Iron and Manganese Reduction in Bering Sea Shelf Sediments

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Special Thanks To:
Primary Production and Iron in the Bering Sea

- Surface waters in the off-shelf region are Fe-limited (Aguilar-Islas et al. 2007)

- Shelf sediments may be a significant source of Fe to surface waters (Hurst et al. 2010)

Fe(III) $\xrightarrow{\text{Reduction}}$ Fe(II)

Rate ??
Greater Carbon Export to Benthos

- Increased sediment O$_2$ consumption
  - Greater significance of anaerobic pathways
    - Higher Fe/Mn reduction rates accounting for greater % of total carbon oxidation

- Increased bioturbation
  - Enhanced cycling of Fe/Mn oxides
Expected Order:

Northern Shelf
Middle Shelf
Outer Shelf
Off Shelf
Hypothesis

Fe and Mn reduction rates and the % of total organic carbon remineralized by these pathways will vary regionally in the following order:

Northern shelf > Middle shelf > Outer shelf > Off shelf
•20 stations sampled aboard the USCGC Healy (HLY0902: April-May 2009)

•19 stations sampled aboard the WHOI R/V Knorr (KNR195-10: June-July 2009)
Up to 16 cores collected at each station

Sediment O$_2$ consumption rates used to estimate total carbon oxidation rates

Flux core set-up
Sediment samples were frozen for later analysis of Fe and Mn.

$^{234}\text{Th}$ tracer used to determine bioturbation rates.
Fe & Mn oxides extracted using an *acidified ammonium oxalate* method (Phillips and Lovely 1986, Davenport 2008)

Flame AA Spectrophotometer
\[
D_b \int_{z_1}^{z_2} \frac{d^2 C}{dz^2} \, dz = \int_{z_1}^{z_2} \Sigma R_{(z)} \, dz
\]

Bioturbation

Fe/Mn reduction

Excess \(^{234}\)Th (cpm g\(^{-1}\))

Excess Fe (µmol cm\(^{-3}\))

\(D_b = 3.34 \text{ cm}^2 \text{ yr}^{-1}\)

\(y = 4.1863x^2 - 40.953x + 99.5\)

\(R^2 = 0.9724\)
NO$_3^-$, Mn$^{2+}$, Fe$^{2+}$ (μM)

Depth where excess Fe/Mn=0

Fe: bottom of PW NO$_3^-$

Mn: bottom of PW O$_2$

Zone of reduction

Depth (cm)
$p < 0.0001$

$\text{Fe Reduction (mmol m}^{-2}\text{d}^{-1})$

$\text{North Middle Outer Off}$

$p = 0.0011$

$\text{Fe Reduction/}C_{\text{oxid}}\%$

$\text{North Middle Outer Off}$
p = 0.0174

p = 0.1539
Summary of Findings

• Fe reduction is a significant pathway for organic carbon remineralization

  • Highest rates of Fe reduction were in regions where we expect highest rates of carbon export

  • In contrast to Fe, regional pattern not as strong in Mn with very low rates in all regions.
The Role of Sedimentary Iron Reduction

Fe(III) Reduction Fe(II)

Avg. Rate = 1.74 mmole m^{-2} d^{-1}

(https://earthobservatory.nasa.gov/IOTD/view.php?id=1423)

Photo by Heather Whitney
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