Dinoflagellates as Signal Carriers

Single Species Dinoflagellate Cyst
Carbon Isotope Ecology across the PETM

Appy Sluijs, Mirja Hoins, Dedmer van de Waal, Bjorn Rost, Joost Frielings, Linda van Roij, Jelmer Laks, Gert-Jan Reichart

Dinoflagellates

- Single-celled plankton
- Symbionts forams and corals
- Harmful Blooms
- Heterotrophs, mixotrophs, autotrophs
- Occur in wide salinity range
- Particularly useful on continental margins
- Geological record:
  - Biomarkers (dinosterol)
  - Resting Cysts: used for ecological reconstructions

Culture Experiments

- Good response of several $\%$ over studied range
- Values and response are species-specific
- Physiological control from MIMS experiments

Hoins et al. 2015. GCA

Physiological Underpinning

$^{13}$C fractionation $\varepsilon_p = a \times \varepsilon_s + L \times \varepsilon_{rubisco}$ (Sharkey & Berry, 1985)

- CO$_2$ / HCO$_3^-$ uptake
  - active HCO$_3^-$ uptake
  - costs energy
  - likely to reduce with higher CO$_2$
  - CO$_2$ ~9$\%$ depleted rel. to HCO$_3^-$

- Leakage
  - in- and outflow of carbon through the cell
  - if low: $^{13}$C depleted in the cell so more $^{13}$C fixation
  - if high: $^{12}$C efficiently replenished, increased fractionation

Dominant processes are species specific

Hoins et al. 2016. JEMBE
Dinoflagellate life cycle and Dinocysts

- Response species specific: biomarker (dinosterol) is not applicable
- Cells versus fossilizable cysts

Analytical Challenges

Dinoflagellate Cysts

- Size: 15 to 150 μm
- Mass: ~10-100 ng
- Typical TC-IRMS: >8 μg of C required
- so hundreds of specimens

Laser Ablation-nano Comb-Gas Chromat-IRMS

Van Roij et al. 2017. RCMS

LA/nC/GC/IRMS Measurements

PE standard

Eucalyptus

Zea mays

Van Roij et al. 2017. RCMS
Van Roij et al. 2017. RCMS

Dinoflagellates as Signal Carriers

LA/nC/GC/IRMS Measurements

Van Roij et al. 2017. RCMS

Dinoflagellates as Signal Carriers

LA/nC/GC/IRMS Analytical Constraints

Van Roij et al. 2017. RCMS

Sluijs et al. 2007; Nature

Paleocene-Eocene thermal maximum, 56 Ma
Warming, Carbon Isotope Excursion and Dinocyst response

Sluijs et al. 2007 Nature
Dinocyst assemblages

Apecto

Inshore

Offshore

Harmful

Bloomer?

Figure S2.

Results of individual analyses (histograms), Shapiro-Wilk tests (Q-Q plots) and sample-size dependency ($\delta^{13}C$ vs Area) for all species (horizontal) and samples (vertical). Error bars below histograms are standard errors of the means of individual dinocyst $\delta^{13}C$ analyses and the PE standard.

Species-specific carbon isotope ratios

• CIE Reproduced in various species
• Offsets between species indicate ecological or biosynthetic differences
• season/intensity of production
• carbon acquisition physiology (leakage and $\text{HCO}_3^- / \text{CO}_2$)
• Indicates preservation of carbon cycle information in dinocysts

Figure DR3.

Absolute abundances of the studied dinocyst species per gram of dry sediment at Bass River.

Dinocyst $\delta^{13}C$

Bass River, NJ

• CIE Reproduced in various species
• Offsets between species indicate ecological or biosynthetic differences
• season/intensity of production
• carbon acquisition physiology (leakage and $\text{HCO}_3^- / \text{CO}_2$)
• Indicates preservation of carbon cycle information in dinocysts

Figure 13

Sluijs & Brinkhuis, 2009

Sluijs et al. in press
Conclusions

• Different response to $pCO_2$
• First ever species-specific fossil dinocyst $\delta^{13}C$ records
• Pronounced and consistent differences between species reflect different habitats or life cycle processes
• Decreased inter-specimen variability of Areoligera during the PETM suggests a more limited niche, either in time (seasonal) or space.

• Opens a new approach for ecological and evolutionary reconstructions based on organic microfossils: dinocysts, pollen, water flea resting egg shells (not kidding), your favorite organic microfossil

Acknowledgements

European Research Council
International Ocean Discovery Program
Netherlands Organization for Scientific Research
Netherlands Earth System Science Centre