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A Holocene palynological record from the northeastern Laptev Sea and its implications for palaeoenvironmental research

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A 844 cm long core PS51/118-3 (77°53.54′ N; 132°11.92′ E) recovered from the upper slope (122 m water depth) of the Laptev Sea (Russian Arctic) has been studied for pollen, spores and aquatic palynomorphs, including freshwater green algae and cysts of marine dinoflagellates. The age model was established on the basis of radiocarbon dates obtained on marine bivalve mollusk shells. The available dates suggest that the analyzed sediment was accumulated during the last ca. 10.8 cal. ka and reveal two intervals with markedly different sedimentation rates, reflecting the sedimentary regime changes of the Laptev Sea shelf during postglacial sea-level rise. Very high sedimentation rates (ca. 4.7 mm per year) in the lower part of the core (120–866 cm) between ca. 9.2 and 10.8 cal. ka BP reflect lower-than-present sea levels, high erosion activity and much closer position of the palaeo-shoreline with the Lena and Yana river mouths to the core site. Dramatic decrease in sedimentation rates (ca. 0.1 mm per year) during the middle and late Holocene interval reflects high sea-level and decreased amount of suspended material transported to the outer shelf by rivers. Despite the location of the core site at the continental slope and far away from the modern coastline pollen, spores and fresh-water algae constitute a major part of the microfossils throughout the whole record, indicating great impact of the Lena and Yana rivers and possibly prevalent wind regime on the pollen and non-pollen-palynomorph (NPP) assemblages. Although a number of short-term (decadal to multi-century) oscillations deviate from the mean Holocene values, pollen taxa percentages and pollen-based numerical biome reconstructions do not show very clear trends. The latter is likely a result of the mixed environmental signal and complex pollen contribution of several large environmental regions and vegetation zones of Siberia drained by the Lena and Yana rivers. The greater pollen contribution of the forested regions to the PS51/118-3 record reflects higher pollen production of the boreal trees and shrubs over the low-productive Arctic vegetation. The intervals of the relative increase in the tundra biome scores in the PS51/118-3 record reflect decreased arboreal pollen production or/and increased landscape openness within the pollen source area and can be correlated (within the uncertainty of the age models) with the cold episodes observed in the Greenland ice and North Atlantic sediment records.

1. Introduction

Over the past decades it became evident that the Arctic is undergoing significant environmental changes, such as increased air temperatures, reduced sea-ice cover and marked changes in amplitude and seasonality of river discharge (Gordeev et al., 1996; ACIA, 2005 and references therein). Most of these changes are already well documented in the Arctic coastal regions and on shelf environments. Therefore, scientific investigations in the Arctic Ocean are in focus of multi-disciplinary international programs (e.g. PAGES, IGBP and listed on the NOAA Arctic theme page http://www.arctic.noaa.gov/research.html), aiming at detailed analyses of marine sediments and providing high-resolution records of Arctic environments. For example, the recently established PAGES-endorsed project "Arctic Holocene Transitions" seeks to advance our understanding of centennial-scale variability in the Arctic

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system and focuses on the transition from the warmer early Holocene to the cooler late Holocene, and the shift in ocean-atmospheric circulation associated with this change in the mean state of climate (http://www.pages-igbp.org/workinggroups/endorsed-and-affiliated/arctic-holocene-transitions). To advance this goal, this project will first focus on generating a coordinated series of summaries for six regions across the Arctic, including Russian Arctic.

The Laptev Sea region in Siberian Arctic is internationally defined as key region for environmental monitoring and investigation of changes in the Laptev Sea system parameters in terms of changing boundary conditions as a result of climate change. Since 1993, it has been intensively studied under the framework of the joint Russian–German collaborative “Laptev Sea System” project (e.g. Kassens et al., 1998, 1999; Bauch et al., 1999, 2001; Rachold and Grigoriev, 1999, 2000, 2001; Hubberten and Romanovskii, 2001; Andreev et al., 2002, 2004; Schirrmeister et al., 2002, 2003; Polyakova et al., 2005; Andreev et al., 2011; Kienast et al., 2011; Naidina and Bauch, 2011; Wetterich et al., 2011; Stepanova et al., 2012; Taldenkova et al., 2012; Tarasov et al., 2013 and references therein).

Late Quaternary terrestrial sediments from lakes, peat lands and coastal sequences archiving various bioclimatic proxies are most commonly used to reconstruct local to regional environmental changes in the Laptev Sea region (e.g. Andreev et al., 2011; Kienast et al., 2011; Melles et al., 2012; Andreev and Tarasov, 2013 and references therein) and to discuss vegetation history (e.g. Pisaric et al., 2001; Müller et al., 2010; Werner et al., 2010), northern tree-line dynamics (e.g. MacDonald et al., 2000, 2008), tree cover changes and climatic fluctuations (e.g. Tarasov et al., 2013).

By contrast to terrestrial pollen records, which are among the most frequently used palaeoenvironmental proxies from the Russian Arctic (e.g. Andreev et al., 2011; and references therein), marine pollen records from Arctic Siberia are rare (e.g. Naidina and Bauch, 2001, 2011). However, numerous studies from other arctic, boreal, temperate and tropical regions (Short et al., 1989; Lézine and Hooghiemstra, 1990; Hooghiemstra et al., 2006) show that palynological investigations of marine sediment cores can provide reliable information on centennial to millennial-scale climatic variability and regional vegetation and environmental changes (e.g. Ekman, 1999; Desprat et al., 2009; Shumilovskikh et al., 2013) and help to establish basis for direct land–sea–ice correlations (e.g. Desprat et al., 2006; Mudie and McCarthy, 2006; Shumilovskikh et al., 2012 and references therein).

The current paper presents new results of palynological investigation of a 844-cm long core PS51/118-3 (77°53.54′ N, 132°11.92′ E) recovered from the eastern part of the Laptev Sea and at a water depth of 122 m. Together with other cores from the Laptev Sea it was used to reconstruct the chronology of the Holocene transgression at the northern Siberian margin (Bauch et al., 2001a,b). Thus the main objective of the current study is to evaluate potentials of marine pollen and non-pollen palynomorph (NPP) records from Siberian Arctic for reconstructing Holocene environments, climate and vegetation dynamics. As the Laptev Sea hinterland is relatively well represented by terrestrial palynological records, this study now allows for a comparison between marine and terrestrial data.

2. Regional setting

The Laptev Sea is a marginal sea of the Arctic Ocean (Fig. 1). It is located between the Taimyr Peninsula and the Severnaya Zemlya Archipelago in the west and the New Siberian Islands in the east. The northern coast of eastern Siberia with its vast and extending northward Lena delta borders the Laptev Sea in the south. The sea has a great impact on the Arctic climate and environments via extensive heat exchange with atmosphere in summer and contribution of a large fraction of the Arctic sea ice in winter.

Today, most of the Laptev Sea belongs to the continental shelf – a gently northwards sloping plain (Fig. 1). This shelf plain occupies an area of about 450,000 km^2 with prevailing water depths of less than 50 m (Atlas Arktiki, 1985; Bauch et al., 2001a,b). The relatively flat shelf turns steeply into the continental slope near 100 m water depth. The sea bottom topography reveals several submerged trough-like valleys connected to the mouths of the main rivers (Bauch et al., 1999 and references therein) and reflecting the last glacial low sea-level stand (Holmes and Creager, 1974; Kleiber and Niessen, 1999). Five major rivers, including Lena, Khatanga, Yana, Anabar and Olenek bring their waters into the Laptev Sea (Fig. 1). The river discharge causes relatively low salinity (particularly at shallow depths) and provides an important contribution to the freshwater balance of the Arctic Ocean. The Lena River comprises ca. 70% of the total share (Dmitrenko et al., 2001) with the peak values during the short summer period (Alabyan et al., 1995; Kassens et al., 1998).

The Laptev Sea is frozen most of the year, though generally ice-free in August and September. The whole region has a severe climate with temperatures below 0 °C over more than 9 months per year and short cool summers. In the coastal area the mean January temperature is about −22 °C, and the mean July temperature is about 5–6 °C (Atlas Arktiki, 1985). Mean annual precipitation is 230–270 mm with 75% of it falling as rain during summer months.

Vegetation of the Laptev Sea region, which may contribute to the marine sediment pollen assemblages, reflects severe climate conditions (Stone and Schlesinger, 1993; CAVM Team, 2003). A narrow band along the coast and the islands are occupied by the scarce arctic tundra communities dominated by grasses, *Dryas* and *Saxifraga* species, and mosses. South of the arctic tundra, subarctic

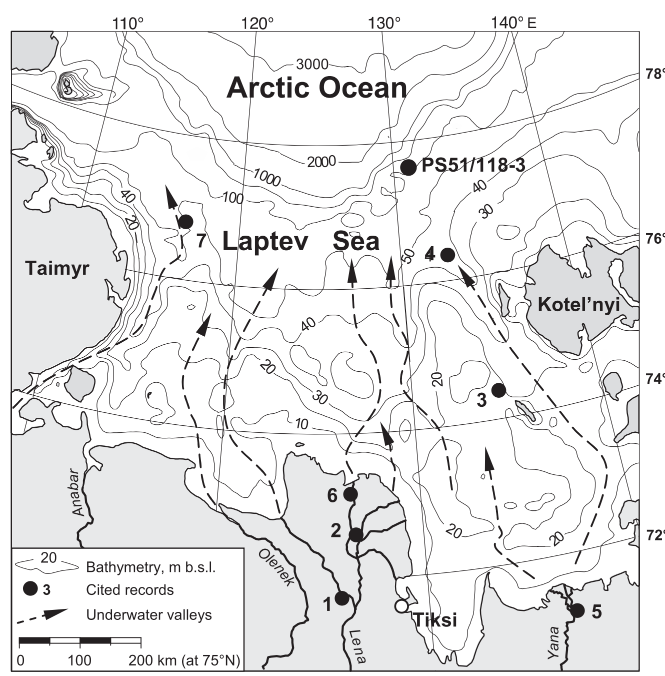

Fig. 1. Map of the Laptev Sea region showing locations of core PS51/118-3 (big black circle) and other locations mentioned in the text (small black circles). 1 – Lake Dolgoe (Pisaric et al., 2001); 2 – Kurungnakh Sise Island, Lena Delta (Andreev et al., 2011; Schirrmeister et al., 2011); 3 – core site PM9462 (Naidina and Bauch, 2001); 4 – core site PS51-135 (Polyakova et al. 2005; Naidina and Bauch, 2011); 5 – Kazach'e site (Andreev et al., 2001); 6 – Nikolay Lake (Andreev et al., 2004); 7 – core site PS51/159-10 (Bauch et al., 2001a,b). Note that Lake Billyakh (65°17′N, 126°47′E, Müller et al., 2009) is situated in the middle part of the Lena River region, i.e. outside the map.