# Long-term trends in coastal hypoxia in the Archipelago Sea of Finland – Is it a natural phenomenon?

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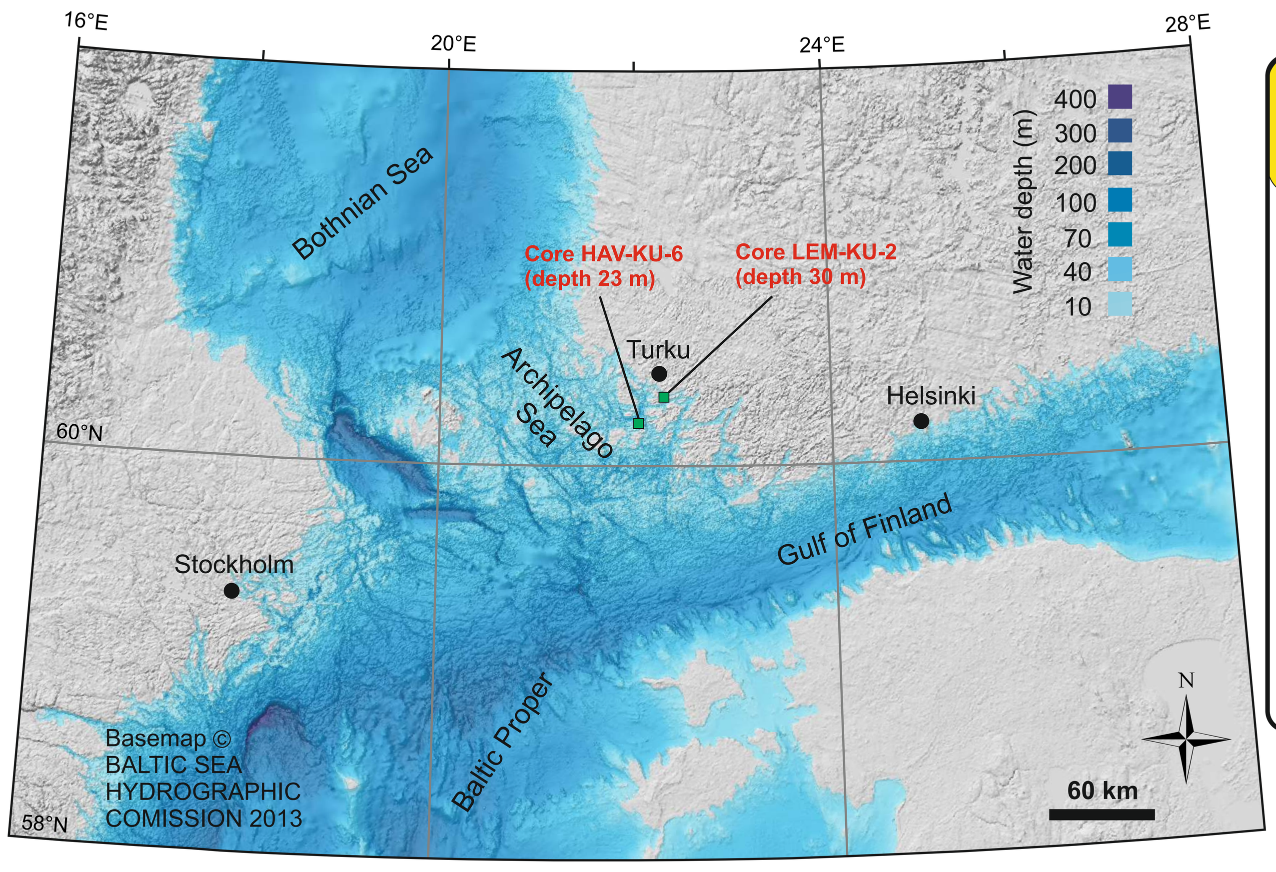
## 1. Introduction

Human-induced spreading of coastal hypoxia is currently a growing global problem that has deleterious effects on marine ecosystems. Although long-term spatiotemporal trends in hypoxia in the offshore areas of the Baltic Sea have been widely studied, coastal areas have received less research interest so far. The relevance of long-term data on coastal hypoxia is underlined by the most recent regional climate models, which project an increase of 2–4 ºC in the sea surface temperature in the Baltic Sea by the end of the 21st century (The BACC II Author Team, 2015), possibly enhancing organic matter delivery to the sea floor.

In this study, we use a multiproxy approach combining sedimentology, ichnology, microbiology, mineral magnetism, and mineral-specific *in situ* microanalyses of long sediment cores to assess shifts in bottom water oxygenation in the Archipelago Sea coast over the past 2000 years, encompassing the known climate anomalies of the Medieval Warm Period (950–1250 AD) and the Little Ice Age (1350–1850 AD).

## 2. Study sites




**The Archipelago Sea**

- Mosaic of ~22 000 islands
- Average water depth: 23 m
- Winter ice cover: 3–4.5 months
- Surface salinity: 5–7 PSU
- Stratification: no halocline, thermal stratification during summer
- Sedimentation rates of up to 5 cm a$^{-1}$

## 3. Aims of the study

- Determine how the coastal areas respond to natural climate variability, such as the Medieval Warm Period (950–1250 AD) and the Little Ice Age (1350–1850 AD) under significantly lower nutrient loading than at present
- Provide data for more accurate projections of the spreading of coastal hypoxia under different future climate scenarios and nutrient loadings
- Compare the modern bottom water conditions with those prevailing during the Medieval Warm Period, when the summer temperatures exceeded the contemporary warming of the end of twentieth century by about 0.5 ºC (Ljungqvist, 2010)

**Projected global warming**

**Reduced $O_2$ solubility in seawater** | **Intensified thermal stratification** | **Enhanced primary production**

**Intensified coastal oxygen deficiency**

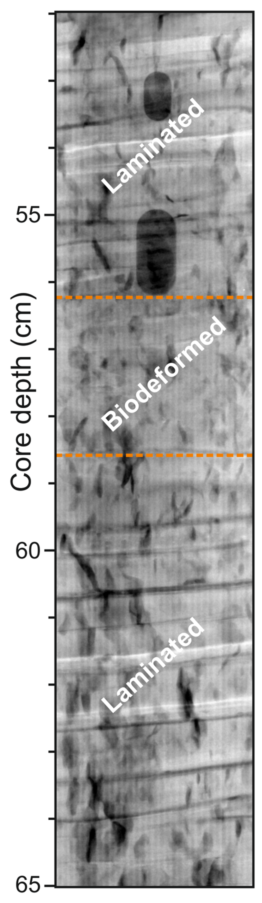
**Release of P from surface sediments** + **Decreased denitrification**

Nutrients

## 4. Preliminary results

### Trace fossil analysis

**The modern multidecadal oxygen deficiency, starting around 1910s, seems to be unprecedented in the studied cores:**



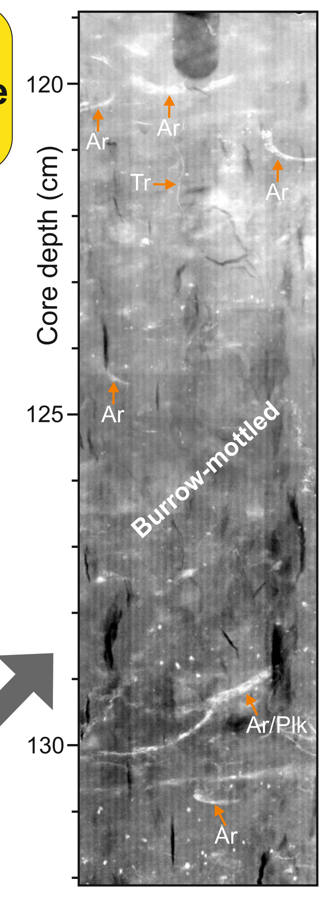

**Sedimentary-fabric of the sediments deposited since 1910s indicates hypoxia**

- No burrowing benthic macrofauna
- Primary laminated fabric well-preserved (varves)
- Oxycline at the sediment-water interface or in the water column
- Temporary oxygenation of the bottom waters allows colonization by opportunistic nectobenthic fauna

➡ **Biodeformed fabric**

**Sedimentary-fabric of the sediments deposited in the 1800s indicates normoxia**

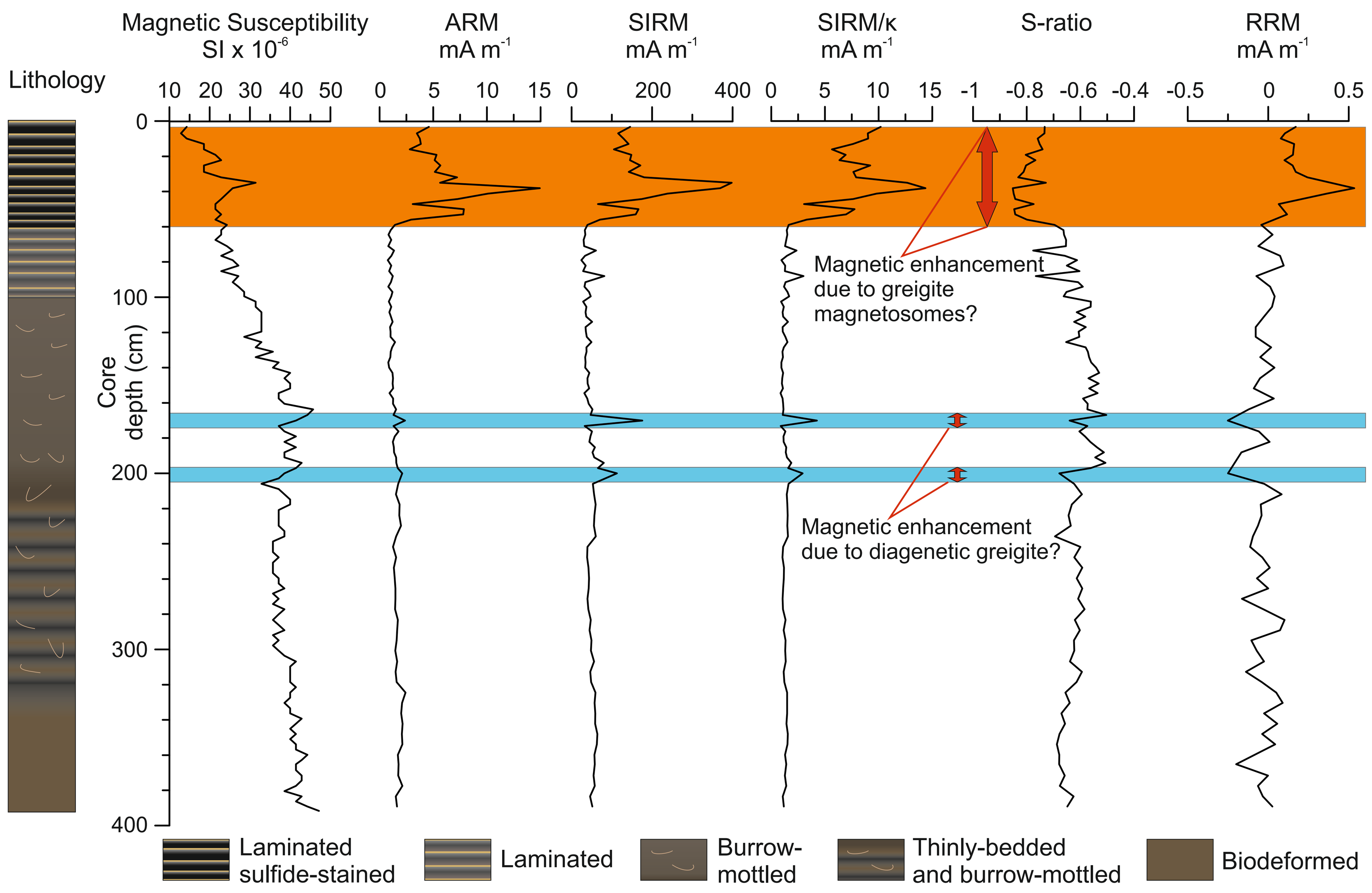
- Active burrow-producing benthic macrofauna
- Strong pyritization along burrow structures
- Oxycline below the sediment-water interface
- Primary sedimentary-fabric completely destroyed
- **Burrow-mottled fabric**




Trace fossils:
Ar = *Arenicolites*
Tr = *Trichichnus*
Plk = *Polykladichnus*

### Mineral magnetic measurements

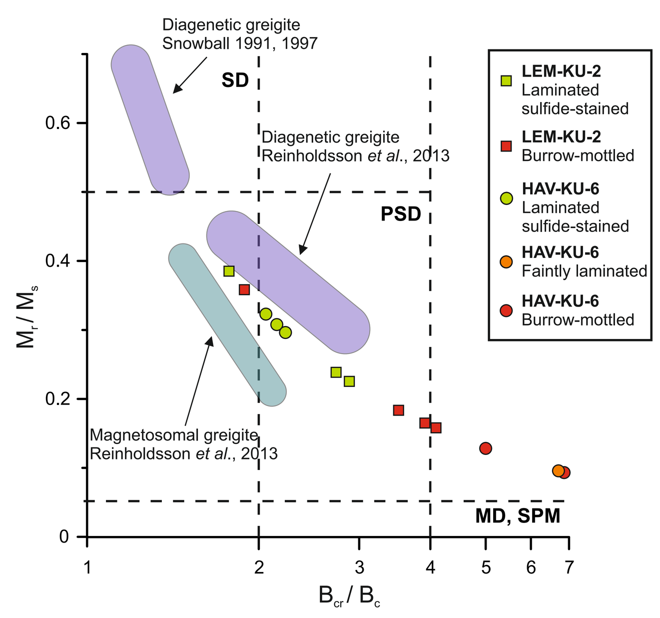
**The topmost 60 cm of the HAV-KU-6 core (deposited since 1930s) is characterized by a significant magnetic enhancement (putatively due to greigite magnetosomes), coinciding with the lithological change from *laminated* to *laminated sulfide-stained* mud:**




- The modern laminated sulfide-stained sediment is magnetically enhanced most likely due to magnetosomal greigite ($Fe_3S_4$) produced by strictly anaerobic magnetotactic bacteria

➡ **Occurrence of magnetosomal greigite provides a proxy for hypoxia?**

- The presence of magnetosomal greigite is supported by the lack of Verwey transition, low coercive force of ~13 mT, low S-ratio, elevated interparametric ratio SIRM/κ, and the aquirement of positive RRM at 5 rpm
- The subtle magnetic enhancements in the burrow-mottled sediment could be due to early-diagenetic greigite formed during arrested pyritization, which is supported by the lack of Verwey transition and the aquirement of negative RRM at 5 rpm.




- The putative greigite magnetofossils (HAV-KU-6, *laminated sulfide-stained*) fall in the pseudo-single domain in the Day plot
- Although the putative greigite magnetosomes most likely were SD in origin, the breakage of the dividing membranes results in PSD behaviour after the deposition (Reinholdsson et al., 2013)

## References

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