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Processes and Palaeo-Environmental Changes in the Arctic from Past to Present (PalaeoArc) – introduction

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PalaeoArc (Processes and Palaeo-Environmental Changes in the Arctic: from Past to Present) is an international research network dedicated to understanding and explaining climate-driven environmental changes in the Arctic from the Early Pleistocene to the present day. This initiative builds upon a strong foundation of previous palaeo-Arctic research programmes dating back to the 1980s.

The legacy began with the Polar North Atlantic Margins – Late Cenozoic Evolution project (PONAM: 1990–1994; Hjort & Persson 1994; Landvik & Salvigsen 1995; Elverhøi *et al.* 1998), followed by the Quaternary Environment of the Eurasian North project (QUEEN: 1996–2002) (Larsen *et al.* 1999; Thiede *et al.* 2001, 2004; Kjær *et al.* 2006). These efforts were succeeded by the Arctic Palaeoclimate and its Extremes programme (APEX: 2004–2012) (Jakobsson *et al.* 2008, 2010, 2014) and the Palaeo-Arctic Spatial and Temporal Gateways programme (PAST Gateways: 2012–2018) (Ó Cofaigh *et al.* 2016, 2018).

The current network of PalaeoArc was launched in 2019, where a new international steering committee was formed to lead activities, annual conferences and field trips from 2019 to 2025. The first meeting took place in Poznań, Poland (2019) (Lyså *et al.* 2019). A second conference, originally planned for 2020 in Pisa, was postponed due to the COVID-19 pandemic and held online in 2021. A PalaeoArc paper collection in *Arctic Antarctic and Alpine Research* (Lyså *et al.* 2022) originates from that conference and reflects the network's broad scientific scope, fostering interdisciplinary discussions on Arctic environmental change across a range of timescales. The third PalaeoArc conference was held in Rovaniemi, Finland, in 2022, and some papers from the conference were published in Bulletin of The Geological Society of Finland (Sarala 2023). Thereafter, conferences were held in Akureyri, Iceland (2023) and Stockholm, Sweden (2024), from which the articles in this special issue originate. The final PalaeoArc conference is scheduled to take place in Tromsø, Norway, in 2025.

The Arctic is experiencing some of the fastest and most dramatic impacts of global warming, with surface air temperatures rising nearly four times faster than the global average between 1979 and 2021 (Rantanen *et al.* 2022). Even if global temperature increases are kept below 2 °C, the region is expected to undergo profound and lasting changes such as loss of sea- and glacial ice, permafrost thaw and shifts in precipitation patterns (AMAP 2017; Fox-Kemper 2021).

To understand these changes and their complex feedback mechanisms, long-term palaeorecords are essential. They offer critical context for current trends and help reveal climate states and transitions beyond the scope of modern observations. Past Arctic climate shifts during the Quaternary caused major environmental transformations recorded in both terrestrial and marine archives. PalaeoArc aims to build on this knowledge by integrating expertise across disciplines to refine reconstructions and improve model-data comparisons. Continued interest in the growth and retreat of Arctic ice sheets, their impact on marine and terrestrial environments and associated environmental changes driven by climate variations, provides valuable analogues for predicting future Arctic responses. However, uncertainties remain regarding earlier glaciations, sea-level changes, and landscape and environmental transformations during the Quaternary, highlighting key areas of research that PalaeoArc aims to advance, as reflected in the papers included in this special issue.

This special issue of Boreas contains 11 papers reflecting three out of the four core themes of the PalaeoArc programme: (i) the dynamics of Arctic ice sheets, ice shelves and glaciers; (ii) the dynamics of high latitude oceans and sea ice; (iii) the dynamics of the terrestrial environment and landscape evolution; and (iv) the climatic response to, and interaction between, these different parts of the Arctic system.

PalaeoArc is founded on the rationale that understanding past Arctic environments is key for understanding current and future changes. The programme also emphasizes inclusivity, fostering collaboration across disciplines, countries and career stages. This is reflected in the diverse authorship of the papers included here,

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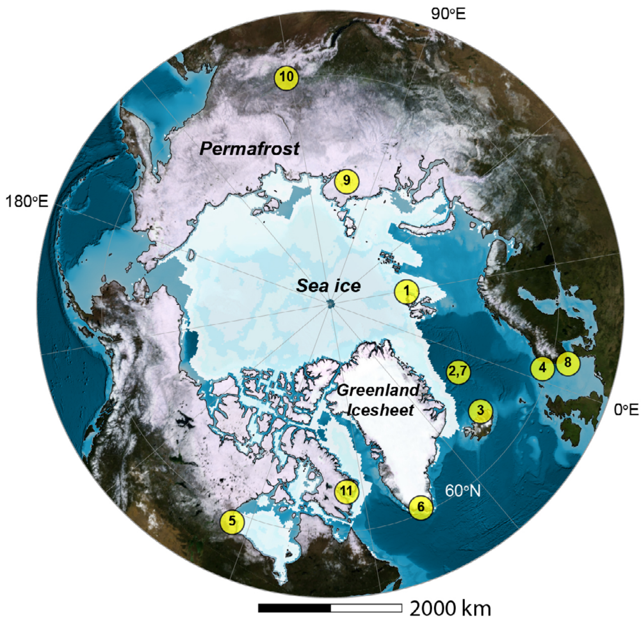

Fig. 1. Location of palaeo-Arctic studies represented in this special issue (yellow circles): 1 = Schomacker *et al.* (2025); 2 = Lyså *et al.* (2025); 3 = Aradóttir *et al.* (2025); 4 = Ottesen *et al.* (2025); 5 = Nishikawa *et al.* (2025); 6 = Larsen *et al.* (2025b); 7 = Larsen *et al.* (2025a); 8 = Holthuis *et al.* (2025); 9 = Andreev *et al.* (2025); 10 = Stieg *et al.* (2025); 11 = Belko *et al.* (2025).

spanning marine and terrestrial research, field and lake studies and different multiproxy methods including chronology, geochemistry and micropalaeontology, across the Arctic and sub-Arctic (Fig. 1).

The dynamics of Arctic ice sheets, ice shelves and glaciers

Schomacker *et al.* (2025) used a multiproxy approach to investigate the Sjuøyane archipelago, northern Svalbard (site 1; Fig. 1), to shed light on the glacial history of the Svalbard-Barents Sea Ice Sheet. Findings suggest that parts of the archipelago were ice-free during the Middle Weichselian interstadial and after the Late Weichselian glaciation, with lowlands deglaciated around 14.7 ka ago and highlands possibly earlier. Holocene environmental changes are recorded in lake sediments, indicating gyttja accumulation since at least 7.0 ka, whereas *in situ*–killed moss sampled suggests Neoglacial cooling beginning around 3.8 ka.

Lyså *et al.* (2025) reconstruct Lateglacial and Early Holocene glacier evolution and environmental changes on the northern part of the island of Jan Mayen (site 2; Fig. 1) through extensive documentation of glacial sediments and landforms, radiocarbon and cosmogenic nuclide exposure dating, as well as stratigraphy and ground penetrating radar surveys. Their results indicate that the Last Glacial Maximum ice cap of Jan Mayen separated into two around 20 ka, followed by intensified melting in the northern part during the deglaciation (~19 ka). The interpretation of the exposure ages is challenging but suggests Lateglacial readvances and the deposition of ice-cored lateral moraines, which later disintegrated under milder climate conditions in the Early Holocene. Late Holocene cooling culminated during the Little Ice Age, causing extensive glacier advances.

Aradóttir *et al.* (2025) studied the geomorphological and sedimentological characteristics of transverse ridges within a major palaeo-ice stream flow-set in northeast Iceland (Site 3; Fig. 1) to improve understanding of the Iceland Ice Sheet (IIS) dynamics during deglaciation. Cross-cutting flow-sets, identified through streamlined subglacial bedforms (SSBs), suggest complex ice-flow behaviour during and after the Last Glacial Maximum. The transverse ridges, interpreted as ribbed moraines, consist of pre-existing glaciofluvial sediments overlain by subglacial till. Internal deformation structures indicate compressional ice flow during formation. Their spatial distribution and oblique orientation to SSBs suggest development beneath lateral shear margins, marking a late-stage shutdown of ice streaming. Formation is attributed to the Younger Dryas and/or Preboreal readvances.

Ottesen *et al.* (2025) use high-resolution 3D seismic data to reconstruct the dynamic history of ice flow from Norway to the North Sea Plateau (site 4; Fig. 1) during the Quaternary period. Focusing on the Marstein Trough, the study examines buried subglacial landforms and acoustic sedimentary facies to describe past glacial processes and the evolution of the Scandinavian Ice

Sheet. Mega-scale glacial lineations demonstrate how ice initially followed a westward direction during early phases of ice sheet buildup, before re-orienting to a north–south flow as the larger Norwegian Channel ice stream developed under full-glacial conditions.

The dynamics of the terrestrial environment and landscape evolution

Nishikawa *et al.* (2025) examine how two shallow subarctic ponds in Canada's Hudson Bay Lowlands (Site 5; Fig. 1) responded to recent climate change. Using a multi-proxy palaeolimnological approach, they integrate changes in chironomid assemblages with geochemical and isotopic indicators of past temperature and environmental conditions. Although the ponds are in close proximity, they experienced distinct hydrological histories. Nonetheless, the study reveals a shared ecological response to warming, with both ponds showing a transition towards more diverse chironomid communities composed of taxa with higher temperature preferences, potentially signalling a decline in ecological resilience.

Larsen *et al.* (2025b) reconstruct the Holocene aeolian activity in southern Greenland (site 6; Fig. 1) using lake sediment records and optically stimulated luminescence dating. They identify two periods of intensified aeolian activity over the past 10 ka, that is, 500–1200 CE and from 1450 CE to present. The aeolian activity is found to have been unrelated to the activities and decline of the Norse settlement, but rather related to changes in North Atlantic atmospheric circulation and glacier advances and associated increased katabatic winds.

Larsen *et al.* (2025a) describe the effect of explosive volcanism on glacier preservation in the southern part of the island of Jan Mayen in the North Atlantic Ocean (site 7; Fig. 1). They discovered glacier ice preserved under a thick cover of tephra and thereby demonstrated for the first time that glaciers were present in this part of the island in the Holocene. This is supported by descriptions of meltwater deposits and channels indicative of jökulhlaups and dating of the timing of glacier advances and retreats.

Holthuis *et al.* (2025) present geological data from southern Norway (site 8; Fig. 1) that indicate falling relative sea level (RSL) over the last 7000 years, contrasting with tide gauge records showing a rise since 1960 CE. To bridge the gap between instrumental and geological records, a salt marsh core was analysed using multiple proxies. Results suggest decreasing tidal influence and salinity over the last millennium, pointing to falling RSL. However, increased marine diatoms and sedimentation rates after ~1930 CE indicate the onset of RSL rise in southernmost Norway around that time.

Based on lake core sediments in the northern Taymyr Peninsula, Andreev *et al.* (2025) (site 9; Fig. 1) reconstruct environmental changes spanning the last 62 ka. The pollen record reveals a shift from open, shrub-dominated landscapes under relatively warm conditions to colder, drier climates marked by increased erosion and lower lake levels. The coldest and driest period during the Last Glacial Maximum coincided with extensive herb dominance, followed by gradual warming, evidenced by rising shrub and sedge presence and indicators of grazing activity. Clear signals of rapid climate oscillations are recorded, reflecting broader regional influences. The onset of the Holocene is marked by significant warming and increased vegetation, followed by a thermal maximum and subsequent gradual cooling to near-modern conditions.

Stieg *et al.* (2025) present a new Siberian lake diatom oxygen isotope record (Lake Khamra) (site 10; Fig. 1) that aligns with Northern Hemisphere trends, showing cooling after Holocene maxima at 11.2 and 6.7 ka. These diatom $\delta^{18}O$ maxima correspond to peak summer insolation and air temperature, whereas centennial variability likely reflects fluctuations in precipitation. Comparing the ~6.2 ka time slice and recent periods reveals greater recent hydroclimatic variability and a sharp total mercury increase alongside $\delta^{13}C$ decline, suggesting anthropogenic impacts on this remote lake system.

The climatic response to and interaction between these different parts of the Arctic system

Belko *et al.* (2025) used new sea-floor geomorphology data from the Broughton and Merchants troughs off southeastern Baffin Island (site 11; Fig. 1) to define the Laurentide Ice Sheet extent during the Last Glacial Maximum. In Merchants Trough, grounding zone wedges, moraines, and ice-stream bedforms suggest the ice sheet reached near modern fjord mouths, with evidence of an ice shelf extending beyond. In Broughton Trough, mega-scale glacial lineations and iceberg scours mark the maximum extent. Differences between the troughs reflect varied ice sources, improving the understanding of the relationship between inland ice dynamics and ice-sheet extent along continental margins.

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