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Late Glacial to Holocene paleoenvironmental change on the northwestern Pacific seaboard, Kamchatka Peninsula (Russia)

Ionel Florin Pendea [a, *], Vera Ponomareva [b], Joanne Bourgeois [c], Ezra B.W. Zubrow [d], Maxim Portnyagin [e, f], Irina Ponkratova [g], Hans Harmsen [d], Gregory Korosec [d]

[a] Lakehead University, Sustainability Sciences Department, 500 University Avenue, Orillia, ON, L3V0B9, Canada
[b] Institute of Volcanology and Seismology, Pip Blvd. 9, Petropavlovsk-Kamchatsky, 683006, Russia
[c] University of Washington, Department of Earth & Space Sciences, Seattle, WA, 98195-1310, USA
[d] State University of New York at Buffalo, Department of Anthropology, 380 MFAC, Buffalo, NY, 14261, USA
[e] Helmholtz Centre for Ocean Research Kiel (GEOMAR), Wischhofstr. 1-3, 24148, Kiel, Germany
[f] V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Kosygin Str. 19, Moscow, 119991, Russia
[g] North International University, Portovaya Str. 13, Magadan, 685030, Russia

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ABSTRACT

We used a new sedimentary record from a small kettle wetland to reconstruct the Late Glacial and Holocene vegetation and fire history of the Krutoberegovo-Ust Kamchatsk region in eastern Kamchatka Peninsula (Russia). Pollen and charcoal data suggest that the Late Glacial landscape was dominated by a relatively fire-prone *Larix* forest-tundra during the Greenland Interstadial complex (GI 1) and a subarctic steppe during the Younger Dryas (GS1). The onset of the Holocene is marked by the reappearance of trees (mainly *Alnus incana*) within a fern and shrub dominated landscape. The Holocene Thermal Maximum (HTM) features shifting vegetational communities dominated by *Alnus* shrubs, diverse forb species, and locally abundant aquatic plants. The HTM is further defined by the first appearance of stone birch forests (*Betula ermanii*) — Kamchatka's most abundant modern tree species. The Late Holocene is marked by shifts in forest dynamics and forest-graminoid ratio and the appearance of new non-arboreal taxa such as bayberry (*Myrica*) and meadow rue (*Filipendula*). Kamchatka is one of Earth's most active volcanic regions. During the Late Glacial and Holocene, Kamchatka's volcanoes spread large quantities of tephra over the study region. Thirty-four tephra falls have been identified at the site. The events represented by most of these tephra falls have not left evidence of major impacts on the vegetation although some of the thicker tephras caused expansion of grasses (Poaceae) and, at least in one case, forest die-out and increased fire activity.

1. Introduction

The Kamchatka Peninsula is located in the northwestern Pacific at the intersection of Arctic, Eurasian, and North American bioclimatic influences (Fig. 1) and is characterized by a highly diverse tectonic landscape. Similar to the North Atlantic region, environmental changes in and around the North Pacific following the Last Glacial Maximum about 20,000 years ago were large and rapid (Praetorius and Mix, 2014). The patterns of variation were complex, and the highly dynamic paleoclimatic and paleooceanograpic couplings between the two northern oceans led to both syn- and diachronicity (Yasuhara et al., 2012; Max et al., 2012; Praetorius and Mix, 2014). In the North Pacific, deglacial warming was mediated by the orbitally forced increase in summer insolation but also by linkages to deglacial variations in the Atlantic meridional overturning circulation (AMOC) and by close atmospheric couplings between the North Pacific and North Atlantic and between the North Pacific and the adjacent landmasses (Max et al., 2012). The latter coupling was probably dominated by the changing position and strength of the two pressure systems that drive the present day climate in the region: the Siberian High and the Aleutian Low (Mock et al., 1998). However, the patterns of deglacial warming, including the development of the Late Glacial cold reversal (the Younger Dryas), are poorly known especially from terrestrial records.

* Corresponding author.
E-mail address: ifpendea@lakeheadu.ca (I.F. Pendea).

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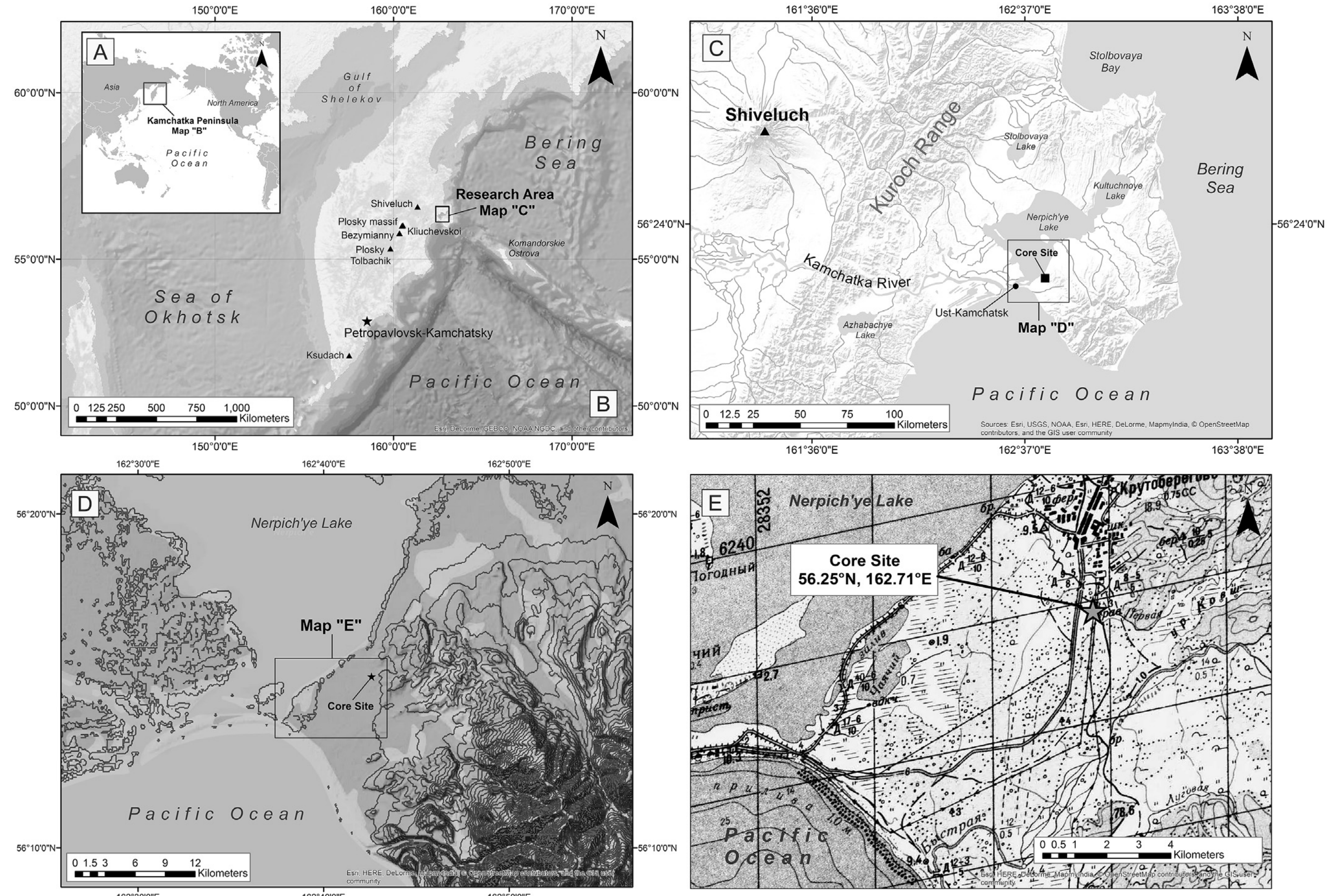

Fig. 1. Location Maps. A) the study region in the global context; B) Kamchatka Peninsula and the surrounding seas; C) detail of east-central Kamchatka; D) DEM detail of the core site near the transition between the Pacific Ocean and a coastal lagoon; E) topographic detail of the core site.

On the Kamchatka Peninsula, the patterns of deglacial paleoclimate and paleoenvironmental change are even less clear than elsewhere in the North Pacific. To date, there is no reliable information on Late Glacial paleoenvironments with the exception of some early studies, mostly in Russian, which report paleoenvironmental data with little to no age control (Neishtadt, 1957; Khotinsky, 1977; Braitseva et al., 2005). By comparison, Holocene paleoenvironments are relatively well documented. From north-central Kamchatka, Andrén et al. (2015), Hammarlund et al. (2015), and Self et al. (2015), among others, present new, high-resolution, multi-proxy lake records, while Nazarova et al. (2013) and Hoff et al. (2014) conducted single-proxy paleoenvironmental reconstructions in southern and central Kamchatka. In addition, recent reassessments of previous pollen-based reconstructions were undertaken by Dirksen et al. (2013). All these studies bring evidence of a highly variable Holocene climate. For instance, Nazarova et al. (2013) analyzed the chironomid remains in lake sediments from the Two-Yurts Lake in central Kamchatka and found a variable Late Holocene climate with four distinct climate periods. Hammarlund et al. (2015) used cellulose-inferred lake-water $\delta^{18}O$ to infer Holocene regional precipitation variability and long-term atmospheric circulation over easternmost Asia.

This paper aims to further our understanding of the Late Glacial to Holocene environmental history of Kamchatka. We use pollen and microscopic charcoal from a 7-m-long sediment sequence and 16 ^{14}C dates to reconstruct vegetation and regional fire dynamics in eastern Kamchatka near the Pacific Ocean - Bering Sea junction (Fig. 1). We specifically address the question of whether Kamchatka's Late Glacial paleoenvironments were similar to those of other locales in the northern hemisphere and, in particular, whether the region experienced the Late Glacial cold reversal known as the Younger Dryas. The existence of a region-wide Younger Dryas (GS1) in the North Pacific has been previously questioned (e.g., Anderson et al., 2002; 2003; Kokorowski et al., 2008). To improve the detection of patterns of climate change we compare our findings to previous paleoclimatic and paleoenvironmental records in the region. In addition, we present some evidence regarding the role of tephra falls from Kamchatka's large-scale explosive volcanism in postglacial vegetation dynamics.

2. General geographical setting

Kamchatka Peninsula (Fig. 1) is a boreal-subarctic landmass of almost 500,000 km^2 bordered by the Pacific Ocean to the east and south, Bering Sea to the northeast, and the Sea of Okhotsk to the west. To the north, a narrow land strip links the peninsula to the Koryak Highlands of southwestern Beringia. Kamchatka lies at the intersection of two opposing climatic influences, one continental subarctic (cold and dry) and one maritime subarctic (cold and wet). To the west, the cold maritime conditions of the Sea of Okhotsk and to the north, the orographic barrier of the Koryak Highlands moderate the influence of the vast continental subarctic landmass of NE Siberia. To the northeast, east and southeast strong cyclonic activity, particularly from the North Pacific, brings cool humid air