Gulf of Mexico climate, Laurentide Ice Sheet meltwater history, and global sea level change during the last glacial cycle

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Research Motivation

1) What was the relation of Laurentide Ice Sheet (LIS) meltwater history to interhemispheric climate change 50-10 ka?

2) When was initial deglaciation of the LIS recorded in the Gulf of Mexico?

3) Did meltwater pulse 1a involve input from the LIS?

Acknowledgements

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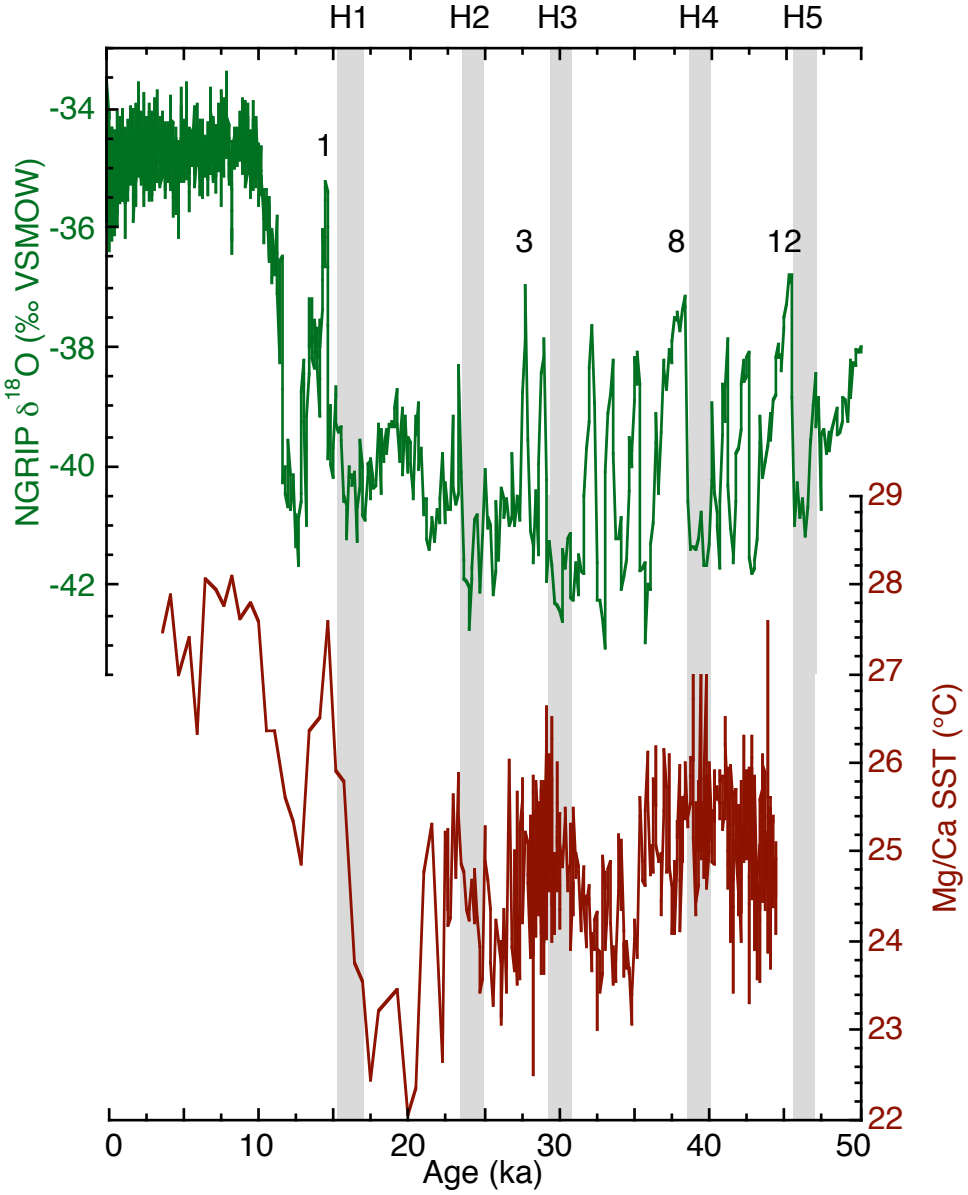
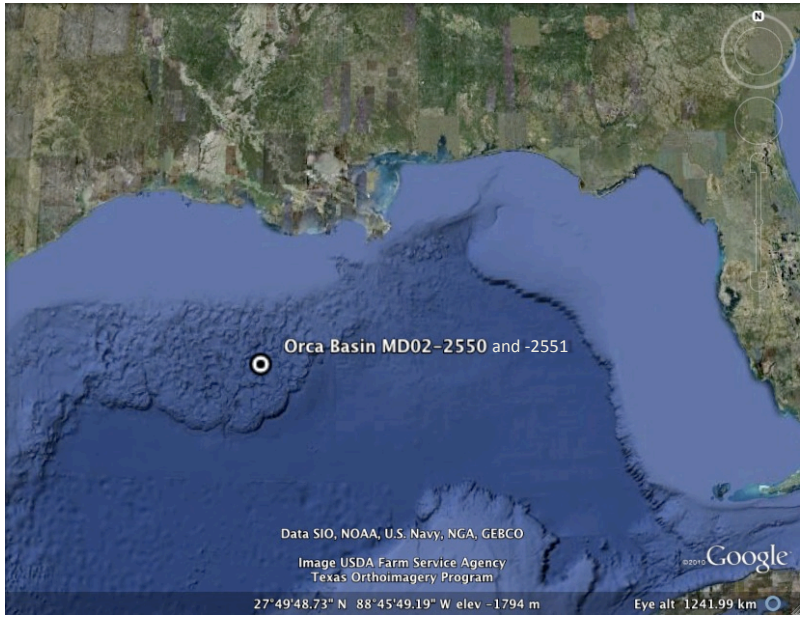
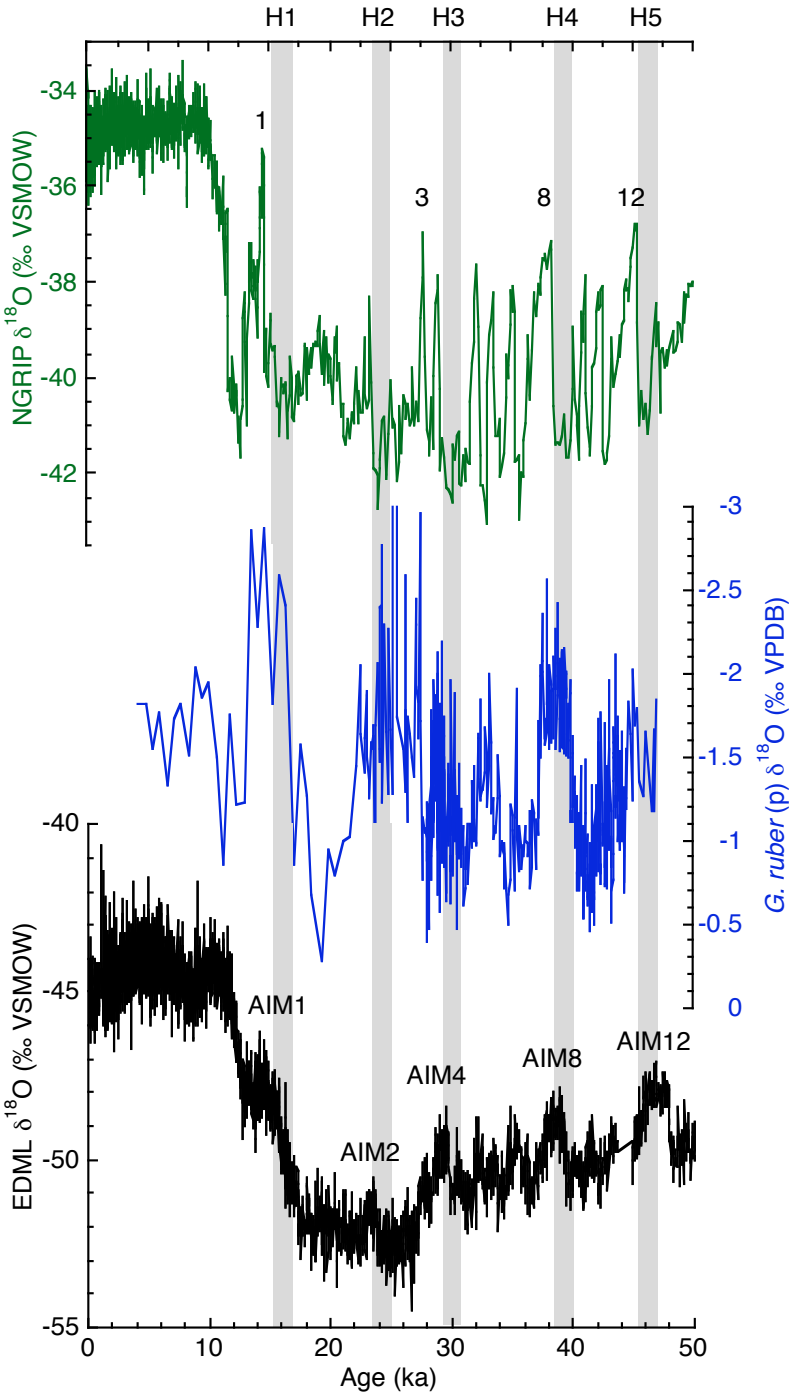
1. Relation of LIS meltwater to climate 50-10 ka





- Foraminiferal Mg/Ca SST indicates ~2°C summer changes during MIS 3 and ~4°C mean increase from LGM to Holocene

- Heinrich stadial events appear to coincide with increased summer SST in the Gulf of Mexico



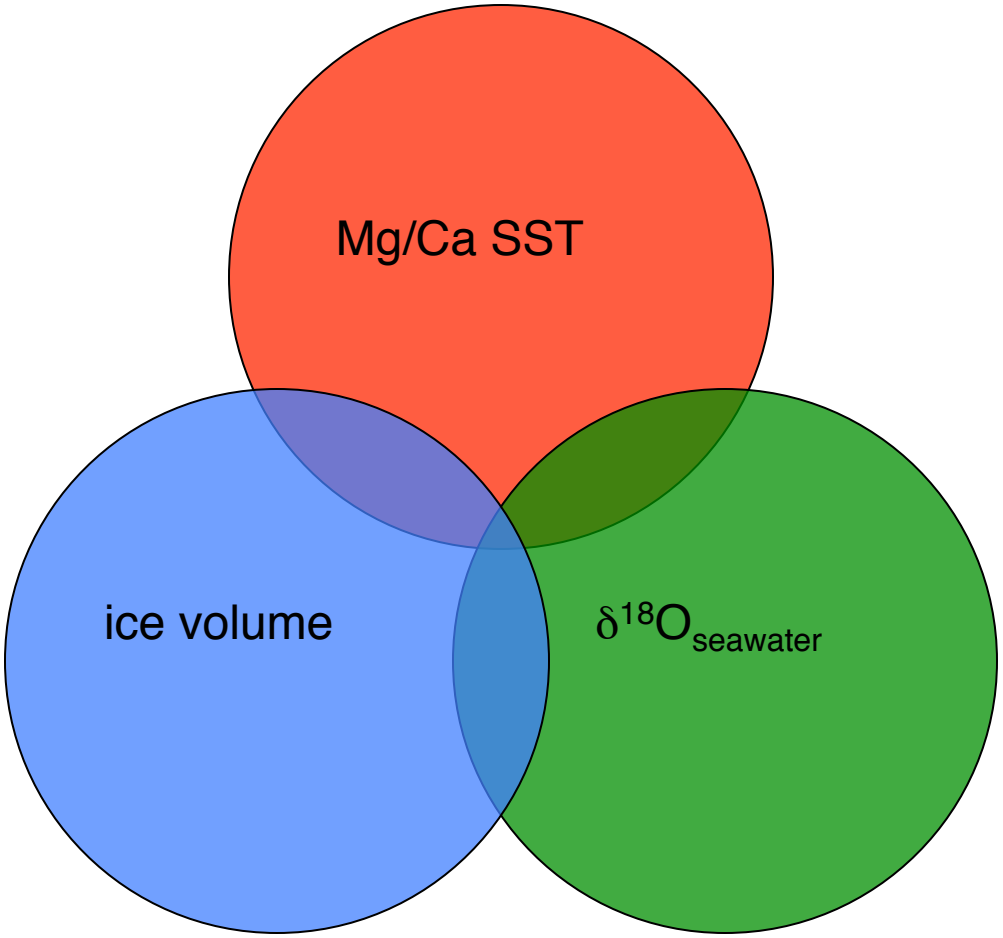
G. ruber (pink) $\delta^{18}O$ and climate

- Foraminiferal $\delta^{18}O$ exhibits five major negative excursions, which do not match Dansgaard/Oeschger events and argue against a simple re-routing hypothesis for D/O events.

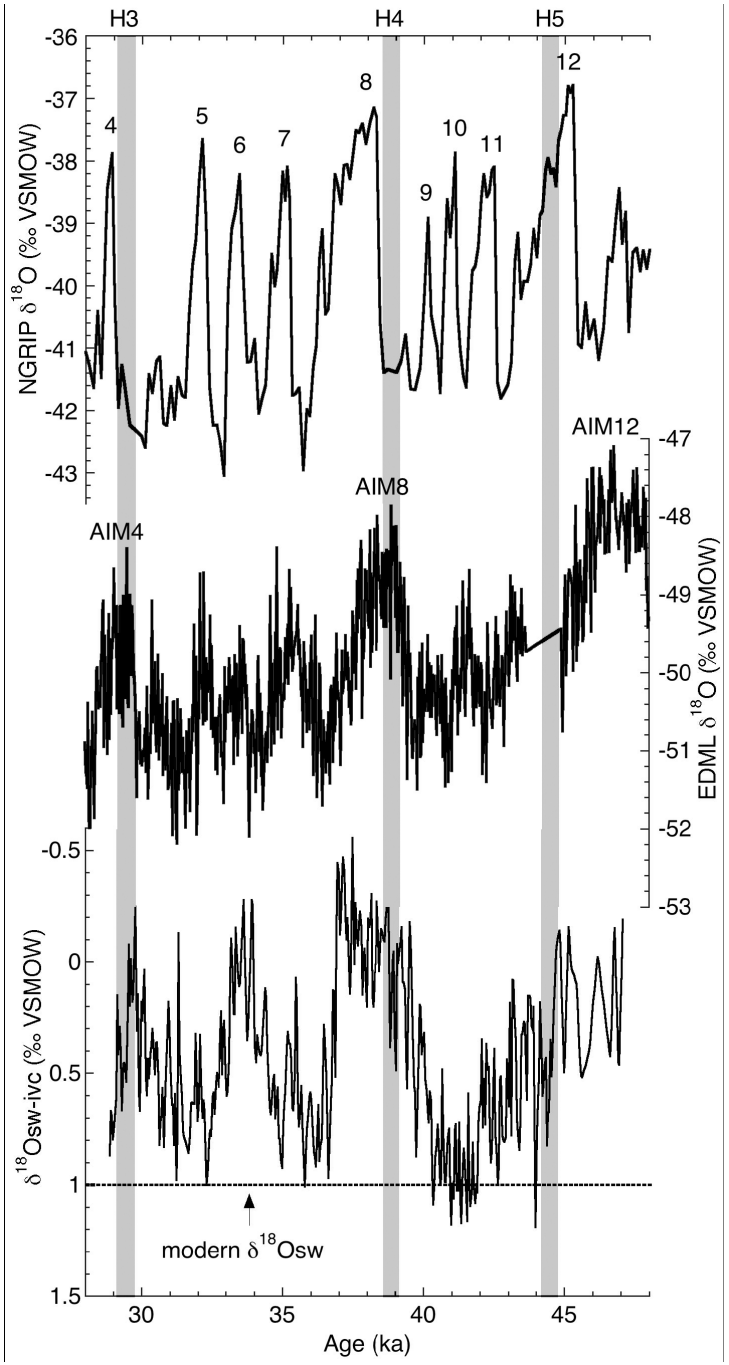
- Instead, inferred LIS melting occurs during Antarctic warming and sea-level rise, suggesting bipolar warming during AIM events.

(Hill et al., 2006; Flower et al., 2012)

$\delta^{18}O_{calcite} = f$ (T, ice volume, $\delta^{18}O_{sw}$)



- **SST fixed by Mg/Ca**
- **Ice volume fixed by sea level records (Stanford et al., 2010)**
- **T°C = 14.9 – 4.8 ($\delta^{18}O_{calcite}$ – $\delta^{18}O_{seawater}$) (Bemis et al., 1998)**



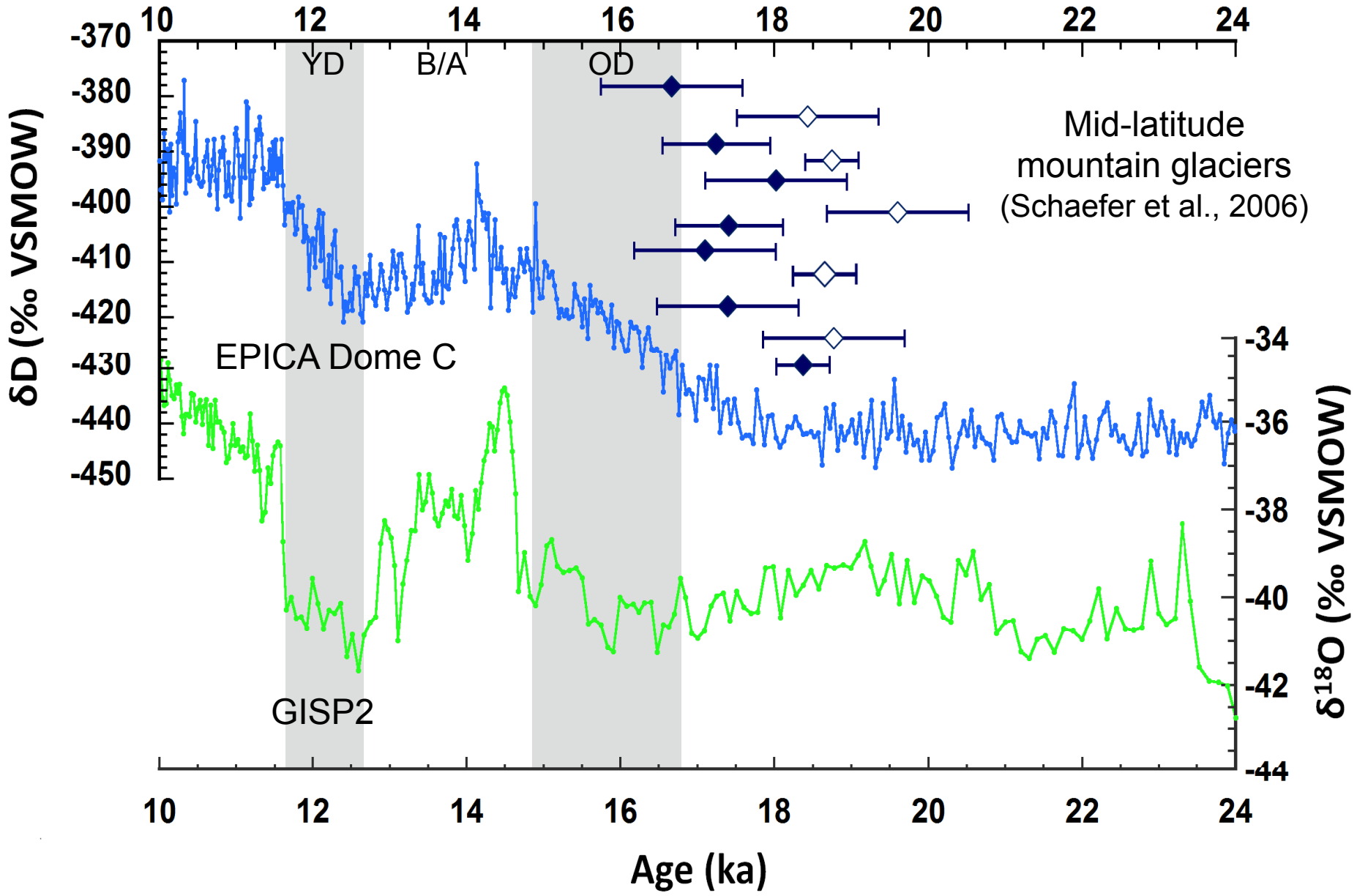
G. ruber (pink) δ^{18}Osw-ivc and climate

- Foraminiferal δ^{18}Osw-ivc exhibits values lower than modern δ^{18}Osw, suggesting summer LIS melting during most of MIS 3.

- Largest LIS meltwater event coincides with AIM8, again supporting bipolar warming during AIM events.

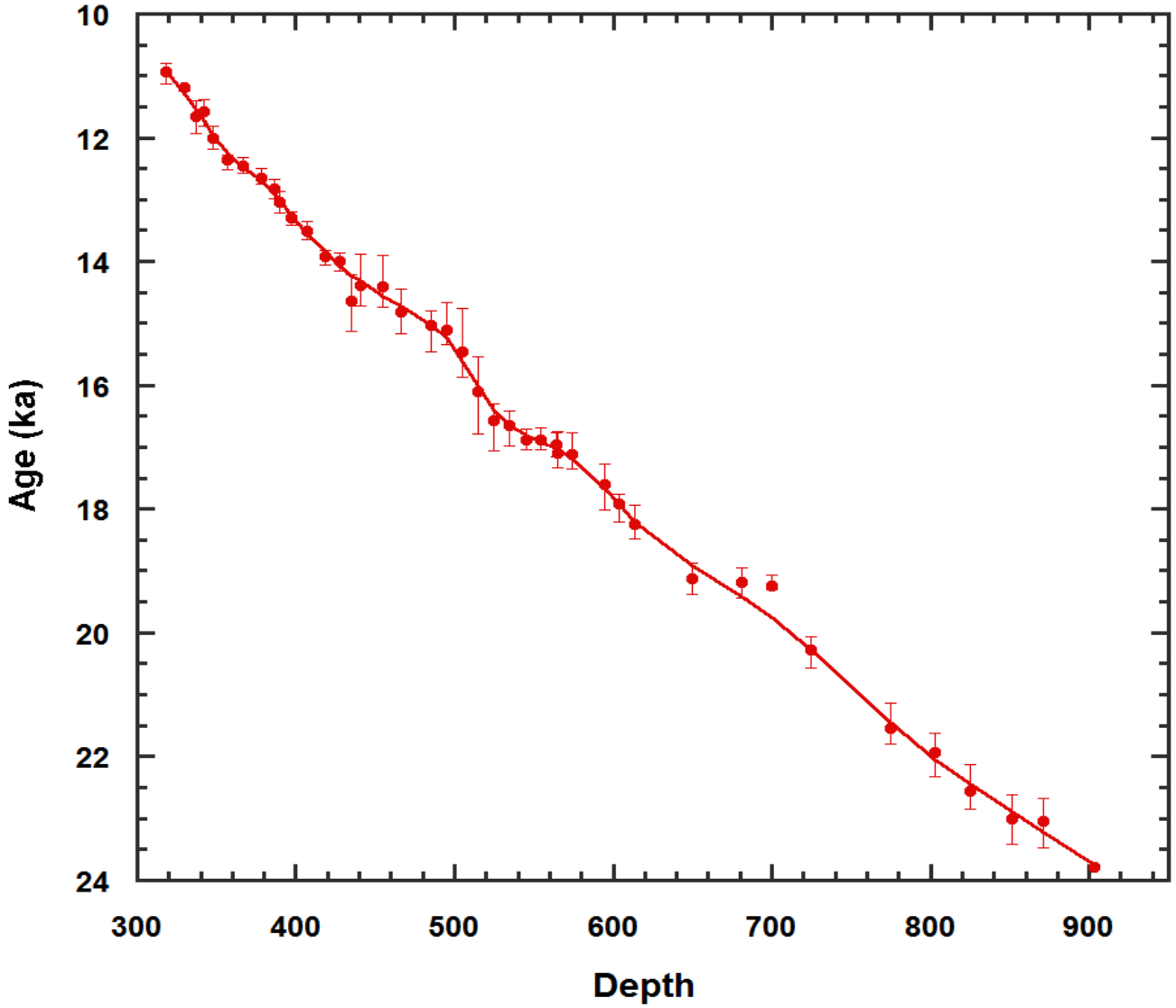
(Hill et al., 2006; Flower et al., 2012)

2. When was initial deglaciation of the LIS recorded in the Gulf of Mexico?

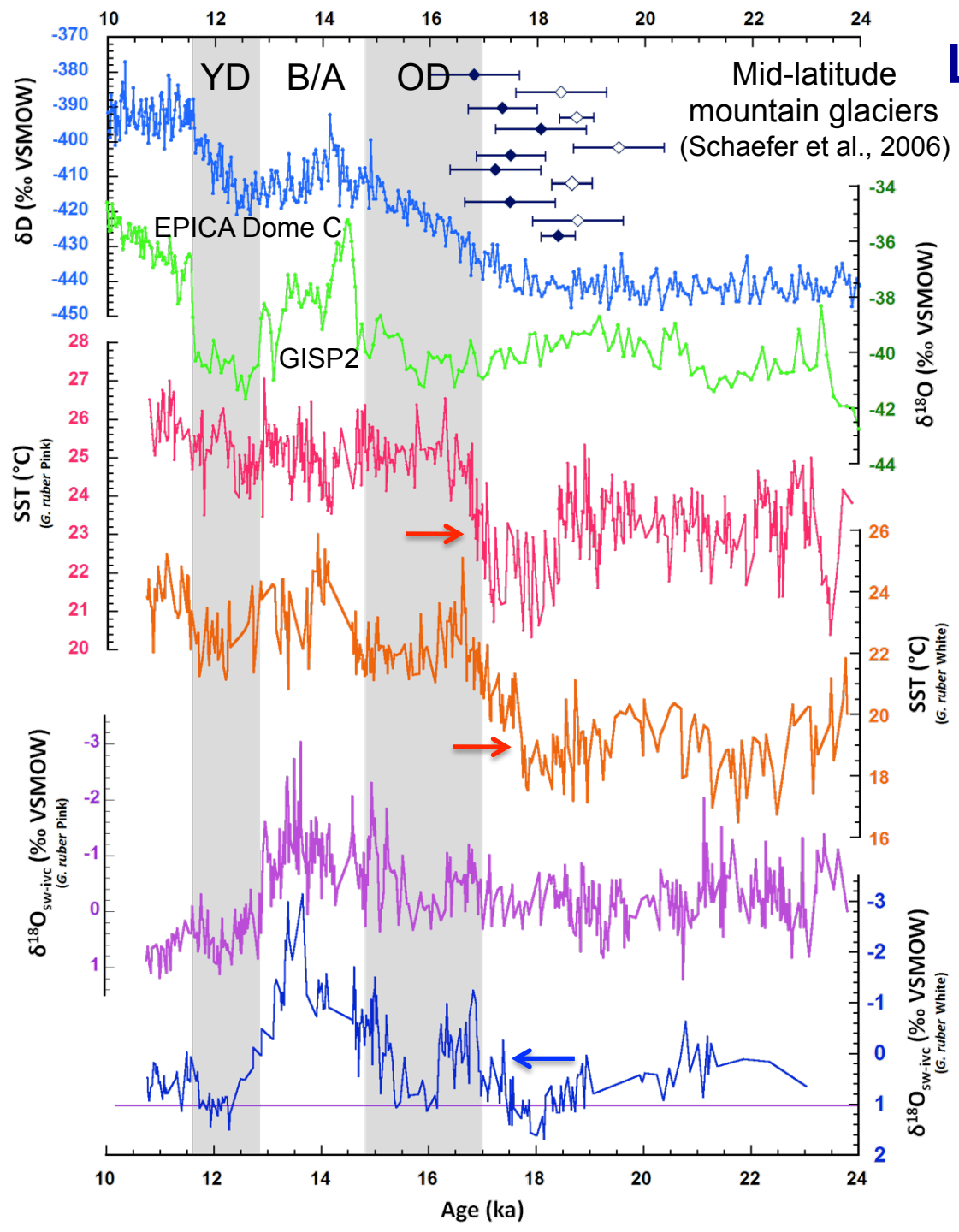


- **Mid-latitude mountain glaciers show "early" deglacial retreat**

Age model for MD02-2550



- 50 AMS ^{14}C dates on *G. ruber* analyzed at Lawrence Livermore National Laboratory
- Calibration to calendar years based on Marine09 (Reimer et al., 2009)



LIS melting based on $\delta^{18}O$

- Mg/Ca SST from core MD02-2550 warms just prior to the Oldest Dryas (Williams et al., 2010)

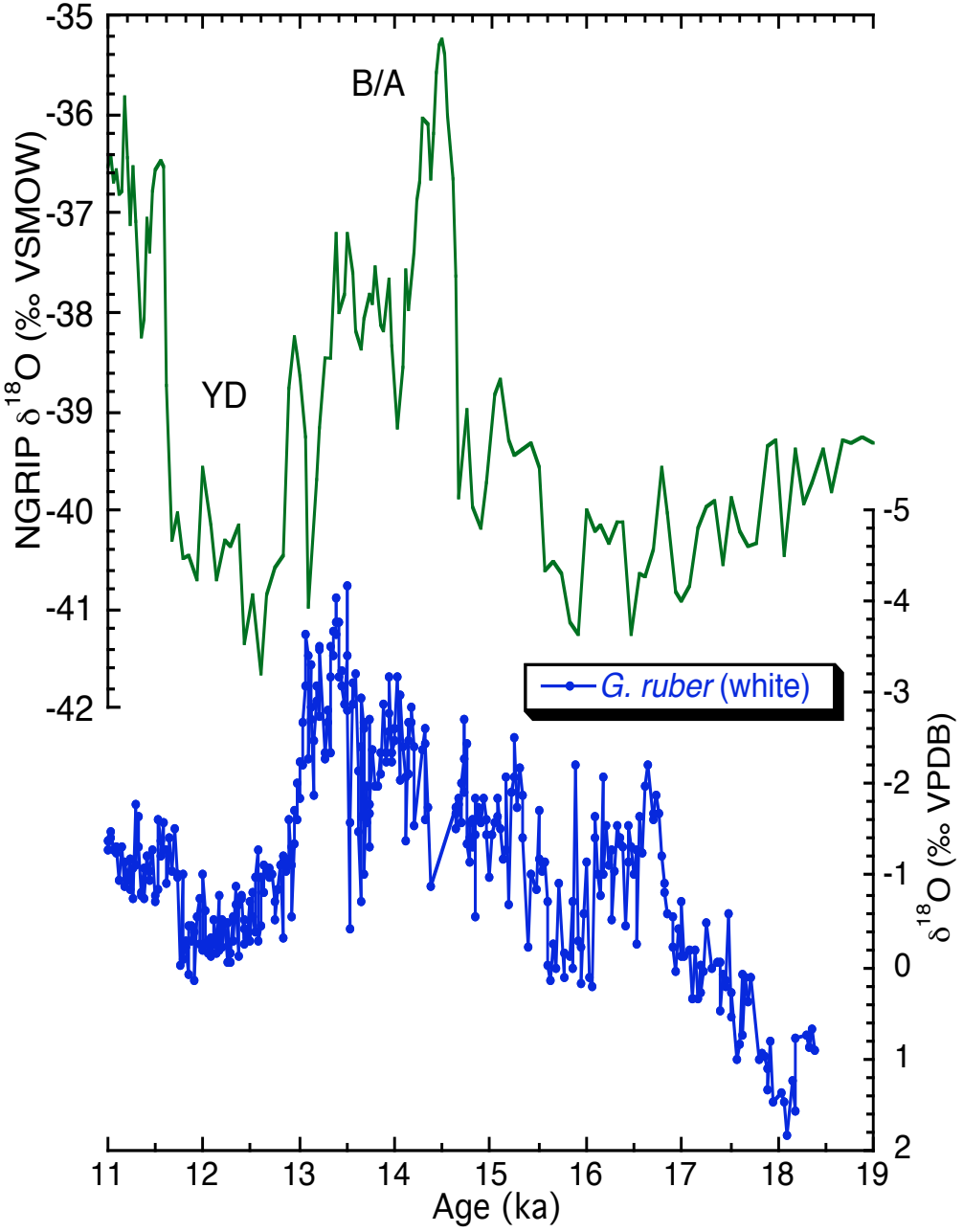
- *G. ruber* (white) δ^{18}Osw-ivc indicates first major LIS melt just prior to and during the Oldest Dryas ca. 17.5 ka (Williams et al., in review; PA23A-1827)

- Timing is consistent with Lake Erie Lobe retreat (Williams et al., in prep.; PA23A-1827

- *G. ruber* (pink) δ^{18}Osw/ivc data consistent with episodic summer LIS melt during LGM (Brown et al., in prep.; PA23A-1828)

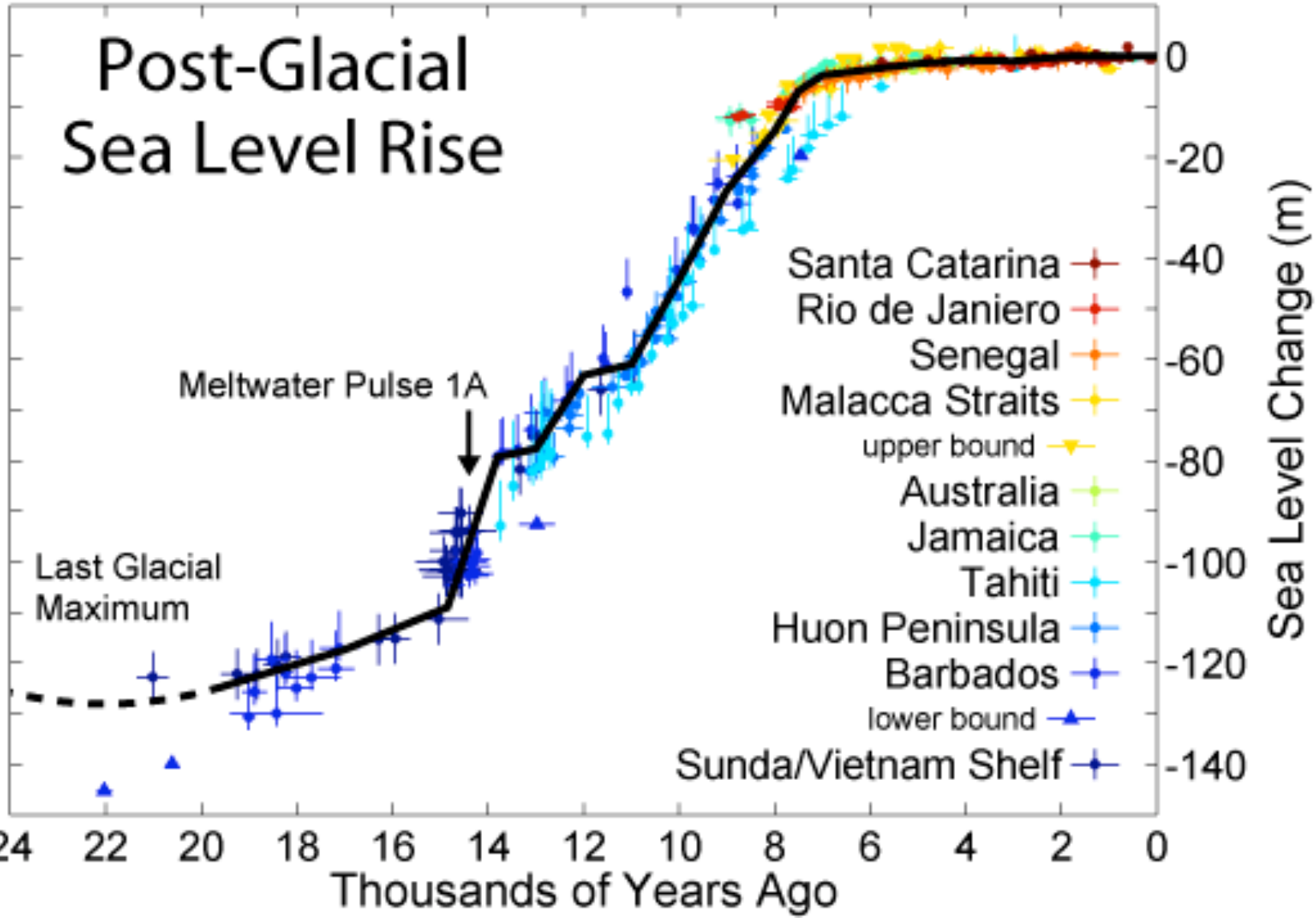
From Brown et al. PA23A-1828

3. Did meltwater pulse 1a involve input from the LIS?



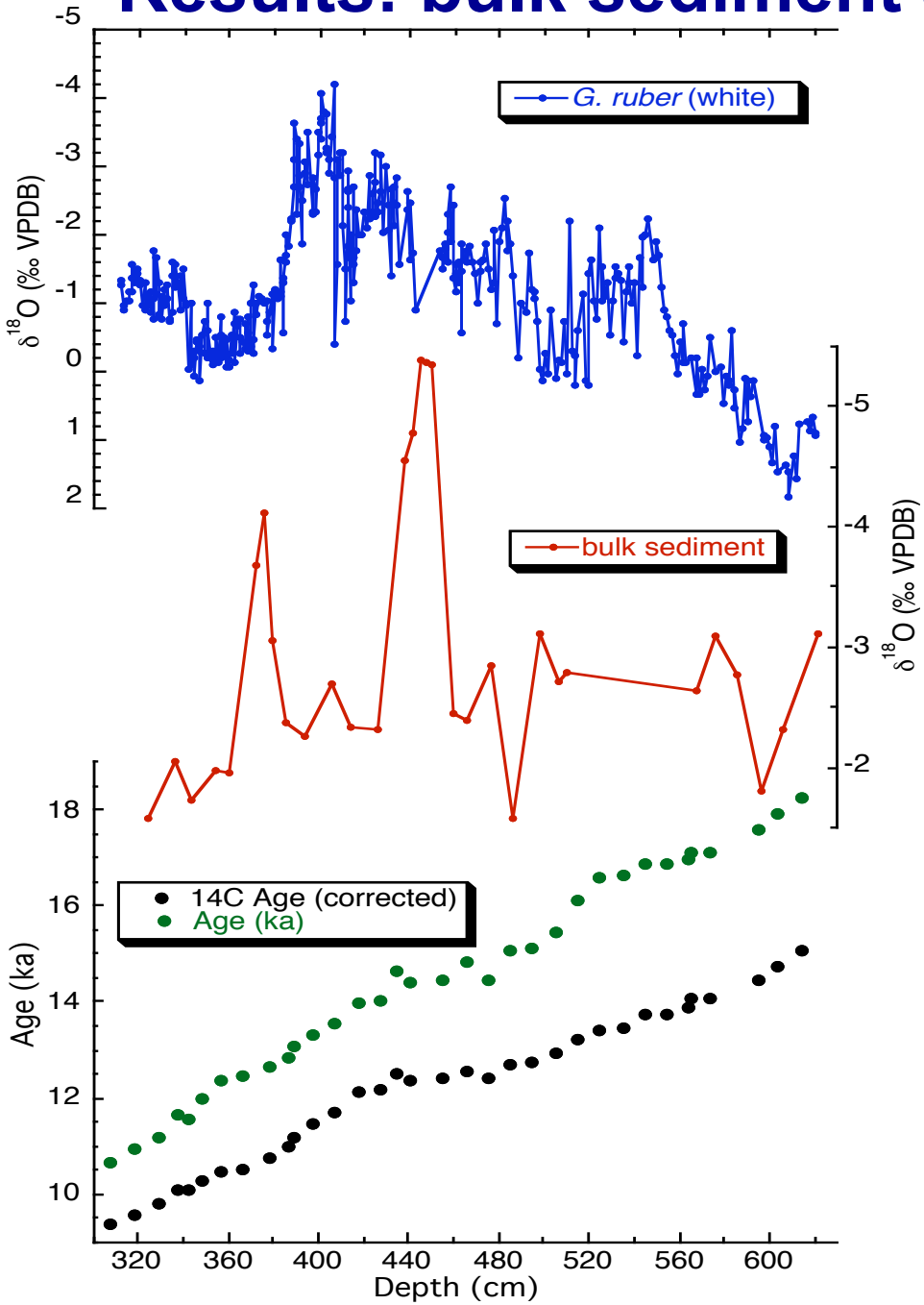
- Foraminiferal $\delta^{18}O$ indicates LIS meltwater from ca. 17.5-13 ka (Williams et al., in review)
- Could data gap due to lack of foraminifera ca. 14.4 ka reflect MWP-1A?
- Hypothesis: MWP-1A brought fine sediment and floodwaters to GOM

Magnitude and timing of meltwater pulse 1a



- 24 m rise in <500 years ca. 14-14.6 ka
- Ice-sheet modeling indicates LIS source but “sea-level fingerprinting” says Antarctica

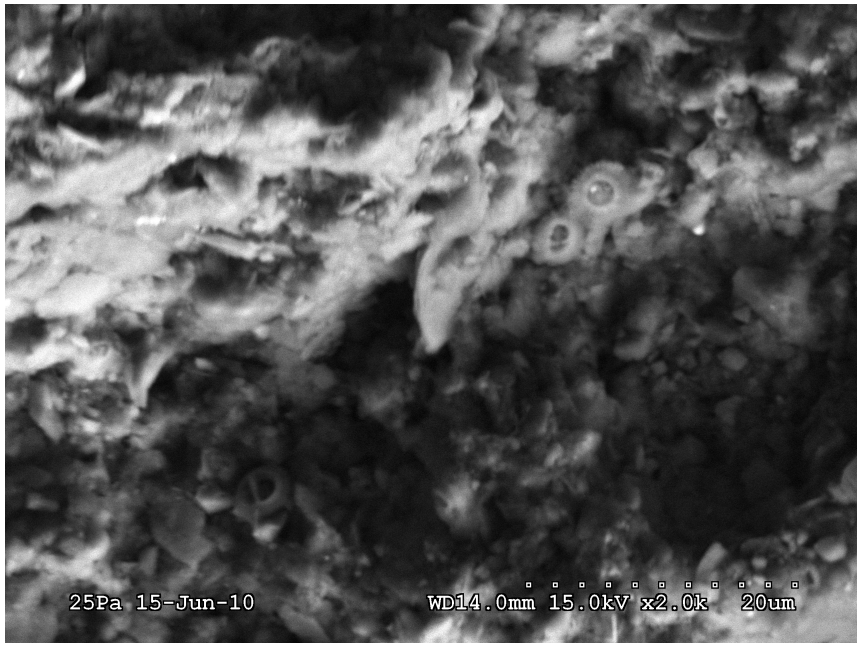
Results: bulk sediment $\delta^{18}O$ from Orca Basin



- Bulk sediment $\delta^{18}O$ reveals two negative excursions to about -4 to -5‰ at 442-453 cm (ca. 14.35-14.54 ka) and 372-380 (ca. 12.57-12.74 ka)

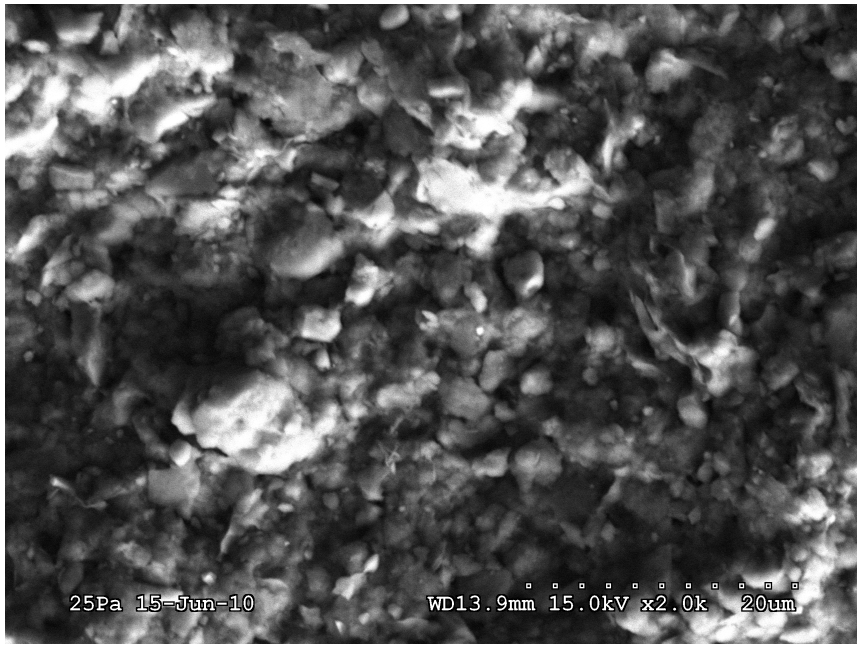
- Fine carbonate sediment from Canadian Paleozoic marine carbonates, analogous to detrital carbonate in the North Atlantic ($\delta^{18}O$ = -5‰; Hodell and Curtis, 2008)

Paleozoic limestones near Montana/Alberta border



Normal sediment SEM

Coccoliths are readily visible in normal sediment (336 cm at 2000X)



Foram-poor interval SEM

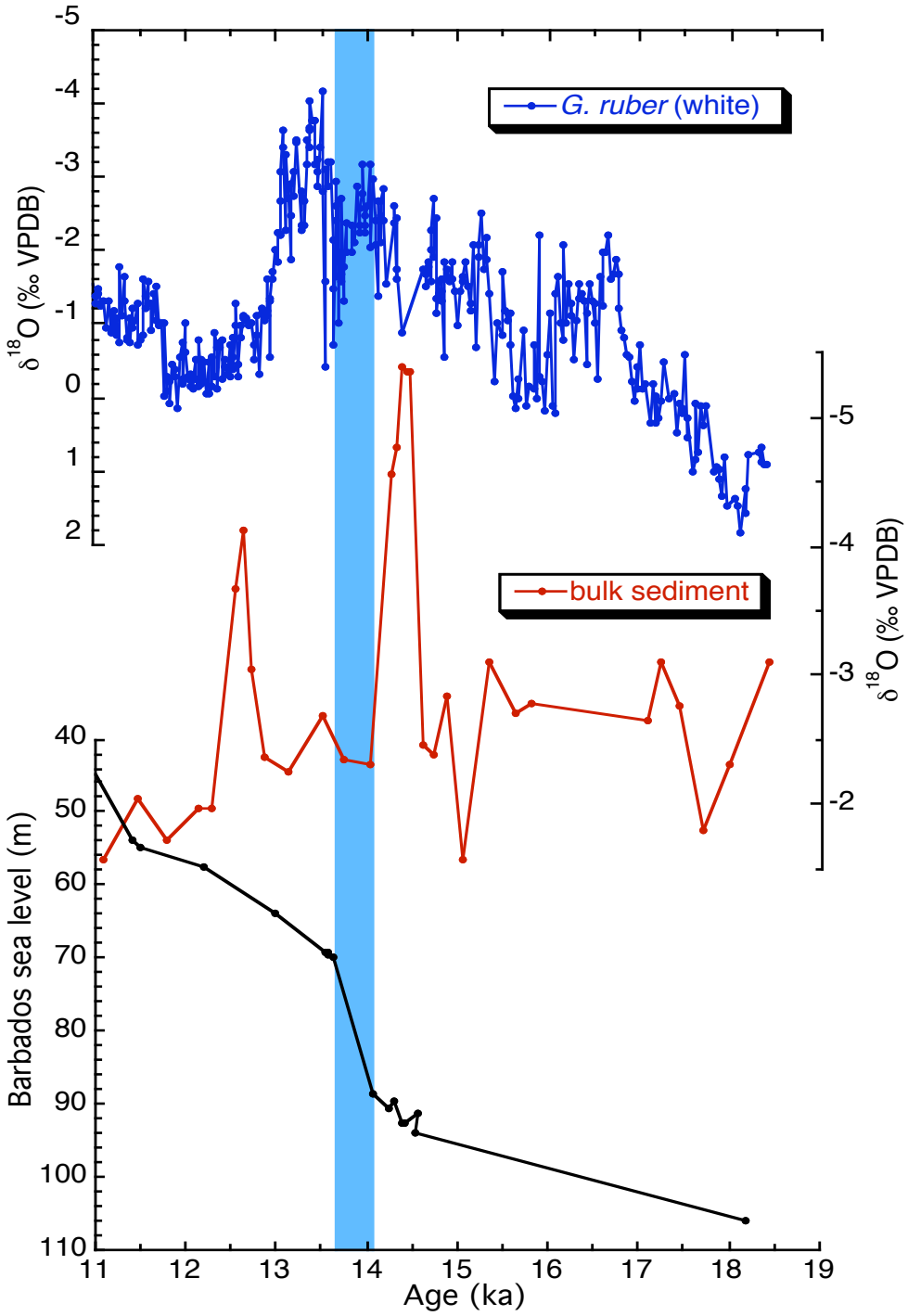
Coccoliths are absent in foram-poor interval (448 cm at 2000X)

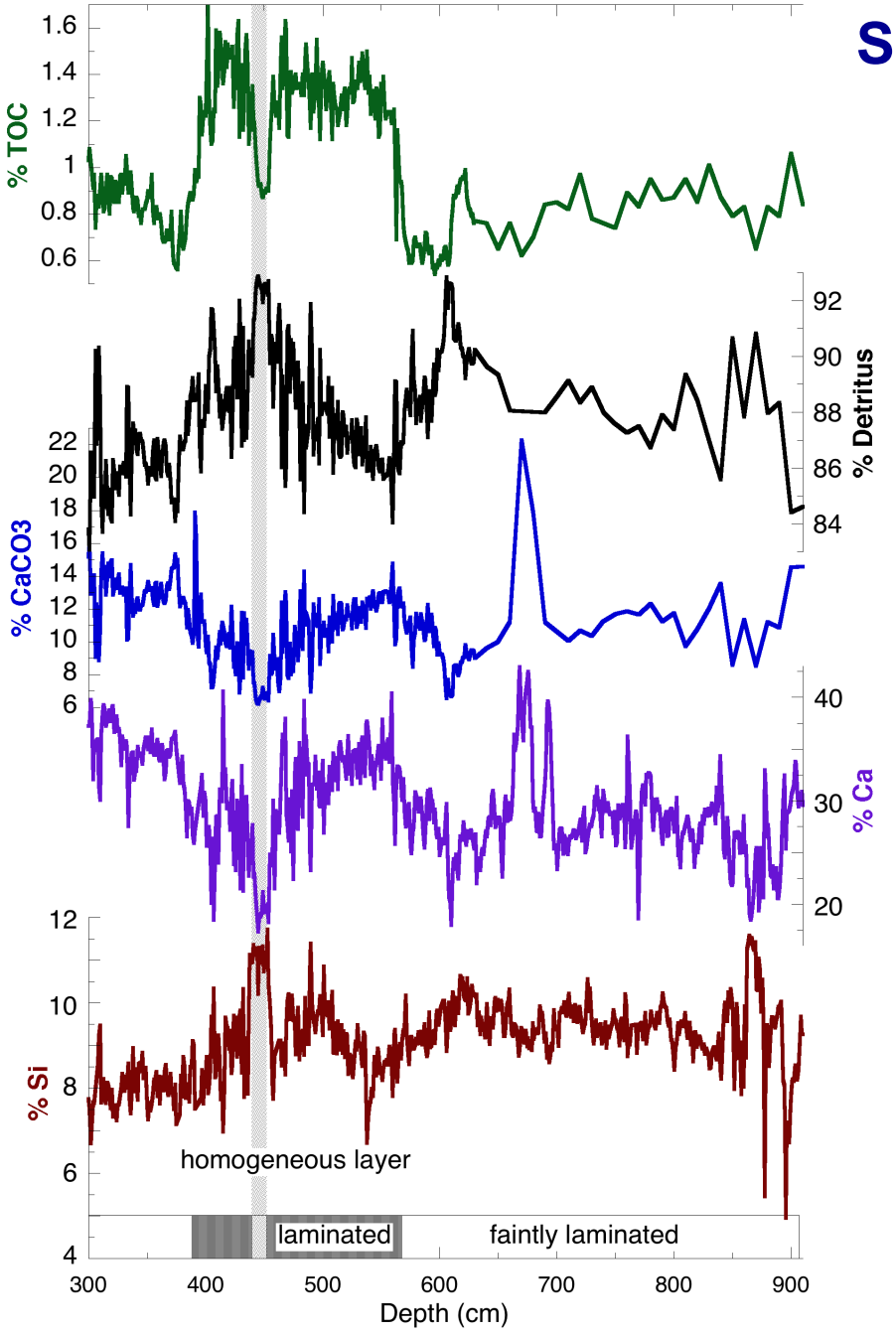
Photo credit: Paul Suprenand, USF

Evidence for MWP-1A?

- First $\delta^{18}O$ excursion from ca. 14.54-14.35 ka seems to precede MWP-1A ca. 13.61-14.17 ka (Stanford et al., 2006)

- However, data from new Barbados drillcores indicate a ~20 m MWP-1A ca. 14.6-13.9 ka (Mortlock et al., 2010)



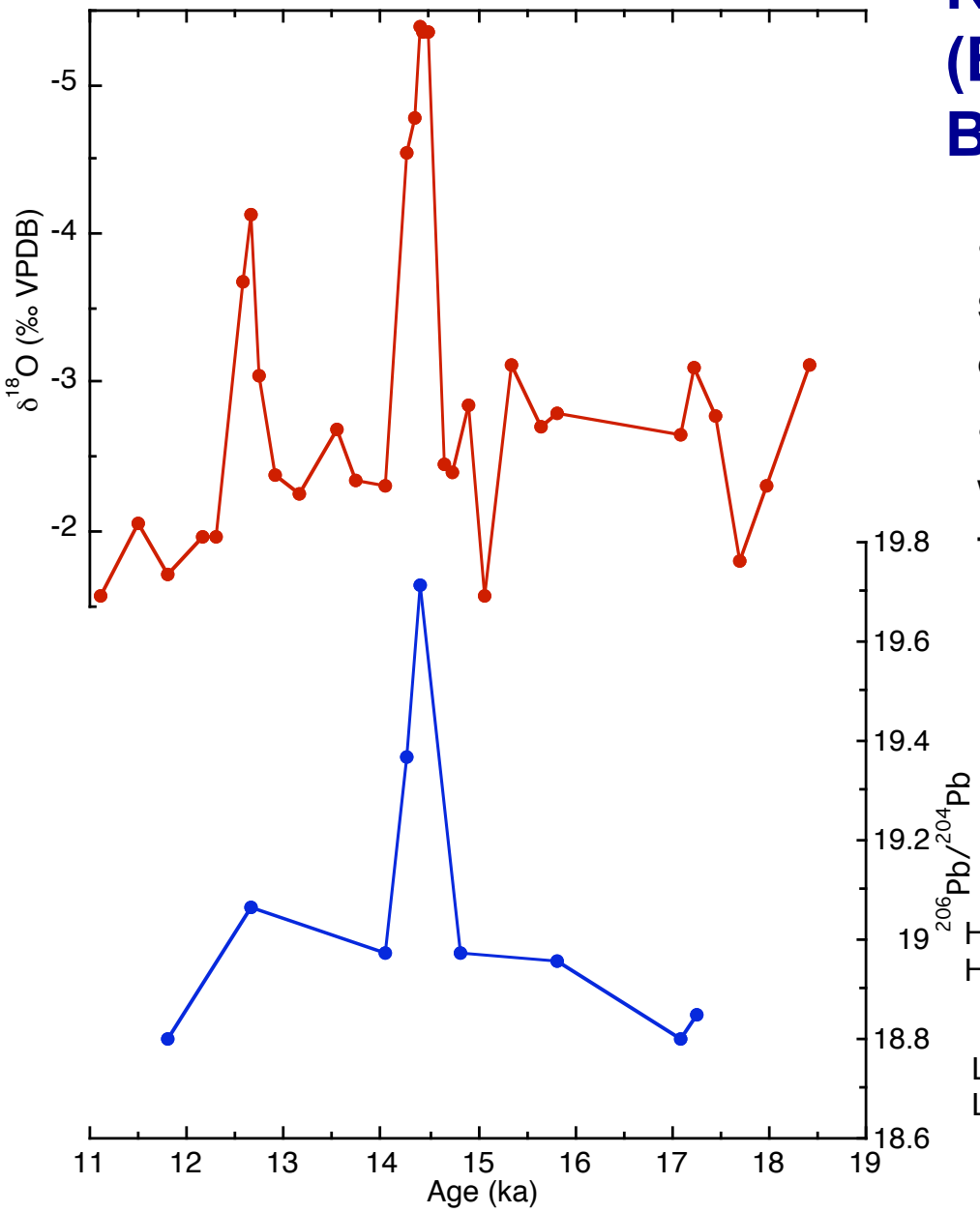


Significant pulse of terrestrial input

- First $\delta^{18}O$ excursion coincides with unique homogeneous layer at 442-453 cm
- Homogeneous layer is marked by distinct minima in %TOC, %$CaCO_3$, and %Ca, (plus $\delta^{13}Corg$; not shown)
- Distinct maxima are seen in %Detritus and %Si (plus %Ti; not shown)
- These spikes are consistent with a significant, brief pulse of terrestrial input, and/or a pause in marine input

(after Meckler et al., 2008, EPSL; plus unpublished XRF scanning data)

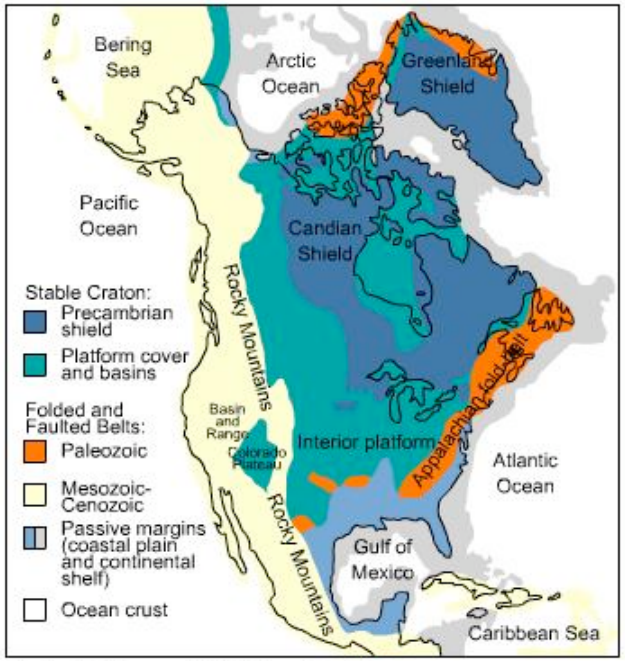
Radiogenic isotope data (E. Martin and N. Biller, UF; Biller et al., 2011, PA23A-1829)



High $^{206}Pb/^{204}Pb$
High $^{87}Sr/^{86}Sr$

Low $^{206}Pb/^{204}Pb$
Low $^{87}Sr/^{86}Sr$

- Peak $^{206}Pb/^{204}Pb$ and $^{87}Sr/^{86}Sr$ (not shown) values coincident with lowest $\delta^{18}O$ (PA23A-1829)
- More radiogenic values are consistent with a spike in older continental material from Canadian sources



Tectonic features of North America. From Press and Siever (1995).

Conclusions

1) Heinrich stadial events appear to coincide with episodic LIS input to the Gulf of Mexico. Association with Antarctic warming and sea level pulses suggest bipolar warming.

2) G. ruber (white) δ^{18}Osw-ivc indicates first major LIS melt just prior to and during the Oldest Dryas ca. 17.5 ka. Timing suggests "early" deglaciation of the LIS relative to the onset of the Bølling.

3) Bulk sediment δ^{18}O, sedimentologic, geochemical, and radiogenic isotope data indicate a significant pulse of terrestrial input 14.54-14.35 ka, including fine carbonate, Mississippi River mud, and Canadian bedrock. Coincidence with MWP-1A would imply an LIS contribution to MWP-1A.