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

Pliocene (future?)

Pollard and DeConto, 2009
Diatom Distribution – Sea Ice Connection
Biogenic Silica (Opal)

- *diatoms*, radiolarians, silicoflagellates, *Chaetoceros* spores, and sponge spicules
- Amorphous silica as opal-A (SiO$_2$$\cdot$$n$H$_2$O)
- Well-preserved in high-latitude sediments
Opal Structure: Oxygen

- Silica tetrahedra - stable
- Absorbed/structural H₂O
- Exchangeable - OH
  - Decreases as silica "ages"
  - Diagenetic timing?

Moschen et al., 2006
Dodd et al., 2017
Diatom Oxygen Isotope ($\delta^{18}O$) values

- Biogeneic silica $\delta^{18}O$ values record formation water
  - $\delta^{18}O$ value
  - Temperature

- Diagenetic alteration
  - may take 100s to 1000s of years

- Paleoceanographic Proxy
  - diagenetic water source
  - diagenesis may provide *additional* paleoceanographic data
ANtarctic geological DRILLing (ANDRILL)
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84m of ice

850m of water

1285m of sediment

http://www.andrill.org
ANtarctic geological DRILLing (ANDRILL)
mid-Pliocene (3.5 – 4.7 Ma)

McKay et al., 2012
“Stacked” Benthic Foraminifera $\delta^{18}$O Curve

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

Lisiecki and Raymo, 2005
Marine Oxygen Isotope Record

- Heavier water molecule preferentially lost through precipitation

- Less $^{18}$O as clouds move inland/toward poles
  - more $^{16}$O in polar ice
  - more $^{18}$O in ocean

- sea ice/brine formation concentrates $^{16}$O in brine
AND-1B Diatom $\delta^{18}O$

- $+32.6$ to $+37.6\%$o
  - ave. $+35.1\%$o
- $TEX_{86}$ SST $3$ to $5^\circ$C
- $\delta^{18}O_{water} = 0\%$o (VSMOW)
  - Calculated Water $T>20^\circ$C
- Unrealistic Antarctic SST
  - even during the mid-Pliocene

Abbott et al., in prep
Calculated Water $\delta^{18}O$ Values

- Formation Temperature
  10°C and 20°C ($\pm$ 5°C)

- Water $\delta^{18}O$ 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 δ¹⁸O

- AND-2A pore waters – yellow and red circles
- AND-1B pore waters – open circles
- AND-1B pore water δ¹⁸O values (calculated) – blue circles

Evaporative brine formation

Cryogenic brine formation

Frank et al., 2010; Abbott et al, in prep.
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?
Sea-ice derived Cryogenic Brine

- Low diatom $\delta^{18}$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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