The role of restricted basins in global biogeochemical cycles

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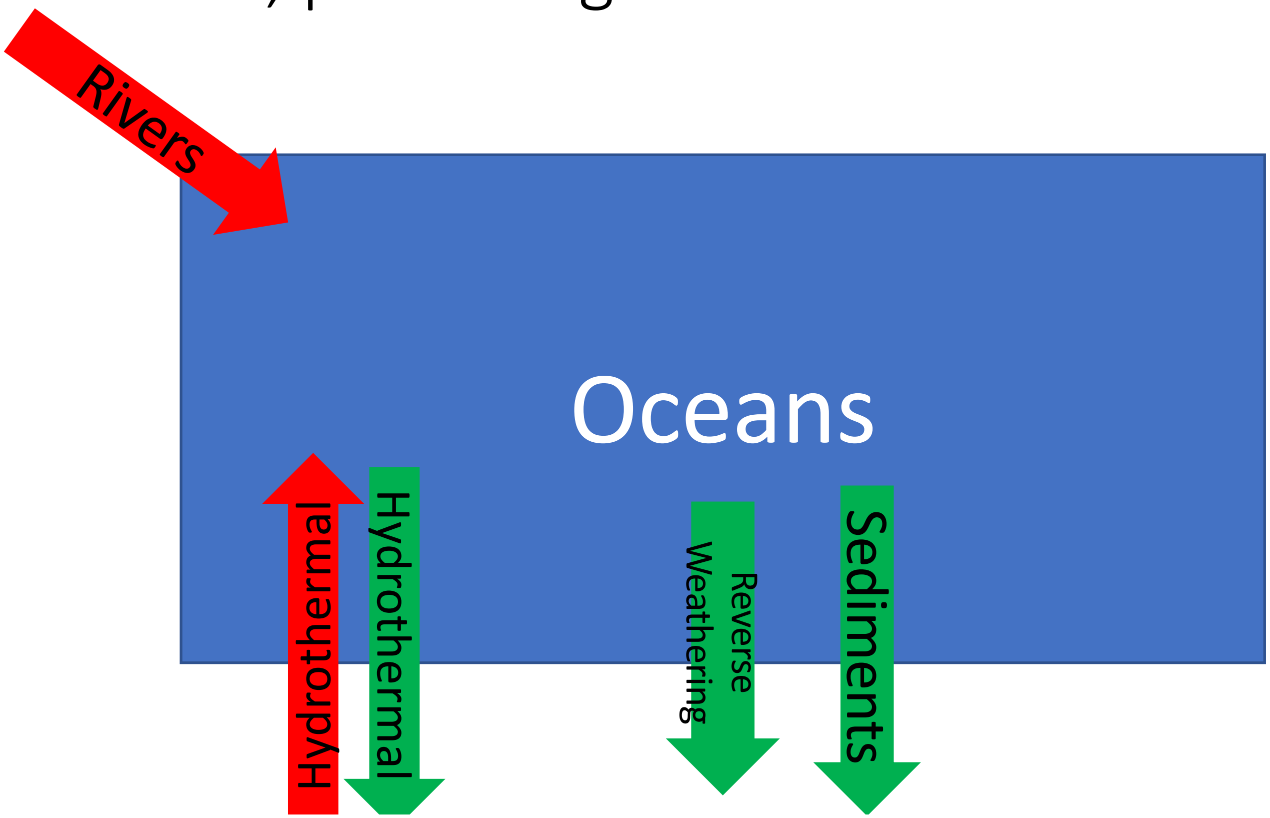
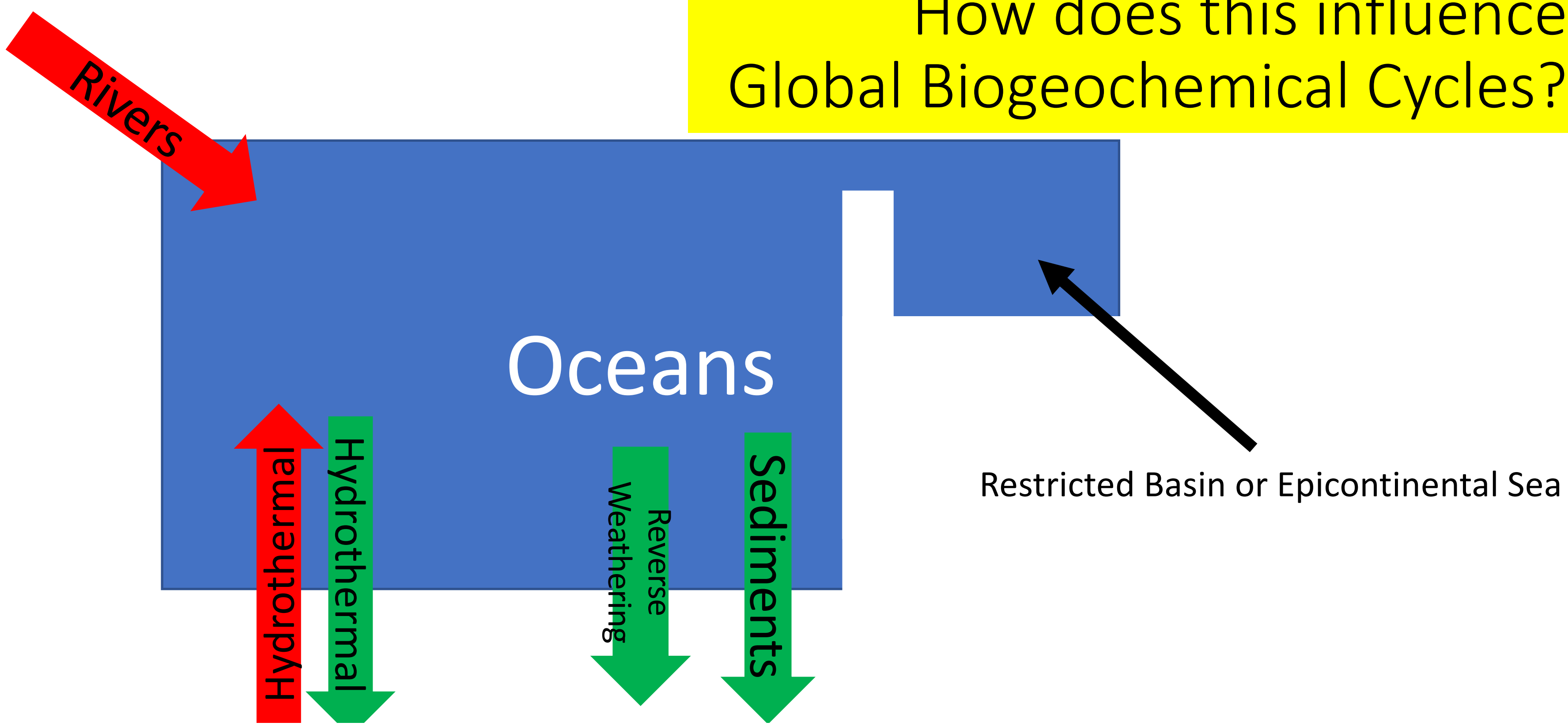
Some things I would have discussed/thought about in my presentation – for discussion in the chat

The traditional view of global biogeochemical cycles are of the oceans – a box – with various sources and sinks to the ocean. These sources and sinks have various rates and concentrations of elements, producing different fluxes to the oceans

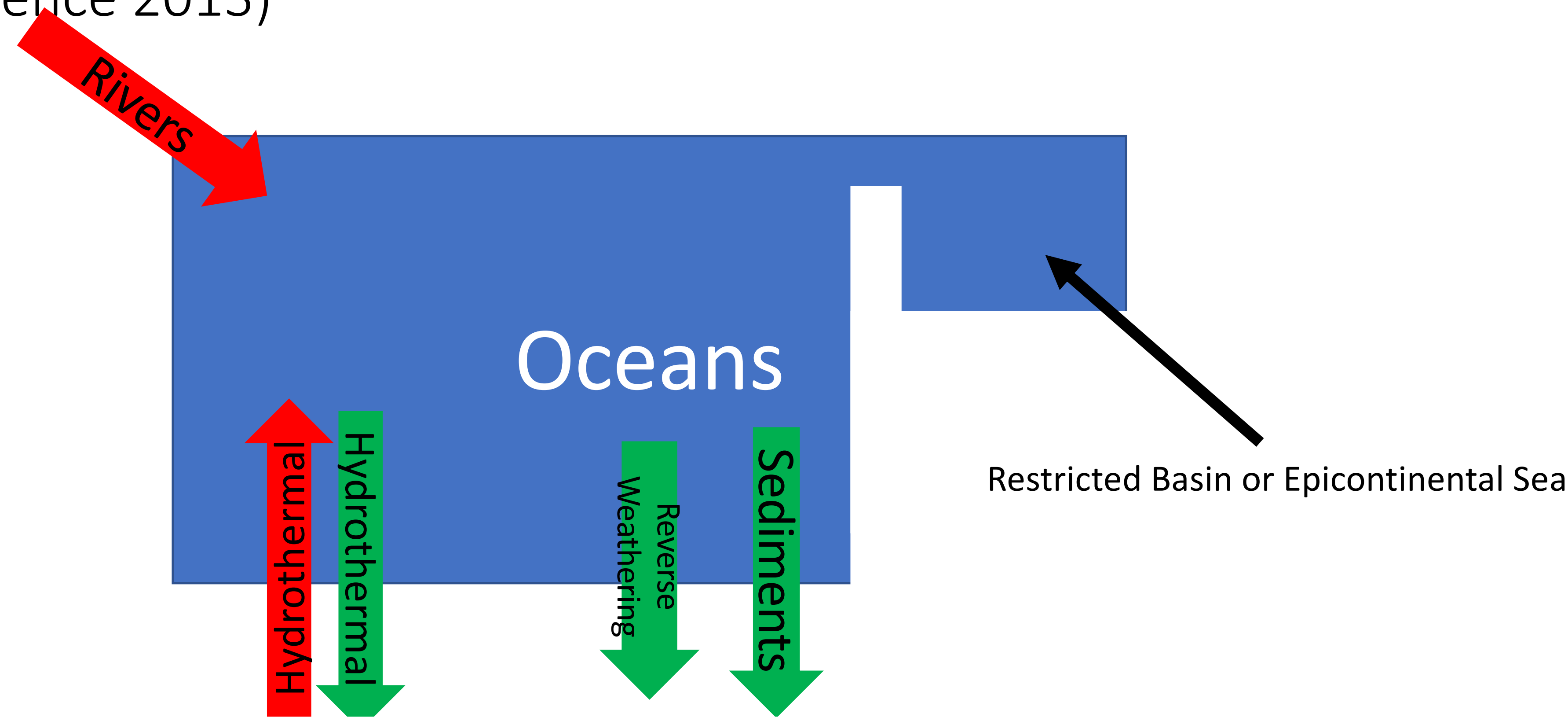


What happens when you have restricted basins (where salt giants form)? What if much of your ocean covers continental landmass in epicontinental seas?

How does this influence Global Biogeochemical Cycles?



Traditionally it was thought that the primary influence was that the deposition of large salt deposits and then their subsequent chemical erosion would change the chemistry of the ocean. The restricted basin would hold excess ions for release on tectonic exposure (e.g. Wortmann et al., Science 2013)



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For example, Higgins and Schrag (2006) suggest that these environments bury much organic carbon which could be rapidly oxidized on exposure and drive perturbations in the carbon cycle

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Earth and Planetary Science Letters 245 (2006) 523–537

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Beyond methane: Towards a theory for the Paleocene–Eocene Thermal Maximum

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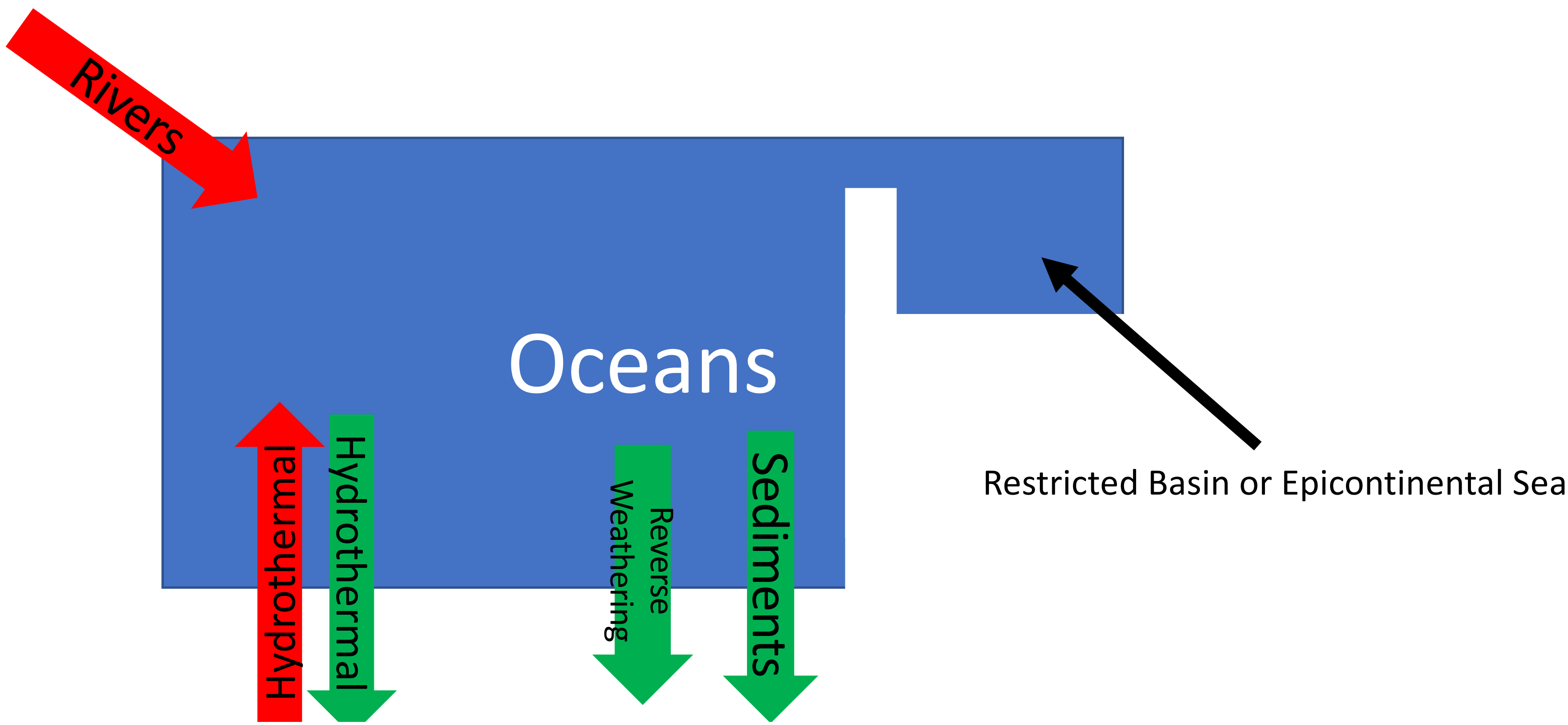
Small changes in sea level can cause a restricted basin or epicontinental sea to become quickly (geologically speaking) isolated from the global ocean.



Two more recent papers suggest that the loss of restricted basins resulted in fundamental changes to the sulfur and nitrogen biogeochemical cycles in the Cenozoic

nature geoscience

ARTICLES

https://doi.org/10.1038/s41561-018-0200-y

Cenozoic record of $\delta^{34}S$ in foraminiferal calcite implies an early Eocene shift to deep-ocean sulfide burial

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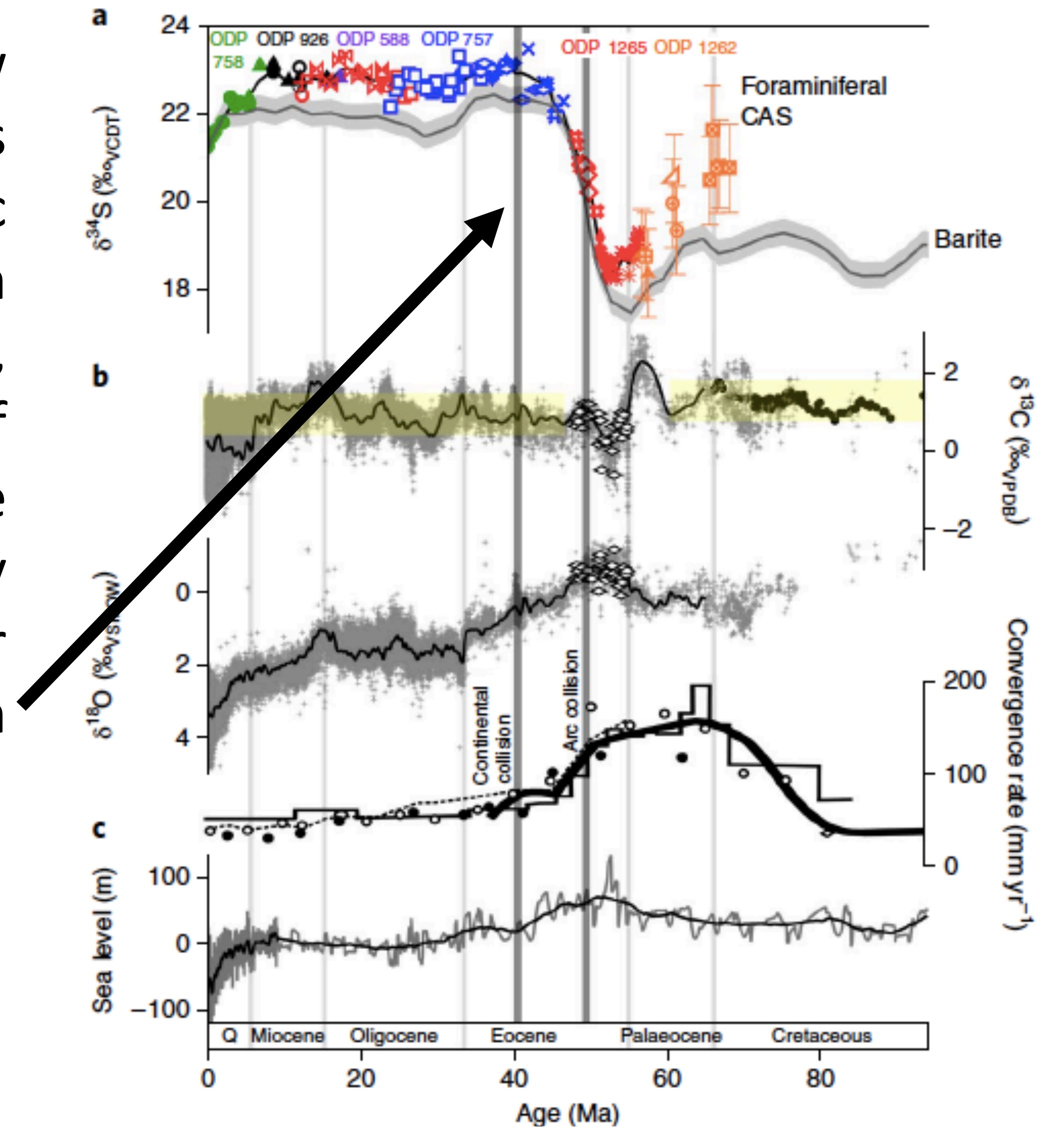
PALEOCEANOGRAPHY

Nitrogen isotope evidence for expanded ocean suboxia in the early Cenozoic

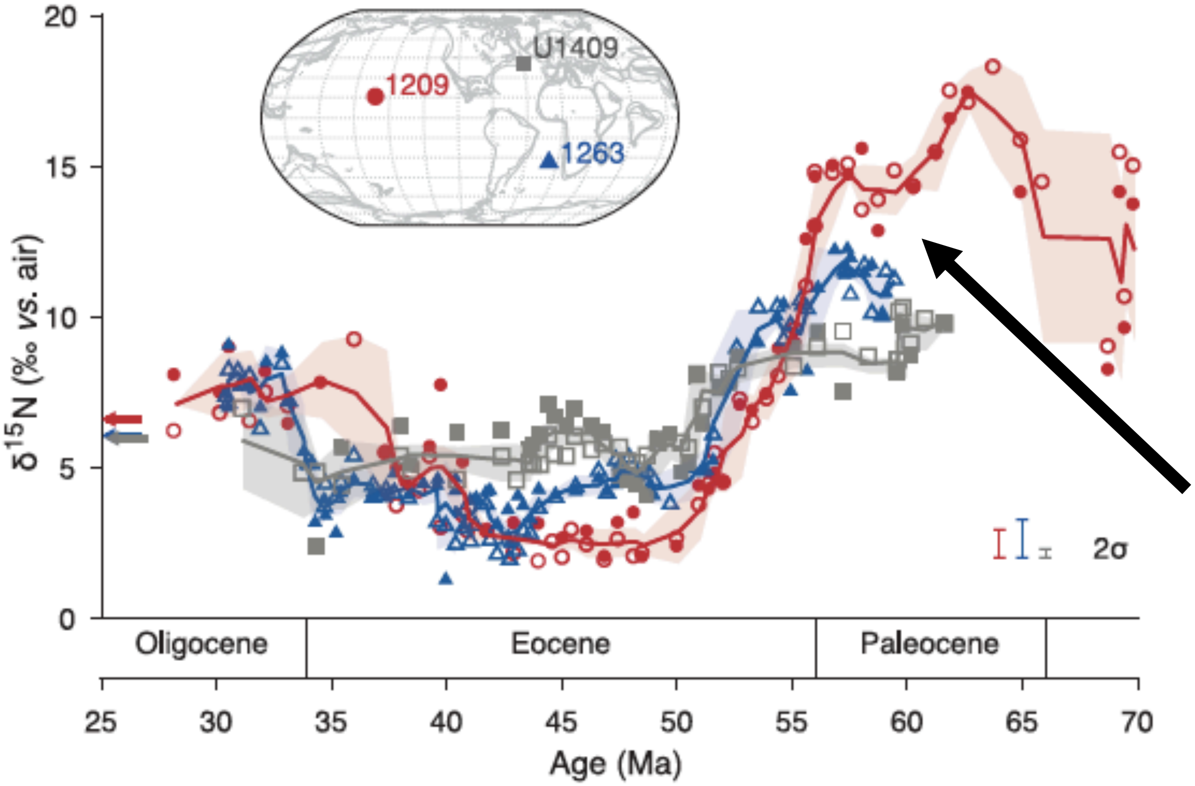
Emma R. Kast[1]*, Daniel A. Stolper[2,3], Alexandra Auderset[4,5], John A. Higgins[1], Haojia Ren[6], Xingchen T. Wang[7], Alfredo Martínez-García[4], Gerald H. Haug[4,5], Daniel M. Sigman[1]

The million-year variability of the marine nitrogen cycle is poorly understood. Before 57 million years (Ma) ago, the $^{15}N/^{14}N$ ratio ($\delta^{15}N$) of foraminifera shell-bound organic matter from three sediment cores was high, indicating expanded water column suboxia and denitrification. Between 57 and 50 Ma ago, $\delta^{15}N$ declined by 13 to 16 per mil in the North Pacific and by 3 to 8 per mil in the Atlantic. The decline preceded global cooling and appears to have coincided with the early stages of the Asia-India collision. Warm, salty intermediate-depth water forming along the Tethys Sea margins may have caused the expanded suboxia, ending with the collision. From 50 to 35 Ma ago, $\delta^{15}N$ was lower than modern values, suggesting widespread sedimentary denitrification on broad continental shelves. $\delta^{15}N$ rose at 35 Ma ago, as ice sheets grew, sea level fell, and continental shelves narrowed.

Pyrite (FeS_2) buried in shallow environments like restricted basins has a higher overall sulfur isotopic composition than pyrite buried in deeper environments (Fike et al., 2015). Sealevel drop closing off restricted basins and forcing pyrite burial into deeper environments may have driven the increase in the sulfur isotope composition of the ocean in the early Cenozoic



Rennie et al., Nature Geoscience, 2018



Nitrogen isotopes in foram-bound organic matter are high when there is water column denitrification and low when there is sediment denitrification. Conditions in restricted basins may have favored anoxic/suboxic water columns and enhanced water column dentrification.

Kast et al., Science 2019

We are currently working on models and acquiring more data and better age models to understand how these various processes might be linked and to explore how there may be coupled changes to biogeochemical cycles associated with the opening and closing of restricted basins.

Open questions: What are the fundamental chemical differences in restricted basins that link global tectonic cycles to changes in seawater chemistry?