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# Tracing the Origin of Sedimentary Organic Matter in Arctic Fjords Using Lipid Molecular Markers

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## 1. INTRODUCTION

The burial and long-term storage of organic matter in marine sediments play a crucial role in regulating the global carbon cycle and atmospheric $CO_2$ levels. Fjords, characterized by high sedimentation rates and organic carbon fluxes, are particularly significant, accounting for around 11% of the annual global marine carbon burial (Smith et al. 2015).

Despite a short productive season and limited vegetation, Svalbard fjords exhibit high area-normalized rates of organic carbon accumulation. The cycling and composition of organic matter in these Arctic fjords are influenced by seasonal changes, water mass dynamics, and various sources including autochthonous production, glacier melt, as well as river and surface runoff.

In the Arctic, both fresh organic matter from primary and secondary producers and refractory material from glacial retreat and permafrost thaw contribute to sediment composition. Ongoing rapid warming is expected to alter hydrographic conditions, organic matter sources, and long-term carbon burial in Svalbard fjords.

Various bulk proxies (e.g., C/N ratio, $\delta^{13}C$, $\delta^{15}N$) and molecular markers (e.g., alkanes, steroids, fatty acids, pigments) are commonly used to trace the sources of sedimentary organic matter in aquatic environments (Bianchi and Canuel 2011; Szymczak-Żyła and Lubecki 2022; Volkman 2006). However, in the Spitsbergen fjords, most studies have focused on bulk indicators, while data on sedimentary lipid biomarkers remain limited.

This study aimed to determine the sources of organic matter in surface sediments from four Spitsbergen fjords by analyzing lipid biomarkers, including:

(i) **n-alkanes** – hydrocarbons produced by both prokaryotic and eukaryotic organisms, may derive from bacteria, plankton, aquatic, and terrestrial plants;

(ii) **saturated cyclic hydrocarbons** (hopanes, steranes) – these compounds with thermodynamically stable configurations are indicators of the origin and maturity of source rock sediments and petroleum;
(iii) highly branched isoprenoid (**IP25**) – a proxy for the occurrence of IP25-producing sea ice diatoms;
(iv) **alkenones** – a proxy of the occurrence of alkenone-producing phytoplankton species (e.g., *Emiliania huxleyi*);
(v) **polar steroids** (sterols and stanols) – derived mainly from eukaryotic organisms, including phytoplankton, zooplankton, and vascular plants.

While previous studies have primarily relied on bulk geochemical proxies to assess organic matter origin in these fjords, our approach focuses on molecular-level evidence. We argue that lipid biomarker analysis provides detailed insights into organic matter sources in Arctic fjords and serves as a valuable baseline for reconstructing past conditions and projecting future changes under climate warming. To the best of our knowledge, no similarly comprehensive lipid biomarker-based investigation has been carried out in the studied fjords.

## 2. MATERIALS AND METHODS

This study investigates four fjords located between 76°N and 79°N in western Spitsbergen, Svalbard (Fig. 1). All fjords receive substantial freshwater input and are influenced by warm Atlantic Water carried by the West Spitsbergen Current. Additionally, Hornsund is affected by cold Arctic Water from the Sørkapp Current, while Adventfjorden experiences the highest anthropogenic impact due to local human activities.

This research focuses on surface sediment samples (0–5 cm layer) collected at nine locations in Spitsbergen fjords during a July–August 2017 cruise aboard R/V Oceania (IO PAS), using a Niemistö-type core sampler. Molecular markers investigated in this work were analyzed according to the procedures described by Krajewska et al. (2023).

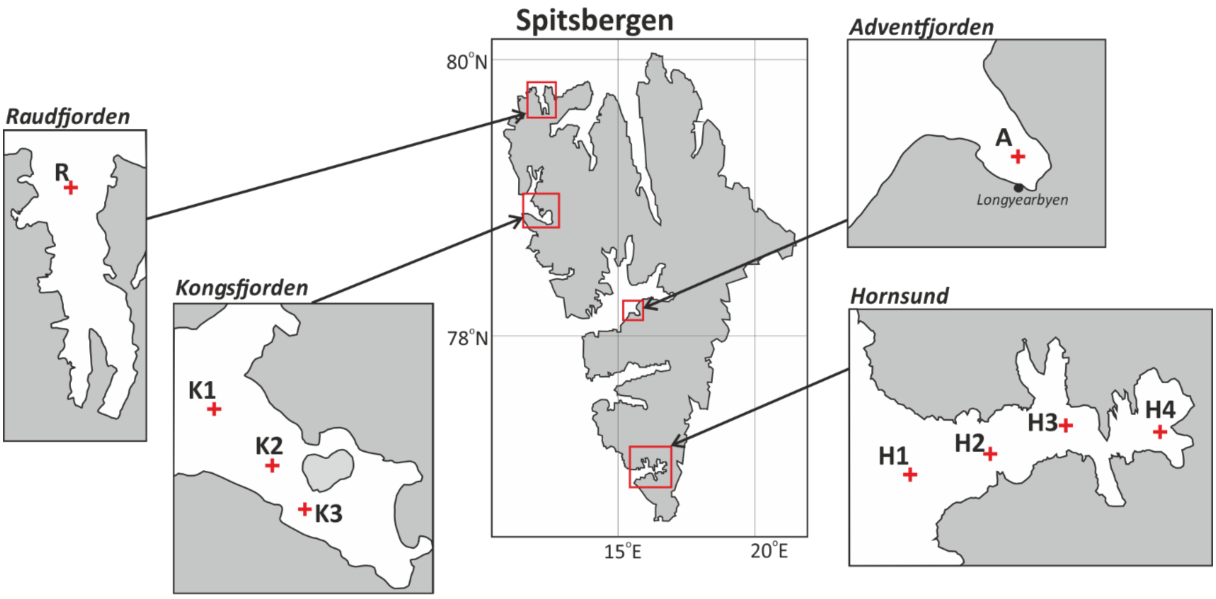


Fig. 1. Locations of sampling sites.

## 3. RESULTS

The concentration ranges for investigated lipid molecular markers in the studied fjords were as follows: 620–1420 μg/g TOC for n-alkanes [Σ(n-C15 – n-C39)], 8.2–101.3 μg/g TOC for hopanes, 0.56–5.1 μg/g TOC for steranes, <LOD–0.073 μg/g TOC for IP25 (highly branched

isoprenoid), 0.67–40.6 μg/g TOC for C37 alkenones, 71–546 μg/g TOC for Σ phytoplankton-derived sterols, 95–510 μg/g TOC for Σ animal-derived steroids, and 53–215 μg/g TOC for Σ land-derived steroids.

## 4. CONCLUSIONS

The results of this study indicate that sedimentary organic matter in the western Spitsbergen fjords originates from a variety of marine (e.g., phytoplankton, animal-derived material) and terrestrial sources (e.g., vascular plants, including Sphagnum mosses). The contribution of sea ice-associated algae to sedimentary organic matter is generally low across the studied fjords. In Hornsund, the input of organic matter from phytoplankton, zooplankton, and terrestrial plants decreases from the outer to the inner fjord.

Notable differences in phytoplankton composition were observed between the southern and northern fjords: haptophytes and cryptophytes are more abundant in the northern fjords (Kongsfjorden and Raudfjorden), while lower abundances of diatoms relative to dinoflagellates are found in northern fjords compared to fjords located farther south (Hornsund and Adventfjorden). The presence of *Emiliania huxleyi*—a species characteristic of temperate environments—in the northern fjords likely reflects strong bio-advection associated with the inflow of warm Atlantic Water.

All studied fjords show evidence of natural petrogenic inputs; however, Adventfjorden appears to be most affected by fossil organic matter, likely linked to anthropogenic emissions from nearby Longyearbyen. Although total alkane concentrations remain relatively stable along the Hornsund transect, other lipid biomarkers display clear decreasing trends, highlighting the need for further investigation into the underlying mechanisms.

This study provides comprehensive lipid biomarker-based assessment of organic matter sources in surface sediments of the western Spitsbergen fjords and contributes to a better understanding of the current state of this rapidly changing Arctic environment.

Selected data from this study have already been reported in Krajewska et al. (2023). The research is being continued with financial support from the National Science Centre, Poland (2023/49/B/ST10/03768).

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