Redox and biogeochemical processes inferred from permafrost porewater extractions

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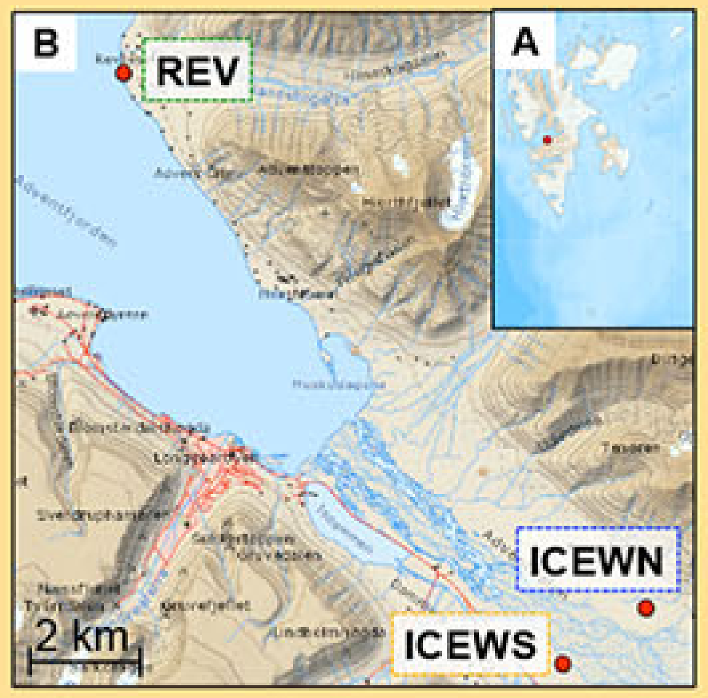
1. Overview

- **Climate change** is causing permafrost to **thaw** in the Arctic coastal lowlands. The resulting **release** of stored organic carbon and nutrients leads to increased **greenhouse gas (GHG)** emissions in Arctic wetlands.
- In Svalbard (**fig. 1**), **isostatic rebound** during the last 10,000 years has created coastal wetlands by exposing more land area.
- The redox evolution of these wetlands influences methane release, as **methanogenesis** occurs once alternative electron acceptors for the microbial oxidation of organic matter have been depleted.
- It is crucial to understand the **redox evolution** of these environments in order to accurately predict the timing and magnitude of methane release.

Objectives

1. Investigate *in-situ* processes contributing to GHG emissions from shallow permafrost (**fig. 1**).
2. Correlate the geochemistry of these permafrost sediments with their **potential to support GHG emissions**



Sites

The study sites are situated on two main types of sedimentary environment:

1) **ICEWS** and **ICEWN** are on aeolian sediments overlying a prograding delta,

2) **REV** is between raised beaches, where overland flow of nivation erosion products has deposited fine sediments.

Ice-wedge polygons have developed at all study sites.

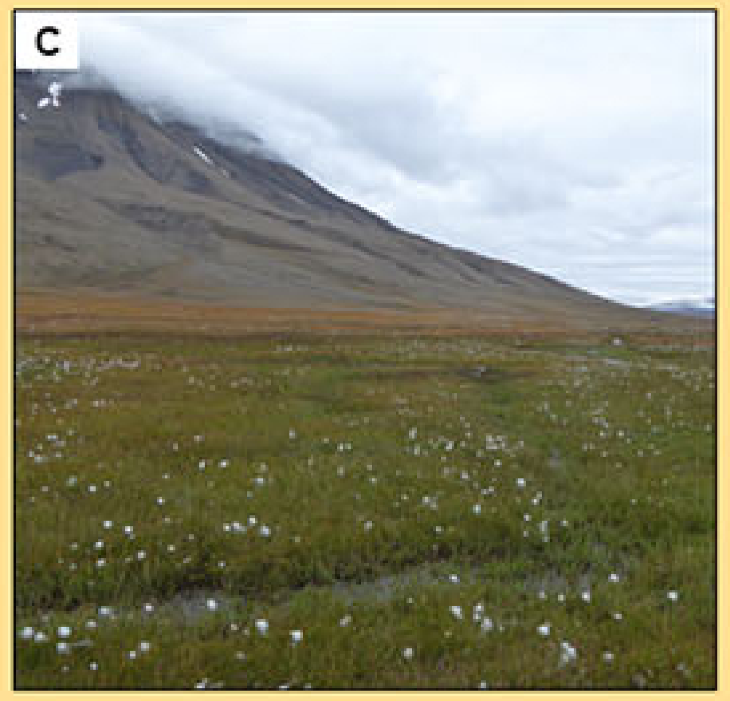


Figure 1. A) Map of the archipelago of Svalbard, and **B)** Map of Adventdalen, with the core locations marked by red circles. 2-metre long cores have been extracted from the REVL, ICEWS and ICEWN wetlands. **C)** Ice-wedged polygon wetlands at ICEWN. Maps courtesy of the **Norwegian Polar Institute.**

2. Methods

Sampling

2-m long, 5-cm diameter cores were collected using motorised hand drilling equipment (**fig. 2**). Samples were processed frozen and porewaters were extracted (**fig. 3**)

Figure 2. Coring permafrost, using body weight to force the drill down.

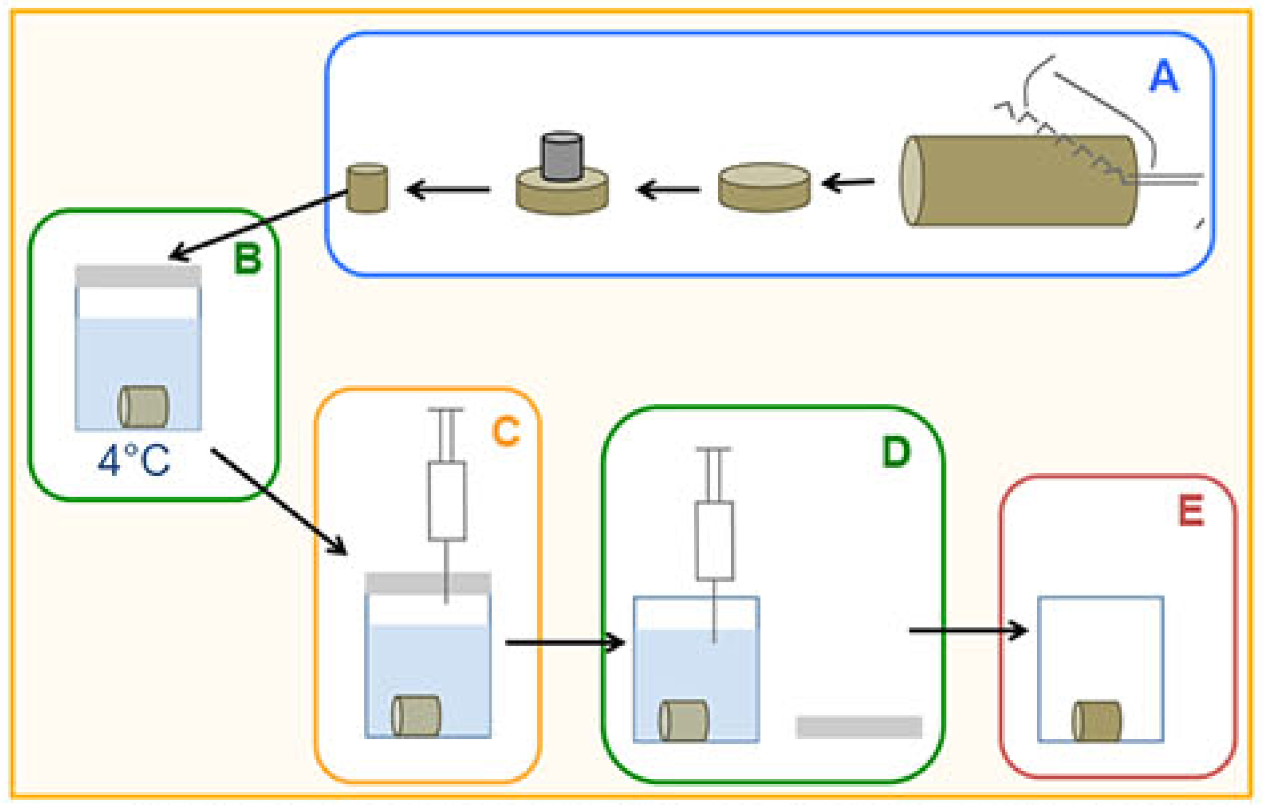


Figure 3. A) Frozen cores were sawed into 2 cm slices, and the inner core samples removed, **B)** Samples were equilibrated at 4°C with de-ionised water in vials with N_2 headspace, **C)** 4 days after **B**, headspace sampled for CH_4 and CO_2, **D)** 7 days after **B**, porewaters sampled anaerobically and filtered, **E)** Sediments dried at 105°C to estimate moisture content.

3. Results

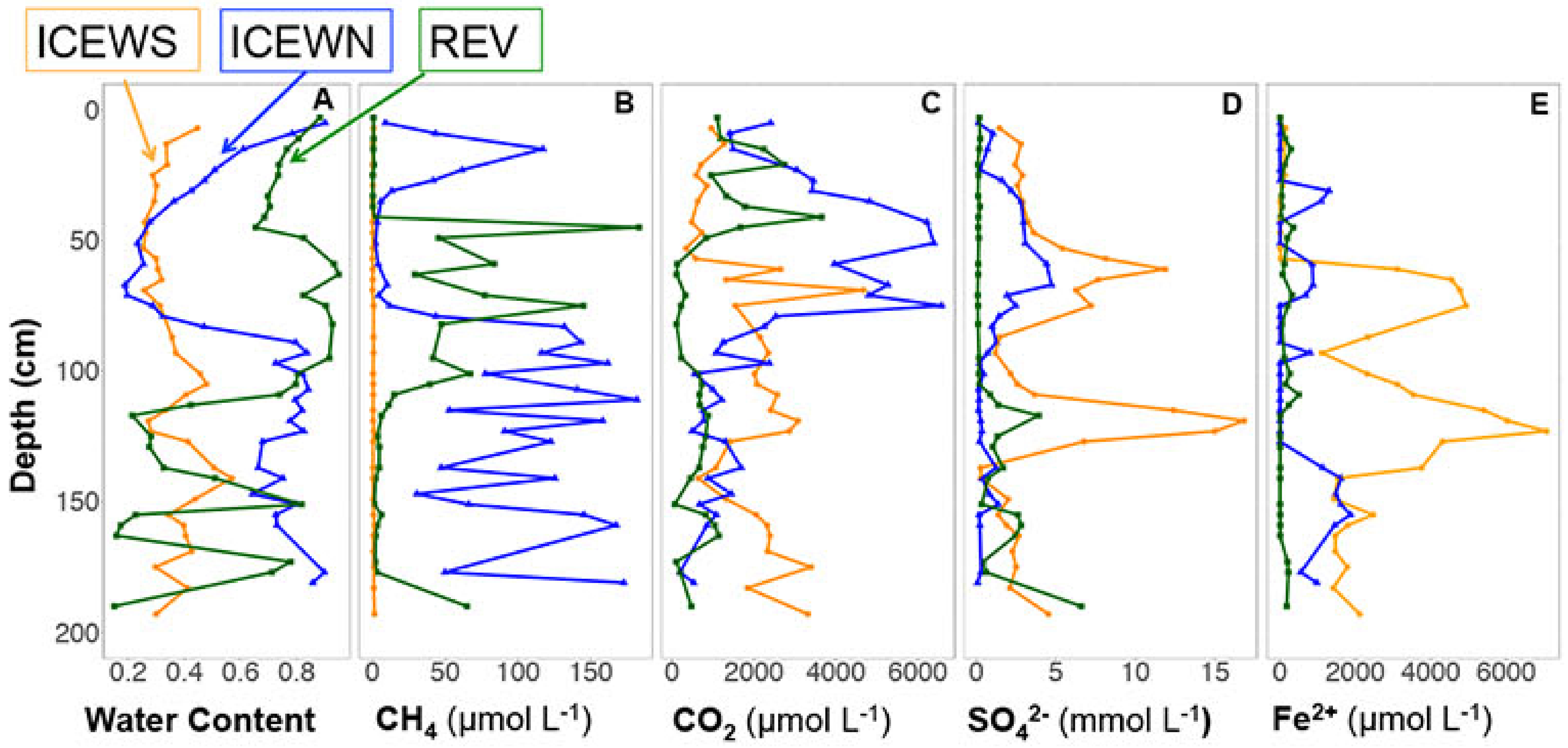


Figure 4. A) Water content, **B)** dissolved methane, **C)** dissolved carbon dioxide, **D)** dissolved sulphate and **E)** dissolved iron, with depth below the ground surface, for each core.

Table 1. Summary of results.

ICEWS	ICEWN	REV
Driest site (**fig. 4A**)	Wetter site (**fig. 4A**)	Wetter site (**fig. 4A**) ; moisture content indicates highly organic material in <1 m depth
Negligible dissolved methane (**fig. 4B**)	Peak in dissolved methane in mid-active layer (20cm), and high concentrations in the permafrost (**fig. 4B**)	Methane maximum at 45 cm depth, which is transition between the active layer and the permafrost (**fig. 4B**)
High concentrations of iron and sulphate in solution (**figs. 4D** and **4E**)	Low concentrations of dissolved iron and sulphate (**figs. 4D** and **4E**).	Lowest levels of sulphate and iron in solution (**figs. 4D** and **4E**)

4. Interpretation and Future

Processes

1. Sulphide oxidation driven by Fe^{3+} **reduction**
- Dominant at the driest site (ICEWS),
- Less apparent at the wetter sites, especially at REV, where dissolved sulphate and iron concentrations are very low, indicating a low redox environment

2. Methanogenesis
- Negligible concentrations of dissolved methane at the driest site (ICEWS), which has a higher redox environment
- High concentrations of dissolved methane at the two wetter sites (ICEWN and REV), both of which have low redox.
- $[CO_{2\,(aq)}] > [CH_{4\,(aq)}]$ for all sites.

Future Work

1. Assess whether the different redox environments can be explained by water and organic matter content.
2. Redox profiles do not resemble marine sediment redox profiles, so need to investigate the influence of freeze-thaw on the wetland redox profiles.
3. Ascertain the sources of sulphate, methane, dissolved inorganic carbon and nitrate through analyses of isotopes.

Porewaters will be sampled *in-situ* from 3 different depths in the active layer at the end of summer 2017.

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