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Late Quaternary vegetation of Chukotka (Northeast Russia), implications for Glacial and Holocene environments of Beringia

Patricia M. Anderson [a,*], Anatoly V. Lozhkin [b]

[a] *Earth & Space Sciences, Quaternary Research Center, University of Washington, Seattle, WA 98195-1310, USA*
[b] *Northeast Interdisciplinary Science Research Institute, Far East Branch Russian Academy of Sciences, 16 Portovaya Street, Magadan 685000, Russia*

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ABSTRACT

Two lake records from the Kankaren region of southern Chukotka, when combined with other palynological and macrofossil data, document spatial and temporal variations in the regional vegetation history since ~21,000 ^{14}C/25,400 cal yr BP. Full-glacial environments were severely cold and arid in central and northern Chukotka, whereas southern sites experienced conditions that were relatively moist, although still drier than present. Southern Chukotka may represent a western extension of environments of the land bridge proper, including a possible "moisture" barrier to intercontinental migration. Shrub *Betula* tundra established earliest in southern Chukotka (~15,800–14,000 ^{14}C/19,000–16,700 cal yr BP; ~13,000 ^{14}C/15,300 cal yr BP central and north), *Pinus pumila* earliest in the north (~9600 ^{14}C/11,100 cal yr BP; ~7600 ^{14}C/8400 cal yr BP south), and shrub *Alnus* earliest in both the south and north (~12,000–11,000 ^{14}C/13,800–12,900 cal yr BP). These patterns support the presence of cryptic refugia for *Betula* and *Alnus* in Chukotka during the full glaciation. In contrast, *P. pumila* probably migrated into Chukotka from populations located in the northern coastal lowlands and from mountainous regions of southwestern Beringia. Evidence for a thermal optimum (~11,000–8000 ^{14}C/12,900–9000 cal yr BP) is strong in northern Chukotka but is absent in central and southern areas.

1. Introduction

During the most recent glacial–interglacial cycle the greatest divergence of modern and ancient environments of Beringia occurred during the Last Glacial Maximum (LGM; peaking at ~18,000 ^{14}C BP/~21,000 cal yr BP; in Western Beringia dated to ~12,500–25,000 ^{14}C BP/~14,700–30,000 cal yr BP). Arctic coasts were located ~600–900 km to the north of modern, and Chukchi Peninsula, the Siberian lowlands, and coastal Alaska were landlocked (Fig. 1). Only the shores of southwestern Chukotka, Kamchatka Peninsula, and the Okhotsk Sea were little changed from today. Although glaciers were more common than present, they generally were limited to mountain valleys, the exception being the extensive ice build-up in southern Alaska (Hamilton, 1994; Barr and Clark, 2012). The full-glacial biota also varied markedly from present. The LGM fauna included a variety of extinct and extant large mammals, the iconic figure being the woolly mammoth (*Mammuthus primigenius*), and insect assemblages from Eastern and Western Beringia were more closely associated with steppe rather than arctic tundra (Guthrie, 1982, 1990; Elias, 2000; Elias et al., 2000). The region-wide vegetation of Beringia was initially viewed as rather monolithic (although with a patchwork of habitats found at the landscape level) with disagreement on whether the plant communities had greater affinity to arctic tundra or steppe-tundra (Hopkins et al., 1982). The nature of the LGM vegetation has been contentious, particularly in the pioneering stages of research when records were limited in number and geographic distribution (e.g., Ritchie and Cwynar, 1982 vs. Guthrie, 1982). However, as additional sites were investigated and more sophisticated analytical techniques, such as linked climate-vegetation models (Bigelow et al., 2003; Kaplan et al., 2003; Allen et al., 2010), became available, ideas about the nature of the LGM vegetation and regional environmental variability have been refined. For example, the predominance of cool, moist habitats in Central Beringia have been proposed as a "barrier" or "filter" that prevented biotic exchanges between Asia and North America, particularly of insects and some larger animals (e.g., woolly rhinos, short-faced bears, camels; Guthrie, 2001; Yurtsev, 2001; Elias and Crocker, 2008).

Unlike the relative stability of the LGM, the late glaciation into the early Holocene (~12,500–8000 ^{14}C/~14,700–9000 cal yr BP) is a time of great global change, and no where is this more evident than in Beringia. With increasing summer insolation, glacial melting,

* Corresponding author.
E-mail address: pata@u.washington.edu (P.M. Anderson).

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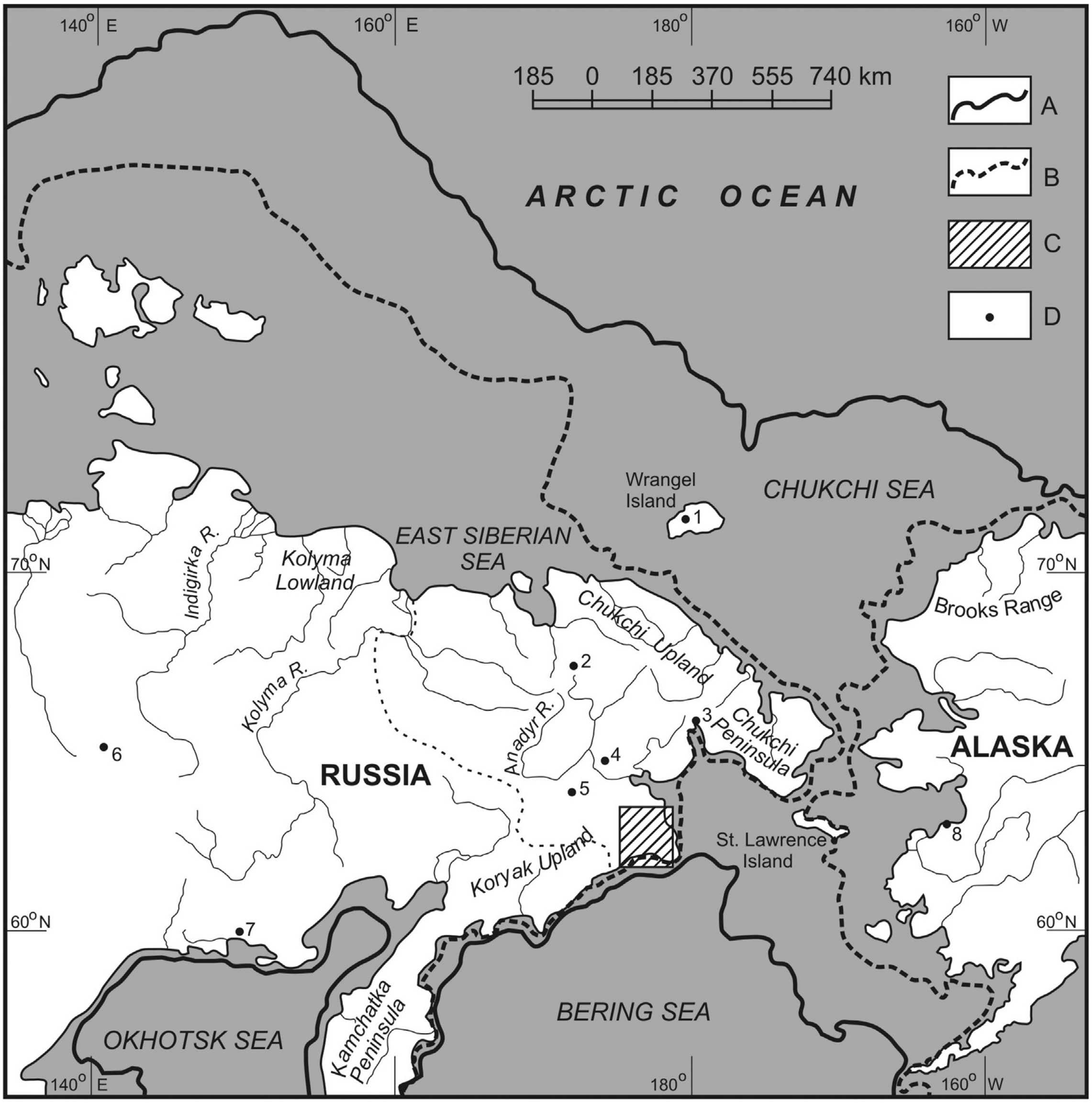

Fig. 1. Map of Beringia showing locations of the: a) approximate location of the 18,000 ^{14}C/21,000 cal yr BP shoreline (following Lozhkin, 2002), b) approximate location of the 12,000 ^{14}C/13,800 cal yr BP shoreline, c) study area, and d) sites mentioned in the text. The 18,000 ^{14}C shoreline corresponds to −100 m depth; the 12,000 ^{14}C line to −37 m depth. The lighter dashed line on the mainland depicts the western boundary of Chukotka. The map key is: 1) Wrangel Island (Mamontovaya River (WR-12) and Tundrovaya River exposures, 2) Lake El'gygytgyn, 3) Kresta Gulf, 4) Anadyr Lowland sites (Sunset, Malyi Kretchet and Melkoye lakes), 5) Ledovyi Obryv, 6) Smorodinovoye Lake, 7) Glukhoye Lake, and 8) Zagoskin Lake. See Fig. 2 for details of the study area.

warming seas, rising sea-levels, and changes in extent and duration of sea ice, the biotic environments of Beringia were being impacted from a variety of atmospheric and marine influences (Bartlein et al., 1991, 1998). Vegetation responses to these forcing factors were marked initially by the spread of shrub *Betula* tundra, followed by the development of a unique deciduous forest/high shrub biome, and finally the establishment of evergreen conifers (*Picea glauca* and *Picea mariana* in Eastern Beringia and *Pinus pumila* in Western Beringia; Edwards et al., 2005; Brubaker et al., 2005). Sites dating to this interval are more abundant than for the LGM, but interpretations are still dominated by data from Alaska and the Kolyma and northern Okhotsk drainages.

The paucity of paleovegetational information from Chukotka, despite it forming a key link between far Western and Central Beringia, has been the result of the limited numbers of sites and/or the weak chronological control in many records from this region (Anderson et al., 2002). For example, 6 palynological records encompass part or all of the full glaciation. Yet studies that employed systematic age-evaluations for inclusion/exclusion of records in regional analyses incorporated only 1 Chukotkan site in Edwards et al. (2000) and Bigelow et al. (2003), 2 sites in Edwards et al. (2005), and 3 sites in Brubaker et al. (2005). Data coverage for the Lateglacial–early Holocene is no better with only 1 of 15 palynological sites from Chukotka having a complete record for the interval (Brubaker et al., 2005; Edwards et al., 2005). Unlike the LGM, vegetation patterns in this more recent interval can be supplemented by radiocarbon-dated macrofossils from peats and paleosols, but here too the data are limited to 8 sites and provide only brief temporal "snapshots" (Binney et al., 2009).

The paleovegetation reconstructions offered for other regions of Beringia largely have been presumed to hold true for Chukotka. Yet this brief overview underscores the limitation of the Chukotkan data for tracing the spatial and temporal variations in the late Quaternary landscapes. The recent addition of continuous records