1st International Conference ‘Processes and Palaeo-environmental changes in the Arctic: from past to present’ (PalaeoArc)

Book of abstracts

Adam Mickiewicz University, Poznań, Poland

Poznań, 20–24 May 2019

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Foreword

PalaeoArc stands for 'Processes and **Palaeo**-Environmental Changes in the **Arctic**: From Past to Present'. It is an international research network established in 2018 as continuation of the previous network programmes, namely PAST Gateways (Palaeo-Arctic Spatial and Temporal Gateways), APEX (Arctic Palaeoclimate and its Extremes), QUEEN (Quaternary Environment of the Eurasian North) and PONAM (Polar North Atlantic Margins – Late Cenozoic Evolution). The major goal of the network is to improve understanding and explain the climatically-induced environmental changes in the Arctic that have taken place in the past and continue in the present-day. There are four major themes to the programme:

1) the dynamics of Arctic ice sheets, ice shelves and glaciers;
2) the dynamics of high latitude oceans and sea ice;
3) the dynamics of the terrestrial environment and landscape evolution; and
4) the climatic response to, and interaction between, these different parts of the Arctic system.

Among the goals of PalaeoArc is to bring together and build bridges between scientists from different countries and career stages, and from different disciplines in Arctic science. This includes marine and terrestrial researchers, working either with field data and on numerical modelling approaches. The network is led by an international Steering Committee representing nine different countries and with Astrid Lysså to be the chair. More details on the PalaeoArc are available at the website: http://www.palaeoarc.no/.

A key focus of the network's activities is an annual international conference that brings together Arctic scientists from a number of disciplines and typically includes a field excursion. The first PalaeoArc meeting takes place in Poznań, one of the oldest cities in Poland. It is an academic city, with Adam Mickiewicz University celebrating 100 years of its activity this year. The researchers of Poznań universities have been involved in polar research for decades, in particular in Svalbard, where Adam Mickiewicz University research station is located. The city of Poznań is also located nearby the southernmost limit of the last Scandinavian ice sheet margin. Thus the research on the ice sheet dynamics, glacial geomorphology and environmental response of climate changes have been always in scope of the studies conducted mainly at the Faculty of Geographical and Geological Sciences – the host of the meeting. During the conference almost 70 scientists from 11 countries are going to discuss a wide scope of exciting topics and newest discoveries related to the Arctic research, during 3 days of oral and poster sessions and a one day field trip. During the latter, the participants are going to visit the landforms and deposits left by the last ice sheet, as well as peculiar Morasko meteorite impact crater field formed in the middle Holocene.

We wish you a productive and enjoyable meeting on behalf of organizing committee

Witold Szczuciński

Abstracts of talks

The impact of transformed Atlantic waters on hydrological conditions in the White Sea during the Post-Glacial based on micropaleontological records

Elizaveta Agafonova[1,2], Yelena Polyakova[1], Yekaterina Novichkova[2]

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The small inland White Sea, which is located in the Western part of the vast shallow Eurasian Arctic shelf, is a key area for detailed reconstruction of the last Scandinavian ice sheet degradation and changes in the Atlantic waters' advection to the Arctic. This report is based on a detailed study of two sediment core sections (6042, 6050) obtained from depths of 61 and 101 meters in the largest Bay of the White Sea, Dvina Bay. Paleoenvironmental reconstructions based on diatoms, aquatic palynomorphs, pollen and spores study along with grain size measurements carbon content and TOC determination (Polyakova et al., 2014; Novichkova et al., 2017). According to radiocarbon (AMS ^{14}C) dating studied cores cover the last ~11 000 cal. years B.P.

Through all over this time diatom assemblages dominated by marine planktonic arctic-boreal and bipolar species of *Chaetoceros*, *Thalassosira*, and *Coscinodiscus* genera, and sea-ice diatoms. The Atlantic water indicative species (*C. radiatus*, *T. oestrupii*, etc.) in the Eurasian Arctic seas (Polyakova, 1997) are also widely represented in the Holocene sediments of the White Sea, giving evidence of the transformed Barents Sea waters' advection. This is supported by the distribution patters of dinocyst species *Operculodinium centrocarpum*, *Pentapharsodinium dalei*, etc. Our data testify the following. In the Boreal period (9300–10700 cal. years B.P.), the entering of the Barents Sea waters into the White Sea abruptly increased. In the Atlantic period (5800–9300 cal. years BP), under the conditions of the Holocene climatic optimum relatively warm-water species are dominating the Dvina Bay's microalgae associations. In the interval of 5800–2600 cal. years BP (Subboreal period), climate cooling and a reduction in the inflow of the Barents Sea waters are detected. Over the past 2500 calendar years, the hydrological regime in the bay has become close to the modern one. The spatial analysis of the early Holocene events, which were established inferred from micropaleontological study and radiocarbon (AMS ^{14}C) dating, made possible to specify the time of Atlantic waters' advection into White Sea basin, the dynamics of the White Sea glacial blade degradation and patterns of climatic optimum development.

The study was supported by the Russian Foundation for Basic Research (Project 19-05-00787 A).

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East Greenland post-LGM ice sheet dynamics and a large rock-fall revealed by swath bathymetry

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High-resolution swath bathymetric data can provide clues to the geological history by revealing the seafloor geomorphology. Submarine glacial landforms, for example, can be used to reconstruct past ice sheet development and landslide debris may reveal areas of past tsunami formation. Here, a geomorphological investigation of swath bathymetric data acquired on five research expeditions of RV Polarstern in three glacier outlet systems of East Greenland (Kejser Franz Joseph Fjord, Kong Oscar Fjord, and Scoresby Sund) will be presented (Arndt, 2018). The investigation refines the, so far, only poorly resolved reconstruction of East Greenland ice sheet development and, in addition, reveals a site of a large rock fall that most probably caused a major tsunami. A combination of the marine geomorphological record with published geological data was used to infer the post-LGM ice dynamics and extents. The investigation suggests that most ice streams likely reached the shelf edge, via cross-shelf troughs, in all three glacier-outlet systems, probably during the LGM. Ice marginal landforms on the shelf and at the fjord entrances indicate a dynamic ice margin with still stands, retreat phases and subsequent readvances. The inferred tentative chronology suggests that in the Allerød-Bølling interstadial, ice retreated to the fjord entrances at Kejser Franz Joseph Fjord and Kong Oscar Fjord, and most probably into the fjord at Scoresby Sund. A subsequent readvance up to a mid-shelf position likely took place in the Younger Dryas. Thereafter, Holocene retreat on the shelf and in the outer fjord areas most likely was rapid, except for two phases of stabilization at the entrance of Kong Oscar Fjord.

Apart from glacial landforms, the swath bathymetry data revealed a large amount of landslide debris in the southern part of Scoresby Sund. The origin of this debris is an up to 1500 m high mountain cliff that likely collapsed sometime in the Holocene. On first approximation, the debris volume is a magnitude larger than the volumes of more recent rock falls, which resulted in devastating tsunamis. The size of the debris, as well as the height of its source, suggests that one or multiple tsunamis most probably once hit the coasts of Scoresby Sund. A ship-time proposal has now been submitted for a more thorough investigation of the rock-fall and successive tsunami formation, as well as to obtain improved constraints on the environmental development of the region since the LGM.

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Surface $\delta^{13}C$ in foraminiferal calcite and it's thermodynamical potential to reconstruct surface ocean properties in the Polar North Ocean

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Variations of stable carbon isotopes ($\delta^{13}C$) as found in fossil records of foraminifers are often used to infer past oceanic changes such as spatial water mass distribution and ventilation. While this inference seems quite well proven for deep-sea species with an epibenthic habitat and in relation with bottom water changes, the δ^{13} C signature in planktic foraminifers is less straight forward to understand due to strong biological effects inherent to the upper few hundreds meters of the ocean. Besides, species-dependent vital effects, the result is a complex of rapidly changing nutrients caused by a variable bioproductivity, the remineralization processes of organic matter, as well as the degree of surface stratification and exchange of the near-surface ocean with atmospheric CO_2.

Many $\delta^{13}C$ records measured on polar species *N. pachyderma* show a very strong similarity in their trends on glacial-interglacial timescales both in the subpolar and polar North Atlantic waters – records from closer to the Arctic may even indicate the existence of a Mid-Pleistocene shift in $\delta^{13}C$ of this species which parallels with the onset of more intensified glacial-interglacial climate contrasts. Surface sediments from the Arctic Ocean, which represent the past 2 ka or so, have extremely high $\delta^{13}C$ *in N. pachyderma* (Spielhagen and Erlenkeuser 1994), indicating a thermodynamic relation between the carbon signature in this species and the ambient temperature of the water. In the Nordic Seas, and all along the main pathway of Atlantic surface water flow into the Arctic, such a thermodynamical relationship is further corroborated in detail by down core records covering the Holocene time interval.

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Does Atlantification of the Barents Sea enhance preservation of organic carbon?

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About half of the total pan-Artic shelf primary production occurs in the Barents Sea. The Polar Front climatically divides the Barents Sea into a northern, cold and harsh Arctic climate and sea-ice-associated ecosystem, and a southern region which has a warmer Atlantic climate with a more biomass-rich ecosystem and lucrative fisheries. However, ongoing climate change causes temperature rise and shifts in regional atmospheric and hydrographic forcing. This leads to strong Arctic sea-ice reduction and the associated alteration of pelagic primary productivity has knock-on impacts to local marine ecosystems, biogeochemical processes and carbon burial rates. Thus, the northern Barents Sea may transform from a cold and stratified Arctic to a southern Barents Sea-like warm and well-mixed Atlantic-dominated climate regime. This may lead to a shift of the typical "sea-ice algae-benthos" ecosystem to a "phytoplankton-zooplankton" dominated ecosystem. However, it is not clear if this ecosystem switch and the concurrent increases in phytoplankton productivity will decrease or increase the export of organic carbon (OC) and, therefore, strengthen or reduce pelagic-benthic coupling and carbon storage and sequestration.

We seek to provide a deeper understanding of how future alterations in the organic material transfer to the Arctic seafloor will change biogeochemical processes and carbon sequestration. In 2017, during the first of three planned annual cruises of the NERC-funded ChAOS project, we collected sixteen surface sediment samples and six short sediment cores along a S–N transect in the Barents Sea. All samples have been analysed for grain size distribution, bulk elemental composition and OC concentration. By combing these geochemical data with literature data, we will present a large dataset of surface sediments and several sediment cores from the northern and southern Barents Sea. Initial results show a strong S–N gradient of the geochemical sediment composition. This pattern seems to be related to the Barents Sea oceanographic setting and terrestrial input from Svalbard. Moreover, the main organic matter source seems to be marine productivity in the Barents Sea. We found an opposing S–N gradient of OC and $CaCO_3$ which may be related to differences in the planktic versus benthic marine productivity. These first findings indicate that the Atlantification of the Barents Sea may result in higher primary productivity but lower carbon burial.

Organic matter sources in North Atlantic fjord sediments

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During the past decade fjords attract notice as important shelf areas for carbon burial due to relatively high sedimentation rates as well as high organic matter input. As terrigenous derived organic matter is more resistant to remineralization than marine organic matter, a comprehensive knowledge of the carbon source is crucial to better constrain organic carbon burial rates in fjord sediments. Recent findings indicate that most of the organic matter in fjord sediments globally to be terrigenous derived. However, these findings are based only on a very few studies from the North Atlantic region.

Here we investigated highly productive fjords in northern Norway and compare our results with both existing and new C_{org}/N_{org} and $\delta^{13}C_{org}$ data from fjords in mid Norway, west Svalbard and east Greenland. The marine organic carbon contribution varies significantly between these fjords and the contribution of marine organic carbon in Norwegian fjords is much larger than previously suggested for fjords in NW Europe and globally. Additionally, northern Norwegian fjords show very high carbon burial rates (73.6 gC $m^{-2}yr^{-1}$) suggesting that these fjords are probably very distinct carbon burial hotspots. We argue that the North Atlantic Current inflow sustains these high burial rates and changes in the current strength due to ongoing climate change is likely to have a pronounced effect on carbon burial in North Atlantic fjords.

Late Quaternary paleoenvironmental records of northern Eurasian large lakes obtained in the frame of RussianGerman research project "PLOT"

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Russian-German project PLOT (Paleolimnological Transect) aims at investigating the regional responses of the quaternary climate and environment on external forcing and feedback mechanisms along a more than 6000 km long longitudinal transect crossing Northern Eurasia. The well-dated record from Lake El´gygytgyn (Melles et al., 2012; Brigham-Grette et al. 2013) used as reference site for comparison the local climatic and environmental histories. Seismic surveys and sediment coring up to 54 m below lake floor performed in the frame of the project on Ladoga Lake (North-West of Russia; 2013), Lake Bolshoye Shchuchye (Polar Ural; 2016), Lake Levinson-Lessing and Lake Taymyr (Taymyr Peninsula; 2016–2017), Lake Emanda (Verkhoyansk Range; 2017). Fieldwork at Polar Ural and Taymyr Peninsula was conducted in collaboration with the Russian-Norwegian CHASE (Climate History along the Arctic Seaboard of Eurasia) project. Here, we present the major results of the project obtained so far. Some of the results recently published in special issue (Melles et al. 2019).

The multiproxy studies of sediment core from largest European Lake Ladoga allow to reconstruct deglaciation history (Gromig et al. 2019) as well as climate and paleohydrology of Lateglacial and Holocene (Savelieva et al. 2019; Kostrova et al. 2019). Low part of the same core used for MIS 5 climatic history reconstruction (Andreev et al. 2019).

A seismic survey of Lake Levinson-Lessing allows to reconstruct the periods of ice advances, marine waters inundations, lacustrine and purely terrestrial conditions in central Taymyr Peninsula (Lebas et al. 2019).

The PLOT project is conducted in the frame of a bilateral Russian-German agreement in the field of polar and marine research and is funded by the German and Russian Research Ministries. The work of G. Fedorov, L. Savelieva, A. Cherezova and N. Kostromina was additionally supported by SPbU-DFG grant (id: 38177967). The work of G. Fedorov, and N. Kostromina also sponsored by RFBR grant (18-05-60291).

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The Younger Dryas and the Northwestern Laurentide Ice Sheet

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Chronologically constrained records spanning the end Pleistocene deglaciation and early Holocene ice margin oscillations in the eastern Canadian Arctic Archipelago (CAA) show little evidence for the Younger Dryas (YD) cold interval (12.9–11.7 ka BP) – an event otherwise widely recognised from the circum-North Atlantic and beyond. Until recently, glacial behaviours coincident with, or in direct response to, the YD in the central and western CAA have been documented only from very limited and ambiguous terrestrial and marine records. This has made any assessment of the impact of the YD, as a climatological event, on the western and central Arctic margins of the Laurentide and lnnuitian ice sheets difficult to determine. However, new work over the last five years has now begun to outline what appears to be a record of re-advance along the northern-central and northwestern margins of the Laurentide Ice Sheet (LIS) coincident with and immediately following the end of the YD chronozone.

This talk explores the latest evidence based on geomorphic, marine sediment core, and seismic data from the central and western regions to suggest that, not only did the Arctic sector of the LIS respond to the YD, but that this response was dramatic and expansive, marked by the rapid establishment and subsequent collapse of multiple extensive floating ice shelves. Further, that this behaviour had major dynamical implications for the stability of the LIS following the YD. Given the proximity of the western CAA to regions implicated in the initiation of the YD event, a linked response to YD forcing mechanisms can be entertained. And while much more work remains to be done to determine the detailed response of the Laurentide margin and to further constrain chronologies, a region-wide YD response is now emerging as a meaningful hypothesis.

The Younger Dryas and Bølling-Allerød paleoenvironments in the Barents Sea

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The late deglaciation sediments in the Barents Sea are generally represented by distal glaciomarine facies comprising laminated clay and sand sequences with minor IRD content overlying on the glaciomarine diamicton of the early deglaciation. Unlike the commonly barren diamicton, late deglaciation sediments have been AMS-14C dated at several locations. To better address the reservoir effect we calibrated all dates with Calib 7.1 Marine13 calibration curve (Reimer et al., 2013) applying Delta R = 71±21 (Mangerud et al., 2006) for the Barents Sea and also alternatively high values Delta R = 200±100 for the YD interval in the Arctic (Keigwin et al., 2018). As a result, our studies provided evidence of diachronous retreat and melting of the Svalbard-Barents Ice Sheet in line with recent publications (e.g. Hughes et al., 2016; Patton et al., 2017). The diachroneity resulted in a variety of local paleoenvironments, notably during the B/A warming (~14.8–12.9 cal ka BP) and YD cooling (~12.9–11.7 cal ka BP). The B/A sediments are generally fine-grained indicating a cessation of massive iceberg calving due to glacier edge retreat above the shoreline. At some locations, laminated layers point to deposition of gravitites and/or contourites mainly from land derived glacier melt-water suspension flows (including laminites and mud with sand lenses). In the NW, NE and SW Barents Sea, the B/A sediments contain rather diverse benthic foraminiferal assemblages suggesting an increase in the flow of chilled subsurface Atlantic water along the Eurasian continental margin and Scandinavian margin, respectively. At some locations, an occurrence of epibenthic species indicate enhanced bottom water dynamics. However, in the SE Barents Sea the B/A and YD sediments are generally barren thus limiting the validity of paleoreconstructions for this part of the basin. The surface Arctic waters were very cold across the whole Barents Sea during the B/A. Although the YD is known to be characterized by harsh polar environments in the area, a relatively high bioproductivity is reconstructed at some locations, in particular due to polynya effects likely associated with katabatic winds, e.g. in the Erik Eriksen Trough. Yet, the increased content of the IRD and sand-silt sediment fractions suggests an intensification of gravity flows, iceberg rafting, extensive sea-ice cover and brine formation in line with very low planktic and benthic foraminiferal $\delta^{18}O$ values. Regardless a possible short-term re-expansion of glaciers to the Barents Sea area at the YD, the subsurface Atlantic water flow is ascertained in the Franz Victoria and Kvitøya troughs, and along the Eurasian continental margin further to the Laptev Sea, while on the west the flow was significantly reduced and bottom-water temperatures remain lower as compared to the B/A interval.

This study is a contribution to the State assignment № 0149-2019-0007.

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Last Glacial Maximum ice sheet margin on Wielkopolska Lowland – passive margin or outlet glacier?

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The southernmost margin of the Scandinavian ice sheet during the Last Glacial Maximum (c. 20 ka BP), its origin and causes of exceptional southward extension have been discussed for decades. Particularly interesting is the problem of the position and character of this margin on Wielkopolska Lowland, where the ice-sheet extend reached the maximum southward limit.

This contribution aims to overview the state-of-art concepts and present regional sedimentation model based on extensive geological and geomorphological mapping. Among the discussed problems are the paleoglaciological implications of the form of the ice sheet margin – passive ice-sheet margin or outlet glacier?

A large impact crater beneath Hiawatha Glacier in northwest Greenland

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We report the discovery of a large impact crater beneath Hiawatha Glacier in northwest Greenland. From airborne radar surveys, we identify a 31-kilometer-wide, circular bedrock depression beneath up to a kilometer of ice. This depression has an elevated rim that cross-cuts tributary subglacial channels and a subdued central uplift that appears to be actively eroding. From ground investigations of the deglaciated foreland, we identify overprinted structures within Precambrian bedrock along the ice margin that strike tangent to the subglacial rim. Glaciofluvial sediment from the largest river draining the crater contains shocked quartz and other impact related grains. Geochemical analysis of this sediment indicates that the impactor was a fractionated iron asteroid, which must have been more than a kilometer wide to produce the identified crater. Radiostratigraphy of the ice in the crater shows that the Holocene ice is continuous and conformable, but all deeper and older ice appears to be debris rich or heavily disturbed. The age of this impact crater is presently unknown, but from our geological and geophysical evidence, we conclude that it is unlikely to predate the Pleistocene inception of the Greenland Ice Sheet.

Late Pleistocene and Holocene pollen stratigraphy of the Lake Imandra sediments (Kola Peninsula)

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Arctic is an important region for understanding present and past climate changes, because polar landscapes are highly sensitive to climate variations. Territory of Lake Imandra, which was covered by Arctic Ice Sheet during the Late Pleistocene (Hughes et al., 2016), was chosen for reconstruction of lateglacial and postglacial conditions of Kola Peninsula. The two cores of bottom sediments were collected during joint field campaign of the Saint-Petersburg State University, Kola science centre and University of Cologne in September of 2017. The preliminary pollen results from corecatchers were obtained in September of 2018 (Kostromina et al., 2018). This report is presented detail pollen records from the core Co1410. The total thickness of the core is about 8.5 m. More than 100 samples with variable interval (8–10 cm for upper part and 2–4 cm for lower part) were analyzed. The 64 pollen, spores and non pollen palynomorph taxa were identified. The *Lycopodium* tablets were used to permit estimation of pollen concentrations (Stockmarr, 1971).

Based on pollen results the core sediments were divided on Holocene and Late Pleistocene parts. Pleistocene – Holocene boundary is at the depth of ~ 4.5 m. The Late Pleistocene part shows low concentrations of microfossils. The trees and shrub pollen taxa (less than 60%) presented by *Betula nana* and *Betula* sect. *Albae. Artemisia*, Chenopodiaceae, Ericaceae, Cyperaceae and Poaceae dominated in herbs pollen taxa. The single grains of *Ephedra* pollen was identified in this zone. The content of spors (Polypodiaceae, *Lycopodium* sp., *Huperzia selago*, *Sphagnum*) remains up to 70%. That pollen spectra may reflects dry conditions, when shrub tundra landscapes with periglacial vegetation communities were dominated. The Holocene part shows the dramatic growth of pollen concentrations (up to 50 000 grains g^{-1}). Increasing of trees and shrub pollen taxa up to 90% is fixed there. *Pinus s/g Diploxylon* is dominated among that taxa. The appearance of *Picea* is noted at depth 2.7 m. Poaceae and Cyperaceae are dominated among herbs taxa. Polypodiaceae dominates in spore group Summarize pollen results it is possible to conclude that excavated sediments formed during lateglacial and Holocene time.

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Benthic foraminifera assemblages along the latitudinal transect in the Svalbard and Norwegian fjords

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The aim of the study was to investigate the benthic foraminifera communities along the latitudinal gradient, from the fjords of northern Svalbard to the southern Norway (area from 80° to 60°N) in order to compare their abundance, biodiversity and sizes of the tests. According to Bergman's rule, it is expected that species of larger size are found in colder environments, and species of smaller size are found in warmer regions.

The Svalbard fjords are particularly exposed to the effects of increasing climate changes, where the retreat of glaciers and the constant decrease of the sea ice cover is observed, leading to the changes in the abundance and distribution of benthic fauna. Svalbard fjords are also considered 'hot spots' for the processes of carbon burial, and benthic foraminifera which build their shells form calcium carbonate may be of great importance in this process. Therefore, it is important to know how the foraminiferal assemblages will change in the process of ongoing oceanographic/climatic changes. The modern analogue to the future of the Svalbard fjords could be Norwegian fjords, today free of tidewater glaciers and sea ice, where the distribution patterns of benthic foraminifera are associated mainly with surface runoff, river inflow, basin morphology and local water mass distribution.

Surface (10 cm) sediment samples for foraminiferal analysis were collected with small gravity corer at stations located in three Svalbard fjords (Rijpfjorden, Wijdefjorden and Isfjorden) and three Norwegian fjords (Balsfjorden, Hjeltefjorden and Raunefjorden) during the cruise of S/Y Oceania in August 2016. Directly after sampling, the cores were cut in 1 cm slices and were stained with rose Bengal solution with 75% ethanol to distinguish living specimens. Water temperature, salinity and turbidity were measured at each station with Mini CTD Sensordata SD202 in 1-second intervals.

The results of our study revealed two foraminiferal assemblages – northern fjords and the southern fjords. Balsfjorden, although located in Norway, is more similar to Svalbard fjords, which is a result of the domination of Atlantic Water in all of the Svalbard fjords and thus, the presence of species preferring the warmer and more saline waters. Foraminiferal abundance and number of species increases southwardly, whereas the test size decreases from northern to southern fjords. Foraminiferal assemblages from the southern Norway reflected the anoxic conditions.

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Deglacial ocean dynamics of the Arctic Ocean and Nordic Seas: insights from authigenic neodymium isotopes

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Radiogenic neodymium (Nd) isotopes are a powerful proxy used in the reconstruction of past changes in water mass distribution and mixing. The Arctic Ocean (AO) and Nordic Seas are an important and dynamic part of modern North Atlantic Deep Water (NADW) formation, which sets the modern global oceanic thermohaline circulation. This region therefore plays an important role in the global climate via the redistribution of heat and the storage of carbon in the deep ocean (e.g. Aagaard et al. 1985). There is evidence to suggest that the deep Nordic Seas may have become both physically and chemically isolated during past glacial periods (Thornalley et al. 2015), while the North Atlantic surface current (NAC) in to this region continued (e.g. Nørgaard-Pedersen et al. 2003). Here we present high-resolution authigenic Nd isotopic records, over the past 25,000 years, from numerous and wide ranging core sites in this region (including the Vøring Plateau, Greenland Sea and Yermak Plateau), and link them to published records south of Iceland in the northern-most North Atlantic (Roberts and Piotrowski, 2015). We probe changes in the connectivity and isolation of the AO and Nordic Seas from the North Atlantic over this period as well as our understanding of the input versus advection driven processes on authigenic Nd isotopes during ice-sheet maximum extent, collapse and subsequent warming.

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Lake basin evolution, problematic tephra and landlocking of Arctic Char; the lake Nordlaguna, Jan Mayen

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Jan Mayen is the northernmost island on the North Atlantic ridge system situated some 550 km north of Iceland. The active volcano Beerenberg in the northern part of the island reaches an elevation of 2277 m a.s.l. All historically known volcanic eruptions have taken place on the flanks of Beerenberg. However, numerous lava flows and tephra deposits are found in the southern part of the island evidencing large volcanic activity in Late-Glacial – Holocene times.

On the west coast of the island, a small embayment called Maria Musch is connected to the Lake Nordlaguna via a short valley. The lake is situated ca. 2 m a.s.l. and is separated from the sea by a 1 km long, up to 200 m wide and 4–5 m high storm barrier. No outlet to the sea exists today. The lake holds a stock of Arctic Char (*Salvelinus alpinus*) which has developed from anadromous char to become landlocked. When and how this happened has been a matter of speculation. Skreslett (1973) suggested that the lake was isolated from the sea some 1500–4000 years ago due to relative sea-level changes. Inspite-of intensive field investigations over the last few years, the Late-Glacial – Holocene sea-level history of the island still remain largely unknown. It may be that the ice-cap covering Jan Mayen during the last glaciation was so thin that relative sea level was below present throughout this time period.

Nordlaguna evolved through several stages as a bay over Middle to Late Pleistocene times. Likely its landward side formed part of the first land bridge between the northern and southern parts of Jan Mayen. Two volcanic eruptions, one of Early and one of Late Weichselian age, resulted in the appearance of an island in the middle of the bay. A beach barrier was formed, likely during a Holocene marine transgression connecting the island to the north shores of the bay. At that time, a shallow tidal channel south of this island connected the almost closed basin with the open ocean. We suggest that Arctic Char entered via this channel and was able to spawn in the basin. A volcanic eruption dated to be younger than ca. AD 1600 closed the tidal channel and is interpreted to have caused landlocking of Arctic Char. Tephra from this eruption is very similar in composition to tephra from the Surtseyan Eggøya eruption that took place AD 1783 on the east coast of the island (Gjerløv 2015). Field evidences suggest that the eruption in the Maria Musch bay is older than the Eggøya eruption, but it cannot be excluded that the two eruptions were the result of the same volcanic event in 1783.

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The glacial history of the Northeast Greenland Ice Stream over the last 45.000 years

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The sensitivity of Northeast Greenland Ice Stream (NEGIS) to prolonged warm periods is largely unknown and geological records documenting the long-term changes are needed to place current observations in perspective. We use cosmogenic surface exposure ages and radiocarbon dates to determine the magnitude of NEGIS margin fluctuations over the last 45 ka (thousand years). We find that the NEGIS experienced a slow early Holocene ice retreat of 30–40 m a^{-1}, as a result of the buttressing effect of sea- or shelf ice. The NEGIS was c. 20–70 km behind its present ice-extent c. 41–26 ka and c. 7.8–1.2 ka during periods of high orbital precession index and/or summer temperatures within the projected warming for the end of this century. Our results demonstrate that the NEGIS was smaller than present for approximately half of the last ~45 ka and is susceptible to even subtle changes in climate, which has implications for future stability of this ice stream.

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Exploring new proxies in Arctic paleocenography

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Paleocenographic reconstructions of the Arctic Ocean are difficult for several reasons, poor preservation of calcareous nanno and micro fossils, and strong fresh-water overprint on oxygen isotopes being only part of the problem. Consequently, new and innovative proxies need to be developed. Here the potential of organic biomarkers, iodine-129/iodine-127, and foraminifer-bound $\delta^{15}N$ variations are explored.

Organic biomarkers were employed to test the source of a distinct gray layer which is widespread in the Eurasian Basin. A first comparison of branched and isoprenoid glycerol dialkyl glycerol tetraether (GDGT) lipids from three different sediment cores suggest that the layer is characterized by a strong increase in organic material originating from soils. A strong increase in the methane index further indicate that dysoxic to anoxic conditions may have developed within the gray layer, something corroborated by the almost complete depletion of Mn seen in and below the layer. Analysis of alkenone chain lengths reveled a distinct decrease in the gray layer, suggesting a dominance fresh water algae over marine algae. Taken together, the biomarker results strongly suggest that the material in the gray layer originated from an ice dammed lake on the Siberian hinterland which likely drained rapidly into the Eurasian Basin.

The radioactive isotope iodine-129 is produced in the Earth atmosphere through cosmic ray spallation of Xenon. Assuming that this flux is constant, variations in the ratio of iodine-129 to iodine-127 in Arctic sediments could possibly reflect variations in sea ice cover, blocking the flux of iodine-129 to the sea floor. First tests on two cores from the Morris Jesup Plateau and the Central Arctic, respectively, are inconclusive. However, a dramatic decrease in both isotopes in the gray layer mentioned above, strongly favors a fresh water source of the deposited material, as fresh waters typically contain an order of magnitude less iodine than does sea water.

Finally, variations in foraminifer bound $\delta^{15}N$ were employed to address variations in nutrient utilization during interglacial periods. First results suggest that foraminifer bound $\delta^{15}N$ may be a good indicator of changes in surface water structure in the Arctic Ocean as the result of variations in fresh water influx from rivers and melting ice sheets.

The Late Weichselian ice cap of Jan Mayen

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Jan Mayen is a young volcanic island situated in the Norwegian-Greenland Sea north of Iceland. Active volcanism has taken place since the island rose up above sea level some 500–600 thousand years ago. Until recently, documentation regarding the last glaciation on the island was almost non-existing. This presentation focuses on the Late Weichselian, and we can now document that the entire island was covered by a glacier.

Presently, the active volcano Beerenberg, reaching 2277 m a.s.l., has an ice cap with several outlets, some of which reach down to sea-level where they are calving into deep water. Well-developed marginal moraines outside many of the outlets withness of larger glacier extent at times in the past. The most conspiciuous ones are suggested to be from the Little Ice Age (Anda et al. 1985). The northern part, Nord-Jan, shows a large contrast to the central and southern part of the island, Sør-Jan. Here, there are no signs of moraine ridges, instead numerous volcanic craters, domes and lavafields dominate the terrain with some more flat-surfaced areas inbetween. These surfaces are often covered with till and glacial erratics. Many of the mountain peaks in Sør-Jan reach elevations of more than 500 m a.s.l., the highest one is 769 m a.s.l.

Whether or not the entire island was ice-covered during the last glaciation has been a matter of controversy. For instance, Imsland (1978) concluded that Jan Mayen had been without major glaciers during the Pleistocene. However, no glacial-geological study has targeted this topic until we started our investigations. We now can now document that Nord-Jan was covered by an ice cap reaching down to sea-level during Late Weichselian. Field mapping in the central and southern parts of the island indicates that the entire island was ice-covered during the Late Weichselian, and that glaciers extended at least down to present sea level. We also have observations demonstrating that ice covered some of the highest peaks in Sør-Jan. Taken together, we suggest that also the shallow shelf south-southeast of the island was glaciated, but this has yet to be proven.

In constraining the age of the Jan Mayen ice cap, we have used ^{36}Cl cosmogenic surface exposure dates on boulders from moraines, from erratics on till, and on bedrock surfaces. Some K/Ar and Ar/Ar dates on volcanic rocks, also provide constraining ages of glacial history.

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The impact of sea surface temperatures on primary productivity in the western Barents Sea since the end of the last glaciation

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The increasing influence of Atlantic Water (AW) in the Barents Sea, a process known as "Atlantification", is leading to the gradual decrease of sea ice in the region, which is set to continue well into the 21st century. To understand the natural variability and biogeochemical impacts of the inflow of AW in the western Barents Sea, we have undertaken the reconstruction of sea surface temperatures (SSTs) and primary productivity in a climatically sensitive area south of Spitsbergen (Storfjordrenna; 253 m water depth) since the last deglaciation (13,950–1200 cal yr BP). The alkenone proxy has been applied to reconstruct SSTs and the alkenone accumulation rate in marine sediments has been used to infer the changes in primary productivity. Our data show that as ice-sheets retreated in Svalbard, the SSTs increased reflecting the increasing influence of AW. These changes were concomitant with the progressive loss of sea ice cover and an increase in primary productivity. The complete transition from the Arctic to the Atlantic domain occurred around 11,500 cal yr BP, as the Arctic Front moved eastward of the study site, but with considerable variability in surface ocean conditions. Around 6200 cal yr BP, we interpret the occurrence of high SSTs as leading to limited winter surface cooling, which probably inhibited convective mixing and the return of nutrients to the euphotic zone and/or enhanced organic matter consumption by zooplankton due to earlier light signal in the ice-free Storfjordrenna. During late Holocene (5000–1200 cal yr BP) low insolation facilitated sea surface freezing and brine production, which launched convective water mixing and increased nutrient resupply to the sea surface, consequently enhancing the primary productivity in Storfjordrenna. We conclude that, on the basis of the paleoceanographic evidence obtained, the modern increasing inflow of warm AW and the disappearance of pack ice on the Eurasian continental shelf are likely to weaken convective water mixing and decrease primary production in the region.

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Path to the future, return to the past: towards an ice-free landscape on Svalbard

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Over the past several decades, climate warming has been very strong over Svalbard, which at 34 × 103 km^2 of glacier cover is the largest single ice repository in eastern Arctic. Temperature increase resulted in substantial melting of local glaciers, but their ice loss pattern is heterogeneous and smaller ice masses display the most negative surface mass balances. Available observations and modelling suggest that future evolution of Svalbard glaciation will likely run towards a complete decay of ice across the archipelago, and that some regions of Svalbard might be already committed to such fate, e.g. central Spitsbergen. Little glacier cover prevailed on Svalbard in mid-Holocene, but important gaps remain in our knowledge about local environment at that time. Expanding the data on mid-Holocene ice extent, deglaciation patterns and chronology might be useful for future studies projecting the environmental changes in the region over the 21st century and beyond.

Changing ice-flow patterns during deglaciation of a dissected fjord landscape in western Norway

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We use observations of 2900 glacial striae to reconstruct the changing patterns of ice flow during deglaciation of the south-western flank of the Scandinavian Ice Sheet. The ice sheet in this sector traversed a landscape of dramatic topographic variations, where fjords hundreds of metres deep are oriented parallel, obliquely, and at right angles to the dominant palaeo-ice-flow direction. We explore the effect of such dramatic changes in subglacial relief on ice flow patterns and implications for the overall speed of deglaciation. Ice-marginal deltas, formed at the retreating ice margin, and dated with decadal precision using relative sea level data, are used to determine the rate of retreat and speed of ice flow pattern changes derived from striae observations.

During the Last Glacial Maximum, ice flow was directed towards the west across the entire study area. In several places ice flow was perpendicular to the long-profile of deep fjords surrounded by rugged high mountains and plateaux, indicating that ice flow at this time moved independently of changes in subglacial relief of up to several-hundred metres. In an extreme case, the ice flow was perpendicular to a narrow (c. 1 km wide) fjord branch, where the relative change in relief from the summits of bordering mountains to the fjord bottom is 1,000 m. We pose the question as to how ice flowed across this change in subglacial relief; was the ice sheet continually grounded, flowing right down to the base of the fjord across and up again on the opposite side, or did a subglacial lake exist beneath the ice sheet at this location?

Observations of cross-cutting glacial striae along some of the wider fjords indicate that calving bays developed during retreat. Formation and progression of such calving bays can be mapped up-fjord using the pattern of striae and their timing and rate of retreat dated with decadal resolution in some places due to the high-resolution chronology we have established using ice-marginal deltas and relative sea level information. Such calving ice fronts in the fjords typically retreated at rates of about 160 m/year. Glacial striae observations demonstrate that ice caps, or smaller ice remnants, became isolated on islands and peninsulas as retreat progressed faster in the fjords than on land. Isolation of such ice masses from the main ice sheet increased the overall speed of deglaciation for this sector of the Scandinavian Ice Sheet.

The different faces of early diagenesis in Arctic shelf sediments

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The expansive Arctic shelf systems form a highly complex transitional zone between surrounding land masses and the deep Arctic Ocean basin, and their sedimentary cover reflects this sedimentological and biogeochemical complexity. Therefore, Arctic shelf sediments are valuable archives of changing environmental conditions in the Arctic (e.g., sea ice extent, water mass distribution), and conventional gravity/piston coring can recover records reaching back to the LGM. However, due to their relatively high primary productivity and proximity to land, Arctic shelf sediments are also rich in biogenic material and reactive detrital minerals, and are therefore prone to undergo extensive but poorly studied diagenetic processes that can overprint primary environmental signals. These diagenetic transformations can be driven by the microbial degradation of organic material (e.g., Strekopytov, 2003; Vandieken et al., 2006), but also by the abiotic dissolution of silicate minerals and/or precipitation of new clay minerals (e.g., März et al., 2015). Here we will review pore water data from gravity cores taken in the Canadian Archipelago (2017, CCGS *Amundsen*) and the Barents Sea (2018, RV *Kronsprins Haakon*) to illustrate the range of diagenetic reactions that can occur within these (mainly Holocene) deposits, and how they can affect micropalaeontological, geophysical and geochemical proxies of past environmental conditions. In particular, we will focus on the potential effect that the dissolution of amorphous silica phases (biogenic opal, volcanic ash) can have on the mineralogy of the sediments, as all gravity cores studied to date display similar patterns of silica removal at depth, indicating the formation of authigenic clay minerals. We will also discuss the potential for the transformation of detrital iron oxides to sulphides (e.g., pyrite) as sulphate reduction increases deeper in the sediments, and the effects this can have on their magnetic properties.

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Reconstruction of the Quaternary Western Arctic Water mases stratification

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In the Arctic Ocean, the relatively cold and fresh halocline sub-surface layer isolates the surface sea-ice from the warm and salty Atlantic water beneath. The recent sea-ice decline affects the stability of the halocline, which limit the heat transfer from intermediate water to surface water, and therefore could further increase sea-ice decline. Here we use the empirical relationship between Mg/Ca of ostracods *Krithe* and bottom water temperature to develop a paleo-record of bottom water temperature at three water depth (434 m, 580 m and 741 m) in the Chukchi Plateau. Using the reconstructed bottom water temperature, we determine the relative position of the halocline and Atlantic water during the Quaternary. During MIS3 we observe the Atlantic layer at the three depths studied suggesting a thicker halocline than today. During MIS 5 and MIS7 the Atlantic layer is present at 580 m and 741 m but not data are available at 434 m suggesting again a thicker halocline than today. However, MIS11 seems characterized by conditions similar as today. The deepening of the halocline during stage MIS3, 5 and 7 suggest a decrease of the freshwater supply and an extensive sea-ice cover during these periods.

Ice wedges: a powerful continental climate archive?

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Ice wedges are a characteristic feature of northern permafrost landscapes. They grow in polygonal pattern mainly by snowmelt that refreezes in thermal contraction cracks that open in winter. Hence, ice wedges and their degradation forms, i.e. ice-wedge casts, are indicative of permafrost conditions. Ice wedges may survive even Interglacials and probably include some of the oldest ice preserved in the Arctic.

Ice wedges may be studied by means of stable isotopes. In high latitudes the stable-isotope composition of precipitation ($\delta^{18}O$ and δD) is sensitive to air temperature. Hence, the integrated climate information of winter precipitation is transferred to individual ice veins and can be preserved over millennia, allowing ice wedges to be used to reconstruct past winter climate. This specific seasonality makes ice wedges unique among terrestrial Northern High Latitude climate archives. Recent studies indicate a promising potential of ice-wedge-based paleoclimate reconstructions for more comprehensive reconstructions of Arctic past climate evolution.

In this presentation we briefly highlight the potential and review the current state of ice-wedge paleoclimatology using examples of recent ice-wedge studies from the Russian and North American Arctic (Opel et al., 2018). Furthermore, we discuss existing knowledge gaps and challenges and suggest priorities for future ice-wedge research to exploit the paleoclimatic potential of ice wedges, particularly in view of their unique cold-season information, which is not adequately covered by other terrestrial climate archives.

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Pleistocene age models of central Arctic Ocean sediments

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Beyond Marine Isotope Stage (MIS) 6 (190–131 ka), proposed Pleistocene age models for central Arctic Ocean sediments rely on cyclostratigraphic approaches that lack independent age control. Existing Pleistocene age models are underpinned by the occurrence of the calcareous nannofossil *Emiliana huxleyi*, which evolved in MIS 8 (300–243 ka). Historically, its first appearance in Arctic Ocean sediments is associated with the last interglacial period, MIS 5 (123–71 ka). Here we present stratigraphic and preliminary calcareous nannofossil biostratigraphy that illustrates, for the first time, the occurrence of *E. huxleyi* in sediments from the Arctic Ocean that are older than MIS 6. The results suggest that the first appearance of *E. huxleyi* in the central Arctic may have been concordant with its documented first occurrence in the Norwegian-Greenland Seas. In an attempt to calibrate the timing of its first occurrence, we used radiometric ages derived from the decay of $^{230}Th_{excess}$ through time. With a half-life of ~76 ka, excesses of ^{230}Th should be detectable in sediments as old as 300–378 ka (4–5 half-lives) (Hillaire-Marcel et al. 2017). If this radiometric clock works in Arctic Ocean sediments, $^{230}Th_{excess}$ should persist deeper in the sediments than the first occurrence of *E. huxleyi*. In all three instances, *E. huxleyi* occurs below the deepest level of $^{230}Th_{excess}$, suggesting that this radiometric approach to dating Arctic sediments is complicated by other environmental factors.

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Millenial-scale glacial palaeoceanography of Baffin Bay: Geochemical tracking of ice sheet breakup, advance and retreat

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Throughout the last glacial cycle Baffin Bay has been influenced by three major ice sheets: the Greenland, Innuitian, and Laurentide Ice Sheets (GIS, IIS, LIS). The IIS and LIS covered areas of Palaeozoic carbonate-rich rocks. These rocks were eroded by ice streams and transported via icebergs into Baffin Bay. These so-called 'detrital carbonate events' resulted in distinct intervals of carbonate enrichment in the sedimentary layers. Two of these carbonate-enriched zones occur in our studied core at ~21–38 cm, and 58–78 cm. Preliminary ^{14}C dates show they correlate to the well-studied Baffin Bay detrital carbonate events, and are also temporally related to Younger and Older Dryas climate events.

At the same time as the carbonate events we also observe an abrupt increase in osmium isotope $^{187}Os/^{188}Os$ (Os_i) compositions to more radiogenic values (~1.5–2.2). During periods of low Ca-enrichment, the Os_i values are less radiogenic (~0.9–1.4). During the last 10 kyrs, Os_i values gradually decrease from ~1.3 to 1.1, similar to the present day North Atlantic Ocean (~1.0).

During detrital carbonate events, the increasingly radiogenic Os_i compositions suggest that as well as Ca delivery via icebergs from the northern LIS and IIS, the provenance of Os, and by inference other detritus, was also sourced from the Archean/Proterozoic terrains of western Greenland, potentially by the GIS (Os_i ~2.8). The less radiogenic Os_i values (0.9–1.4) during lower Ca-enrichment intervals could potentially be a baseline to which values return when there is less influence from continental erosion and iceberg delivery, and more influence of oceanic Os from the Atlantic. The lowest Os_i values could also be influenced by an influx of weathered Paleocene mafic lithologies ($^{187}Os/^{188}Os$ = 0.13–0.14) from Disko Island, the surrounding islands and the shelf, and/or from Baffin Island. In conclusion, our new osmium isotope data provide further insight into glacial advance, retreat, and sediment provenance within Baffin Bay during the past 20 kyrs. Trace element and rare earth element analysis is also underway to further this understanding.

Digging up the past: Ancient environmental DNA as a new tool for documenting paleoceanographic changes in the Arctic

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Ancient environmental DNA (aDNA) is usually defined as genetic material retrieved directly from environmental samples such as sediments, ice or permafrost and represents an important source of information on past biodiversity. Early studies on aDNA proved that marine sediments are excellent DNA repository and it is possible to track historical records of various groups of organisms, including those that have no fossil record. Molecular approach gained an access to hidden diversity and thus might serve as an important tool to validate or refine paleoecological information obtained with other proxies.

Our first attempt to evaluate the use of aDNA as paleoceanographic proxy was the analysis of 1,000 years old foraminiferal record from Hornsund fjord (Spitsbergen). Molecular analysis revealed extraordinary richness of foraminiferal community, mainly due to the detection of non-fossilized monothalamous taxa. Moreover, aDNA revealed even small environmental changes, that were not clearly indicated by fossil record. Promising results of this study prompted the use of aDNA as paleoenvironmental proxy. Further step was to extend the aDNA record beyond the last millennium by analyzing sedimentary records from Svalbard region that span 4,000 years and 150,000 years, respectively. To provide the most complete view of eukaryotic community, we targeted a wide range of taxa, including foraminifera, phytoplankton (including diatoms and radiolarians), and zooplankton. The data inferred from molecular analyses correlated well with local environmental changes as well as with large-scale environmental variability driven by glacial-interglacial cycles, e.g., inflow of Atlantic and Arctic water masses, variability of sea-ice cover, and productivity.

Moreover, aDNA approach provides an opportunity to track the intragenomic variability of certain taxa and to establish the relation between the paleoceanographic changes and the occurrence of different haplotypes. Our record revealed the presence of two genetic subtypes of planktonic foraminifera *Neogloboquadrina pachyderma* type I during the last 150,000 years, one of them was present throughout the entire record, while the appearance of the second subtype was correlated with the reorganization of oceanographic conditions after the Last Glacial Maximum.

Despite the limitations of aDNA approach, resulting from the degraded nature of aDNA or potential technical biases, it may provide a powerful means to reconstruct paleoenvironments more comprehensively and to better understand what is driving past Arctic environmental changes.

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Planktonic foraminifera signal reconnection of Arctic and Atlantic oceans via Arctic Canada after Termination I

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The marine channels of the Canadian Arctic Archipelago (CAA) are primary pathways for water and heat exchange between the Arctic and Atlantic oceans. During the Last Glacial Maximum (18 ^{14}C ka BP), grounded confluent Laurentide and Innuitian ice sheets occupied the CAA, blocking any exchange between these two major oceans. A series of marine sediment (piston) cores extending to the end of the last glaciation and taken along the main E-W axis of the CAA provide valuable insights into regional paleoceanographic evolution. Of particular interest is a prominent signal of planktonic foraminifera (*Neogloboquadrina pachyderma*) at 11 cal ka BP following deglaciation. Planktonics are rare in the modern central CAA due to shallow water depths and the restricted, sill-controlled oceanographic circulation, rather dwelling in adjacent Atlantic-origin watermasses offshore (Baffin Bay, Beaufort Sea). *N. pachyderma* in the sedimentary record is accompanied by heavy benthic and planktonic ä^{18}O values and increased benthic foraminifera indicative of high current activity (*Lobatula lobatula*). Collectively, this signals inflow of relatively warm and saline Atlantic-derived Arctic Intermediate Water below 250 m, presumably facilitated by glacioisostasy and ice gravitational effects enhancing water depths by 80–125 m. This would have occasioned greater oceanic connection to adjacent ocean basins (Baffin Bay), and implies separation of Laurentide and Innuitian ice sheets by 11 cal ka BP. After an environmental amelioration (less seasonal sea-ice) indicated by benthic foraminifera and possibly linked to a regional Holocene Thermal Maximum, planktonic foraminifera disappear from the sedimentary record by 6 cal ka BP. This is likely a function of glacioisostatic rebound driving significant postglacial shallowing and excluding Arctic Intermediate Water inflow. 'Modern' oceanographic conditions are established characterised by sill-driven oceanographic circulation which restricts water throughflow to Arctic Ocean Surface Water.

Aeolian activity observations in Ebba Valley (central Spitsbergen) in the years 2012–2018

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Studies were conducted in central Spitsbergen characterized by dry polar climate variation. In the Arctic environment there are favourable conditions for occurrence of aeolian transportation such as low air and soli humidity, low and sparse vegetation cover, presence of fine material and incidence of strong gusty winds. At the same time aeolian processes are relatively difficult to measure in real time, mostly due to their turbulent and local nature.

Measurements were conducted on test sites representing different morphological and vegetation conditions: the surface of old raised marine terraces with rich tundra vegetation, the sandur area, solifluction slopes and alluvial cones with poor tundra coverage, as well as frontal moraine of the glacier almost without any flora. Plastic trays (0.035 m2) filled with glass marbles and local gravel material were used to measure aeolian accumulation during summer seasons (July-September), as well as field mapping of aeolian forms and continuous meteorological monitoring were also carried out.

Obtained results show high randomness of the material hitting the aeolian traps, even for those trays located at the close range. Calculations based on the average long-term series showed that the most important factors which decided about aeolian transport and accumulation rates were: close presence of fine, unconsolidated and dry mineral material and density of the plant cover.

These findings point to the need for careful analysis of the accumulation rates of older aeolian and loess cover layers, taking into account the local conditions prevailing during the deposition period.

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LiDAR-based mapping of glacial geomorphological landforms in Finland

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The multi-year project for glaciomorphological mapping in Finland based on airborne LiDAR (Light Detection And Ranging) interpretation has revealed new data for the morphological interpretation. For mapping, a new definition of the landform categories has been launched (Putkinen et al. 2017) and the process still continues. The LiDAR-based advanced morphological mapping with existing geological data offers an unprecedented methodology to interpret and categorize glacial landforms rapidly and cost-efficiently. In the glaciated terrain, particularly, it is effective in an examination of landscape development and glaciodynamic themes. These landforms include lineated features such as flutings, drumlins, and mega-scale glacial lineations; horizontal deltaic surfaces; and continuous, sharp-crested esker ridges delineated by kettle hole systems.

The mapping process combines the main geological unit (deposit) and new, landsystems-based glacial geomorphological feature information. So far the LiDAR data coverage has been the most complete in southern and central Finland. The focus has been in the areas of active ice lobes in those areas, where previously detected large mega-scale glacial features, such as mega flutings, drumlins, end moraine complexes and glacial melt water systems show up in LiDAR-based digital elevation models (DEM) in greater detail than ever before. More than hundreds of thousand lineation features, hummocky moraine formations, transversal moraine ridges and esker ridges together with other glaciofluvial morphologies have been mapped so far and work is continuing together with the increased coverage of LiDAR DEM.

Applications of new glacial landform database are numerous. The basic form of use is, of course, geomorphological interpretation and reconstructing of glaciodynamic processes within certain areas, such as in the area of single ice-lobe advance or complex glaciated terrain. One good example is the glaciomorphological interpretation in the area of active Kuusamo Ice-lobe in the eastern Finland (Sarala & Räisänen 2017). Furthermore, the new database can be used as a framework when applying Quaternary geological knowledge to land use management, including groundwater resources, mineral exploration, and environmental impact assessment procedures. Analysis of geological characteristics from the LiDAR DEM needs comprehensive theory-based knowledge about sedimentary environments, landform-sediment assemblages and their relations to the glacial processes and systems. In Finland and in other glaciated terrains, the core of glacial dynamic interpretation is based on spatiotemporal understanding of a variety of phenomena and interacting processes during glacial advance, re-advance phases and deglaciation.

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Southwest Greenland shelf glaciation during MIS 4 more extreme than during the Last Glacial Maximum

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Although geological and modelling evidence indicate that the last glacial inception started in NE Canada, only little is known about the glacial response of the nearby western Greenland Ice Sheet (GIS) during the first main glacial advance of marine oxygen isotope stage 4 (MIS4). Moraine ridges on the southwest Greenland outer shelf ('Outer Hellefisk Moraines') are generally assumed to outline the maximum GIS extent during the Last Glacial Maximum (MIS2). Here we present results from a multi-proxy study of a marine sediment core collected about 60 km south-west of the Outer Hellefisk Moraines. Our study demonstrates that the most extreme SW Greenland shelf glaciation occurred during MIS 4, with another prominent glacial advance dated between 34 and 40 kyr BP. In contrast, the MIS2 glaciation appears to have been less severe. Our data further suggest a significant influx of relatively warm Irminger Sea Water transported by the West Greenland Current since MIS 4. This likely limited the extent of the MIS2 glaciation on the SW Greenland shelf. Decreased precipitation over the southwest Greenland region re-ported in atmospheric modelling studies as a downstream effect of a much larger MIS2 Laurentide Ice Sheet may have played an additional role.

Bioturbation on the Yermak Plateau: Relationship to sea ice conditions and productivity

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The Arctic Ocean is partly covered by sea ice throughout the year and almost completely in winters. The variability in these sea-ice conditions highly influence the Earth's global energy budget by affecting the surface albedo, which in turn controls the exchange of heat and moisture between the atmosphere and the ocean and contributes to global heat transfer. In spite of the Arctic having such an importance in the global climate system, our knowledge about Arctic climate variability on longer time scales is quite limited.

One of the main problems is the poorly constrained age control. So, in my work, I have used the radiocarbon dating method to obtain dates from different depths in order to construct a better age model for the Yermak plateau. This area which is located at the entrance to the Arctic Ocean off the north-western coast of Svalbard is highly sensitive to climate change. Another part of my work is to understand the past sea ice variability. For this part, I have studied the X-Ray Radiography images of sediment cores from different depths and have observed the abundance of bioturbation structures from different depths to understand the paleo sea ice record from this region, as it is directly related to changes in one of the environmental parameters i.e. food availability. The availability of food in a certain location is highly controlled by geographical position through the relation with ice margin or continental shelves. Consequently, temporal variations in bioturbation abun-dance and trace fossil diversity have the potential to reveal changes in food flux, and con-sequently the sea-ice conditions. Therefore, this study of bioturbation pattern and trace fossils has a great potential to provide an important source of paleoenvironmental infor-mation for the Arctic Ocean.

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Late Glacial to Holocene variability of ocean stratification and Arctic freshwater export off Northeast Greenland

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The western Fram Strait is the main conduit for sea ice and freshwater from the Arctic Ocean. Here we present new data from two sediment cores obtained in 2015 from the NE Greenland continental margin to reconstruct in high temporal resolution the variability of this export and its effect on water mass stratification. Stable oxygen and carbon isotopes ($\delta^{18}O$, $\delta^{13}C$) were measured on both thin- and thick shelled specimens of planktic foraminifers *Neogloboquadrina pachyderma*. Since *N. pachyderma* is known to attain the thick carbonate crust of adult specimens in deeper water, the isotopic difference between thick-shelled (morphotypes 1 and 2, according to Eynaud, 2011) and thin-shelled specimens (morphotypes 4 and 5) is proposed to record the salinity difference between subsurface and surface-near waters. In Late Glacial sediments only minor $\delta^{18}O$ differences between the morphotypes suggest an upper water mass structure with only minor salinity differences. The high $\delta^{13}C$ difference of >0.5‰ is ascribed to strong quantitative differences in the decomposition of isotopically light organic carbon within the upper water column (likely from intense ice coverage and reduced bioproductivity) which precludes that the $\delta^{18}O$ similarities merely result from a reduced vertical migration activity of the foraminifers. After 18 ka, a series of $\delta^{18}O$ spikes (amplitudes >1.5‰ in morphotypes 4/5) reflect a number of freshwater events at the NE Greenland margin, likely related both to the export of freshwater from the Arctic Ocean and the early decay of the nearby Greenland Ice Sheet. Within these spikes, $\delta^{18}O$ and $\delta^{13}C$ differences of *N. pachyderma* morphotypes reach maximum values, pointing at extreme salinity differences in the upper few hundred meters of the water column and likely high portions of isotopically light dissolved inorganic carbon from terrestrial sources (meltwater). In the Holocene, $\delta^{18}O$ differences are reduced to ca. 0.5‰ and relatively low $\delta^{13}C$ differences may indicate an activity of organic carbon decomposition reaching significantly deeper in the water column than in the glacial and deglacial, possibly related to enhanced bioproduction and higher C fluxes. Good correlation of isotopic spikes in *N. pachyderma* records between core sites with 200 km N-S distance suggest that these features did not result from merely local freshwater events.

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Sea-level change and the role of polar ice sheets

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Polar ice sheets are principal drivers of major sea-level change at global and regional scales. The impacts of the waxing and waning of polar ice sheets are twofold: (i) the direct glacio-isostatic response in the near-field region, and (ii) the control of large-scale sea-level fluctuations worldwide. Long-term climate history reveals a relatively stable ice sheet on the Antarctic continent since Oligocene times and highly variable conditions in the polar regions of the northern hemisphere since the onset of Pleistocene glacial cycles 2.5 Ma ago (Miller et al., 2011).

Deglaciation of the last, the Weichselian glacial cycle started rapidly at 19.5 ka BP and ended around 6.0 ka BP with a sea-level rise (slr) of around 125 m derived from land-based ice melt. Remarkable are two meltwater pulses, periods of highly accelerated slr from 14.7 to 14.3 ka BP and 9.0 to 8.2 ka BP respectively with an amplitude of 15 m or more of relative slr. Drastic volume losses of the polar ice sheets in a short period of time preceded those sea-level jumps which cannot be fully explained up to now (Hanebuth et al., 2000; Liu et al., 2016).

If we look at the present-day global slr of ±3 mm/year, the relative contribution of Greenland ice melt is 25% compared to >10% from Antarctica (IPCC, 2013). The observed loss of shelf ice and underflow of oceanic waters to the low-lying continental basement below the ice are accelerating the seaward flow of land based ice. This could provoke instability of large parts of the Greenland and West Antarctic ice sheets (De Conto and Pollard, 2016). The loss and melt of Greenland's ice sheet would result in a global slr of 6.5 m; the West Antarctic ice volume would contribute another 8 m. This is much more compared to glacier melt outside the polar regions and thermal expansion of seawater which are the main components of slr today. The potential threat of future devastating slr requires more detailed observation and better understanding of polar ice sheet dynamics.

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Human-induced changes of modern Arctic sedimentary environments: two case studies on the distribution and fate of mine tailings disposed to fjords in northern Norway

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The extraction of raw materials from bedrock leads to the generation of "leftover" materials produced during mechanical and often chemical separation of the mined ores that are disposed as so-called tailings, either onshore or offshore. The latter often named submarine tailings placements or disposal alters the natural processes, consequently changing the environmental conditions and, thus, affecting the ecosystems to various degrees. We present two case studies form fjords in northern Norway – Repparfjorden and Bøkfjorden – exemplifying human-induced changes in the marine sedimentary environment caused by the disposal of submarine mine tailings.

Repparfjorden is an approximately 13 km long, up to 4 km wide and c. 37 km^2 large fjord with an outer and an inner basin, separated by a sill of maximum 50 m water depth. Approximately 1 Mt of mine tailings resulting from copper-ore mining were discharged to the inner basin during the 1970's (Kvassnes and Iversen, 2013). Bøkfjorden is ~23 km long, on average 2 km wide and c. 70 km^2 large fjord constituting a part of a larger fjord system with three branches, multiple embayments and several small islands. An about 30-m-high threshold is found in the middle part of the fjord. Approximately 56 Mt of mine tailings resulting from iron-ore mining were released to the innermost part of the fjord between 1971 and 1997 (Skei et al., 2010). An additional 13 Mt were released between 2009 and 2016 (Norwegian Environment Agency, https://www.norskeutslipp.no).

We performed multi-proxy analyses in 1-cm intervals on 17 short sediment cores from Repparfjorden and 12 cores from Bøkfjorden, respectively. Core locations were evenly spread throughout both fjords. The analyses included grain-size distribution and total organic carbon content. In total twelve cores from both fjords were analysed using ^{210}Pb and ^{137}Cs radioisotope techniques to establish chronologies, as well as to calculate sediment and mass accumulation rates.

The tailing-affected sediments in Repparfjorden constitute an up to 9-cm thick layer of primarily silty sediments of bimodal distribution depleted in organic matter content. Sediments with these properties cover an area of about 5 km^2 and are almost exclusively found in the inner part of the fjord, between the sill and the fjord head (Sternal et al., 2017). They extend up to about 3.5 km beyond the termination of the discharge pipeline. High-resolution swath bathymetry reveals that the tailings occur in series of cone-shaped structures that retained their original shapes after the disposal cessation (Andersson et al., 2018). The highest during-disposal sediment accumulation rate (4.3 mm yr^{-1}) exceeds the average pre- and post-disposal rates by a factor of 1.9 and 3.1, respectively. Mass accumulation rates (0.6 g cm^{-2} yr^{-1}) during the disposal exceeded the natural rates by a factor 2.0 and 3.5, respectively. Following the estimated average natural MAR the calculated amount of natural sediments deposited over the affected area

during 6 years would be ~66 kt. By comparison, 1 Mt of tailings were discharged during 6 years. This implies that the natural deposition equals 7% of the tailings deposition.

In Bøkfjorden the tailing-affected sediments are present in most of the investigated sediment cores retrieved from the inner and middle parts of the fjord, as well as in some cores from the outer fjord, covering an area of about 25 km^2. The tailing-affected sediments are mostly composed of silt and sandy silt of unimodal distribution. Organic matter content is very low. The 32-year-lasting disposal of the tailings led to the formation of a fan-like structure (1.5 km^2) at the discharge pipeline outlet in the innermost part of the fjord. Multiple channels incise this fan. These merge further out-fjord into an about 5-km-long meandering channel system with levees. The channel terminates at a threshold with a vertical drop of 30 m. A field of submarine dunes developed at the foot of this threshold. The estimated average natural sediment accumulation rate in the non-affected outer part of the fjord (3.5 mm yr^{-1}) is lower than the accumulation of tailing-affected sediments in the middle part of the fjord (factor of 2.7); the relevant mass accumulation rate (0.3 g cm^{-2} yr^{-1}) is higher by the factor of 4.3. Assuming that the estimated rates are representative for the entire fjord ~2.5 Mt of natural sediments would be deposited over the area of 25 km^2 during 32 years. By comparison, 69 Mt of tailings were discharged during 32 years. This implies that the natural deposition equals 4% of the tailings deposition.

The influence of tailings is in both fjords highest in the proximity to the discharge point located in the inner fjords. It decreases towards the fjord mouth. The most prominent impact of the tailings disposal on the sedimentary environments in the fjords is the formation of additional sedimentological structures including cones, a fan, a channel system with levees and sand dunes.

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Varietal mineral analysis of sediment provenance for revealing dynamics of Arctic ice sheets

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With the increased availability of in-situ micro-analytical techniques, provenance studies increasingly utilize geochemical or isotopic signals in single grains of a specific mineral (Clift et al., 2008). Even, the Pb and Nd isotopic compositions of detrital feldspars can be used as a possible provenance tool. As detrital feldspars commonly represent one sedimentary cycle, grains can be tracked back directly to their sources. Information on the variation in chemical composition of individual heavy minerals will provide valuable information for identifying sediment sources when compared with that of chemical mineralogy from potential source rocks, sampled from older sedimentary successions, river sands and glacial tills on land. Heavy mineral varieties can be established based on electron microprobe (EMPA) analyses and heavy mineral types can quantified by Mineral Liberation Analysis (MLA), which utilize a rapid scanning electron microscope particle analyser.

We have utilized varietal mineral analysis for retreat history of the southwestern sector of the Barents Ice Sheet by studying late glacial ice-rafted debris (Kaparulina et al., 2018). In marine environment there is a specific need to evaluate sediment source for components of crystalline rock as well as a possible involvement of recycled marine sediments. The Fennoscandian, Spitsbergen and Barents Sea ice sheets behaved in a very dynamic way when these were disintegrated. A present terrestrial study relates to glacial dynamics of the eastern sector of the Scandinavian Ice Sheet (SIS) in Northern Ostrobothnia. A 140 m long sediment core was drilled overlying the Mesoproterozoic Muhos Formation in Tupos, 20 km south from Oulu. Our target is to reveal possible variabilities in provenance areas and ice flow directions by studying tills for composition of heavy minerals with comparison to a 50 meters thick sediment sequence cored in Muhos that also include multiple till units, where the earliest presumably was pre-Weichselian (Lunkka et al., 2013). Such investigations for both Tupos and Muhos drill cores will be important additional contributions to the glacial advance-retreat reconstruction for the eastern sector of the SIS in central western Finland.

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Geological record of tsunami in western Greenland

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Arctic coasts, although known to be affected by tsunamis of various origin, e.g. landslide (Buchwał et al. 2015; Benjamin et al. 2018) or iceberg-generated events (e.g. Long et al. 2015), are little studied in regard to tsunami sedimentary evidence. Here we report on the effects of a landslide-triggered tsunami that occurred on 21st November 2000 in Vaigat, northern Disko Bugt in west Greenland (Dahl-Jensen et al. 2004). We studied the erosional and sedimentary features of this tsunami along coast-perpendicular transects in a range of geomorphological settings. The field descriptions were supplemented by terrestrial laser scanner and DGPS mapping, as well as sedimentological and geochemical analyses. The tsunami run-up reached 50 m a.s.l. and inundated over 300 m inland. The tsunami frequently caused erosion of existing beach ridges whilst erosional niches were formed inland. The tsunami deposits mainly comprised gravels and very coarse sand and formed sheets up to 30 cm thick. Their deposition was likely manily related to backwash as evidenced by field observations, deposits mineralogy and grain size trends (coarsening landward). At several sites boulder deposits reaching over 1 m in diameter were left, often transported as parts of icebergs. A characteristic feature related to tsunami deposits were "mud pats" – up to 1 m in diameter and about 20 cm thick silty deposits arranged in circles and covering the tsunami deposit. They are interpreted as the result of melting of icebergs washed inland by the tsunami. The specific polar coast environment including relatively steep fjord coasts, presence of permafrost and icebergs affect the final depositional sedimentary record of tsunamis. Apart from coastal plains, coastal lakes are also promising sedimentary archives for tsunami deposits. Examples, of landslide-generated and iceberg-roll generated tsunami deposits in lake sediment sequences reveal both their potential as well as limitations (Long et al. 2015). It is very likely that the frequency of the tsunami events has increased recently.

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The dynamics of southern sector of the last Scandinavian ice sheet inferred from streamlined bedforms

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Ice streams play crucial role in ice sheets drainage. Reconstruction of their spatial and temporal activity allows for better understanding of the past ice sheets dynamics and climate interactions. During the Weichselian glaciation, western Poland was occupied by two branches of Baltic palaeo-ice stream i.e. Odra and Wisła ice streams. Dynamics of the former Odra ice stream is largely unknown. However, recent increase in availability of high-resolution remote sensing products permitted detailed mapping of the glacial landform in a regional scale. Here, we used high resolution LIDAR data that enabled creation of digital elevation model of 0.4 m ground sampling distance, for mapping mega-scale glacial lineations (MSGLs), drumlins and flutes. Their proper recognition and description in central west Poland is a challenge due to diminishment of the forms by either covering them with younger, typically aeolian deposits, washing out or anthropogenic activity. Geomorphological mapping across an area over 60 000 km^2, reveal over 450 streamlined bedforms much of which are revealed for the first time. They represent a variety of sizes, amplitudes and elongation ratios. They have been organised into several flow-sets, and assigned to four paleao-ice streams, the branches of Odra paleao-ice stream. The results enabled to present new pattern of ice streams and their activity in central west Poland, that was characterised by high dynamism, thus opposite as in conventional model for this area in which the area is considered as an inter-stream zone.

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Variability of species-specific foraminiferal radiocarbon ventilation ages in the Greenland Sea since the last glacial

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The deep convection is one of the key processes in the ocean circulation. It is responsible for the formation of deep water masses and crucial for the ventilation of the deep ocean. It is also important for the Earth's climate as the deep water masses can store large amounts of excess heat and carbon from the atmosphere. One of the regions where deep open-ocean convection takes place is the central Greenland Sea. The intensity of this process changes over time but the exact course of its evolution remains largely unknown. We reconstructed the ventilation of subsurface and bottom water masses since the last glacial using radiocarbon ventilation ages obtained by calculating the offset of species-specific benthic and planktic foraminiferal radiocarbon dates from the atmospheric ^{14}C values. The results show high ventilation ages (up to a few thousand radiocarbon years) during Heinrich Stadial 1 indicating that the deep convection was almost completely absent during that time. Situation changed completely during the Bølling-Allerød interstadial, when the ventilation ages decreased significantly, indicating a full recovery of the convection process after the ice age. The recovery was interrupted in the Younger Dryas, the coldest phase of the deglaciation. The deep convection process intensified again in the early Holocene to reach a maximum in middle Holocene. Finally, after around 3,000 years BP the intensity of the deep convection decreased to its present-day level. The results also show extreme differences in radiocarbon ventilation ages between individual benthic species (especially *Pyrgo spp*. vs. non-miliolid species) but the reason for this bias remains uncertain.

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New palaeomagnetic ages from the Yermak Plateau agree with amino acid racemization geochronology from foraminifera globally

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Amino acid racemization (AAR) geochronology is a powerful tool for dating Quaternary marine sediments across the globe, yet its application to Arctic Ocean sediments has been somewhat limited. Anomalous rates of AAR in foraminifera from the central Arctic were reported in previously published studies, indicating that either the rate of racemization is higher in this area, or inaccurate age models were used to constrain the sediment ages. This study investigates racemization rates in foraminifera from three well-dated sediment cores taken from the Yermak Plateau during the 2015 TRANSSIZ Expedition. D and L isomers of the amino acids, aspartic acid (Asp) and glutamic acid (Glu), were separated in samples of the planktic foraminifera, Neogloboquadrina pachyderma and the benthic species, Cassidulina neoteretis to quantify the extent of racemization. In total, 241 subsamples were analysed, extending back to MIS 7. Two previously published power functions, which relate the extent of racemization of Asp and Glu in foraminifera to sample age are revisited, and a comparison is made between the ages predicted by these calibrated age equations and independent geochronological constraints available for the cores. The analyses reveal an excellent match between ages predicted by a global compilation of racemization rates for N. pachyderma, and confirm that a proposed Arctic-specific calibration curve is not applicable at the Yermak Plateau. These results generally support the rates of AAR determined for other cold bottom water sites, and further highlight the purportedly high rate of racemization indicated by previous analyses of central Arctic sediments. Future work will focus on extending this study into the central Arctic Ocean, where independent chronologies for a number of cores are being constructed using OSL dating of quartz grains and calcareous nannofossil biostratigraphy.

Abstracts of posters

New late Quaternary paleoenvironmental record from Lake Emanda (Verkhoyansk Mountain, East Siberia)

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The environmental history of the region was investigated within the scope of the German-Russian project PLOT. The Lake Emanda field campaign with seismic profiling and sediment coring was carried out in August 2017. The lake is about 7.5 km long, 6.5 km wide and located in Verkhoyansk Mountains (65°17.64'N, 135°45.55'E, 671 m a.s.l). Coring was built on seismic profiling conducted with the Innomar equipment. The shallow seismic revealed that the lake is made up of a western and eastern lake basins. Core Co1412 was retrieved from the western basin at and a water depth of 14.6 m. A 6.1 m sediment sequence was retrieved using the UWITEC equipment. Stratigraphic and geochemical analysis of the core include grain size analysis, X-Ray Flurescence scanning, Multi-Sensor Core Logger measurements, determination of TIC, TOC, TN, TS and water content as well as pollen, chironomid, diatom studies.

The revealed pollen assemblages can be subdivided into 7 main zones (PZ): PZ 1 (605–425 cm) is dominated by *Betula, Alnus*, *Pinus* and *Larix* pollen. The assemblages indicate that the sediments were formed during an interval with climate conditions similar to the Holocene ones. However, high contents of *Sphagnum* spores as well as Cyperaceae and Ericales pollen point to wetter soil conditions. The interglacial character of the revealed pollen assemblages may point to MIS 5 age of the sediments. The sediments also contain numerous green algae remains (*Pediastrum, Botryococcus*, Volvocales). PZ 2 (425–240 cm) is dominated by pollen of Poaceae, Cyperaceae and *Artemisia* indicating the cold and dry climate conditions. According to AMS ^{14}C dates the sediments were accumulated during MIS 2. PZ 3 (240–150 cm) is dominated by Poaceae, Cyperaceae, *Artemisia, Betula,* and *Alnus* pollen indicating the warmer climate conditions in comparison with PZ 2 interval. PZ 3 sediments were accumulated during Bölling/Allerod. *Betula* and *Alnus* pollen contents are lower in PZ 4 (150–125 cm) pointing to colder and drier climate coinciding with Younger Dryas cooling. The upper PZs show increase of *Betula, Alnus*, *Pinus* and *Larix* pollen contents reflecting changes in local vegetation during the Holocene.

The sediments are also studying for chironomid. The highest species diversity has been found at the Holocene and late glacial sediments (0–150 cm) with the strong decline of the species diversity and presence in the sediments between 344 and 432 cm. The only Holocene sediments (121–0 cm) contain diatoms which can be subdivided in 3 zones reflecting the stages of lake history during the Holocene. The 27 Holocene samples were also processed for $\delta^{18}O_{diatom}$ analysis. The $\delta^{18}O$ values range between +22.5 and

+27.3‰. Maximum values (+26.7–27.3‰) at the 84–93 cm depth probably reflect the Holocene Thermal Maximum. The absolute minimum (+22.5‰) at the 5 cm depth likely corresponds to the Little Ice Age. The observed gradual depletion of 4.8‰ in $\delta^{18}O_{diatom}$ in line with an overall Holocene temperature decrease.

Seasonal changes, spatial variability and origin of suspended organic matter in Hornsund, Spitsbergen

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Carbon stable isotope composition ($\delta^{13}C$) of suspended organic matter (SOM) was investigated to recognize temporal and spatial variability, as well as sources of particulate carbon delivered to the sediments of an Arctic fjord, Hornsund, Spitsbergen. Sampling was carried out between May 2015, when most of the investigated area was covered with sea-ice, and late August 2015. Samples were taken from a number of sites in central part of Hornsund, Burgerbukta, Samarinvagen and Brepolen bay in the innermost part of the fjord. One litre water volume, sampled from a range of depths between water surface and 100 m, was filtered using GFF filters. $\delta^{13}C$ values of the SOM were measured after acid treatment of the filters to remove carbonates. $\delta^{13}C$ values of SOM varied both temporarily and spatially reflecting the variable sources of organic carbon, namely the marine production in situ, fresh marine organic carbon brought from the shelf with currents and "old" carbon delivered from land. The samples were most ^{13}C-enriched (–22.4‰) in June, at the time of an intensive primary productivity within the fjord. Later, during the warm season, with the more intensive glaciers melting and thus supply of the suspended sediment load containing the old terrigenous carbon, $\delta^{13}C$ values of SOM decreased in all the localities studied towards the carbon isotope values of the local terrestrial end-member, i.e., $\delta^{13}C$ values of the old organic carbon in the bedrock. Change in $\delta^{13}C$ values of SOM was also observed with increasing distance from glaciers, e.g. in front of the Samarinbreen and reflect changes in intensity of primary production and supply of the old carbon.

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Assessment of preservation potential of subtle glacial landforms based on time-series of UAV and high-resolution satellite imagery: comparison of polythermal (Svalbard) and temperate (SE Iceland) glacial landsystems

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Ongoing glacier retreat results in the continuous exposure of proglacial areas. Such areas contain valuable information about glacial process-form relationships, which manifest in specific landform assemblages. However, the preservation potential of freshly exposed glacial landforms is very low, as proglacial terrains are one of the most dynamic parts of the landscape. Therefore, rapid mapping and geomorphological characterization of such areas are essential from a glaciological and geomorphological point of view for proper understanding and reconstruction of glacier-landform dynamics and chronology of glacial events. Annual patterns of recession and relatively small areas exposed every year, mean that the performing of regular aerial or satellite survey is expensive and therefore impractical. Recent advances in technology enable the development of low-cost alternatives for traditional aerial surveys. Small unmanned aerial vehicles (UAV) can be used to acquire high-resolution (several cm) low-altitude images. The UAV-based pictures can be subsequently processed through the structure-from-motion process to generate detailed orthomosaics and digital elevation models.

In this study we surveyed forelands of various glaciers on Iceland and Svalbard representing different types of proglacial landscapes: Fláajökull (annual push moraines); Hofellsjökul (bedrock bedforms and push moraines); Fjallsjökull (marginal drainage network); Rieperbreen (crevasse squeeze ridges and longitudinal debris stripes); Ayerbreen (transverse debris ridges); Foxfonna (longitudinal debris stripes); Hørbyebreen (geometric ridge network); Ebbabreen (controlled moraine complex). UAV campaigns were conducted using a low-cost quadcopter platform. Resultant orthophotos and DEMs enabled mapping and assessment of recent glacial landscape development in different types of glacial landsystems. Results of our study indicate that preservation potential of geometric ridge networks and debris stripes produced by polythermal glaciers on Svalbard is very low (< 5 years), whereas subtle landforms indicative for temperate conditions: annual push moraines (Iceland), flutings (Iceland and Svalbard) can survive decades without being seriously modified.

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The First Svalbard Holocene Assembly: Introducing the SVALHOLA Network

*The SVALHOLA Network**

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Climate change is one of the most serious challenges facing society today. Hence, there is a pressing need to improve our knowledge of natural climate variations and establish long-term reference values. The climate on Svalbard during the Early and Mid Holocene resembles the current climate regime on Svalbard (i.e. warmer regional waters, increased precipitation and reduced land-based ice cover). Yet, unlike those earlier periods, solely natural driving forces cannot explain the current changes.

The first Svalbard Holocene Assembly was held the 1st–3rd of February 2019 at The University Centre in Svalbard (UNIS) in Longyearbyen, Norway, funded by the Research Council of Norway and the Svalbard Science Forum. The workshop gathered international researchers and institutions involved in studies of Holocene glacier and climate history on Svalbard in order to discuss recent research developments, identify priorities in research activities, and plan for future directions. The workshop united thirty-six early career and senior researchers as well as students with experience in marine, terrestrial,

lacustrine and cryosphere fields in addition to ice-sheet modelers. One of the key objectives of the workshop was to discuss interdisciplinary collaboration and correlation between environments.

As a product of the Svalbard Holocene Assembly, the SVALHOLA Network was developed as an international working-group by the workshop participants. The network will strive to i) initiate collaborative projects between research groups, ii) promote holistic studies that synthesize evidence from sedimentary archives (terrestrial, marine, lacustrine and cryosphere) and iii) develop multi-disciplinary projects that combine field-data with climate proxy records and modelling studies. Organization, collaboration and an holistic approach are key ingredients for better understanding the Holocene glacial, landscape and climate history of Svalbard. This knowledge provides a critical perspective to assess the future of Svalbard's landscapes, ecosystems, and human population in a changing Arctic.

Biogeographic distribution and diversity of modern benthic foraminifera in the Arctic: implications for the paleoenvironmental interpretation.

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Benthic foraminifera provides fossil records that are commonly used as proxy for paleoenvironmental reconstructions in the Arctic. The valuable information about the past oceanographic changes can be retrieved by investigating foraminiferal assemblages as well as geochemical composition of the foraminiferal shells. Extracting precise information about the past environments depends on the knowledge on modern faunal analogues and a thorough understanding of how these relate to the environment. However, the knowledge of the modern formanifera is scattered among numerous local to regional studies that were performed over the last century, covered various parts of the Arctic, and have never been summarized to provide a pan-Arctic distribution pattern in relation to the environmental variability.

In this study, we compile state-of-the-art knowledge on the present biodiversity and distribution patterns of both calcifying and non-carbonate benthic foraminifera in the Arctic to provide a baseline for future changes monitoring and predictions as well as a reference for the paleoenvironmental interpretations. The data from over 53 reports published between 1962 and 2017, covering the Arctic region has been collected into a single base with standardized taxonomic nomenclature and used to document the regional patterns of modern foraminifera diversity and distribution in Arctic marine environment. Overall, the compiled benthic foraminifera dataset covering 27 Arctic marine ecoregions contained representatives of 4 classes, 10 orders, 97 families, 248 genera and about 636 (including unique records of genera indicated as multiple species 'spp.') or 568 ('unique spp.' excluded) species. The order Rotaliida, composed of calcareous species, was the most common and species-rich, it made 29% of the Arctic benthic foraminifera species. Furthermore, based on species composition similarities we distinguished seven larger biogeographic units – ecoprovinces, which consisted of one or more ecoregions. The central Arctic ecoprovinces shared 123 common species with Atlantic shelves; however, 308 species remained distinct for the central Arctic.

Ba/Ca ratios and oxygen isotopic composition of planktonic foraminifera in the Arctic Ocean as a tool for reconstructing paleo-riverine freshwater input

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The riverine freshwater input to the Arctic Ocean has profound impacts on global climate and ocean systems. When large amounts of freshwater from rivers and melting ice sheets enter the Arctic Ocean, the decrease in seawater salinity may change the ocean stratification as well as circulation. Such freshwater discharge potentially can influence the formation of North Atlantic Deep Water and subsequently the global climate and ocean systems. However, the long-term influences and interactions between riverine freshwater input and the ocean system have not been fully understood. Oxygen isotopes in planktonic foraminifera, commonly used to indicate the freshwater discharge events, have biases caused by other environmental factors such as seawater temperature, pH-value, or vital effects. In order to avoid these biases, we apply the Ba/Ca in planktonic foraminifera as a proxy for riverine freshwater input. The primary source of Ba in seawater is from continental weathering brought to the ocean by rivers (Martin and Meybeck, 1979). One of the advantages of this proxy is that Ba/Ca in planktonic foraminifera is not affected by any other environmental factor and has a positive correlation with Ba content in seawater (Hönisch et al., 2011). Also, no vital effect on Ba/Ca in planktonic foraminifera has been observed (Hönisch et al., 2011). In this study, the Ba/Ca ratios are analyzed by coupled plasma mass spectrometry in the High-precision Mass Spectrometry and Environment Change Lab, National Taiwan University, Taiwan. This study will reconstruct the spatial difference of Ba/Ca ratios and identify the riverine freshwater events in the Arctic Ocean from Marine Isotope Stage 3 (MIS3) to Holocene by combining the Ba/Ca in planktonic foraminifera and oxygen isotopic records. The preliminary results are based on two cores, AO96-B7 and LOMROG12-TC03, located on the Lomonosov Ridge. The Ba/Ca ratios in AO96-B7 increase during early MIS1, but no signal of decrease in oxygen isotopes has been found. The peak of Ba/Ca ratios and oxygen isotopes in LOMROG12-TC03 show up simultaneously during late MIS3, which may imply a riverine freshwater input event. In conclusion, the Ba/Ca in planktonic foraminifera has promising potential to reconstruct the variations of riverine freshwater discharge in the past.

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Holocene magnetostratigraphy and paleoenvironmental changes in the NE Barents Sea: Insights from NRM and ARM demagnetization using an automated cryogenic magnetometer at the Geological Survey of Norway

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Natural remanent magnetization (NRM) and Anhysteretic remanent magnetization (ARM) from U-channels of a 3 m long sediment core from the northeastern Barents Sea (~72.5°N 32.5°E) were stepwise demagnetized and measured using an automatically operating cryogenic magnetometer system at the Geological Survey of Norway. The magnetometer setup comprises an automated sample feeding, dynamic measurement design, operation and measurement monitoring, plus a customised output-to-database data handling with 24/7 remote quality control and operator interaction.

NRM and ARM demagnetization data are combined with measurements of magnetic susceptibility, wet bulk density and XRF elemental composition from high-resolution core-logging. The high-resolution (3 mm) U-channel NRM measurements allow reconstruction of palaeoinclination and relative declination to establish a chronostratigraphic framework of sediments that are otherwise poor in datable material. Comparison of NRM and ARM may provide a proxy for local geomagnetic palaeofield intensity. Besides palaeomagnetic age information, the combined results offer the opportunity to study sediment transport and deposition during the regional deglaciation history, spatial and temporal sea-ice fluctuations and the variability of marine palaeoproductivity during the Holocene.

Holocene environmental variability on the Wandel Sea shelf (NE Greenland)

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The western Fram Strait is the major gateway for sea-ice export and polar water masses from the central Arctic Ocean. Unlike the eastern Fram Strait, high resolution sedimentary records are scarce due to perennial ice coverage. Here, we present a 37 cm long sediment record of a giant box core, retrieved from the northern Wandel Sea (83.07°N, 20.32°W; 226 m water depth) during expedition PS115.1 (2017). We investigated the core for changes in paleoenvironment during the Holocene using sediment composition, foraminifer assemblages and isotopic composition of benthic and planktic foraminifers. The age model is based on four AMS radiocarbon dates. The sediment is generally fine-grained with the sand fraction rarely exceeding 5 wt. %. Sand fraction and foraminifer proportions correlate well throughout the core, indicating that coarse terrestrial input was comparatively low during the time of deposition. Both proxies show fluctuations in the lower part of the record (37–29 cm depth), low values for the central part (29–17 cm core depth) and an increase towards the core top. We interpret our data to reveal a highly fluctuating ice edge with numerous freshwater inputs during the older part of the sediment record, followed by a freshening of the subsurface water during the Holocene Thermal Maximum, and a subsequent progressive cooling during the Neoglacial. Benthic foraminifer isotope records display changes in Atlantic Water inflow on the shelf areas at times of seasonally open waters, especially during the Early Holocene. Exceptional high sedimentation rates calculated for the first 5 cm may be attributed to bioturbation and winnowing effects. This may be related to a changing current strength as a response to decreasing Atlantic Water advection to the central Arctic.

Spatiotemporal changes in the concentration and composition of suspended particulate matter in front of Hansbreen, a tidewater glacier in Svalbard

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Tidewater glaciers supply large amounts of suspended particulate matter (SPM) and freshwater to fjords and affect oceanographic, sedimentological and biological processes. Our understanding of these processes, is usually limited to the short summer season. Here, we present the results of a one-year-long monitoring of the spatial variability in SPM characteristics in a context of oceanographic and meteorological conditions of a glacial bay next to Hansbreen, a tidewater glacier in Hornsund (southern Spitsbergen). The observed range of SPM concentrations was similar to ranges measured in other sub-polar glaciated fjords, especially in Svalbard. The major source of SPM is the meltwater discharge from the glacier. The maximum water column-averaged SPM concentrations did not correlate with peaks in freshwater discharge and were observed at the beginning of the autumn season, when the fjord water transitioned from stratified to fully mixed. The observed spatiotemporal variations in the total SPM, particulate organic matter (POM) and particulate inorganic matter (PIM) are likely controlled by a combination of factors including freshwater supply, water stratification and circulation, bathymetry, the presence of sea ice, biological productivity and sediment resuspension. During the ablation season, the SPM maximum concentrations were located within the upper water layer, whereas during the winter and spring, the greatest amounts of SPM were concentrated in deeper part. Thus, typical remote sensing-based studies that focus on SPM distributions may not reflect the real SPM levels. POM and PIM concentrations were correlated with each other, during most of the time suggesting that they may have a common source (Moskalik et al. 2018).

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Mid Pleistocene productivity events in the subpolar NE Pacific: iron fertilization from aeolian dust and icebergs

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IODP Expedition 341 succeeded in recovering a continuous sedimentary record of Miocene to Late Pleistocene climate history at drill Site U1417 in the Gulf of Alaska, NE Pacific. Site U1417 sediments provide an excellent opportunity to reconstruct North Pacific sea surface conditions during late Neogene large-scale (global) climate transitions. The Mid Pleistocene Transition (MPT) – one of the most prominent intervals of global Quaternary climate change – is clearly identifiable in Site U1417 sediments (Jaeger et al., 2014). To fully exploit the environmental information archived in U1417 sediments, a sampling strategy has been pursued that permits direct correlation of different (independent) proxy data obtained from biomarker, micropalaeontological, sedimentological and geochemical (XRF) analyses. Mid Pleistocene SSTs in the Gulf of Alaska are in good agreement with SST reconstructions for the North Atlantic and the NW Pacific. A general cooling at about 1 Ma supports earlier hypotheses of an overall Northern Hemisphere ocean cooling as a prerequisite for the increase in continental ice volume. While phytoplankton productivity seems rather independent from SST at Site U1417, it is strongly related to elevated TAR values depicting enhanced input of terrestrial leaf-wax lipids (Meyers, 1997). The transport of these lipids is supposed to be effected by strong winds carrying dust from Alaskan loess deposits to the open ocean as well as by icebergs released from Alaskan tidewater glaciers. The latter is supported by the occasional coincidence of high IRD contents and TAR values. The close relationship between the TAR record, Ba/Al values and the abundance of diatoms, however, strengthens that together with the leaf-wax lipids also iron-bearing dust was exported leading to high productivity events at Site U1417 throughout the Mid Pleistocene. The distinct "on-off" pattern in diatom productivity evolved with the onset of the MPT, which suggests that the expansion of the Northwest Cordilleran Ice Sheet lead to an effective production of glacigenic iron-rich dust that was exported i) by strong northwesterly winds and ii) by icebergs. The observation that productivity peaks in the Gulf of Alaska are not confined to glacial or interglacial periods points to a rather local feedback between the export of iron-bearing dust and an immediately responding ocean surface. The identification of these hitherto unconsidered fertilization mechanisms that potentially fostered ocean productivity and hence the sequestration of atmospheric carbon into the deep ocean are further detailed by Müller et al. (2018).

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Large subglacial meltwater system on the northern Svalbard margin: implications for the ice sheet hydrology and glacial dynamics

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With the warming climate, the role of hydrological processes in the ice sheet dynamics is becoming increasingly more important, yet their diagnostic morphological and sedimentary facies are poorly understood in modern as well as ancient geological records.

Across the modern Barents Sea area, the Late Weichselian Svalbard-Barents Sea Ice Sheet (SBIS) was mostly warm-based and its large-scale dynamics was organized into fast-flowing large ice streams and relatively slow-moving inter-stream areas along its western and northern margins (Ottesen et al., 2007; Hogan, et al., 2010; Fransner et al., 2018). In the central part of the Barents Sea, numerous tunnel valleys have been mapped and interpreted to record a widespread subglacial meltwater erosion underneath the SBIS (Bjarnadottir et al., 2017). Subglacial meltwater features on the seafloor north of Svalbard have been previously suggested as well (Fransner et al., 2018) but so far not documented in detail.

Here we present new geophysical and geological evidence documenting for the first time a major subglacial meltwater feature on the northern Svalbard margin. Using high-resolution swath bathymetric data, chirp subbottom profiles and sediment gravity cores, c. 100 km long cross-shelf channel system and associated sediment fan were mapped north of Nordaustlandet. The channel system appears to be sourced in Duvefjorden and continues northwards in a somewhat sinuous pattern consisting of sections with variable morphology. The channel is most pronounced on the outer shelf where it is up to 2 km wide and up to 150 m deep. At the shelf edge, near the northern end of the channel, a large sediment fan is developed.

This paper presents the first results of a detailed sea floor study of a subglacial meltwater channel and associated outwash fan system north of Nordaustlandet and discusses its implications for the ice sheet hydraulics and dynamics on the northern Svalbard margin.

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Late Pleistocene-Holocene Evolution of Gydan Peninsula, Western Siberia, Russia

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Despite the long history of geologic surveys (since 1950s), Gydan Peninsula remains one of the least studied regions in the Russian Arctic due to its remoteness, vastness and relatively recent start of gas development. Hence, the Quaternary history of Gydan remains uncertain and disputable. Since the first works (Sax, 1953, Zarrina et al., 1961), there were debates concerning the prevalence of marine or terrestrial sedimentation, number, timing and extension of glaciations, etc. Most of the studies (Danilov, 1978, Avdalovich, Bidgiev, 1984) initially considered Quaternary sediments in the region as marine and/or glacial-marine and suggested a series of extensive transgressions in the Pleistocene. Other works (Astakhov, 1976, Grosswald, 1988) developed a glacial theory for the region. During the 1990–2000s, great efforts on dating of Quaternary sediments in the West Siberian North were made as a part of large international projects, such as QUEEN and PECHORA (Svendsen et al., 2004, Astakhov and Nazarov, 2010). New findings proposed smaller marine extensions than it had previously been thought, but greater glacial impact on the landscapes (Astakhov et al., 2016). Despite these abundant data, there is still lack of information on absolute age of the sediments; spatial coverage of the area by Quaternary studies remains insufficient; explicit regional correlations of sedimentary sequences are required.

We present new data on Quaternary sediments of Gydan Peninsula based on the results of the expeditions in 2012–2017 for five key sites: Cape Khonarasalya, western coast of Yavay Peninsula, Cape Nyadasalya, south-western Gulf of Enisey coast and the area of Parisento Lake. During fieldwork, we examined outcrops up to 20 m height from different topographic levels (from 0 to 50 m above sea-level) in different landscapes. Applying lithologic analysis, radiocarbon and OSL dating, as well as satellite imagery interpretation, we defined origin and age of these sediments. On the western coast of Gydan Peninsula (Cape Khonarasalya), marine clays and sands lie in the lower part of the outcrops; they are overlaid by similar marine and deltaic MIS 5 sediments folded by an ice sheet during a following glaciation. Above, glacial clays and loams with sandy inclusions of presumably MIS 4 age lie. At the top of the section, lacustrine and alluvial interstratified sands and loams were found (Baranskaya, 2016). On the north-western coast of Yavay Peninsula, we described marine silts and clays (MIS 3 or older) with overlying lacustrine sandy loams and peats (MIS 3-2) (Baranskaya, Onoshko, 2016). On the northern coast (near Nyadasalya Cape, Mammouth Peninsula), we described marine clays and sands, which are not older than MIS 5, overlaid by glacial clays containing massive ground ice (presumably MIS 4), terrestrial loams containing remnants of mammoths (MIS 3), lacustrine, alluvial and boggy sands and peats (Early and Middle Holocene) (Baranskaya, 2016). In the coastal cliffs of the Gulf of Enisey, a marine regressive sequence (MIS 5) outcrops, on which loams with massive ice beds, terrestrial sands and lacustrine-boggy loams are imposed (Baranskaya et al., 2019, in press). In the area of

Parisento Lake, alluvial/lacustrine interlaminated loams and sands of MIS 3 age lie, overburden with lacustrine thin sands of MIS 3–2 age with mammoth fossils.

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Deglacial evolution of the oxygen minimum zone in the subarctic North Pacific

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The Bering Sea is a semi-enclosed marginal sea connecting with the Arctic Ocean via the Bering Strait. During glacial-interglacial glacioeustatic sea level changes, the Bering Strait was episodically opened, thereby influencing paleoceanography of the western Arctic Ocean. Thus, detailed study of paleoceanographic conditions in the Bering Sea area is necessary for understanding environmental changes in the High Arctic. Here, we present high-resolution data on oxygenation changes in the intermediate and deep waters of the western Bering Sea during the last deglacial interval. Benthic foraminiferal assemblages were studied in two sediment cores, SO201-2-85KL (57°30.30' N, 170°24.79' E, w.d. 968 m) and SO201-2-77KL (56°19,90' N, 170°41,97' E, w.d. 2163 m), retrieved from the intermediate-depth and deep parts of the Shirshov Ridge, respectively, in the western Bering Sea. According to the approach developed by Tetard and co-authors (2017) for the northeastern Pacific, statistical treatments were applied to species abundance matrices to identify three oxygen-related groups which have been used to semiquantitative estimates of oxygen concentrations.

Oxic conditions (around 2 ml/L) are suggested at intermediate depths through the LGM – Heinrich I interval, whereas deep waters seem to be suboxic with highly variable oxygen concentrations between 0.8 and 2 ml/L during the same period. High oxygenation at intermediate depths was likely related to active intermediate water formation on the northern Bering Sea shelf and to a low sea surface bioproductivity. Suboxic deep water conditions could be explained by their origin from the low-oxygenated Pacific deep waters. Strongly dysoxic environment with oxygen concentrations around 0.1 ml/L are reconstructed for deep waters at the Bølling /Allerød, however, similar oxygen concentrations appeared at the intermediate depths after a 0.9 kyr delay. The development of OMZ seems to be related to sea surface bioproductivity rise, reduction of intermediate water formation and upwelling of old nutrient-rich deep waters to the intermediate depths. The 0.9 kyr delay might be linked to a gradual sea ice margin retreat during the climate warming. During the Younger Dryas and Early Holocene, intermediate and deep waters underwent strong oxygen deficiency which was more pronounced at the intermediate depths. The deep waters are characterized by modern oxygen concentrations (1.6–1.7 ml/L) during the Mid-Late Holocene. A comparison of micropaleontological, geochemical, isotopic and XRF data demonstrates that oxygenation changes were driven by variations in circulation and sea surface bioproductivity during the last deglacial interval.

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Paleoenvironmental changes in Vilkitzkii Strait (western Laptev Sea) during the last 12.5 kyrs

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The history of paleoenvironmental variability since 12.5 ka is reconstructed for the western Laptev Sea based on high-resolution records of marine sediment core AMK5636 from 225 m water depth in Vilkitzkii Strait including lithology, planktic and benthic microfossils, AMS^{14}C dating, stable isotope composition of carbonate tests and biomarkers. Three major intervals in the regional paleoenvironmental history were established.

The Late deglaciation (11.7–12.5 cal.ka) corresponds to the Younger Dryas cool period. At 12.3–12.5 cal.ka, the absence of benthic microfossils, uniform fine-grained composition of sediments and extremely rare ice-rafted debris (IRD) suggest a dense and perennial sea-ice cover in Vilkitzkii Strait. Slightly ameliorated environmental conditions and the inflow of Atlantic-derived waters are assumed for the time period between 12 and 12.3 cal.ka, based on the presence of Atlantic water index species *Cassidulina neoteretis* among benthic foraminifers (Lubinski et al., 2001). During the short interval between 11.9 and 12 cal.ka, a strong freshening event occurred in the region of Vilkitzkii Strait, likely related to the Kara Sea freshwater input. This assumption is evidenced by several findings: huge numbers of authigenic vivianite concretions that are formed under anaerobic conditions at the sea floor, likely related to freshwater-induced water stratification; extremely low numbers of microfossils and a predominance of opportunistic foraminiferal species *Elphidium clavatum*; extremely high abundances of coal fragments within the coarse-grained IRD, that might be transported from western Taimyr.

Early Holocene (11.7–8 cal.ka) climatic indicators reveal the warmest conditions within the last 12.5 cal.kyrs. A very low IRD content and growing abundances of benthic microfossils give evidence of a strong reduction in the summer sea-ice cover extent, surface water warming and growing bioproductivity. The common Arctic cold water species *Cassidulina reniforme* predominates among benthic foraminifers. This indicates a less stratified water column due to shelf flooding, active winter sea-ice and brine formation. The Atlantic water indicator *C. neoteretis* is almost absent. Similar findings of a considerable reduction or absence of *C. neoteretis* have been made previously in early Holocene sediments of other cores from the Laptev Sea continental slope (Taldenkova et al., 2012).

In mid-late Holocene (<8 cal.ka) deposits the progressive cooling is revealed by enhanced IRD input after 7 cal.ka. Six IRD peaks at *c.* 7, 5.2, 4, 3.3, 2.1 and 1.5 cal.ka reveal a 1–1.5 kyrs periodicity in climate fluctuations. Severe sea-ice conditions are indicated by increasing portions of «river-proximal» benthic foraminifers (Polyak et al., 2002) which were probably ice-rafted from coastal regions. The increasing water depths are indicated by the presence of the relatively deep-water species *Melonis barleean*us. Peaks of *Nonion labradoricum, Islandiella norcrossi, Stainforthia loeblichi* reflect periodically

high sea-ice marginal productivity at the core site. The reappearance of *C. neoteretis* of about 10–15% evidences Atlantic-derived waters inflow.

The research was carried out in the frame of the joint Russian-German research project "Changing Arctic Transpolar System" (CATS), supported by the Ministry of Science and Higher Education of the Russian Federation (project no. RFMEFI61617X0076) and by the German Ministry of Education and Research (project no. 03F0776).

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Adam Mickiewicz University Polar Station "Petuniabukta"

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In the years 1984–2018 twenty three scientific expeditions were organised to the Petunia Bay (Petuniabukta) area on Svalbard. Over past 35 years different accommodation and social facilities were in use:

- "Skottehytta" wooden house located on the eastern coast of Petuniabukta – years 1984–2009 (I–XIV AMU Expeditions)
- camping camp on the eastern coast of Petuniabukta – year 2010 (XV AMU Expedition)
- two container buildings located on the eastern coast of Petuniabukta – years 2011–2015 (XVI–XX AMU Expedition)
- three container buildings located on the western coast of Petuniabukta – since 2015 (XX–XXIII AMU Expedition)

The current infrastructure of the Station consists of 2 residential containers, each with an area of 10 m^2 and a third social-laboratory container with an area of 18 m^2. This allows for a comfortable stay and research for up to 10 people. The station operates seasonally in the summer months (July-September).

Many interdisciplinary scientific projects are realised based on the Station infrastructure:

- Dickson Land Ice Masses Evolution
- Snow cover variation on glaciers and non-glacierized areas of central Spitsbergen (Polish Svalbard Snow Programme)
- Slope system functioning in high Arctic Svalbard conditions
- Species diversity and diatomological dynamics of fresh-water reservoirs
- Dendrochronology and dendrogeomorphology based on analyses of Arctic shrubs
- Matter circulation in the Billefjorden land and sea geoecosystem
- Geomorphological mapping of the Billefjorden catchment area
- Hydrodynamics of the proglacial rivers
- Tourism in the area of central Spitsbergen
- Paleogeographic development and contemporary functioning of tidal flats under polar conditions
- Monitoring of polar geoecosystems – implementation of elements of Integrated Monitoring of the Natural Environment to polar conditions
- TeaComposition H_2O – Global Initiative of Water Pollution
- Topoclimatic research and studies of the temperature profile and air pollution in the 0–500 m layer
- Aeolian and niveoaeolian accumulation in periglacial and glacial environments in central Spitsbergen (Ebba Valley)
- Mechanisms controlling the evolution and geomorphology of rocky coasts in polar climates
- Geochemistry and hydrochemistry of the Billefjorden area

Beenchime Salaatinsky crater in northern Yakutia – origin and late quaternary records in the 8-km circular structure

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Beenchime Salaatinsky Crater (BSC) is a 8 km wide, multi-million-year-old ring structure located west of the Olenyok River in northern Yakutia. This is an area that has not been covered by Pleistocene time glaciers (Ehlers, J., Gibbard, P.L., 2007; Niessen et al., 2013). Short-term scientific goals of our study were (i) to reveal the origin of the crater (impact crater or volcanic crater) based on mineral analysis and (ii) to evaluate prospective Quaternary sediment records in the basin. Following earlier geomorphological surveys, it is assumed that the basin is the result of a volcanic explosion similar to Kimberlite Pipes elsewhere found in Yakutia (Pinchuk et al., 1971). Alternatively, a meteorite impact has been blamed, because suevitic breccias were identified (Mikhailov et al., 1979, Masaitis, 1999). According to geomorphological age estimates, the crater is believed to be between 65 and 40±20 Ma old (EarthImpactDatabase), but a robust physical dating is actually missing.

We sampled several landforms of the basin interior after digging soil pits into the ground and extracting short cores from the underlying permafrost. Sample sites were a peat plateau and ancient river terraces. In addition, a modern lake depression in the central part, 300 m in diameter and 4 m deep at maximum, has been studied using 50 MHz ground penetrating radar profiles and short cores. Bedrock samples were taken from representative sites of outcropping Paleozoic formations inside and outside BSC. Thin sections from bedrock were analyzed using polarized light microscopy. In fact, shocked quartz grains with PDFs (planar deformation features) were found in samples taken from a Permian sandstone outcropping in the crater interior. The crystallographic orientations were measured using a U-stage microscope. Some other samples of the crater rim were found to be only slightly shocked.

We sum up our results in a preliminary scenario, which suggests a Paleozoic meteoritic impact event, a Mesozoic overburdening of the area and a subsequent erosion in the course of the Olenyok Uplift. Finally, we propose late Quaternary landscape dynamics based on sediment dating using AMS ^{14}C and sediment properties in the crater; fluvial sediment transport is documented for the MIS 3 and MIS 1 periods whereas mid to late Holocene lake formation results from thermokarst dynamics. A distinct grain size change in the fine silt fraction from coarser to finer indicates increasing aridity in the area with lake level lowering during late Holocene time.

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New constraints on relative sea-level changes and ice sheet history in Svalbard from the radiocarbon dating of detrital marine shells in raised beaches and ground penetrating radar surveying

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Insight into the High Arctic coastal zone evolution is crucial to decipher landscape changes and associated shifts in sediment fluxes triggered by climate change. The gravel-dominated beaches of the Svalbard Archipelago provide an excellent location to examine the processes that control High Arctic coastal change. Of special interest are the mechanisms by which coastal systems respond to enhanced landscape change following deglaciation. Existing sediment budget studies in Svalbard have focused attention on quantifying the volumes of sediment transported by glacial rivers and derived from glacier erosion and reworking of fluvial catchment sediment. Little attention has been paid to the functioning of sediment storage and reworking systems within coastal zone over various stages of the Holocene.

Our research aims to address this deficiency by improving our understanding of the mechanisms of Holocene adjustment of the High Arctic coastal zone to non-glacial conditions. In this paper, we summarize the results of a pilot study led by our research team on uplifted beaches at Bjonapynten, Tempelfjorden, central Spitsbergen. Flights of raised beaches are emblematic of Arctic coastlines and record evidence for changes in relative sea-level change, glacio-isostatic adjustment, sea-ice extent, storminess, and variations in sediment supply.

Our research was based on a combination of methods including aerial photogrammetric and GIS analyses, ground penetrating radar surveys, sedimentological tests of coastal deposits, novel approach in radiocarbon dating of uplifted beaches and field-based geomorphological mapping. Our results document significant changes in rate of relative sea-level fall, sediment flux and coastal response (rate of coastal progradation, style of beach ridge formation) under intervals characterized by warming climate, retreating local ice masses, a shortened winter sea-ice season and thawing permafrost. We discuss our new data in the context of previously published RSL data and coastal evolution studies from Svalbard. Finally, data from isotopic dating, georadar soundings, and geomorphological mapping of beach ridge system are interpreted together with previous palaeoglaciological and paleoenvironmental reconstructions to discuss style and impact of deglaciation of High Arctic landscape evolution.

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Geochemical record of post-Little Ice Age natural and anthropogenic environmental changes in an Arctic fjord – Billefjorden, Svalbard

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Fjords of Svalbard have the potential to provide high resolution sedimentary and geochemical records of palaeoenvironmental changes. The present work focused on Billefjorden, subjected to major changes due to post-Little Ice Age rapid recession of glaciers, as well as to mining-related anthropogenic impact. The fjord is supplied with geochemically contrasting sediments from two major sources: a single large tidewater glacier Nordenskiöldbreen, draining basin composed of Proterozoic crystalline rocks, and a number of smaller glaciers occupying basins built of sedimentary rocks (mainly carbonates and sandstones). The aims of the study were to provide modern geochemical baseline and sediment provenance pattern in fjord surface sediments, to interpret geochemical record of post-Little Ice Age period in sediment cores, estimate organic and inorganic carbon burial rates and assess anthropogenic impact due to the past activity in Pyramiden – one of the northernmost coal mining sites. The study was based on geochemical analyses of major, trace and rare earth elements, carbonates, coarse grain component analyses, as well as previously published datings. The composition of surface sediments revealed distinct spatial variation related to local geology, suggesting fast deposition of sediments within a few km from the sources. The effects of grain size and contemporary biogenic carbonate production on the analysed glacimarine muds geochemistry were negligible. During the previous century, a gradually increasing trend in the ratio of carbonate-related elements and silica- and aluminosilicate-related elements (typical for crystalline rocks) in sediments from the central part of the fjord was documented and was likely related to increasing distance from retreating front of tidewater Nordenskiöldbreen. This trend accelerated around the 1950s, likely due to the retreat of the tidewater glacier into the shallower water causing a significant reduction in sizes of produced icebergs, which disintegrated and released sediments much closer to the source. The organic carbon burial rate in the central fjord cores was similar to other fjords of Svalbard, while the inorganic, carbonate-related carbon (IC) burial rate is so far the highest recorded in Svalbard and reached over 50 gIC/m^2/year. The impacts associated with anthropogenic activity were limited to the records of elevated contents of coal grains and zinc in the sediments, which were correlated in time with the local coal mining intensity.

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On the origin of carbon in Arctic fjord sediments – insights from Hornsund fjord, Svalbard

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Fjords are considered as globally important carbon sinks. Carbon sequestration and subsequent burial in marine sediments are important parts of carbon cycle. However, to assess the role of carbon storage in modern fjords it is important to assess the origin of carbon – does it come from primary production in marine environment or is it delivered from land. In the second case it is important to assess if it comes from modern plants or is eroded from older geological strata. Most of the estimates so far were made for temperate fjords. Here we attempted to approach the problem for Hornsund – an Arctic fjord with catchment covered covered by glaciers, and thus with limited supply of modern terrigenous organic carbon. The present study is based on analysis of organic carbon in suspension, in terrigenous sediments (end members) and fjord sediments (surface sediments, as well as high resolution analyses of sediment cores). The major methods included analyses total organic carbon content, analyses of carbon stable isotopes, as well as of radiocarbon 14C. Sedimentary organic carbon age analyses (^{14}C) was used for calculation of modern carbon fraction. The obtained dataset for over 200 samples was supplemented by independent dating of sediment cores with ^{210}Pb and ^{137}Cs, grain size analyses, bulk geochemical analyses and XRF scanning. The analyses of stable isotopes of carbon, commonly used as proxy for determination marine vs terrestrial origin of organic matter revealed large variations and seasonality, when analysed in suspended sediments. However, they were much more uniform, when analysed in the sediment cores. The application of simple two end-members model appeared to be difficult, nevertheless a significant contribution of the terrigenous origin carbon was revealed. The analyses of ^{14}C in organic carbon (in total organic carbon fraction as well as in residual organic carbon fraction) revealed that the contribution of the modern carbon is secondary in comparison with the old carbon (exceeding in age the limit of radiocarbon method, so being over 50,000 years old). This leads to conclusion that most of the organic carbon buried in Hornsund fjord comes from erosion of sedimentary rocks in the glaciated catchment. It is likely that similar pattern may be in other fjords with glaciated catchments.

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Impact of geothermal heat flux on thermal balance of palaeo-ice streams, central west Poland case study

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Subglacial energy balance comprises of upward heat conduction, geothermal heat flux (GHF) and mechanically generated heat. While being positive it facilitates melting and can impact ice flow if sustained over long period. In case of thin, low slope terrestrial ice streams near marginal zone, insulating effect of ice is reduced. In addition, below central part of an well lubricated ice stream, the shear heating can be significantly reduced due to cross-flow transmission of the force to its marginal parts (Raymond 2000). In such case geothermal heat becomes key factor that can lead to sustaining positive subglacial energy balance and thus fast ice streaming. The southern sector of Scandinavian Ice Sheet in central west Poland was occupied by Odra palaeo-ice stream with its several branches that protruded c. 200 km far from Szczecin Costal Region. The area of fast ice streaming, confirmed by presence of numerous mega-scale glacial lineations (MSGLs) coincides with geothermal heat flux of above 80 mW m^{-2}, elevated along the inner zone of the Variscan Deformation. High GHF is connected with high mantle heat flow in that region and contrasts with low GHF in NE Poland (even as low as 40 mW m^{-2}). Here, we quantitatively analyse whether it is possible that elevated geothermal heat flux could maintain fast ice streaming, counteract freezing or enable reaching melting point. For the analysed area minimal GHF needed to reach pressure melting point was estimated at the level of 60 mW m^{-2}. Together with low shear heat transmitted to the bed of ice streams in central west Poland, GHF becomes a primary factor for heat delivery to the ice/bed interface of ice streams.

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Implications for the processes of carbon burial from $\delta^{13}C$ of foraminifera tests and $\delta^{13}C$ of sediments in which they live.

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A study of foraminiferal assemblages and their tests $\delta^{13}C$ was carried out in Norwegian and Svalbard fjords. The sampling stations were located in different thermal conditions ranging from warmer fjords of southern Norway, to Arctic fjords, located in the northern part of Svalbard. We used 10 cm cores sliced in 1 cm samples, to analyse the spatial variability of: foraminiferal assemblages, foraminiferal tests $\delta^{13}C$, and sedimentary $\delta^{13}C$.

The carbons stable isotopes ratio in foraminifera tests is often successfully used as a proxy for such environmental conditions as paleoproductivity and water masses ventilation. It is a well-established proxy in modern palaeoceanography research. However, studies rarely focus on how $\delta^{13}C$ in contemporary foraminifera corresponds with the sediments in which they thrive. In our study we coupled the stable isotope composition of foraminifera tests and their surrounding sediments. This gave us new information on how the $\delta^{13}C$ of foraminifera is connected to $\delta^{13}C$ of sediments in which they live. The study was carried out in six fjords, characterized by different thermal regimes. This additionally allowed us to see if the foraminiferal tests $\delta^{13}C$ is correlated to sedimentary $\delta^{13}C$ or other, local environmental conditions such as temperature.

The ä^{13}C is also a proxy for type of water masses. High productivity waters are characterized by high $\delta^{13}C$ values as primary produces discriminate against the heavier carbon isotope (^{13}C). The old, bottom waters which have been separated from the surface for a long time are characterized by low $\delta^{13}C$ signature, as they pick up the decomposed organic matter (Lynch-Stieglitz, 2007). Thanks to this dependence we determined the signal of local waters in the $\delta^{13}C$ of both foraminifera tests and sediments.

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Annual changes in surface morphology of alluvial and colluvial fans quantified using UAV surveys, central Svalbard and southeast Iceland

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Different processes are responsible for the construction of fans and cones, including a whole range from gravitational mass movements to fluvial transport and deposition. To understand fan evolution and its response to environmental changes it is necessary to obtain knowledge of fan morphology, processes acting on fans, and how these processes change in various temporal and spatial settings. However, despite the number of studies related to alluvial and colluvial fans in cold environments, our understanding of the evolution of fans in such conditions is still limited. The purpose of this study is to provide detailed data on short-term transformations of fan surfaces in cold environments based on examples from Svalbard and Iceland.

We mapped and quantified seasonal dynamics of topography for four debris-flow-dominated fans located in the vicinity of Adventdalen (central part of Spitsbergen Island, Svalbard archipelago), and for three fans in the foreland of Breiðamerkurjökull (SE Iceland). Time series (2015–2018) of unmanned aerial vehicle (UAV) surveys and structure-from-motion approach enabled us to create cm-scale digital elevation models (DEMs) and orthomosaics. DEMs were coregistered and used to calculate volumetric changes, whereas orthomosaics allowed investigations of geomorphological processes related to the recorded transformations.

Our results demonstrated that the seasonal dynamics of fan surfaces was very diversified in time and space. Some sections of fans were stable over four years despite the occurrence of an active layer, and topography "prone" to erosion/deposition. Conversely, relatively short periods of activity of processes such as debris flowing or thermokarst erosion resulted in serious transformations recorded for other fragments of fans.

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Geomorphic effects of glacial lake outburst flood recorded by multi-temporal UAV surveys, Zackenberg, Northeast Greenland

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Zackenberg River in Northeast Greenland (74°30'N; 20°30'W) drains local ice cap situated approximately 30 km from the seashore. River floods related to the outburst of the ice-dammed lake have regularly been reported since 1996, usually in July or August. This study presents geomorphological investigations of the results of the flood which happened on the 6th of August 2017. We mapped 2 km long section of the river, located near the river mouth and Zackenberg Research Station to quantify short-term riverscape response to the flood. Three survey sessions utilizing small quadcopter were performed on 5th August 2017 (a day before the flood started), 6th August 2017 (during the high-water conditions) and 8th August 2017 (after the river returned to the average water level). From each survey session, detailed orthomosaic (2 cm cell size) and digital elevation model (DEM, 7 cm cell size) have been produced. Volumetric changes were quantified using geomorphic change detection approach by subtraction of DEMs from subsequent periods. Planimetric transformations were investigated using time-series of orthomosaics.

Riverbanks retreated by a mixture of two main processes: strong currents removed material, and thermo-erosion of permafrost in the banks resulted in the development of overhanging sections or collapsing of large blocks of sediments and ground ice. The maximal later erosion recorded as an immediate effect of this single flood event was up to 9 meters. However, the occurrence of overhung sections and tension cracks indicate that further bank failure is likely to happen. Morphology of river channel also changed, and numerous gravel and sand bard migrated as a result of the flood. Collected information present a useful analog of the geomorphic response of small river channels affected by large floods. Our study also indicates the suitability of small, budget UAVs, for monitoring of rapid changes, even in relatively harsh Arctic environment.

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Micropaleontological study of a sediment core collected on the Bellsund Drift (Svalbard): the last 2 ka

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The last 2000 years BP are important to understand the recent climate change. Moreover, the studies of environmental changes recorded in this period offer the possibility to understand how our climate can change in the near future. With these premises, we present the results of the combined study of diatom and foraminifera assemblages together with the sedimentological characteristics of the long Calypso core GS191-01PC. This core was collected on the Bellsund Drift (south-western margin of Spitzbergen) during the expedition of the RV G.O. Sars (5–15 June 2014), in the framework of the Project Eurofleets-2 PREPARED. The study focuses on the 2000 year BP with the final aim to understand paleoclimatic variations. Diatom assemblage shows that warm periods are characterised by *Coscinodiscus* group and in same levels there are high percentages of the fresh-water diatom *Aulocoseia spp.* One the other hand, cold periods are characterised by the presence of the cold species *Thalassiosira antarctica* and higher percentage of the polar planktonic foraminifera *Neogloboquadrina pachyderma*.

The preliminary results of the micropaleontological and sedimentological analyses allow to recognize an alternation four different climatic periods. On the base of the age model, constructed with ^{14}C AMS and paleomagnetic data, we interpret these periods as the Little Ice Age and the Dark Age Period interbedded with the Roman Warm Period and the Medieval Warm Period.

Optically stimulated luminescence dating of sediments from the Lomonosov Ridge

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Establishing a solid chronological framework for Arctic marine sediments is a critical first step towards deciphering palaeoceanographic change in this climatically sensitive and remote ocean basin. However, this has historically been more challenging than in other ocean basins. Optically stimulated luminescence (OSL) dating has provided the only absolute late Quaternary ages for central Arctic sediments, and it has considerable potential to contribute to the development of chronologies in other parts of the Arctic Ocean.

This study applies OSL and infrared stimulated luminescence (IRSL) geochronology to multi-grain quartz and feldspar samples from a sediment core taken from the Lomonosov Ridge off the Siberian shelf during the 2014 SWERUS-C3 Expedition. A myriad of late proposed age models exists for this, and other neighbouring cores in the region. Resolving this controversy is important in order to determine the timing and extent of glacial activity on the Siberian shelf during MIS 4–6. Furthermore, advancing the chronology of late Quaternary sediments in this sector of the Arctic will benefit the next IODP expedition into the Arctic.

The preliminary results from OSL and IRSL show that quartz OSL and feldspar IRSL ages of the samples range in age from 11 ka to 189 ka. A number of quartz samples have significantly skewed small-aliquot dose distributions, which may suggest incomplete bleaching and thus age overestimation; the application of the minimum age model (MAM) partly counters this effect. The generally higher IRSL ages for the same samples could also point in the same direction, although the similar ages for different grain-size fractions do not. The preliminary results closely support some of the more recent age models proposed for this area and may help to better demarcate boundaries between marine isotope stages.

Does the share of Foraminifera derived carbon in the sediment carbon pool reflect environmental changes in the geological past? Preliminary results from NE Greenland

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Increasing atmospheric CO_2 concentrations within the past two centuries have led to major CO_2 absorption by the oceans. Ongoing ocean acidification has changed the saturation state of the seawater in relation to calcium carbonate particles. This has reduced the ability of calcifying benthic and planktonic organisms to produce their tests and skeletons. An important part of the carbon cycle is the carbon burial process. A significant role in this process play Foraminifera. They absorb carbon as CO_2 from seawater while forming their tests. When a foraminifera dies, it gets buried by sediments. The organic matter disintegrates but the carbon built into the test remains 'trapped' in ocean sediments, excluding foraminiferal carbon from the carbon cycle even for millions of years.

Our previous studies have shown that Foraminifera are responsible for 38% of inorganic carbon production in present-day Adventfjorden, Spitsbergen. Further analyses of samples from Norwegian and Svalbard fjords indicate even 90% of modern foraminiferal contribution to carbon burial processes. This study aims to investigate the inorganic carbon contribution over the geological past. The research hypothesis is that the content of Foraminifera carbon in marine sediments is higher during the relatively warm periods than during the cold climatic phases. The main goal of this study is to investigate the foraminiferal organic and inorganic carbon pool in sediments of the Northeast Greenland continental margin in relation to environmental variables during the late Quaternary. The project is based on the assumption that Foraminifera play an important role in the carbon burial process due to the incorporation of calcium carbonate into their tests. The results of the proposed project will provide the first quantitative data about carbon burial in the Holocene and the Pleistocene sediments of the eastern Greenland continental margin.

The foundation for the study is a sediment core retrieved during R/V Oceania cruise in August 2017 from NE Greenland continental slope. The OCE2017-GR2-GC core contains a sediment record of the last 30 thousand years with a time resolution sufficient to reconstruct inorganic carbon content of sediments in relation to millennial-scale environmental changes. It witnessed a transition from fully glacial conditions of the Last Glacial Maximum, through Bølling-Allerød interstadial and Younger Dryas cold event, to the Holocene Thermal Maximum and the further evolution of the present interglacial. The results of this project will expand the knowledge about carbon burial process in the deep marine environment as well as about foraminiferal assemblages in western Nordic Seas and will contribute to the understanding of their role in the changing environments of the late Pleistocene and the Holocene.

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Late Pleistocene environmental variability off NE Greenland

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The Fram Strait is the only deep-water connection where warm and cold water masses are exchanged between the Arctic and all major ocean basins. But so far, only little is known about the past climate and oceanographic conditions of the western Fram Strait near Greenland. Here we present a Late Pleistocene sediment record from the NE Greenland margin, obtained during expedition PS93.1 (2015) of RV Polarstern. The 756 cm long sediment record (81.2°N, 7.3°W, 1549 m water depth) was radiocarbon-dated using planktic foraminifers (*N. pachyderma*). This led to a calibrated surface age of 12.6 cal. ky BP and an age about 52.2 cal. ky BP at 187 cm. A multiproxy approach, involving stable oxygen and carbon isotope records and microfossil data (e.g., foraminifer species like *B. aculeata*, *P. bulloides*, *S. rolshauseni*), is used for the rest of the record, allowing a correlation to available global and regional records. With the use of proxies like sediment composition, foraminifer contents, ice-rafted debris and the isotopic composition of planktic and benthic foraminifers, we reconstruct the environmental variability off NE Greenland during the Late Pleistocene with particular attention to the freshwater export from the Arctic, sea-ice coverage, Atlantic Water advection and the glacial history on North Greenland in the highest possible temporal resolution. Variations in source-specific terrigenous sediment components furthermore allow to differentiate between different source areas of ice-transported material and reflect the history of the circum-Arctic ice sheets, including the Greenland Ice Sheet. First results show highly variable foraminifer contents, including time intervals without any foraminifers at all, likely due to unfavorable environmental conditions. The presence of benthic foraminifer *P. bulloides* indicates the interval of MIS 5a. Additionally, multiple freshwater events can be identified by outstanding low oxygen isotope values paired with low carbon isotope values. These events must be related to rapid changes of the configuration and extent of ice sheets on circum-Arctic continents and shelves.

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