In-situ capping of Sweden’s fiberbanks:

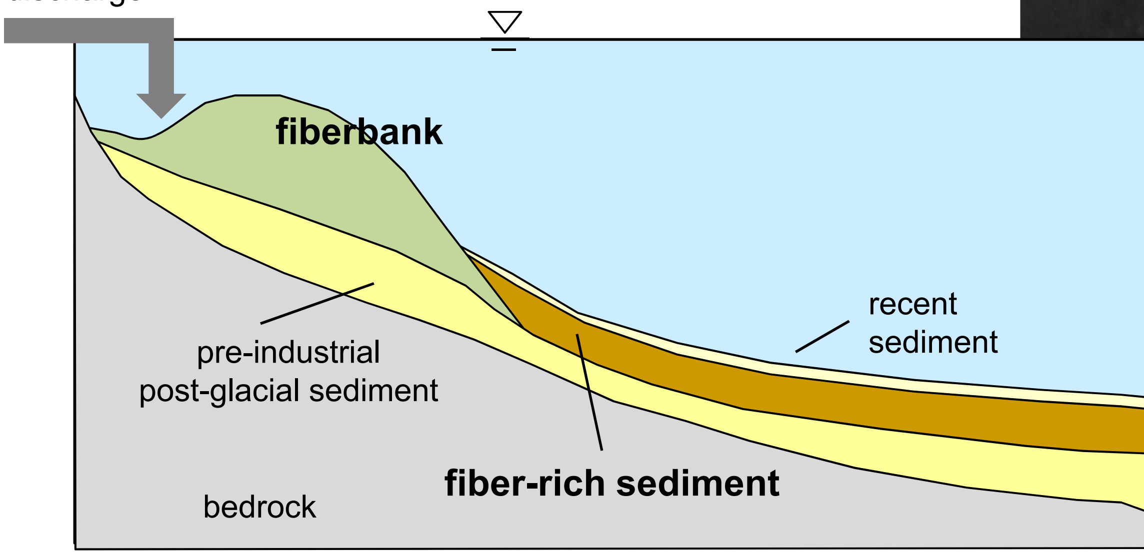
Will remedies established for minerogenic sediments also ”work” on these unique, organic-rich sediments?

Dr. Alizée P. Lehoux, Uppsala University, Sweden
Prof. Ian Snowball, Uppsala University, Sweden
Dr. Joe Jersak, SAO Environmental Consulting AB, Sweden

Battelle sediment conference, 11-14 February, 2019, New Orleans, LA, USA

What are fiberbanks?

what we call ”fiberbanks” are deposits of cellulose-rich material settled out from decades of historical discharges of wastewater from pulp mills and paper factories

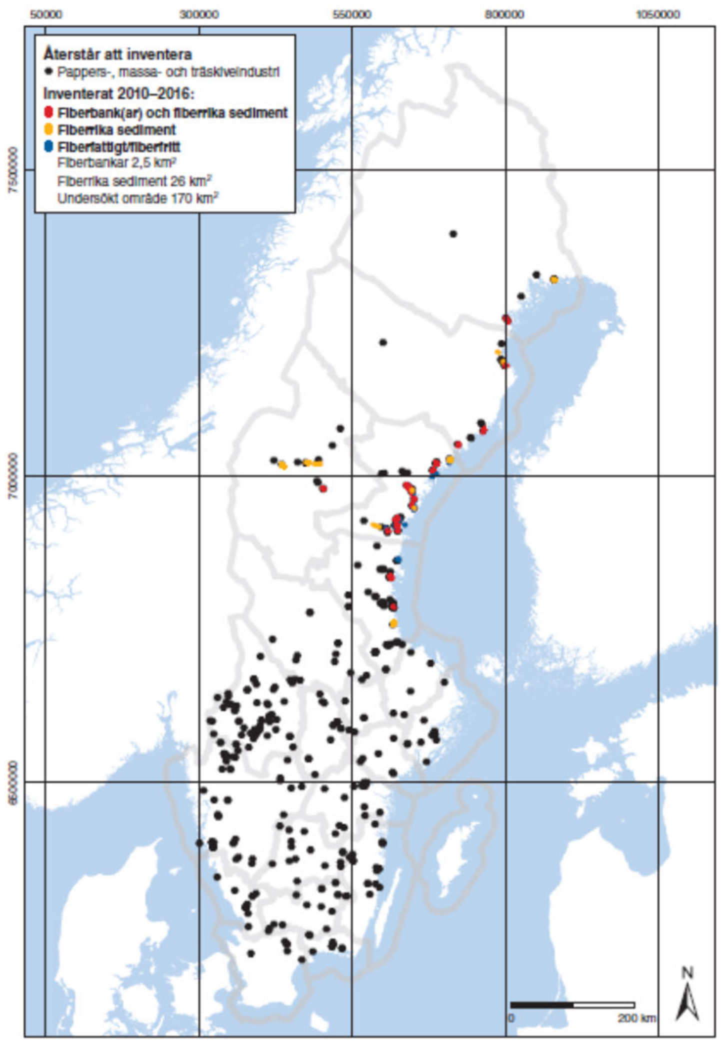


Source: SGU, 2014

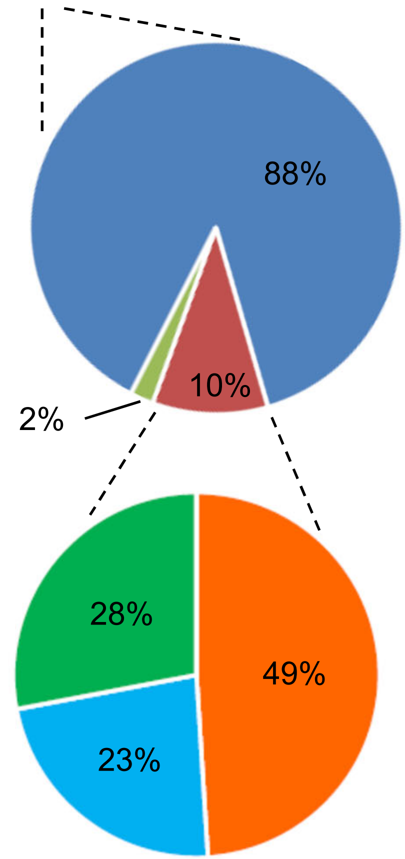
fiberbanks also occur in other countries

fiberbanks + fiber-rich sediments = ”fiberbank sediments”

Swedish fiberbank occurrence



383 known areas (sites) with potential fiber waste-generating activities



- 39 sites investigated so far
- 8 sites remediated so far (2 capping, 6 removal)
- 336 sites yet to be investigated

- fiberbanks and fiber-rich sediments found at 19 sites
- fiber-rich sediments only found at 9 sites
- no fiber sediment (of any type) found at 11 sites

Source: SGU, 2017

Not all fiberbank deposits and materials are the same

Sandviken

larger-sized wood particles

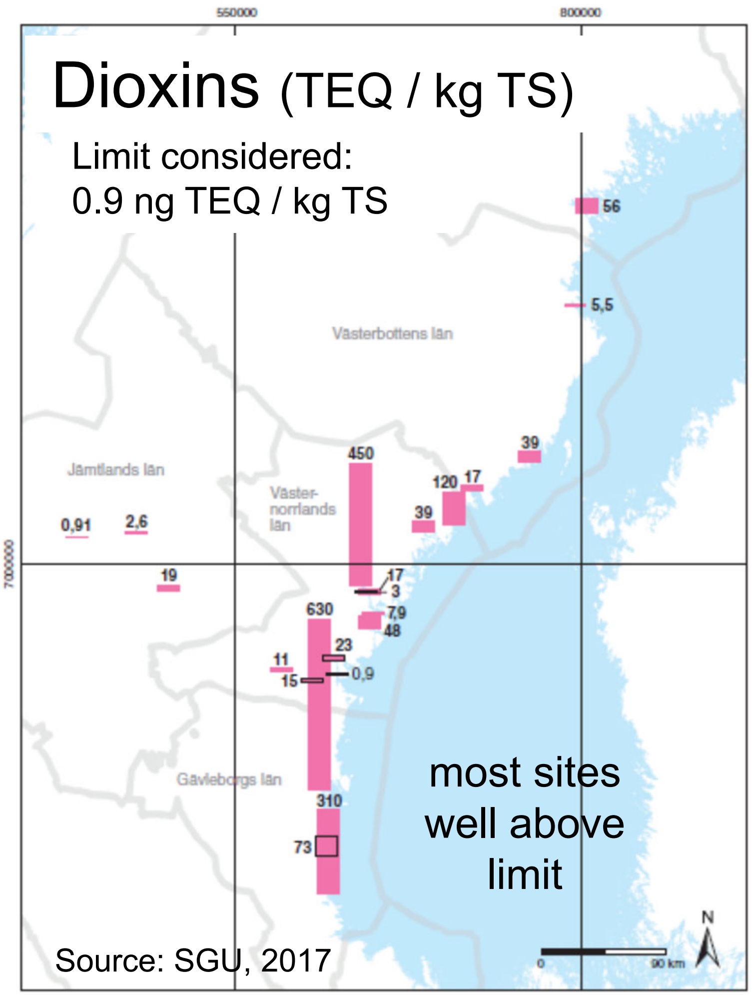
Väja

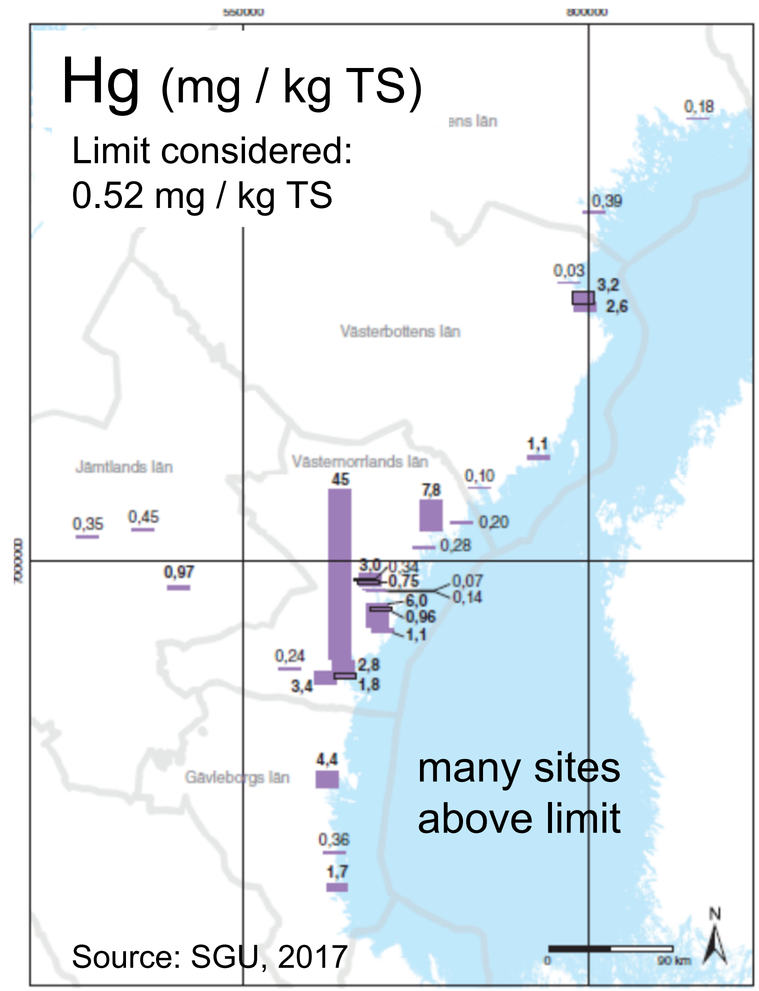
finer-sized fiber particles

Ocean Surveyor, SGU

Fiberbanks are contaminated
by organics, metals, and/or organometals

for example





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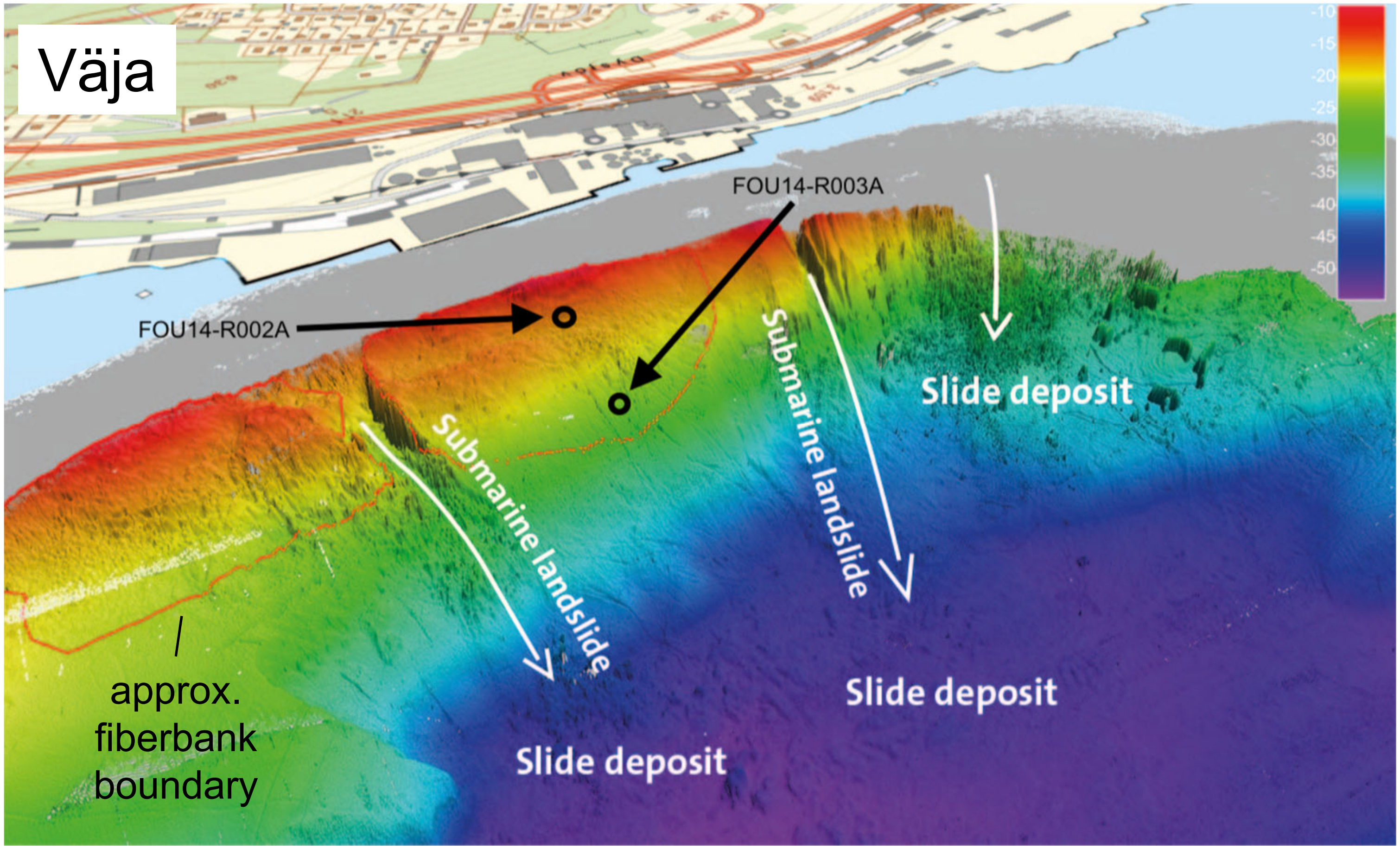
Some fiberbanks are inherently unstable *especially in steeper, near-shore areas*

Source: SGU



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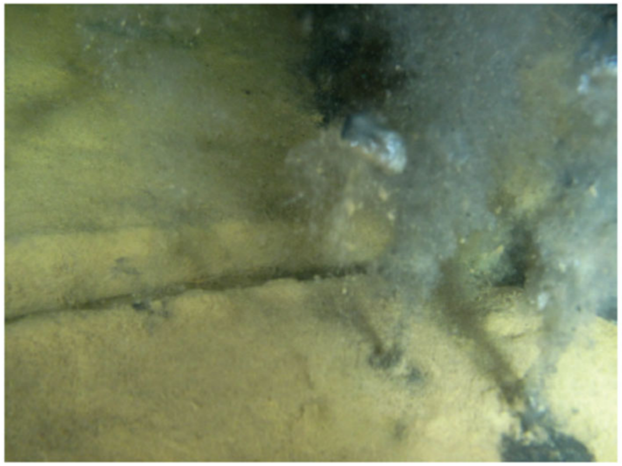
Two key features of many fiberbanks

pockmarks

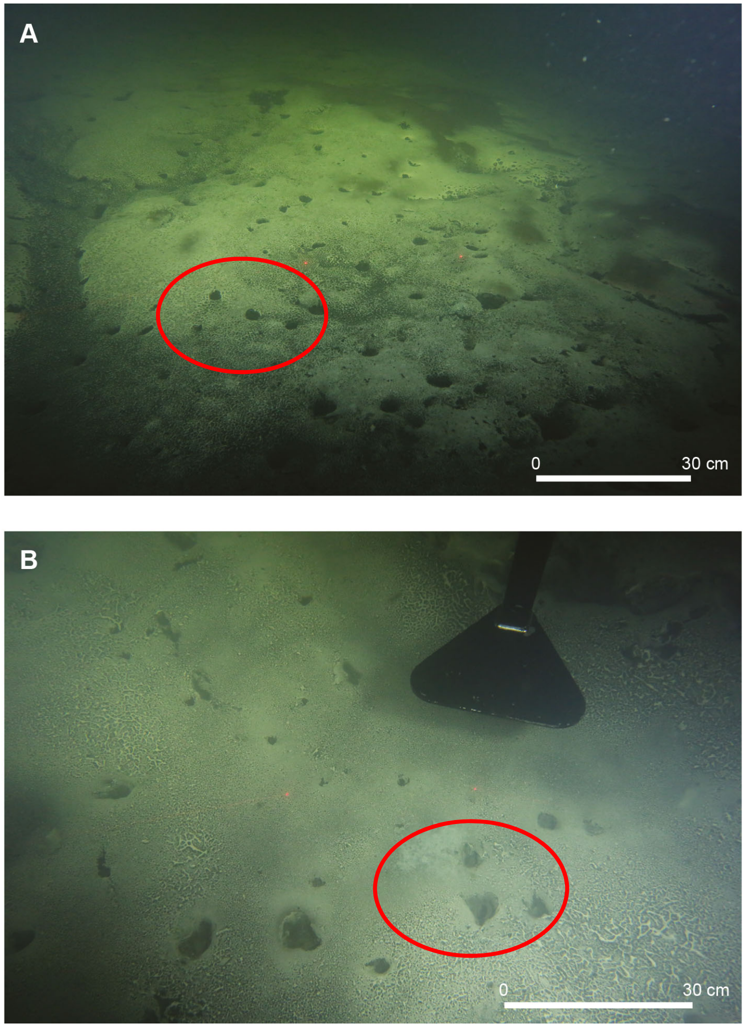
Väja

gas

Sandviken



pockmarks
- formed by gas release
- facilitate continued gas release



Source: SGU

Risks

- Risk assessment work is ongoing
- Results will likely indicate unacceptable risks at many sites, mainly
  - Contaminant spreading from fiberbanks to adjacent and even off-site areas
  - Benthic exposure in adjacent areas of fiber-rich sediment
- Benthic exposure at/on fiberbanks may vary
  - Could be low for some, because not attractive habitat
  - Could be higher for others, where a relatively thin (~10 cm or so) natural cap occurs – better habitat

Managing Sweden's ”fiberbank problem”

- Huge challenge (economic, technical, political)
  - Tip-of-the-iceberg understanding of how widespread, serious the problem really is
  - Many sites likely need management, most large impacted areas and volumes
  - Both fiberbanks, fiber-rich sediments are top priorities
  - Limited funds, need to prioritize (make tough decisions)
  - Minimal experience (anywhere) using established ex-situ, in-situ methods for remediating fiberbank sediments
    - To-date, total of 3 fiberbank capping projects, globally

Why not in-situ capping remedies?

- Decades-long global track record indicates capping can “work” (meet remedial objectives) at impacted **minerogenic** sediment sites, as indicated by

Location	Isolation capping projects		Thin-layer capping projects	
	Conventional	Active	Conventional (EMNR)	Active (in-situ treatment)
Internationally	122	40	10	15
Norway	11	5	1	3
Sweden	5	0	1	0

Source: Jersak et al., 2016

- Could simply *assume* also applicable to fiberbanks
  - Involves the same types of contaminants
  - Involves the same types of sediment processes, responses
  - Very soft and compressive, like many minerogenic sediments

But far too many unknowns
compared to capping minerogenic sediments

- Are responses of fiberbanks (not fiber-rich sediments) to capping the greatest challenge?
- Is gas an *even bigger* problem, especially for fiberbanks?
- Are fiberbanks *even more* compressive, low-strength?
- Can fiberbanks physically support isolation caps and remain geotechnically stable, including on slopes?
- Can isolation caps physically and chemically isolate sediment contaminants long-term? Would active materials help?
- Is thin-layer capping (conventional or active) worth considering for fiberbanks?
- Is Hg biogeochemistry *even more* complicated, especially for fiberbanks?

FIBerbank REMediation *FIBREM*

- 3 yr project (2017-19)
- UU, MARUM, SGI, SLU, SGU, SAO
- VINNOVA funded
- Google "FIBREM"

Objective 1

Develop field methods for characterizing in-situ fiberbank properties

Objective 2

Lab testing applicability, effectiveness of established in-situ capping remedies

- Multiple sub-objectives and related tests
- Initial research focusing on
  - different fiberbank materials
  - isolation capping, conventional ("sand")
  - degree of chemical isolation achieved
  - gas and its possible effects
  - stability, including on slopes

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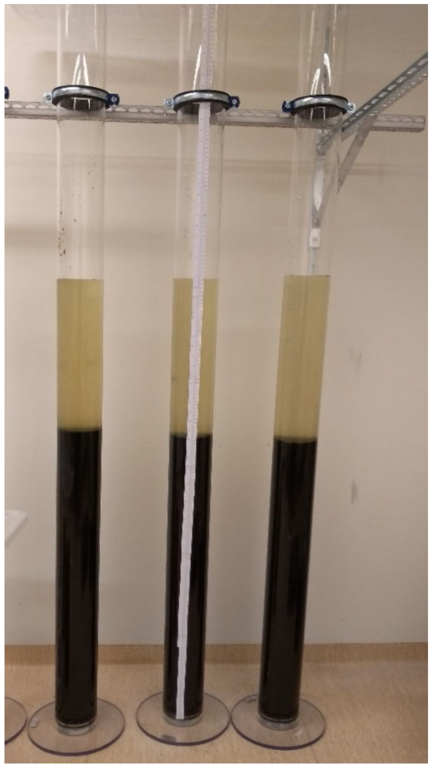
An unexpected start to the journey
initial testing at room temperature, ~ 20°C

seawater

Väja
fiberbank
material



160 hrs
later…

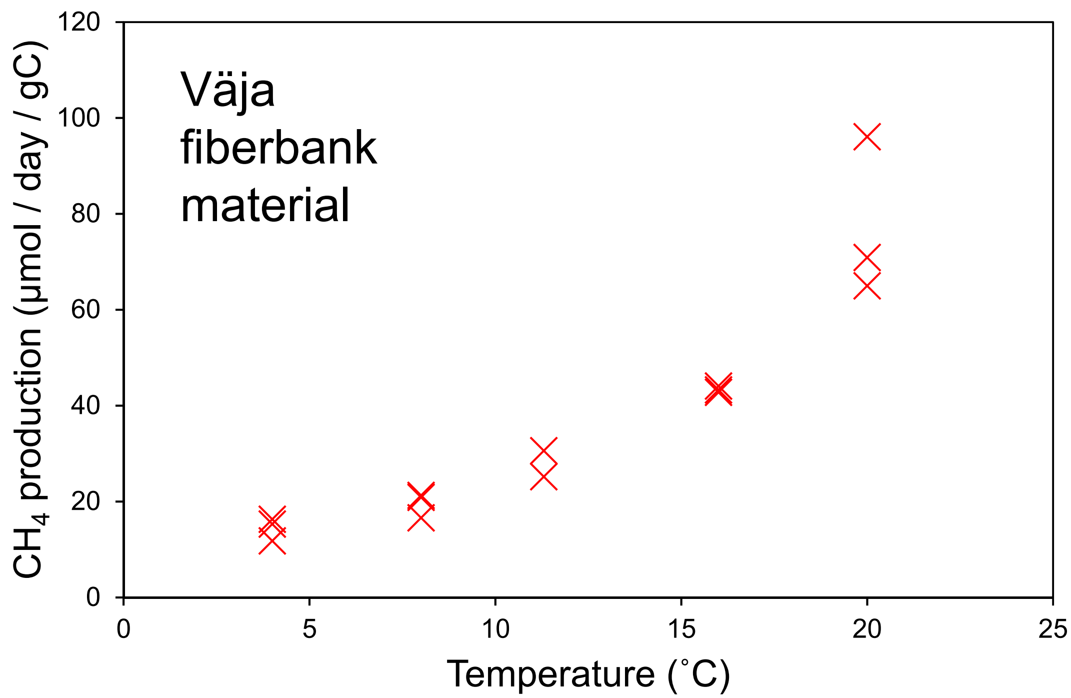
Väja
fiberbank
material

seawater

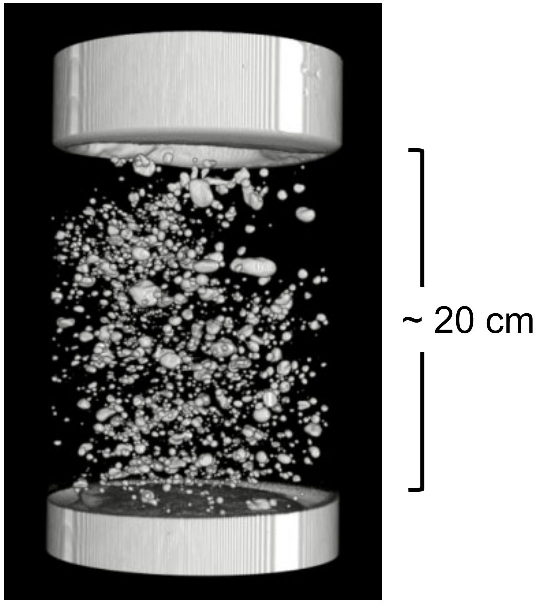
sediment gas build-up + de-watering + density decrease
= ”floating sediments”

Needed to conduct testing at lower temps

strong connection between temp and gas



gas bubbles in
Väja fiberbank material



computer
tomography
(CT) image

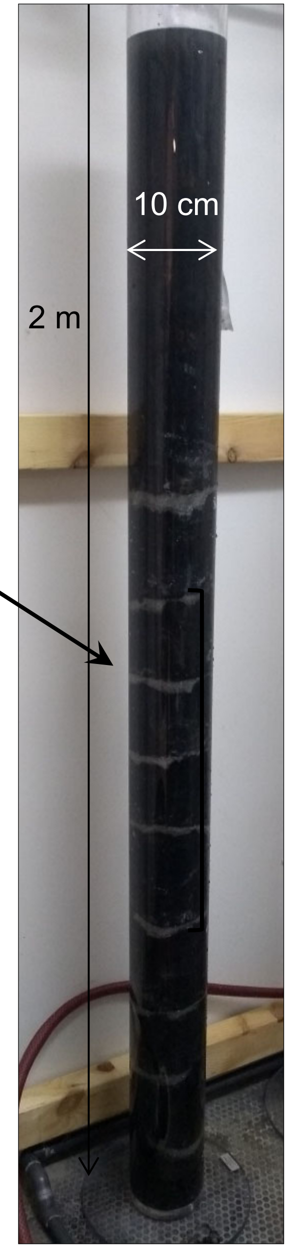
methane production drops and levels off – but does not stop – near 4 °C

Compression tests

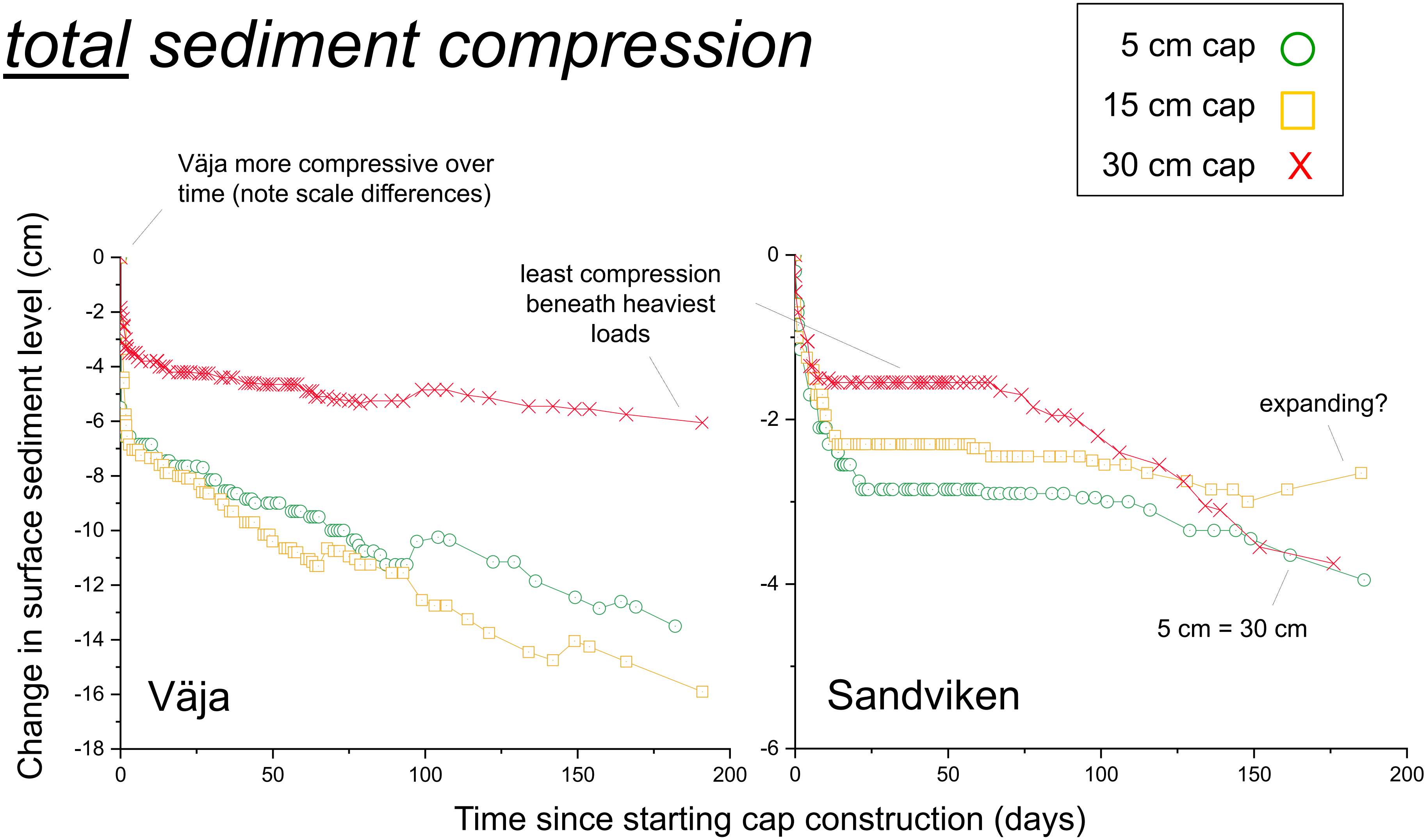
Different fiberbank materials (sediments)	Väja vs Sandviken
Range of total cap thicknesses (loads)	5, 15, or 30 cm
Testing temp	4.5 ± 1 °C
Capping material	0/4 mm crushed stone
Sediment columns	Re-constructed
Water columns	Seawater (artificial)
Testing timeframe	Months

placed multiple thinner layers to gradually build up total cap

monitored depth-discrete sediment compression by including visual ”tracer layers”

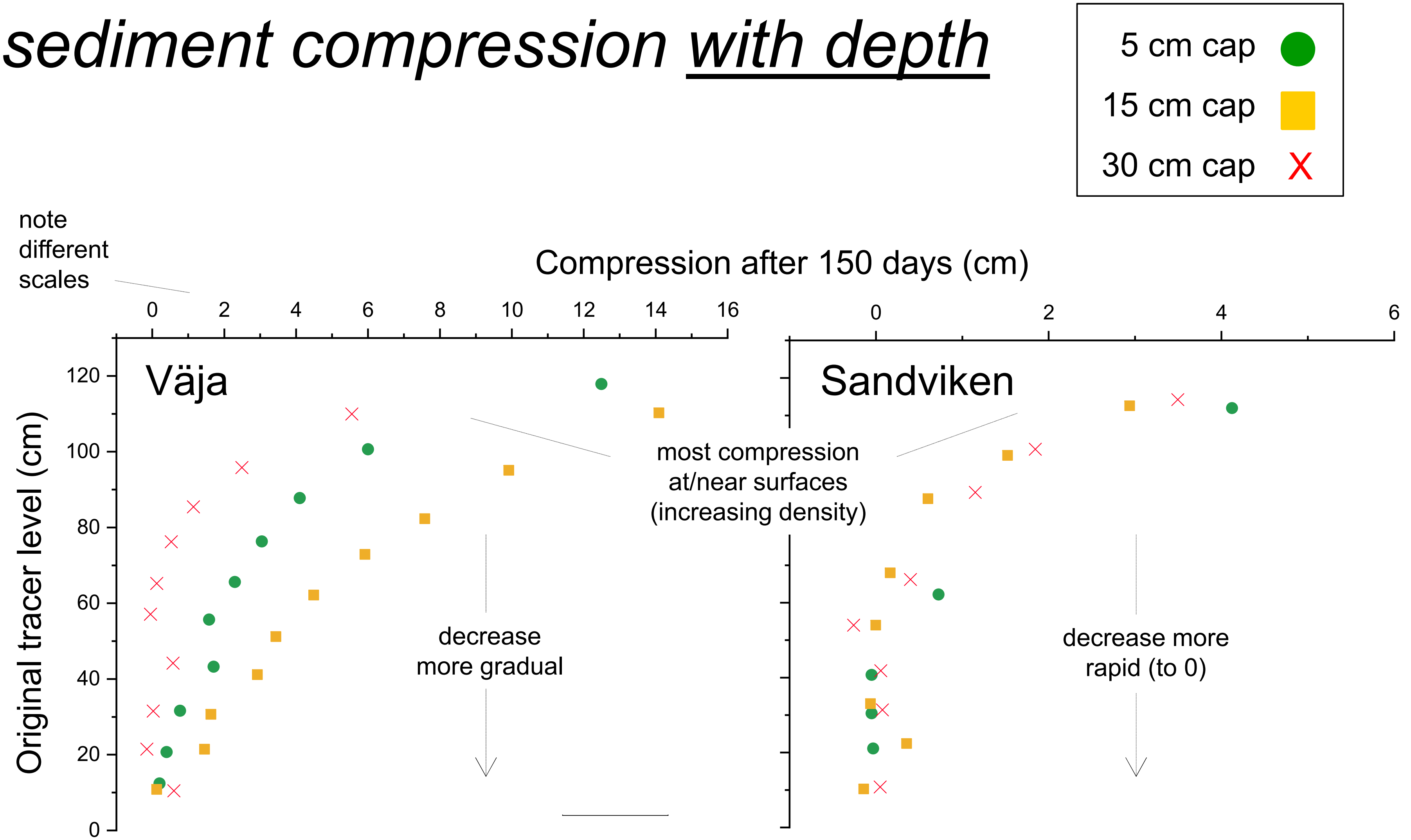


Results
total sediment compression

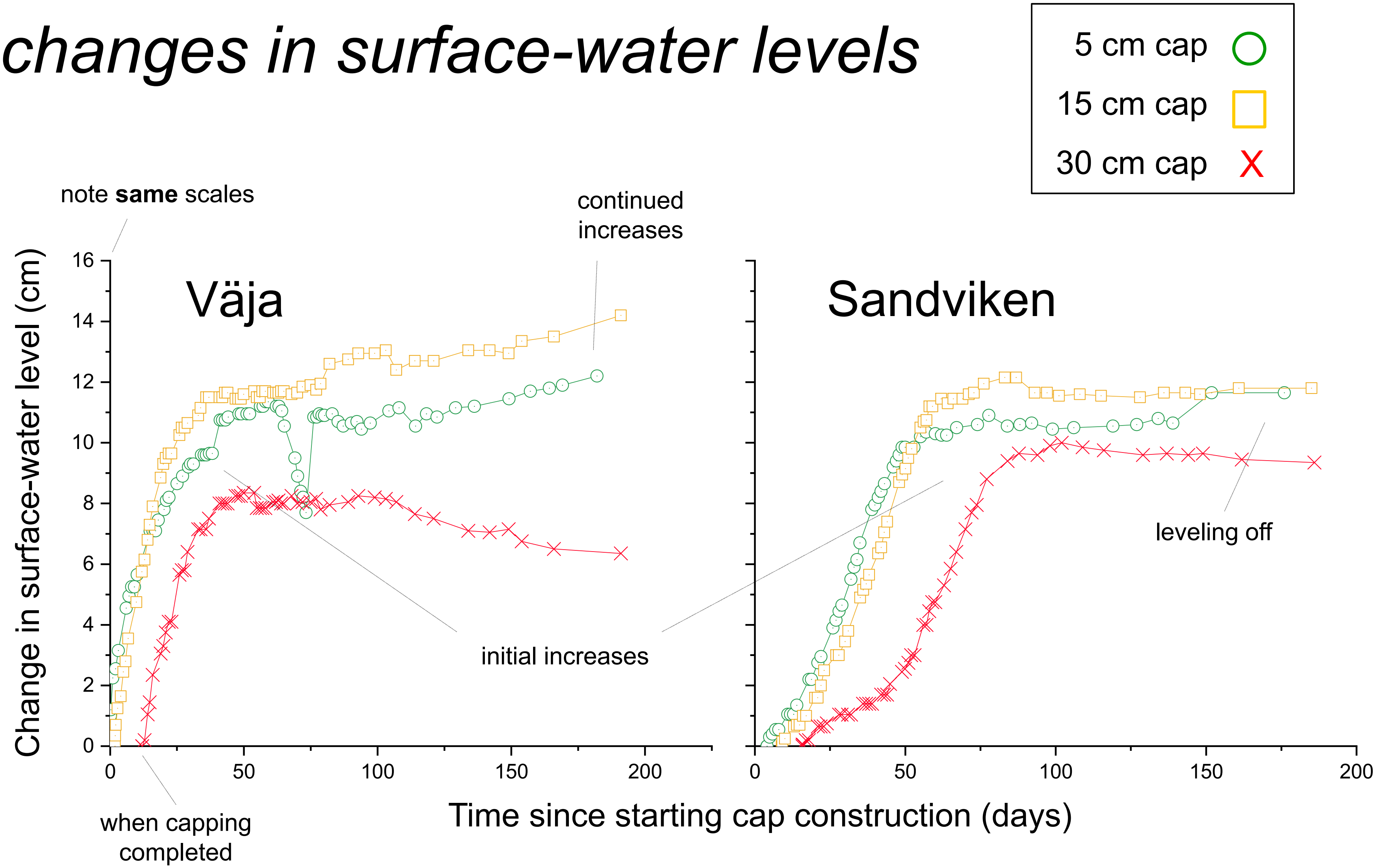


Results

sediment compression with depth



Results
changes in surface-water levels

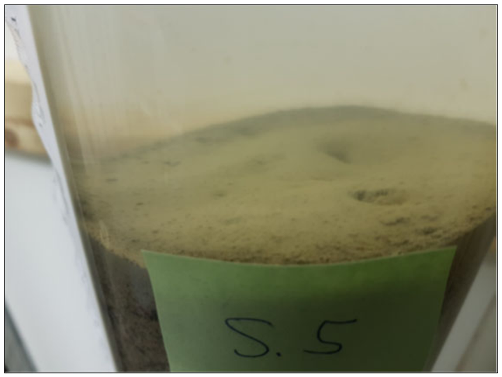


Results

Sandviken – pockmarks at cap surfaces

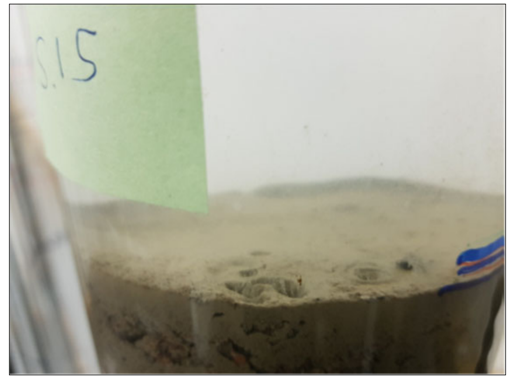
when first noted after capping

5 cm cap



38 d

15 cm cap

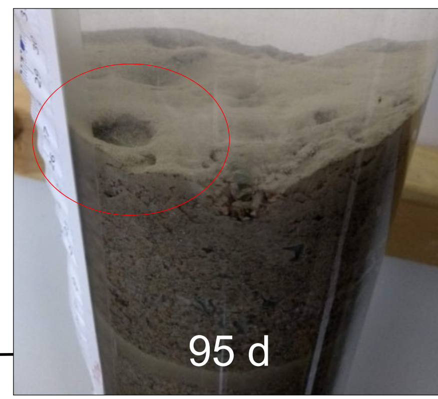


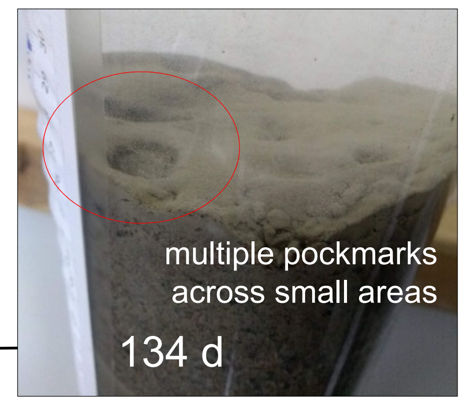
43 d

30 cm cap

58-61 d

15 cm cap, over time (example)





Results

Väja - pockmarks at cap surfaces

15 cm cap

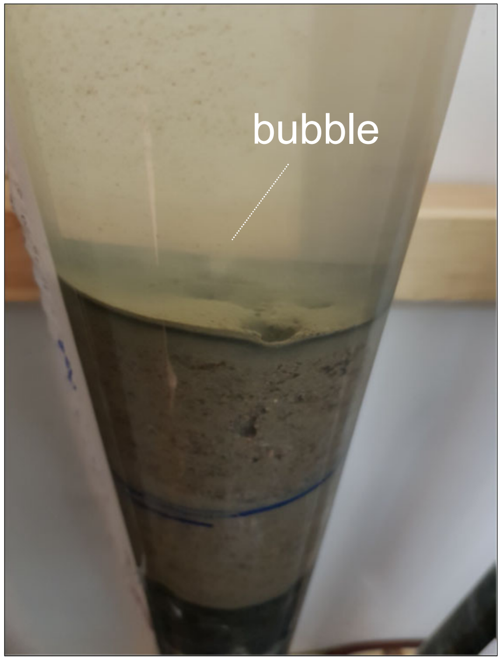
multiple pockmarks across small areas

5 cm cap

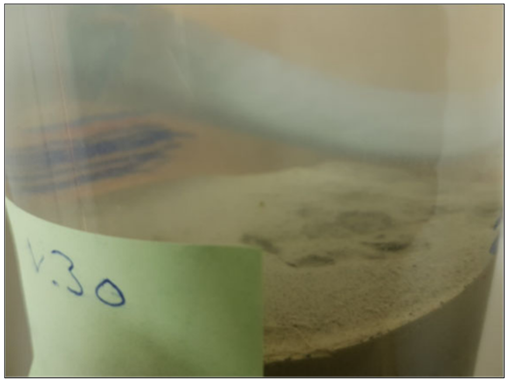
30 cm cap

when first noted after capping

> 10 d (after black layer)



36-39 d

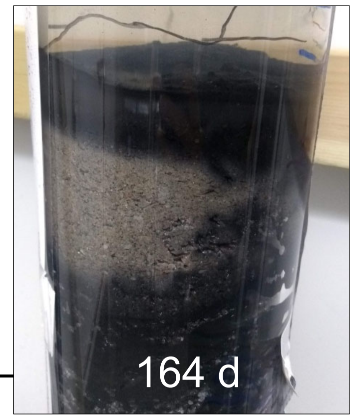


31 d

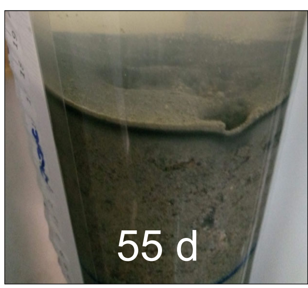
Results

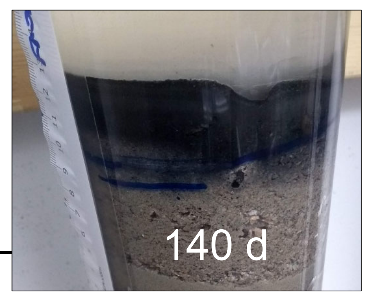
Väja – ”black layer” at cap surfaces

5 cm cap over time (first noted at 10 d, ~ 2.5 cm at 206 d)



15 cm cap over time (first noted at 29 d, ~ 2 cm at 190 d)





30 cm cap, no layer

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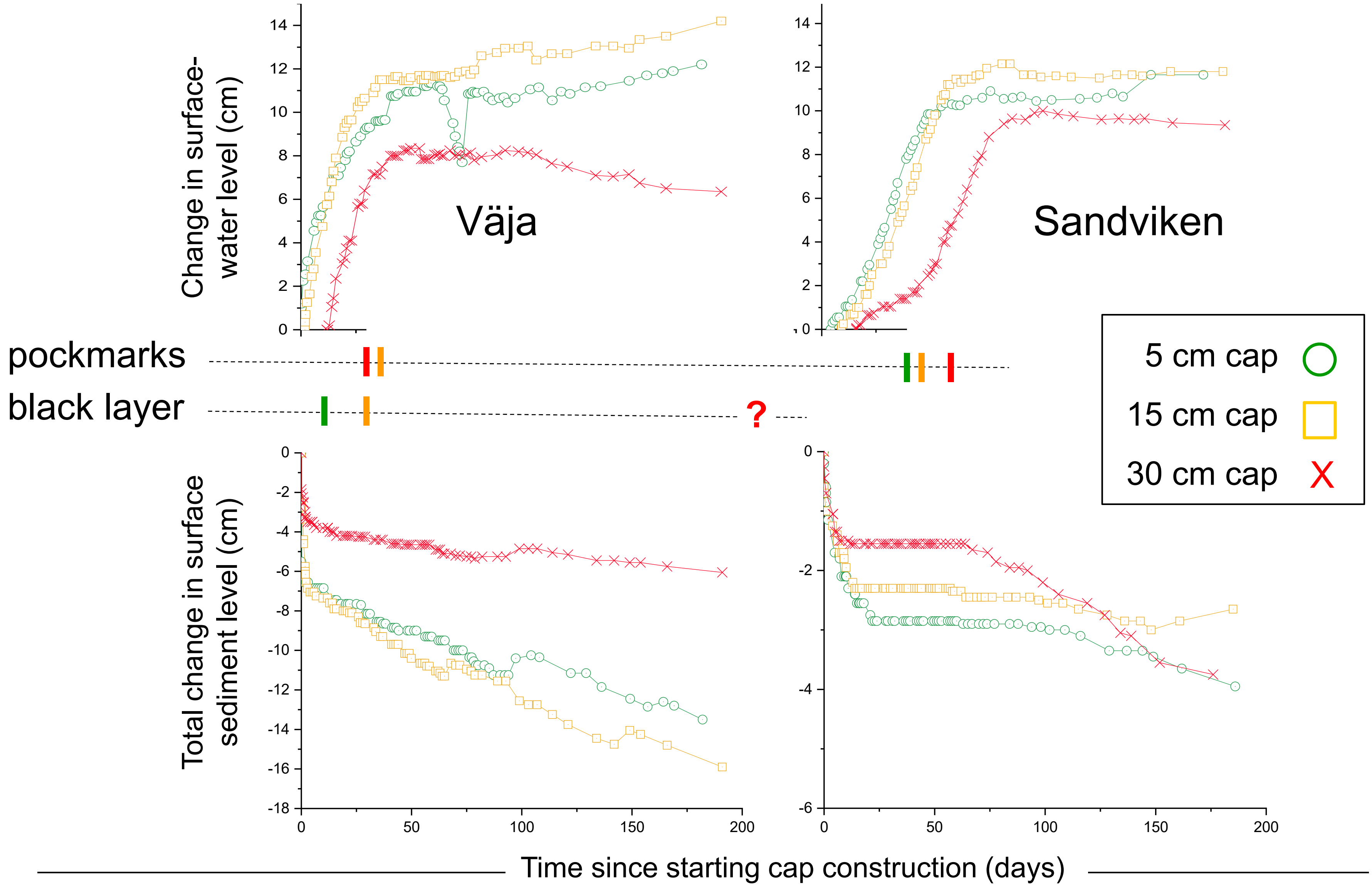
Results combined



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Summary
what we see

Expected

- Most compression at/near surface, initially rapid, continues for months
- Väja more compressive (finer-sized particles)
- Gas bubbles in sediment and cap pore spaces

Not expected

- Compression inconsistent with loads, and over time
- Increases in water levels, and water-column thicknesses, atop caps
- Pockmark formation, persistence, and growth
- Black-layer formation and growth atop Väja caps

Apparent (& approx.) relationships-in-time between phenomena

- See first pockmarks just before peaks in water levels
- Sandviken, 30 cm cap, first pockmarks at start of 2nd compression

Conclusions
interpretations of what we see

Gas controls everything, directly or indirectly

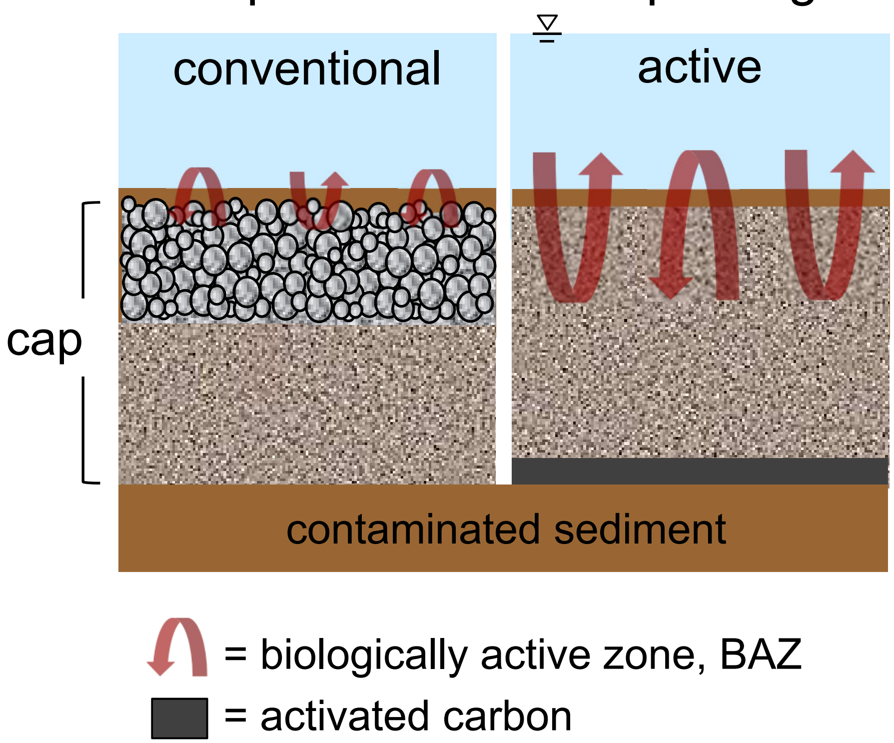
- Buildup in sediment counters its tendency to compress
- Buildup/movement displaces some porewaters upward
- Continued buildup/movement forms conduits through caps, allowing gas release – thus, pockmarks at cap surfaces
- Conduits/pockmarks facilitate continued upward movement/release of gas, and more porewaters
- Greater gas release allows greater compression, esp. for thinner caps; more complicated for thicker caps
- Black-layer investigations ongoing – focus on origin, contamination status

Conclusions
with respect to long-term contaminant transport

- Gas may accelerate contaminant transport through caps (even thicker ones) in multiple ways
  - Displaces contaminated porewaters upward
  - Conduits facilitate upward migration of contaminated gas bubbles, porewaters, and/or colloidal particles
  - Causes formation of contaminated surface deposits
- Gas-facilitated contaminant transport may "overshadow" recognized diffusive and advective mechanisms – both in rate and magnitude
  - Perhaps regardless of type of fiberbank sediment

Conclusions
with respect to meeting remedial objectives

conceptual isolation-cap designs

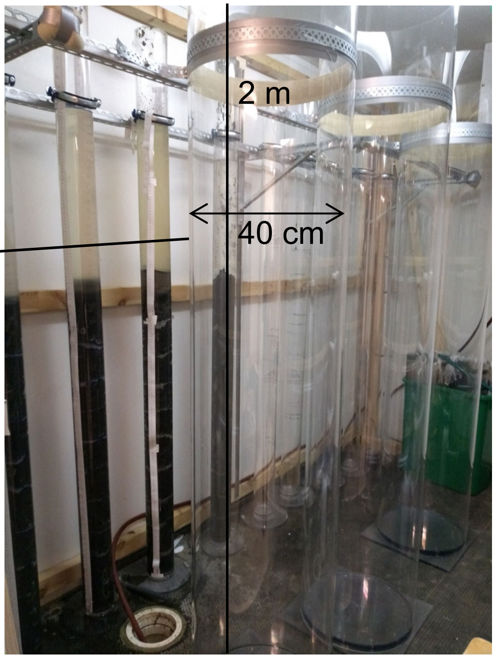


can we meet long-term remedial objectives when isolation capping fiberbanks?

chemical isolation of BAZ from sediment-borne contaminants	?
physical isolation of BAZ from sediment	?
sediment protection against erosion and spreading	?

Path forward
Follow-up lab testing – ongoing, upcoming

Contaminant-transport tests
- Objective: Characterize contaminant (metal and organic) fluxes before, during, and after capping
  - Design and approach very similar to compression testing, but using much larger columns



Contaminant-transport tests: Focus on gas
- Objective: Quantify transport of contaminants by gas bubbles through various cap thicknesses
  - Columns, 90 cm tall x 16 cm dia.

Stability tests
- Objective: Evaluate geotechnical stability of capped fiberbank material, including on slopes
  - Large-scale tanks

Thanks for your attention

FIBREM project collaborators

- UU: Uppsala University, Department of Earth Sciences
  - Prof. Snowball, project lead
- SAO: SAO Environmental Consulting AB
- SGI: Swedish Geotechnical Institute
- SLU: Swedish University of Agricultural Sciences
- SGU: Swedish Geological Survey
- MARUM: Center for Marine Environmental Sciences, University of Bremen, Germany’

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