Faculty of Science

# Water movement and solute transport in permafrost wetlands: *implications for inorganic carbon cycling*

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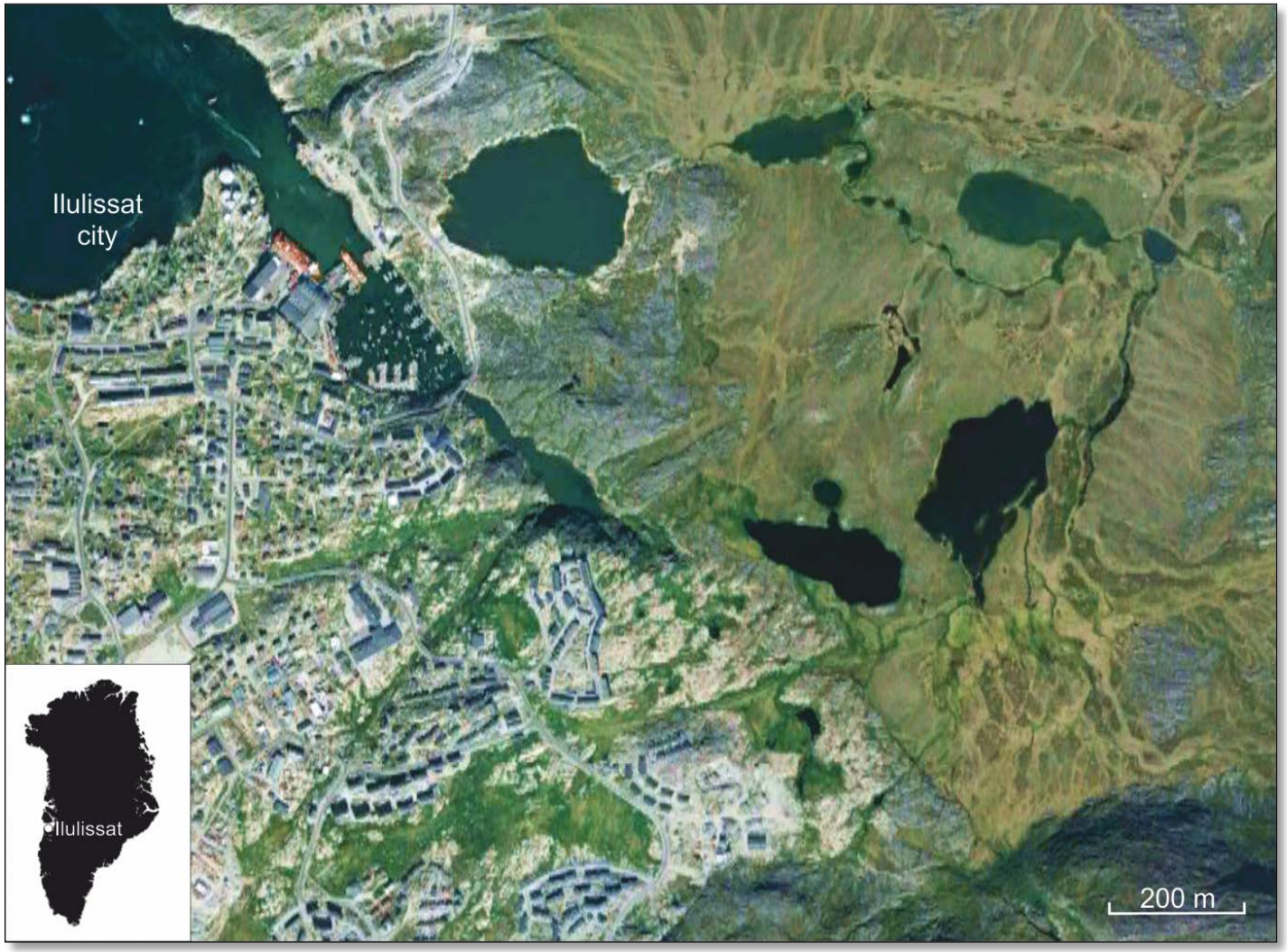
*Reference*: Soren Jessen, Hanne Dahl Holmslykke, Kristine Rasmussen, Niels Richardt and Peter Engelund Holm: **Hydrology and pore water chemistry in a permafrost wetland, Ilulissat, Greenland**. *Water Resources Research*. Accepted 25 April 2014. *In press*.

# Field site, Ilulissat, Greenland

*Peat wetland, mean annual air temp. −4 °C, precip. 260 mm*



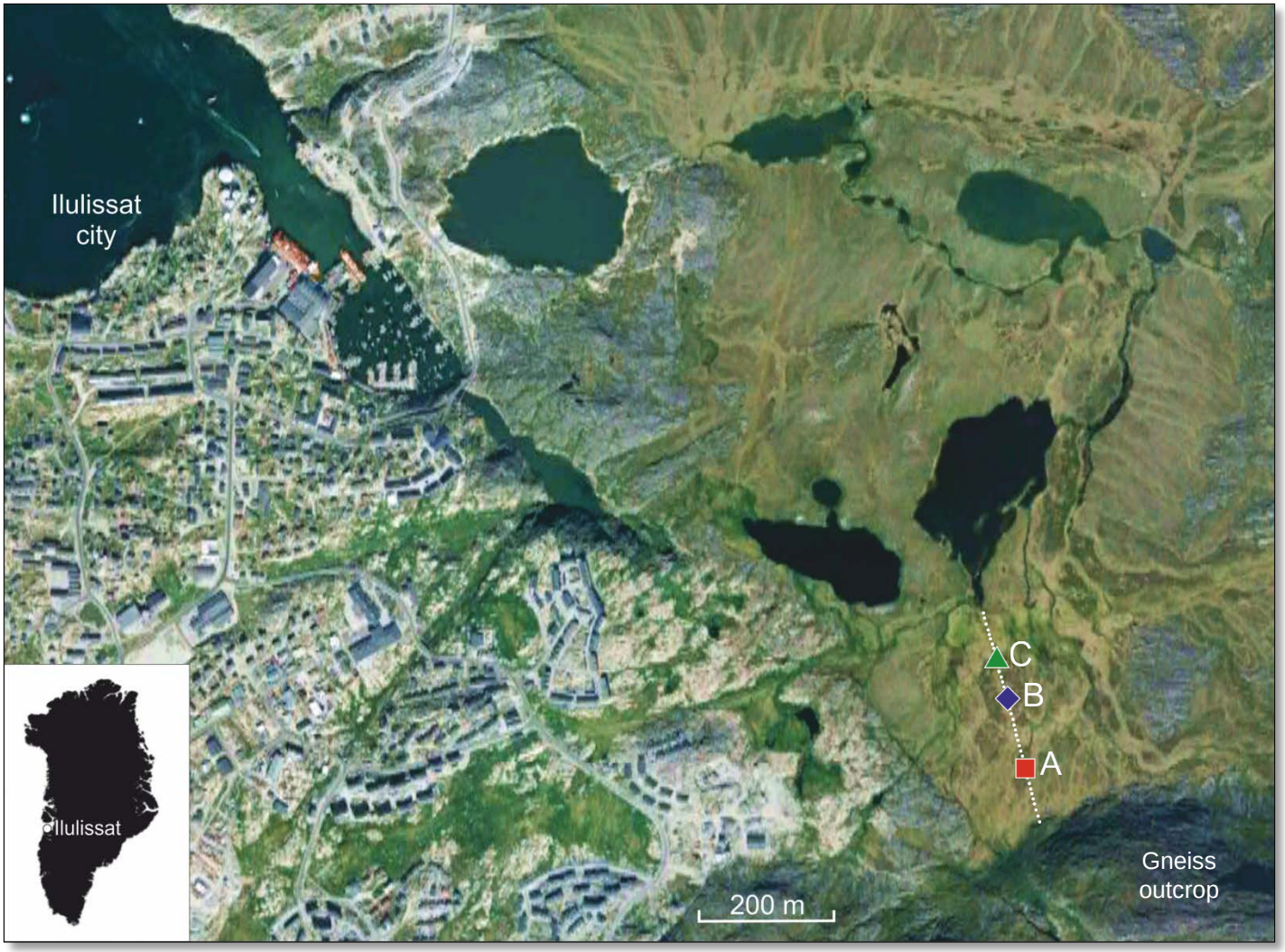
# Objectives

*i.* Water and solute movement in active layer

*ii.* Carbon cycling, and ebullition of $CO_2$ and other greenhouse gases

# Location of transect and profiles A, B and C

*Head measurements, slugs tests and water sampling*

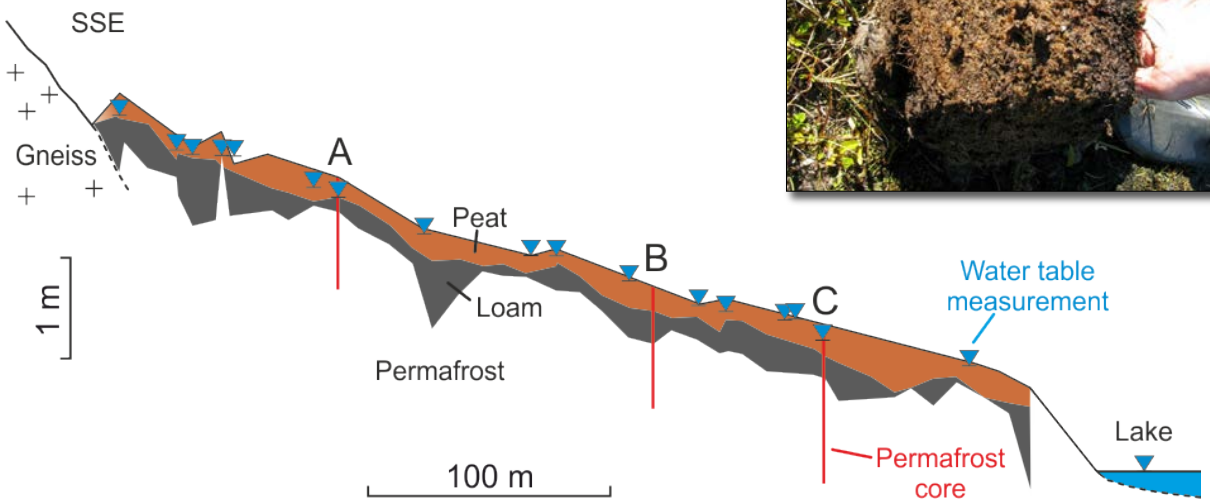


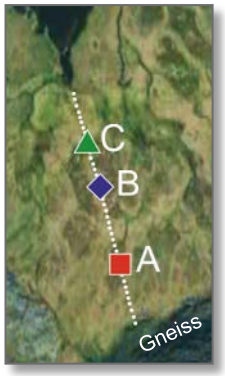
# Water sampling

*Suction lysimeters*


*Melting of core pieces*

# Active layer hydrogeology

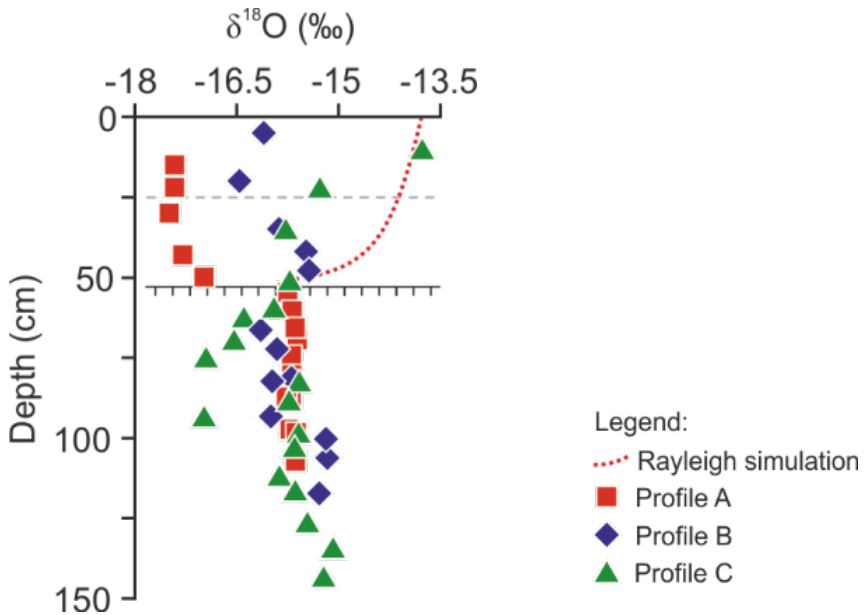



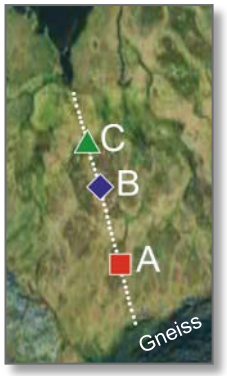


- *~0.25 m peat, underlain by ~0.3 m loam*
- *Water table ~5 cm below ground*
- *Hydraulic conductivity of peat ≫ loam*

# Vertical water movement in active layer

## *Stable isotopes of water, $^{18}O_{H_2O}$ data*

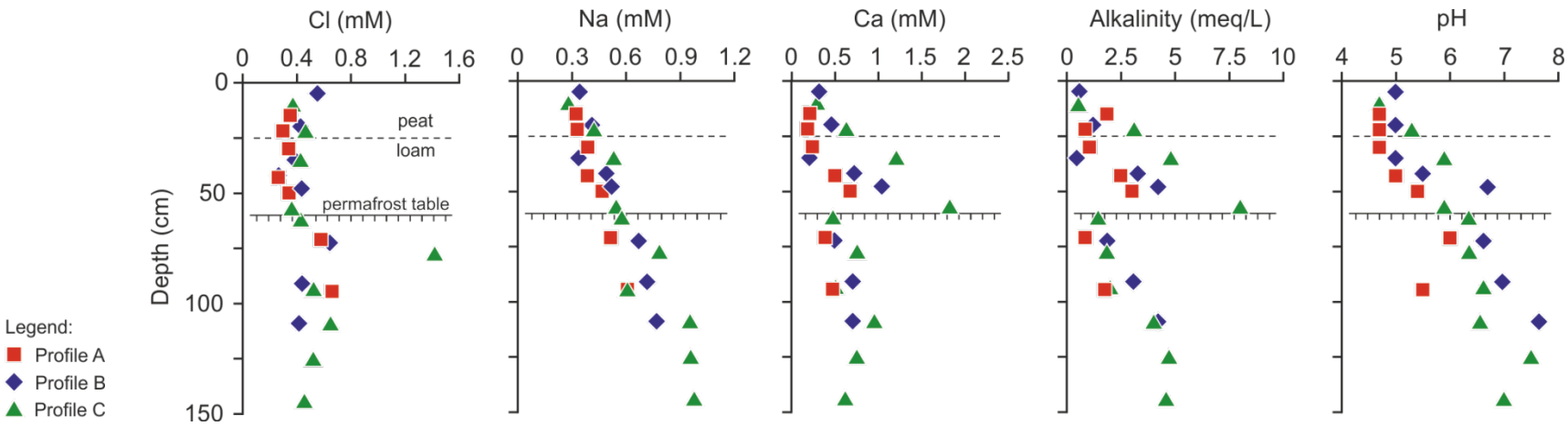



- *Freeze-thaw dynamics not dominant water movement control*
- *Rapid freeze-up and/or simultaneous phase transition at all depths*
- *Evaporative enrichment with increasing travel distance*

# Vertical solute transport in active layer

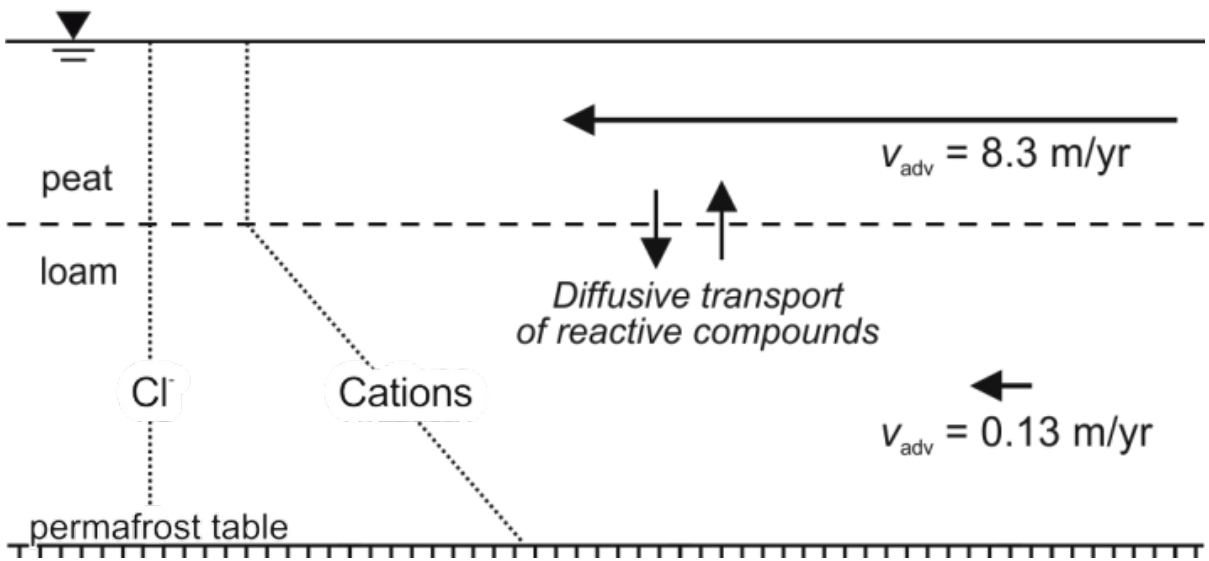
## *Distribution of major ions*




- *Solutes transport not controlled by salt-rejection/freeze-thaw dynamics*
- *Upwards diffusion of weathering products*
- *Low concentrations in peat sustained by frequent flushing*

# Conceptual model

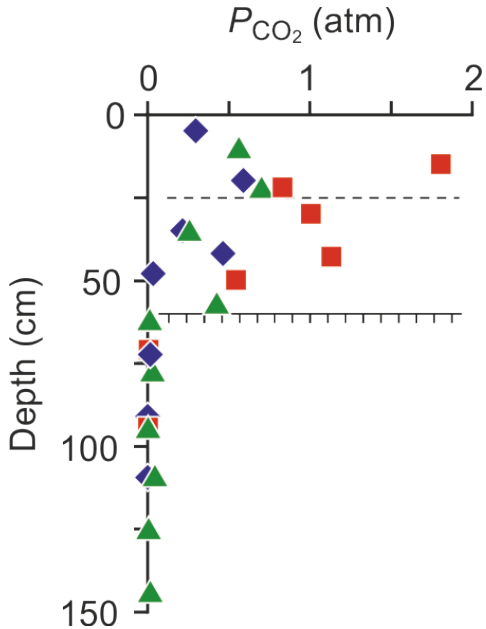
*Water movement and solute transport in the active layer*




- *…freeze-thaw dynamics do not* move *lots of water, or cause salt rejection, but can still control water chemistry!*

# Greenhouse gas emission via bubble ebullition

*Highly elevated partial pressures of $CO_2$ ($P_{CO_2}$)*




- *Total gas pressure must exceed 1 atm!*
- *Ebullition feasible pathway for $CO_2$ emission from the wetland*
- *Other greenhouse gases will diffuse into the gas bubbles, and become emitted along with the $CO_2$*

# Freeze-thaw dynamics control carbon cycling

*"Cryogenic carbon cycling"*

$CO_{2(g)}$ in bubble inclusions

$\uparrow\downarrow$

$$CaCO_{3(s)} + CO_{2(aq)} + H_2O \rightleftarrows Ca^{2+} + 2HCO_3^-$$

Fall freeze-up: $\leftarrow$

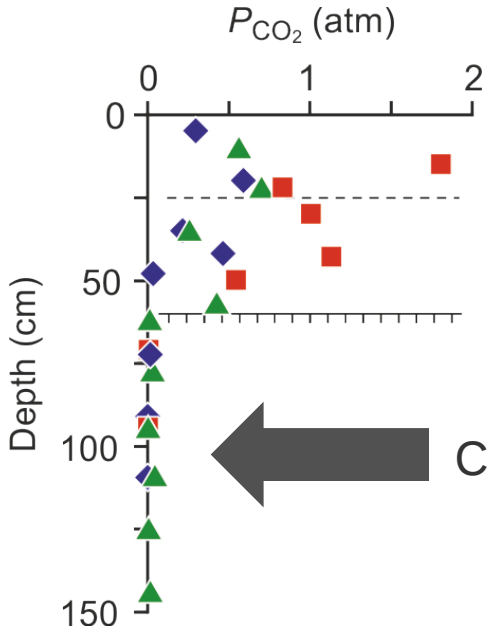
Spring thaw: $\rightarrow$

*"Cryogenic carbon cycling":*

- *...inorganic carbon sequestration by carbonate precipitation during fall freeze-up*
- *...inorganic carbon release by (partial or complete) carbonate re-dissolution during summer*

# Cryogenic carbon cycling

## *Method artefact: $CO_2$ escape during melting of core pieces*



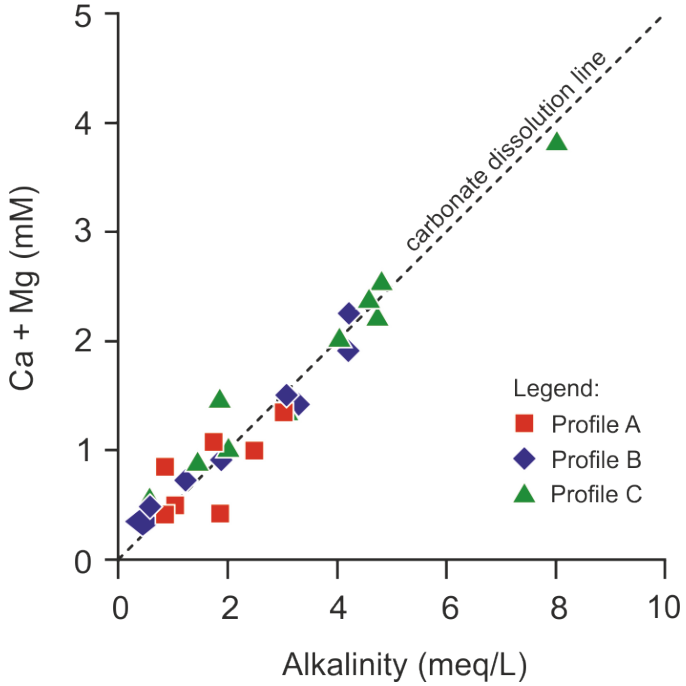

$CO_{2(g)}$ escaped during melting of core pieces

$$CaCO_{3(s)} + CO_{2(aq)} + H_2O \leftarrow Ca^{2+} + 2HCO_3^-$$

- *$CO_2$ in bubble inclusions was liberated during melting of core pieces in containers with a large headspace*

# Cryogenic carbon cycling

## *Fixed stoichiometry Ca-Mg-$HCO_3$ water type*




- *Fixed stoichiometry is strong indication of carbonate mineral control on dissolved inorganic carbon*

# Summary & implications

*"Water movement and solute transport in a permafrost wetland: implications for inorganic carbon cycling"*

- *Conceptual model: Water movement and solute transport is dominated by diffusion and advection processes*
- *Water movement and solute transport did not seem dominated by freeze-thaw dynamics or salt-rejection*
- *"Cryogenic carbon cycling": $CO_2$ cycling via cryogenic carbonate formation and dissolution*
- *Bubble ebullition is a feasible pathway for greenhouse gas emissions from permafrost wetlands*

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