https://doi.org//10.3301/ABSGI.2021.02

Pisa, 24-28 May 2021

ABSTRACT BOOK

a cura della Società Geologica Italiana

Dipartimento
di Scienze della Terra,
Università di Pisa, Italia

Pisa, Italy

PALAEOARC 2021

24th - 28th May, 2021

2nd International Conference on 'Processes and Palaeo-environmental changes in the Arctic: from past to present'

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Società Geologica Italiana

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KEY NOTES

Distally deposited tephra constrains High Arctic post-glacial sea level and glaciers

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Keywords: Holocene, cryptotephra, glacial isostatic adjustment, glaciers, relative sea level.

The distal deposition of tephra in far-field locations resulting from explosive volcanism has the potential to geochronologically constrain sedimentary archives and landforms. Tephrochronology is unparalleled in spatial and temporal precision, providing the potential to investigate synchronicity or lag-response to climate forcing. With this technique, we constrain a Late Glacial glacier re-advance on Svalbard and suggest minimum uplift rates during the Younger Dryas were over three times greater than previous estimates. The identification of cryptotephra (non-visible) horizons, outside the extent of visible fallout, has greatly expanded the field of application of tephrochronology. While the cryptotephra revolution has triggered a burst of investigations using low-concentration tephra to constrain distal sedimentary sequences, as of yet, few investigations have used this tool to constrain the age of glacial landforms. Here we constrain a moraine formed from glacier re-advance (12.8-12.2 cal. ka BP) into a high relative sea level during the early Younger Dryas period, with the first identified occurrence of the Icelandic Vedde Ash in Svalbard. Low concentrations (~20 shards/g dried sediment) of the bimodal Vedde Ash (*c.* 30-80 µm) were identified in a lake sediment record collected from the Heftyebreen foreland, a tributary to Grønfjorden, western Spitsbergen. Given that the cryptotephra was deposited within a lacustrine isolation-basin ("Heftyevatnet"), we further reconstruct a minimum rate of glacioisostatic rebound during the Late Glacial. Strong and longstanding evidence suggests that west-coast cirque glaciers were less extensive during the Late Glacial than the Late Holocene. However, the Late Glacial Heftyebreen moraine suggests Svalbard glaciers and their dynamics during this period may not be so simple.

Ancient Environmental DNA – a Proxy in Quaternary Geology

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Keywords: Environmental DNA (eDNA), State-of-the-art, Proxies in Quaternary studies.

Every living organism releases its DNA into the wider environment in one way or the other. Thus, ancient environmental DNA (eDNA) has an unparalleled capacity for tackling the grand challenge of scaling biological function from genes to landscapes towards a holistic understanding of ecological systems in an increasingly changing world. Yet most ancient studies have used DNA from macrofossils (e.g., bones, teeth) to make ecological and evolutionary inference, limiting the findings to a discrete temporal and spatial record in select suitable environments from a subset of species that leave behind such remains. Consequently, much of the natural world has been so far overlooked by the field of ancient DNA. While there has been a notable increase in the number of ancient eDNA studies in recent years these have mostly focused on basic taxonomic characterisation of younger sediments from colder regions, with few studies venturing into the deep past, warmer climatic regions, and complex ecological and evolutionary questions. The full potential of eDNA for studying the long-term dynamics of ecological systems will not be reached without a stepwise change in the way eDNA is retrieved, processed and analysed. Here, in this overview, we will address the conceptual revolution in the field of ancient eDNA with potential far-reaching implications for various branches of Geo-biological and archaeological sciences.

Tracing past methane emissions in the Arctic Ocean

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Keywords: Methane, gas hydrate, Arctic, geochemistry, micropaleontology.

Methane (CH_4) is a greenhouse gas, with a global warming potential ~28 times higher than that of carbon dioxide (CO_2) on a 100-year time scale. Methane hydrates, ice-like solids that consist of methane and water, are large in the Arctic. They are climate-sensitive old carbon reservoirs that have the potential to release large quantities of methane, as the Earth continues to warm. While methane hydrates have been always intrigued scientists, in the last few years they have received even more attention. Some scientists raised the alarm that large quantities of CH_4 might be liberated by widespread destabilization of climate-sensitive gas hydrate deposits trapped in marine and permafrost-associated sediments (Bohannon, 2008; Whiteman et al., 2013). Because the Arctic is warming much faster compared to lower latitudes, then the question is if recent and anticipated temperature rise, especially in the Arctic, could destabilize these hydrates and cause a release of methane into the water column and possibly to the atmosphere. Most of the methane released from hydrate dissociation is consumed in the sediment and water column by microbial oxidation (Boetius, et al., 2000), and a major impact on global warming from this methane is very unlikely. However, multiple observations report on-going methane emissions from several sectors of the Arctic oceans. But when this methane started to be emitted? Are the releases increasing or decreasing? In this presentation an overview of geochemical and micropaleontological investigations from several sector of the Norwegian Arctic will be presented with the aim of shading light on Arctic methane emissions from the last deglaciations.

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Labrador Sea ocean circulation and west Greenland Ice Sheet extent during the last glaciation

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Keywords: Labrador Sea ocean circulation, West Greenland Ice Sheet extent, marine sediment cores, foraminifera.

There is still relatively limited knowledge on the Labrador Sea ocean circulation and its impact on the west Greenland Ice Sheet (GrIS) during the last glacial period (Marine Isotope Stages 4-2). MIS 2, and especially the Last Glacial Maximum (LGM, 23-19,000 yr BP), designates a period of extensive glacial extent and very cold conditions on the Northern Hemisphere. However, also during MIS 4 several regions of the Northern Hemisphere seems to have experienced extensive glaciation (e.g. Mangerud et al., 1999; Knies et al., 2000). Yet until recently (Griem et al., 2019; Seidenkrantz et al., 2019) there was little information from the Greenland region.

The strength of North Atlantic ocean circulation during the last glacial period has been highly debated and especially for the LGM it has hitherto been considered to have been weaker than today. Based on investigations of two marine sediment cores from the Davis Strait (1033 m water depth) and the northern Labrador Sea (2381 m), we see no evidence of warm-water flux to the West Greenland region during MIS 4, although the influx of Atlantic-sourced water at subsurface depth became extensive during MIS 3 (Seidenkrantz et al., 2019). In contrast to MIS 4, our records demonstrate a significant influx of Atlantic-sourced water at both subsurface and intermediate depths during the LGM (Seidenkrantz et al., 2019, 2021). Although surface-water conditions were cold and sea-ice loaded, the lower strata of the (proto) West Greenland Current carried a significant Atlantic (Irminger Sea-derived) Water signal, while at the deeper site the sea floor was swept by a water mass comparable with present Northeast Atlantic Deep Water (Seidenkrantz et al., 2021). The persistent influx of these Atlantic-sourced waters entrained by boundary currents off SW Greenland suggests an active Atlantic Meridional Overturning Circulation during the LGM. Immediately after the LGM, deglaciation was characterized by a prominent deep-water ventilation event and potentially Labrador Sea Water formation, presumably related to brine formation and/or hyperpycnal meltwater flows. This was followed by a major re-arrangement of deep-water masses most likely linked to increased overflow at the Greenland-Scotland Ridge after ca 15 kyr BP.

Our results also suggest that in the southern Davis Strait region the most extreme Greenland shelf glaciation of the last glacial cycle occurred during MIS 4, with another prominent glacial advance 37-33 kyr BP. These periods also corresponds to periods with reduced influence of warm Atlantic-sourced water to the West Greenland region, suggesting that varying advection of warm water was an important factor deciding the extent of the west GrIS during the last glacial period.

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The Cenozoic Arctic Climate and Sea Ice History
A Challenge for IODP Expedition 377 (Arctic Ocean Paleoceanography – ArcOP)

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Keywords: Paleoceanography, Arctic, Cenozoic, IODP.

With the successful completion of the Arctic Coring Expedition – ACEX (IODP Expedition 302) in 2004, a new era in Arctic research began. For the first time, scientific drilling in the permanently ice-covered central Arctic Ocean was carried out, penetrating 428 meters of Quaternary, Neogene, Paleogene and Campanian sediments on the crest of Lomonosov Ridge (Backman et al., 2008). While highly successful, the ACEX climate record also has some important limitations. Based on the original age model (Backman, et al., 2008), the ACEX sequence contains a large hiatus spanning the time interval from late Eocene to middle Miocene. However, this hiatus was challenged by osmium isotope data which suggest a condensed interval of very limited sedimentation (Poirier & Hillaire-Marcel, 2011). Together with the generally poor core recovery, this prevents a detailed and continuous reconstruction of the Cenozoic climate history. Finally, the ACEX sites remain the one and only drill holes in the central Arctic Ocean.

Following-up ACEX and its cutting-edge science, a second IODP drilling campaign has been proposed and now scheduled for Aug-Sep 2022: IODP Expedition 377 (Arctic Ocean Paleocanography – ArcOP) (complete drilling proposal and further details are available at: http://www.ecord.org/expedition377/). Overall goal of ArcOP is the recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet the highest priority paleoceanographic objective, the continuous long-term Cenozoic Arctic Ocean climate history with its transition from the early Cenozoic Greenhouse world to the late Cenozoic Icehouse world. Furthermore, sedimentation rates two to four times higher than those of ACEX permit higher-resolution studies of Arctic climate change in the Pleistocene and Neogene. Key objectives are related to the reconstruction of the history of circum-Arctic ice-sheets, sea-ice cover, Siberian river discharge, and deep-water circulation and ventilation and its significance within the global climate system. This goal can be achieved by careful site selection, appropriate drilling technology, and applying multi-proxy approaches to paleoceanographic, paleoclimatic, and age-model reconstructions. At the proposed primary site, about 230 m of Plio-Pleistocene, 460 m of Miocene, and >200 m of Oligocene-Eocene sedimentary sequences might be drilled/cored. Background information and details about the IODP ACEX and ArcOP expeditions are available in the review by Stein (2019).

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ABSTRACTS

Atlantic Water advection into Kandalaksha Bay (the White Sea, the European Arctic) during Holocene inferred from diatom and aquatic palynomorph assemblages

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Keywords: The Arctic, diatoms, aquatic palynomorphs, Holocene, the White Sea.

The outer part of the Kandalaksha Bay, which corresponds to the Precambrian graben (Baluev et al., 2009), is characterized by descending tectonic movements, which contributed to continuous marine sedimentation.

Sediment core PS-6066 (65°99'N, 35°54'E; water depth, 226 m) was obtained using a gravity corer from outer Kandalaksha Bay, NW White Sea, during Cruise 80 of R/V "*Professor Shtokman*" in 2006. In core PS-6066, the sediments are represented by olive-gray silt with hydrotroilite (140-242 cm), dark olive silt with hydrotroilite (4-140 cm), and dark brown clay silt (0-4 cm). Ages of sample levels were determined by linear interpolation between the calibrated ^{14}C dates, and they correspond to the last ~11 cal ka BP (Preboreal). The lower part (183-228 cm) of core PS-6066 corresponds to the cold-water low-productivity marine bay that existed during the Preboreal. Values of the CD-criterion (lower than 0.04) in aquatic palynomorph assemblages indicate an extremely low inflow of fresh water in this part of Kandalaksha Bay. The high proportion of relatively warm-water diatom species, which are typical for Atlantic Waters (Polyakova & Novichkova, 2018) and high values of the AH-criterion supported transformed Atlantic waters penetration from the Barents Sea in the first half of the Boreal time in outer Kandalaksha Bay. Transgression Folas reflected by an increase in total diatom concentration (165-183 cm) and the abundance of *Coscinodiscus radiates* and *Shionodiscus oestrupii* at the end of Boreal time. Maximum values of AH-criterion (109) in the core indicate an increase in Atlantic Water advection. The maximum diatom concentrations (116-140 cm), an increase in dinocyst amount are characteristic for transgression Tapes and are associated with an increase in water productivity and favorable hydrobiological conditions of climatic optimum. Significantly lower diatom and aquatic palynomorphs concentrations and the low number of relatively warm water species can be explained by unfavorable hydrobiological conditions of the first part of the Subboreal (51-116 cm). The microfossil associations also clearly show the influence of the Trivia transgression in the second part of Subboreal by an increase in diatom and aquatic palynomorphs concentrations and relatively warm-water diatom species. The gradual decrease in the relatively cold-water species and increase in freshwater species were noted in the sediments of the Subatlantic time (4-51 cm). The composition of the diatom assemblage in the upper part of the core shows a significant amount of freshwater species, indicating an increasing influx of riverine water. Contemporaneously, freshwater species could appear as a result of migration and melting of seasonal ice from the coastal parts of the bay.

This research was carried out in the framework of the State Assignment of Ministry of Science and High Education, Russia (theme no. 0128-2021-0006) and supported by the RFBR (project no. 19-05-00787).

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Provenance study of the De Long Trough sediments: defining the mineralogical signature of the East Siberian Ice Sheet

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Keywords: Glacial sediments, heavy minerals, East Siberian Ice Sheet, De Long Trough.

The glacial history of the Arctic has classically been interpreted from marine records on the fluctuations of the Eurasian and North American ice sheets. The existence, size, and timing of the East Siberian Ice Sheet (ESIS), however, is still under discussion. Although it is widely believed that East Siberia was basically free of glacial ice during the Last Glacial Maximum (LGM), the sediment record from the De Long Trough possibly offers new evidence on whether large ice sheets were present on the East Siberian Sea and continental margin during the previous glacial periods. This recently discovered glacially scoured cross-shelf trough extends to the edge of the continental shelf north of the De Long Islands in the East Siberian Sea (O'Regan et al. 2017).

This research concentrates on defining the mineralogical signatures and distribution of the ESIS. Mineralogical provenance indicators such as heavy mineral assemblages and sediment compositions can be studied to evaluate sediment transportation by icebergs and sea-ice. Sediment materials from the East Siberian shelf and slope were collected during the 2014 SWERUS-C3 expedition. From the De Long Trough sites, nine samples from core SWR-24GC, including diamict and overlying sediments, and two diamict samples from core SWR-23GC were selected for closer investigation. For correlation purposes, diamict samples were selected also from core SWR-29GC from the Southern Lomonosov Ridge and core SWR-20GC from the East Siberian sea/shelf. The De Long Trough cores contained a basal diamict, and their visual and physical properties closely resemble a pervasive diamict unit recovered across the southern Lomonosov Ridge off Siberia. Comparing the mineralogy of the De Long Trough and the Southern Lomonosov Ridge diamicts enable to determine if there is a specific mineralogical signature in the De Long Trough diamicts delivered from this sector of the ESIS. The heavy minerals in these samples were analyzed by FE-SEM-EDS at the Centre for Material Analysis, Oulu University. As preliminary data, the diamicts in core SWR-24GC consist predominantly of amphiboles and pyroxenes with minor garnet and epidote content. In comparison, there is a prominent increase in amphibole content in the upper part of core SWR-29GC diamict with less pyroxenes. The overlying sediments from the last glacial cycle in core SWR-24GC show an increase in iron oxides content. In this provenance study, the obtained detailed geochemical compositions of the heavy minerals can be compared to source rock compositions in the East Siberian region.

This research is a part of the University of Oulu funded research project 'Loss of Ice in the Arctic System (LIAS): geological perspective of global environmental change'. The Finnish Cultural Foundation provides additional funding for this research.

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Lakes and trees on the deglaciating margin of the Scandinavian ice sheet during MIS 3 in northern Sweden

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Keywords: deglaciation, supraglacial, ice-walled-lake plains, Veiki moraine, Middle Weichselian.

The origin of the so called Veiki moraine zone in northern Sweden has been debated, but the leading interpretation is that this area of hummocky moraine represents supraglacial basin deposits formed at the margin of the Scandinavian ice sheet during an Early Weichselian interstadial (Lagerbäck, 1988; Hättestrand, 1998). However, the age of the deposits has been challenged by M. Hättestrand (2008), who proposed a Middle Weichselian age based on pollen records.

Our new luminescence dating of Veiki moraine plateaus in the northernmost part of the zone (the Lainio arc) does indeed confirm the proposed Middle Weichselian age. The ages have relatively low resolution but date the formation of the plateaus consistently to 55-35 ka, i.e. in Marine Isotope Stage (MIS) 3 rather than in MIS 5. Data from mapping, coring and geophysical investigations do, however, support the supraglacial origin of the Veiki moraine. The Lainio arc and the Veiki moraine zone thus represent the margin of the Scandinavian ice sheet during at least one re-advance or still-stand during a MIS 3 deglaciation. At that time, ice-walled lakes formed on the ice close to the margin. The ice surface was debris-rich and deposition of minerogenic and organic material took place in these lakes. Several of the lakes appear to have merged and partly drained during their existence, possibly reflecting a changing slope of the ice surface. Macrofossils found in organic lake deposits suggest that the ice surface was vegetated, even by trees. When the ice had melted, the lake deposits were left as topographic highs in the landscape, forming ice-walled-lake plains, locally called Veiki moraine plateaus.

These plateaus were overridden by the Scandinavian ice sheet during the Last Glacial Maximum (LGM) but were not or only little affected by this, likely due to the ice being cold-based. However, during the deglaciation of the LGM ice sheet, meltwater eroded or re-shaped some of the Veiki moraine plateaus, particularly in the western part of the zone.

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Internal architecture of drumlins revealed by sedimentological data and ground-penetrating radar - a case study from Bustarfell, NE-Iceland

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Keywords: Drumlin, Ground-penetrating radar, Ice stream, Iceland.

The study of drumlins and other streamlined subglacial bedforms is critical for understanding the behavior of ice streams. A recently described streamlined terrain in NE-Iceland preserves the flow sets of several cross-cutting palaeo-ice streams that were probably active during the Last Glacial Maximum (LGM) and throughout the deglaciation. Within the Vopnafjörður flow set in NE-Iceland, the internal architecture of two drumlins from the Bustarfell drumlin field have been studied by combining ground-penetrating radar (GPR) and sedimentological data. GPR is a useful technique to investigate the large-scale internal architecture of drumlins as studies based on sedimentological work are restricted due to open sections. For the GPR data collection, 16 profiles were surveyed with 50 and 100 MHz antennas that penetrated down to a maximum depth of 16 m and 9 m, respectively. Between 5 and 7 generalized radar facies and surfaces have been identified to describe and interpret the surveyed profiles. Results from the lithostratigraphic logs indicate that the drumlins are composed of massive till beds, which show deformation structures and fissility and are sometimes separated by glaciofluvial material. The logs and the GPR profiles correlate relatively well in the upper part of the drumlins (< ~5 m depth) whereas continuous to discontinuous undulating reflectors in the lower part (> ~5 m depth) are not visible in the stratigraphic logs but might represent fluvial material that has undergone deformation. Post glacial sediment (< ~4 m depth) can be seen on the lateral flanks of the drumlins and occasionally on their lee side. Based on these findings, a preliminary hypothesis is that subglacial erosion, accretion and shear deformation contributed to the development of the drumlins under fluctuating pore-water pressures. The results can provide valuable insight into the dynamics of palaeo-ice streams in NE-Iceland and the processes operating at their beds.

Decadal glacier changes using object-based image analysis

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Keywords: Landsat, Glaciers, OBIA.

Glaciers are an important component of the cryosphere and are key indicators of climate change. Temporal changes in glacial extent help with understanding the decadal impact of climate change however, data of temporal variation of glaciers are not widely available for many parts of the world. Research indicates that climate change has had a significant impact on glacier recession, particularly in Alaska, where glacier meltwater is a large contributor to global sea-level rise. Therefore, it is important to identify glacier recession within this region. 397 glaciers in Alaska are selected from the Randolph Glacier Inventory (RGI) to assess temporal changes and develop a method that can be easily applied to other regions in the Arctic. In this study, Landsat satellites images, acquired in the years 1986, 2002, and 2019 are used to quantify changes. An Object Based Image Analysis (OBIA) method was applied to generate glacier outlines. OBIA is a process that can create segments/objects of a satellite image before classification based on spectral properties and neighbourhood pixels. Comparison between the manually corrected outline of RGI and the outlines derived using the OBIA show a 90.34% agreement. The generated outlines reveal that the glaciers are retreating. In 1986, the total glacierized area is 828.61 km^2, 752.15 km^2 in 2002, and 572.18 km^2 in 2019. From 1986 to 2002 the total loss of glacier ice is 76.46 km^2. The ice continues to decrease, from 2002 to 2019, 179.97 km^2 glacier ice was lost. An overall loss of glacier ice from 1986 to 2019 is 256.43 km^2. The results show that ice loss is greater after 2002 to 2019 and that the OBIA is a promising method for accurately mapping glaciers, reduces the time required for manual correction and can be applied in other glacierized regions.

Asymmetric Growth of the Eurasion Ice Sheet during the Saalian and its Implication for Reconstructing Eemian Environments

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Keywords: Saalian glaciation, Eurasian ice sheet, northern Russia, last interglacial sea level, MIS5e-Eemian climate.

The Eemian climate development and sea level rise in the North Polar region after the penultimate glacial maximum (PGM) differed significantly from the Holocene climate pattern after the LGM. It has been suggested that the cause for it must be sought in the particular volumes and maximal geographical extensions of the Saalian (pre-Eemian) and Weichselian (pre-Holocene) ice sheets, respectively. While in the mid-latitudes both interglacials show a comparable, insolation-driven climate development after each glacial maximum, this pattern deviates in Arctic and sub-Arctic realms. But, understanding the paleoenvironmental history of that important region is particularly hampered by a scarcity of continuous Eemian records, especially on land. To fill that gap a 4.5 m thick sequence of Eemian marine beds from just south of Kanin Peninsula (Arctic Russia). The sequence directly overlies Saalian till and allows for a detailed evaluation of past events and their chronology vs. ocean records by using a multiproxy data set. The record is time-coeval with the collapse of the huge Saalian shelf-based ice sheet which left a glaciostatically overdeepened Barents-Kara Sea shelf region. The situation provided a pathway for rapid inundation of the Eurasian margin as far east as the Taymyr Peninsula causing an early post-Saalian regional sea level high. The oldest marine sediments reflect a period of harsh, fluvially-affected environmental conditions with cold turbid waters and heavy seasonal sea-ice cover. The later occurrence of a typical Arctic shelf and deep-sea microfossil assemblage together with broad-leaved species in pollen spectra is representative of the climatic amelioration in the early Eemian. The final stage of the record is marked by regression due to regional glaciostatic adjustment. Although conditions remained largely humid and warm - these did gradually deteriorate towards the end of the record - there is no direct indication from the microfossil community for enhanced penetration of warm Atlantic waters. The rich malacofauna, among them abundant *Arctica islandica*, however, reflect conditions akin to the early Holocene in Svalbard's fjords. At face value, U/Th ages of this species indicate that these sediments were deposited shortly after the PGM during early global sea level rise.

Speciation and stable isotope composition of sedimentary carbon and nitrogen in NW Barents Sea continental margin during last deglaciation

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Keywords: Northwestern Barents Sea, deglaciation, KOBr/KOH treatment, inorganic nitrogen, proxy.

Total organic carbon to total nitrogen ratios (C_{TOC}/N_{TN}) and their isotopic compositions ($\delta^{13}C_{TOC}$ and $\delta^{15}N_{TN}$) are largely applied proxies to discriminate between continental and marine-sourced organic inputs to aquatic depositional environments, thus resulting particularly suitable to investigate past climate, sea-level and land-level changes (Lamb et al., 2006). In sediments affected by strong supply of terrestrial organic matter (TOM), inorganic nitrogen (IN), bound to clay minerals as ammonium, tends to overestimate the contribution of TN in the calculation of the C/N molar ratio. Consequently, organic nitrogen (ON) should be preferred over TN (Schubert & Calvert, 2001).

Surficial sediments from western Barents Sea are today subject to great inputs of TOM (Knies & Martinez, 2009). We hypothesized that such an interference could be even more accentuated in Late Pleistocene sedimentary records (~20÷11.7 cal ka BP) from this area: during that period, this province of the basin was affected by sediment laden meltwaters related to the retreat of the last glacial ice sheets, representing a considerable source of TOM (Lucchi et al., 2015).

Our study was focused on three sediment cores retrieved from the Kveithola and Storfjorden glacigenic depositional systems (northwestern Barents Sea). We used a KOH-KOBr treatment to separate the ON fraction and quantify the IN contribution to these sediments during last deglaciation. Our results suggested that the TOC-TN scatter-plots, commonly used to assess the IN content when the TOM inputs are low, could not be employed, as analytical measurements indicated that IN represented a significant amount of the nitrogen pool. Specifically, IN (particularly abundant in the sediments deposited during the early stages of the deglaciation) well correlated with clay mineral distribution at each study site. Therefore, in order to define the correct sources of the sedimentary organic matter in glacial termination sequences, we strongly recommend the analytical determination of IN and the use of C_{TOC}/N_{ON} rather than the commonly employed C_{TOC}/N_{TN}.

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Massive ice beds distribution and the boundaries of Late Pleistocene glaciation at Western Siberian lowlands

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Keywords: Massive ice beds, thermal denudation, permafrost, retrogressive thaw slump, thermocirque.

Massive ice beds (or tabular ground ice) are a unique phenomenon in the permafrost zone of the northern hemisphere. Massive ice beds are found mainly in the coastal arctic lowlands and lie mostly in Pleistocene (less often in Holocene) sediments. The main part of massive ground ice is a relic of the Pleistocene period, and no modern in-situ formation of them has been found so far, except for the cases of burial of glacial ice and snowpacks, and the formation of ice on the seabed in places of gas emission (Melnikov, Spesivtsev, 1995). Massive ice beds remain a stumbling block in paleogeographic reconstructions – the same ice beds are considered by researchers to be buried glacial ice and indicate the presence of glaciation during the formation of frozen strata, or being initially intrasedimental ice, claiming the absence of large-scale glaciation in the Arctic coastal lowlands in the Middle and Late Pleistocene.

In publications following the results of QUEEN project, many beds of massive ice were classified as buried glacial ice (Svendsen et al., 2004). Within the framework of the "glacialist" concept, the State Geological Map of Quaternary Deposits (2015; 2018) on a scale of 1: 1 000 000 to the north of Western Siberia were compiled. On the contrary, among the permafrost scientists who have studied permafrost in the north of Western Siberia since the 1970s, the prevailing idea is intrasedimental formation of massive ice beds and the absence of ice sheets here in the Pleistocene (Badu, 2017).

Comparison of the modern thermocirques (retrogressive thaw slumps) distribution boundaries at the Western Siberian north revealed that the area with the maximum density of thermocirques distribution at the Gydan ridge is located directly to the north of the border of the Late Pleistocene Kara glaciation. However, thermocirques could have been formed not only due to massive ice beds degradation.

The work has been supported by RSF project 19-77-00051.

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Geomorphic evidence for cross-cutting palaeo-ice streams in NE-Iceland

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Keywords: Palaeo-ice streams, ice sheets, streamlined subglacial bedforms, ribbed moraine, Iceland.

Palaeo-ice streams in the Iceland Ice Sheet have been previously suggested on the basis of the configuration of fjords and valleys, striations, glaciotectonics and streamlined landforms, as well as numerical modelling. Based on the new ArcticDEM and satellite and aerial imagery, geomorphological mapping and spatial analysis of transverse and streamlined subglacial bedforms is conducted in order to reconstruct the configuration and dynamics of past ice streams in northeastern Iceland. The data shows considerable variation in density and elongation ratio of streamlined subglacial bedforms between different areas. This suggests cross-cutting ice streams that fluctuated and migrated over time. During times of great ice-sheet thickness, probably during the LGM, dominant ice-flow was towards the north, cutting across north-east trending valleys. In contrast, upon ice-sheet thinning during the last deglaciation, ice flow became constrained by topography dominantly towards the north-east and east. This is supported by troughs overlapping at different depths on the shelf off NE-Iceland. The detailed geomorphological mapping sheds a new light in the dynamics and deglaciation of the Iceland Ice Sheet and the configuration of past ice streams within it, providing important constraints for future conceptual and numerical modelling.

Deep Flow Variability Offshore South-West Svalbard (Fram Strait)

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Keywords: Fram Strait, deep-sea thermohaline variability, slope currents, wind-induced processes, shelf-slope dynamics.

Water mass generation and mixing in the eastern Fram Strait are strongly influenced by the interaction between Atlantic and Arctic waters and by the local atmospheric forcing, which produce dense water that substantially contributes to maintaining the global thermohaline circulation. The West Spitsbergen margin is an ideal area to study such processes. Hence, in order to investigate the deep flow variability on short-term, seasonal, and multiannual timescales, two moorings were deployed at ~1040 m depth on the southwest Spitsbergen continental slope. We present and discuss time series data collected between June 2014 and June 2016. They reveal thermohaline and current fluctuations that were largest from October to April, when the deep layer, typically occupied by Norwegian Sea Deep Water, was perturbed by sporadic intrusions of warmer, saltier, and less dense water. Surprisingly, the observed anomalies occurred quasi-simultaneously at both sites, despite their distance (~170 km). We argue that these anomalies may arise mainly by the effect of topographically trapped waves excited and modulated by atmospheric forcing. Propagation of internal waves causes a change in the vertical distribution of the Atlantic water, which can reach deep layers. During such events, strong currents typically precede thermohaline variations without significant changes in turbidity. However, turbidity increases during April–June in concomitance with enhanced downslope currents. Since prolonged injections of warm water within the deep layer could lead to a progressive reduction of the density of the abyssal water moving toward the Arctic Ocean, understanding the interplay between shelf, slope, and deep waters along the west Spitsbergen margin could be crucial for making projections on future changes in the global thermohaline circulation.

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First detection of microplastics in deep marine sediments from the Kveithola Trough, Barents Sea

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Keywords: Plastic pollution, Accumulation, Arctic, deep sea.

The distribution of microplastics (MPs) in the marine environment is a growing concern. MPs have been detected from tropical to polar waters, from shallow to deep layers of the water column. Once in the sea, abiotic (photo-degradation, hydrolysis, etc.) and biotic (biodegradation, biofouling, etc.) processes lead to changes in density and buoyancy, which facilitates MPs sinking to the seabed. So much so that ocean sediments are considered as the ultimate destination for small plastic fragments (Woodall et al., 2014). For a long time, the Arctic Regions have been considered as pristine environments and at lower risk to the treat of MPs. Plus, the remoteness and the difficulty of carrying out research in deep marine environments, has lead to a scarcity of available data on MPs occurrence and distribution (Tirelli et al., 2020).

In this study, sediments from the Kveithola Trough, a trough engraved on the margin of the Barents Sea bank, were analyzed for the occurrence of MPs for the first time. Our aims were to understand if such area is affected by MPs and to have a first insight of how oceanographic currents may act on the transport of MPs.

The upper 0 - 5 cm of sediment cores were analyzed from two sampling sites: PS99-1/05-2 (74° 50.56' N, 17° 38.27' E, 295 m) and PS99-1/06-4 (74° 50.75' N, 18° 10.55' E, 336 m) (Lucchi et al., 2016). MPs were extracted from sediments using a high-density separation approach. Each MP was described based on its morphology under an optical microscope and the plastic polymers were chemically confirmed using µFT-IR (Lusher et al., 2020). Sediment grain-sizes analyses were performed with the particles and shape analyzer, CAMSIZER X2. Compared to other analyses on Arctic regions (Tirelli et al., 2020), a relatively low occurrence of MPs (0.19 MP g^{-1} dw, n= 13) was detected in the Kveithola Trough. The particles were exclusively fibres with the longest axis ranging from 800 µm to >10,000 µm. The polymers detected were polyamide (29%), elastane (21%), cellulosic materials and polyethylene (14%), viscose and polypropylene (1%). MPs were found along both cores and accumulation was dated between 1998 and 2014 for site PS99-1/05-2 and between 1980 and 2003 for core PS99-1/06-4.

Considering depths at which cores were sampled, the main transport agents were shallow (e.g. West Spitsbergen Current, WSC) and bottom currents (e.g. East Spitsbergen Current, ESC) in addition to the sinking of MPs driven by density increases. Due to the remoteness and the distance from inhabited areas, MPs could derive from the degradation of fishery gears, boat coatings, oil and gas offshore industries or maybe were driven since long distances by strong oceanic currents (Lusher et al., 2015). Further analyses are needed to better understand the distribution and the source of MPs in this trough, additionally older sediments layers must be analyzed to define the effective vertical distribution of MPs.

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Geo-Environmental Response to Present Climate Warming in Subarctic East Siberia

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Keywords: Climate change, MAAT, permafrost degradation, thermokarst processes, geohazards.

The present climate change in northern Eurasia shows a steadily progressing warming trend, most prominent in the continental NE Siberia. In central Yakutia, this corresponds to a constant MAAT rise of ~0.07°C over the past decades (from –9.6°C in 1980 to –6.7°C in 2020) with apparent patterned 5–7 year climate cycles accompanied by strengthened seasonal extremality (Czerniawska & Chlachula, 2020). The most intensive temperature shifts characterize the spring (April–May) months with up to ~5°C air temperature rise over the last 40 years most pronounced since 2006. The shifted temperature balance has dramatic geo-environmental impacts on the natural and occupation settings of the investigated region between the central Lena, Aldan and Amga Rivers due to the accelerated permafrost decay with the progressively thawed ground layer. Field observations, the LANDSAT images along with the DEM models from the key monitored locations show large-scale top surface collapses, relief subsidence, disintegrated slope slumping, mass sediment wasting, progressing thermokarst development with alas lake and marshland expansion, palsa field formation and ground salinization. The synergic interactions of the regional climatic variations with the local geological and topographic configuration and the character of vegetation-cover predispose the frozen ground's thermal stability status and delineate the forms and the scales of the regional permafrost-landscape restructuring.

The locally-specific site geomorphology, surficial geology, slope orientation, vegetation cover, affecting albedo, and the top soil thermal energy budgets constitute the main parameters of ground ice melting, structural compaction of the dominantly yedoma sediments, and the ice volume loss. The co-acting factors—temperature, precipitation, topography, bedrock lithology, the insolation rate affecting the geo-relief in the association with the anthropogenic actions on the landscape (such as construction and logging) account for the particular sites' permafrost degradation differences of the exposed cryolithic base, mostly preserved from Pleistocene and reaching up to 300 m in depth. The DEMs display the most active geomorphic thermokarst processes in the low-elevated terrains (150–200 m asl.) with the SW/S–oriented topographic exposures along channels susceptible to most dynamic mass wasting. These topographic settings impacted greatly by the strong fragmentation and spatial orientation of the regional relief of an increased solar energy intake, exhibit vigorous cryolithic ablation and ground collapses. The maximum seasonal active layer thaw (in July–early August) varies from 0.6 to 1.3 m depth, occasionally reaching up to 2 m on the forest-free thermokarst terraces. The peaks of the permafrost-thaw fluvial discharge in late spring and early summer generate active bank erosion, the fluvial network restructuring and overall shifts in the regional hydrologic systems.

The current thermokarst processes demonstrate the subartic landscape's vulnerability and aggravated geo-environmental risks. The negative effects of the progressing ground thaw and destabilization due to warming generate acute environmental and engineering problems in the formerly permafrost-stable central and northern areas of East Siberia. Pervasive cryolithic degradation reinforced by wild and human-induced forest directly affects vegetation cover and the occupation habitats of the Yakut settlements. The seasonal ice-melt processes intensified during the last several years poses major risks to local communication and transport infrastructure, as well as drinking water supplies. Monitoring of the cryogenic hazards and the assessment of the socio-economic impact is crucial for the sustainment of the communities and regional development. Expanding open landscapes within the tundra-forest zone due to the territorial permafrost retreat provide new pastures contributing positively to rural economies.

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Water masses variability in inner Kongsfjorden (Svalbard) during 2010-2020

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Keywords: Atlantification, Kongsfjorden, Water masses variability, Temperature trends.

Kongsfjorden is an Arctic fjord located in the Svalbard archipelago. The fjord's hydrography is influenced by the warm and saline Atlantic water transported by the West Spitsbergen Current (WSC) and the cold and fresh Polar waters circulating on the shelf (Svendsen et al., 2002). Once several conditions are satisfied, Atlantic waters from the WSC can extensively flood the fjord (Cottier et al., 2005; Tverberg et al., 2019). A decade of continuous observations is analysed to examine changes in water properties and water masses variability in inner Kongsfjorden, with a special focus on Atlantic water intrusions. Data have been gathered by the Italian National Research Council (CNR) through the Mooring Dirigibile Italia (MDI) and summer CTD surveys. MDI was deployed in September 2010 at 105 m depth and comprises various temperature and salinity sensors placed at different depths. The analysis of temperature and salinity time series reveals a positive linear trend since 2010. However, both variables present a change point at the beginning of 2017, with more recent years exhibiting a negative trend. No significant tendencies were found when considering the monthly depth-averaged temperature. Yet, the depth-averaged temperature is rapidly rising in the warmest months of the year (0.26 °C/yr), whereas it does not show a significant trend in coolest months. Temperature and salinity observations gathered at 25 m and 85 m depth are used to depict water masses variability according to previous water masses classifications (Sundfjord et al., 2017; Tverberg et al., 2019). The inner Kongsfjorden shows large volumes of highly diluted Atlantic water at the beginning of the record. Instead, recent years feature more and more pure Atlantic waters culminating in protracted intrusions in 2016, 2017 and 2019. Atlantic waters are always confined near the bottom and they are never seen at 25 m, whilst summer freshwater is found only in the near surface. The timing of occurrence of these two water types seems to be related: the presence of large freshwater volumes close to the surface are preceded by the arrival of warm and saline waters. This evidence is interpreted as the melting signal of Kronebreen, the largest tidewater glacier in Kongsfjorden, triggered by the intrusion of Atlantic waters. In addition, the extensive advection of warm and saline waters of Atlantic origin in summer/autumn 2016 and 2017 is the key factor explaining the observed long-term variability in temperature and salinity. MDI and CTD observations are used to assess the hydrographic inter-annual variability in Kongsfjorden by characterising winter scenarios as defined in Tverberg et al. (2019). Eventually, the observed long-term water mass variability is put in perspective with the large-scale circulation. Kongsfjorden temperature series and water masses variability appear to be linked with the WSC meridional heat transport.

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Sedimentary ancient DNA - a new proxy to investigate the impact of environmental change on past and present biodiversity in Nordic Seas (NEEDED) - an overview of the research project

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Keywords: Ancient DNA, Holocene, climate change, biodiversity, carbon burial.

The vastness of the sea is full of various forms of life that dwell in the water column and at the sea bottom. Most of this marine biome is composed of microorganisms or small-sized animals that form the base of the marine food web. They are abundant and highly diverse. They play a key role in the functioning of the marine ecosystem and potentially could be a rich source of information the interplay between biodiversity and climate. Unfortunately, most of them disappeared without leaving any fossil traces. Only few microbial groups, those with hard skeletons, are preserved in the fossil record. These scarce microfossils provide a precious but very limited glimpse into the immense richness of marine biodiversity and its response to past environmental change.

Our project proposes a novel way to study the past environment using the DNA preserved in marine sediments. After their death, the organisms living in the sea sink to the bottom where they are eaten, decomposed by the other organisms or preserved in the sediment. Fortunately, their DNA remains preserved either inside the undigested cells or as free molecules attached to the sediment. Although this DNA is strongly degraded, it is still possible to recover DNA fragments and identify their origin. Thus, the marine sediments provide invaluable archives of almost everything that has been living there in the past.

In this project we will use this archived DNA to reconstruct the history of marine life in Nordic Seas during the last 20,000 years. We will analyze sedimentary DNA from six well-dated cores collected at the Svalbard and Greenland shelves. By using multiple genetic markers, we will follow changes in composition of different groups of organisms, from microalgae to single-celled protists and animals. We will integrate these historical biodiversity data with the information about past environmental change provided by classical palaeoceanographic proxies (i.e. microfossils, stable isotopes). The results of our study will help to understand how the marine organisms responded to climate change in the past and whether this response is similar to what we observe today. In particular, we will analyze the impact of climate change on biodiversity during the mid-Holocene Thermal Maximum, about 9,000 to 5,000 years ago and compare it to the current global warming. We will test the hypothesis that the past increase of sea surface temperature in Nordic Seas was associated with an increase of biodiversity, lower productivity and reduced carbon burial. These results will be relevant for what can be expected in the near future if the Nordic Seas continue to warm at the current pace.

Project financed by the Norwegian Financial Mechanism 2014–2021 (85%) and national co-financing (15%) within GRIEG Programme. “Sedimentary ancient DNA - a new proxy to investigate the impact of environmental change on past and present biodiversity in Nordic Seas”. Programme Operator: National Science Centre. Project No. 2019/34/H/ST10/00682.

Distribution, Characteristics and Formation of Esker Enlargements

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Keywords: Esker enlargement, subglacial hydrology, conduit collapse, ice margin, ice sheet.

Eskers are ridges of glaciofluvial sediment deposited in subglacial, englacial and supraglacial conduits. They are typically depicted as being straight to sinuous features, however, their planform morphology can be highly diverse. Esker enlargements are spatially confined ridge sections that are significantly wider than the trunk ridge (typically 250-400 m) and that reconverge downflow. They can be expressed as complex ridge networks or massive sediment bodies. We mapped over 1300 esker enlargements across Fennoscandia and Keewatin, Canada to investigate their distribution and morphological characteristics. We find that esker enlargements are largely absent below marine limits, and tend to become more abundant in areas of faster ice retreat; they form local clusters along particular esker ridges, and can occasionally be traced laterally between adjacent esker systems. Our study demonstrates that esker enlargements are common features of esker ridges in Fennoscandia and Keewatin, and based on morphological observations, we link their formation to roof collapses in subglacial conduits. The distribution of esker enlargements indicates that subglacial conduit collapse became an increasingly significant process during the final stages of deglaciation of both the Laurentide and Fennoscandian ice sheets, and may be a key driver controlling the pattern and rate of ice sheet retreat of land-terminating ice margins. This has implications for understanding the future behaviour of the Greenland Ice Sheet, where climatic warming is causing ice-surface thinning, increased subglacial discharge and retreat of marine terminating glaciers back onto land.

Dynamics of the central sector of the Cordilleran Ice Sheet through the last glacial cycle

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Keywords: Cordilleran Ice Sheet, last glacial cycle, deglaciation, late Pleistocene climate reversals.

The Cordilleran Ice Sheet (CIS) repeatedly covered western Canada during the Pleistocene and attained a volume and area similar to that of the present-day Greenland Ice Sheet at the Last Glacial Maximum. Recent numerical modelling of the CIS during the last glacial cycle (~120 ky) suggests that the central sector of this ice sheet, located in mountainous northern British Columbia, played an important role during both the advance and retreat phases with the ice sheet reaching a maximum extent during both Marine Isotope Stages 4 and 2 (Seguinot et al., 2016). Additionally, glacial isostatic adjustment (GIA) based ice thickness models of the CIS indicate that the rapid climate oscillations at the end of the Pleistocene had a dramatic effect on the CIS. The abrupt warming at the onset of the Bølling-Allerød caused significant thinning of the ice sheet, resulting in a fifty percent reduction in mass, while the subsequent cooling caused the expansion of alpine glaciers across the former central sector of the CIS (Peltier et al., 2015; Lambeck et al., 2017; Menounos et al., 2017). However, the mountainous terrain and remote location have thus far impeded our understanding of this important region of the CIS, and the empherical evidence required to validate these numerical models is lacking.

Here we use the glacial landform record from the central sector of the CIS to reconstruct the ice advance and retreat dynamics in northern British Columbia. We use the well-established approaches of flowset mapping and the glacial inversion method (Kleman & Borgström, 1996; Kleman et al., 2006) to unravel the complex ice flow directions and to understand the ice retreat pattern within this mountainous region. Numerous high elevation meltwater channels suggest the early emergence of mountain peaks above the ice sheet and the configuration of ice marginal landforms, particularly lateral meltwater channels, eskers, kame terraces and ice-contact deltas, allows the westward retreat of the ice margin to be traced towards ice dispersal centres in the Skeena and Coast mountains. Hundreds of arcuate, sharp-crested terminal moraines delineate the extent of alpine glaciers, ice caps and ice fields that regrew on mountain peaks above the CIS and numerical dating indicates that this readvance occurred during the Late Glacial period. Additionally, at some locations, cross-cutting relationships indicate the interaction of the local readvance glaciers with the trunk glaciers of the CIS, allowing the extent of the central sector of the CIS during the Late Glacial period to be reconstructed for the first time.

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Age composition and distribution of winter ice cover in the north-eastern part of the Kara Sea for the period 1997-2020

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Keywords: Age composition, ice cover, Kara Sea, ice thickness.

Age composition is the most important characteristic of the winter ice cover in the Arctic and Arctic seas, including the north-eastern part of the Kara Sea, whose ice limits navigation along the Northern Sea Route in the Taimyr Peninsula and the Severnaya Zemlya Archipelago. The study of the age composition of the ice in the north-eastern part of the Kara Sea is important for the practical analysis of navigation between the western and eastern waters of the Arctic seas of Russia, as well as for monitoring current climate changes.

The main source of information is the electronic maps of AARI for the period 1997-2020, which allow analyzing the main gradations of age composition during the winter period: young, first-year thin, first-year medium, first-year thick and old ice.

During the cold season, there is a consistent (from month to month) and orderly change in the area of ice of a particular age, in accordance with the overall increase in the thickness of the ice cover. In the first half of winter in the north-eastern part of the Kara Sea, young and first-year thin ice with a total thickness of up to 70 cm prevails; in the middle of winter, first-year medium ice with a thickness of 70-120 cm prevails; in the second half of winter, first-year thick ice with a thickness of more than 120 cm.

The series of observations from 1997-2020 consists of two fundamentally different parts: before and after the mid-2000s. Since the mid-2000s, there have been drastic changes in the age structure. The main content of the changes is that in the age composition of all winter months, the area of relatively thick (in thickness) ice decreases and, accordingly, the area of relatively thin (in thickness) ice increases.

On average for the period after the mid-2000s: first, the area of young and first-year thin ice with a total thickness of less than 70 cm increased, and, second, the area of first-year medium, first-year thick and second-year (and long-term) ice with a total thickness of more than 70 cm decreased; there is a characteristic border of ice thickness of 70 cm, on different sides of which there are multidirectional changes in the age composition of the ice cover.

In accordance with the evolution of the age composition, there are long-term changes in the ice thickness weighted average for the space of the north-eastern part of the Kara Sea, which has decreased by about 20-40 cm over the past decade and a half.

Bottom water temperature controlled sea ice variability at glacial abrupt climate changes in the northern Nordic Seas

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Keywords: Mg/Ca, sea ice, benthic foraminifera, Nordic Seas, Heinrich Stadial.

Arctic warming in the same rates as present-day climate change have occurred during abrupt climate oscillations during the last glacial period, when the climate oscillated in a few decades from cold long-lasting stadials to warm and shorter interstadials. Although Arctic sea-ice variability is widely thought to be a key component of the ocean-atmosphere feedbacks during the last glacial climate change, it is still poorly understood what drove changes in sea-ice cover. Sea ice acts as a lid limiting the ocean-atmosphere exchanges, and it is therefore sensitive to changes in both the atmosphere and the ocean. Here, we investigated the millennial-scale relationship between bottom water temperature (BWT) and sea ice variability during Marine Isotopic Stage 3 and 2 in Western Svalbard margin using benthic foraminiferal Mg/Ca and molecular biomarkers (IP_{25}, HBI III and calculated sea-ice indicators). Our record shows generally open ocean conditions during warm interstadials and extensive sea ice cover during cold stadials. Bottom water warmings (up to 5°C) occur during stadials, and particularly during Heinrich Stadials, when an extensive sea-ice layer covered the Nordic Seas preventing the loss of heat of the warm subsurface Atlantic water layer. The new sea ice biomarker distribution in core HH15-1252PC is tightly linked to BWT, with rapid reductions in the spring sea-ice cover occurring synchronously to the decrease in BWT within stadials and surfacing of the subsurface warm water. This synchroneity highlights the role of BWT in controlling the sea-ice cover in the Nordic Seas at sub-millennial timescales.

Benthic foraminifer and ostracod assemblages in the Beaufort Sea continental shelf over the last millennia: Evidence of unprecedented changes in the last two centuries

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Keywords: Benthic foraminifers, ostracods, Beaufort Sea, Last Millennia, Climate Change.

The Inuvialuit ancestors, the Thule People, first occupied the northwestern American coasts about 1,000 years ago (Alunik et al., 2003). Today, the harvest of marine resources in the nearshore areas is still of great importance for local communities in terms of subsistence and cultural practices (Usher, 2002). In this context, we undertook a research project with the complementary aims to (1) reconstruct environmental variations in marine waters from the Beaufort Sea continental shelf over the last millennia and (2) disentangle the effects of the recent anthropogenic forcing. To meet these objectives, we used micropaleontological records, mostly based on benthic foraminifers and ostracods, from sediment core PG2303-2/3 retrieved at 43 meters depth in the Herschel Basin, off northern Yukon.

The Herschel Basin allowed for continuous accumulation of sediment at a mean rate of 0.3 cm/yr (Pfalz, 2007). The benthic foraminifer concentrations range between 15 and 135 foraminifers/g, with raw counts (>100 specimen) allowing for population analyses. *Elphidium clavatum* and *Cassidulina reniforme* dominate the assemblage throughout the record. However, an occurrence peak of *Triloculina trihedra* at ~1300 CE and an increase of *Haynesina nivea*, *Eoeponidella pulchella*, *Stainforthia feylingi* and *Textularia earlandi* during the last two centuries mark the record. Ostracods record concentrations ranging between 0 and 9 ostracods/g. The ostracod assemblages are dominated by the euhaline taxa *Cytheropteron* spp. and *Cytheropteron suzdalskyi*. *Paracyprideis* spp., which can tolerate a wide range of salinities, is also abundant, particularly in the ~1800-1900 CE interval.

From these results, we suggest that the last two centuries were marked by important changes in the benthic fauna biodiversity on the Beaufort Sea shelf, with no equivalent since the occupation of the land by the Inuvialuit and their ancestors. Ultimately, this recent change indicates important variations in water mass properties, possibly linked to increase melting of land ice and sea ice in response to Human activities.

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Insights into Arctic shelf carbon cycling from Barents Sea sediments: Is the "rusty carbon sink" really a carbon sink?

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Keywords: Barents Sea, Holocene, carbon, iron, diagenesis.

Ongoing global climate change requires detailed knowledge of the carbon cycle and its feedback mechanisms. The Arctic region currently experiences significant warming, a dramatic loss of sea ice, and an increase of primary productivity. Thus, the transformation from a seasonally ice-covered to an open ocean forces Arctic marine ecosystems to adapt. This has important repercussions on the Arctic carbon cycle, including atmospheric CO_2 uptake by photosynthetic algae, the deposition of their organic remains at the seafloor, and long-term sequestration of organic carbon into sediments, particularly on Arctic shelves.

Understanding the mechanisms responsible for enhancing the stability and long-term storage of organic matter in marine sediments is important for predicting how the global carbon cycle will respond to ongoing climate change, but critical aspects of this carbon sink remain unresolved. One such aspect is the "rusty carbon sink", by which organic matter gets associated with reactive iron phases (on average 10-20% of total organic carbon in surface sediments; Lalonde et al., 2012), and thus stabilised and physically protected against microbial degradation. The long-term efficiency of this "rusty carbon sink", however, is unknown and depends on the persistence of the carbon-iron association below the uppermost, oxygenated layer of marine sediments where microbially driven diagenesis is most intense.

To address the diagenetic stability of the "rusty carbon sink", we investigated the chemical composition of sediments and pore waters at four locations in the Barents Sea down to ~30 cm sediment depth (up to ~7,000 years old). Our results clearly underline the importance of the role of reactive iron phases for organic carbon burial (Faust et al., 2021). In particular, we find that despite clear evidence of early diagenesis in these Arctic marine sediments, ~15-20% of the total organic carbon remains associated with iron below the top ~30 cm of sediment. This proves, for the first time, that the "rusty carbon sink" is not disabled by microbial degradation processes and that significant amounts of the sedimentary organic carbon are shielded against transformation back to CO_2 on at least millennial timescales. The spatial and downcore distribution of the iron-carbon coupling, however, seems to be unrelated to sea ice cover, Atlantic water inflow, or proximity to land. Based on our data, future Arctic warming might therefore neither enhance nor decrease average carbon burial through the association with iron minerals. But open questions remain about the timing, location and nature of the iron-carbon coupling. The Fe(II)/(III) redox boundary (at ~5-10 cm sediment depth), where fresh reactive iron phases precipitate, is not where the iron-carbon coupling is established, as iron-bound carbon contents are already high at the seafloor. It is therefore possible that the chemical association is created on land and transferred to the Barents Sea via sea ice.

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Postglacial environmental history on LGM Ice Marginal Zone in northwestern Russia as reflected by lake sediment records

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Keywords: Valdai Highlands, paleoclimate, paleolimnology Late Glacial, Holocene.

The new obtained results of lacustrine sediments multi-proxy studies from two lakes provides a crucial information concerning Late Glacial and Holocene environmental changes in northwestern Russia. Lakes Zvan and Piros located in the eastern part of the Valdai Highlands, which is the marginal zone of the last Scandinavian ice sheet. Ground-penetrating radar profiling was carried out on both lakes and several sediment cores up to 5 m long were retrieved. The cores were subject to visual analysis of lithological facies, the analysis of the organic carbon and nitrogen content, pollen and diatom analyzes. Chronostratigraphic control based on detailed pollen record and number of radiocarbon dates. Several important events in landscape dynamic are detected since the time when ice sheet retreated from the area (≥16 cal. ka BP). Prior to ~ 14 cal. ka BP: vast dead ice masses and ice-dammed deep, cold water bodies covered most of the land area. ~ 14 cal. ka BP: increase of temperature and humidity resulted in abrupt environmental changes such as dead ice degradation, deep water basins drainage, and significant change in vegetation cover with first appearance of spruce in the landscape. ~ 10 cal. ka BP: establishing of the modern-like landscapes characterized by modern lake systems and marked by onset of organic type of sedimentation. ~ 2 cal. ka BP: the onset of modern tendency of increasing lake trophic state, water-level lowering, increasing of paludification in the area. In the same time the onset of agricultural land use is detected, which partly can be a reason for environmental changes.

Comparison of our data with well dated pollen record from Ladoga Lake reveal the fact that environment of the northwestern Russia region achieved the full interglacial conditions only by the Middle Holocene as no differences in time of environmental response on global forcing in-between southern and northern parts of the region observed since that time.

The last ice shelf of the NW Laurentide Ice Sheet

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Keywords: Ice shelf, Northwest Passage, Laurentide, Holocene, Deglaciation.

Sediment core records, recovered by the CCGS Amundsen as part of a 2016 ArcticNet cruise in M'Clintock Channel in the central Canadian Arctic Archipelago (CAA), provide a unique sedimentary history of large-scale Early Holocene ice shelf occupation and collapse. Well-constrained by foraminiferal radiocarbon dates and taken together with detailed flow-set mapping and chronologies on adjacent Victoria and Prince of Wales islands, the record illustrates a late stage floating ice advance of over 375 km (equating to an ice shelf area >55,000 km^2) from the M'Clintock Ice Stream draining the southward retreating margin of the deglaciating northwestern sector of the Laurentide Ice Sheet (NW LIS). Ice shelf advance occurred after 10.5 cal BP followed by sequential retreat from its north maximum, some one hundred cal. years later. By 9.6 cal ka BP the ice shelf had completely collapsed and ice retreated rapidly back on to mainland Canada.

Ice rafted debris and foraminiferal assemblages from calving margin and post-ice shelf glacimarine facies in the core record confirm that the formation and subsequent demise of the M'Clintock Ice Shelf resulted in the irreparable draw-down and destabilisation of the NW LIS and permitted the commencement of marine throughflow from Amundsen Gulf and the Arctic Ocean into the central CAA and the final establishment of similar-to-modern oceanic circulation by 8.8 cal ka BP. Those same foraminiferal assemblages further implicate warm Arctic Ocean Intermediate Water of re-circulated Atlantic origin, penetrating southwards from Viscount Melville Sound, as the primary driver of ice shelf retreat and collapse.

This record adds to the growing inventory of extensive and often catastrophic deglacial ice shelves identified from the Late Pleistocene and Early Holocene of the CAA and suggests that not only were short-lived large-scale ice shelves common during deglaciation, but that they may have been ubiquitous in this complex archipelago setting. This geological record of widespread ice retreat and ice shelf instability at the end of the Last Glaciation serves as a source of vital analogues for ongoing and future human-induced high latitude climate change and can provide important constraints on modelled forecasts of Antarctic ice shelf behaviour under rising sea levels and warming ocean conditions.

Paleontological and sedimentological evidences in the Holocenic sedimentary record of the Bellsund Drift (Svalbard – Arctic)

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Keywords: Foraminifera, Grain size, Contouritic deposits, Bellsund Drift, Holocene.

The Arctic region represents a sensitive area to climatic variations. The Bellsund Drift is located in the Fram Strait area, between Greenland and Svalbard, and represents the only deep connection to the Arctic Ocean. In this strait occurs the interaction of two water masses, the warm Atlantic Water (AW) and the cold Arctic water (ArW). This interaction produces an important heat and mass exchange with the Arctic Ocean, influencing the climate in the entire Arctic region.

During the EUROFLEETS-2 Cruise PREPARED on board the R/V G.O. Sars, June 2014, a Calypso piston core GS191-01PC (1647 m water depth), was collected in the Bellsund Drift area. The core contains a high-resolution depositional sedimentary record of the last 20 kyr (Lucchi et al., 2014). For this work, we focused on the expanded Holocene sequence (more than 5 m-thick), defined using the age model constructed by Caricchi et al. (2019). Our study is based on the benthic and planktic foraminifera and grain size analysis.

The millennial record of the Bellsund Drift indicates a progressive increase of the water temperature, due to the incoming of the warm Atlantic water and the decreasing extension of sea-ice, which retreat by melting, producing cold superficial water masses facilitating the incoming of the AW into the entire water column. The IRD input during the end of the Upper Pleistocene indicates diffuse sea-ice and cold conditions. Higher productivity and warmer conditions characterised the Early Holocene. A shift from warm to colder conditions occurred during the Mid Holocene, affecting the ocean productivity. The Late Holocene showed the prevalence of surface cold-water conditions related to the sea ice melting, determined by increased AW heat inflow to the Arctic.

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Changes in Foraminifera Bound Nitrogen Isotopes: Implications for Quaternary Interglacial variations and Climate change

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Keywords: Arctic Ocean, Foraminifera, Nitrogen isotopes.

The Arctic Ocean plays fundamental role in the global climate system. Arctic snow and ice cover play an important function by reflecting solar radiation back to the space. Also, the melting and formation of sea ice can impact the surface sea water density which influence production of Arctic Intermediate and Bottom water masses, critical for sustaining a strong Atlantic Deep water circulation which forms a part of the Atlantic Meridional Ocean Circulation (AMOC). Our understanding of past environ mental and climatic changes in the Arctic, and how these changes are related to other components of the climate system, are still restricted due to lower abundance of calcareous micro and nano fossils and low sedimentation rates. In addition, the conventional isotope $\delta^{18}O$ is biased by fresh water influx which makes paleo-reconstructions difficult. Arctic Ocean forms a crucial part of the global conveyer belt. Despite of such great importance of the Arctic climate system, we have very little information about earlier millennial climate changes in this region. In this study we are using a, $\delta^{15}N$ as a proxy which gives us information about variations in surface water structure. Foraminiferal-bound $\delta^{15}N$ preserved in the calcite tests have been shown to represent ambient sea-water nitrate values at the time of calcification. Because the $\delta^{15}N$ values of the sea water are controlled by the degree of nutrient utilization in the surface waters, the $\delta^{15}N$ values measured in the foraminifers allows us to reconstruct variations in the surface water structure. Preliminary investigation suggests that foraminifer-bound $\delta^{15}N$ is a good tracer for variations in surface water structure in the Arctic Ocean during times of large changes due to melting ice sheets and changes in the amount of fresh water influx from the rivers.

New testate amoebae calibration data set from permafrost peatlands NW Siberia (Russia)

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Keywords: Testate amoebae, climate, biotic proxy, transfer function.

Testate amoebae are unicellular protists, which live in a wide range of ecosystems such as soils, lakes, wetlands, or estuaries (eg.: Mitchell et al., 2007). Sensitivity to environmental variables, preservation of shells in sediments, a high diversity of morphology and the broad range of sizes make them useful as a biotic proxy in palaeoecological studies (CIT) (Charman, 2001). Many studies have demonstrated their potential in reconstructions of past hydrological dynamics in peatlands and their response to climate change or human impact (eg.: Lamentowicz et al., 2015; Łuców et al., 2020; Słowiński et al., 2016). This resulted in often use of testate amoebae-based transfer functions in reconstructions of hydroclimatic conditions in the Holocene peat archives (eg.: Charman, 2001). Although some taxa are treated as cosmopolitan, local testate amoebae assemblages may differ (Mitchell et al., 2007). If we want to better understand how fragile ecosystems like boreal and permafrost peatlands in W Siberia respond to climate change, we need to create a local testate amoeba transfer function. We studied the testate amoebae living in the peatland's habitats in the critical region where permafrost degradation is now occurring. Therefore, we have modelled the relationship between modern testate amoebae communities and water-table depth (DWT) as well as microhabitat to create a calibration data set to apply in the quantitative reconstructions of the hydrological dynamics. The calibration data set is based on 76 surface samples collected in 2019 in the Khanymey region (NW Siberia, Russia). During the sampling, the depth to the water table was measured, so that the samples represented the wide range of the moisture gradient from +38 cm (dry) to -20 cm (inundated surface). In each sample, 150 shells were counted. In this study, we identified testate amoebae taxa characteristic not only for *Sphagnum* but also for *Cladonia rangiferina*, which has never been done before. We think that the new testate amoebae calibration data set can be used in the future by scientists researching this part of Siberia and it will enrich just constructed the Asian data set (CIT).

The study was supported by the National Science Center grant no. 2019/35/O/ST10/0290

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Ribbed moraine in Iceland

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Keywords: Quaternary geology, Icelandic Ice Sheet, Ribbed moraine, Geomorphology, Sedimentology.

Ribbed moraine is a landform area consisting of transverse, subglacial ridges that typically occur within the onset or trunk-flow zones of ice streams. Investigating the distribution, morphology and internal architecture of ribbed moraine ridges can thus shed light on ice sheet dynamics and subglacial processes operating underneath ice streams. We describe the ribbed moraine in Iceland for the first time based on geomorphological and sedimentological data from the Vopnafjörður region in NE-Iceland. The ridges have a dominant transverse orientation to the estimated ice flow direction towards the northeast. Their shape, average length, width and height is 112 m, 66 m, 6.4 m, respectively, and their average spacing is 125-160 m (Helgadóttir, 2020). The ridges occur predominantly upstream from fields of streamlined subglacial bedforms but are in some places superimposed on them, indicating ribbed moraine formation subsequent to the streamlined bedforms. The sedimentology and architecture of the ridges is characterized by little or undeformed glaciofluvial gravel capped by subglacial traction till. A preliminary conceptual model suggests that the ribbed moraine ridges formed as a result of extensional ice flow in a transition zone between the ice divide and ice streaming (Helgadóttir, 2020). Relatively low subglacial porewater pressure underneath transverse crevasses facilitated the influx of subglacial material into these areas resulting in the formation of transverse ridges. Passive retreat upon ice stream shut down was then key to the preservation of the ridges. Further studies of ribbed moraine in Iceland could elucidate whether it is a final imprint of a stagnating ice sheet or represents a thermal transition between cold-based ice divides and warm- based ice streams during the deglaciation after the Last Glacial Maximum.

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Mean summer insolation and sea level as natural drivers of the Arctic climate and sea-ice cover

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keywords: Arctic Ocean, summer season insolation, sea-level, heat fluxes.

The status of this ocean throughout the late Quaternary climatic cycles needs to be re-assessed. If several deep-sea records about its paleoceanography and paleoclimate have been published during the last 20 years, their chronostratigraphic frame, set from a Mn-oxide based cyclostratigraphy, must now be revised, at least beyond the radiocarbon time frame. A set of recent studies, based in particular on the radioactive decay in sediments of ^{230}Th- and ^{231}Pa-excesses and their extinction ages converge towards the need to re-anchor all marine records to the position of the Brunhes/Matuyama transition, as it was initially set by Clark and others in 1980. In most cases, this results in significantly lower sedimentation rate estimates, leading to re-assign "warm" intervals to older interglacials than those initially proposed (e.g., sediments initially assigned to MIS 11 are likely from MIS 15). This climatostratigraphic revision demonstrates that the Arctic Ocean "interglacials" were of distinct amplitude and timing *vs* those of lower latitudes, with in particular well-recorded MIS 7 and 15 intervals. Warmings were primarily governed by the mean Summer season insolation at 65°N, and not the June solstice peak. Sea level acted as a second important driver, as it governed i) the submergence of the Arctic Ocean shelves, ii) the development of "sea-ice factories, iii) the flux of low-salinity Pacific waters through the shallow Bering Strait, in fine, iv) the freshwater budget of the Arctic Ocean Through feedbacks, such as its freshwater export that impacts the Atlantic Meridional Overturning Circulation the Arctic Ocean may have triggered out-of-phase climate/ocean instabilities in the Northern Hemisphere, as it is likely to do it under its present freshening and reduction in sea-ice cover.

Holocene variability of the northeastern Laurentide Ice Sheet in the Clyde Inlet area, western Baffin Bay, from radiogenic isotope records in marine sediments

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Keywords: Radiogenic isotopes, Mineral assemblages, Holocene, Baffin Island, Ice-sheet retreat.

The reconstruction of Holocene ice sheet fluctuations helps understanding the response of ice sheets to a changing climate. This knowledge is crucial for modelling future ice sheet fluctuations as well as global eustatic changes. While large-scale spatial and temporal variations of the Fox Basin-Baffin Island ice dome (NE Laurentide Ice Sheet, Canada) have been well documented, information on high frequency Holocene fluctuations and the final decay are still limited. To reconstruct Holocene ice sheet margin fluctuation of one of the eastern outlet glaciers, we study two marine sediment cores from the Clyde Inlet fjord (GeoB22346-3, Clyde Inlet head; GeoB22357-3, adjacent continental shelf), northeastern Baffin Island. The reconstruction is based on the radiogenic isotope composition (Sr-Pb-Nd) and mineral assemblage of the detrital sediments from the cores, recording bedrock erosion along the active ice margin, as well as along ice-streams and subglacial drainage patterns (e.g. eskers and their deltas). They may thus be used to reconstruct spatial and temporal variations in meltwater discharge into Baffin Bay and the position of the active margin fluctuations in the interior of the country. Changes in mineralogical and radiogenic isotope compositions at the proximal core site suggest ice margin and drainage fluctuations rather than a constant retreat throughout the Holocene. In detail, the data indicate that the retreat of the Laurentide Ice Sheet during the early Holocene was interrupted by multiple ice sheet advances followed by a period of minimum extent of the ice sheet and alpine glaciers during the mid Holocene. From ~3.5 ka onwards, changing radiogenic isotope compositions and mineralogical assemblages suggest an advance of alpine glaciers in the Clyde inlet region during neoglaciation. Shelf sediment provenances are dominated by relatively homogenized Baffin Island inputs from the mid to early Holocene, but record a slightly offshore ice margin position during the late Pleistocene.

Formation of Crevasse Squeeze Ridges – a case study from Trygghamna, Svalbard

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Keywords: Crevasse squeeze ridges, surging glaciers, Trygghamna, Svalbard.

Crevasse squeeze ridges (CSR´s) are landforms that have been described exclusively from the forefields of surge-type glaciers and ice-stream conduits. The processes controlling CSR formation have been discussed since the landform was first defined in the mid-1980s. This work describes ridges that are arranged in a rectilinear network and predominantly orientated transverse or oblique to former ice-flow direction in glacier forefields in Trygghamna, western Svalbard. In order to understand the geomorphic context of these landforms, detailed marine and terrestrial maps were produced via remote sensing and field mapping. Additionally, stratigraphic investigation into several CSR´s in cross-sections highlight ridge architecture, sedimentology, structures in relationship to surrounding landforms and sediments. Findings suggest that CSR´s form from basal till being squeezed into basal crevasses during surges and subsequently are transported englacially before deposition after the surge culmination. A conceptual model for the formation and preservation of CSR´s is proposed. The results do not only further contemporary understanding of CSR´s in surge-type glacier settings but may also apply to large-scale surging lobes or ice stream shut-down settings.

Terrigenous biomarkers in a marine sedimentary record from the Kongsfjorden (Svalbard) and inferred environmental changes during the post-Little Ice Age.

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Keywords: Terrigenous biomarkers, paleoenvironmental changes, source-to-sink, Kongsfjorden, Svalbard.

Fjords are unique marine ecosystems particularly sensitive to anthropogenic pressure and represent a key area where to investigate how climate warming can perturb the ocean-land-glacier continuum (Bianchi et al., 2020). Under suitable conditions, high sediment accumulation rates in fjords allow the high-resolution paleoclimate study of both marine and terrestrial-derived components, to reveal past and present environmental changes. Here we explored the response of the Kongsfjorden (N-W Svalbard) and surrounding terrestrial environment to the post-Little Ice Age (LIA) climate change by using a suite of bulk geochemical proxies and terrigenous biomarkers (*n*-alkanes, fatty acids, glycerol dialkyl glycerol tetraether, lignin phenols, and cutin acids) from a high-resolution marine sediment core archive. C:N and $\delta^{13}C$ data suggested a predominant input of marine organic carbon into the fjord, which was also confirmed by low values of the branched and isoprenoid tetraether index. In contrast, the depleted bulk radiocarbon content indicated a significant contribution of fossil and/or petrogenic organic matter to the marine sediments. Low carbon preference index (CPI) and average chain length (ACL) of lipids also suggested substantial input of ancient organic matter, but without a specific temporal trend during the LIA. The post-LIA phase, instead, showed distinct mobilization of *n*-alkanes marked by low CPI and ACL value, which confirms a significant contribution of mature organic carbon to the modern Kongsfjorden sediments (Kim et al., 2011). Overall low lignin phenols abundance suggested lack of substantial input of vascular plant-derived material into sedimentary organic carbon. Conversely, we found a pronounced cutin acids increase during the early common era, probably deriving from mosses and liverworts. The source of this significant mobilization is under investigation, however could be related to the rapid glacier retreat documented for the Kongsfjorden in the same period (Bourriquen et al., 2018), which determined a pronounced melt-water runoff and an increased availability of ice-free areas for the colonization of pioneer plants.

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Stratigraphic revelations of the onset of Arctic/Atlantic throughflow in the Arctic Island Channels

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Keywords: Northern Baffin Bay, Holocene, Foraminifera.

The Arctic Island Channels (AIC) are conduits for low-salinity, nutrient-rich Arctic surface water (ASW) and sea ice into the North Atlantic with consequences for the Atlantic Meridional Overturning Circulation (AMOC). The channels were blocked to Arctic/Atlantic throughflow by confluent ice sheets until the early Holocene. However, the timing of opening of the channels is poorly constrained as is the ensuing development of the North Water polynya that occupies northern Baffin Bay today, with productivity fueled by nutrient rich ASW. Sediment cores from key sites near the mouths of these channels capture sediment sequences that reflect environments of icesheet retreat through to the development of modern conditions in northern Baffin Bay. Foraminiferal assemblage data from these cores provide insight into the environmental conditions during deglaciation and establishment of the Arctic/Atlantic throughflow and also provide ^{14}C dates to constrain the timing of events. A pair of ^{14}C dates on benthic and planktic foraminifers from the same sample suggests that the local reservoir correction, $\Delta R = 600$ years, can be applied to early Holocene dates on benthic organisms in the deep shelf trough sites of our cores (>580 m) in this area. In Lancaster Sound cores, glaciomarine conditions as defined by pebbly mud lithofacies overlying till begin by 11.1 cal ka BP and end at about 10.5 cal ka BP based on lack of >2 mm clasts interpreted as ice rafted detritus (IRD). The overlying mud unit with pyritized burrows and highly abundant calcareous benthic and planktic foraminifers as well as an increase in biogenic silica suggests that Lancaster Sound may have been open to the Arctic Ocean by 10.5 cal ka BP, ~2000 years prior to opening of Nares Strait. Benthic foraminiferal assemblages transition from dominance of *Stainforthia feylingi* and glaciomarine species reflecting glacial meltwater to dominance of *Islandiella norcrossi* and marine productivity species during the high foraminiferal abundance interval, reflecting a transition to greater Atlantic Water and reduced meltwater dominated conditions in the early postglacial period between 10.5 and ~8.5 cal ka BP. An agglutinated faunal zone with >80% agglutinated foraminifers and greatly decreased foraminiferal abundance coincides with a change to increased bioturbation, increased biogenic silica and lower sedimentation rates. This zone begins soon after 8.7 cal ka BP based on ^{14}C dates on seaweed macrofossils in 3 cores and is similar in timing to the opening of Nares Strait to ASW through flow.

Spatio-temporal Ba/Ca variations of planktic foraminifera (*Neogloboquadrina pachyderma*) in the Arctic Ocean

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Keywords: Planktic foraminifera, Ba/Ca ratios, Ba cycle, river input, biological removal.

Freshwater runoff in the Arctic Ocean has a profound role in the ocean circulation. To understand the long-term variability of freshwater runoff and its influence on ocean, geological records are the primary tools, and Ba/Ca ratios in planktic foraminifera is a relatively new proxy. As the source of seawater Ba is mainly from river input, the Ba/Ca ratios has proved to be a reliable river runoff indicator in tropical and temperate regions. However, few studies have applied Ba/Ca ratios in the Arctic Ocean, and modern observations suggest that besides river input, biological activities may also be involved in the seawater Ba cycle (e.g. Roeske et al., 2012). Hence, the aim of this study is to understand the main controlling factors of foraminiferal Ba/Ca ratios, and whether this proxy can be used as a river indicator in the Arctic Ocean. Six cores and 11 surface sediment sites were selected in this study. The planktic foraminifera, *Neogloboquadrina pachyderma* (sinistral) was analyzed for element/Ca ratios on an Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at the National Taiwan University. The results across the Eurasian Basin show that the foraminiferal Ba/Ca ratios increase at sites closer to the Laptev and Kara Seas, which are close to Eurasian rivers. This spatial pattern resembles modern observational Ba concentration, suggesting the Ba/Ca ratios in *N. pachyderma* are able to reflect the spatial variations of seawater Ba in the Arctic Ocean. The temporal variability of foraminiferal Ba/Ca ratios in the central Arctic Ocean shows higher values in Marine Isotopes Stage (MIS) 1 compared to MIS 2 & 3. This decrease in Ba/Ca ratios from interglacial to glacial period is an opposite trend to river input records as river input is larger during interglacial periods. This opposing trend could be caused by biological removal. Strong productivity during interglacial periods decreases Ba/Ca ratios through increasing the intensity of biological removal, while low productivity during glacial periods increases Ba/Ca ratios due to weaker Ba removal. Although the detailed pathway of Ba in the seawater is still unclear, our results from foraminiferal Ba/Ca ratios suggest that the Ba cycle in the Arctic Ocean is not only affected by river input, but productivity should also be considered.

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Comparison of landform and sediment production during different glaciation phases: A case study of polythermal glaciers on Svalbard

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Keywords: Glacier, glacial geomorphology, glacial landsystem, Arctic, Spitsbergen.

The widespread recession of glaciers in Svalbard observed since the Little Ice Age (LIA) termination provides an excellent opportunity to study differences in the production of landforms and sediments in different phases of glaciation. This study aims to characterise landform assemblages associated with the maximal extent of glaciers, the early stage of retreat, and the current advanced retreat stage. The study area is located in Petunibukta, Svalbard. These are High-Arctic settings, characterised by low precipitation and occurrence of continuous permafrost. Around Petuniabukta, an area of 26 km^2 has been exposed from under the ice due to glacier retreat since the termination of LIA (Ewertowski & Tomczyk, 2015, 2020).

We propose the following pattern of changes in sediment transfer pathway and landform creation stages. During the glacier advance phase, most of the debris entrained into the glacial systems in the Petuniabukta area originated from steep valley sides and bedrock incorporation. At this stage, most of the glaciers formed large laterofrontal ice-cored moraine complexes. In the early recession stage, the supply of rock debris from the slopes diminished but was still important for some glaciers. In an advance recession stage, the delivery of debris from valley sides stopped almost entirely, as large lateral moraines prevented debris from the valley side to enter the glacier transport system. It is also probable that subglacial debris incorporation is less efficient than during the advance phase due to changing glaciers' thermal regime. While most glaciers are still polythermal (Rachlewicz et al., 2007), large portions of ice masses are now probably frozen to bed (Małecki et al., 2017). Corresponding landforms, therefore, are mostly fluted till plains with little ablation deposits. Our observations indicate that some of the elements of modern glacial landsystems on Svalbard can be used as analogues for interpreting the Pleistocene glacial record in European lowlands.

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Time scales of glacial landform creation and depositional efficiency, southern sector of Scandinavian Ice Sheet, Poland

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Keywords: Glacial geomorphology, ice sheet, Vistulian, landform, time scale.

Ice sheets are one of the most effective transportation agents which move sediments from one place to another. This study deals with the concept of ice sheets' depositional efficiency (Boulton et al., 1985). We developed a landform classification that reflects the time, dynamic and thermal regime needed to create them. This model was tested based on data from the central-western part of Poland (Wielkopolska region) – an area covered by the Scandinavian Ice Sheet during the Last Glacial Maximum.

According to the simple analogy presented by Boulton et al. (1985), the glacial transporting system can be regarded as a moving conveyor belt to which material is added by erosion and lost by deposition at many points along its length, but with a net discharge at the terminus where the majority of the material is dumped at the end of the conveyor belt. However, types of sediment-landforms associations, which are created in the marginal zone of ice sheets (end of "conveyor belt"), are not only the function of standstills duration but also are related to other factors, e.g.: (1) amount and position of debris within ice masses; (2) amount of meltwater; (3) linkage between glacifluvial and glacial transport system. These three factors depend on the wide variety of other elements such as thermal regime of submarginal zone and type of movement related to it, climate conditions in the marginal zone (including lack or occurrence of permafrost), and how debris is transported throughout the glacial system and subsequently released and redeposited.

The average debris load of an ice sheet is small. Therefore, to produce significant landforms, it is necessary to elevate basal debris-rich ice in the terminal zone of an ice sheet, e.g., by active ice flow towards a long-term stationary terminus, thereby importing sufficient debris to construct thick tills as the enclosing ice melts. Hence, prominent frontal moraines indicate relatively long-term ice sheet standstill positions and a steady-state mass balance. A fast glacier retreat will produce a thin accumulation of sediments. Whereas stationary or slowly retreating glacier front can produce thick accumulations by tectonic stacking of marginal ice (and debris included in it) or by dumping debris – hence, such phases reflect steady states or near steady states when the volume of the ice arriving at the margin equals the amount of ice melted every year. Such standstills indicate a balanced ice mass budget and an ice sheet close to dynamic equilibrium. These general relations hold whether the moraines are push moraines, dump moraines, or 'moraines' composed of ice-contact fluvioglacial sediments.

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Lake water isotope gradients in arctic and subarctic Fennoscandia: implications for precipitation isotope proxy reconstructions

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Keywords: Lake water isotopes, precipitation isotopes, seasonality, hydroclimate, proxy interpretation.

Amplified warming in the northern high latitudes has a profound impact on the hydrological cycle. Precipitation is predicted to increase this century, but projected trends remain uncertain and rely on sparse observations to describe complex spatiotemporal patterns. Stable isotopes of oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) in precipitation are sensitive to changes in atmospheric temperature, moisture, and circulation, and can be used to infer changes in the hydrological cycle. Quantifying precipitation seasonality during past warm periods elucidates the mechanisms causing precipitation change and puts recent changes into a long-term context. To investigate changes in the past, we can use $\delta^{18}O$ and $\delta^{2}H$ in organic materials preserved in lake sediments. Yet, despite similar precipitation input to lakes within a region, differences in lake and catchment morphometry and lake water residence time may cause the lakes to exhibit a wide range of precipitation seasonality and evaporation. Hence, it is critical to understand the dynamics controlling lake water isotopic composition to make accurate paleoclimate inferences.

We analysed $\delta^{18}O$ and $\delta^{2}H$ of 136 lakes in arctic and subarctic Fennoscandia. We collected most samples during the first week of July, in 2018, 2019 and 2020, grouping them into 'coastal' and 'transect' lakes. The coastal lakes span from the outermost North Norwegian coast to the inner fjords, whereas the transect lakes are located along a 460-km-long NW-SE transect extending to Bothnian Bay. The coastal lakes fall close to the global meteoric water line (GMWL) but have variable isotopic composition. This could be explained by heterogeneous atmospheric conditions attributed to local topography and proximity to the ocean. In contrast, the transect lakes are relatively ^{2}H-depleted, likely due to greater distillation as moisture moves inland, and have lower deuterium excess values due to greater evaporative enrichment. Transect samples collected in 2019 and 2020 fall along slightly different local evaporation lines (LELs). The 2020 LEL intersects the GMWL at a more depleted value than in 2019, suggesting more ^{2}H-depleted source water in 2020 compared to 2019. This could be due to a wetter winter season 2019-2020, causing greater runoff of depleted winter moisture the following spring, which is supported by Bayesian inflow modeling indicating more winter-biased inflow values in 2020 relative to 2019. Closer to Bothnian Bay, the lakes have similar modeled inflow values but exhibit larger inter-lake water $\delta^{2}H$ variability, indicating that other factors influence the lake water isotopic composition. These factors may include more complex connectivity between lakes and groundwater in wetland areas and competing impact of moisture from the North Atlantic and Bothnian Bay. We propose that coastal lakes in this region are more useful for precipitation isotope proxy reconstructions, whereas inland lake water isotopes more likely reflect changes in evaporation.

Preliminary results of pollen study from East-Siberian sea sediments

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Keywords: Pollen analysis, marine sediments, East Siberian Sea.

The cores of sediments and bottom samples fat 81 stations were collected during field campaign of VNIIOkeangeologiya within the framework of the "Program for State Geological Mapping of the Territory and Continental Shelf of the Russian Federation" in September – October of 2020 (Gusev et al., 2020). The surface sample for pollen analysis was carried out on each station. The cores with total thickness more than 50 cm were obtained with variable interval (4-10 cm). This report is presented detail pollen records from core located in paleovalley of Indigirka River.

The core MS-2036 (75°24'02,14" N, 167°07'02,20" E) with total thickness about 1.2 m was carried out from 65 m depth. The 28 samples were analyzed. The 20 pollen, spores and non-pollen palynomorph taxa were identified. The *Lycopodium* tablets were used to permit estimation of pollen concentrations (Stockmarr, 1971). Three pollen zones were distinguished according to changes in pollen spectra. The first zone (PZ-1) from 1.2 m to 0.5 m characterized by domination pollen of *Betula* (25%), *Alnaster* (7-15%), *Salix* (5-15%) in shrub taxa and Cyperaceae (20-25%), Poaceae (17%) in herbs. Pollen of *Artemisia* and Ericaceae are also present. The pollen concentration varies between 1000 and 2500 pollen grains g^{-1}. The second zone (PZ-2) from 0.5 m to 0.12 m shows domination of herbs pollen taxa (65-70%). Cyperaceae and Poaceae is prevailed in this group. Pollen concentration decrease to 600-1000 grains g^{-1}. The third zone (PZ-3) from 0.12 m to surface shows low concentrations of microfossils (250 pollen grains g^{-1}). The single grains of pollen and spores were identified. The PZ-1 – PZ-2 boarder have a good correlation with disappearance of mollusk shells. The *Portlandia arctica* (Gray), *Hiatella arctica* (Linnaeus) and few another types were identified from 0.9 m to 0.46 m. The pollen records from excavated sediments may reflect vegetation signal from arctic and typical tundra conditions. The pollen spectra from PZ-1 matches well with Holocene pollen spectra from Bolshoy Lyahovsky island (Andreev et al., 2011).

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The Lateglacial and Holocene vegetation history of the central Kola Peninsula Region (NW Russia) inferred from the Lake Kamenistoe pollen record

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Keywords: Pollen analysis, bottom sediments, radiocarbon dating.

The reconstruction of environmental history and studies of modern landscapes of the Arctic regions may be helpful in predicting the local to global-scale natural variability of climate and vegetation in the future. Lake Kamenistoe in the central Kola Peninsula, which was covered by the ice sheet during the Late Pleistocene glaciation, was chosen for the reconstruction of the Lateglacial and Holocene environments of the region. The core of bottom lake sediments was collected by the research team from the Kola Science Center and St. Petersburg State University in July of 2018. In this presentation we discuss obtained pollen records supported by conventional ^{14}C age determinations.

The total thickness of the Lake Kamenistoe core sediment is about 1.35 m. The 30 sediment samples (taken every 4-5 cm) were analyzed and the 34 pollen, spore and non-pollen palynomorph taxa were identified. The *Lycopodium* spore tablets were used to estimate pollen concentrations. Based on the obtained results, the core was divided into Late Pleistocene and Holocene parts. The boundary between these stratigraphic units lies at a depth of 1.1 m. The Late Pleistocene pollen spectra show low pollen concentrations. *Betula*, *Salix*, *Artemisia*, Chenopodiaceae and Cyperaceae pollen predominate and point to tundra-steppe associations. For the Early Holocene, birch forest-tundra can be reconstructed, which was replaced by birch forests about 10,000 cal. y. BP. The most favorable (warmest) conditions occurred between 7800 and 6000 cal. y. BP. The pine and birch forests associated with this interval. The spruce appeared in the study area in the Middle Holocene, but the significant increase in spruce pollen correlates with the Middle to Late Holocene transition. Pine and spruce forests dominate in the modern vegetation cover. The correlation of our results with previous data (Kreminetski et. al., 2004, Snyder et. al., 2000 and etc.) shows significant variations in the pollen percentages of tree and shrub taxa and probably reflect the mosaic vegetation cover throughout the entire of Early Holocene.

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Initial Analysis of Sediment Cores from Lake Melville, Canada, Suggesting a Potential Late Glacial-to-Holocene Sediment Sequence

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Keywords: Laurentide Ice Sheet, Last Glacial, subglacial lake, Lake Melville, Labrador.

Lake Melville is a fjord-type lake situated at the mouth of the Hamilton Inlet System in Labrador, Eastern Canada. At its western end, riverine freshwater influx is prominent whereas the eastern part receives a significant amount of saline water due to a shallow connection to the Labrador Sea by the Rigolet Narrows.

Lakes, fjords, and inlets on the Canadian shield have long been considered as having been fully excavated during the last glacial. Accordingly, the sediment infill of Lake Melville until now was interpreted as a typical glacial sequence (Syvitski & Lee, 1997). The final retreat of the Laurentide Ice Sheet (LIS) at the end of the last glaciation started approximately 10,000 years ago at the eastern end of the lake, and it was completely ice-free by 8,000 years BP (King, 1985; Syvitski & Lee, 1997). Only during the past few years, sites have been discovered in Canada that contain sediments dating back from before the last deglaciation (e.g., Christoffersen et al., 2008). With its thick sediment package (up to 400 m), Lake Melville is another candidate for a sediment record that reaches back in time before the last deglaciation because it potentially persisted as a subglacial lake underneath the LIS.

During expedition MSM84 in 2019, new hydroacoustic data and several sediment cores were collected. Initial sediment-physical measurements and lithological investigations were conducted on a nearly 14 m long sediment core (MSM84_18-1). The results indicate a significant change in lithology and selected sediment-physical parameters within the lowermost two meters of the sediment sequence. First ^{14}C-dates of gastropod and bivalve remains resulted in a preliminary age model with an extrapolated basal age of ~11.6 ka cal BP, slightly younger than the Late Glacial, but pre-dating the local deglaciation. We assume that the significant sedimentological changes encountered in the lowermost part of the sediment core point at sediment deposition in a subglacial lake environment. This is in accordance with preliminary results from the sediment echosounder data. In a next step, and in order to test the hypothesis of a former subglacial Lake Melville and hence deposition of pre-deglacial sediments, we will conduct further multi-proxy analyses on several sediment cores, and significantly improve the age model.

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A New Relative Sea-Level Database for Norway

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Keywords: Relative sea-level, Norway, GIA.

Despite a rich history of research into post-glacial shoreline displacement, Norway lacks a unified collection of national relative sea-level data. A new initiative aims to develop a new post-glacial relative sea-level database, incorporating high-quality data from the entire Norwegian coastline. The database constitutes an integral part of a larger relative sea-level and glacial isostatic adjustment modelling project administered by the Geological Survey of Norway (QUANTSEA) that is ongoing. The database is populated with sea-level index points (SLIPS) and closely follows the international HOLSEA template, allowing future integration into large, global datasets. To date, over 1000 SLIPS have been assembled from previously published studies. They comprise wave-cut platforms, deltas, beach ridges, isolation basins, cave sediments, submerged peat, and salt marshes, which were dated using radiocarbon ages, tephra, pumice, biostratigraphy, inferred ages, and terrestrial cosmogenic nuclide exposure ages. All radiocarbon ages, from both recent and older literature, were recalibrated using the IntCal20 and Marine20 calibration curves. Additional data fields include latitude, longitude, sample elevation, SLIP type, relative sea-level (relative to modern, local Mean Sea Level), and age and elevation uncertainty, among others. Where possible, sample elevations were confirmed using high-resolution digital elevation models derived from LiDAR. New uncertainties were also applied to sites with poor constraints for sample location/elevation. Once completed, the database will comprise an important constraint for future glacial isostatic adjustment modelling of Scandinavia and will thus help improve future relative sea-level projections over the next century and beyond. The database will also be relevant to studies of past ice sheets, Nordic history and archaeology, oceanography, paleoclimatology, and geophysics, among others.

Lake basin formed by interaction of volcanism and land surface processes – the Lake Nordlaguna on Jan Mayen

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Keywords: Lake basin formation, Jan Mayen, volcanic, glacial, tectonic.

Large lake basins of the world are classified according to their main processes of formation, e.g. as structural, volcanic and glacial basins. These processes are regionally controlled, but the type and location of a basin is often influenced by processes operating on a local scale. Formation of a small lake basin on the volcanic island of Jan Mayen sheds light on the importance of different processes in its evolution.

Lake Nordlaguna is a small lake situated on the west coast of the island at the foothills of the large, ice-covered volcano Beerenberg. The lake is predominantly bounded by steep mountain slopes, and a wide beach barrier separates it from the ocean. The outlet to the ocean was blocked in AD 1732 due to volcano-tectonic uplift and the lake has since then been landlocked (Larsen et al., 2021).

Jan Mayen is a young volcanic island. The oldest date so far gave an age of 564±6.0 ka, and is from a rock face towards the lake. This dates the emergence above sea level of a small volcanic island which is now a mountain fringing the present lake. Volcanic eruptions over the next hundreds of thousand years formed separate small volcanic islands that over time merged into a horseshoe-shaped range with the opening facing the ocean to the west. The last of these eruptions took place some 21 ka ago. It started sub-glacially, protruded through the ice surface and locally speeded up the deglaciation of the island that was already ongoing (Lyså et al., 2021). The formation of the beach barrier separating the lake from the sea in the west is undated. Obviously, it is Holocene in age, and Larsen et al. (2021) argued that it formed during the Tapes transgression.

The lake Nordlaguna owes most of its origin to volcanic processes. It has been glaciated at least once (Lyså et al., 2021), but modification of the basin by glacier activity seems modest. The processes that formed the beach barrier turned the basin into a lake, but these did not affect the bedrock basin itself.

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Cosmogenic nuclide inheritance in Little Ice Age moraines - a case study from Greenland

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Keywords: Greenland Ice Sheet, glaciers, Holocene, Moraines, Cosmogenic exposure dating.

Cosmogenic exposure dating is one of the most widely used methods to constrain the deglaciation history of former glaciated areas. In Greenland, more than 1000 cosmogenic ^{10}Be exposure ages (^{10}Be ages) have been published within the last two decades. However, a recurring problem is that many of these studies have reported variable amounts of nuclide inheritance making the ^{10}Be ages too old and difficult to assess without large datasets or independent age control. In this study, we test the accuracy of ^{10}Be dating of Holocene moraines using independent age constraints from threshold lake records. In Kangerlussuaq, West Greenland, the ^{10}Be ages of the Ørkendalen moraine system are highly clustered with a mean age of 6.8±0.3 ka (no outliers). In contrast, the nearby LIA moraine yields scattered ^{10}Be ages ranging from 2.5 to 0.1 ka but with a mean of 0.18±0.06 ka after excluding outliers which coincides with independent age constraints from threshold lakes and boulder kill dates. At Gletscherlukket, Southeast Greenland, the ^{10}Be ages of the LIA moraine range from 10.2 to 1.6 ka with a mean of 1.9±0.2 ka after excluding outliers. This is ~1.7 ka older than recorded in the proglacial threshold lakes and suggests that all samples from this site contain a significant amount of nuclide inheritance. Our results are consistent with other reports of skewed ^{10}Be age distributions in LIA re-advance moraines and it probably reflects nuclide inheritance from exposure during the Holocene Thermal Maximum when the glaciers in Greenland were inside the LIA extent. In contrast, there is no evidence of nuclide inheritance in the Ørkendalen moraines, most likely because the glacial erosion was more intense prior to the formation of the moraines i.e. sometime between the advance phase during Last Glacial Maximum position and the subsequent lateglacial and Holocene deglaciation. Our results highlight a potential pitfall related to dating re-advance moraines using cosmogenic exposure dating and we recommend using a multi-method dating approach.

Evolution of potentially sub-glacial Lake Manicouagan (Canada) derived from high-resolution reflection seismic data

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Keywords: Laurentide Ice Sheet, East Canada, high-resolution reflection seismic.

The eastern Canadian provinces Québec, Newfoundland and Labrador are key areas of Cenozoic to present climate change. During glaciations, vast areas of Northern North America were covered by thick ice sheets such as the Laurentide Ice Sheet (LIS). Lakes, fjords and inlets on the Canadian shield have long been considered as having been completely excavated by glaciers during the last glaciation (Wisconsin glaciation). Hence, they comprise deposits of glacial and post-glacial age, but not from ages before the last glaciation. Recent studies, however, show that deep lakes exist, which have been subglacial water bodies during glaciated periods and hold sedimentary deposits of pre-Wisconsin age. Lake Manicouagan is an old meteorite impact crater, located in the province of Québec, 220 km north of the Saint Lawrence River. In 2016 we carried out an expedition to Lake Manicouagan to image the basement morphology and sedimentary infill with a high-resolution reflection seismic system. The dataset reveals an incised valley, which is narrow in the lower part and wider in the upper part. The data support the theory that the lower part of the valley is the relict of a pre-Wisconsin, fluvial system and was not, or only partly, eroded by the LIS during the Quaternary glaciations. The upper part of the valley was possibly modified by Quaternary glaciers leading to a wider cross section and a decrease in sinuosity. Seismic data show that the valley is filled with sedimentary sequences of more than 250 m in thickness. This suggests that the sedimentary infill of the lake provides records of pre-Wisconsinan age due to its thickness. Hence, Lake Manicouagan holds a unique archive to study paleoclimate history and the evolution of the LIS from an area that was directly affected and generally overprinted by the ice shield.

A quasi-annual record of time-transgressive esker formation

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Keywords: Esker, time-transgressive formation, De Geer moraine, Laurentide Ice Sheet, subglacial hydrology.

Eskers are traditionally identified as slightly sinuous ridges of glaciofluvial sand and gravel deposited in subglacial, englacial or supraglacial drainage channels, and are common in formerly glaciated regions (Storrar et al., 2014). But despite being widely used to infer properties of the subglacial channelised drainage system and to reconstruct and constrain ice-retreat histories, it is not known whether eskers form synchronously in long conduits (Brennand, 1994) or if they represent a time-transgressive deglacial signature of deposition along drainage pathways (De Geer et al., 1910; Mäkinen, 2003). Here we present new geomorphological mapping of beaded eskers (series of aligned sediment mounds) in Keewatin, Canada. Esker beads frequently show a close 1:1 association with De Geer moraine (i.e., each bead is associated with a corresponding ridge) and are therefore interpreted to be quasi-annual ice-marginal deposits formed time-transgressively at the mouth of subglacial conduits during deglaciation (Livingstone et al., 2020). Under our time-transgressive interpretation, esker bead spacing constrains the typical pace of deglaciation in central Nunavut, and provides a minimum bound on annual sediment fluxes. We suggest that the prevalence of esker beads across this predominantly marine-terminating sector of the Laurentide Ice Sheet is a result of sediment fluxes that were unable to backfill conduits at a rate faster than ice-margin retreat. Conversely, we hypothesise that esker ridges form when sediment backfilling of the subglacial conduit outpaced retreat, resulting in headward esker growth close to but behind the margin. The implication, in accordance with recent modelling results (e.g., Hewitt & Creyts, 2019), is that eskers in general record a composite signature of ice marginal drainage.

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Exploring the influence of frontal ablation on global glacier mass change projections

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Keywords: Glaciers, ice-ocean interaction, climate change, modeling.

Mountain glaciers across the world are contributing around one-third to the recent barystatic global mean sea-level rise, and relevant for regional hydrological changes. Although the majority of Earth's glaciers is land-terminating, roughly one-third of the glaciated area drains into an ocean or a lake. Due to the interrelation of surface and frontal mass budget, marine-terminating glaciers are subject to different dynamics than land-terminating ones, which are only forced by the atmosphere. This means that mass changes of marine-terminating glaciers cannot only be explained by changes in the atmospheric forcing. Thus, if ice-ocean interaction is not explicitly treated in a mass-balance model, calibration using, e.g., geodetic mass balances will lead to an overestimation of these glaciers' sensitivity to changes in atmospheric temperatures. However, most large-scale glacier models are not yet able to account for this process and frontal ablation remains an elusive feature of glacier dynamics, because direct observations are sparse. We explore this issue by implementing a simple frontal ablation parameterization in the Open Global Glacier Model (OGGM). One of the major changes this entails is the lowering of marine-terminating glaciers' sensitivities to atmospheric temperatures in the model's surface mass-balance calibration. We then use this model, forced with an ensemble of atmospheric temperature and precipitation projections from climate models taking part in the Climate Model Intercomparison Project's sixth phase (CMIP6), to project global glacier mass change until 2100. The main aim of this work is to investigate the influence of the frontal ablation parameterization on those projections. We find that introducing the parameterization of frontal ablation, but ignoring changes in ocean climate, reduces the spread between different emission scenarios in 2100.

Northern Hemisphere Holocene hydroclimate inferred from a circum-Arctic stack of lake sediment oxygen isotope records from biogenic silica ($\delta^{18}O_{BSi}$)

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Keywords: Oxygen Isotopes, Diatoms, Climate, Hydrology, Lakes.

Lake sediments constitute important terrestrial archives of past climate and environments. While different kinds of proxy data can be obtained from these sediments, oxygen isotopes ($\delta^{18}O$) are of particular interest in paleoclimatology. They record changes of climate and hydrology in a quantitative way. Commonly, $\delta^{18}O$ is measured on carbonates (i.e. ostracods) and biogenic silica (mainly diatoms). While oxygen isotopes in lacustrine carbonates ($\delta^{18}O_{CaCO3}$) have been studied extensively for several decades, they are subject to complex species-dependent fractionation processes and not available globally. Lacustrine oxygen isotope records from biogenic silica ($\delta^{18}O_{BSi}$), on the other hand, likely do not display species-dependent fractionation effects (or only very minor) and offer insight even in data-sparse regions devoid of carbonates, such as the Arctic.

More than 40 lacustrine $\delta^{18}O_{BSi}$ records from mid- and high-latitude regions of the northern hemisphere have been published to date. Interpreting case studies of $\delta^{18}O_{BSi}$, however, is challenging due to a complex interplay of climatic and hydrological factors. Therefore, these individual case studies have been complemented with additional efforts addressing climatic and hydrological backgrounds, laboratory techniques, possible species-dependent fractionation as well as deposition and dissolution effects.

Here, we combine records from sites across northern Eurasia and North America to a circum-arctic stack in order to infer common underlying trends throughout the Holocene. With this work, we aim at providing new insight on the variability of Holocene hydroclimate as well as on the interplay between lacustrine archives and the $\delta^{18}O$-proxy. This improves both the usability of $\delta^{18}O_{BSi}$ for proxy-model comparison and our understanding of the general constraints for interpreting lacustrine $\delta^{18}O_{BSi}$ records.

Late Quaternary palaeoceanography and sea-ice history in the Kveithola Trough Mouth Fan (NW Barents Sea)

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Keywords: Fram Strait, microfossils, paleobiological proxies, sediment cores.

The north-western continental margin of the Barents Sea represents an important gateway for the influx of the relative warm and saline Atlantic Water (AW) towards the Arctic Ocean. The AW influx into the Arctic Ocean varied considerably over the late Quaternary playing an important role on the climatic conditions of the Arctic (i.e. Werner et al., 2013). The western Barents Sea represents a key area to study the palaeoceanographic conditions, which occurred during the past. We present the high resolution (centennial scale) foraminiferal study of two cores collected from the Storfjorden-Kveithola depositional system (NW Barents Sea) during the EGLACOM and CORIBAR projects. The aim is to reconstruct the paleoceanographic and paleoenvironmental evolution after the Last Glacial Maximum, using expanded sedimentary sequences (over 6 m thick Holocene record in the core collected on the Kveithola Trough Mouth Fan, Carbonara et al., 2018; Caricchi et al., 2018).

The chronological framework defined by the paleomagnetism (Charicchi et al., 2018), evidences that the ecobioevents highlighted by the planktic microfauna occurred more or less synchronously throughout the studied area. The high diversity of the assemblage reveals an early Holocene Climatic Optimum terminating with the 8.2 Ka cold spell, characterised by a low diversity assemblage dominated by the high primary productivity indicator, *Turborotalita quinqueloba*.

The benthic foraminiferal assemblage indicates deglaciation conditions before the Holocene. In the glaciomarine sediments, the benthic assemblage mainly contains *Cassidulina reniforme*, *C. neoteretis*, *Islandiella helenae/norcrossi* and *Cibicides lobatulus*. The significant occurrence of very small taxa (> 63 µm), such as *Stetsonia horvathi* and *Seabrookia earlandi*, suggests conditions of low productivity related to permanent sea ice conditions during the medium-late Holocene. In the late Holocene, the increasing occurrence of *Epistominella arctica*, *E. exigua* and *Eilohedra nipponica*, phytodetritus feeders, records mostly seasonal sea ice conditions.

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Short-term hydroclimate changes in the Lake Bolshoye Shchuchye biogenic silica isotope record ($\delta^{18}O_{diatom}$) linked to snow variability in the catchment

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Keywords: Oxygen isotopes, diatoms, lake hydrology, centennial-scale changes, snow, Holocene.

Diatom oxygen isotopes ($\delta^{18}O_{diatom}$) from lacustrine sediments have proven to be reliable proxies to trace the hydrological and climate dynamics in the catchment of a respective lake, and are generally linked to the temperature and the water isotope composition ($\delta^{18}O_{lake}$). These background conditions may vary over time constrained by the individual hydrological changes in a given climate field. Diatom oxygen isotopes are excellent recorders of these changes, especially in high-latitudes where carbonates are widely absent, and have been linked to changes in the individual hydrological characteristics in the catchment, such as: (1) air temperature, (2) air-mass contributions, (3) inflow changes, (4) evaporation rates and (5) glacial meltwater influx. In general, the corresponding diatom isotope-based hydroclimate records show a ~5‰ variability over the Holocene and are rather smooth depending on the residence time and turn-over rate of each lake.

Lake Bolshoye Shchuchye (67°53’N; 66°19’ E; 187 m a.s.l) is the largest and deepest freshwater lake located in the Polar Urals, Arctic Russia. Its $\delta^{18}O_{diatom}$ record generally follows a decrease in summer insolation, in line with the northern hemisphere (NH) temperature history. However, Lake Bolshoye Shchuchye is exceptional, as short-term, centennial-scale changes of 5-7‰ are notable in the $\delta^{18}O_{diatom}$ values. As most of these minima and maxima are confirmed by more than one data point, and were measured twice, these are no methodological artefacts. The question arises why these extremes occur and what could be the responsible mechanism(s) behind this short-term variability. The recent isotope geochemical background helps setting Lake Bolshoye Shchuchye in its recent hydrological context as a well-mixed monomictic lake, covered more than half of the year by ice, implying negligible evaporative effects. As a deep and voluminous lake, ca. 30-50% of the water of Lake Bolshoye Shchuchye need to be exchanged with isotopically light water within short time to account for these 5‰-isotopic shifts in $\delta^{18}O_{diatom}$. These changes occur in the Holocene, contemporaneous with and similar to NH glacier advances (Nesje, 2009). However, potential Holocene glacier advances in the Lake Bolshoye Shchuchye catchment are not known and have left no significant imprint on the lakes’ sediment biogeochemistry. Accordingly, the only other source of light isotope composition is snow, known to be transported in significant quantities and with large variability to the leeward side of the Polar Urals (Mangerud et al., 2008). Hence, we hypothesize snow being the dominant agent responsible for the observed short-term changes in the $\delta^{18}O_{diatom}$ record. To our understanding, this is the first time such drastic hydrological changes have been documented for a lacustrine diatom oxygen isotope record.

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Mapping and dating Holocene advances of Nansenbreen on Erdmannflya, Svalbard

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Keywords: Glaciation, sea-level, glacial landforms, radiocarbon, Svalbard.

Arctic temperatures are rising twice as fast as global temperatures. Understanding the effect of this change on glacial retreat and associated meltwater contributions to sea-level rise is of critical importance.

This study aims to map and date the complex moraine system of Nansenbreen, a glacier on the north-western coast of Isfjorden, in Svalbard. Mapping and dating this moraine sequence allow us to understand the glacial, fluvial, and sea-level history and dynamics of the area, thus enabling a better understanding of the evolution of paleo-climates and palaeo-environments in Svalbard and glacier responses to those forcing mechanisms. Based on aerial photographs, field observations, and radiocarbon dating of *in-situ* terrestrial and marine material from the moraine itself, this study reconstructs conditions back in the Holocene. Adjacent to the moraine system at Nansenbreen, the lake Straumsjøen provides additional information of environmental change and moraine evolution elucidated by sediment core analysis. Together, records such as this help increase the resolution of regional histories of Holocene glacial variability and thus help to better forecast the future of glaciers and their impact on local and global landscapes. This history predates the Anthropocene, thus affording a backdrop against which to monitor the evolution of the Svalbard cryosphere to current extreme levels of warming.

Impacts of Arctic gateways on sediment routing in northern Baffin Bay

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Keywords: Baffin Bay, Lancaster Sound, Nares Strait, Holocene, Paleoenvironmental reconstruction.

The Baffin Bay is a key area for reconstructing changes in past climate, ice sheet behavior, sea-level, and ocean circulation, given it was bordered by the Greenland (GIS), Laurentide (LIS), and Innuitian Ice Sheets (IIS) during the Last Glacial Maximum (Dyke et al., 2002). Presently, Baffin Bay is a pathway for Arctic water entering it from the north mainly via the Lancaster Sound and the Nares Strait, and for North Atlantic water from the south via the Davis Strait. However, the through flow along the northern gateways stayed shut until early Holocene and only opened after the retreat of the various ice sheets (Dalton et al., 2020). These gateway openings controlled the connectivity of Baffin Bay (and the North Atlantic Ocean) to the Arctic and probably resulted in very different water and sediment routing systems in Baffin Bay. Using two radiocarbon-dated gravity cores, retrieved from off Lancaster Sound (GeoB22336-4) and Nares Strait (GeoB22315-2), spanning from the last deglaciation through the Holocene, we evaluate the impacts of these Arctic gateways on sedimentation patterns and sediment provenance in northern Baffin Bay. Deglacial to early Holocene deposits consist of gravely-silty glaciomarine sediments, broadly mirroring proximal-distal ice margin conditions, suggesting intense melting of bordering ice sheets and melt-water discharge. During this time, the Lancaster core is dominated by Ca-rich layers, evidenced by the relatively higher Ca/Sr ratios and the strikingly inverse correlation of Ca to other terrestrially sourced elements, similar to Baffin Bay Detrital Carbonate sourced from ice stream activities from IIS north of the bay. In contrast, the Nares Strait core is dominated by coarse-grained poorly sorted Al-Si-K-rich sediments, which are possibly products of glacial erosion locally sourced from the adjacent GIS margin. Upon opening of the Nares Strait at the end of early Holocene (~ 8.1 ka BP), a marked shift in the sediment delivery processes is observed. After the Nares Strait opening, the sediment compositions off Lancaster Sound and Nares Strait became very similar and the change in elemental ratios off Lancaster Sound points to a shift in sediment provenance documenting the onset of the dominant control of sediment input to northern Baffin Bay through Nares Strait.

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Holocene paleoceanography of Lincoln Sea and Sherard Osborn Fjord, Northern Greenland, based on benthic foraminifera and ostracodes

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Keywords: Paleoceanography, Holocene, Foraminifera, Ostracode, Arctic.

The Holocene paleoceanography of the Lincoln Sea, Nares Strait and Sherard Osborn Fjord was reconstructed based on foraminiferal and ostracode assemblages from four radiocarbon-dated sediment cores. Two main foraminiferal zones were identified, a lower zone dominated by *Cassidulina teretis* (Cronin et al., 2019; also called *C. neoteretis*, Jennings et al., 2011) and an upper zone characterized by *Cibicides lobatulus* and *Nonionellina iridea* with decreased abundances of *C. teretis.* For the two cores outside the Sherard Osborn Fjord in the Lincoln Sea, and the core inside Hall Basin, Nares Strait, the transition between these zones occurs around ~ 8,000 – 9,000 cal yr BP. For the core inside the Sherard Osborn Fjord, near the mouth of Ryder Glacier, this transition occurs later, around ~6,200 cal yr BP. *C. teretis* has been interpreted to represent the presence of subsurface Atlantic Water during the deglaciation of Hall Basin (Jennings et al., 2011) and dominates benthic assemblages throughout the four cores. Increases in *Cibicides lobatulus* is associated with coarser sediments at shallower depths with more current activity (Polyak et al., 2002), indicating an increase in stronger currents in the upper zone of the core. Increases in *Nonionellina iridea* in the upper zone is interpreted to represent a period of marine productivity that would require an increase in open water (Jennings et al., 2011). Greater abundances of productivity-indicator benthic foraminifera taxa suggest an increase in nutrient-rich Pacific Water that fueled high phytoplankton productivity in surface water of the Arctic shelves after sea ice cover retreated (Jennings et al., 2011). The sedimentologic and paleoceanographic data from these cores reflect ice retreat throughout the lower zone, transitioning to a period of increased ocean circulation and marine productivity. Continued analysis of the common *Krithe* spp*., Polycope* spp*., Cytheropteron* spp*.,* and *Rabilimis* spp. ostracode fauna present in these cores will help determine the timing of Holocene faunal and lithology changes.

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Ice-wedge and pore-ice stable-isotope paleoclimatology at the Batagay megaslump (East Siberia)

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Keywords: Stable isotopes, ground ice, Batagay megaslump, seasonality, continentality.

In recent years, permafrost ground ice (i.e. ice wedges and pore ice) has been increasingly utilized as a paleoclimate archive for the Late Pleistocene and Holocene, mainly using stable isotopes from water as proxies for local air temperatures (Porter & Opel, 2020). Due to their specific formation processes (frost cracking in winter and crack infilling mainly with snowmelt in spring), ice wedges have a unique winter seasonality, whereas pore ice integrates summer or annual precipitation stored in the seasonally thawed active layer.

The world's largest retrogressive thaw slump at Batagay in the Yana Upland, East Siberia (67.58 °N, 134.77 °E), provides unique access to Middle and Late Pleistocene permafrost deposits usually deeply buried in the frozen ground. The Batagay megaslump exposes syngenetic ice wedges and composite wedges (ice–sand wedges) along with pore ice in four cryostratigraphic units: (1) the lower ice complex, (2) the lower sand unit, (3) the upper ice complex, and (4) the upper sand unit. A woody bed above the lower sand is remarkable (Murton et al., 2017). The Batagay permafrost sequence discontinuously spans at least 650,000 years (Murton et al., under review).

Here, we present ice-wedge stable-isotope data ($\delta^{18}O$, δD, d excess) from all four units and a nearby site as well as pore-ice stable-isotope data throughout the entire Batagay sequence. Our work-in-progress dataset also comprises precipitation stable-isotope data from winter snowpack and summer rain as a preliminary modern stable-isotope framework for this region.

The high continentality of the study region – with extremely low winter temperatures and warm summers – is clearly reflected in the stable-isotope composition of modern snow as well as of relict ice wedges. First results show that ice wedges formed during MIS 3 (upper ice complex) and the Holocene (nearby river terrace) have stable-isotope compositions that are distinctly more depleted than those of the same period from other study sites in East Siberia (Opel et al., 2019). The ice wedges of the lower ice complex are likely the oldest ever analysed for stable isotopes (MIS 17/16, Murton et al., under review) and also point to cold winter temperatures during formation in the early Middle Pleistocene. Stable-isotope signatures of composite wedges from both sand units are similar to those of pore ice. The latter is characterized by highly elevated d excess values and requires detailed studies of formation processes and seasonality. Current work on samples taken in 2019 focusses on a detailed assessment of MIS 3 ground-ice stable isotopes and the development of a ground ice chronology.

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The Holocene dynamics of Ryder Glacier and ice tongue in north Greenland

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Keywords: North Greenland, Lincoln Sea, Ryder Glacier, Holocene.

The northern sector of the Greenland ice sheet is considered to be particularly susceptible to ice mass loss arising from increased glacier discharge in the coming decades. However, the past extent and dynamics of outlet glaciers in this region, and hence their vulnerability to climate change, are poorly documented. In the summer of 2019, the Swedish icebreaker *Oden* entered the previously unchartered waters of Sherard Osborn Fjord, where Ryder Glacier drains approximately 2% of Greenland's ice sheet into the Lincoln Sea. Here we reconstruct the Holocene dynamics of Ryder Glacier and its ice tongue by combining radiocarbon dating with sedimentary facies analyses along a 45 km transect of marine sediment cores collected between the modern ice tongue margin and the mouth of the fjord. The results illustrate that Ryder Glacier retreated from a grounded position at the fjord mouth during the Early Holocene (>10.7 ± 0.4 cal ka BP) and receded more than 120 km to the end of Sherard Osborn Fjord by the Middle Holocene (6.3 ± 0.3 cal ka BP), likely becoming completely land-based. A re-advance of Ryder Glacier occurred in the Late Holocene, becoming marine-based around 3.9 ± 0.4 cal ka BP. An ice tongue, similar in extent to its current position was established in the Late Holocene (between 3.6 ± 0.4 and 2.9 ± 0.4 cal ka BP) and extended to its maximum historical position near the fjord mouth around 0.9 ± 0.3 cal ka BP. Laminated, clast-poor sediments were deposited during the entire retreat and regrowth phases, suggesting the persistence of an ice tongue that only collapsed when the glacier retreated behind a prominent topographic high at the landward end of the fjord. Sherard Osborn Fjord narrows inland, is constrained by steep-sided cliffs, contains a number of bathymetric pinning points that also shield the modern ice tongue and grounding zone from warm Atlantic waters, and has a shallowing inland sub-ice topography. These features are conducive to glacier stability and can explain the persistence of Ryder's ice tongue while the glacier remained marine-based. However, the physiography of the fjord did not halt the dramatic retreat of Ryder Glacier under the relatively mild changes in climate forcing during the Holocene. Presently, Ryder Glacier is grounded more than 40 km seaward of its inferred position during the Middle Holocene, highlighting the potential for substantial retreat in response to ongoing climate change.

Deglacial and Holocene environmental variability in the western Franz Victoria Trough, Barents Sea

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Keywords: Palaeoceanography, Barents Sea, Atlantic water, foraminifera, ice- and iceberg-rafted debris.

Changes in the Atlantic water inflow to the Arctic Ocean play important role in its water mass structure, heat balance and sea-ice extent. The Franz Victoria Trough (FVT) in the Barents Sea is one of the gateways for Atlantic and Arctic water mass exchange in the Arctic. Deglacial and Holocene sediment records from the FVT help reconstructing the variability of Atlantic water inflow in relation to the Barents-Kara ice sheet decay and meltwater input.

The 150-cm long gravity core AT19-22GC (81˚15,283' N, 39˚11,808' E) was recovered during the Russian expedition "TRANSARKTIKA-2019" on the western FVT slope from the 454 m water depth. The downcore records of sand fraction and ice-and iceberg-rafted debris (IRD) suggest the stratigraphic subdivision into deglacial unit enriched in coarse-grained fractions and IRD (95-150 cm) and the overlying Holocene unit.

The deglacial sediments are characterized by the high relative abundance of Atlantic water indicative species *Cassidulina neoteretis* (up to 50%). This allows correlating them with the Bølling-Allerød and Younger Dryas (YD) records of the cores from the eastern FVT (Lubinski et al., 2001) and other troughs on the Barents Sea continental slope (Ślubowska et al., 2005; Ivanova et al., 2019). Water column in the troughs was stratified due to the influence of surface meltwater from decaying ice sheet and subsurface inflow of Atlantic water with its Fram Strait branch.

The period of the YD - early Holocene transition shows a change in dominant species: instead of *C. neoteretis* opportunistic *Elphidium clavatum* and cold water arctic species *Cassidulina reniforme* predominate among benthic foraminifers. This change likely reflects growing influence of the Barents Sea branch of Atlantic waters (cf. Lubinski et al., 2001), probably in combination with extensive sea-ice cover.

In the benthic foraminiferal assemblage from the Holocene part of the sequence (excluding the uppermost 30 cm) *C. reniforme* and C. *neoteretis* are equally abundant averaging 20-30%. Only in the upper part the representation of C. *neoteretis* increases. A similar trend has been previously related to the enhanced influence of Atlantic water with the Fram Strait branch around 2-3 cal ka (Lubinski et al., 2001). Calcareous benthic foraminifers are rare in the uppermost 30 cm of the core where they are replaced by agglutinated species. This may be a result of high productivity conditions at the ice marginal zone in the late Holocene that caused dissolution of calcite.

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A time-transgressive perspective of glacial erosion beneath the Eurasian ice sheet

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Keywords: Glacial erosion, Eurasian ice sheet, cosmogenic nuclide, glacial buzzsaw, ice sheet model, landscape evolution, erosion rate.

Ice sheets play an important role in sculpting landscapes across geological timescales. However, constraints regarding the efficacy and controls on glacial erosion are poorly known, in particular for polar ice sheets over timescales of 100,000 years and more. The Eurasian ice sheet complex shaped the North Atlantic passive margin and northwestern European continental shelf through kilometre-scale denudation processes, sediment transfer, and concurrent isostatic responses, whilst broad swathes of inter-fjord uplands and the terrestrial hinterland, including the Baltic Shield, survived multiple glaciations relatively unmodified. Recently, these views have been challenged by new cosmogenic measurements demonstrating glacial erosion and extensive modification of high plateaus between the fjords of western Scandinavia. Erosion of these low relief/high altitude surfaces has been linked to long-term glacier equilibrium altitudes, yielding a distinctive bimodal erosion/elevation distribution and associated hypsometric curve that has been interpreted as a glacial buzzsaw mechanism, implying that on geological timescales there is a climatic control on mountain elevation.

We integrate geological data with ice sheet modelling to investigate the time-transgressive erosional patterns during the last glacial cycle (<123 ka) beneath the Eurasian ice sheet complex. Our results are independently assessed against a database of ^{10}Be measurements using standard Monte Carlo simulations, and demonstrate extreme rates and a complex spatial variability of glacial erosion ranging from 0 to >5 mm per year across contrasting topographic settings and geological provinces. Bedrock lithologies and thermomechanical boundary conditions are key factors determining long-term erosion rates, and we find limited support for the supposition that polar ice sheets are ineffective agents of landscape development. Though our analysis lends limited support for a bimodal signature of erosion across western Fennoscandia over the entire glacial cycle, we find a thermomechanical control on erosion across high-elevation plateaus during deglaciation phases. Whilst climate perturbations can dramatically impact bulk erosion over short, sub-millennial timescales, we propose that evolving ice dynamics, influenced by subglacial relief and fast flow during ice sheet build-up and deglaciation, is the more effective control on long-term patterns of erosion and the subsequent glacial legacy in the landscape. Moreover, our analysis ostensibly upholds the notion that ice sheets can simultaneously appear both "able and feckless" agents of erosion.

Early Holocene variations of sea-ice, NE Svalbard: Spring sea-ice was always present

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Keywords: Highly-branched isoprenoid biomarkers (HBIs), IP_{25}, stable isotopes, Barents Sea.

Today's rapid changes, such as warmer waters entering the Arctic Ocean, make it important to obtain information about natural variations in ocean currents and sea-ice in this climatically-sensitive region. Both sea-ice cover and thickness have changed dramatically in recent years. In order to better understand the causes and consequences of these changes, it is pivotal to know the past sea ice conditions. In this study, we have investigated stable isotopes ($\delta^{18}O$, $\delta^{13}C$) from benthic foraminifera and highly-branched isoprenoid biomarkers from two sediment cores northeast of Svalbard, a key area for Arctic-Atlantic ocean interactions. Depth-age modelling was based on fourteen AMS ^{14}C radiocarbon datings that cover the period ca. 6,000-13,000 cal. yr BP. Sea-ice biomarkers (IP_{25}, $IPSO_{25}$) and pelagic biomarkers (HBIs III, IV) are present throughout the investigated time interval. The results show that the sea-ice decreases sharply during the Younger Dryas cold climate period and is at a minimum at the beginning of our current interglacial warm period. Yet, spring sea-ice concentration was intermediate (i.e., 10-50%, sensu Köseoğlu et al., 2018) at the beginning of the Holocene, where the $\delta^{18}O$ records also indicate a sub-surface inflow of relatively warm Atlantic Water. The current data show that warmer-than-present conditions and Atlantic Water inflow during the Holocene Thermal Maximum did not cause sea-ice to disappear, but that the northern Barents Sea may potentially be the southern limit of spring sea-ice cover. This new knowledge and proxy values will be combined with several other reconstructions to establish natural reference values for sea ice in this area of the Arctic Ocean.

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Petrographic and mineralogical composition of sediments as an indicator of glacier retreat in Franz Victoria Trough: first results from core AT19-22GC

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Keywords: Deglaciation, minerals, petrographic composition, Barents Sea, Arctic Ocean.

Franz Victoria Trough (FVT) serves as a pathway between the Barents Sea and the Arctic Ocean thus holding the record on important processes caused by the input of meltwater and the inflow of warm Atlantic waters that controlled regional climatic changes during the Pleistocene (Lubinski et al., 1996; Polyak et al., 1997). It is a key region for studying the mechanisms of the redistribution of terrigenous particles in the Arctic Ocean during ice sheet disintegration. Detailed petrographic and mineralogical analysis of the coarse fraction from the Late Pleistocene beds of the northern Barents Sea has not been carried out so far. The newly obtained data on the composition of coarse sediment fraction from the FVT will be useful for reconstructing regional paleoceanographic processes related to the general climate changes during the late Pleistocene.

Petrographic and mineral composition of coarse lithic grains was studied in the 150 cm long core AT19-22GC obtained in FVT at 454 m water depth during Transarktika-2019 expedition (Frolov et al., 2019). The total of 74 samples were taken continuously as 2-3-cm thick slices, washed over 63-micron mesh size sieve and then dry-sieved. Coarse-size fractions 0.5-1 mm, 5-10 mm, and >10 mm were studied separately.

According to the changes in lithological characteristics, the core is divided into deglacial and Holocene parts at 93-95 cm. A clear pattern is noted: grains from >10 mm size fraction are evenly distributed (1-2 per sample) only below 93-95 cm, and the number of grains from 5-10 mm size fraction reduces sharply from about 15 to 1 at this boundary.

Black shale, quartz, siltstone, sandstone, quartzite, argillite, and carbonates together comprise 84%. Relative abundances of quartz and siltstone increase towards the Holocene section, while other rock types prevail in deglacial units and decrease upcore: black shale - from about 30% to 7%, quartzite - from 6% to 3%, sandstones decrease fivefold, and carbonates also experience a fall. A conclusion can be made that the islands of Franz Josef Land were not the major source area of iceberg-rafted coarse debris, as basalt, the local index rock, is absent in the core. Significant representation of sandstone, quartzite, and carbonates points to Victoria and Belyi (Kvitøya) islands located to the southwest of the core site (State Geological map, 2006) from where the icebergs supposedly drifted in the northeastern direction. The origin of black shales is not clear yet. The absence of strong fluctuations in the petrographic composition within the deglacial part of the core allows implying that the source area remained rather stable during the observed period.

This research was funded by “The Changing Arctic Transpolar System (CATS)” Fellowship Program. The authors thank the Russian-German Otto Schmidt Laboratory for Polar and Marine Research (OSL) for providing laboratory facilities, and M. Y. Burnaeva for the assistance in mineral identification.

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Surface warming during the MIS 11 and MIS 5 interglacials in the Arctic Ocean based on planktic foraminifera

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Keywords: Paleoceanography, Arctic, foraminifera, Quaternary, sea-ice.

Marine Isotope Stage (MIS) 11, ~424-374 ka, and MIS 5, ~130-80 ka, were warm Pleistocene interglacials associated with sea-surface temperatures (SSTs) in many ocean regions higher than those of the pre-industrial. Both periods are regarded as possible analogs for the Holocene because MIS 11 atmospheric carbon dioxide (CO_2) concentrations were similar to the pre-industrial period, and MIS 5 temperature reconstructions resemble possible future warming scenarios. Here, we analyzed planktic foraminiferal assemblages from eight piston cores from multiple ocean ridges, including the Northwind, Mendeleev, Alpha, and Lomonosov Ridges, to reconstruct SST changes across both interglacials in the Arctic Ocean. Cores were dated using $\delta^{18}O$ stratigraphy, biostratigraphy, and tuning various physical and biological features to the Lisiecki and Raymo $\delta^{18}O$ (LR04) curve and astronomical timescale. Assemblages include several species indicative of specific conditions, including a distinct planktic foraminiferal morphotype, likely equivalent to *Globigerina exumbilicata* (Herman, 1974), that may have taxonomic affiliations to *Turborotalita egelida*, a species considered dominant in Arctic MIS 11 sediments. *Turborotalita quinqueloba*, a typically subpolar species found in the North Atlantic and Arctic Seas, and *Neogloboquadrina pachyderma,* a polar planktic foraminifera, were also present in MIS11 and MIS 5 samples. In the MIS 5 interval, *T. quinqueloba* and *N. pachyderma* are the dominant species, both averaging ~40% abundance. The morphotype of *G. exumbilicata* only reaches a maximum abundance of 25% from 124-119 ka (MIS 5e). However, the *G. exumbilicata* morphotype reaches up to 95% abundance during peak warming within MIS 11, ~410-400 ka. Its abundance then declines to 60% during short stadials at 393 and 381 ka when it co-occurs with *T. quinqueloba*. *Neogloboquadrina pachyderma* is notably absent during the MIS 11 interval. These unique MIS 11 and MIS 5 assemblages containing the morphotype of *G. exumbilicata* consistently lacked an abundance of *N. pachyderma*, which dominated during MIS 3 and MIS 1. This suggests that sea-surface conditions were distinct from those of MIS 3 and MIS 1 and may have had warmer SSTs and therefore minimal summer sea-ice, or opportunistic foraminifera reflecting greater surface productivity during this time.

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Modelling methane production and emission from thawing sub-sea permafrost on the warming Arctic Shelf

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Keywords: Methane gas, thawing subsea permafrost, reaction-transport model, sediment column, Arctic.

The Arctic shelf hosts a large, yet poorly quantified reservoir of relic permafrost. It has been suggested that global warming, which is amplified in polar regions, will accelerate the thawing of this subsea permafrost, thus potentially unlocking large stocks of comparably reactive organic matter (OM). The microbial degradation of OM in the thawing and generally anoxic permafrost layer has the potential of producing and, ultimately, releasing important fluxes of CH_4 to the atmosphere. Because CH_4 is a potent greenhouse gas, such a release would further intensify global warming. However, the potential role of subsea permafrost thaw on microbial CH_4 production and CH_4 emissions from Arctic sediments currently remains unconstrained.

Here, we use a nested model approach to address this critical knowledge gap. We developed a pseudo-three-dimensional reaction-transport model for permafrost bearing sediments on the Arctic shelf to estimate the production, consumption, and, efflux of CH_4 on the Arctic shelf in response to projected subsea permafrost thaw. The model accounts for the most pertinent biogeochemical processes affecting methane and sulfur cycling in permafrost bearing marine sediments.

It is initialized based on an existing submarine permafrost map (SuPerMap, Overduin et al. 2019) and forced by a range of projected thawing rate scenarios derived from the Max Planck Institute Earth System Model (MPI-ESM) simulation results for the period 1850-2100. Critical model parameters, such as permafrost OM content and its apparent reactivity are chosen based on a comprehensive analysis of published experimental data. Here, we present the output of this environmental scenario ensemble.

Simulation results reveal that CH_4 production rates are highly sensitive to changes in the apparent reactivity of permafrost OM. Although simulated CH_4 production rates vary over a large range (0.001-130 PgC produced over 250 years), they generally highlight the potential for producing and, thus releasing large amounts of methane from thawing subsea permafrost on the warming Arctic Shelf.

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Neoglacial plateau ice cap behaviour in central Spitsbergen constrained by subglacially preserved vegetation.

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Keywords: Holocene, ice caps, Neoglaciation, Svalbard, ice-buried vegetation.

Cold-based glacial ice is well known to preserve underlying landforms produced by earlier processes, but can also preserve pre-existing organic material and vegetated ground. With current rapid climate warming, overall glacier retreat in the Arctic is exposing formerly ice-buried in situ vegetation at the margin of cold based ice bodies. Radiocarbon dating of these bryophytes and angiosperms constrains the timing of advance of ice over the specific location where the vegetation was collected. Widespread sampling, identification, and dating of vegetation emerging from various ice bodies can permit the reconstruction of the conditions and timing of the latest ice advance in a given region. While this method has been used in a range of places in the North American Arctic, its application elsewhere has hitherto been limited.

Here we sampled 11 in situ preserved bryophyte patches melting out of the margins of three plateau ice caps: Bassen, Foxfonna, and Frostisen, in central Spitsbergen, Svalbard. While we cannot state when this Neoglacial ice growth initiated, we found that Bassen was already advancing between 2.2 and 1.5 cal ka BP, and Foxfonna and Frostisen between 1.5 and 1.2 cal ka BP, the ice caps being as big as today already before these periods, implying an earlier inset of the Neoglaciation.

Reconstructing constraining ages on the timing and style of Late Holocene glacier readvances helps to develop a clearer understanding of cold-based ice cap responses to climate change and can therefore contribute in developing more nuanced projections for future ice caps behaviour.

The impact of air temperature on aeolian deposition rates in periglacial conditions (Ebba Valley, central Spitsbergen)

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Keywords: Aeolian deposition, Sediment dating, Periglacial conditions, Arctic, Svalbard.

Detailed measurements of aeolian processes at high latitudes are not currently carried out on a large scale. Aeolian activity is an important element of the denudation system of polar regions, which are particularly affected by climate changes. The study combined field measurements and calculations of contemporary and past aeolian deposition rates for one of the central Spitsbergen postglacial valleys (Ebba Valley). The obtained results were based on seven summer season field measurement campaigns (2012-2018), as well as on AMS ^{14}C and OSL dating of niveo-aeolian and aeolian sediments. It was possible to estimate that, on average, the Ebba Valley was covered with around 560 $g \cdot m^{-2}$ of aeolian material every year (2012-2018). Contemporary mean aeolian deposition rates ranged from 0.1 to 22.9 $g \cdot m^{-2} \cdot day^{-1}$ over the different parts of the valley and averaged from 2.1 to 12.3 $g \cdot m^{-2} \cdot day^{-1}$ over the studied 2012-2018 summer seasons. Strong relationships ($r^2=0.71$, $p=0.017$) between mean air temperature and mean aeolian deposition were observed, indicating the importance of the fresh, easily available, source material delivered to the valley by fluvioglacial processes. Moreover, aeolian deposition dependence on the source material reflected in the local nature of the process. Material transported over long distances was likely to be deposited in fjord waters.

Modelled past niveo-aeolian and aeolian deposition rates showed that ongoing climate changes were influencing aeolian activity, as well as the whole morphological system. Niveo-aeolian deposition rates estimated for the period since the 11th century, through the Little Ice Age, till the second half of the 20th century showed a rather constant value of 0.05 cm per year. Since then the calculated deposition rate has significantly increased and achieved 0.3 cm per year, which may also be related to rising air temperatures and pan-Arctic environmental changes.

The study was funded by the Polish National Science Centre (Grant No. 2014/15/N/ST10/00825).

Beach ridges of the Laptev Sea (Arctic Siberia) and their value as coastal archives

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Keywords: Holocene coastal dynamics, landscape evolution, wave climate, geochronology, sedimentary archives.

Beach ridges form along wave-dominated shorelines and have a long tradition of study in the Arctic. Classic investigations into the age, elevation, and geomorphology of these deposits focused on the quantification of isostatic uplift rates in previously glaciated areas of North America and western Eurasia (e.g. Dyke et al., 1991; Forman et al., 1997). Even though, similar coastal landforms are widely encountered in far-field sites of the Siberian Arctic, they remain largely unstudied. As these coastal depositional systems react sensitively to changes in e.g. sediment supply, storm frequency, or wave climate, they hold a certain capacity as paleoenvironmental archives (Tamura, 2012). The extent and duration of the open-water season in the Arctic near-shore zone influence the delivery of wave energy to the coast by increasing both fetch and the probability for the occurrence of wind-forced storm surge events.

This presentation will review the environmental context of coastal dynamics in the Laptev Sea and outline the potential of beach-ridge studies to further our understanding of Holocene coastal landscape evolution and regional climate forcing. Several beach-ridge sites were surveyed during two expeditions to Buor Khaya Bay in the southern Laptev Sea (Sander at al., 2019; Sander et al., in press) and provided first descriptions of the geomorphological, chronological, and sedimentary characteristics of such coastal depositional systems in the area. Our findings indicate that the post-glacial relative sea-level rise stabilized earlier than previously thought and that periods of substantial beach-ridge progradation were in the past limited to warmer-than-present climate conditions. Pronounced changes in progradation patterns are a conspicuous feature in the surface geomorphology of beach-ridge systems at several sites across the Laptev Sea. These unconformities suggest a non-linear coastal evolution over the Holocene, likely driven by changes in wave climate and/or sediment supply.

At each site, the timing and causes for change must be carefully investigated, but the analytical framework developed during these first studies is simple, precise, cost-effective, and likely applicable to most of the prominent beach-ridge systems in the area. These coastal sedimentary archives thus hold an underexplored potential to contribute to a better understanding of past environmental changes and long-term coastal dynamics in the Laptev Sea.

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Bacterial communities associated with acid sulphate soils in the sub-Arctic

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Keywords: Acid sulphate soil, bacteria, environment, geochemistry, geohazards.

In Finland and Sweden, the occurrence of acid sulphate soils has now been mapped for several years (in Finland since 2009). It has been shown that extensive areas are located on the coastal plains of Finland and Sweden but information about the presence of acid sulphate soils in the Barents region and Norway is still unknown. In the northern Baltic Sea areas, more metals are released into the environment from acid sulphate soils than from the entire industry. It is also well-known that in the Barents region of Russia, acid sulphate soils were formed due to acid rain from the 1930´s and have formed a major environmental problem.

Microbes play important roles in acid and metal release from the sulphate soils, but the extent or mechanisms of the environmental risks are poorly understood. Recently, it has been possible to study the structure and functions of diverse microbial communities by utilizing next generation sequencing and other modern molecular methods. The community structure or impacts of microbiota in geochemical processes of the acid sulphate soils as well as the sub-Arctic soils have not been investigated and the effect of low temperatures with long periods of sub-zero soil temperatures are poorly understood.

In the project 'Geo-Bio Hazards in the Arctic Region – HazArctic' (funded by the Kolarctic CBC, EU, Russia, Norway, Sweden and Finland), areal extension, mechanism and risk for oxidation of two kinds of environments are studied. Those factors can produce hazardously acid substances in: (1) man-made mining areas and (2) potentially hazardous sulphur-bearing Litorina sediments which can be oxidized due to descent of ground water level. In this presentation, particular focus is in the study of microbes' role in the bio-geo interaction in possible hazardous environments, both man-made mining areas and "natural" sulphur-rich fine-grained sediments. Research of the bio-geo interaction:

– Forms a link between bacterial community structures with geochemical factors in soil
– Investigate the role of different bacterial groups in acid production and metal dissolution from acid sulphate soils
– Identify novel bacteria linked to the oxidation of sulphides
– Provide the basis for future studies which will guide strategies to prevent threats to ecosystem health, food production and human exposure to metals.

Sedimentation History of the central Lena Delta, Northern Siberia

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Keywords: Lena River, sediments, Late Quaternary, Northern Siberia, permafrost.

Abstract

Climate change leads to permafrost thaw and environmental change in the Lena Delta, the largest Arctic delta. Determining the past and modern river regime of thick deltaic deposits blanketing the Lena mouth in northeastern Siberia is crucial for understanding the history of delta formation and carbon sequestration in the area and the formation of an Arctic sea ice cover as driven by the large Lena freshwater input to the Arctic Ocean. Several studies focused on reconstructing the Holocene Lena Delta history (Schwamborn et al., 2002; Bolshiyanov et al., 2015). Here, we propose three possible scenarios of the landscape depositional history, based on a new 65 m long core (SAM18-01) with coarse-grained (pebble-to-gravel) stratigraphy at the core bottom, which will reach further back in time. The core has been extracted close to the delta apex (Jongejans et al., 2019).

For reconstruction of the sedimentation history, the following depositional models are considered: (i) a standard model where a fluvial regime turns into a deltaic regime in the course of the sea level rise that reduces the gradient between the delta zero level and the erosional base in the hinterland; this process took place over thousands of years at the late Pleistocene/Holocene transition in the Laptev Sea (Bauch et al., 2001), (ii) a depositional model that this core contains cycles of sediment deposition; this could indicate changing source areas or changing sedimentation rates, (iii) a model connected to hinterland glaciation processes as the bottom core part may represent till sheet deposits possibly pointing to glaciation events in the Siberian hinterland back to 200.000 years (Spielhagen et al., 2004).

Using the new sediment record, this study applies a set of cryolithological techniques. These include (i) tracing petrographic changes of the bedload composition based on modal analysis, (ii) XRF and XRD analysis to track bulk sediment mineral changes, (iii) heavy mineral analysis to track sediment provenance change of the sand component, (iv) $\delta^{18}O$ and δD stable isotope composition from ground ice for detecting changes of water types and in the permafrost history, (v) ^{14}C-AMS dating for constructing an age model from organic detritus, (vi) and quantification of total organic carbon for establishing organic carbon burial estimates depending on stratigraphy. Based on the available data the presentation highlights preliminary conclusions.

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Past, present and future sea-level change in the Russian Arctic

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Keywords: Sea-level change, Russian Arctic, Glacial Isostatic Adjustment, tide gauges, projections.

Understanding relative sea-level (RSL) changes driven by global, regional, and local processes that vary in space and time are important to accurately constrain future projections and their uncertainty. In the Russian Arctic, RSL changes since the last glacial maximum (LGM; ~26 ka BP) are spatially variable and driven primarily by glacial isostatic adjustment (GIA) due to the proximity to the former Eurasian ice sheet complex. Here we present a short review of past, present and future RSL change in the Russian arctic using RSL data from a quality-controlled database (Baranskaya et al., 2018), GIA model RSL predictions (Peltier et al., 2015), instrumental measurements and probabilistic future projections (Kopp et al., 2014).

Past sea levels in the western Russian Arctic (e.g., Barents Sea) located underneath ice at the LGM show RSL falling from ~60 m at 10 ka BP to ~10 m at 4.5 ka BP at 9.1 mm/year and driven by postglacial uplift. In the eastern Russian Arctic in regions located outside the former ice sheet margin (e.g., Laptev Sea) at the LGM, RSL rose from -22 m at 10 ka BP to a ~2 m highstand at 6.5 ka BP at 6.8 mm/year and driven by ice-equivalent sea-level rise.

Present sea levels in the Russian Arctic derived from tide-gauges continue to reflect spatially variable GIA. Tide-gauge data from Polyarniy (under ice at LGM) shows RSL falling 0.12 mm/year from 1926 CE to 1989 CE, whereas sea-level trends from Dunai (outside ice at LGM) show RSL rising 0.23 mm/year from 1951 CE to 2010 CE. Satellite altimeter observations have supplemented tide-gauge measurements since 1993 revealing spatial variability at annual to decadal scales driven by atmosphere/ocean dynamics.

Future sea levels at Polyarniy show RSL by 2100 under RCP 2.6 is projected to rise 14 cm while RSL by 2100 under RCP 8.5 is projected to rise 38 cm. At Dunai, RSL by 2100 under RCP 2.6 is projected to rise 38 cm, while RSL by 2100 under RCP 8.5 is projected to rise 71 cm. The melting of the Greenland ice sheet and nearby glacial ice will combine to cause projected RSL magnitudes lower than the global mean due to static equilibrium effects. Furthermore, magnitudes of RSL change will also likely be exacerbated due to uncertainty associated with ice sheet dynamics.

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Freshwater and riverine input in Arctic system: insight from biomarker proxy

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Keywords: Biomarker, Freshwater, Organic matter, Arctic Ocean, river input.

Studies have shown that Arctic sea ice variability conditions influence the earth's energy budget by affecting its albedo (Rudels et al. 1996; Holland & Bitz, 2003; Serreze & Francis, 2006) and global ocean circulation (Dieckmann & Hellmer, 2010). To understand the Arctic sea ice distribution, we need to first understand its behavior during varying environmental and climatic conditions. One of the factors that affects the sea ice and Arctic ocean surface water conditions is freshwater and riverine input into the Arctic pool from different sources (Aagaard & Carmack, 1989; Fahl & Stein, 1999). The shelves near major riverine sources of the Arctic circle can be used as the ideal locations to study various processes like sea ice distribution and production and flow of freshwater and terrigenous matter. The proxy which I would like to use to accomplish my objectives of identifying the organic carbon sources (marine, terrigenous or aquatic) and sea ice extent would be compound specific organic geochemical tracer known as biomarkers which has already been well established as a paleo environmental tracer in mid and low latitude open ocean areas. I would like to start the study by measuring bulk parameters i.e. TOC and C/N ratio and then will move towards the compound specific biomarkers which are n-alkanes and GDGT to understand the organic matter source and the use of IP_{25} to understand the sea ice extent (Belt et al., 2007). This multi-proxy biomarker analyses could give us a better insight of relation between sea ice extent and riverine inflow and give us an understanding of global ocean water circulation.

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Applications of unmanned aerial vehicle (UAV) surveys and Structure from Motion photogrammetry in glacial and periglacial geomorphology

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Keywords: Glacial geomorphology, Paraglacial geomorphology, Unmanned aerial vehicle, Mapping, Drone.

Unmanned aerial vehicles (UAVs, UAS, drones) combined with Structure-from-Motion (SfM) photogrammetry have emerged over the last decade as the basis for a very efficient workflow in glacial and periglacial geomorphology by filling the spatial gap between traditional ground-based surveys and aerial or satellite remote sensing data. UAV-generated data offers flexible spatial and temporal resolution, thus enabling a shift from a pure description of geomorphological forms to a better understanding of process-form relationships, e.g., by quantification of short-term landscape changes in response to various drivers. In this study, we presented a review of recent applications of UAV and SfM in the field of glacial and periglacial geomorphology, which revealed the following information:

1) Diverse research topics (mainly geomorphological mapping and geomorphological change detection analysis) and an increase in the number of publications in 2020 (22 papers) prove the enormous usefulness of this method and its growing popularity.

2) Most of the studies were conducted in the Arctic and the Alps, with a smaller number in Antarctica, Himalayas, Andes, and Alaska. The popularity of the Arctic (especially Svalbard and Iceland) and the Alps should come as no surprise. Climate changes, resulting in an increase in the average air temperature, tend to cause dynamic reactions in the glacial and periglacial landscape. The Arctic is also a natural "field-based laboratory" – the effects of climate change in the Arctic are much more intense than in other regions. Therefore, we can use Arctic-based observations to infer about the future effects of climate warming in other areas, i.e., we may use the results of detailed quantification of processes in Arctic settings to speculate about the magnitude of future geomorphological changes in the lower latitudes.

3) In most cases, the study area did not exceed 1 km^2, but some observations were also made of the entire glacial foreland. Multi-rotors were the most popular type of UAV used. In nearly all publications, RGB images were used to develop orthomosaics and DEMs with a spatial resolution from 0.02 m to 0.20 m. Most of the operators used an autonomous flight mode.

The presented overview highlights the utility of UAVs for obtaining images, which can be used to develop high-resolution orthomosaics and DEMs, thereby enabling a detailed geomorphological mapping as well as a precise identification of their morphological characteristics - that would not be possible using other remote data sources. As to the multi-temporal surveys, increased research interest on the process-form relationship is expected, and a significant contribution to this type of research could be made through the more widespread use of a combination of UAV-based images with ground photogrammetry and archival aerial images.

This study was funded by Narodowe Centrum Nauki (National Science Centre, Poland), grant number 2019/35/B/ST10/03928.

Low salinity in the western Fram Strait (79°N) at 12.7 - 10.2 ka related to NE Greenland continental shelf deglaciation

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Keywords: Fram Strait, Northeast Greenland, deglaciation.

Sediment core PS93/031-5 from the NE Greenland continental margin (79.3°N, 3.5°W, 2135 m water depth) has been analyzed to reconstruct the Late Quaternary environmental history in the western Fram Strait and the deglaciation of the adjacent NE Greenland shelf. The core was investigated for grain sizes, sediment composition (by XRF core scanning), the lithological composition of ice-rafted debris (IRD >250 µm), and stable oxygen and carbon isotopes of planktic and benthic foraminifers. The age model is based on seven radiocarbon datings which cover the interval between 21 and 4 ka, with a hiatus between 18.6 and 12.7 ka. Of particular interest is a 10 cm thick, fine-grained, laminated section deposited 12.7-10.2 ka. According to the dating results, the lower part of this section may have been deposited within only one or two decades. Stable isotopes measured on two morphotypes of planktic foraminifers *Neogloboquadrina pachyderma* from the laminated interval suggest that near-surface salinities at site PS93/031 decreased during a strong freshwater event by up to 4-5 practical salinity units, if compared to the last glacial maximum and the early/middle Holocene (10.2-4 ka). While the IRD composition is dominated by quartz and feldspar grains (>75 grain-%) throughout the core, the laminated section shows a characteristic increase in fragments of sedimentary rocks which may be derived from the Paleozoic foldbelts and basins in NE Greenland. This is supported by characteristic changes in the elemental composition derived from XRF core scanning.

The NE Greenland shelf morphology is characterized by two major troughs which were formed during the glacial(s) by continental ice mainly fed by the North-East Greenland Ice Stream. Our results may indicate a two-phase retreat of the ice sheet margin on the shelf during the last deglaciation. The first ice front recession recorded in our core occurred before 12.5 ka (onset unknown) and resulted in a strong export of freshwater and fine-grained sediments through the (northern) Westwind Trough towards the continental margin. Benthic foraminifer isotope data from the laminated section suggest reduced bottom water salinities, possibly from the sinking of sediment-laden water plumes at the trough mouth and the southward transport by bottom currents of low-saline waters and sediments along the margin. During the younger part of the deglaciation (ca. 12-10 ka) the ice recession was possibly slower (as indicated by lower sedimentation rates at site PS93/031) and/or the sediment transport occurred mostly southward through Norske Trough. The freshwater event at the continental margin ceased when the ice sheet margin reached the modern coastline.

Has the Svalbard archipelago reached a climate tipping point? Evidence from an ice core study

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Keywords: Svalbard, ice core, climate, tipping point.

The Arctic as a whole is undergoing faster warming than the rest of the world. The Svalbard archipelago is particularly sensitive to temperature increases due to the moderate altitude of the main ice fields and its geographical position on the Atlantic storm track. Though the greatest temperature increases have been observed during winter, enhanced summer temperatures are also increasing in time and altitude, enlarging the areas affected by melting. In 2012, 2015, 2017 and 2019 four shallow cores were recovered from the top of the Holthedalfonna ice field (1100 m a.s.l.) to study the response of specific geochemical parameters (in particular $\delta^{18}O$) to the rapid warming in the higher North Atlantic. The high-resolution climate signal obtained from these four shallow cores covers the period from 2003 to 2018 and can be used in complement with a longer ice core record (124 m deep) collected in 2005 at the same location to provide a context for climate change in the Arctic extending back to the 17th century. In our combined record, we observe a more negative $\delta^{18}O$ signal, starting from 2005/2006, although the opposite was expected since the Svalbard annual atmospheric temperatures are increasing. Comparing the $\delta^{18}O$ composite record with Svalbard meteorological and oceanic measurements, sea ice cover, glacier mass balance, as well as biological processes we have discovered that several parameters\ phenomena changed in the period between 2004 and 2006. This might be the first time that a climate shift and its effect of the environment and atmospheric processes, have been determined in the Arctic and could indicate that a tipping point have been crossed.

Record of sea-level change, fluctuations of sea-ice and post-glacial landscape transformation extracted from Svalbard beach ridge plains – case study of Bjonapynten, Svalbard

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Keywords: Beach-ridge, coastal evolution, sea-level change, Holocene, Svalbard.

Uplifted beaches are characteristic features of coastal Svalbard, apart from serving as natural indicators of past shorelines, have been used to detect changes in sediment supply, sea-ice duration, or storminess. Here, we present a detailed record of Holocene relative sea-level changes, fluctuations of glaciers and sea-ice and development of frozen ground conditions over the Holocene period preserved in a Svalbard coastal deposits. Our study is based on the beaches of Bjonapynten cape in central Spitsbergen, one of the best-preserved beach-ridge systems in the Arctic. Precise shell-based radiocarbon dating revealed that the formation of raised beach sequence progressed through three major phases of relative sea-level change. Firstly, sea level rapidly fell from about 42 m a.s.l at 10.8 cal kyr BP to 32 m a.s.l at 9.2 cal kyr BP. Secondly, another rapid sea level drop sea level occurred and later on sea level fall was more gradual and reach close to present by 2.2 cal kyr BP. Internal structure of uplifted beach examined through ground penetrating radar showed that beach system sedimentation was dominated by continuous swash accretion of sediment under fair-weather conditions. Variations in ridge-swale architecture were controlled by changes in the duration of sea-ice cover and distance to advancing or retreating tide-water glaciers in the fjord system. We found that during warmer (sea ice-free) phases of the Holocene (Early-Holocene) beach ridges were formed almost two-times faster than in cooler conditions. Warmer climates of Early and Mid- Holocene were also favourable for supplying beach ridge plain progradation with sediments from deglaciated slopes and reworked glacial landforms. With climate cooling, starting ca. 5 cal. kyr BP, sediment supply was reduced and occurred only during short melt-out seasons. Late Holocene cooling was marked by the development of permafrost which creeped down from extensive talus slopes and dissected beach ridges by frost fissure polygons.

The reconstructed postglacial relative sea level history and detected shifts in sediment supply add valuable information to the postglacial landscape reconstruction studies of Svalbard Archipelago.

This is a contribution to National Science Centre project: *'ASPIRE - Arctic storm impacts recorded in beach-ridges and lake archives: scenarios for less icy future'* (UMO-2020/37/B/ST10/03074).

Last century sediment accumulation rates in fjords of Svalbard (Arctic) – underrated hot spots for organic carbon burial

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Keywords: Fjords, tidal flat, sedimentation rate, ^{210}Pb and ^{137}Cs dating, glacimarine sedimentation.

The Svalbard region is particularly sensitive to global climate changes as proved by modern monitoring data and past records. One of the most evident effects is the rapid retreat of glaciers during the last century observed in most fjords in Svalbard. The retreat has resulted in changes in fjord shapes, formation of new coasts (e.g., Strzelecki et al., 2020), alteration of sediment delivery and accumulation rates (e.g., Szczuciński et al., 2009). The goal of this study is to provide a review of the existing sediment accumulation rate assessments (104 records) in fjords of Svalbard based on short-lived radionuclides (^{210}Pb and/or ^{137}Cs-based) and supplemented with new data (65 sediment cores) from high accumulation rate sites in inner Hornsund fjord (southern Spitsbergen), as well as from intertidal zone of fjord-head delta in Petuniabukta (Billefjorden, central Spitsbergen). Application of ^{210}Pb and ^{137}Cs short-term radionuclides allows for comparison of sediment accumulation rates in the same time scale (c. 70 to 100 years). The results prove the sediment accumulation rate to be in the order of several mm to several tens of cm per year. Because most of the previous studies focused on central parts of the fjords, the high sediment accumulation rate areas (hot spots) – in fronts of tidewater glaciers and on inner fjord delta slopes, are generally understudied. However, the total mass accumulation rate calculations revealed that, despite the smaller surface area, these hots spots accumulated several times more sediments than the remaining parts of the fjords. In consequence, the total amount of sediment stored in the fjord is much bigger than previously assessed, as well as higher is the carbon burial rates. The available data suggest that this kind of fjords may serve as significant sediment and carbon sinks, largely exceeding other polar marine environments. The study was funded by Polish National Science Centre grant No. 2013/10/E/ST10/00166.

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A new long record of the Pleistocene glacial/interglacial environmental variability in the Amerasian Arctic Ocean (Mendeleev Ridge)

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Keywords: Stratigraphy, paleoceanography, Pleistocene, Mendeleev Ridge, Arctic Ocean.

Pleistocene sediment sequences of the semi-enclosed Arctic Ocean record variations in ice sheets extent on surrounding continents and related sea-level fluctuations, changes in sea ice cover and bioproductivity, as well as interactions with waters from surrounding oceans. We present here the results of a multiproxy-based investigation of core KD12-03-10C (79°27,75' N, 171°55,08' W, water depth 2200 m) from the Mendeleev Ridge that contains calcareous microfossils throughout its 575 cm long sediment sequence. Lithological (grain size, ice- and iceberg-rafted debris (IRD) counts), planktic $\delta^{18}O$ and $\delta^{13}C$ records of *Neogloboquadrina pachyderma* sin. and *Turborotalita egelida*, micro- and macrofossils (planktic and benthic foraminifers, ostracods, molluscs, cirripeds, polychaets) data are constrained by four AMS^{14}C datings from the uppermost 24 cm aging back to MIS 1-3. Downcore alternation of nine IRD peaks (corresponding to glacials and glacial terminations of MIS 15/16-16, MIS 11/12-12, MIS 9/10-10, 2 peaks during MIS 7-8 ("compressed" stratigraphy and highest IRD concentration), MIS 5/6-6, MIS 5d, MIS 3/4-4, MIS 1/2) and several peaks in the abundance of planktic and benthic fossils together with the changes in species composition and the occurrence of stratigraphic index-species give evidence for temporally consistent sediment accumulation. The lower IRD-free sediment unit older than MIS 16 (450-575 cm) characterizes mild climatic conditions with seasonal sea-ice cover and high bioproductivity. Similar environments are assumed for the interglacial of MIS 11 distinguished by the dominance of subpolar symbiont-bearing planktic foraminifer *T. egelida*. Since MIS 11, cooling trend is reflected by enhanced amplitude of $\delta^{18}O$ and $\delta^{13}C$ variations, changes in microfossil assemblages pointing to more permanent sea-ice cover together with the stronger influence of the North Atlantic deep waters, and increase in the share of carbonates from the Laurentide ice sheet among the IRD.

Paleomagnetic study of the same core (Piskarev & Elkina, 2017) gave contradictory age estimations with the Bruhnes-Matyama boundary at 123.5 cm core depth, in the layer that we date back to the end of MIS 7. They also claim that they have found 5 tephra-bearing layers, with the one at 170-175 cm originating from an eruption that formed a giant caldera on the Gakkel Ridge about 1000 km away from the studied site. Based on paleomagnetic data, the age of this eruption is 1.1 Ma. We analyzed >63 µm fraction from the same 5 sediment intervals using JEOL JXA 8200 electron microprobe and were not able to identify in any of them either a single glass shard or any glass coating on minerals. None of the phases analyzed have unequivocally volcanic origin. The mineral assemblage is rather typical for terrigenic material sourced from granitic rocks. Hence, the Gakkel caldera eruptions around 1.1 Ma remain elusive.

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Relative sea-level changes since the Last Glacial Maximum and Glacial Isostatic Adjustment in the Russian Arctic

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Keywords: Glacial Isostatic Adjustment, Sea-level change, Russian Arctic, Heterogeneity, Viscosity.

Relative sea-level (RSL) data, spanning the Last Glacial Maximum (LGM) to present, reveal the vertical land motion and provide important constraints to Glacial Isostatic Adjustment (GIA) models. The Russian Arctic is an essential region for the study of GIA because it was covered by a large ice sheet at the LGM. However, few GIA studies have been conducted in this region due to the lack of high-quality RSL data. The GIA and its uncertainties are important components for future sea-level projections.

We have recently-released a quality-controlled RSL database from the Russian Arctic (Baranskaya et al., 2018). The database consists of 359 sea-level index points from isolation basins, raised beaches and marine terraces, deltaic salt marshes (laidas), and transgressive contacts in columns of bottom marine sediments, 78 marine limiting dates from in situ marine mollusc shells or sediments containing marine diatoms and foraminifera and 92 terrestrial limiting dates from autochthonous freshwater peat, as well as alluvial, lacustrine, boggy, and aeolian deposits. RSL fell rapidly in the western Russian Arctic (Barents and White seas) during the Holocene due to the deglaciation of the Eurasian ice sheet complex. In contrast, RSL rose constantly along the Timan coast and Kara Sea shelf due to proglacial forebulge collapse. Data from the Laptev Sea coasts and shelf and the New Siberian islands demonstrate deglacial RSL rise with a mid-Holocene highstand.

We compare the RSL database from the Russian Arctic with 1D and 3D GIA models. The RSL predictions of the 1D models ICE-6G_C (VM5a) (Peltier et al., 2015) and ICE-7G_NA (VM7) (Roy & Peltier, 2017) are found to well fit the deglacial RSL data along the southern coast of Barents Sea and on Franz-Josef-Land, but notable misfits are evident in the White Sea region. We find 3D model predictions (with a fixed ice model) improve the fits in White Sea while retaining comparable fits in other regions. Similarly, via tuning the ICE-7G_NA ice model in the White Sea area (with a fixed Earth model), we can improve the fits with the deglacial RSL data in the White Sea. The comparable fits of the best-fit 3D model and the ICE-7G_NA (VM7) model with locally modified loading history to the deglacial RSL data implies that the uncertainty in the ice model might be improperly mapped into 3D viscosity structure when a fixed model of deglaciation history is employed. We conclude that the uncertainty in ice model and correlation/interaction between the ice and Earth models need to be considered carefully in future GIA studies.

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Ventilation history of the Nordic Seas deduced from planktic and benthic radiocarbon ventilation ages

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Keywords: Ocean circulation, foraminifera, Nordic Seas, deglaciation, radiocarbon.

Changes in Earth's climate over the last deglaciation were largely driven by shifts in ocean circulation. We present a comparison of four subsurface and bottom water radiocarbon ventilation age reconstructions from the central and southern Nordic Seas, an area particularly suitable to reconstruct changes in the Atlantic Meridional Overturning Circulation. The planktic records reach up to 2000 years and exhibit significant spatial and temporal diversity suggesting that the ventilation of subsurface waters was influenced by local conditions such as e.g., sea-ice and meltwater input, changes in mixed-layer depth and/or changing contributions of water masses with different ^{14}C signatures. Benthic records, despite covering a significant depth range (1000-3000 m), show a common general pattern, with weaker ventilation during Heinrich Stadial 1 and the Younger Dryas and stronger during the Bølling-Allerød and the Holocene. They reflect regional shifts in overturning circulation and suggest that the deep Nordic Seas have been generally bathed by a single water mass. Taking into account significant offsets in ventilation ages between different benthic species, we recommend using possibly narrow taxonomic or ecological groups of benthic foraminifera to reconstruct past bottom water ventilation. This study was supported by grant no. 2016/21/D/ST10/00785 funded by the National Science Centre, Poland.

Atlantification along the Fram Strait at the beginning of the 20th century driven by Subpolar-Polar connections

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Keywords: Atlantification, Fram Strait, AMOC, biomarkers, foraminifera.

Sea ice loss and expansion of Atlantic waters into the Arctic Ocean are considered as the preeminent examples of the recent changes occurring in the Arctic. This phenomenon, generally known as "Atlantification", is however poorly investigated in pre-industrial times. Here, we combined a robust chronology with biomarkers and microfaunal data to reconstruct the Atlantification at the gate of the Arctic Ocean (Kongsfjordern, Svalbard; Fram Strait). We found that the Atlantification began in the early XX century, much earlier than the modern documented changes. Our results suggest that the heat transport to the Fram Strait suddenly increased in the early XX century because of reduced surface heat loss at subpolar latitudes which, eventually, initiated the Atlantification. Overall, our study provides the first historical perspective on the Atlantification and reveals Subpolar-Polar connections, much stronger than previously thought, which are capable of shaping the Arctic climate variability. The signs of Atlantification documented in this study are currently not reproduced in climate simulations participating in the Climate Model Intercomparison Project Phase 6 (MIROC-ES2L and MRI-ESM2.0). Overall, this implies an incomplete process understanding of climate forcing during the industrial era.

Modern patterns in sedimentary Fe and Mn cycling within the Eurasian Arctic margin and implications for the interpretation of the Arctic sedimentary record

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Keywords: Biogeochemistry, Barents Sea Slope, Yermak Plateau.

Sediments rich in manganese (Mn) create brown layers that have been used for stratigraphic correlation in paleoceanographic studies in the Arctic, where other means of correlation may be limited (Löwemark et al., 2014; März et al., 2011). In some regions of the Arctic, these brown layers are also enriched in Fe, whereas in others, distinct orange, Fe-rich sediments have been identified (Tessin et al., 2017). To understand and interpret these sedimentary records, it is necessary to constrain modern Arctic Fe and Mn cycling. Here, we present evidence of Fe and Mn cycling within the Eurasian margin region of the Arctic Ocean that separates the archipelago of Svalbard from the open Arctic Ocean basin (Tessin et al., 2020). We use paired sediment and pore water geochemistry to investigate spatial and downcore patterns of Fe and Mn in nine locations spanning the northern Svalbard continental slope, the Sophia Basin, and the Yermak Plateau from materials collected on the TRANSSIZ cruise (PS92) in 2015. Our results indicate that Mn and Fe are remobilized in northern Barents Sea slope sediments underlying seasonally ice-free waters. In contrast, Fe and Mn are not remobilized from Yermak Plateau and Sofia Basin sediments, which experience more permanent ice coverage. These regional patterns are best explained by the spatial distribution of primary productivity and organic carbon flux to the seafloor, and the subsequent diagenetic dissolution of Fe and Mn (oxyhydr)oxides. This work adds to the context for evaluating metal oxide enrichments in the Arctic marine sedimentary record, highlighting the significant spatial variability that these records can exhibit in response to carbon export patterns.

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Glacier dynamics, deglaciation history and sedimentary processes in Recherchefjorden, Svalbard

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Keywords: Submarine landforms, sediment cores, glacier dynamics, Recherchefjord, Svalbard.

Many glaciers on Svalbard advanced considerably during the Little Ice Age (LIA) depositing large terminal moraine ridges (Svendsen & Mangerud, 1997).

However, a number of recent studies suggest that the pre-LIA advances were more extensive than previously thought and that occasionally multiple advances/surges occurred at fjord-terminating glacier margins (Noormets et al., 2021). Consequently, the LIA advances of glaciers were often constrained by the prominent pre-existing terminal moraines.

In this study, bathymetric, subbottom acoustic, and sediment core data are used to investigate the dynamic glacial history of Recherchefjorden. The new bathymetric and subbottom acoustic data show that a approx. 10 km long and 4.5 km wide fjord is constrained by a sill at its mouth and is divided into a lager outer and smaller inner basin by a large transverse moraine ridge. Paintings from 1839 made during the La Recherche Expedition illustrate that the Recherchebreen glacier margin reached the location of the transverse moraine at that time. This moraine has been suggested to be from LIA (Moskalik et al. 2018).

A sediment core, collected in the inner basin, consists of diamict in the bottom, covered by generally upwards fining, mixed-sandy-silty layer, overlain by mud at the top suggesting decreasing glacial influence with possibly some turbulent sedimentary environment associated with the Recherchebreen glacier margin activity during the deposition of the mixed layer. Detailed bathymetric data reveal several debris flows on the distal flank of the large moraine ridge and numerous small ridges in its crest and in the inner basin supporting the dynamic deglaciation of the inner fjord with the glacier margin potentially reaching the large transverse moraine multiple times during the Holocene.

Radiocarbon ages of mixed foraminifera from the sediment cores that are currently being analysed will hopefully provide an age model for the palaeoenvironmental reconstruction and glacier activity in Recherchefjorden in the Holocene.

The glacier became land-based around 1900 and it had a surge in 1960 reaching the coastline. Currently, the glacier is undergoing a surge that started in 2019.

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Paleoenviromental changes during the last 2 ka BP in the Eastern Side of Fram Strait

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Keywords: Micropaleontology, Fram Strait, 2 ka BP, paleoenvironmental changes.

Polar regions regulate the climate through the heat exchange between ocean and atmosphere, the sea ice formation or melting, and bottom water formation. Lately, the scientific community has been focusing on the study of the last 2000 years. This interval gives information about climate natural variability versus change induced by human activity. Moreover, the studies of environmental changes recorded in this period offer the possibility to understand how our climate may evolve in the near future. This study is focused on the last 2 ka BP and has the aim to understand the paleoenvironmental variations in the eastern side of Fram Strait, through multidisciplinary micropaleontological and sedimentological analyses, focussing on the diatom assemblages. Two long Calypso cores GS191-01 PC (19.68 m) and GS191-02 PC (17.37 m) were collected on the Bellsund and Isfjorden Drift, during the expedition of RV G.O. Sars (5th–15th June 2014), in the framework of the project Eurofleets-2 PREPARED. Here we present the study of the first 80 cm for core GS191-01PC and the first 18 cm for core GS191-02 PC corresponding to the last 2 ka years BP. The investigated sedimentary sequence is dominated by muddy, bioturbated sediments with very rare/sparse IRD (Ice Rafted Debris). The Diatom assemblage was analysed every 2-cm, corresponding to a resolution of 30 years for GS191-01PC and at every 1-cm in core GS191-02PC, corresponding to a resolution of 126 year. On the basis of the age model proposed by Caricchi et al. (2019), the multi-proxy analyses on the diatoms and foraminifera assemblages, and sedimentological data, allowed us to distinguish in the record four different climatic periods indicated as Units.

Unit A (2000 - 1500 cal yr BP) is the older, and indicates relatively warm conditions, suggesting the influence of warm water with a cooling period between between 1800 to 1700 cal yr BP, characterized by increased sea ice coverage and the presence of cold water masses.

In unit B (1500 - 1300 cal yr BP) is period of cooler conditions compared with the previous one, and it is characterized by the presence of extended sea ice and a minor inflow of the warm water.

Unit C (1300- 700 cal yr BP) records a warming surface water with presence of freshwater of continentally origin. Unit C ends with the worsening of climatic conditions characterized by a progressive cooling.

Unit D (700 cal yr BP to recent) represents a cooling period characterized by extended sea ice coverage and an increased distribution of cold-water taxa.

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Testing micro- and nannofossil bioevent correlations in the central Arctic Ocean: is the Pleistocene biostratigraphy consistent?

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Keywords: Arctic Ocean, Biostratigraphy, Foraminifera, Pleistocene.

The limited diversity and poor preservation of micro- and nannofossils in the central Arctic Ocean make age-modelling for Quaternary palaeoclimate reconstructions challenging. Cyclostratigraphy using lithologic variability tied to relatively poorly calibrated foraminifera biostratigraphic events has been the dominant tool for developing Pleistocene age models. Recently, the coccolitophore *Pseudoemiliania lacunosa*, which went extinct during marine isotope stage (MIS) 12 (478-424 ka), was identified in a sediment core from the Lomonosov Ridge. Together with the identification of the coccolithophore *Emiliania huxleyi*, which evolved during MIS 8, the glacial-interglacial units in this core could be delineated back to MIS 14 (~500 ka BP) based on these nannofossil findings. Here we compare this new nannofossil biostratigraphy with the foraminifer biohorizons that are recognised in central Arctic Ocean sediments. The foraminiferal composition and lithologic variability of a new core from the Alpha Ridge are presented. The core contains an interval dominated by *Turborotalita egelida*, a planktonic foraminifer that is increasingly being adopted as a marker for MIS11 in sediment cores from the Amerasian Basin of the Arctic Ocean. Our results show that a MIS 11 age for the *T. egelida* horizon is hard to reconcile with the new age-constraints provided by the nannofossil biostratigraphy. Instead, the emerging bio- and lithostratigraphy implies that Amerasian Basin sediments predating MIS 6 are older than currently assumed, and that the *T. egelida* horizon predates MIS11. These results thus point out the age uncertainty of glacial-interglacial units in the Amerasian basin predating MIS 6, and show that future work should reconcile the micro- and nannofossil biostratigraphy of the Amerasian and Eurasian basin.

Postglacial opening of Vilkitsky Strait and its paleoceanographic impact on Kara and Laptev seas

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Keywords: Palaeoceanography, Kara Sea, Laptev Sea, Vilkitsky Strait, Holocene.

Today Vilkitsky Strait (VS) acts as the major pathway for surface water inflow from the Kara Sea into the Laptev Sea. Relatively fresh water, primarily sourced from large rivers such as Ob and Yenisey, is thereby transported via the Vilkitsky Strait Current (Janout et al., 2015).

In this study we investigate the development of the regional paleoceanography using a multi-proxy approach, including AMS^{14}C dating, carbon and oxygen isotopes, grainsize analysis, IRD counts and the analysis of benthic foraminifers, ostracods, pollen and aquatic palynomorphs. The study is based on sediment core AMK5636, which was taken from 225 m water depth within the VS and covers the past 14 ka.

The early part of the record is characterized by a transition from a foraminiferal assemblage with Atlantic Water indicative species *Cassidulina neoteretis* prior to 13 ka, through the almost fossil-barren interval (13-12.5 ka) to an assemblage dominated by the opportunistic species *Elphidium clavatum* (12.5-12.2 ka) and *Cassidulina reniforme* (since 12.2 ka). The occurrence of vivianite concretions within the fossil-barren interval suggests a strong water stratification caused by enhanced freshwater influence at that time. These early changes were likely related to the initial opening of VS caused by the rising regional sea level (cf. Bauch et al., 2001).

Between 12.5 ka and 7 ka relatively high values of δ^{18}O and low values of δ^{13}C together with high values in Total Organic Carbon in the sediment indicate conditions with increased surface water productivity and reduced sea ice cover. Rising concentrations of freshwater algae (*Botryococcus braunii, Pediastrum boryanum*) indicate a growing contribution of the freshened Kara Sea surface waters.

From around 7 ka a strong decrease in sedimentation rate, lighter δ^{18}O values, heavier δ^{13}C values, a higher diversity among aquatic palynomorphs and the reoccurrence of C. *neoteretis* indicate a return to more marine conditions in combination with a more severe sea-ice regime and brine formation.

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Geomorphology, hydrology, and chronology of Holocene jökulhlaups along the Hvítá River, Iceland: implications for Icelandic Ice Sheet dynamics

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Keywords: Jökulhlaup, paleoflood, geomorphologic mapping, hydraulic modelling.

Glacial outburst floods (jökulhlaups) have occurred across Earth throughout the Quaternary, often leaving a geomorphologic, sedimentological, and climatic legacy that extends far beyond the source region and can persist for millennia. Furthermore, they pose an increasing geohazard in glaciated landscapes worldwide due to climate-driven ice retreat. Iceland experiences more frequent jökulhlaups than nearly anywhere on Earth, though most research focuses on floods triggered by subglacial volcanic and geothermal activity. However, abundant geomorphologic evidence also exists for non-volcanogenic floods from proglacial lakes, which may serve as a better analogue for most global jökulhlaups and help reconstruct Icelandic paleoclimate and ice sheet dynamics.

As the Icelandic Ice Sheet retreated across Iceland in the Late Pleistocene-Early Holocene, meltwater lakes formed at ice margins and periodically drained in jökulhlaups. Some of the most catastrophic floods drained from ice-dammed Glacial Lake Kjölur, surging across southwestern Iceland from the interior highlands to the Atlantic Ocean. These floods left extensive geomorphologic evidence along the modern-day course of the Hvítá River, including canyon systems, scoured bedrock, boulder deposits, and Gullfoss—Iceland's most famous waterfall. The largest events reached an estimated peak discharge on the order of 10^5 m^3 s^{-1}, ranking them among the largest known floods in Iceland and on Earth. Yet, all our evidence for the Kjölur jökulhlaups comes from only one publication from a quarter-century ago (Tómasson, 1993).

This project employs a combination of field, modelling, and geochronological methods to better constrain flood timing and dynamics at this underexplored site. This talk synthesizes geomorphologic field mapping, HEC-RAS hydraulic simulations and paleohydraulic calculations, and cosmogenic nuclide exposure dates to reconstruct Kjölur jökulhlaup routing, hydrology, and chronology. It situates these events within the context of Pleistocene-Holocene Icelandic Ice Sheet retreat and existing paleoenvironmental records, presenting a series of scenarios of ice margin positions and glacial lake locations. Finally, it assesses the Kjölur jökulhlaups as an analogue to contemporary glacial outburst floods in other Arctic and alpine regions in terms of flood frequency, dynamics, and landscape impact.

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Ancient permafrost of the Batagay megaslump (East Siberia) – first insights into chronostratigraphy

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Keywords: Permafrost, chronology, western Beringia, Batagay megaslump.

Age information from ancient permafrost is key for understanding permafrost formation, stability and decay, and allows for interpreting past climate and environmental conditions over Pleistocene timescales. However, reliable permafrost geochronology is challenging, especially for deposits beyond the radiocarbon dating limit at about 50,000 years before present.

The headwall of the world's largest retrogressive thaw slump at Batagay in the Yana Upland, East Siberia (67.58 °N, 134.77 °E), exposes four generations of ice and sand–ice (composite) wedges that formed synchronously with permafrost aggradation (Opel et al., 2019). The exposed Batagay stratigraphy separates into a lower ice complex that is covered by a lower sand unit, an upper ice complex and an upper sand unit. Two woody beds below and above the lower sand are remarkable (Murton et al., 2017).

We apply four dating methods to disentangle the chronology of the Batagay permafrost archive: optically-stimulated luminescence (OSL) dating of quartz and post-infrared infrared stimulated luminescence (pIR-IRSL) dating of K-feldspar as well as accelerator mass spectrometry-based Cl-36/Cl dating of wedge ice and radiocarbon dating of organic material (Murton et al., under review). All four chronometers produce stratigraphically consistent and comparable ages. However, OSL appears to date Marine Isotope Stage (MIS) 3 to MIS 2 deposits more reliably than pIR-IRSL, whereas the latter is more consistent with Cl-36/Cl ages for older deposits.

The age information obtained so far indicates that the Batagay permafrost sequence is discontinuous. The lower ice complex developed at least 650,000 years ago, potentially during MIS 16 and represents the oldest dated permafrost in western Beringia and the second oldest known ice in the Northern Hemisphere. The age of the overlying lower sand is poorly constrained, indicating formation some time during MIS 16–4. The upper ice complex formed during MIS 4–2 and the upper sand during MIS 3–2, respectively. Thus, the ancient permafrost at Batagay potentially provides one of the longest terrestrial records of Pleistocene environments in western Beringia.

Additional sampling for all dating approaches presented here took place in spring 2019, and is part of ongoing research to enhance the geochronology of the exceptional palaeoenvironmental archive of the Batagay megaslump.

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MIS 2 extraglacial sedimentary environment in the Vychegda - Severnaya Dvina fluvial system: proglacial lakes, rivers, and wind

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Keywords: Last Glacial Maximum limits, southeastern flank, proglacial lake, alluvial and aeolian sedimentary pattern.

The MIS 2 maximal glacial boundary of the southeastern sector of the Scandinavian Ice Sheet (SIS) along with the interpretation of the MIS 2 sedimentary environments in the Severnaya Dvina River basin are highly debatable and controversial (Zaretskaya et al., 2018; 2020). Scenarios of the LGM glacial advance, ice-dammed lakes formation and reversal runoff into the Caspian basin through the Keltma spillway have been proposed and discussed in (Larsen et al., 2013; Zaretskaya et al., 2018). The LGM glacial limits advancing farther eastwards into the valleys of Severnaya Dvina and Vychegda were proposed in (Lavrov & Potapenko, 2005; Lysa et al., 2011; 2014; Fredin et al., 2012; Larsen et al., 2013). An alternative scenario of limited distribution of southeastern glacial lobe and corresponding proglacial lake within the Severnaya Dvina valley and evidence for fluvial and aeolian deposition in the Vychegda basin was proposed by another group (Sidorchuk et al., 2001; Zaretskaya et al., 2014; 2018; 2020; Panin et al., 2020). The 2017 drilling in the Keltma canyon and the OSL-dating of its sedimentary fill showed that the palaeovalley was occupied by a glacial lake by the end of MIS 6; and the last overflow event could have occurred at the end of MIS 5, corresponding with the Early Weichselian proglacial Lake Komi in the Pechora basin (Panin et al., 2020).

Our studies were motivated by the above-mentioned controversies in paleogeographic reconstructions for the Vychegda – Severnaya Dvina fluvial system. Extensive investigations through these valleys (24 new sections) allowed us to state that the alluvial and aeolian sedimentary pattern dominated within the Vychegda basin during the MIS 2 (Zaretskaya et al., 2020): the 2nd (27–17 ka BP) and 1st (17–11.7 ka BP) alluvial terraces had been forming, and the incision of Vychegda took place ca 17 ka BP due to probably the final drainage of the proglacial lake in the Severnaya Dvina valley and climate-driven increase of river water runoff. The LGM proglacial lake was spatially restricted within the Severnaya Dvina valley and extended upstream not more than 120 km from the ice margin established in (Svendsen et al., 2004) as it was found that the lake did not reach the Vychegda – Severnaya Dvina confluence (Zaretskaya et al., 2020). The LGM-lake had the unstable hydrodynamic regime with alternating periods of glaciolacustrine and alluvial sedimentation. Active aeolian sedimentation started in the second half of MIS 2 (ca 17-16 ka BP, according to OSL dating) and large dunes and cover sands had been formed within the Vychegda and Severnaya Dvina valleys.

The research was supported by Russian Science Foundation, project 17-17-01289.

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Late Pleistocene and Holocene marine deposits of East Siberian Sea: new data

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Keywords: East Siberian Sea, geophysics, diatoms, geochemistry, pollen.

We present preliminary results of investigation of Quaternary deposits from the East Siberian Sea. We performed complex study of three sediment cores, sampled in southern, south-western, and northern parts of the sea. The corresponding strata are exposed at the sea depths from 10 m to 34 m and belong to the different types of acoustic deposit sections at the different types of sea bottom relief. Sediments sampled in the southern part of the sea are dated 4700±20 y.a. at the core interval 57-58 cm. Diatoms form a marine complex, which correlates with a complex of gastropods. Cores, taken at the south-west and north of the sea, are dated 15790±35 y.a. and 18250±40 y.a. respectively. Both cores characterize by compound stratigraphy, diversity of diatoms and specific pollen assemblage, which makes these deposits be branded as Late Pleistocene littoral or continental sediments, covered with Holocene marine section. In addition, we compared the results of the study on these cores with the materials of our predecessors and data, received for other cores, which were also radiocarbon dated. The complex approach allows us an assessment of some Late Pleistocene and Holocene sea and sea-coast landscape dynamics.

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