are taken primarily from Ehlers and Gibbard's CDs 1 and 2 that were derived from various scholarly, public domain, and copyrighted sources. These include the public domain Digital Chart of the World (Rose, 2004) and ESRI, Inc. (Ehlers and Gibbard, 2004). ESRI used public domain sources and modified, cleaned, and transformed these data (ESRI Data License Agreement.pdf from

Ehlers and Gibbard, 2004, CDs 1 and 2). The integrated analysis also used Penn State URL DCW: http://www.maproom.psu.edu/dcw/dcw_about.shtml and Manley's Postglacial Flooding of the Bering Land Bridge: A Geospatial Animation employed ETOPO2v2c Global Gridded 2-min Database, NGDC Marine Geology and Geophysics Division, National Geophysical Data Center (NGDC), and National Oceanic and Atmospheric Administration (NOAA), URL: <http://www.ngdc.noaa.gov/mgg/global/etopo2.html> (Manley, 2002). Radiocarbon dates were calibrated using IntCal 09 and OxCal 4.1 <http://c14.arch.ox.ac.uk>.

Integration of these data provides a paleogeographic foundation for diachronically interpreting the biological and geological constraints influencing the first human colonization of the Americas. These maps represent the synthesis of extensive glacial mapping, compilations of large numbers of radiocarbon determinations, and regional sea level curves. This scientifically accurate intercontinental scale interpretation more precisely defines the presence, absence, and character of paleogeographic corridors beginning about 18,000 cal BP (15,000 ¹⁴C BP) (Fig. 2A) until circa 12,500 cal BP (10,500 ¹⁴C BP) (Fig. 2F). The analysis couples the temporal and spatial deglaciation sequence of North America following the LGM with the progression of post-Pleistocene sea level rise on the Bering and Chukchi continental shelves (Fig. 2A–F). By comparing synchronic events in the interior of northern North America with the Northwest Coast, the parameters limiting and facilitating human colonization are more clearly identified and linked to archeological evidence necessary to define the character and timing of colonization.

* Fax: +1 505 277 1547.

E-mail address: jdixon@unm.edu.

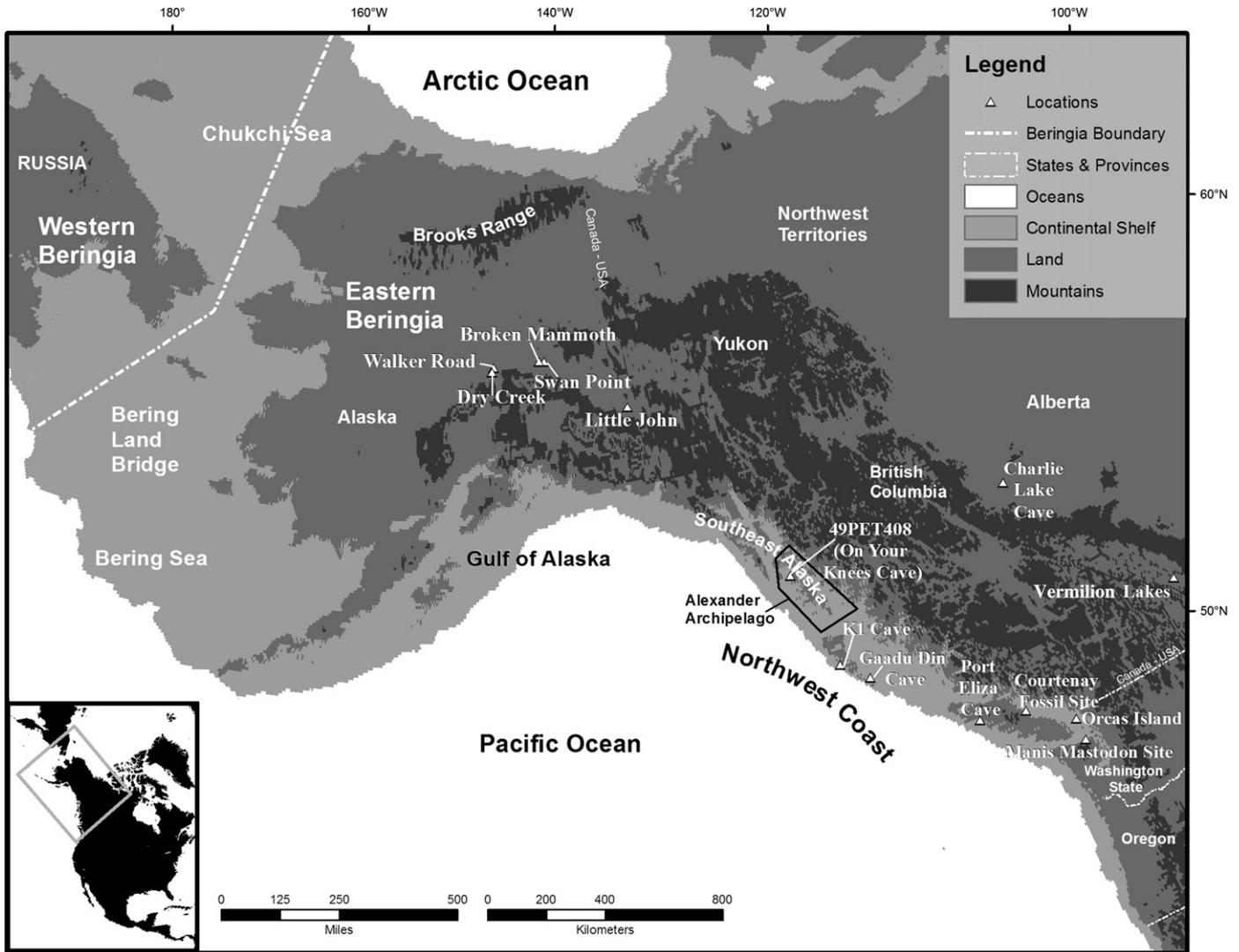


Fig. 1. Map of Northwest North America and adjacent maritime regions illustrating significant geographic locations and key archeological sites discussed in the text.

2. Mid-continental route

Nearly 80 years ago, Johnston (1933) suggested the possibility that a relatively narrow strip of unglaciated land may have existed in Canada between the Laurentide and Cordilleran ice sheets during the late Wisconsin glaciation of North America. If this relatively narrow “ice free corridor” had existed, it would have provided a terrestrial environment between Asia and areas south of the continental glaciers through the Last Glacial Maximum (LGM). Theoretically, such a corridor would have enabled the dispersal of plants, animals and humans between these two regions during late-glacial times. The idea of an “ice-free corridor” has played a significant role in stimulating field research and efforts to interpret North American biogeography, glacial history, and archeology.

Multidisciplinary evidence resulting from a number of independent investigations led an increasing number of investigators to conclude that an ice-free corridor did not exist throughout the Late Wisconsin (Wilson, 1983, 1990, 1996; MacDonald, 1987; Burns, 1996, 2009; Jackson and Duk-Rodkin, 1996). There is now broad consensus that a corridor did not exist during the LGM (Fig. 2A). Because of the confusion generated by the application of the term “ice free corridor,” several researchers have suggested alternative terminology defined strictly on geographic grounds including “Western Corridor”

(Beaudoin, 1989) and “western interior route” (Burns, 1996:111). The opening of the ice-free corridor (or more accurately stated, deglaciation corridor) probably occurred between 15,000 and 14,000 cal BP (12,500–12,000 ^{14}C BP) (Dyke, 2004) (Fig. 2C and D). This construct of the glacial geology is based primarily on glacial mapping and radiocarbon dating. It defines constraints that provide a useful framework for interpreting the colonization of the Americas.

These data indicate that by at least 14,000 calendar years ago (12,000 ^{14}C BP) (Fig. 2D) a narrow deglaciation corridor had opened between the Laurentide and Cordilleran glaciers in west central Canada. The processes of deglaciation re-established a terrestrial connection between eastern Beringia and regions south of the continental glaciers. It enabled the migration of terrestrial plants and animals southward from Beringia and northward from areas south of the continental glaciers from distinctly different environments that had been isolated from each other for about 10,000 years (Young et al., 1994). The mid-continental deglaciation corridor was significantly different than other newly deglaciated regions because it lay sandwiched between two massive wasting continental glaciers. Most newly deglaciated terrain at the end of the Pleistocene was adjacent to large biomes and this enabled biological colonization to occur rapidly along a broad front. However, the deglaciation corridor was unique in that it had only two relatively narrow openings to

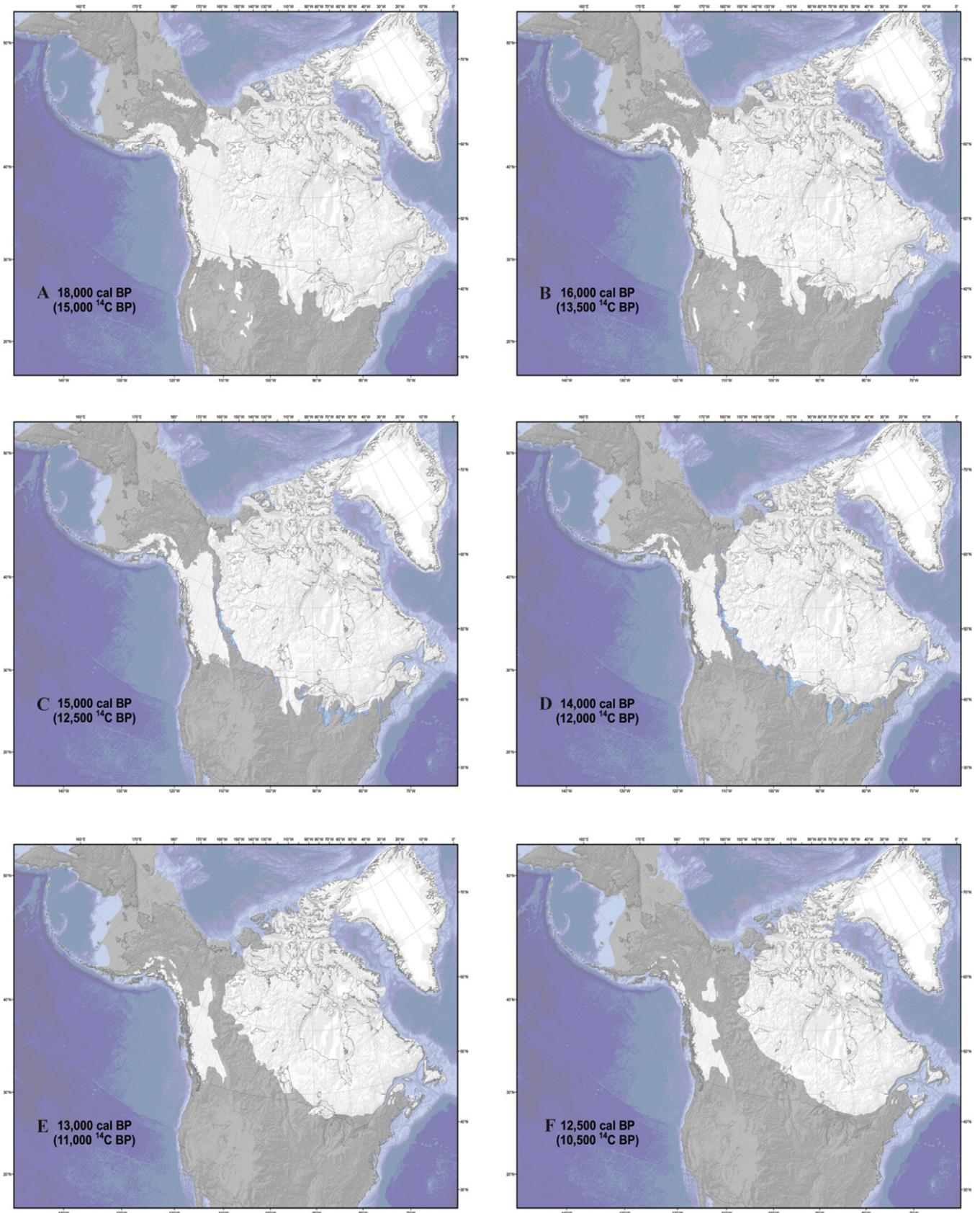


Fig. 2. Last Glacial Maximum (LGM) deglaciation sequence in relation to sea level rise on the Bering Land Bridge between 18,000 cal BP (15,000 ^{14}C BP) and 12,500 cal BP (10,500 ^{14}C BP). Extent of glaciation in relation to sea level: A) circa 18,000 cal BP (15,000 ^{14}C BP); B) circa 16,000 cal BP (13,500 ^{14}C BP); C) circa 15,000 cal BP (12,500 ^{14}C BP); D) circa 14,000 cal BP (12,000 ^{14}C BP); E) circa 13,000 cal BP (11,000 ^{14}C BP); F) circa 12,500 cal BP (10,500 ^{14}C BP).

larger adjacent ecosystems at its northern and southern extremes (Fig. 2C and D). The geographically restricted termini of the deglaciation corridor greatly limited the opportunities for species colonization.

This newly created terrain was restricted by massive melting glaciers on two sides and this created formidable difficulties for human colonization. Immediately following deglaciation it was a relatively narrow strip of terrain (Fig. 2C) that was geologically unstable and biotically impoverished. Initially, the deglaciation corridor was characterized by shifting streams, rivers, melt water channels, regions of stagnant debris covered ice, strong katabatic winds, outburst floods, and irregular shifting glacial deposits (Wilson, 1996; Wilson and Burns, 1999; Mandryk et al., 2001; Clague et al., 2004). Melt water lakes filled large areas between the receding continental glaciers (Fig. 2C and D) (Smith and Fisher, 1993; Smith, 1994; Dyke, 2004:388–389). Large proglacial lakes and soft, boggy substrates of the continuous and progressively deglaciating terrain were impediments to recolonization of the corridor by large mammals (Burns, 2009). Fiedel (2004) suggests the proglacial lakes may have been attractive “oases” to facilitate human migration through the corridor. Although the lakes may have provided temporary seasonal habitat for migratory waterfowl that may have transported seeds for colonizing plants into the region, they appear to have been relatively short lived and biotically impoverished. Geologic evidence indicates the newly formed glacial lakes were silt-laden and probably had few fresh water aquatic resources. There is no paleontological evidence to suggest the presence of fish, beaver, muskrat, waterfowl, or aquatic plants during the early period of deglaciation. Floral resources in the deglaciation corridor were scarce also. Based on an evaluation of the pollen data from the deglaciation corridor, Mandryk (1990:77)

concluded that it was “unlikely that such a sparse vegetation in harsh climatic conditions could have supported viable human populations.”

As deglaciation progressed, the late Wisconsin fauna of western North America south of the ice sheets advanced northward. Slightly later, elements of the predominately Asian fauna of eastern Beringia colonized the new terrain of the deglaciation corridor from the north. The paleontological record suggests that southern small horned *Bison* moved northward, and replaced the late Pleistocene large horned *Bison* occupying Alaska and northwestern Canada (Shapiro et al., 2004; MacDonald and Cook, 2009:227). This may suggest that plants and animals originating from the southern end of the corridor had an advantage colonizing northward as the climate warmed. Conversely, northern species may have been at environmental disadvantage in their attempts to colonize southward as deglaciation progressed.

Wilson (1996) suggests that establishing the chronology for the arrival of bison may be one of the most informative methods for timing the “ecological opening” of the deglaciation corridor. Bison are useful because they disperse over vast areas in relatively short periods of time and their remains are abundant. Charlie Lake Cave is located in eastern British Columbia about half way between the northern and southern termini of the deglaciation corridor (Fig. 3). Subsequent morphological and DNA analyses suggests that classification of eastern Beringian bison (traditionally classified as *B. occidentalis*) may require reassessment (Wilson et al., 2008). Although the northern clade is genetically distinguishable from the southern clade, it is primarily on the basis of extensive mitochondrial diversity. This reanalysis provides additional evidence that primary dispersal of North American bison was by *B. antiquus* northward from the northern plains to eastern Beringia (Wilson et al., 2008). Several artifacts have

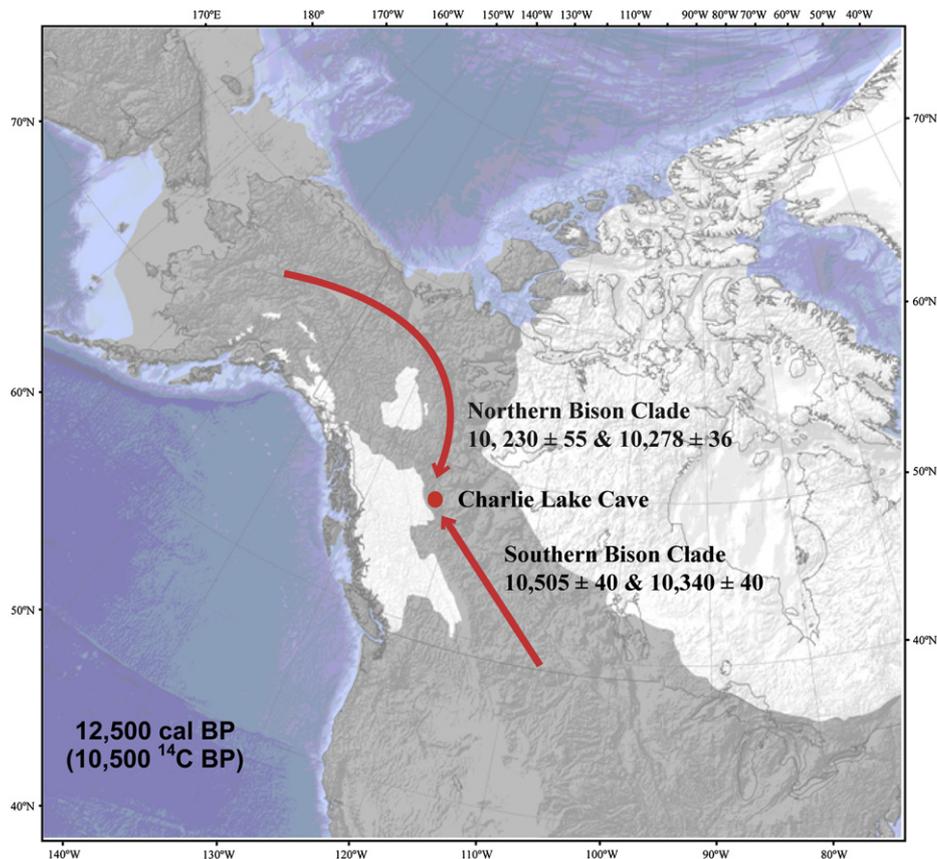


Fig. 3. Glacial limits circa 12,500 cal BP (10,500 ¹⁴C BP) depicting the location of Charlie Lake Cave radiocarbon dated bison remains. Arrows are used to illustrate the southern movement of the northern clade of bison and the northern movement of the southern clade that made contact by circa 12,500 cal BP (10,500 ¹⁴C BP).

been recovered from the oldest archeological component (Component 1) at the cave including a projectile point that the investigators suggest was derived from the late fluted point tradition to the south (Fladmark et al., 1988; Driver et al., 1996). MtDNA analysis of four bison bones from Component 1 at Charlie Lake Cave indicates that the bison bones are from two distinct clades (bison that share homologous features and common ancestry). Two radiocarbon determinations run on bison bones from the northern (eastern Beringian) clade were dated to $10,230 \pm 55$ [12,145–11,713 (94.4%) cal BP] and $10,378 \pm 36$ ^{14}C BP [12,401–12,086 (95.4%) cal BP]. Two specimens from the southern (North American plains) clade dated to $10,505 \pm 40$ [12,601–12,225 (95.4%) cal BP] and $10,340 \pm 40$ ^{14}C BP [12,389–12,035 (95.4%) cal BP] (Driver, 2001; Shapiro, 2003; Vallières, 2004). The bison remains from the northern and southern clades recovered from Charlie Lake Cave provide a minimum limiting date for the ecological opening of the central areas of the deglaciation corridor and suggest the deglaciation corridor may have been suitable for human subsistence by about 11,500–11,000 ^{14}C BP (13,500–13,000 cal BP). These dates correlate well with dated bison and horse bones from southern Alberta and indicate that by circa 11,000–11,500 ^{14}C BP (13,500–13,000 cal BP) these large mammal species had begun to colonize deglaciated areas of the southern corridor (Burns, 1996, 2009). Wilson (1996) regards the period 13,000–12,500 cal BP (11,000–10,500 ^{14}C BP) (Fig. 2E and F) prior to forestation as the critical interval during which bison were able to expand their range into the deglaciation corridor.

The oldest reliably dated archeological evidence from the southern region of the deglaciation corridor is from locality A at the Vermilion Lakes Site where a series of radiocarbon determinations date the occupation between circa 10,800–10,300 ^{14}C BP (Fedje et al., 1995). The fact that there are no other reliably dated archeological sites from the deglaciation corridor until circa 10,500 ^{14}C BP (12,500 cal BP) has been interpreted by several researchers as additional evidence suggesting the deglaciation corridor was biotically impoverished and not capable of supporting hunter gatherers (Wilson, 1983; Driver, 1996; Driver et al., 1996; Fladmark, 1996; Jackson and Wilson, 2004). Although para-glacial processes may have destroyed many of the earliest sites (Driver, 1998), the apparent lack of older archeological sites suggest that there may have been as much as a 500 year lag from the time the corridor was free of surface ice until geological stability and ecological productivity were sufficiently advanced to permit colonization by large mammals and people.

As early as the 1960s archeologists began to suspect that the Paleoindian tradition artifacts were younger in eastern Beringia than they were in areas south of the continental glaciers. These early observations were based on the fact that the northern examples typologically resembled artifacts that dated to the later periods of the Paleoindian tradition from the western Great Plains (Wormington and Forbis, 1965) or from geologic contexts that suggested they were possibly younger than comparable examples found south of the continental glaciers (Dixon, 1976). Fluted projectile points from eastern Beringia are typologically distinct and are generally exhibit multiple basal flutes, or basal thinning flakes (Fig. 4). Many exhibit basal edge grinding and they are generally not as finely flaked and smaller than examples from the North American plains. The projectile points from eastern Beringia more closely resemble typologically similar projectile points from western North America (Willig et al., 1988), and this suggests they may trace their origins to the intermountain adaptations of the far western regions of North America, south of the continental glaciers.

The creation of unoccupied habitat as a result of deglaciation necessitates an actual movement of people northward rather than the transmission of material cultural traits northward by diffusion (transmitted from one group to the next). The archeological evidence from professionally excavated and well-dated pre-Clovis

archeological sites south of the continental glaciers also suggest much earlier dates for the initial colonization of the Americas. Monte Verde (Dillehay, 1984, 1988, 1997), Cactus Hill (Jones and Johnson, 1997; McAvoy and McAvoy, 1997), Meadowcroft Rock Shelter (Adovasio et al., 1990; Adovasio and Pedler, 2004), the Chesrow complex (Overstreet, 1993, 1998), Miles Point (Lowery et al., 2010), and other sites suggest that human entry into the Americas occurred prior to the emergence of an ecologically viable mid-continental deglaciation corridor about 13,000 cal BP (11,000 ^{14}C BP). Because these archeological sites predate the physical emergence and ecological viability of the interior deglaciation corridor, humans had to have colonized regions south of the continental glaciers via another route.

There is now general consensus among archeologists working in eastern Beringia that the Paleoindian tradition first appears in eastern Beringia about 12,500 cal BP (10,500 ^{14}C BP) (Goebel and Buvit, 2011). People living south of the continental glaciers expanded northward along with the northward movement of bison and other species colonizing the deglaciation corridor from the south.

The earliest reliably dated sites in eastern Beringia are Swan Point (Holmes, in press, 2001; Holmes and Crass, 2003) and the Little John Site (Easton et al., 2011). Both of these sites date to 14,000 cal BP and demonstrate that humans were firmly established deep in the interior of eastern Beringia during late glacial times. These and other early eastern Beringian sites have sequences of occupations that are sometimes, but not always, characterized by microblade industries. By about 13,000 cal years ago small triangular, concave base, and basally thinned point types appear at several of these sites. Sometimes they are found in association with the Dyuktai microblade assemblages and sometimes they are not. The appearance of this bifacial technology in eastern Beringia at this time may be the tangible evidence of contact between the people of eastern Beringia with the Paleoindian population moving northward through the newly established deglaciation corridor at the end of the Pleistocene (Dumond, 2011).

3. Northwest coastal corridor

Interdisciplinary research during the past two decades has developed extensive information about the quaternary geology, sea level history, and paleoecology of the Northwest Coast. Although some researchers recognized the potential significance of the Northwest Coast as a possible LGM migration corridor to the Americas (Heusser, 1960; Fladmark, 1978, 1979; Gruhn, 1994), prior to 1990 the region received comparatively little scientific attention. This was because early geologic interpretations hypothesized that during the late Pleistocene the region had been covered by a continuous ice sheet extending westward from the mainland across the islands of the Northwest Coast to terminate at or near the edge of the continental shelf (Coulter et al., 1965; Prest, 1969; Nasmith, 1970). However, subsequent field research indicates that **sizable areas of Southeast Alaska were ice-free along the inner continental shelf during and toward the end of the last glacial maximum** (Mann, 1986; Clague et al., 1989; Reger and Pinney, 1992; Mann and Hamilton, 1995; Carrara et al., 2003; Kaufman and Manley, 2004; Hetherington et al., 2004; Ager et al., 2010).

Unlike the mid-continental deglaciation corridor that restricted biological colonization to relatively small northern and southern openings, the Northwest Coast was adjacent to the Pacific Ocean that provided a source for immediate biological colonization along its broad western front. Also coastal refugia provided locales from which established populations of fish, marine mammals, and avifauna, as well as terrestrial plants and animals, were immediately able to colonize newly deglaciated habitats.

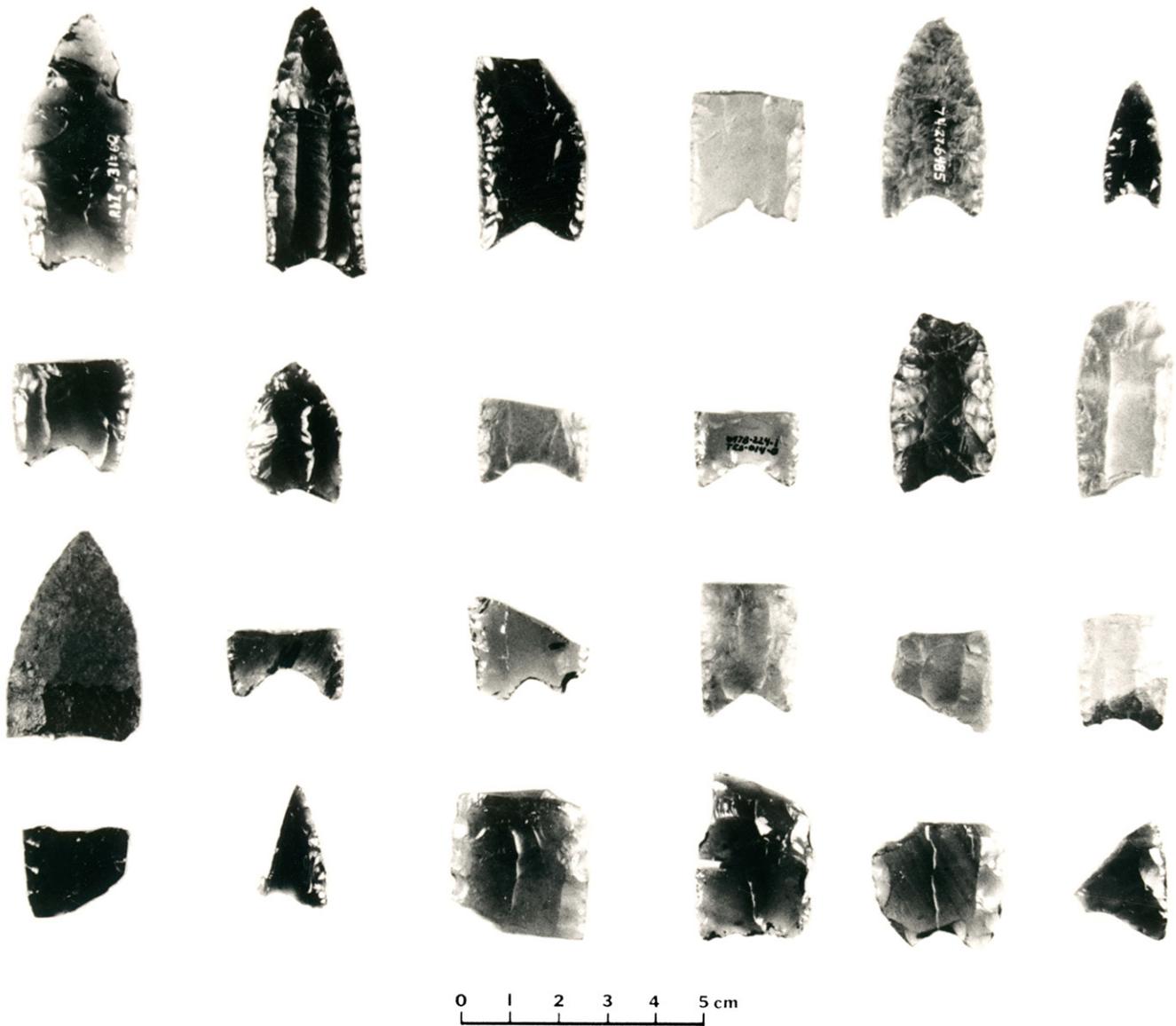


Fig. 4. Northern Paleoindian fluted projectile points from eastern Beringia (Dixon, 1999:188).

The timing of the LGM was not the same through western Canada and the Gulf of Alaska, and timing of the maximum ice advance varied locally (Clague et al., 2004:86). In Southeast Alaska and British Columbia, the LGM occurred between 29,000 and 18,000 cal BP (25,000–15,000 ^{14}C BP) (Mann, 1986). During the LGM, perhaps lasting until about 18,000 cal years ago, sea level was about 100–120 m lower than it is today and many large glaciers along the Gulf of Alaska extended to the edge of the continental shelf. Vast areas along adjacent regions of the coast may have been deglaciated beginning about 16,000 cal BP (13,500 ^{14}C BP) (Blaise et al., 1990; Bobrowsky et al., 1990) possibly providing a coastal corridor for people using watercraft to move south along the coast from eastern Beringia. Mann and Peteet (1994:146) indicate that except for a 400-km coastal area between southwest British Columbia and Washington State, the Northwest Coast of North America was ice free by 16,000 cal BP (Fig. 2B).

Extensive late Pleistocene vertebrate fossil deposits have been discovered at On Your Knees Cave and several other caves in the Alexander Archipelago dating between 35,400 to over 44,500 years BP (prior to the LGM). This research has led to a preliminary history

of colonization and extinction of vertebrates on the islands of the Alexander Archipelago by Heaton and Grady (2003). The research demonstrates that during the LGM and early post glacial times the archipelago supported several high latitude cold adapted species of mammals including brown bear (*Ursus arctos*), red (*Vulpes vulpes*) and arctic fox (*Alopex lagopus*), caribou (*Rangifer tarandus*), ringed seal (*Phoca hispida*), and marmot (*Marmota caligata*). These species became extinct in the Alexander Archipelago and/or migrated to higher latitudes as the climate warmed at the end of the LGM.

Direct radiocarbon dates on ringed seals from caves in the Alexander Archipelago demonstrate their occurrence throughout the LGM when the climate was colder and characterized by extensive sea ice (Heaton and Grady, 2003). Today ringed seals primarily occupy the Arctic Ocean, Baltic and Bering Seas, and Hudson Bay. These cold adapted marine mammals are closely associated with sea ice and ice flows and they retreated northward as the climate along the Northwest Coast became increasingly temperate at the end of the Pleistocene. The LGM presence of common seal (*Phoca vitulina*), also known as the harbor or spotted seal, is significant. Today harbor seals range throughout the north Pacific Rim, from the Bering and Chukchi

Seas southward to California. They breed both on ice and land. In most areas they depend on beaches and offshore rocks for birthing, resting and molting (ADF&G 1973). Their habitat requirements support geologic interpretations indicating the existence of unglaciated refugia during the LGM (Carrara et al., 2007).

Heaton and Grady (2003) have also dated Stellar Sea Lion (*Eumetopias jubata*) to the early LGM in Southeast Alaska. Farther to the south this same species has been dated to about 14,570 cal BP ($12,570 \pm 70$ ^{14}C BP) at the Courtenay fossil site on Vancouver Island, British Columbia (Harrington et al., 2004). Like harbor seals, the range of Stellar Sea Lion extends from California's Channel Islands along the north Pacific Rim to northern Japan. During the breeding season (June) they require land where they form rookeries. When traveling and feeding, they often rest on headlands and offshore rocky islets. These large marine mammals can weigh as much as 2400 pounds and, like harbor and ringed seals, they feed on a variety of marine foods including rockfish, sculpin, greenling, sand lance, smelt, salmon, halibut, flounder, octopus, shrimp and crab (ADF&G 1973). A large number of avian and fish remains have also been excavated from the caves of the Alexander Archipelago; however, much of this collection remains unidentified and undated.

The caves in which the Alexander Archipelago marine mammal fossils were found are generally located within 1 km of the coast and at elevations higher than sea level. Many of the bones exhibit modification by carnivores, such as punctures and gnaw grooves, indicating that they were transported to the caves by predators and/or scavengers. Arctic and red fox remains are directly dated to the LGM and these animals may have transported some of these remains to the caves (Heaton and Grady, 2003). Radiocarbon determinations run directly on the bones of brown and black bear, caribou, and river otter bracket the LGM. These and other data led Heaton and Grady (2003:46) to suggest that these species likely survived the LGM in coastal ice-free refugia along with the arctic marine fauna documented by well-dated pinnipeds.

The presence of ringed and harbor seals and sea lion dating to the LGM inferentially indicate the presence of their prey that include a wide variety of fish, crustaceans, and cephalopods. Although much more work remains to be done, collectively these data suggest that marine resources and biotically viable coastal refugia were present along the Northwest Coast during the LGM. At this time (29,000–18,000 cal BP) the ocean supported large marine mammals, birds, and fish. Terrestrial plant and animal resources were available in refugia.

In addition, fossil evidence of brown and black bears, as well as genetic studies conducted on living bear populations, suggest that these species may have been continuous long-term residents along the Northwest Coast (Heaton et al., 1996). These large omnivores feed on a variety of plants, berries, roots, and fungi, as well as fish, insects, and mammals. Most brown bears derive most of their dietary energy from vegetable matter and, like humans, their diet varies greatly based on resource availability and opportunity in different areas. The study of the diets of prehistoric vertebrates on the islands derived from stable isotope analysis, the distribution of endemic mammals, and pollen and plant macrofossil analysis provide insights into past environmental conditions and better understanding of the ecological interactions among species during various stages of deglaciation (MacDonald and Cook, 1996; Heaton and Grady, 2003; Clague et al., 2004; Carrara et al., 2007).

On Your Knees Cave (49-PET-408) is located on Protection Head, a peninsula at the northwest end of Prince of Wales Island in the Alexander Archipelago in Southeast Alaska (Fig. 1). Humans used the cave repeatedly for approximately 12,000 cal years BP. It contains bone and shell tools from different chambers of the cave

ranging between $10,300 \pm 50$ ^{14}C BP and 1760 ± 40 ^{14}C BP, documenting several periods of human use. The most extensive use of the cave occurred about 9200 ^{14}C BP and is associated with the oldest human remains known from the Northwest Coast. Carbon isotope values from human bone suggest the individual was raised primarily on a diet of marine foods. Obsidian associated with the human remains is from Mt Edziza in British Columbia and Suemez Island in Southeast Alaska (Lee, 2001). The location of the site on an island, the use obsidian from sources on the mainland and another island, and the isotopic values derived from human bone suggests that the people who used the site were coastal navigators with an economy based on maritime subsistence. In addition, they directly procured, or had established trade networks to obtain, obsidian and other tool stone that required the use of watercraft. A worked bone tool dated to 10,300 ^{14}C BP is the oldest artifact recovered from site (Dixon et al., 1997; Dixon, 2001).

The southern end of the coastal corridor was suitable for human occupation before circa 18,000 cal years B.P., and again about 16,000 cal years B.P. At Port Eliza Cave located on the west side of Vancouver Island, British Columbia a suite of radiocarbon determinations document vole, mountain goat, marmot, numerous species of fish including salmon, birds, and mollusks between about 20,000 and 18,000 cal BP (circa 18,000–16,000 ^{14}C BP) (Al-Suwaidi et al., 2006). There is a hiatus in the faunal record between about 18,000 and 14,500 cal years ago when the site appears to have been glaciated. Mountain goat remains dating to circa 14,500 cal BP deposited in the cave demonstrates that the ice had retreated by this time. Analysis of the sediments and the cave's flora and fauna indicate that this region of the coast was unglaciated and biotically capable of sustaining humans prior to 18,000 cal BP and after 14,500 BP (Al-Suwaidi et al., 2006).

At K 1 Cave on the Queen Charlotte Islands (Haida Gwaii), bear bones have been radiocarbon dated at $14,390 \pm 70$, $11,250 \pm 70$, and $11,150 \pm 50$ ^{14}C BP and indicate sufficient biotic resources during this time to sustain these large omnivores (Ramsey et al., 2004). Basal fragments of two bifacial projectile points were also recovered from the cave directly associated with bear bones dated to circa 10,600 ^{14}C BP (Fedje et al., 2008). A typologically similar projectile point was recovered from Gaadu Din 2 cave associated with a date of 10,220 ^{14}C BP (Fedje et al., 2008).

The data from Vancouver Island and the Alexander Archipelago suggest that the LGM was diachronous along the Northwest Coast and that glaciation reached its maximum extent during the interval between circa 20,000 and 16,000 cal years ago. These data demonstrate that during the LGM ice conditions were severe. Some terrestrial plants and animals survived in refugia along the coast; and marine species, such as ringed seal, survived in locally favorable marine environments. Refugia along the coast appear to have served as centers for biotic dispersal immediately following deglaciation about 16,000 years ago.

While it is theoretical possibility that humans with high latitude maritime adaptations may have been able to "island hop" using watercraft between refugia along the Gulf of Alaska and Northwest Coast, this would have been a difficult and dangerous undertaking. At the height of the LGM many large glaciers extended from the coastal mountains to the edge of the continental shelf. Many of these large calving glaciers were tens of kilometers across (Carrara et al., 2003; Clague et al., 2004) and probably presented significant barriers separating refugia and inhibiting movement along the coast. Although it is evident that subsistence resources including fish, birds and large marine mammals were present in some areas, travel between refugia seems unlikely at that time. However, travel would become safer prior to the onset of the LGM and again when the glaciers receded and refugia expanded during the late LGM (Fig. 5).

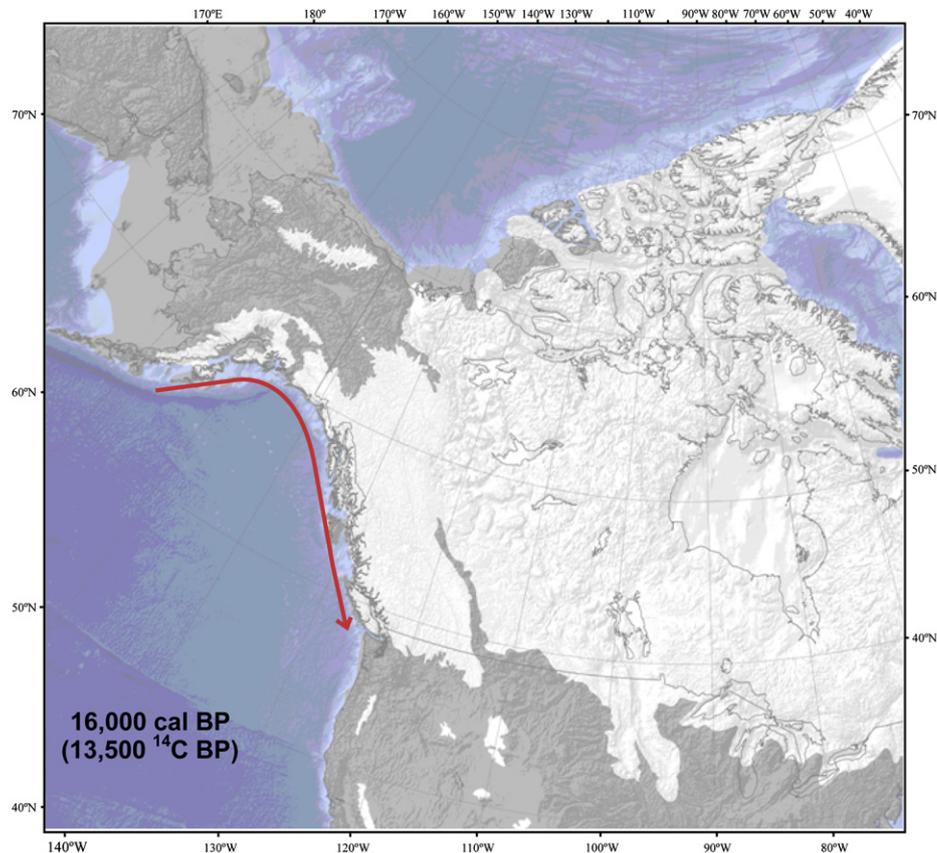


Fig. 5. Extent of glaciation and sea level circa 16,000 cal BP (13,500 ¹⁴C BP) illustrating deglaciated islands and areas of the continental shelf. The arrow depicts the postulated route of human colonization to southern regions of the Americas predating the opening (deglaciation) of the mid-continental corridor.

As deglaciation began, the coasts of Alaska and British Columbia were dynamic and rapidly changing environments. Melting glaciers released water into the oceans, causing sea level to rise. At the same time, deglaciation removed tremendous weight from the land causing it to rebound at different rates depending on the load of LGM ice. Also at the same time, tectonic movement of the massive plates forming the earth's crust contributed to changes of sea level relative to the land. The timing and scale of these three processes largely determined the location of the shoreline and its movement through time.

Data suggest that deglaciation progressed more rapidly along the coast than in the interior of the continent as a result of warm Pacific water (Clague et al., 2004). Brown bear are reliably dated in the Alexander Archipelago by 14,949–13,888 (95.4%) cal BP (12,295 ± 120 ¹⁴C BP) (Heaton and Grady, 2003:29). Other terrestrial species, such as caribou were expanding their range from LGM refugia (Heaton and Grady, 2003). Warmer water maritime species were established offshore and along the coast, and ringed seals retreated north. Based on an analysis of interdisciplinary paleo-ecological data from the north and west Pacific Rim, Erlandson et al. (2007) suggest a “kelp forest ecosystem” stretched from Japan to Baja California during late Pleistocene/early Holocene times. They hypothesize that this continuous ecosystem could have facilitated migration by coastal adapted people along the southern coast of Beringia from northeast Asia to North America possibly as early as 16,000 years ago.

At the southern end of the coastal corridor, late Pleistocene bison (*Bison antiquus*) remains have been reported from three different localities on Vancouver Island and another six sites on Orcas Island (Fig. 1). Radiocarbon determinations indicate that

these specimens range in age between approximately 11,750–10,800 ¹⁴C BP (13,750–12,800 cal BP). These discoveries, and the mountain goat bones from Port Eliza Cave, indicate that these islands were connected to the mainland at the end of the Pleistocene (Wilson et al., 2009). Taphonomic analysis of the bison remains from the Ayer Pond site on Orcas Island dating to 11,760 ± 70 ¹⁴C BP suggest to the investigators that the bison at this site may have been butchered by early hunters (Wilson et al., 2009). Two radiocarbon dates (11,850 ± 60 ¹⁴C BP and 12,000 ± 310 ¹⁴C BP) run on seeds and wood associated with bison and mastodon remains from the Manis Mastodon site indicate that these species were present on the Olympic Peninsula in Washington (Gustafson et al., 1979). The growing bodies of data suggest that at the southern terminus of the Northwest Coastal corridor early human settlers may have encountered the late Pleistocene large mammal fauna of North America that are commonly associated with Paleo-Indian sites elsewhere on the continent.

If ever there was an ice-free corridor during the LGM, it was not in the interior regions of northern North America, but along the Northwest Coast. Although the growing body of data demonstrates the possibility of human colonization along the Northwest Coast during the LGM, it is not until sometime between 17,000–15,000 cal BP that the deglaciation was sufficiently advanced to create a relatively safe and biotically continuous corridor along the coast (Fig. 5) (Dixon, 2001). An earlier migration along the Northwest Coast sometime prior to about 20,000 years is also possible, but there are insufficient archeological data to support it. Compared to the mid-continental deglaciation corridor, the coastal corridor was deglaciated earlier and became ecologically viable thousands of years earlier.

4. Discussion

It is still not known when, how or why people first colonized the Americas. Converging lines of evidence corroborated by independent research from several disciplines including archeology, geology, and paleontology, all confirm that a terrestrial “ice free corridor” did not exist during the LGM. Evidence suggests that a geologically stable and environmentally viable terrestrial corridor between eastern Beringia and regions south of the continental ice was not available for human occupation until circa 13,000 cal BP (11,000 ¹⁴C BP). People colonizing the corridor from the south possibly made contact with the inhabitants of eastern Beringia sometime about 13,000 cal BP. People had settled areas of North America south of the continental glaciers prior to deglaciation, and must have reached areas south of the continental ice by a way other than a mid-continental terrestrial route.

This analysis illustrates that the Bering Land Bridge connected the Americas to Asia prior to 18,000 cal BP (15,000 ¹⁴C BP) until the about 10,000 cal BP. However, eastern Beringia remained a terrestrial extension of Asia terminating in a “cul de sac” blocked by glaciers until a biotically viable deglaciation corridor was established about 13,000–12,500 cal BP (11,000–10,500 ¹⁴C BP). **A biologically viable corridor stretched along the Northwest Coast from the southern coast of the Bering Land Bridge to regions south of the continental glaciers by about 16,000 cal BP (13,500 ¹⁴C BP).**

The coastal corridor has been criticized because no sites older than about 12,500–13,000 years old have been documented along the Northwest Coast. It is important to recognize that several Northwest Coast sites (On Your Knees Cave, K 1 Cave, and Gaadu Din 2) are equal in age, and possibly older than, sites dated in the area of the mid-continental deglaciation corridor. **Erlandson et al. (2008)** have documented human occupation of all the major regions of the Pacific Coast by at least 13,000–11,500 cal BP. Occupation of the Pacific coastal zone of the Americas is contemporaneous with Folsom and Clovis period occupations in the interior regions (**Erlandson et al., 2008**). Researchers suspect that older sites along the Northwest Coast may have been submerged by post-Pleistocene sea level rise. Archeological site predictive modeling and survey on the adjacent continental shelf along the Northwest Coast is necessary to test these hypotheses (**Josephans et al., 1997; Monteleone and Dixon, 2010**). There is considerable potential for discovering late Wisconsin age sites dating to the time of the coastal corridor along the Northwest Coast; however, the potential for late Pleistocene age archeological sites in the interior mid-continental corridor is extremely low.

Traditionally the colonization of North America from Asia has been envisioned as a terrestrial migration of people moving from Asia across the Bering Land Bridge and then southward from Beringia immediately following deglaciation, or earlier through the hypothetical ice-free corridor. However, **these data suggest that areas south of the continental glaciers had been colonized prior to the establishment of a geologically stable and biotically viable deglaciation corridor.** Archeological data indicate that people employing late Paleoindian technology began to move northward from areas south of the continental glaciers and that artifacts ascribed to the Paleoindian tradition do not appear in eastern Beringia until about 12,500 cal BP (10,500 ¹⁴C BP).

Alternative routes to the Americas are few, with all remaining LGM colonization hypotheses requiring the use of watercraft. **Based on the genetic and linguistic relationships between most Native Americans and northeast Asians, northeast Asia appears to be the most probable region of origin for the first Americans. Consequently, human colonization along Northwest Coast, either prior to or subsequent to the LGM, along the North Pacific Rim appears to be the most viable hypothesis for an initial migration from northeast Asia based on the current state of knowledge.** However, colonization of the American continents was a complex process possibly

taking thousands of years involving multiple migrations possibly from different areas of the world.

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