A Pliocene marine diatom oxygen isotope record of cryogenic brine formation in the Ross Sea, Antarctica

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Antarctic Ice in a Warming World

Today











Pollard and DeConto, 2009

Diatom Distribution – Sea Ice Connection



MIT Darwin Project, ECCO2, MITgcm

Biogenic Silica (Opal)

- <u>diatoms</u>, radiolarians, silicoflagellates, Chaetoceros spores, and sponge spicules
- Amorphous silica as opal-A (SiO₂•nH₂O)
- Well-preserved in high-latitude sediments





Opal Structure: Oxygen

- Silica tetrahedra stable
- Absorbed/structural H₂O
- Exchangeable OH
 - Decreases

 as silica
 "ages"

 Diagenetic

 timing?





Diatom Oxygen Isotope (δ^{18} O) values

- Biogeneic silica δ^{18} O values record formation water
 - δ^{18} O value
 - Temperature
- Diagenetic alteration
 - may take 100s to 1000s of years
- Paleoceanographic Proxy
 - diagenetic water source
 - diagenesis may provide <u>additional</u> paleoceanographic data



Wilson et al. (2012)



http://www.andrill.org



Wilson et al. (2012)



"Stacked" Benthic Foraminifera δ^{18} O Curve



- 57 globally distributed ocean sediment cores
- record of global ice volume over the past 5.3 Ma

Marine Oxygen Isotope Record



Water, slightly depleted in ¹⁸0, evaporates from warm sub-tropical waters,

- Heavier water molecule preferentially lost through precipitation
- Less ¹⁸O as clouds move inland/toward poles
 - → more ¹⁶O in polar ice → more ¹⁸O in ocean
- sea ice/brine formation concentrates ¹⁶O in brine

AND-1B Diatom $\delta^{18}O$



- +32.6 to +37.6‰
 ave. +35.1‰
- TEX₈₆ SST 3 to 5°C
- $\delta^{18}O_{water} = 0\%$ (VSMOW) Calculated Water T>20°C
- Unrealistic Antarctic SST
 even during the mid-Pliocene

Abbott et al., *in prep*

Calculated Water δ^{18} O Values



- Formation Temperature 10°C and 20°C (± 5°C)
- Water δ^{18} O values Whillans Ice Stream Grounding Zone -2.0‰ (VSMOW)

SIMS Ocean water (Frank et al, 2010) -1.0‰ (VSMOW)

AND-2A Pore Water (Frank et al, 2010) ave. -8.3‰ (VSMOW)

Abbott et al., in prep

Pore Water Chemistry and $\delta^{18}O$

- AND-2A pore waters yellow and red circles
- AND-1B pore waters open circles
- AND-1B pore water δ^{18} O values (calculated) blue circles



Warm Pliocene: Cryogenic Brine?



Grasby et al., 2013; Staudigel et al., 2018

Warm Pliocene: Cryogenic Brine?



Grasby et al., 2013; Staudigel et al., 2018

Orbitally-paced cryogenic brine formation during the mid-Pliocene?



Abbott et al., in prep

Sea-ice derived Cryogenic Brine

- Low diatom δ^{18} O values = Cryogenic Brine (Frank et al, 2010; Staudigel et al., 2018; Yang et al, 2018)
- Brine Source and Timing
 - Seasonal sea ice
 - Orbitally-paced cryogenic brine formation
 - Contribution of connate (older) brines
 - Warmer than present Ross Sea
 - What does it look like?
 - spatial and temporal distribution of sea ice

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