Expanded Oxygen Minimum Zones in the Oceans during the Paleocene/Eocene Thermal Maximum indicated by I/Ca in Planktic Foraminifera

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WILL OXYGEN MINIMUM ZONES EXPAND IN A WARMING WORLD? 
LESSONS FROM THE GEOLOGICAL PAST.
WHAT PROXIES CAN WE USE TO RECONSTRUCT PALEOXYGENATION?

A LARGE VOLUME OF LOW OXYGEN WATERS IN OXYGEN MINIMUM ZONES (OMZ) IS NOT IN CONTACT WITH THE SEA FLOOR: proxy based on calcite shells of planktic foraminifera

CROSS SECTION NE PACIFIC SUBARCTIC OMZ; Wright et al., 2012, Nature Reviews in Microbiol.
Paleocene-Eocene planktic foraminifera:

Genera *Morozovella, Acarinina*: have photosymbionts, calcify in surface mixed layer (M)

Genus *Subbotina*: calcifies in deeper, thermocline waters (D)

*John et al., 2013, Phil. Trans. Roy. Soc. A.*
THE I/Ca PROXY (I/Ca in calcite):

- Iodine speciation in the modern oceans: **iodide (I⁻)** vs. **iodate (IO₃⁻)**
- **Total iodine** (iodate + iodide) ~ 0.45 µM.
- Residence time ~ 300 kyrs.
- Iodate is **micronutrient**: primary productivity -> iodate loss
- **Iodate**, not iodide is built into calcite
- **I/Ca reflects oxygenation**: high at high iodate (higher oxygen levels)
No information on I/Ca in foraminifera culture experiments.
Iodate and Oxygen Minimum Zones

VERTEX, eastern tropical North Pacific

Rue et al., 1997
Primary productivity and $O_2$ control iodate concentration in seawater -> I/Ca in planktic foraminiferal calcite.

$D$ = I/Ca in deep thermocline calcifiers (*Subbotina*); $M$ = I/Ca in mixed-layer calcifiers (*Acarinina*, *Morozovella*)

**NO OMZ:** iodate increases downward from mixed layer, $D>M$

**OMZ:** at shallow levels: $D<M$

**OMZ:** at deep levels, $D>M$
Can we observe a link between productivity and I/Ca in foraminifera in the Paleocene?
(in warmer oceans than today, before PETM warming)

Average I/Ca in mixed-layer planktics (*Acarinina*, *Morozovella*) compared to modeled export productivity (Winguth *et al.*, 2012, *Geology*), and microfossil evidence for productivity levels.
**PETM RECORDS:**

I/Ca values decreased overall, minimum values around PETM, indicated by grey curve (Carbon Isotope Excursion).

Likely due to **deoxygenation** *(increased stratification, increased remineralization organic matter)*: no evidence for widespread increased productivity.
Sites **865 (Pacific), 690 (Weddell)**: + D-M values -> no or deep OMZ.
Site **738 (Indian)**: D-M values declining, deep OMZ is shoaling.
Sites **1262-1263 (Walvis Ridge)**: - D-M values, lower at shallower site. OMZ over Site 1263 throughout, intensified deoxygenation.
Positive correlation: average D-M value and modeled minimum oxygen levels in the water column.
CONCLUSIONS

✧ I/Ca in foraminiferal tests is a promising proxy for oxygen levels throughout the water column, more testing and calibration is necessary (e.g., effects of temperature, carbonate saturation state, vital effects).

Preliminary benthic data, Site 1263, Walvis Ridge: infaunal (*O. umbonatus*, right) MUCH lower I/Ca than epifaunal (*N. truempyi*, left), as expected. Large variability during PETM.
SPECULATIVE CONCLUSIONS

• Widespread expansion of OMZs might have influenced PETM pelagic ecosystems during past global warming (PETM), as predicted for the future.

• Compression of the zone above the OMZ may have been a (partial) cause of changes in planktic foraminiferal assemblages during hyperthermal events, commonly attributed to changes in ocean stratification.

• Enrichment in fish debris above the base of the CIE at Pacific Ocean sites might reflect a mortality event due to expansion of the OMZ.
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Zhou et al., 2014: I/Ca evidence for upper ocean deoxygenation during the PETM; Paleoceanography, doi: 10.1002/2014PA002702