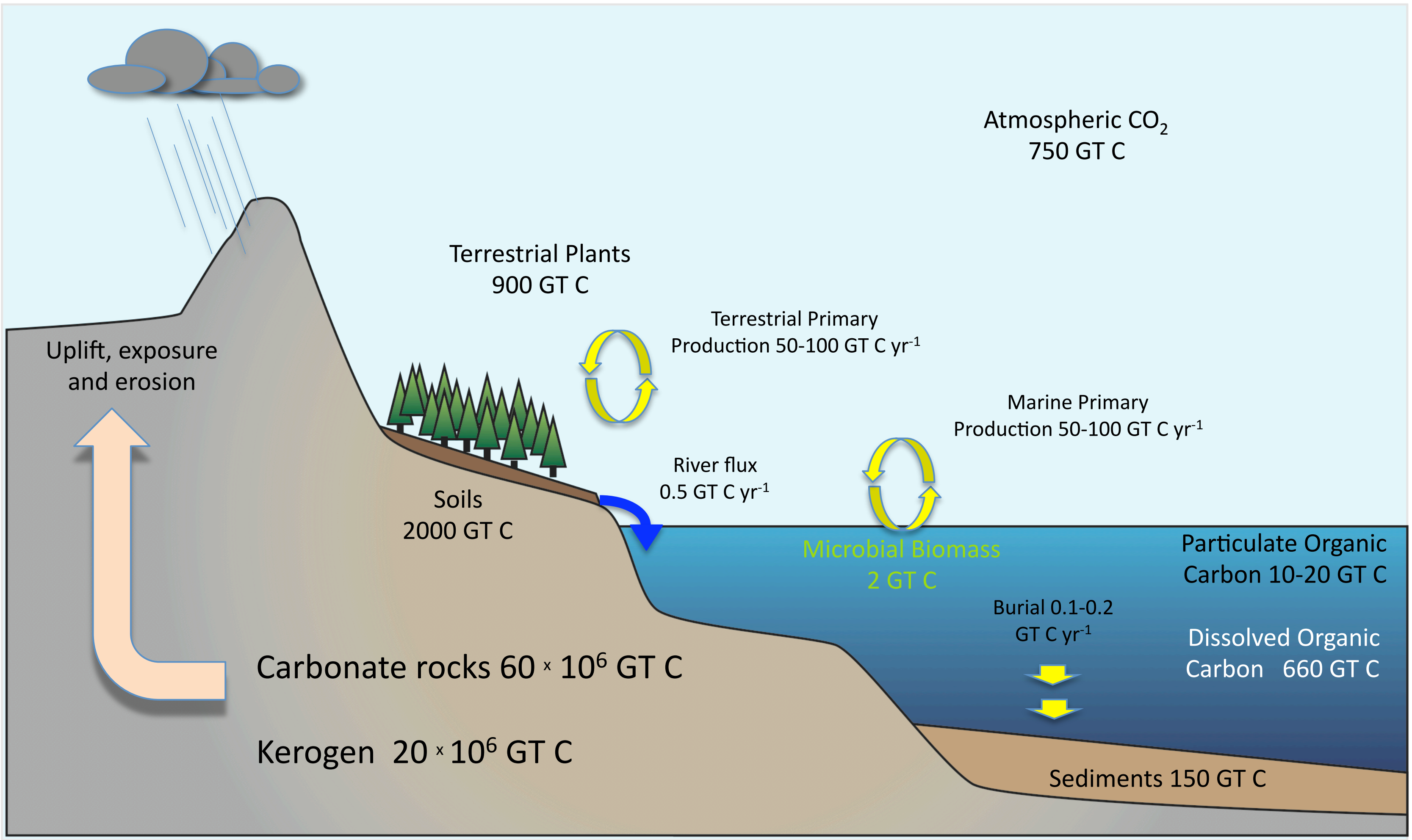
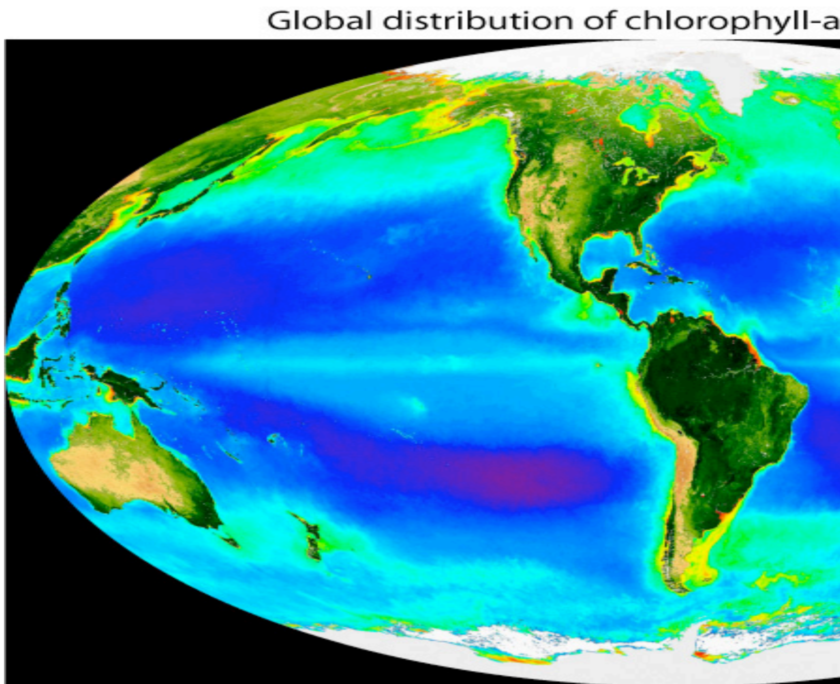
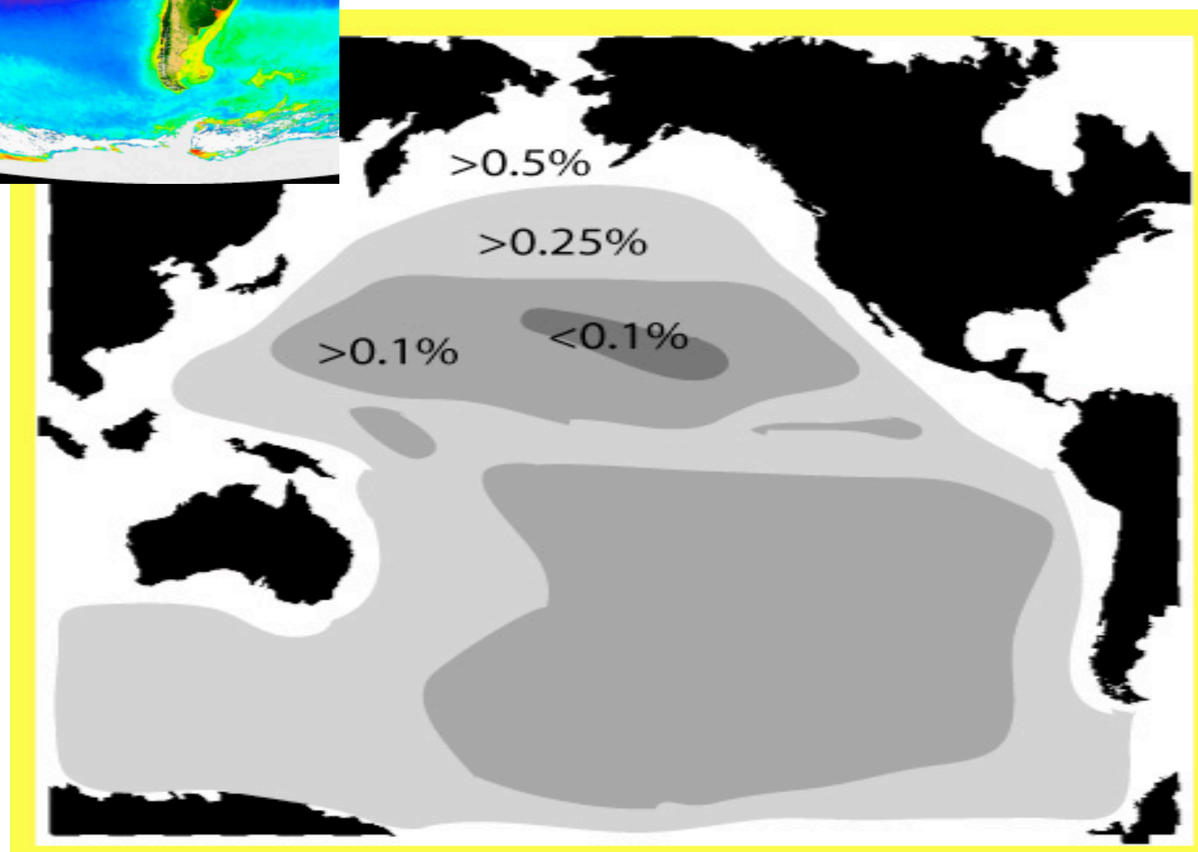

Atmospheric CO_2
750 GT C
Terrestrial Plants
900 GT C
Terrestrial Primary
Production 50-100 GT C yr^{-1}
Marine Primary
Production 50-100 GT C yr^{-1}
Uplift, exposure
and erosion
River flux
0.5 GT C yr^{-1}
Soils
2000 GT C
Microbial Biomass
2 GT C
Particulate Organic
Carbon 10-20 GT C
Burial 0.1-0.2
GT C yr^{-1}
Dissolved Organic
Carbon 660 GT C
Carbonate rocks 60×10^6 GT C
Kerogen 20×10^6 GT C
Sediments 150 GT C



Carbon preservation factor 1: carbon rich sediments underlay regions of high water column productivity. High primary productivity leads to higher carbon flux leads to greater carbon burial (though unknown mechanisms)



<u>What is Carbon Preservation?</u>

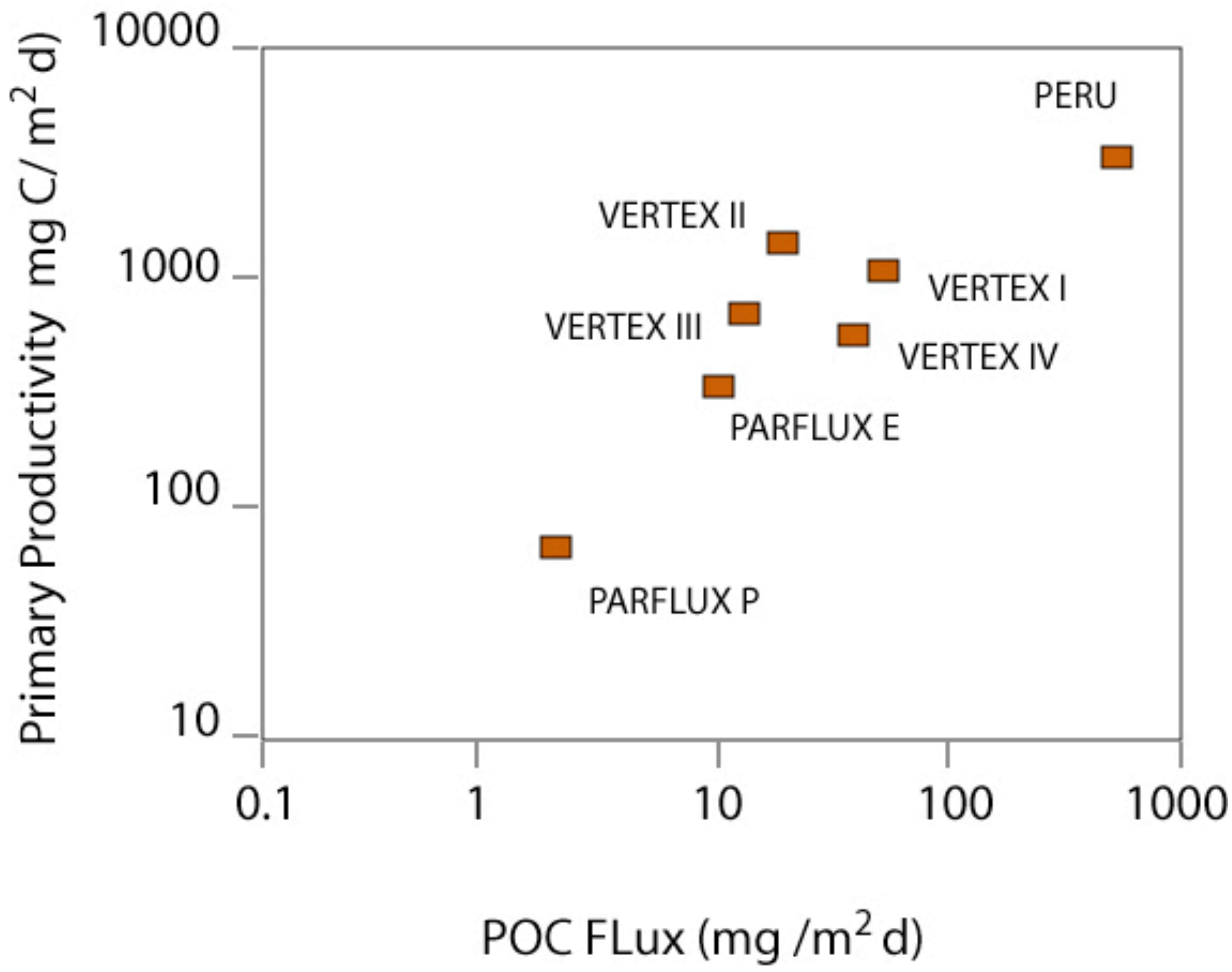
Is it % OC in sediments?

Is it C_{org} accumulation rate?

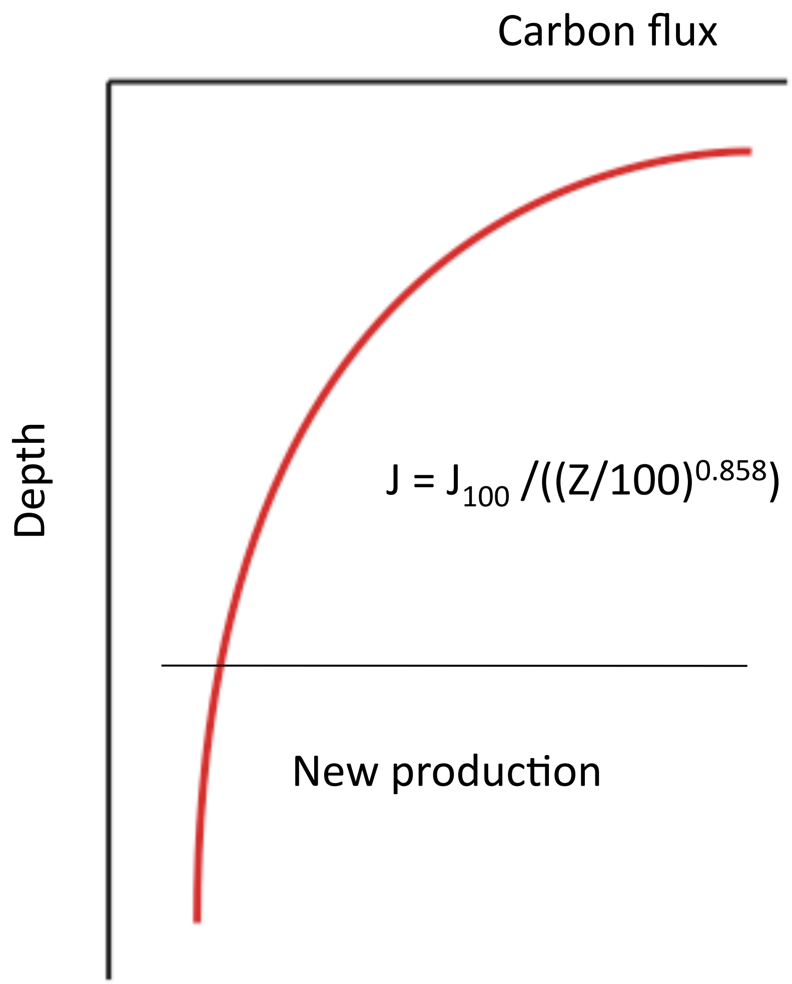
Is it C_{org} accumulation normalized to input?

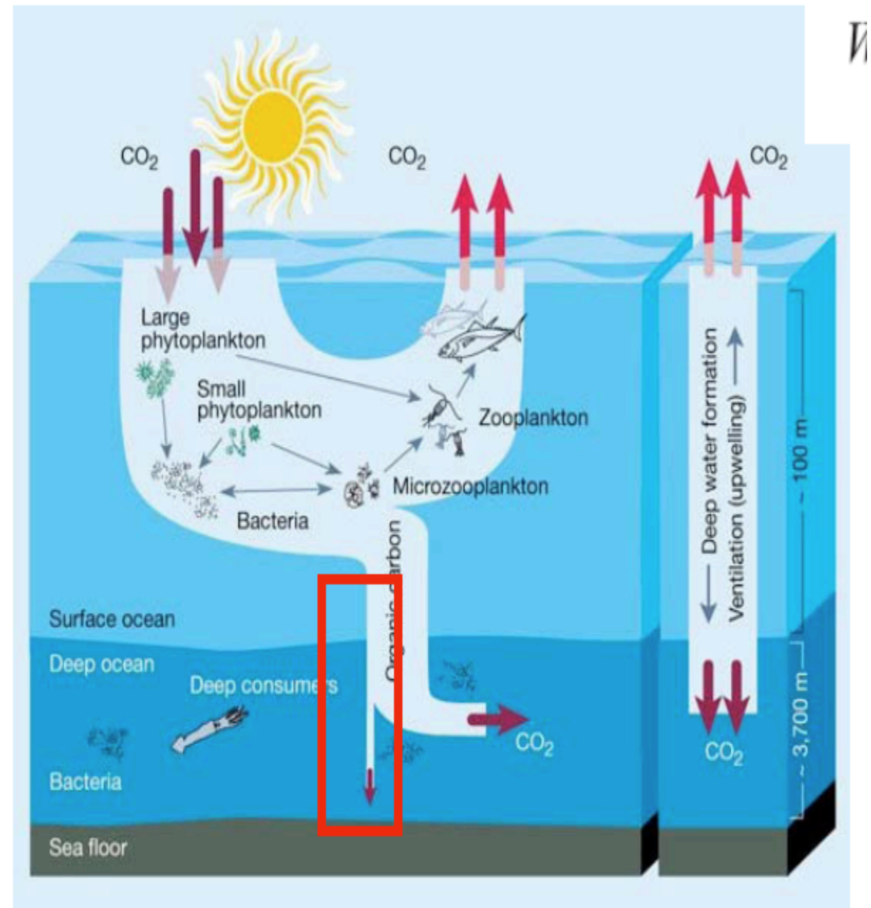
To understand how C preservation is regulated, we try to correlate environmental factors then study the underlying mechanisms

Carbon Preservation factor #1. The argument for productivity……



What drives carbon flux?

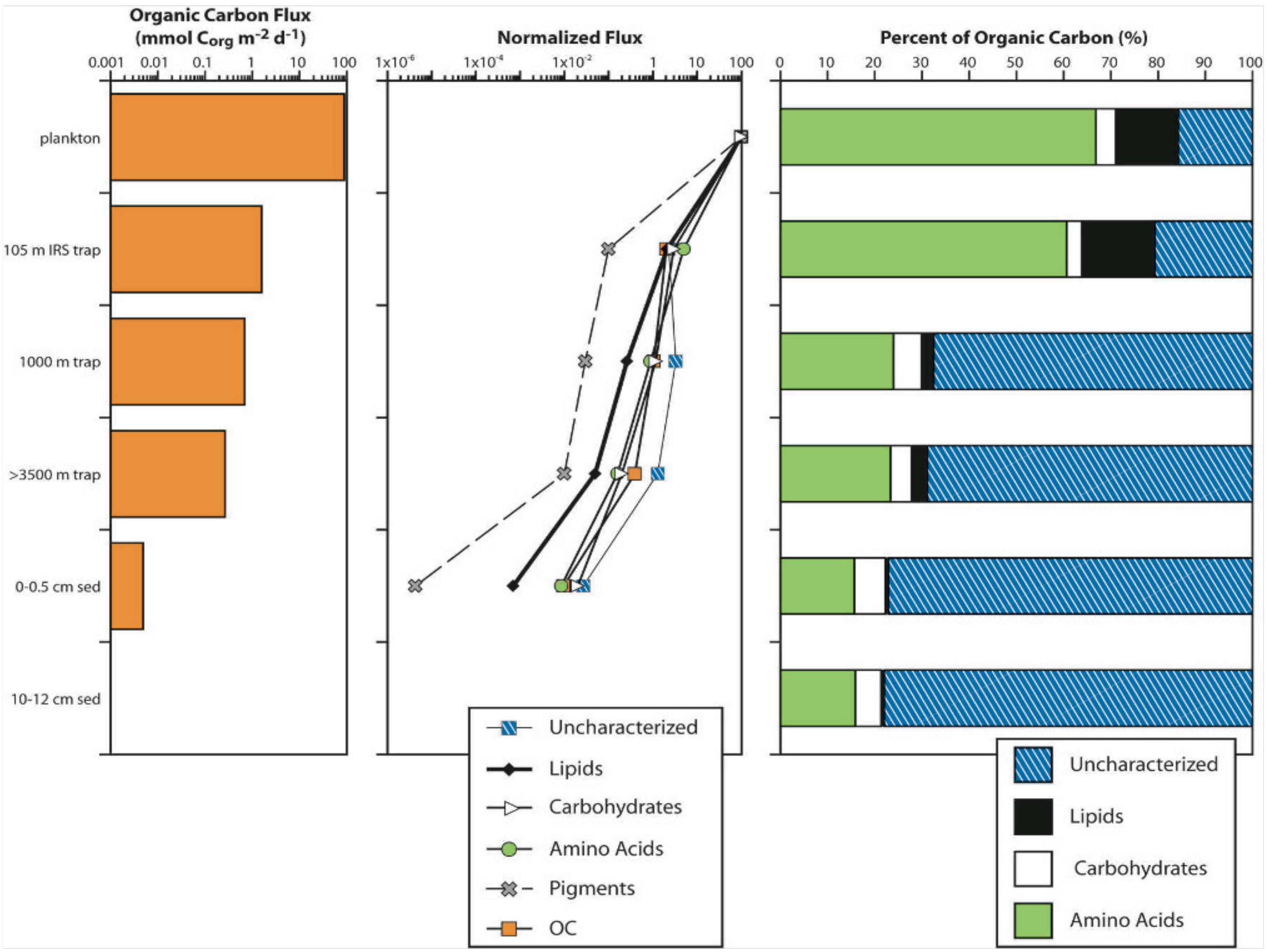




Martin et al (1987) DSR v 34; 267-285

C flux is closely coupled to the biological processing of organic matter

Do molecular level analyses give a fair representation of POM composition?



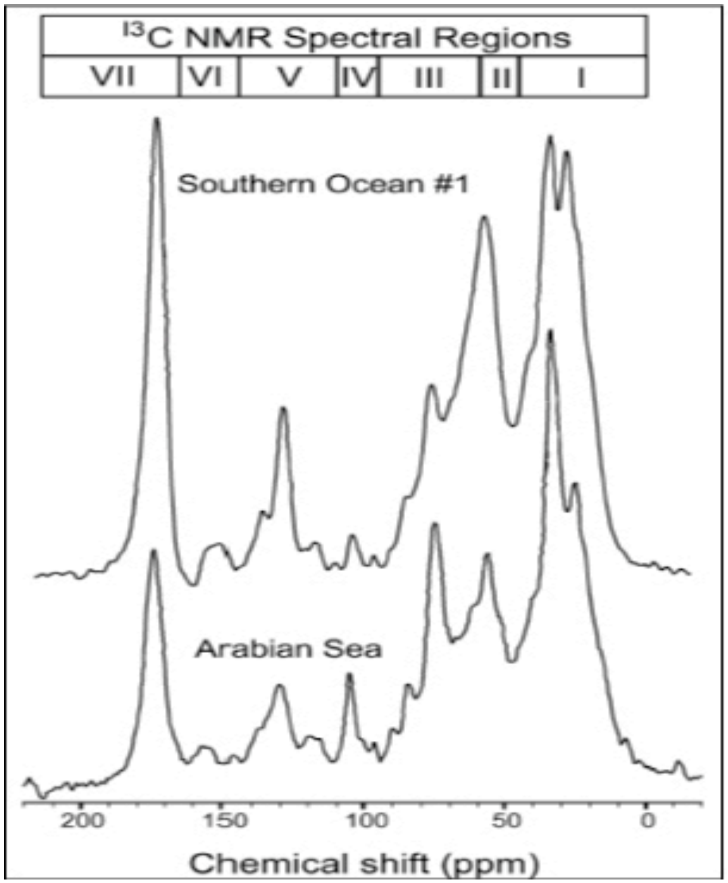
C:N = 6.6

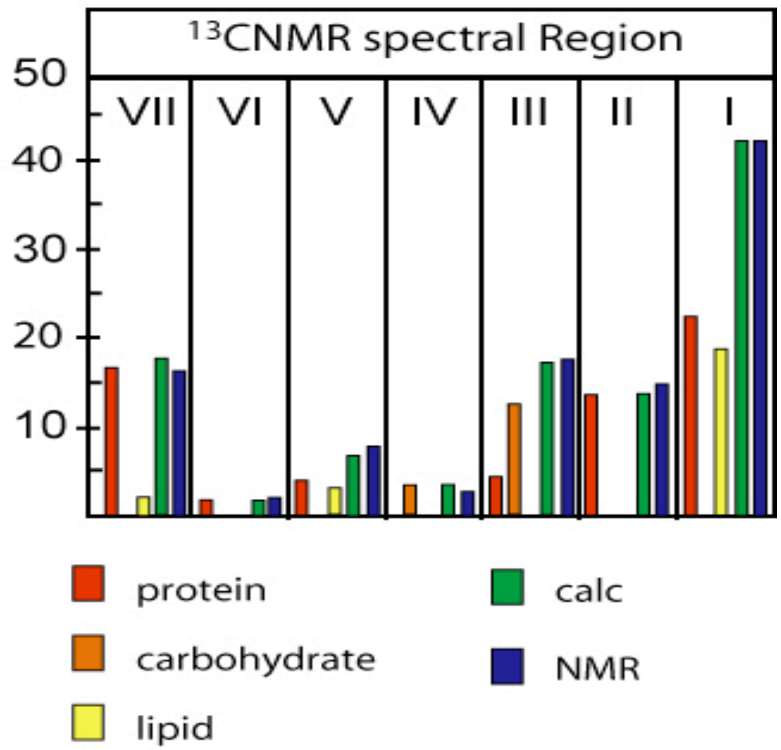
C:N = 9.0

From Lee et al. (2004) Ambio 33, 565-574

How well do we know the composition of marine algae?

$CH_3CH(N)COOH$	proteins	I, II, III, VII
$C(H_2O)$	carbohydrates	III
$CH_3(CH_2)_nCOOH$	lipids	I, V, VII





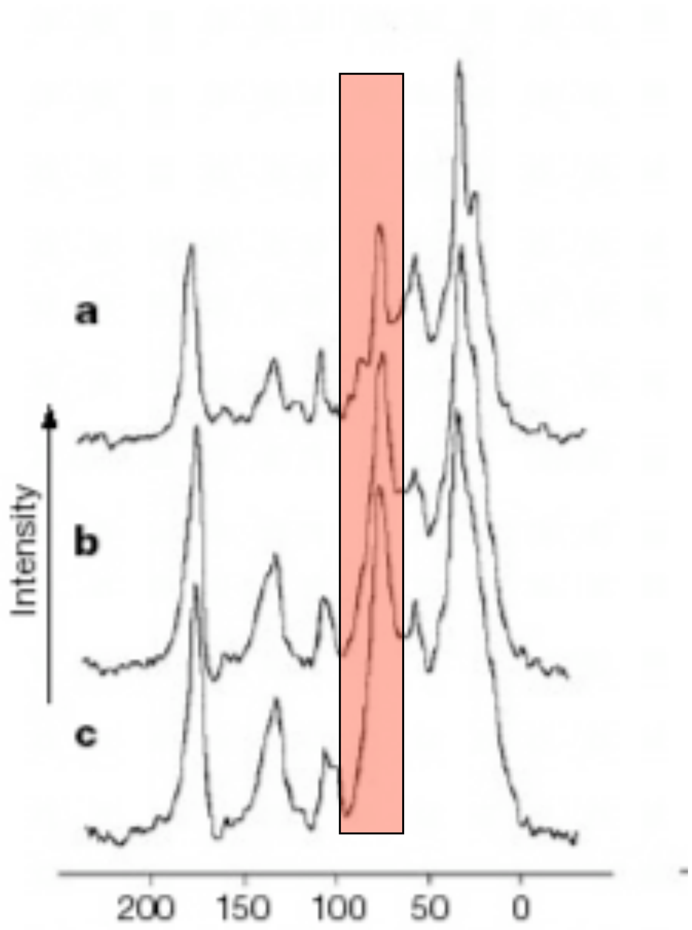
Hedges et al. (2002) Marine Chemistry v 78, pp 47-63

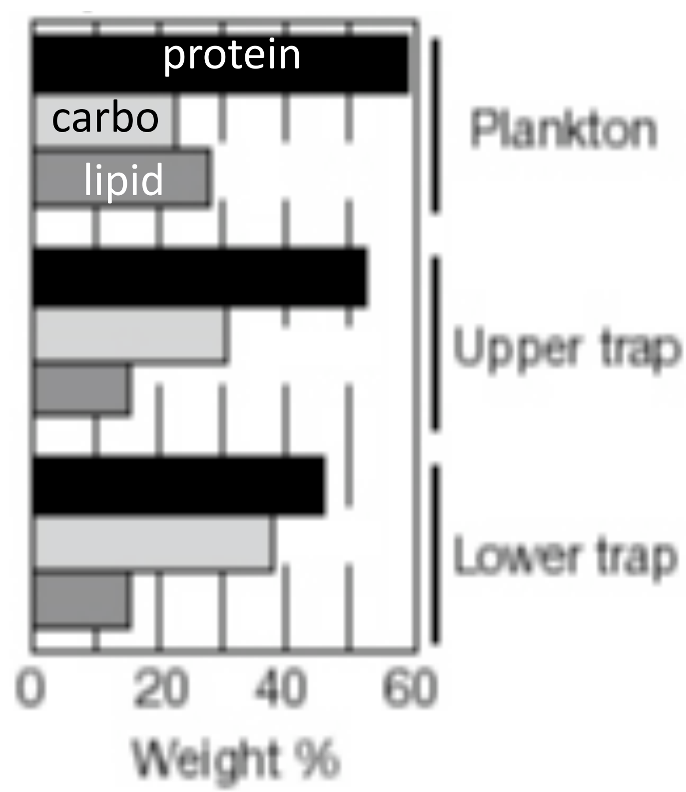
^{13}CNMR of phytoplankton, shallow and deep sediment trap material (Equatorial Pacific)

Surface

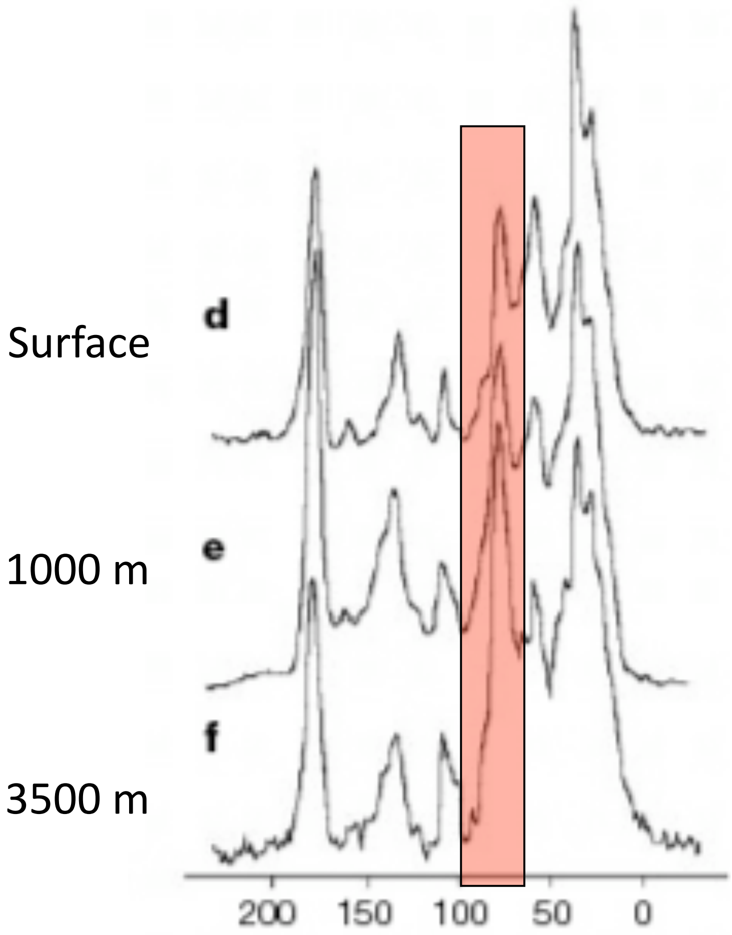
1000 m

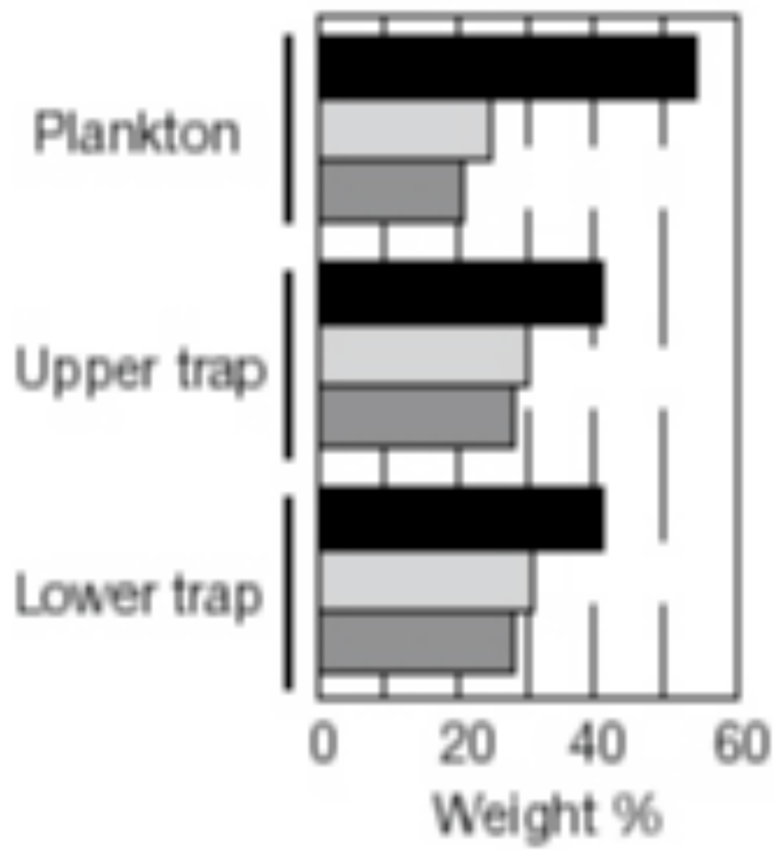
3500 m



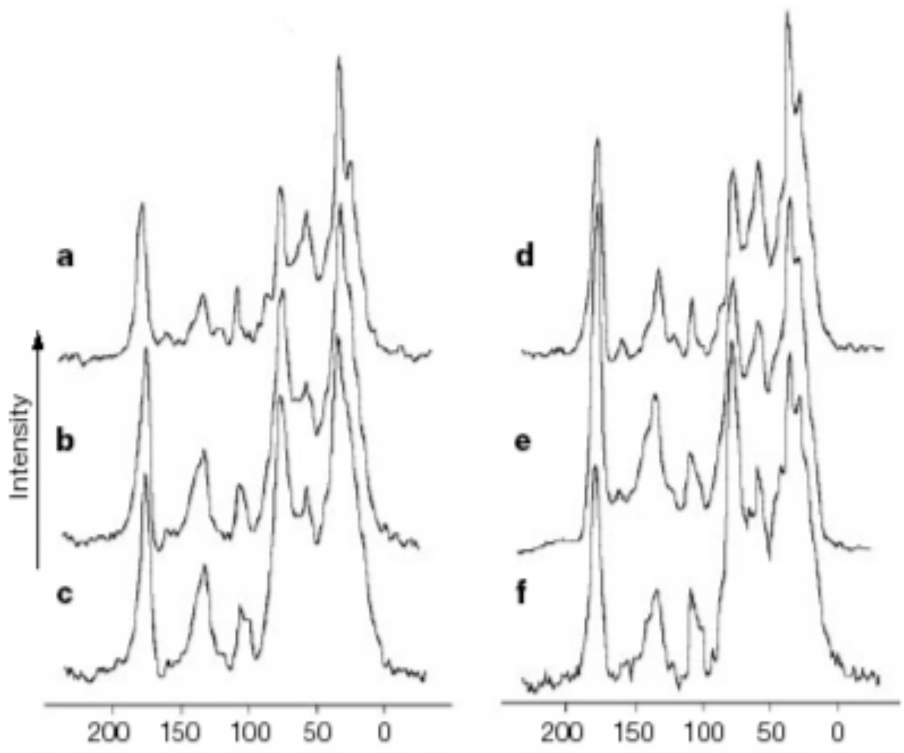


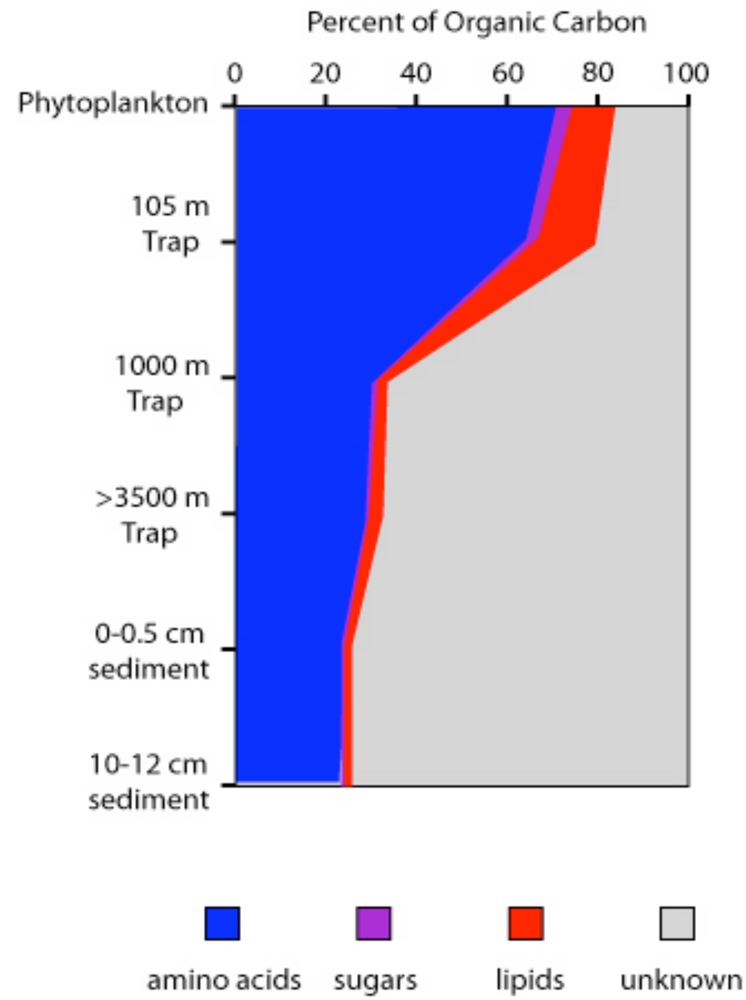
^{13}CNMR of phytoplankton, shallow and deep sediment trap material (Arabian Sea)





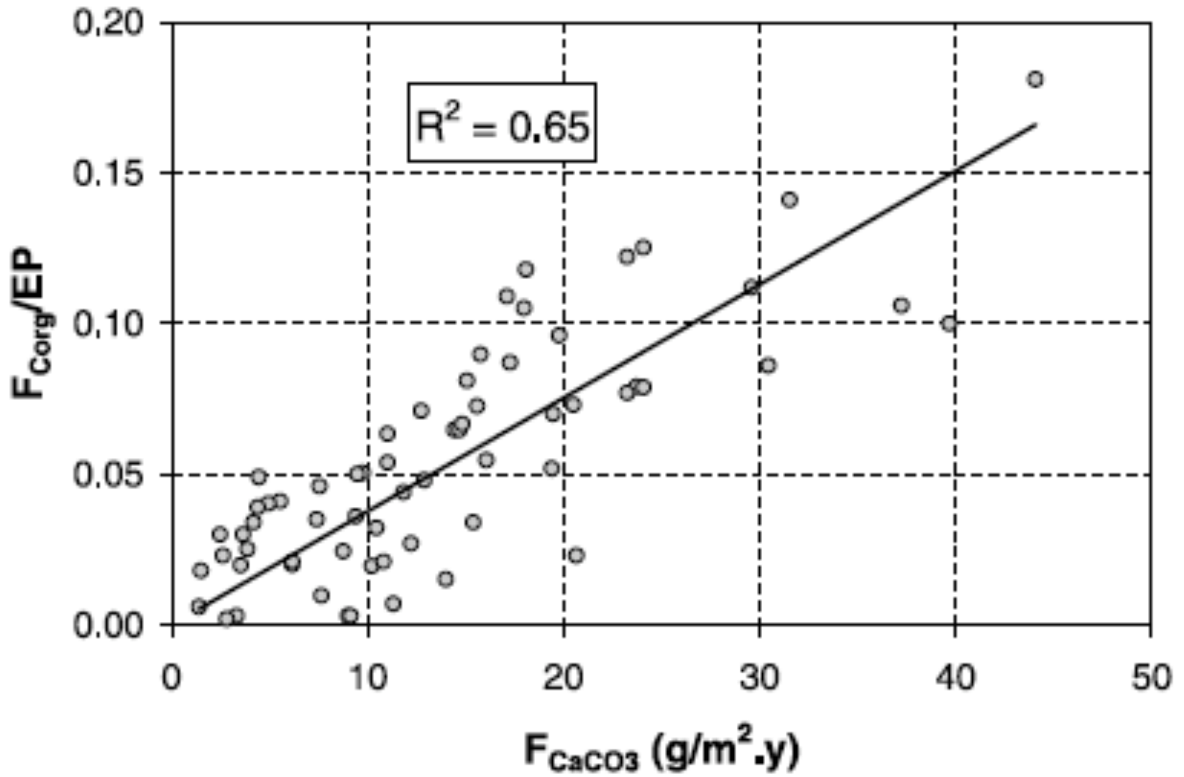
From the small changes in the ^{13}CNMR spectra of sinking POM, Hedges et al. infer that there is preferential degradation of proteins And selective preservation of carbohydrates and lipids. But these the effects are fairly small. In general, degradation acts non-selectively, and that *preservation occurs via physical protection*.





Reconciling selective and nonselective preservation the effects of mineral ballast on C flux

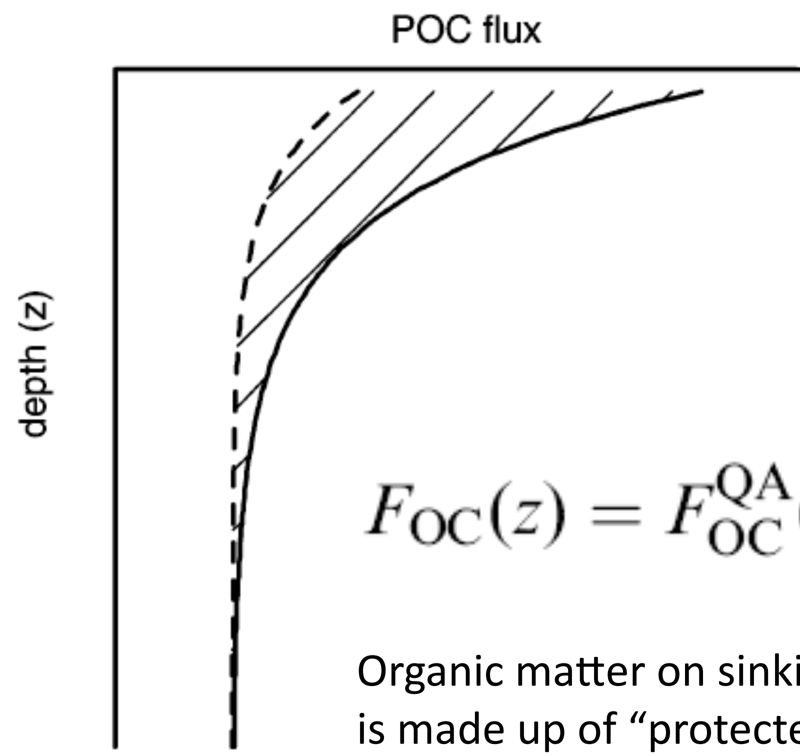
As more of the material is ballasted, the F_{org}/EP increases



F_{org} = Flux of organic carbon; EP = export production

Francois et al. (2002) GBC 16 doi:10,1029/2001GB001722, 2002:

Reconciling selective and nonselective preservation
the effects of mineral ballast on C flux



$$F_{OC}(z) = F_{OC}^{QA}(z) + F_{OC}^{E}(z).$$

Organic matter on sinking particles
is made up of “protected” and “nonprotected”
forms. The “nonprotected OM is lost in the
upper water column, “protected is not, and its
flux will vary with the amount of mineral flux.

R.A. Armstrong et al. / Deep-Sea Research II 49 (2002) 219–236

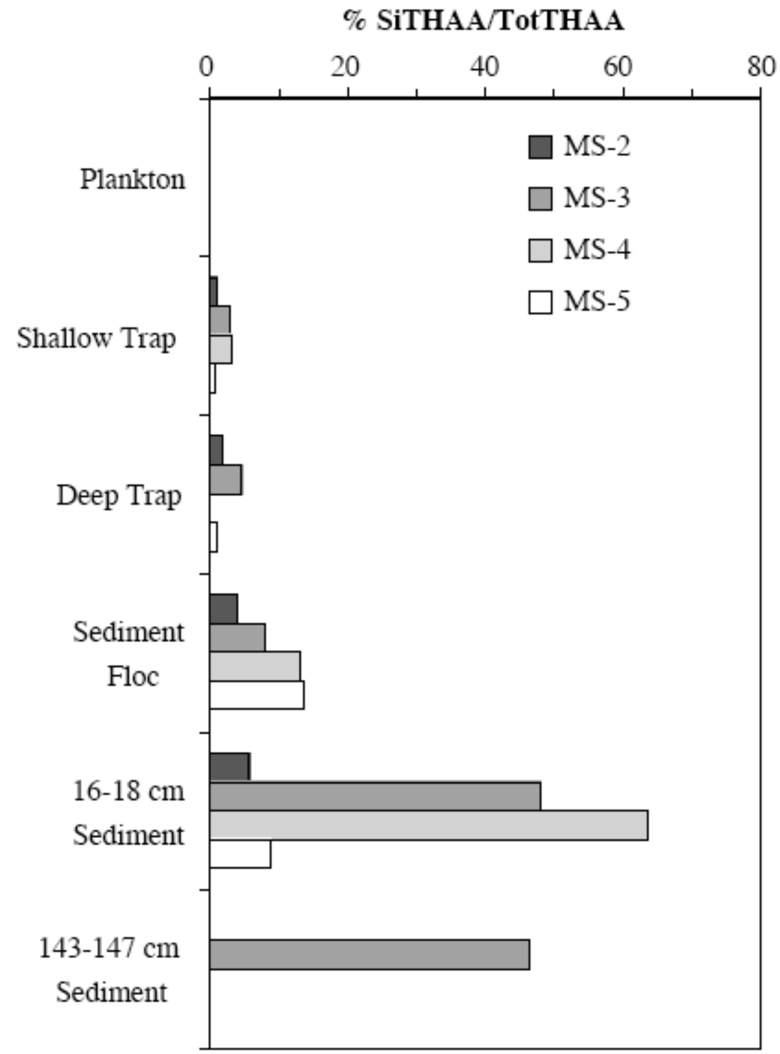


Fig. 5. The fraction of TotTHAA (THAA + SiTHAA) made up by SiTHAA as a function of depth in the water column and sediment. THAA includes calcium carbonate-bound amino acids (CaTHAA). Plankton values are 0.02–0.05%.

Testing the mineral protection hypothesis:

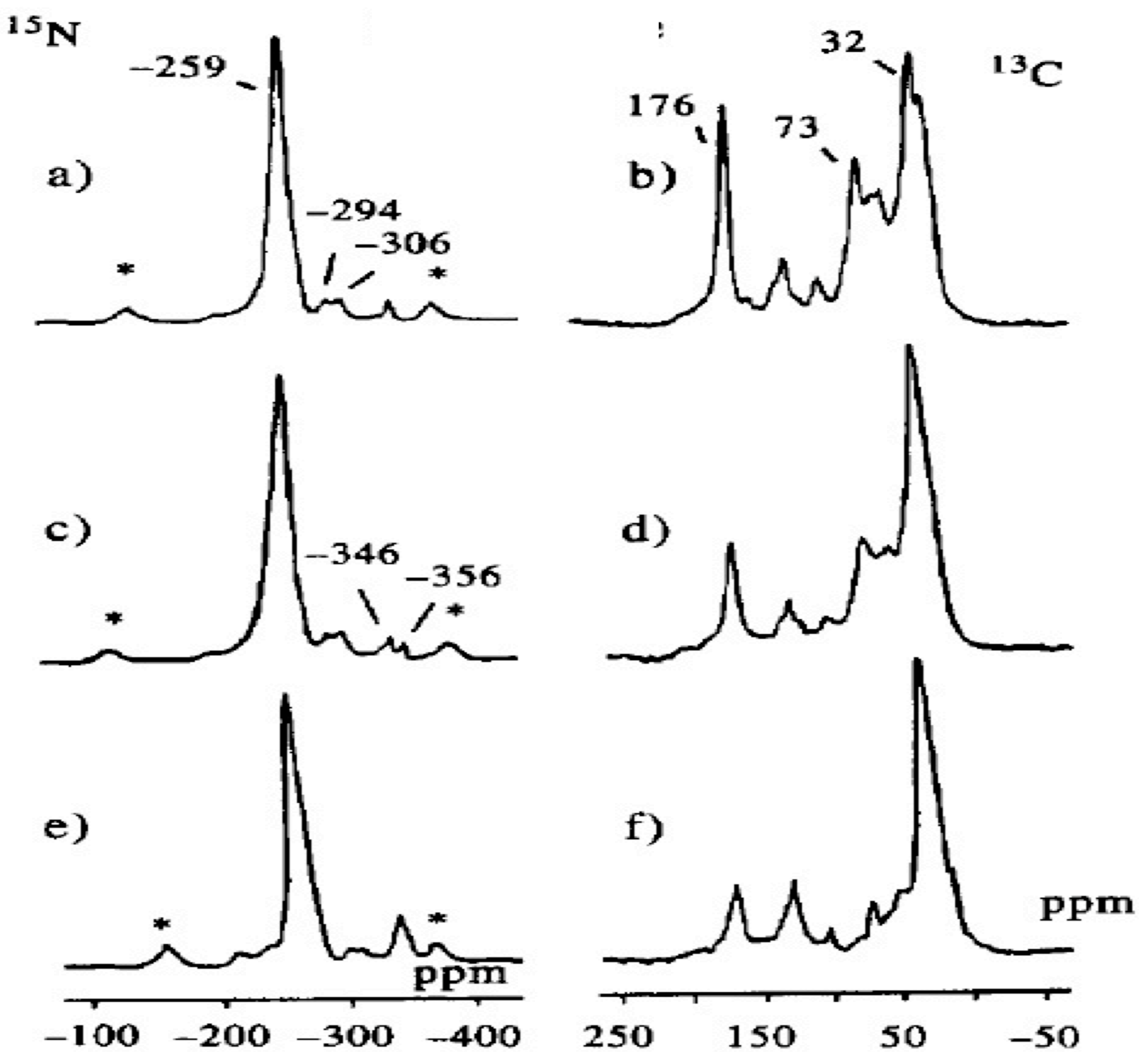
Do mineral bound amino acids make up a large fraction of the sinking POM at at depth in the ocean?

….not really, at least
not in the southern ocean.

A.E. Ingalls et al. / Deep-Sea Research II 50 (2003) 713–738

^{15}N- and ^{13}CNMR study of laboratory algal degradation

Knicker et al *Org Geo* **24**, 661-669



Fresh algae

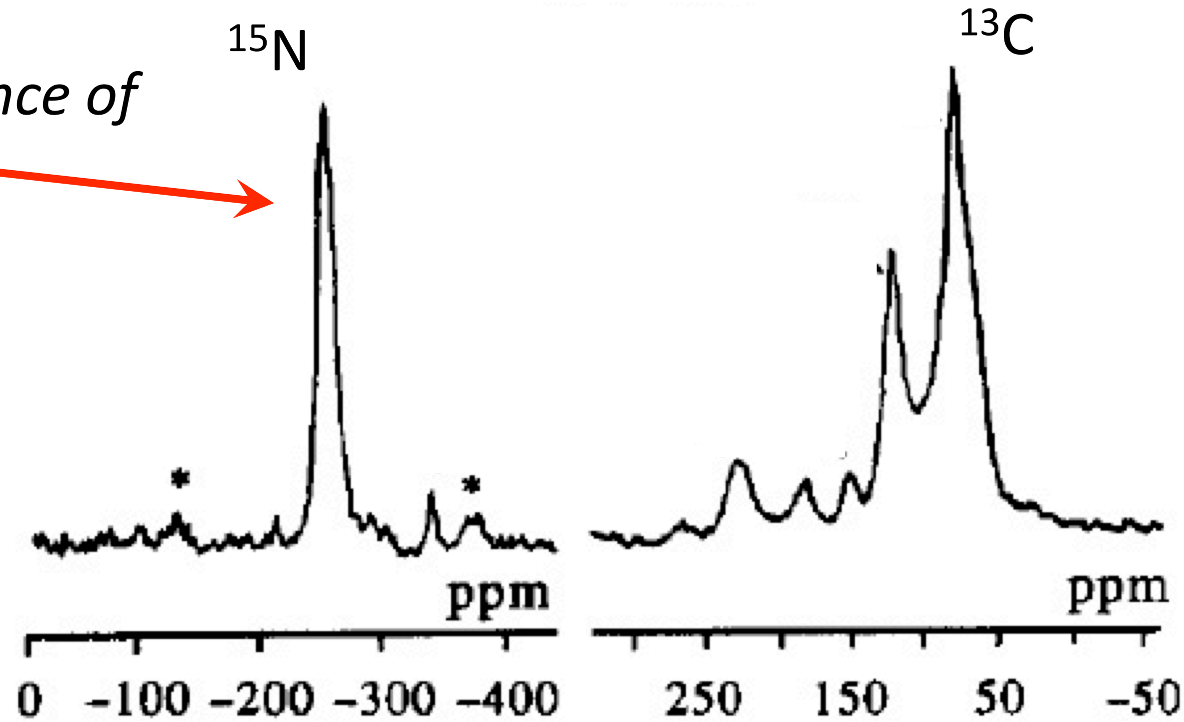
Algal compost (60 d)

Algaenan
(nonextractable POM)

^{15}N and ^{13}CNMR of an algal 4000 yr old sapropel from Mangrove Lake, Bermuda

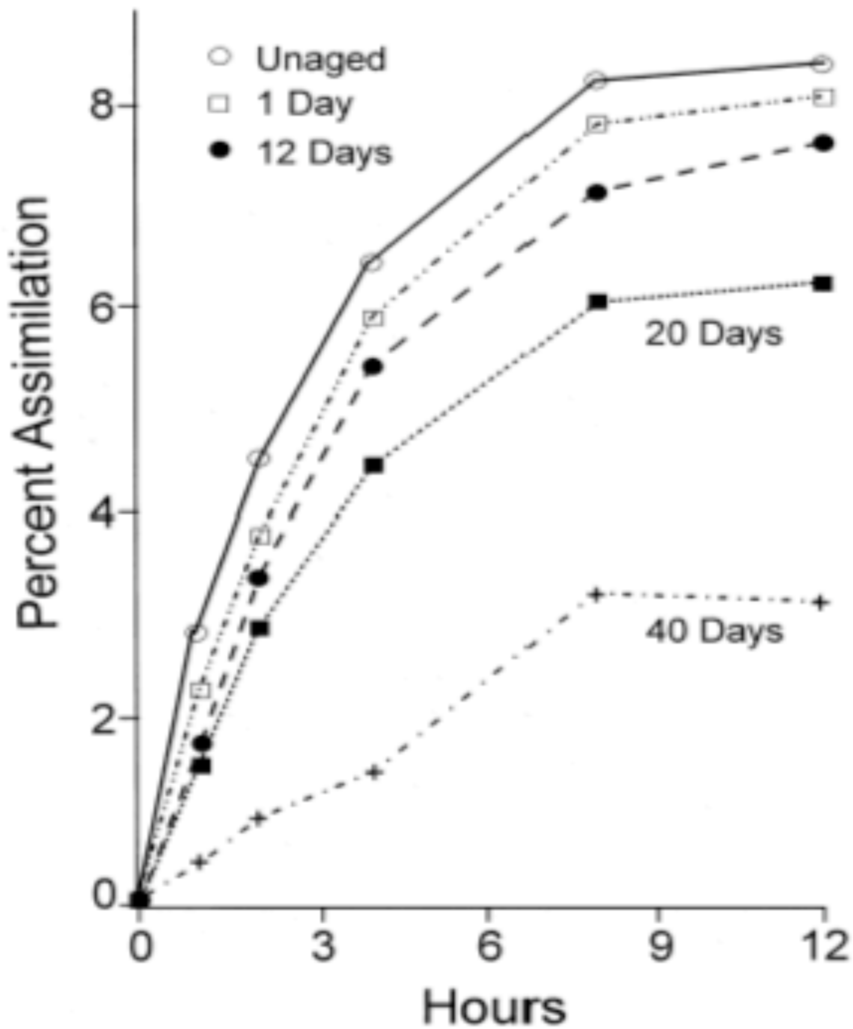
Knicker et al *Org Geo* **24**, 661-669

Note presence of Amide (?)…



Knicker reasons that amide comes from protein, which should be labile. Preservation suggests some form of physical protection

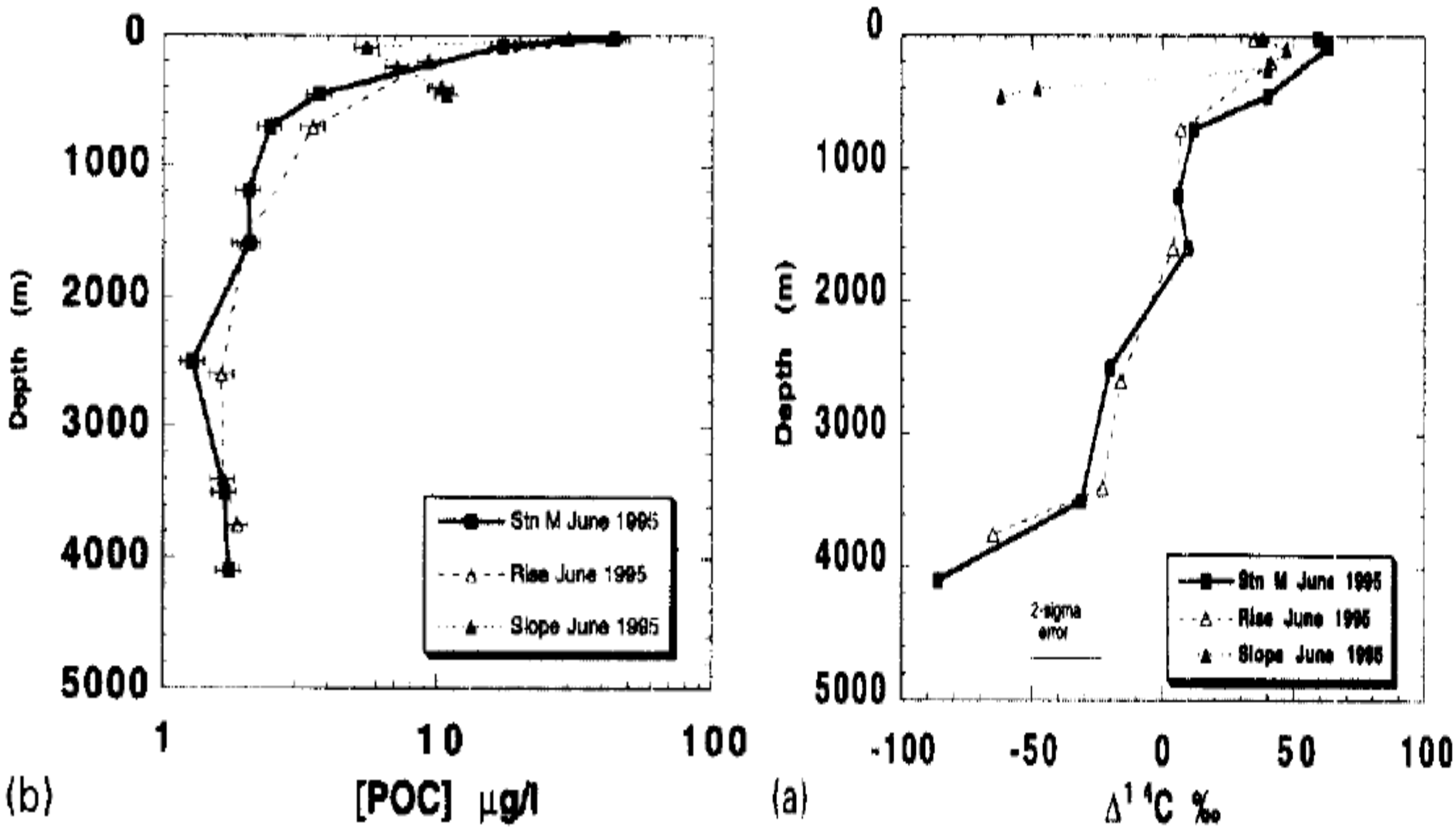
but is protein labile?
The effect of aging on protein degradation



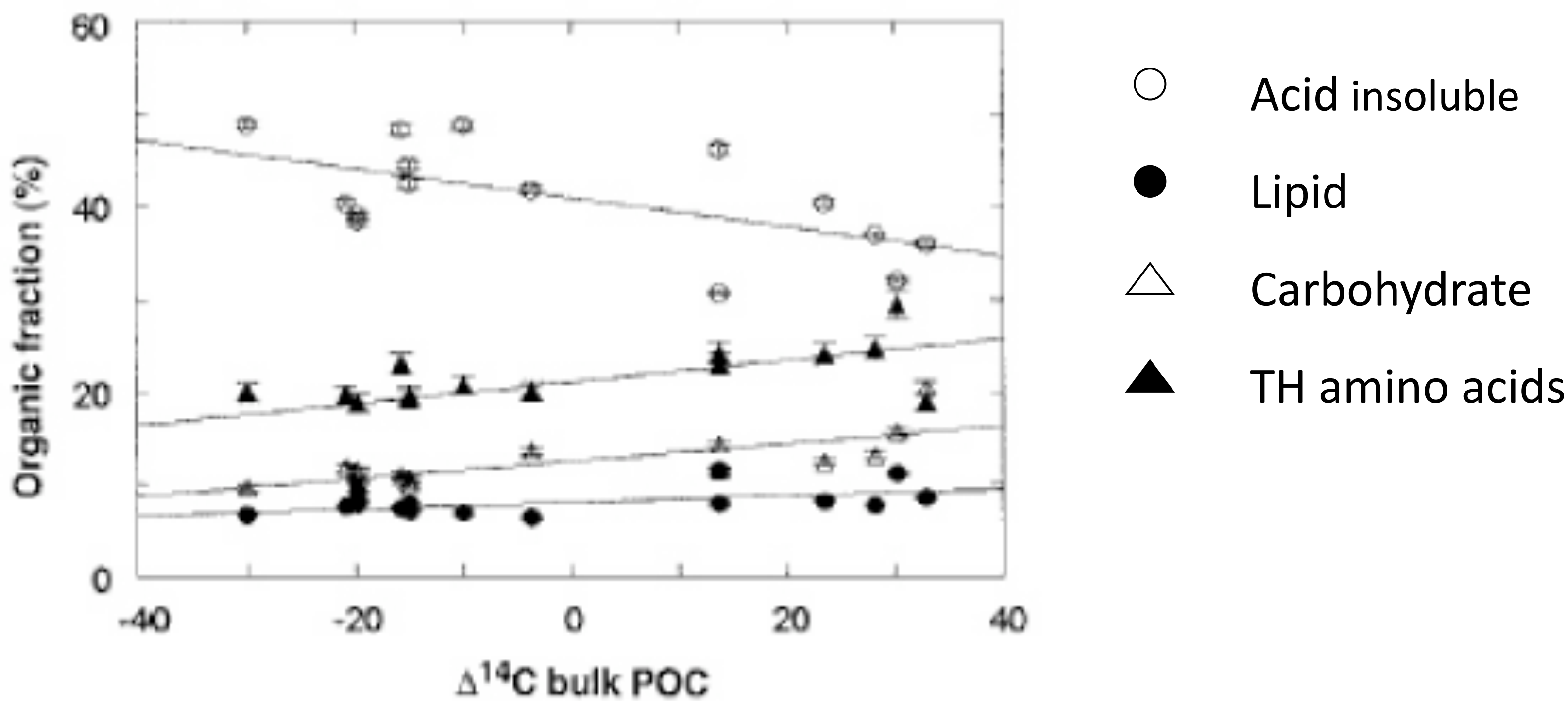
Keil and Kirchman

Particle dynamics and radiocarbon distribution in POC

Druffel et al. DSR (1990) 45: 667-687

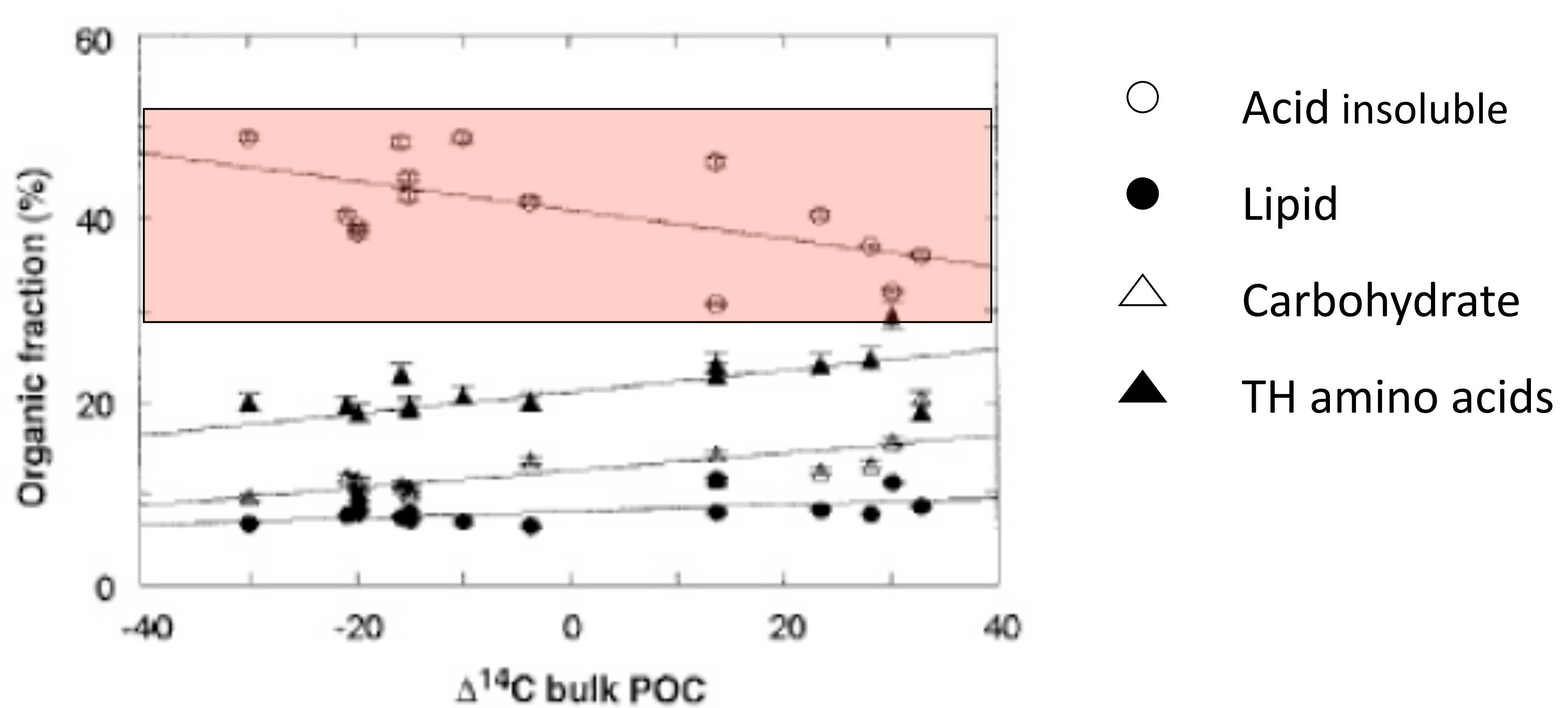


Another way to think about selective preservation….
What are the isotopic consequences of degradation?



J. Hwang & E.R.M. Druffel (2003) *Science*, **299** 881-884

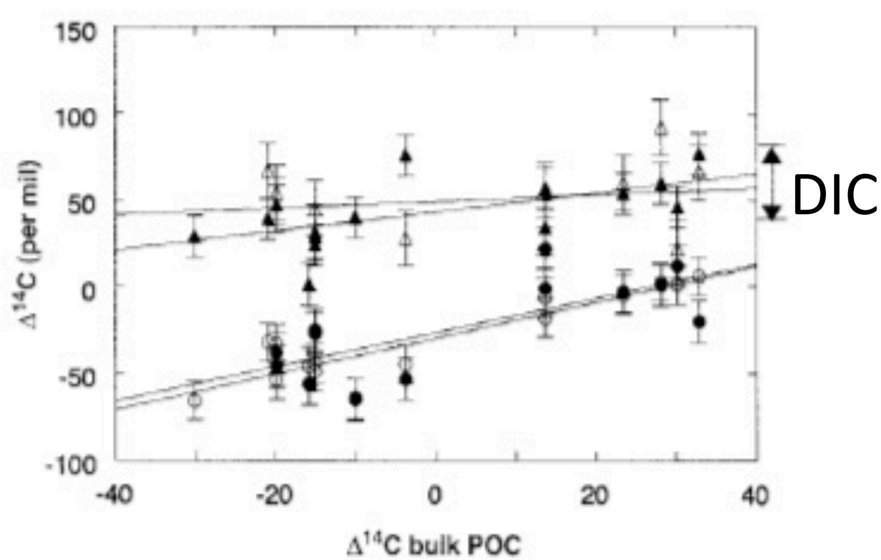
Another way to think about selective preservation….
What are the isotopic consequences of degradation?

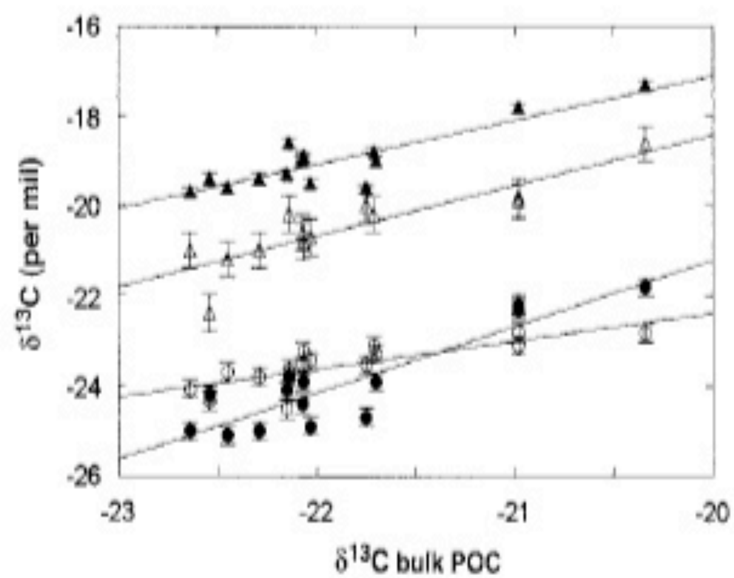


As organic matter ages (14C) the amount of acid insoluble C increases…..

J. Hwang & E.R.M. Druffel (2003) *Science*, **299** 881-884

And the C isotope ratios of the acid insoluble fraction looks a lot like lipids….





○	Acid insoluble	△	Carbohydrate
●	Lipid	▲	TH amino acids

J. Hwang & E.R.M. Druffel (2003) *Science*, **299** 881-884

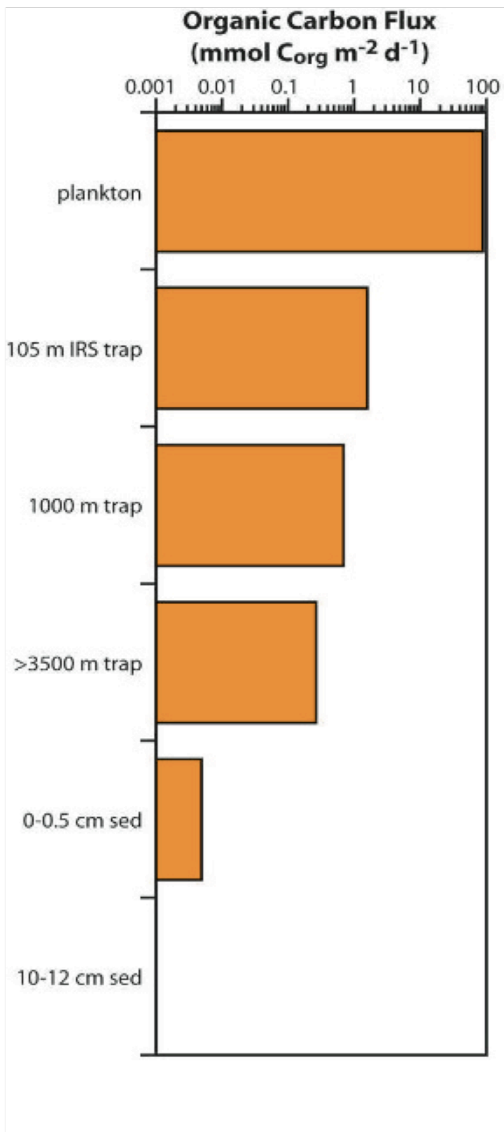
Many studies have shown that the production of organic matter in the water column impacts the amount of export on large particles.

The loss of organic carbon between production and export is very large- most organic carbon is respired in place (euphotic zone or just below), and only a small fraction (10%) leaves the upper ocean. Some of this export is mineralized durning transit to the sea floor and at the sediment water interface. < 1% of organic carbon is buried.

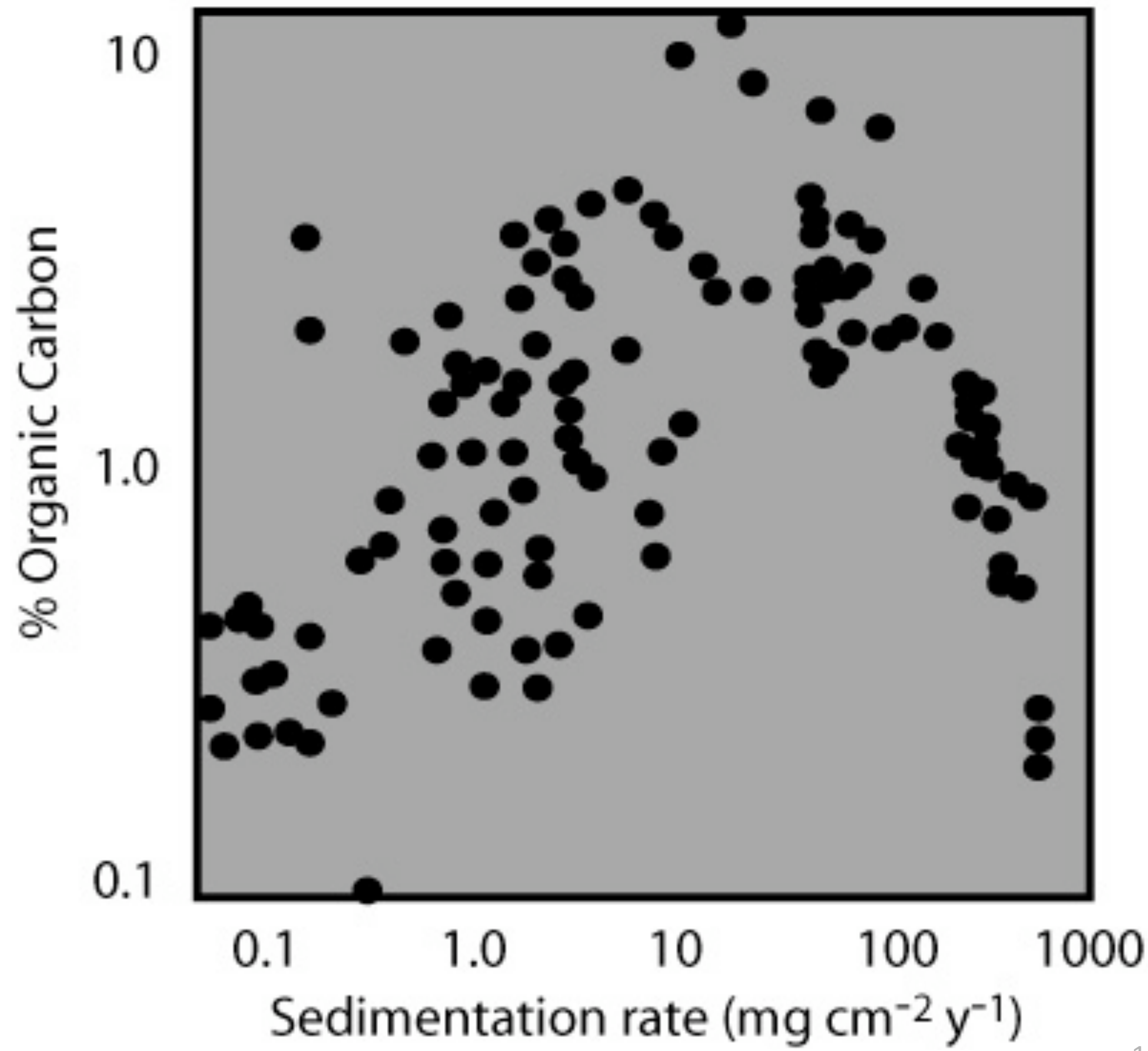
Molecular analyses of suspended and sinking particles have been made for many decades to explore how the organic composition of OM changes during cycling in order to understand how we can interpret the sedimentary record, and why carbon is buried and preserved in sediments.

The results of these studies are inconclusive, and depend on the assumptions and approach used. However, it is clear the molecular composition of OM is edited, both at the specific compound level and in the transfer of organic matter from a fraction we can characterize to one we cannot characterize (MUC- molecularly uncharacterizable carbon).

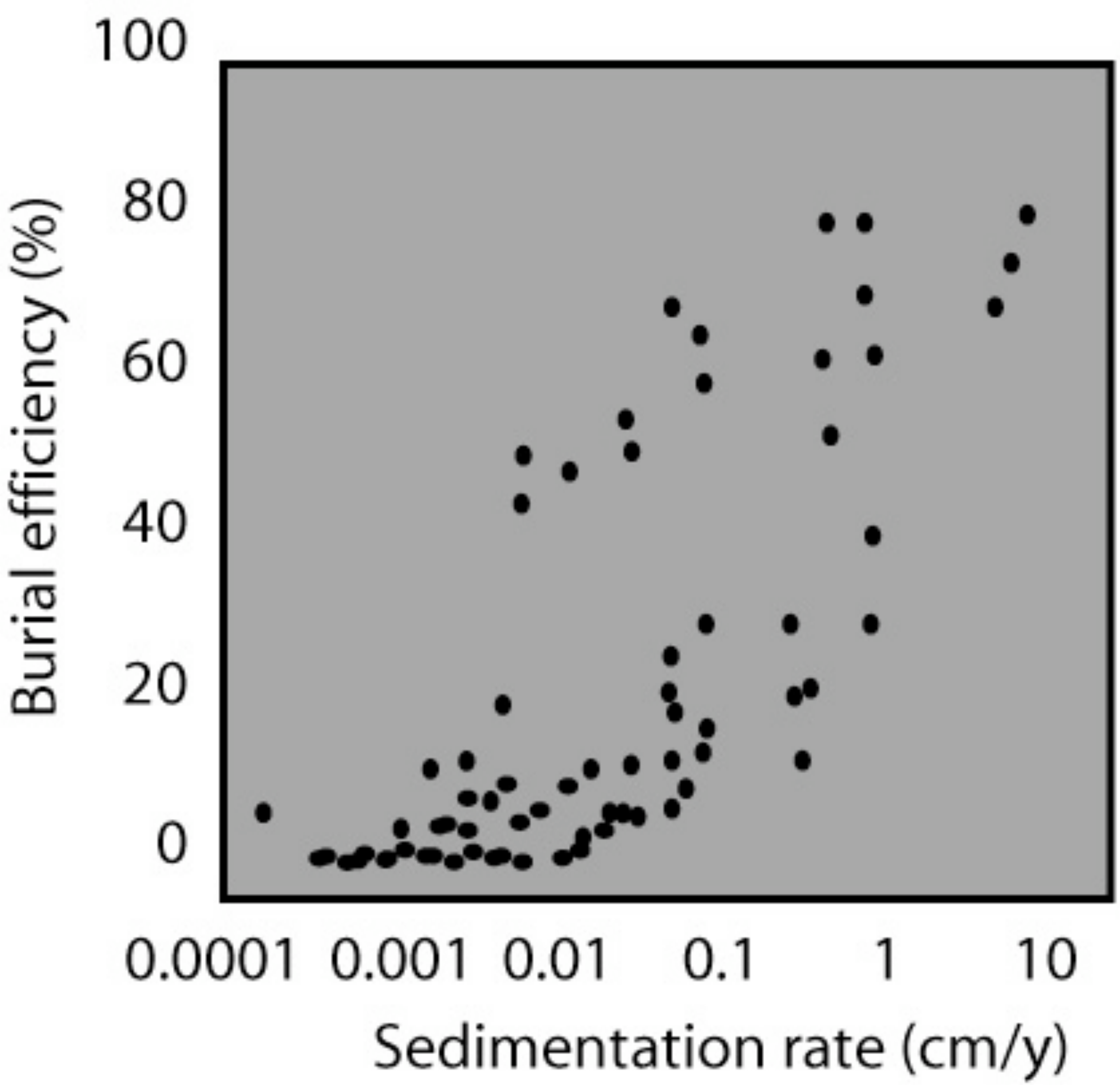
The origin of MUC has led to different conclusions as to why it exists and why it is Preserved (mineral sorption, geoplymerization, physical protection….).



Relationship between % OC and sedimentation rate



Relationship between burial efficiency and sedimentation rate



$$\frac{\text{Carbon buried}}{\text{Carbon flux}} = \text{BE}$$

Burial efficiency accounts for dilution by low carbon debris (carbonate, silica)

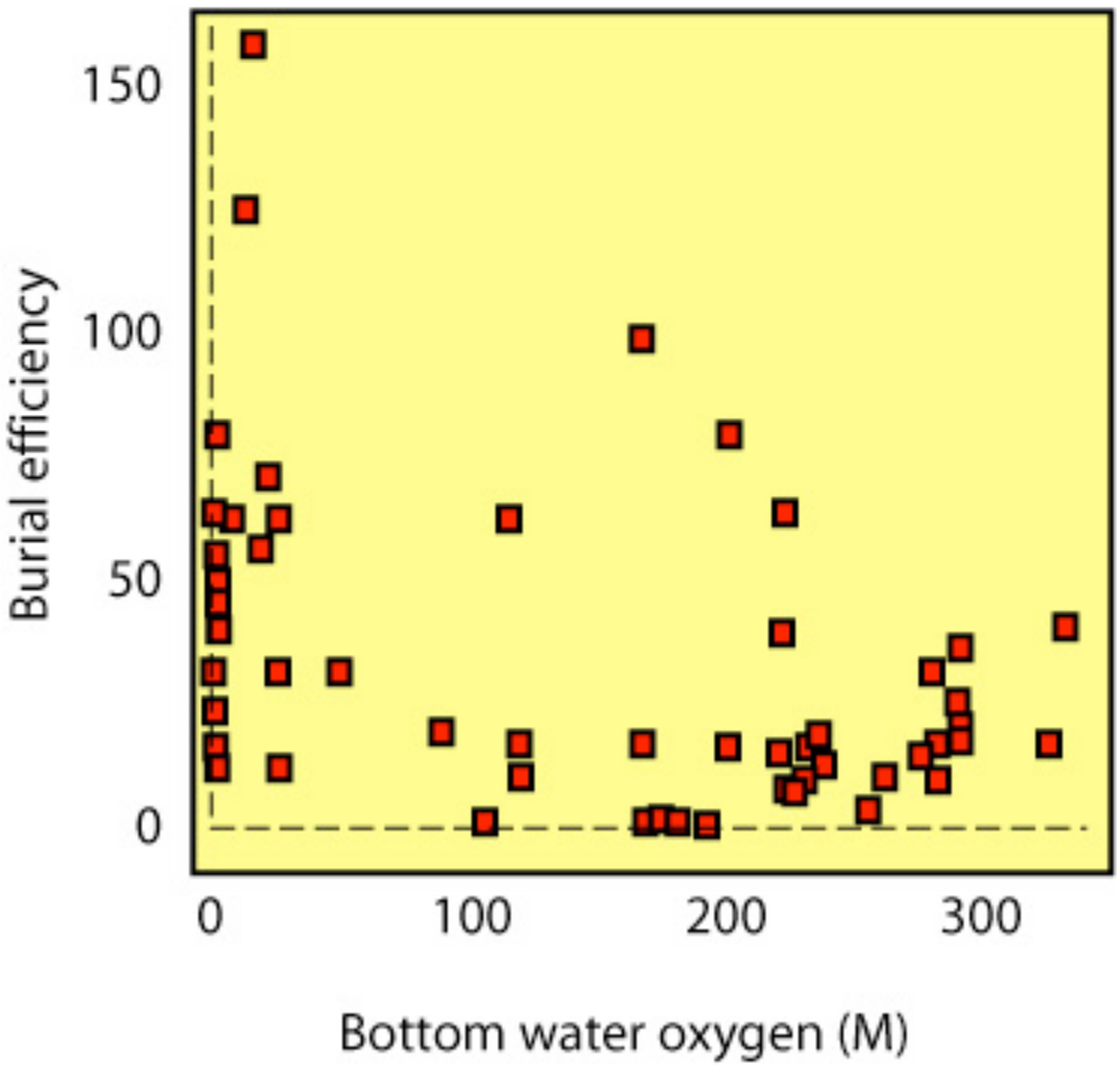
1) Rapid burial moves the C out of the zone of most intense remineralization.

2) Rapid burial "caps" the sediment column and inhibits exchange of O_2, NO_3^-, etc.

3) Rapid burial often occurs at sites where there is a lot of recycled organic carbon.

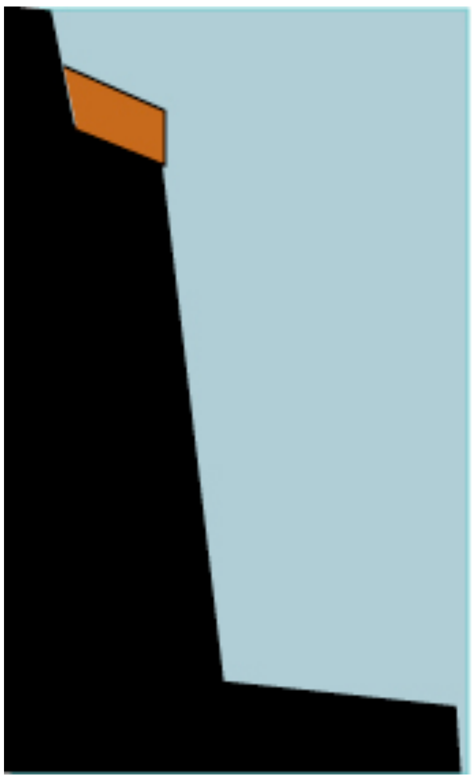
CP factor # 2 the effect of oxygen

The effect of bottom water oxygen on burial efficiency

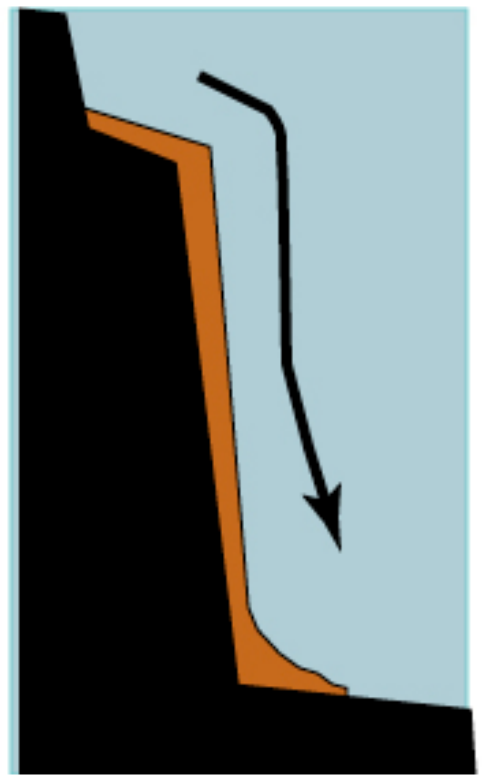


The effect of oxygen on carbon preservation in Maderia Abyssal Plain Turbidites

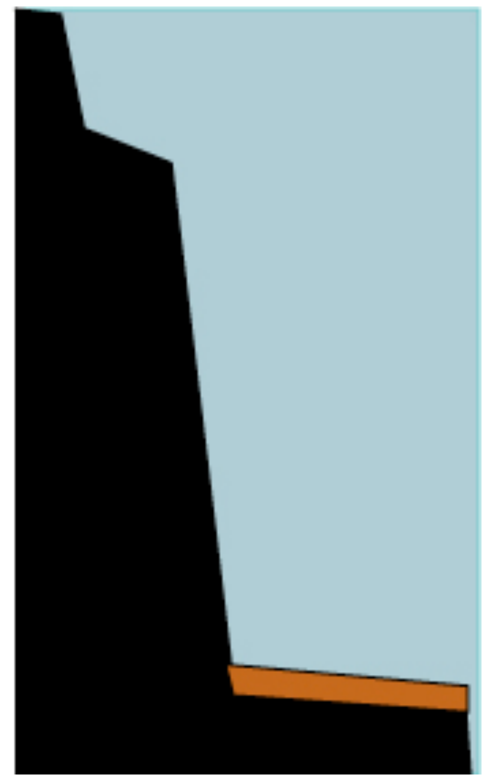
Before…



During…



and Voila!



The effect of oxygen on carbon preservation in Maderia Abyssal Plain Turbidites

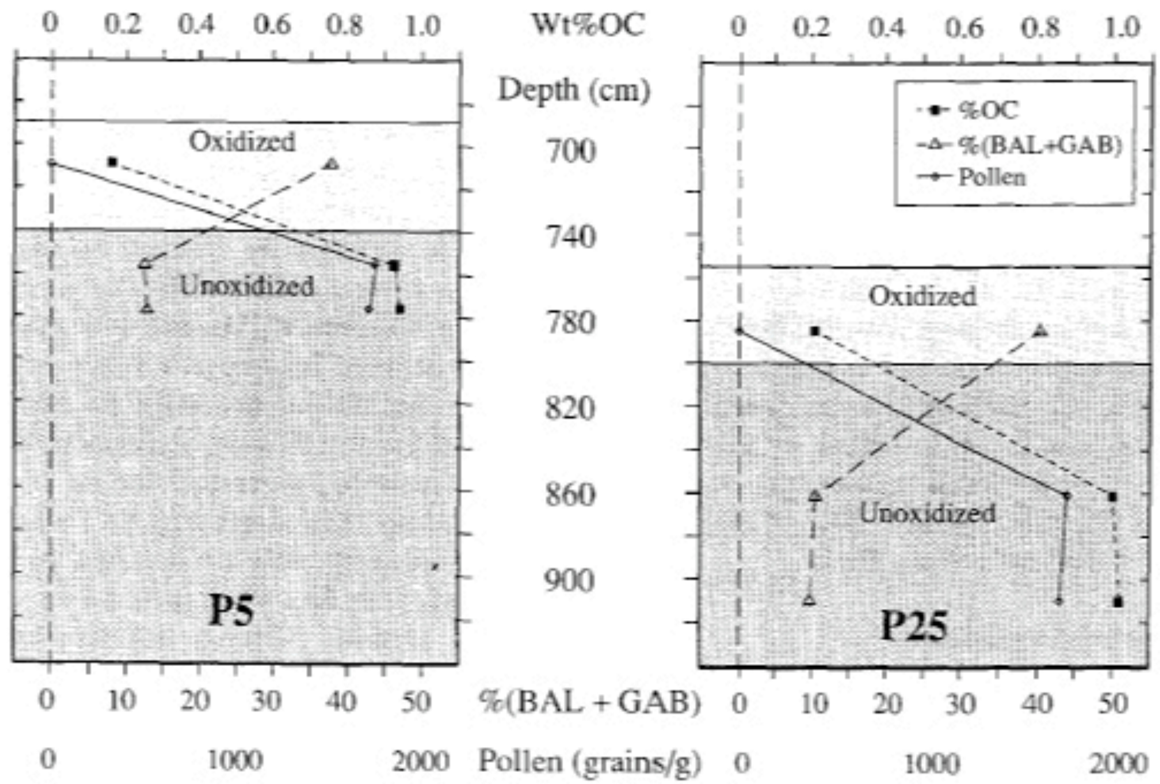
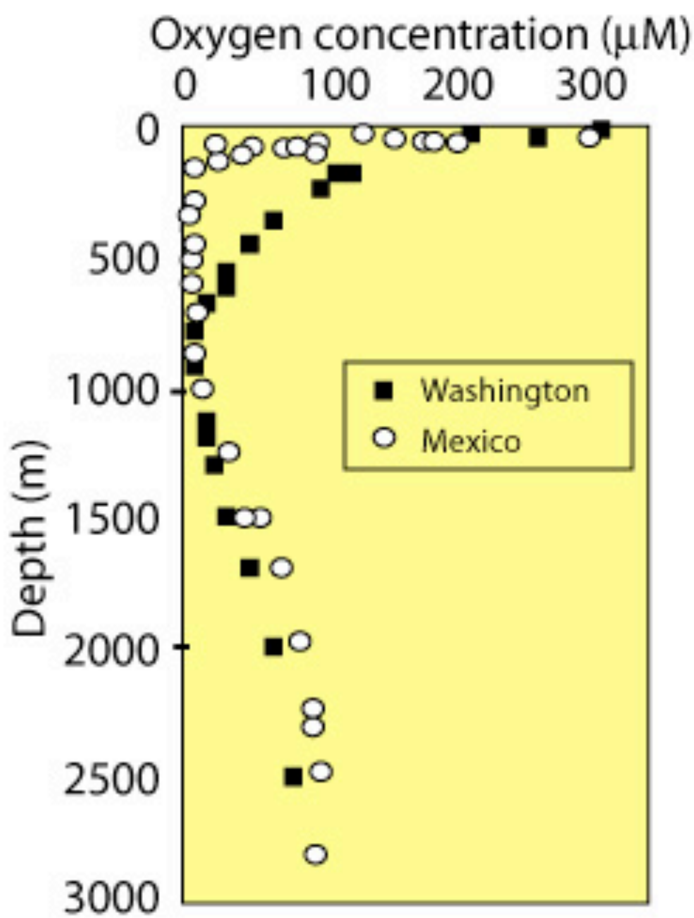
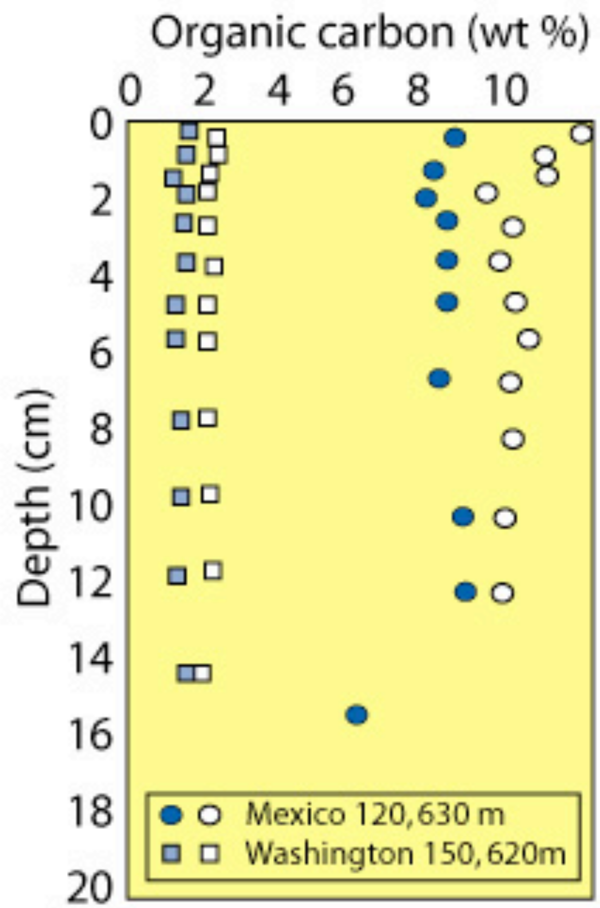


Fig. 10. Depth distributions of (a) weight percent organic carbon, (b) combined mole percent of two nonprotein amino acids (β-alanine plus γ-aminobutyric acid), and (c) total pollen abundances (grains g^{-1}) in oxidized and unoxidized sediments from two cores of the f-turbidite collected at separate sites in the Madeira Abyssal Plain (data from Cowie et al., 1995; Keil et al., 1994b).

The effect of oxygen on carbon preservation in continental margin sediments

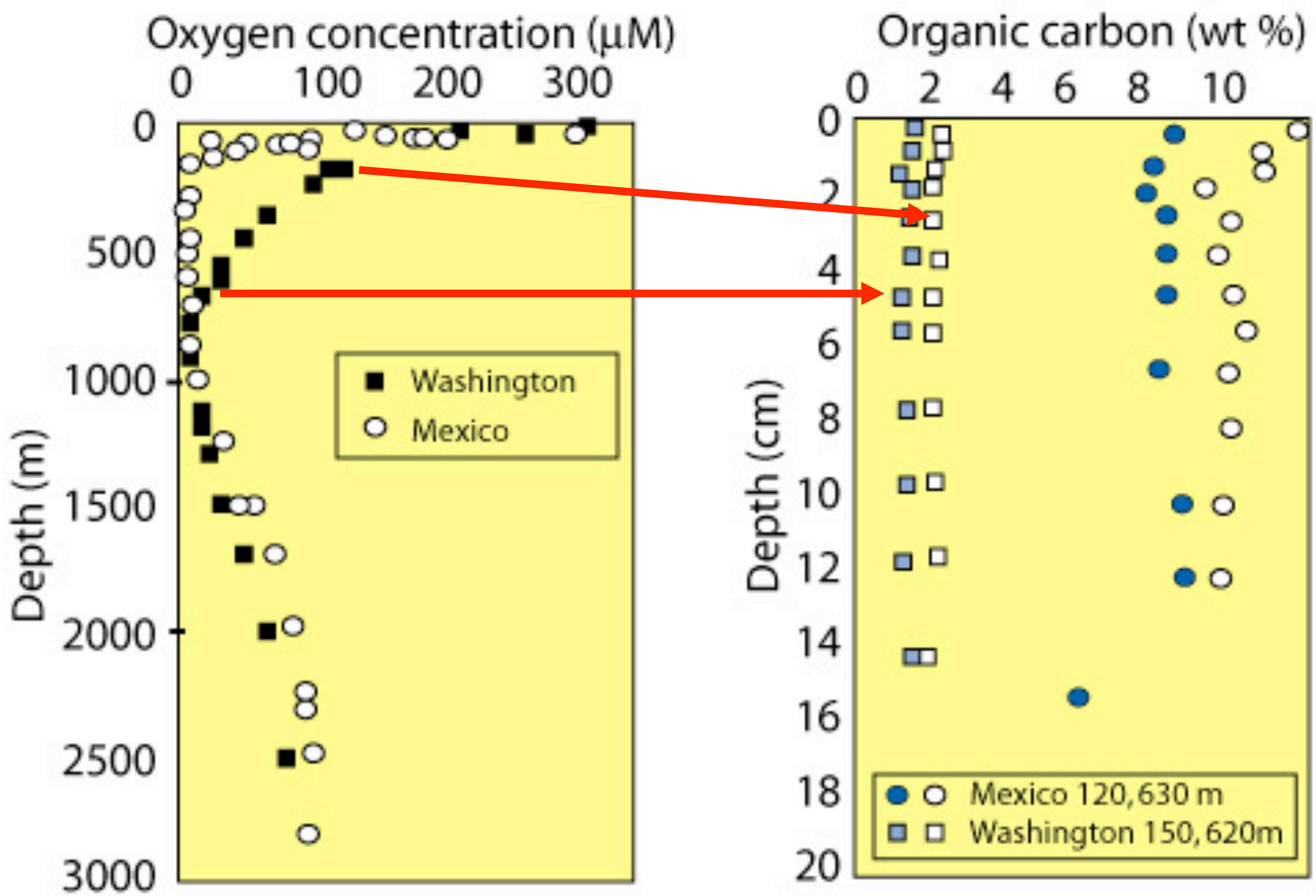
pp on Mexican shelf < Washington shelf; sedimentation rates are similar; O_2 is very different





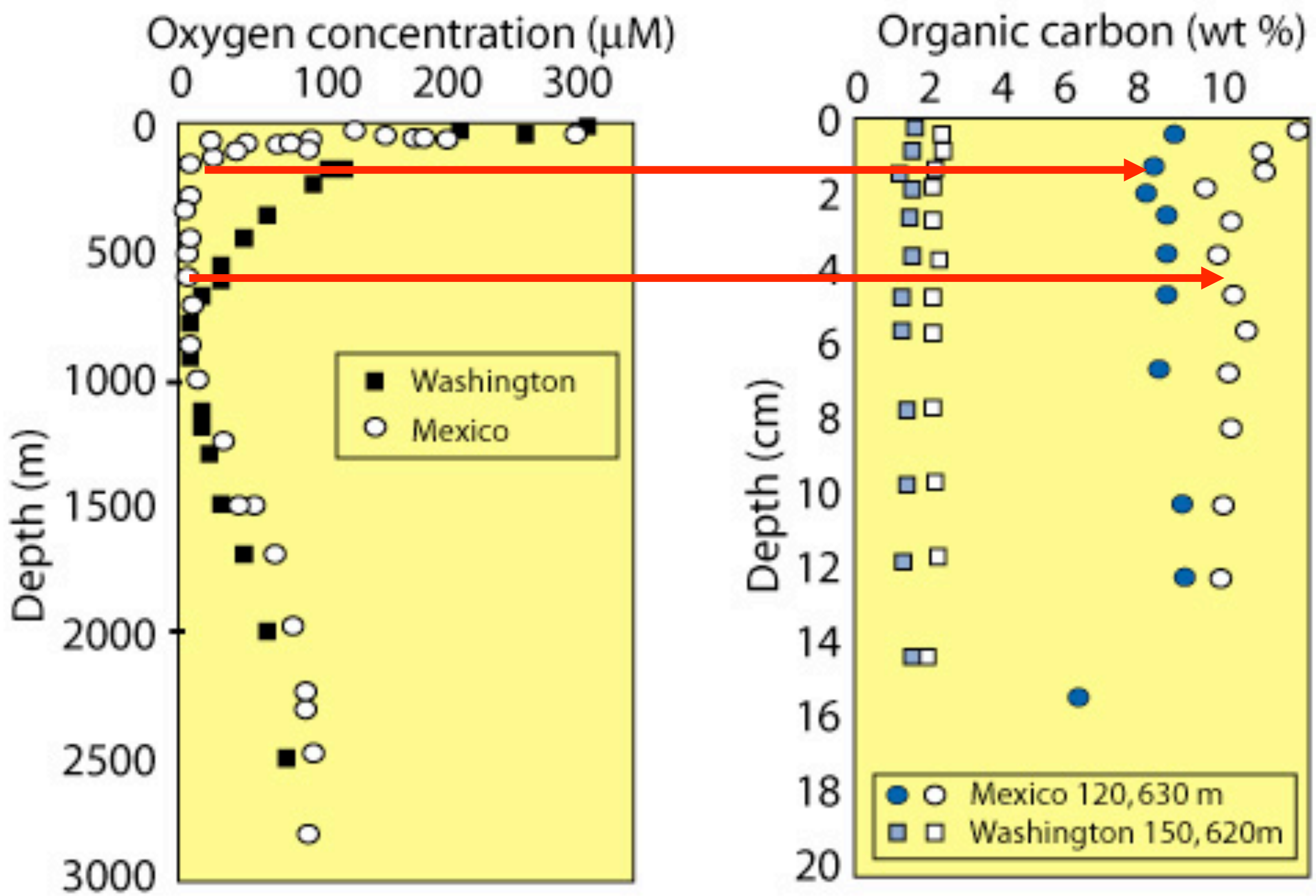
Hartnett et al. (1998) Nature v391, 572-574

The effect of oxygen on carbon preservation in continental margin sediments



Hartnett et al. (1998) Nature v391, 572-574

The effect of oxygen on carbon preservation in continental margin sediments



Hartnett et al. (1998) Nature v391, 572-574

Comparison of Washington and Mexican margin sediments

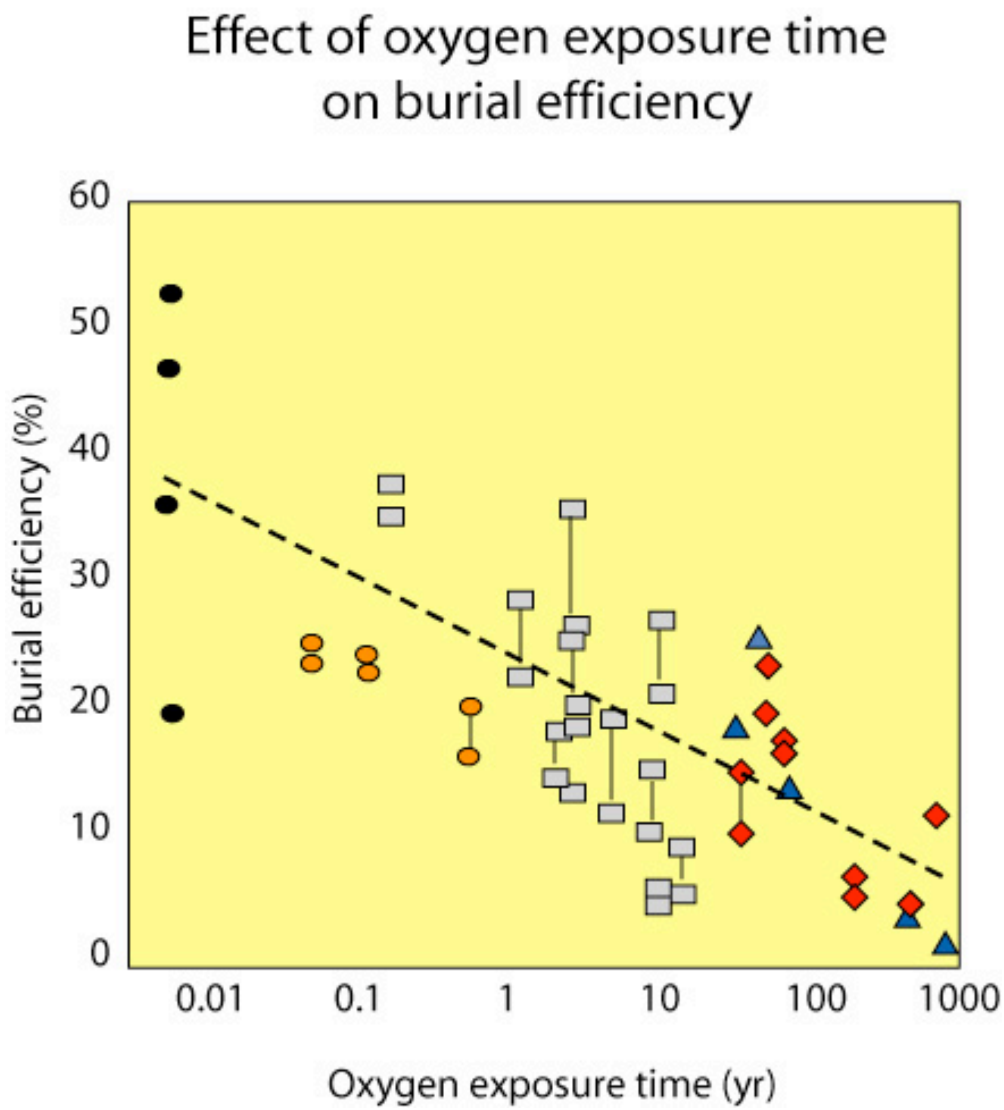
Table 1 Measured and calculated parameters for Washington and Mexican margin sediments

	Bottom water O_2 ($\mu mol\ l^{-1}$)	Organic carbon (wt%)	Sediment accumulation rate* ($mg\ cm^{-2} yr^{-1}$)	Organic carbon burial ($\mu mol\ cm^{-2} yr^{-1}$)	Organic carbon oxidation ($\mu mol\ cm^{-2} yr^{-1}$)	Burial efficiency (%)	O_2 exposure time (yr)
Washington							
Shelf†							
Average ($n = 8$)	92.8	1.31	102	117	675	15.1	3.92
Range	(77–106)	(0.55–1.8)	(61–130)	(28–169)	(506–790)	(3.75–17.8)	(1.1–10.5)
Upper slope							
Average ($n = 6$)	71.5	1.59	66.9	90.1	316	25.7	6.42
Range	(38–104)	(0.5–2.8)	(37–100)	(27–210)	(91–607)	(4.69–42.7)	(1.4–14.4)
Mexico							
Shelf‡							
Average ($n = 4$)	15.4	4.7	14.9	50.9	183	23.3	0.252
Range	(3–0)	(2.9–7.1)	(9.1–25.6)	(195–392)	(157–200)	(18.8–26.3)	(0.051–0.587)
Slope							
Average ($n = 4$)	5.3	10.1	6.87	61.7	91.3	38.2	0.032
Range	(0.0–12)	(7.5–12.8)	(4.1–12.7)	(160–845)	(55–121)	(19.9–53.1)	(0.0–0.16)

* Sediment accumulation rates and wt% OC determinations were made on the same cores; these cores were collected at the stations where benthic flux chamber measurements were made.
† Washington shelf and upper-slope stations had depths in the range 0–200 m and 200–600 m, respectively.
‡ The Mexican shelf extends to ~150 m and the Mexican slope stations range from 150 to 1,000 m.

Hartnett et al. , Nature 1998

The effect of oxygen has been refined somewhat to adjust for differences in exposure time, which is related to sedimentation rate (depth of O_2 penetration/sedimentation rate) = OET



What are the potential mechanisms? Aerobic and anaerobic degradation

Cellulose

↓

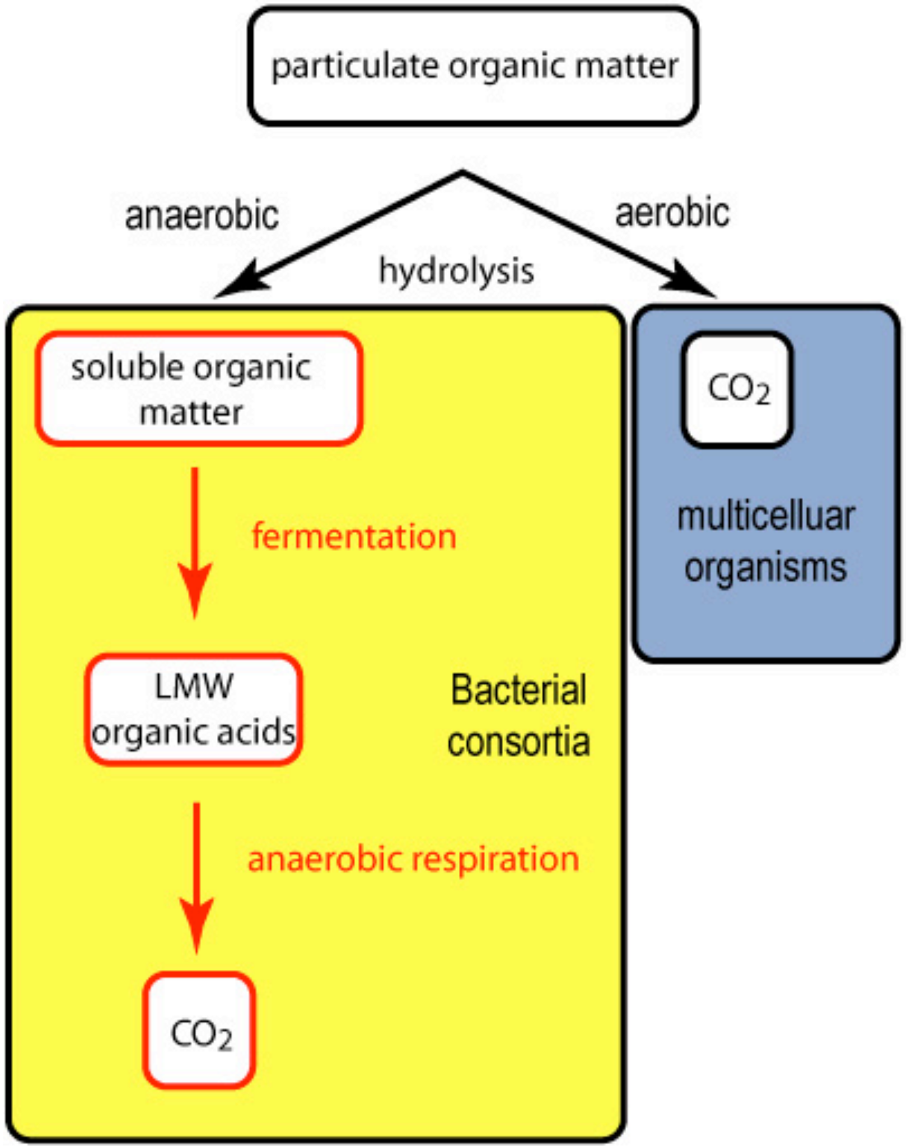
Glucose

↓

Acetic Acid

↓

CO_2



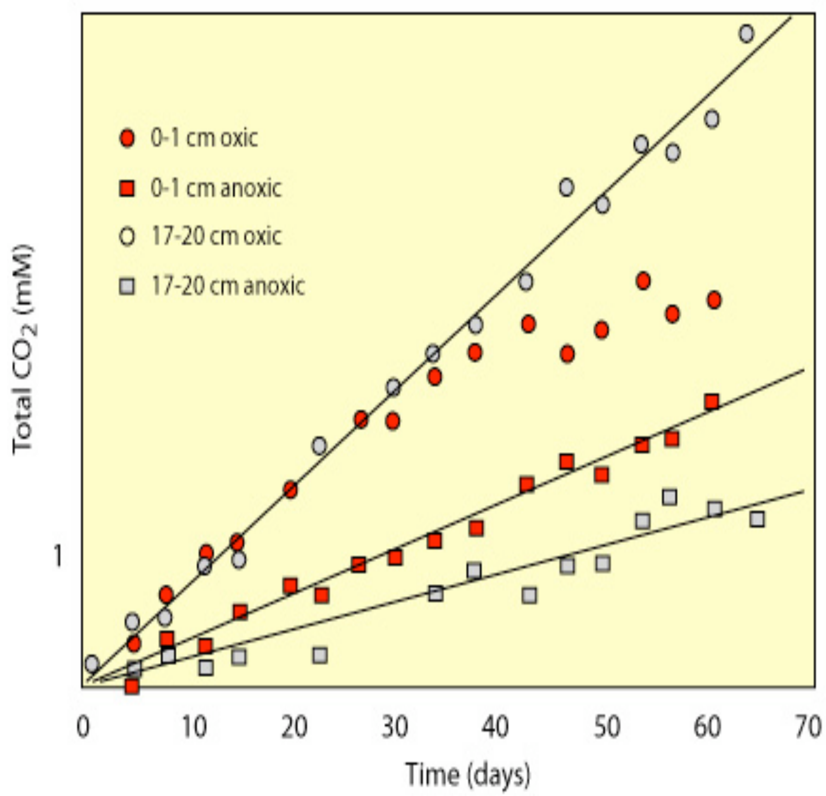
Cellulose

↓

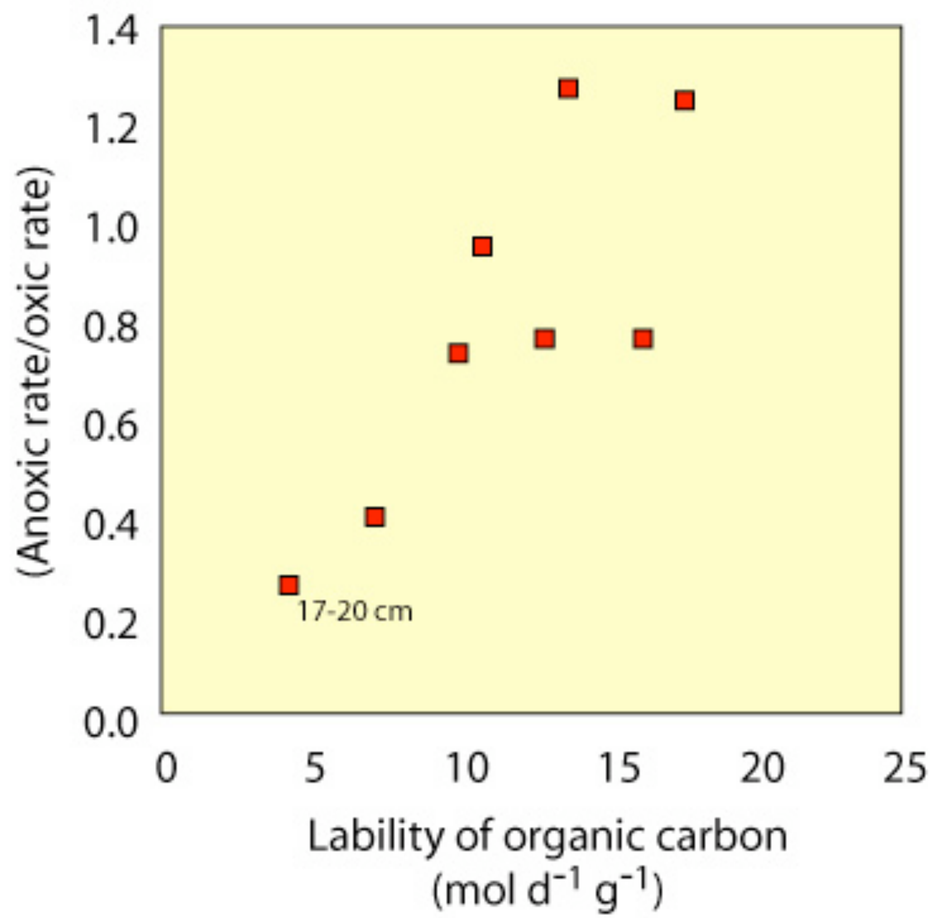
CO_2

Is carbon more efficiently respired under oxic or anoxic conditions ?

Respiration of carbon in 0-1 cm and 17-20 cm sediment under oxic and anoxic conditions



Oxidation rate and the lability of organic carbon



Summary……

There are a number of ways to think about carbon preservation in sediments - % OC, burial efficiency, C accumulation rate.

There are sharp reduction in C transfer in the euphotic zone and at the sediment water interface, so that processes occurring at these two sites are considered to be key determinants of C preservation.

There is a general (but weak) correlation between sedimentation rate and % OC in sediments and burial efficiency, suggesting some sort of relationship, but the underlying factors are not clear.

There is no relationship between bottom water oxygen and burial efficiency. Oxygen appears to play a factor, and its effect has been refined to include both oxygen concentration and sedimentation rate (contact time).

The structure of heterotrophic communities in oxic and anoxic systems is Thought to be an underlying factor in C preservation. Anaerobic processes Can mineralize labile carbon as quickly and efficiently as aerobic processes, but This is not true for reworked organic matter. Composition may make a difference.