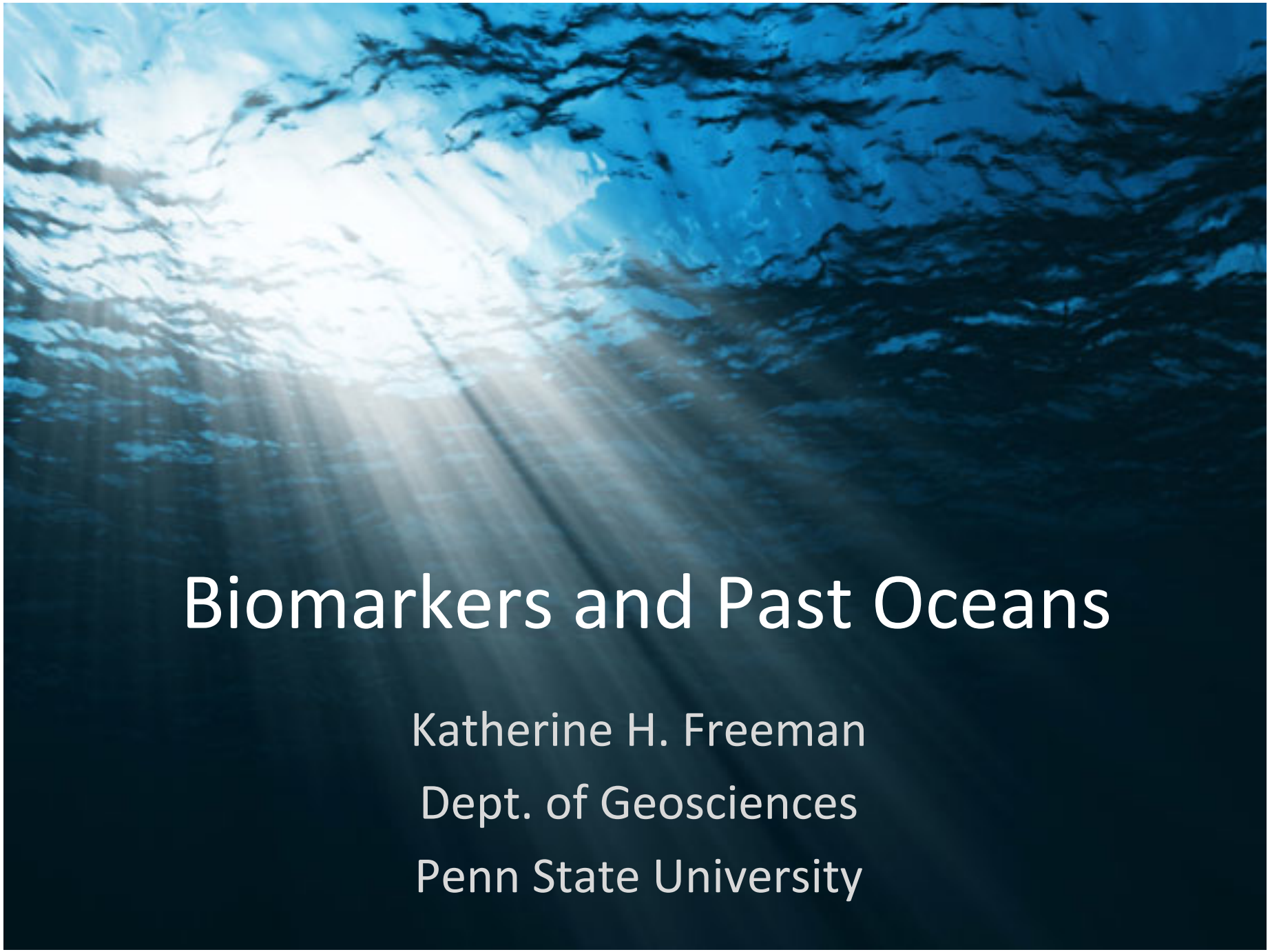
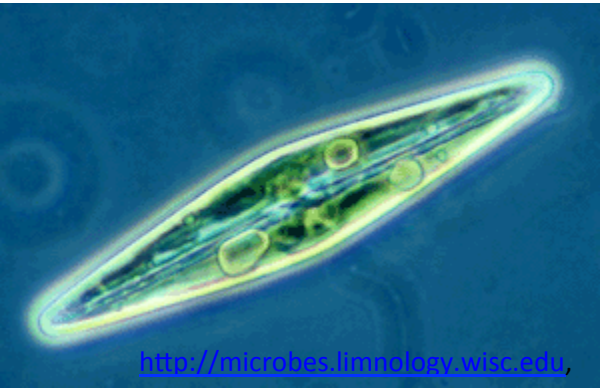


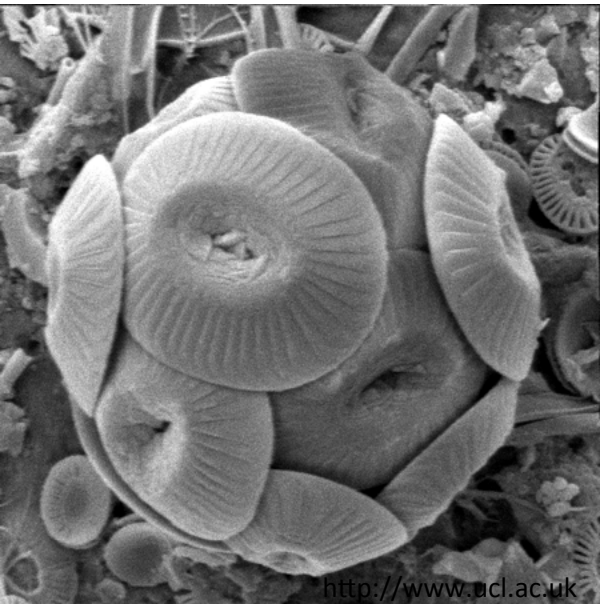
Biomarkers and Past Oceans

Katherine H. Freeman

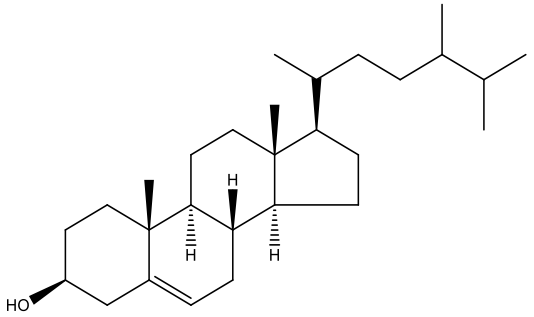
Dept. of Geosciences

Penn State University

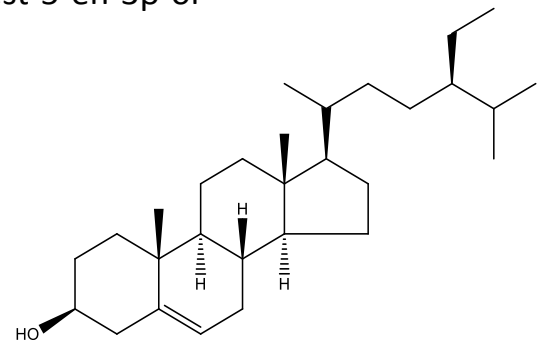




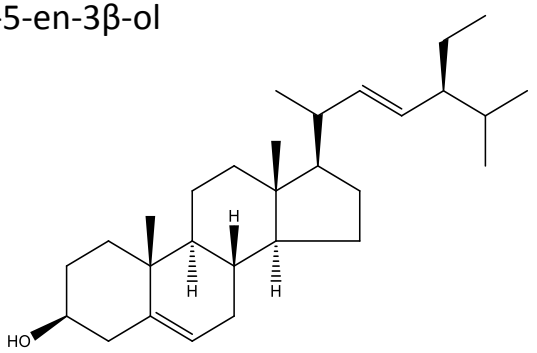
Phytosteroids



Campesterol
24β-methylcholest-5-en-3β-ol

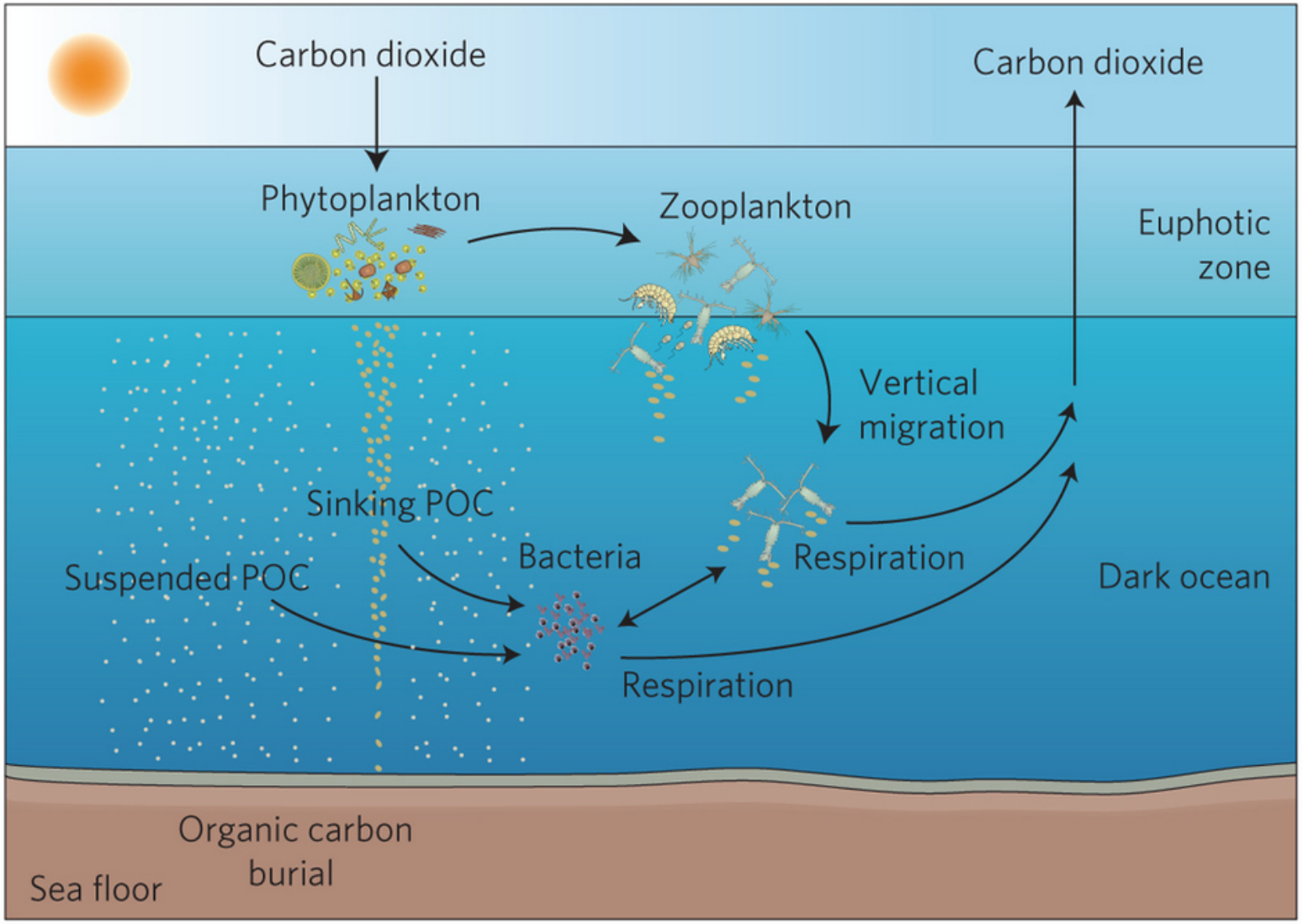


β-sitosterol
24β-ethylcholest-5-en-3β-ol



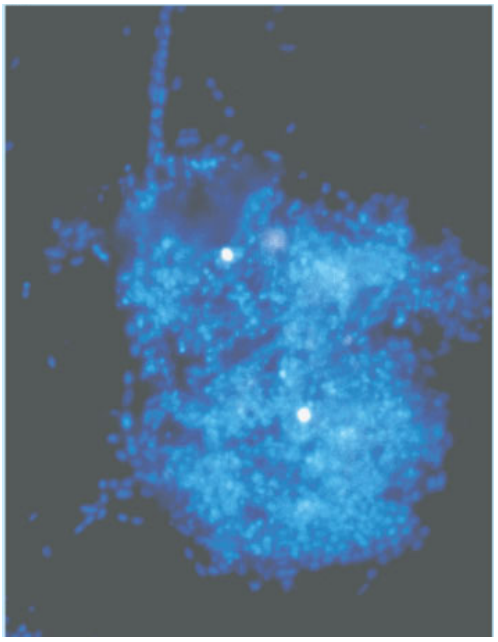
Stigmasterol
24β-ethylcholest-5,22*E*-dien-3β-ol

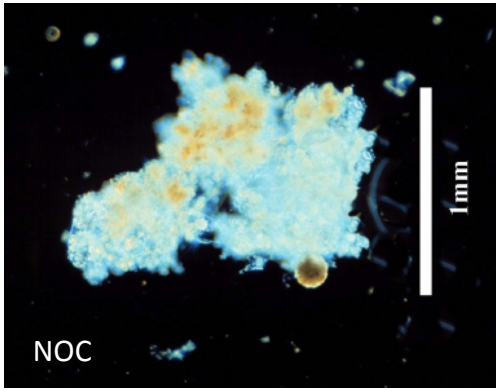
Marine carbon is produced by algae and cycled by grazers and microbes



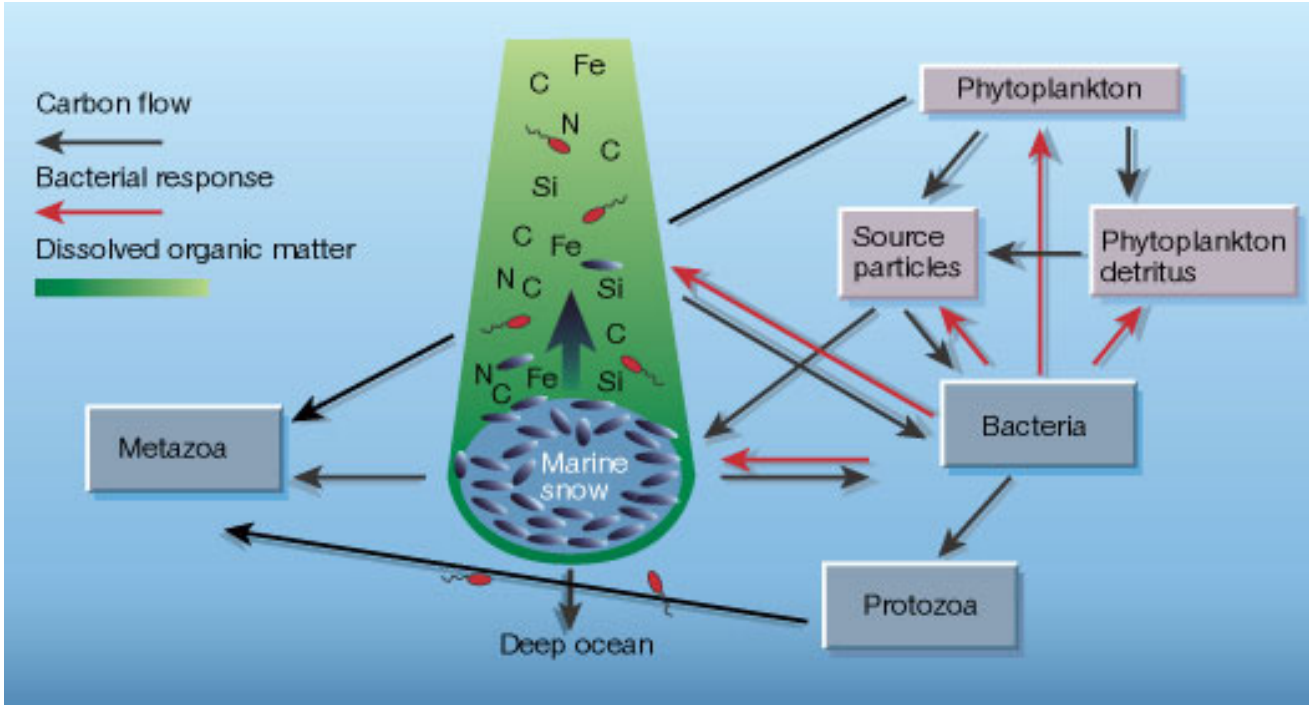
Herndl and Reinthaler, 2013

Suspended marine organic matter creates its own microbial party





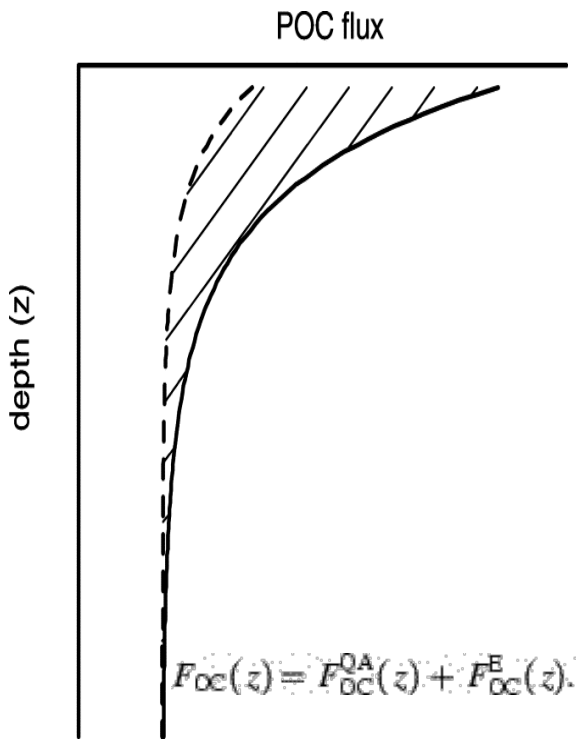
#planktonpoo

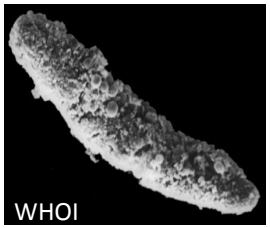


Alldredge et al., 1993
Kiørboe, T. & Jackson, 2001; Azam and Long, 2001
Hmelo, Mincer and Van Mooy, 2011

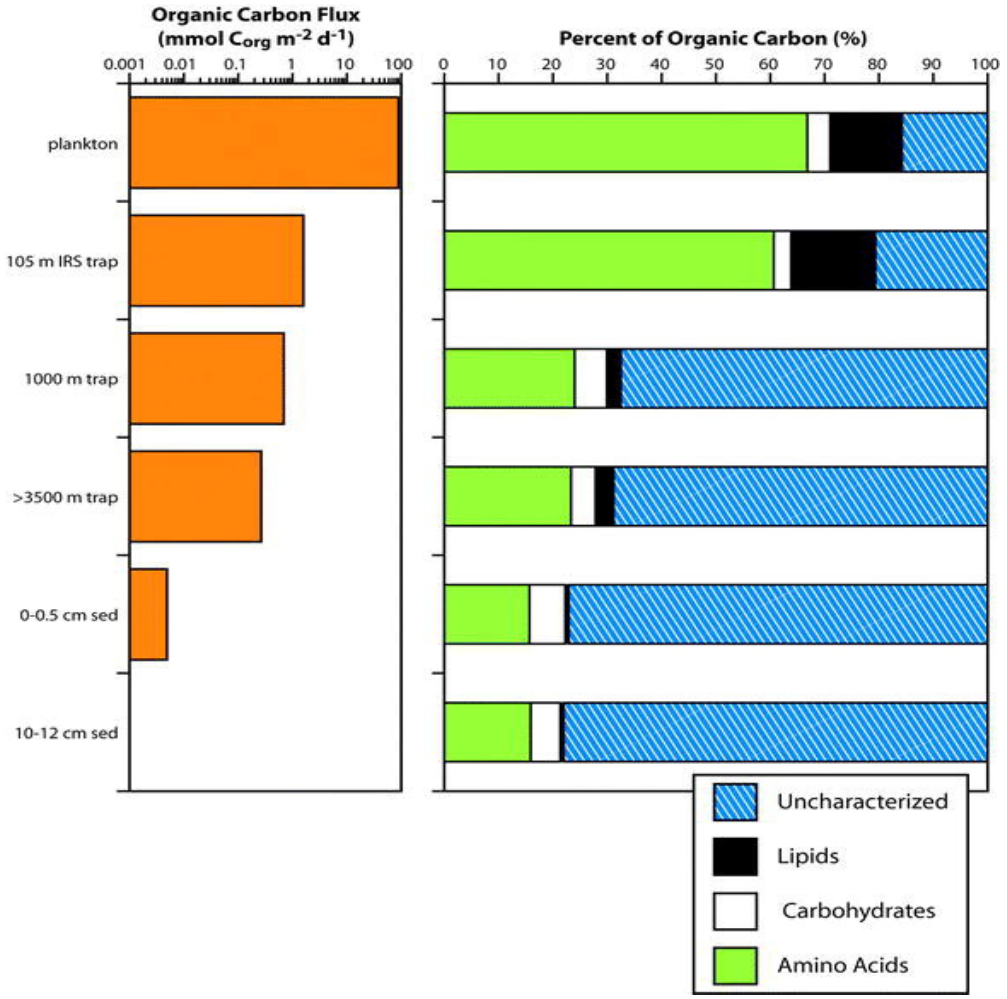
Sinking Organic Matter

protected and ballasted by minerals, yet most is lost and what's left is increasingly unanalyzable

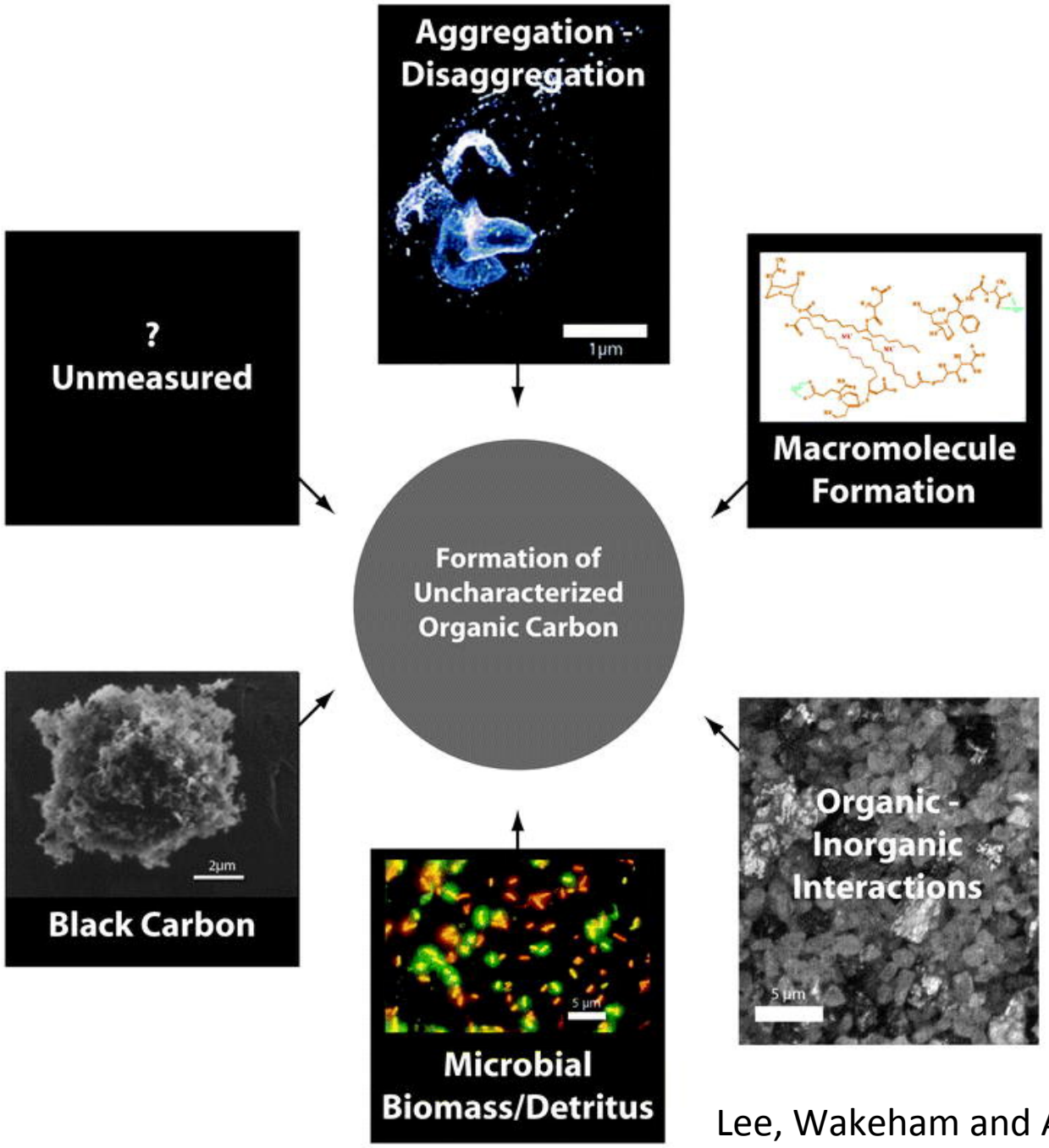




Armstrong et al., 2001

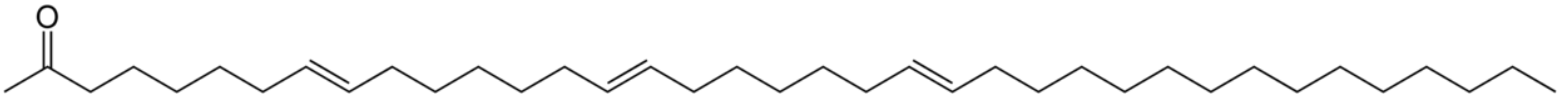


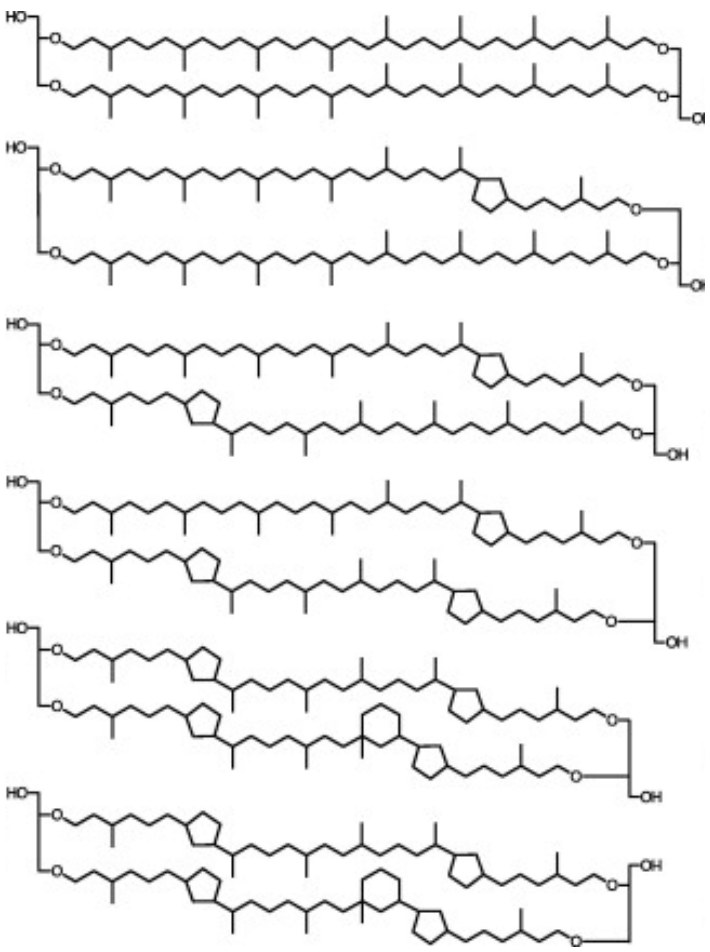
Lee, Wakeham and Arnosti, 2004

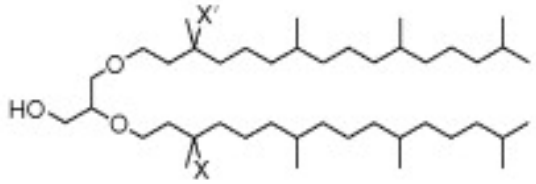


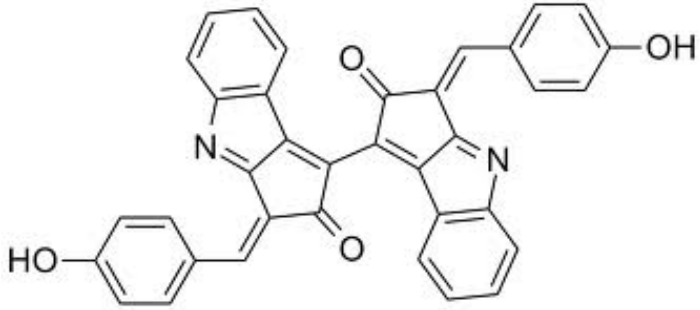
Lee, Wakeham and Arnosti, 2004

Molecular trash: not reactive or rapidly transported



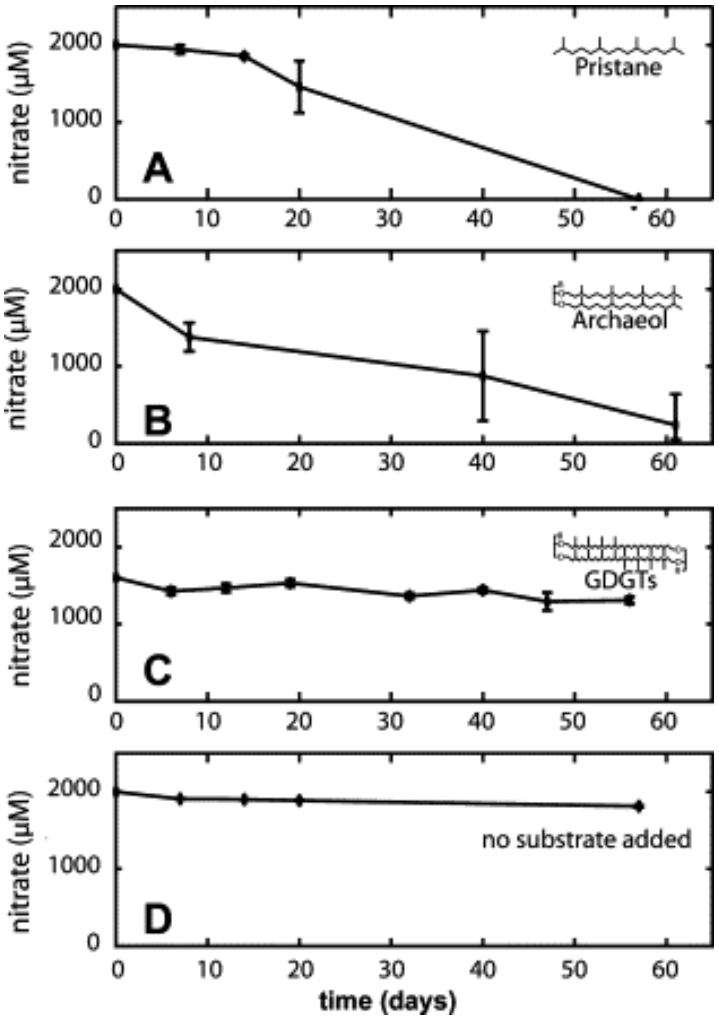






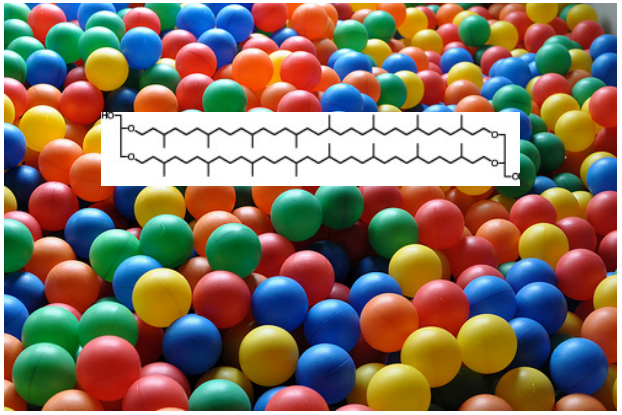
Who eats the trash?

Why aren't we up to our elbows in it?

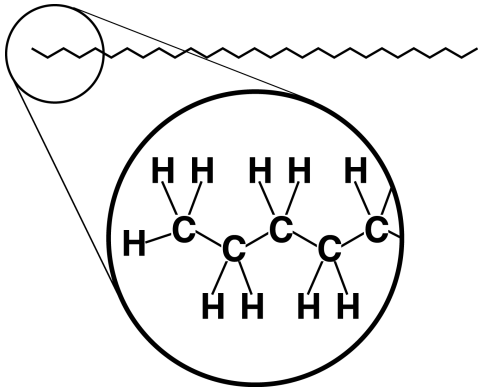


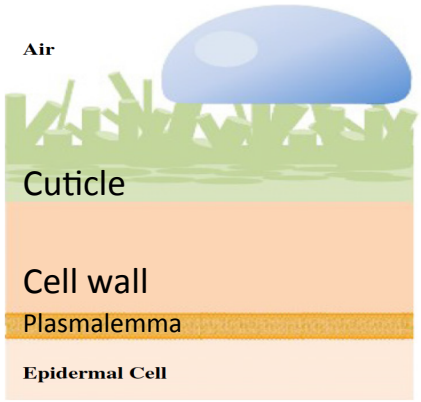
Dawson et al., 2013

Gammaproteobacteria related to *Pseudomonas stutzeri*

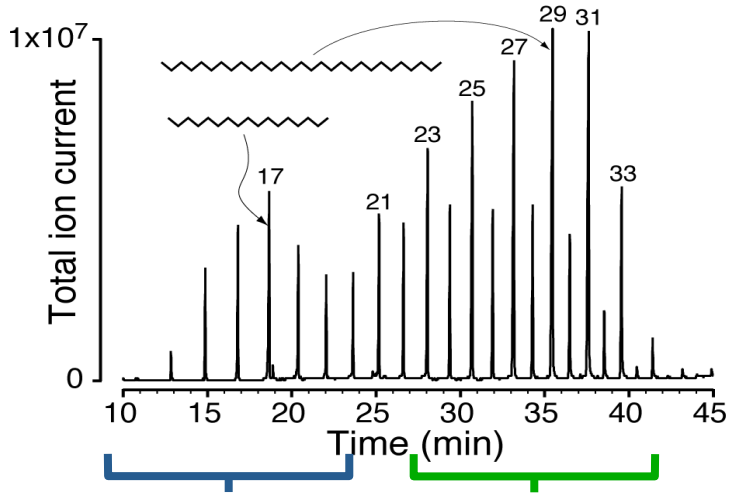


Sometimes molecular trash is imported





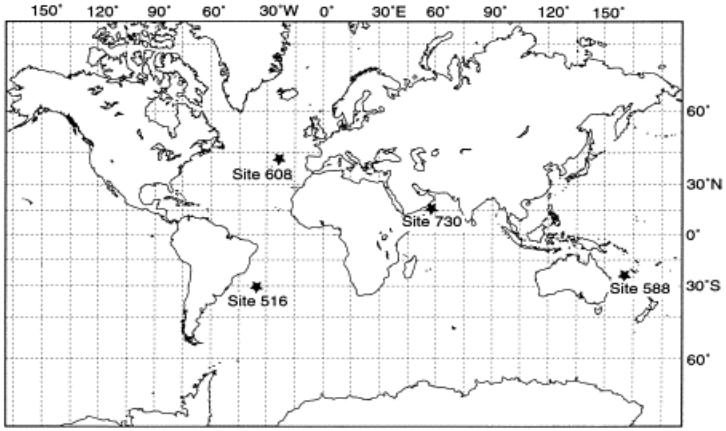
Bernard and Joubès, 2012

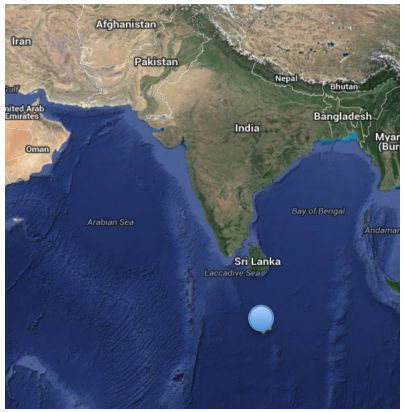


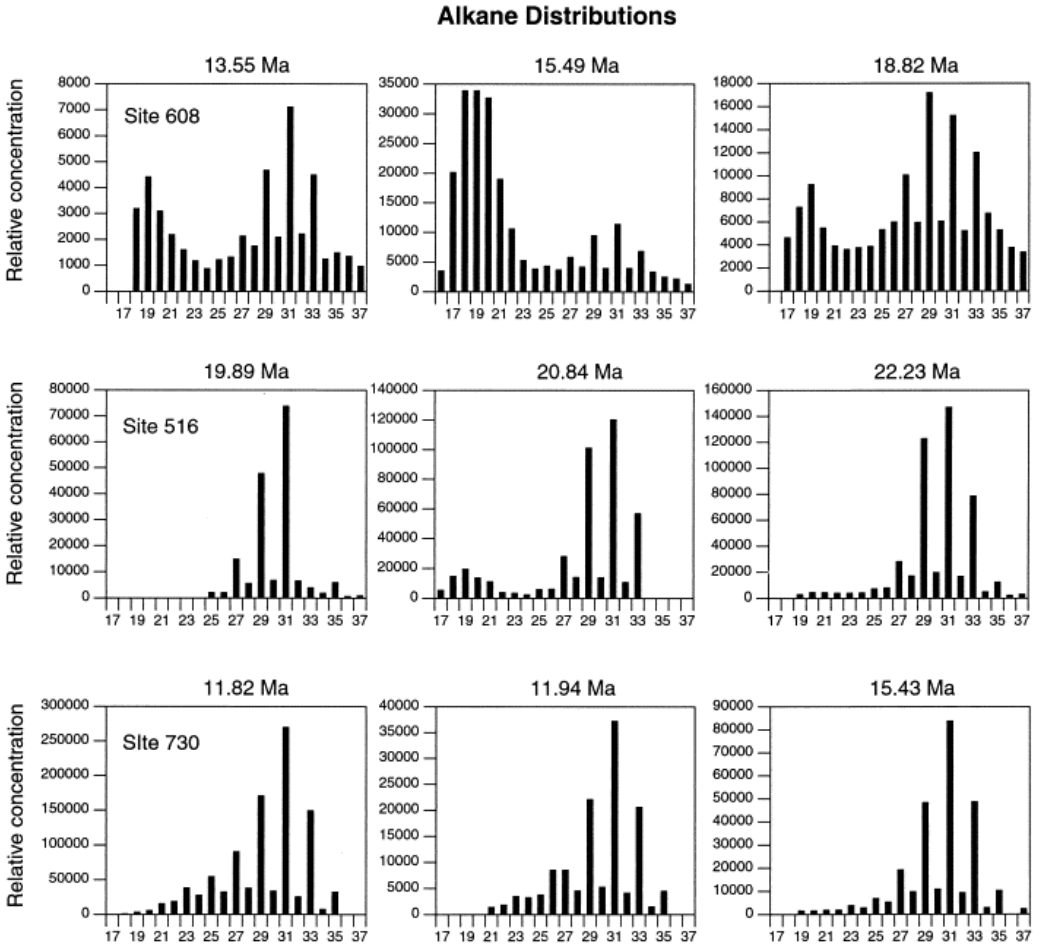
algae & bacteria

plant leaf wax

Imported molecular trash:
Leaf waxes are in marine sediments… everywhere





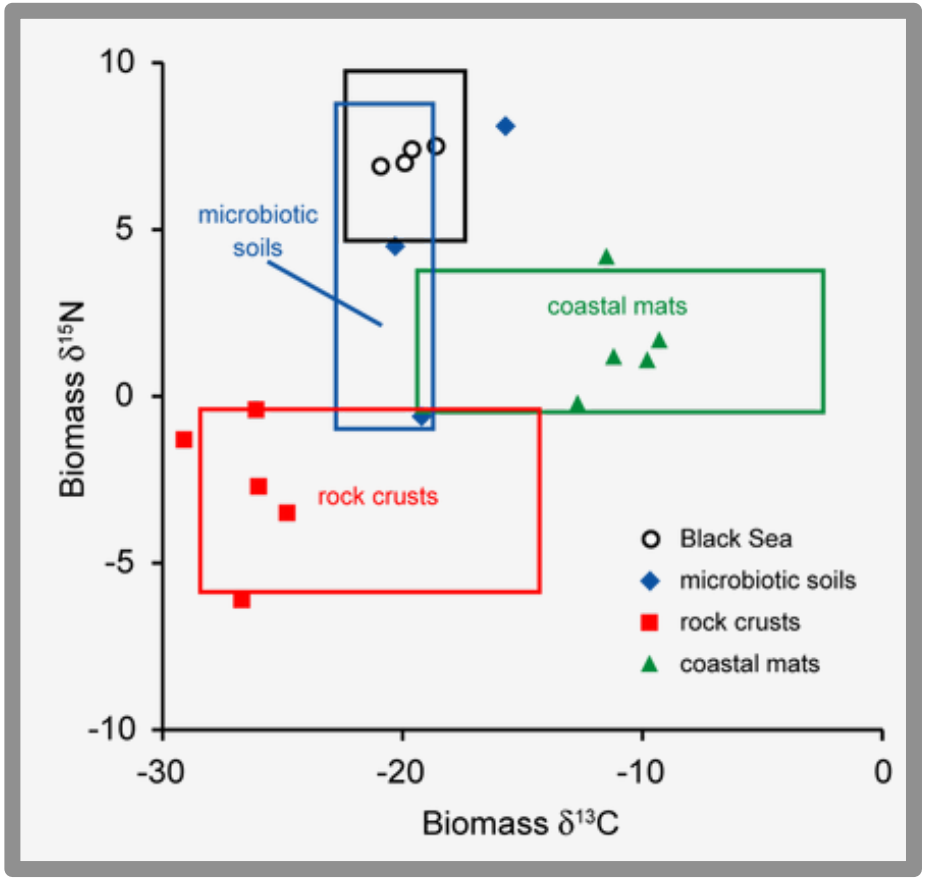


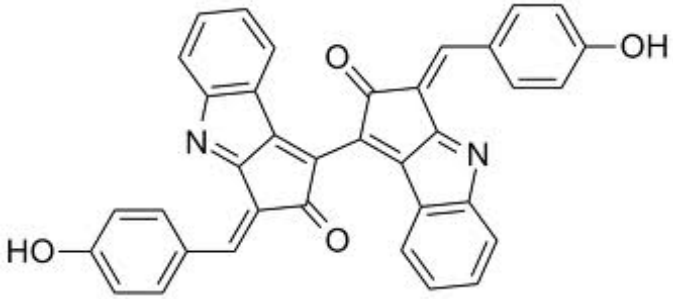
Freeman and Colarusso, 2001

Pagani, Freeman and Arthur, 2000

Sometimes molecular trash is imported

Fulton et al., 2012

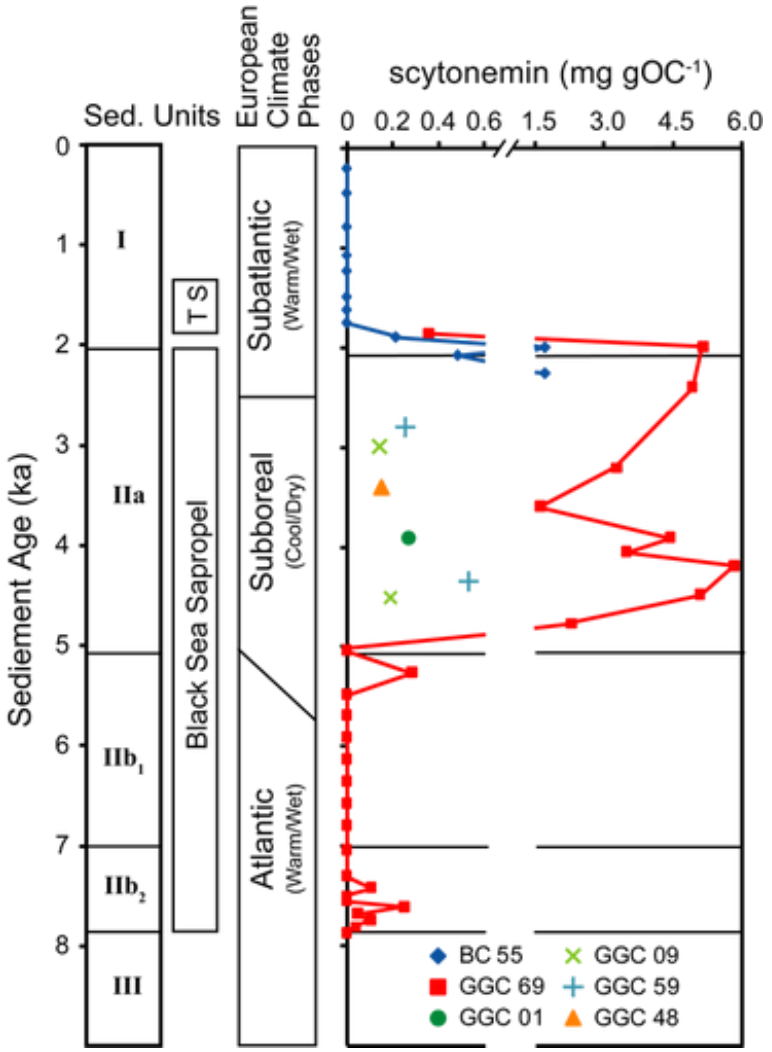


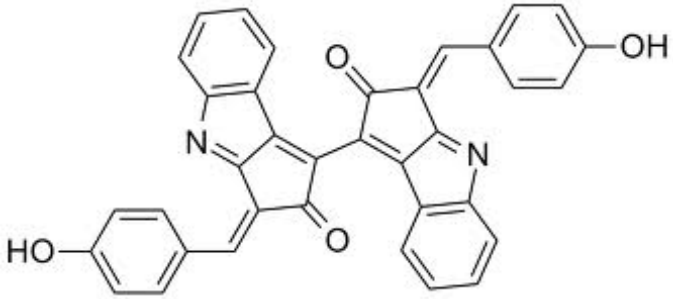


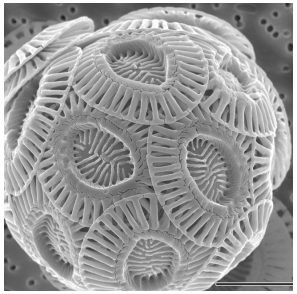
Microbiotic soils

Sometimes molecular trash is imported

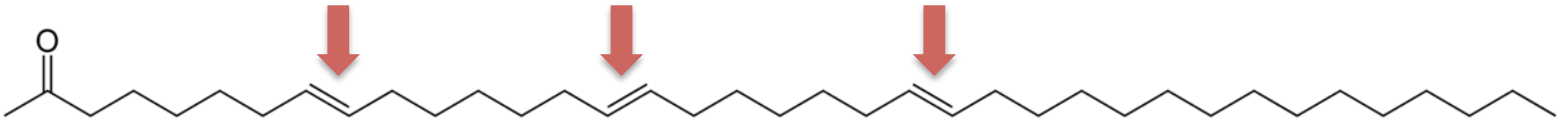
Fulton et al., 2012

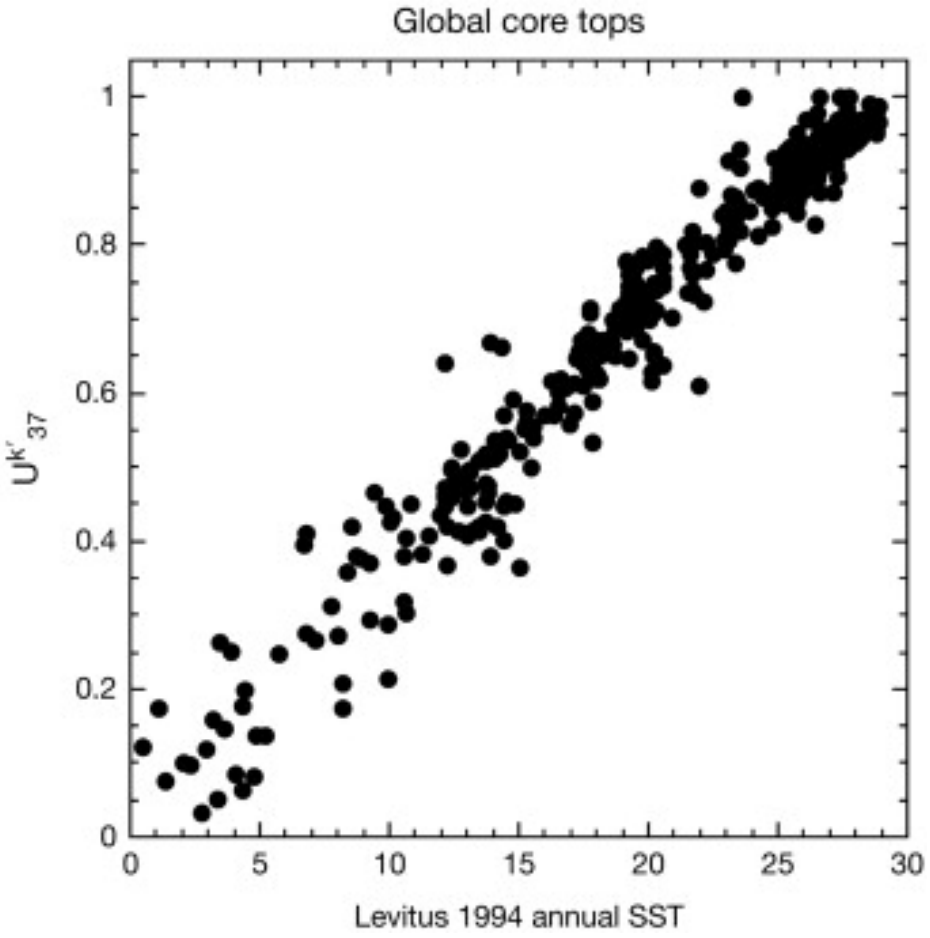




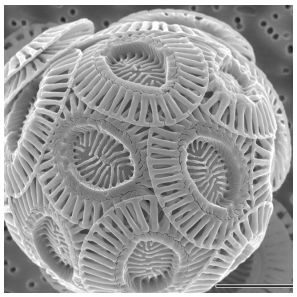


Alkenones: double bonds record SST

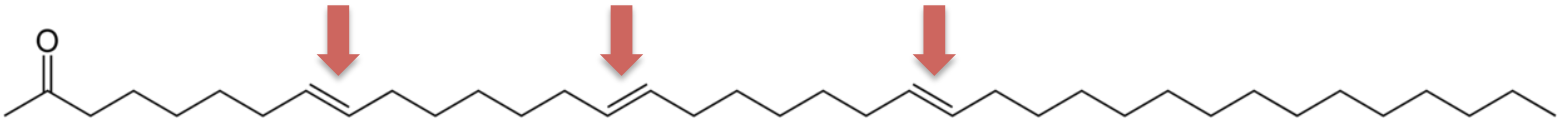


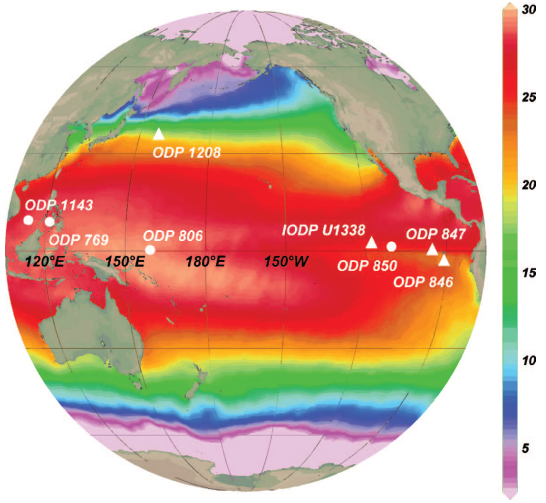


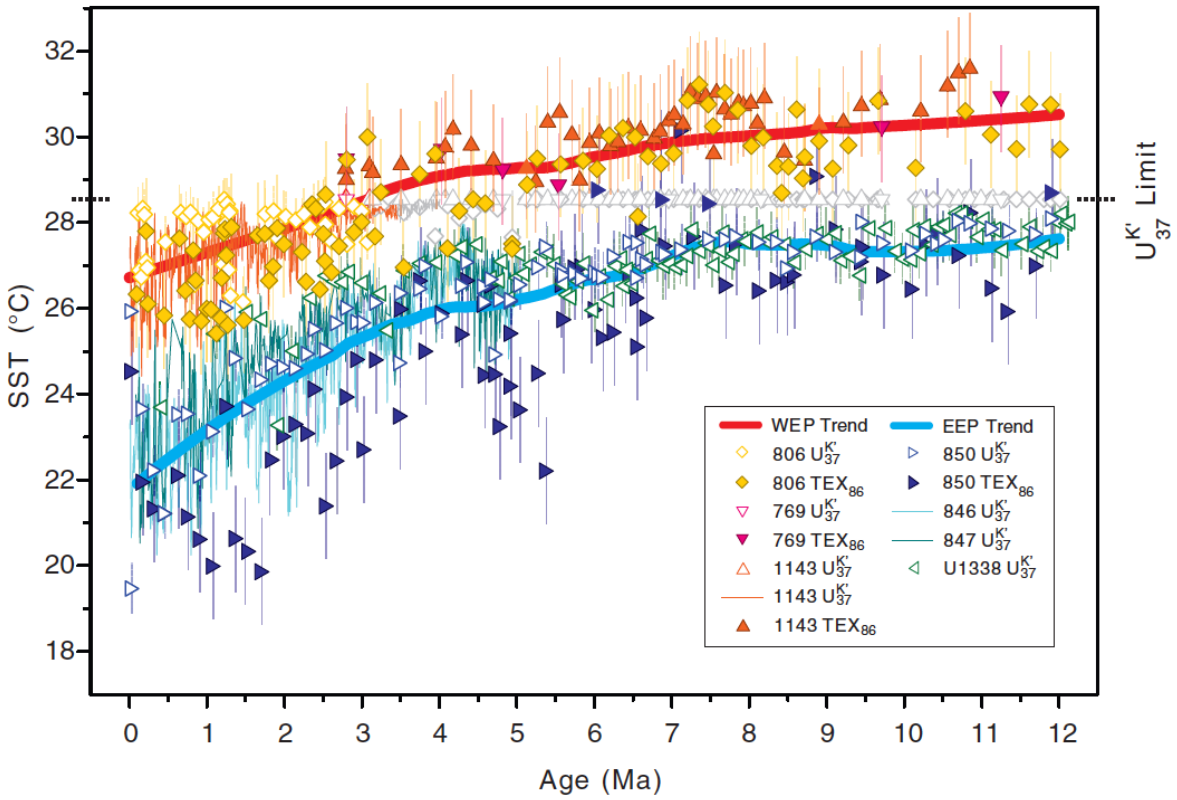
Herbert, 2013



Alkenones: double bonds record SST

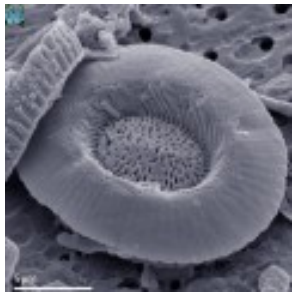




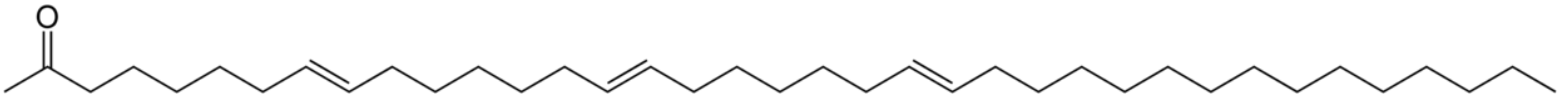


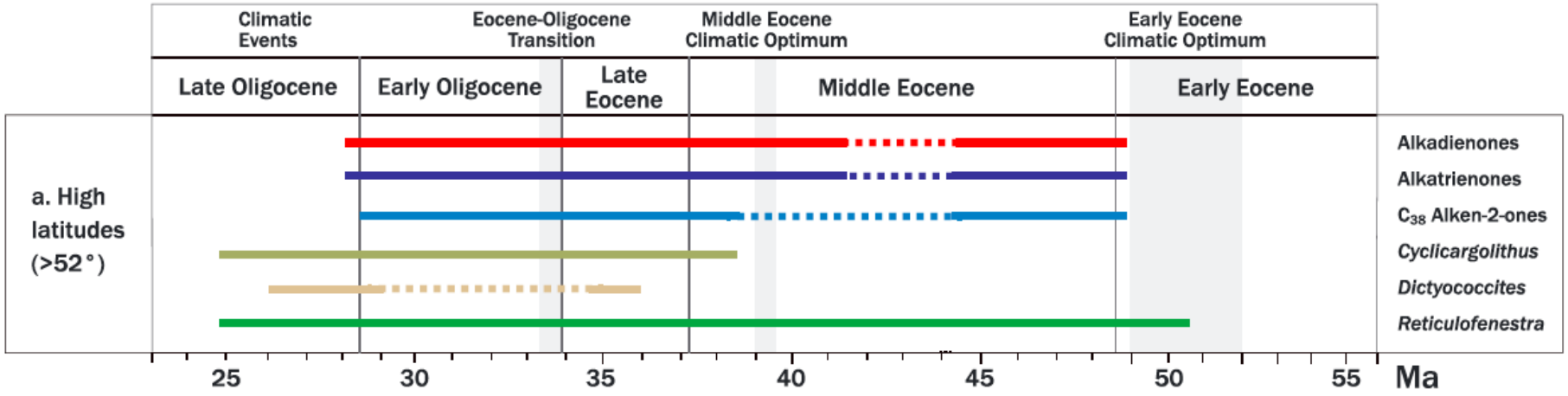
When did El Niño patterns start?

Zhang et al., 2014



Oldest alkenones?

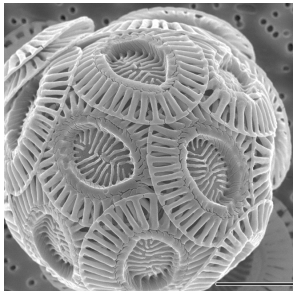




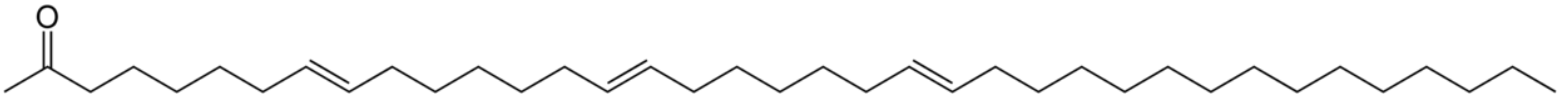
Sediment age, million years

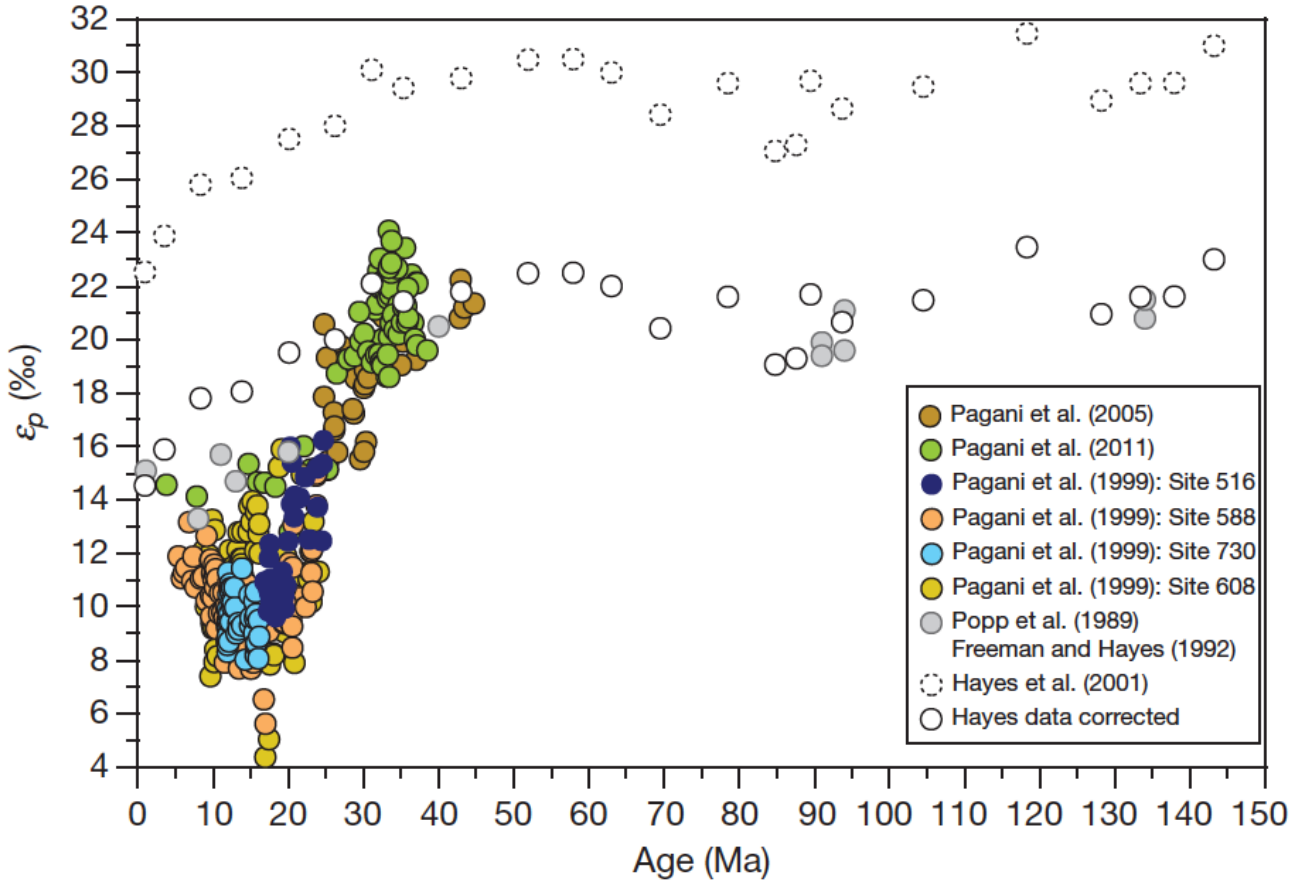
Noelaerhabdaceae:
Cyclicargolithus, *Dictyococcites*, and *Reticulofenestra* genera

Brassell, 2014



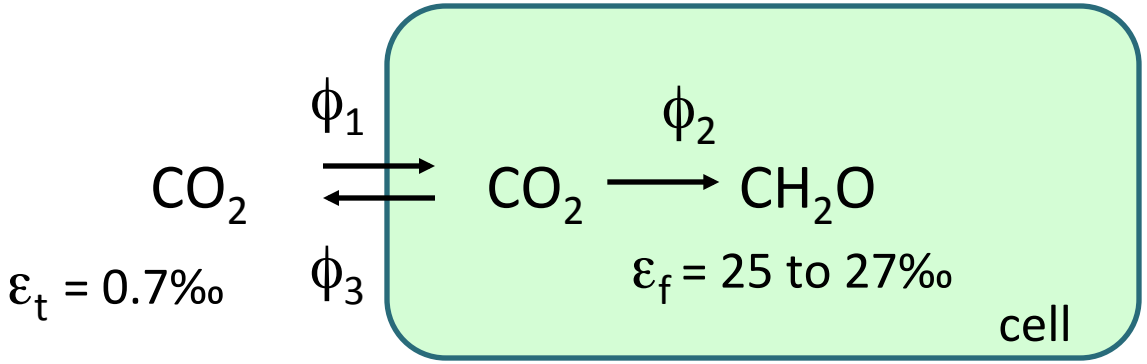
Alkenones record phytoplankton $^{13}C/^{12}C$





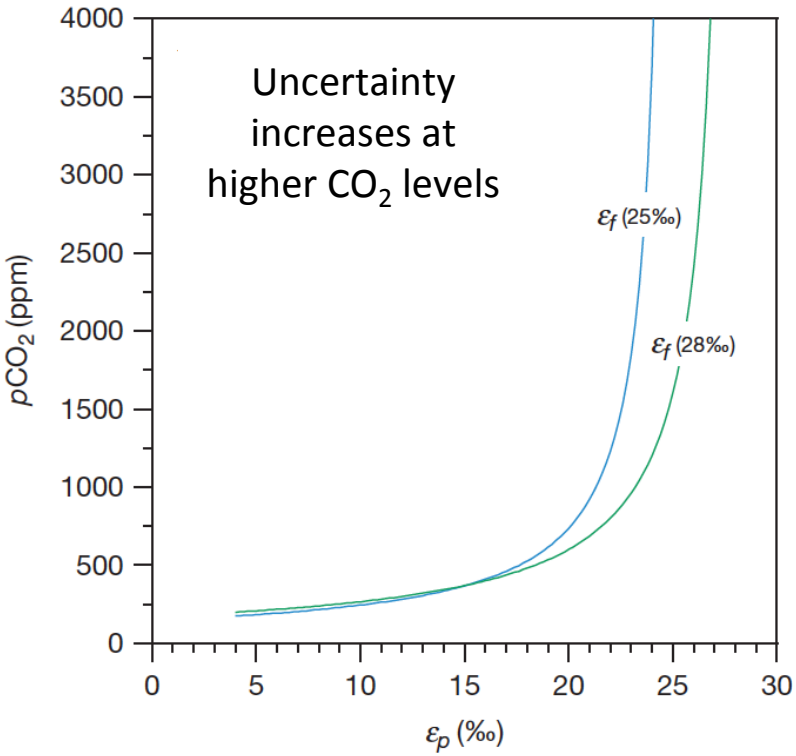
Pagani, 2014

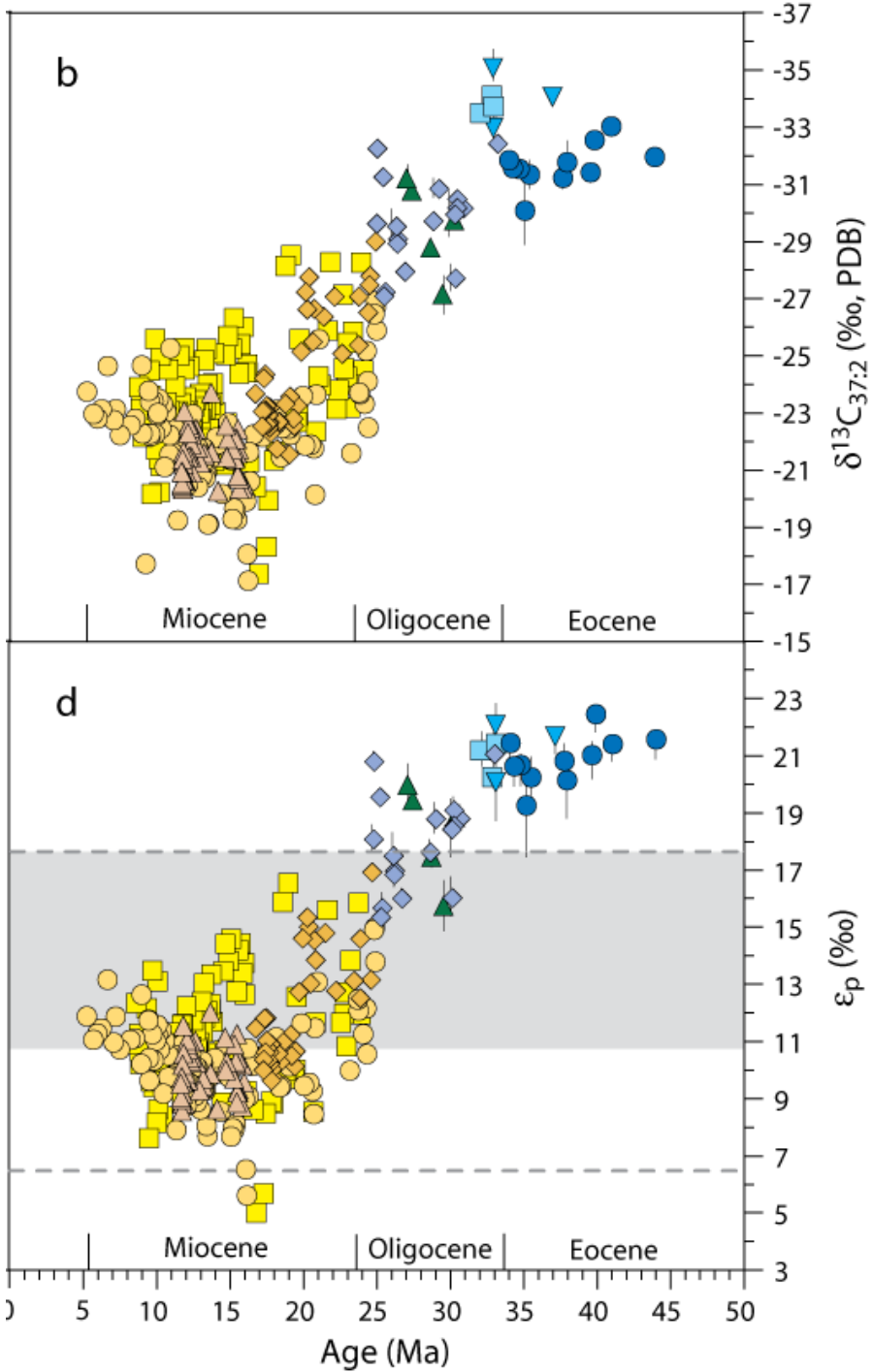
Isotope Fractionation During Photosynthesis by Algae

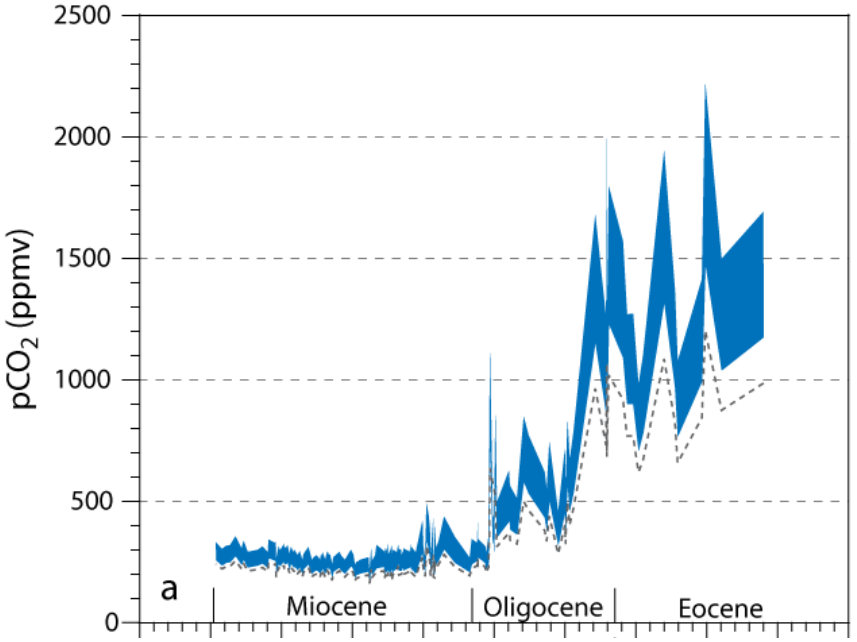


$$\varepsilon_p = \varepsilon_f - f_2 (\varepsilon_f - \varepsilon_t) \cong \delta_a - \delta_f$$

$f_2 = \phi_2 / \phi_1$ (demand / supply)







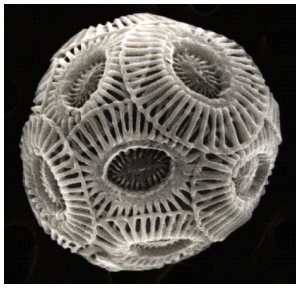
Alkenone Paleobarometry

- CO_2 drop since the Eocene

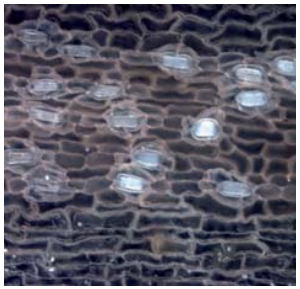
Pagani et al., 1999; 2000; 2005, 2011

CO_2 Proxy Records

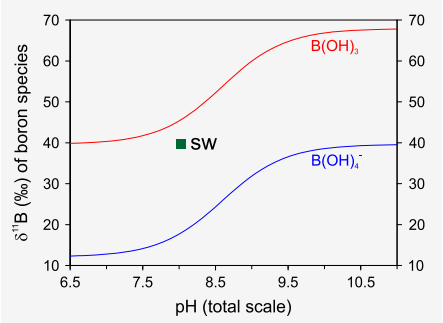
Alkenone carbon isotopes

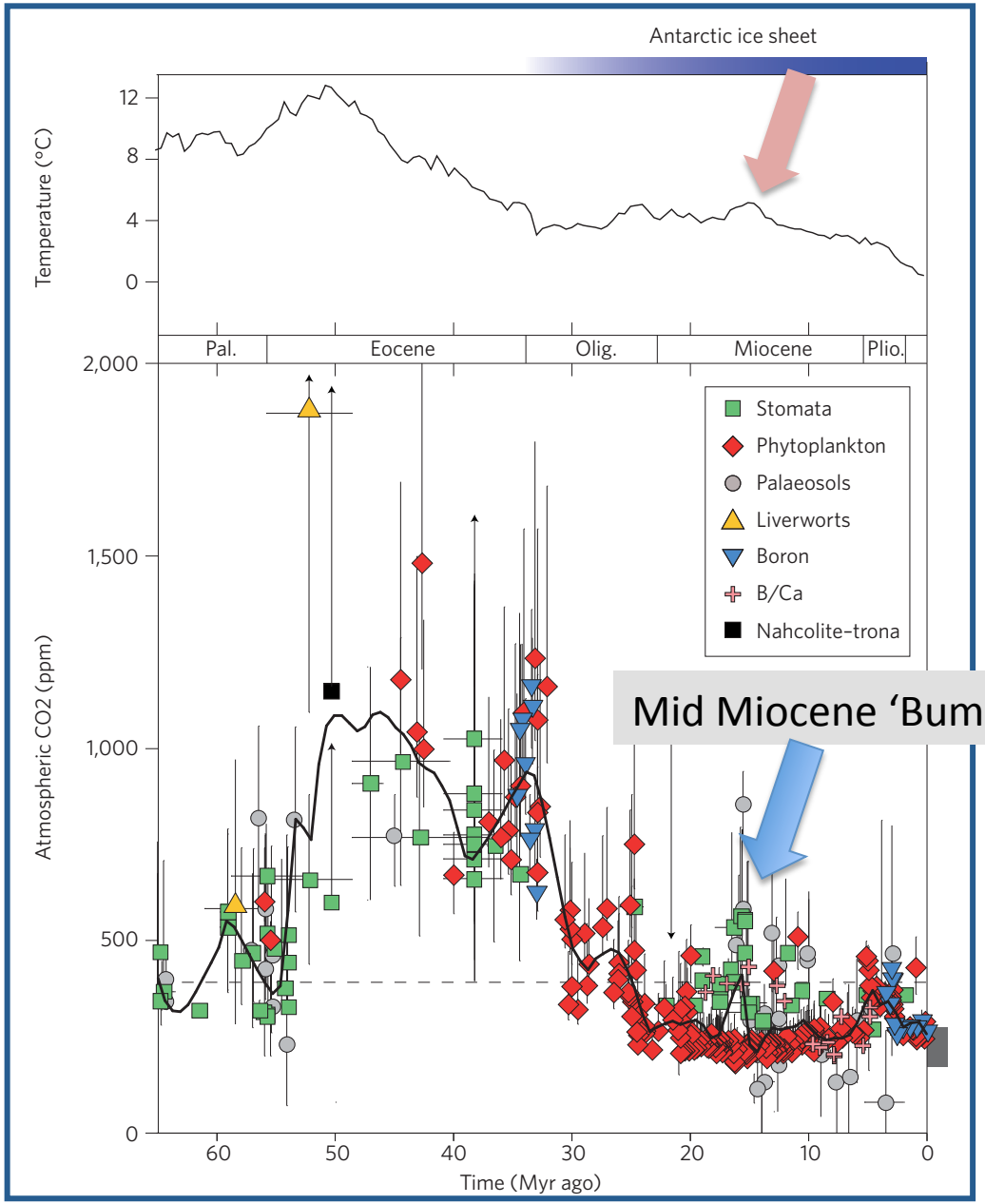


Stomata density



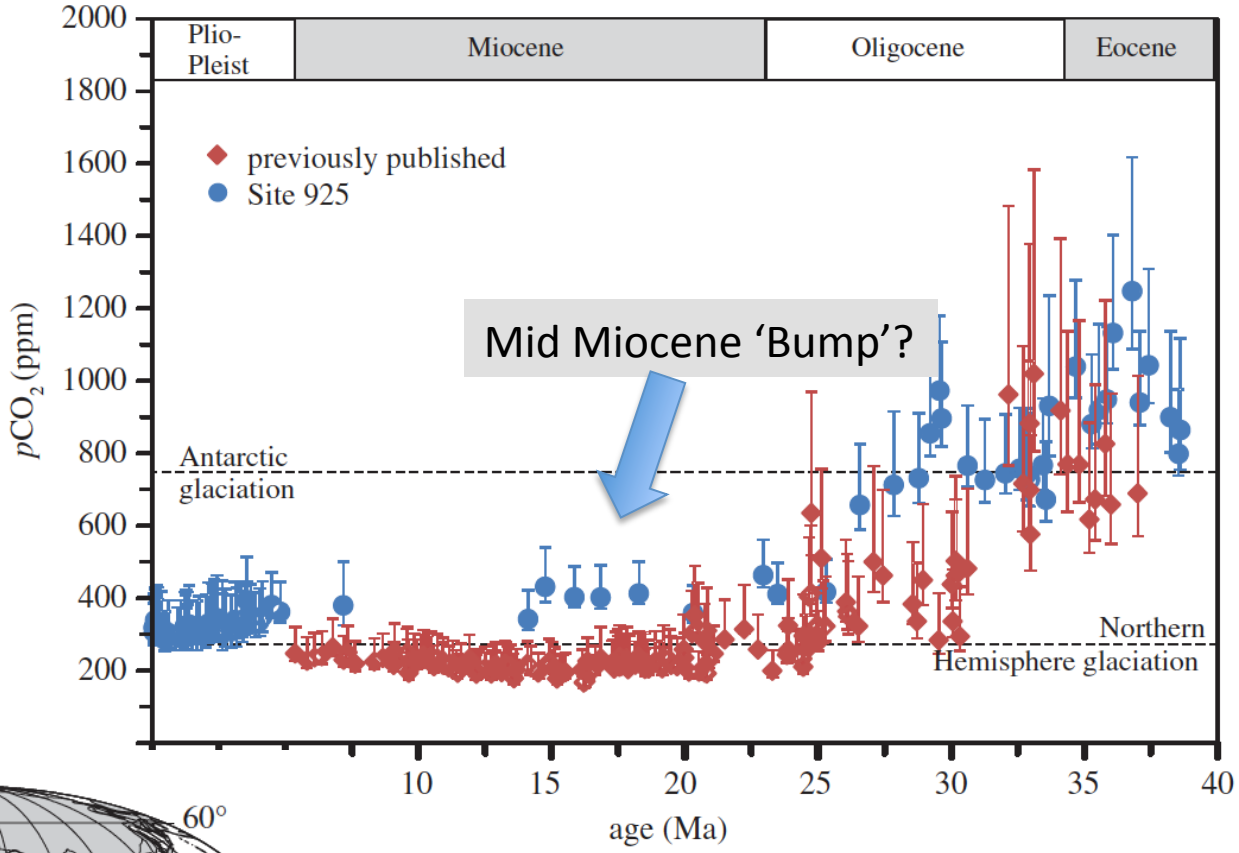
Boron isotopes

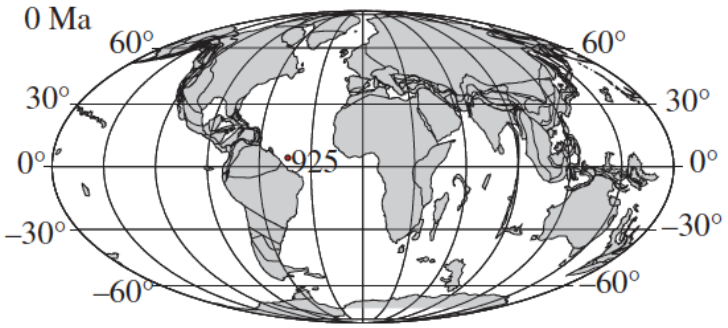




Royer and Beerling, 2011

The Miocene Bump:
Was CO_2 high in the middle Miocene?





Zhang et al., 2013

Shark Bay, Australia
National Geographic

Biomarkers and past oceans:

- Resistant to transport and decay loss
- Indicate sources of organic matter
- Sometimes imported from land
- Proxies for temperature, CO_2, redox
- Microbial biogeochemistry