What are the mechanisms of C preservation?

Primary production: The higher PP, the higher the flux of OM, the more rapidly the C/N/P transits the “reactive” zone of active C degradation.

Oxygen: Anaerobic systems require microbial consortia to degrade OM that are inherently less efficient than aerobic organisms. Low oxygen limits the presence of aerobic respiration thereby preserving C. Longer initial preservation, or other factors (presence of S-) may lead to more extensive “geopolymerization” that more permanently preserves C.

There are intrinsically labile and non-labile structures of biomolecules. The mix of these will affect the amount of C preserved.

If you want to understand why C is preserved in marine sediments, look at where it is buried….

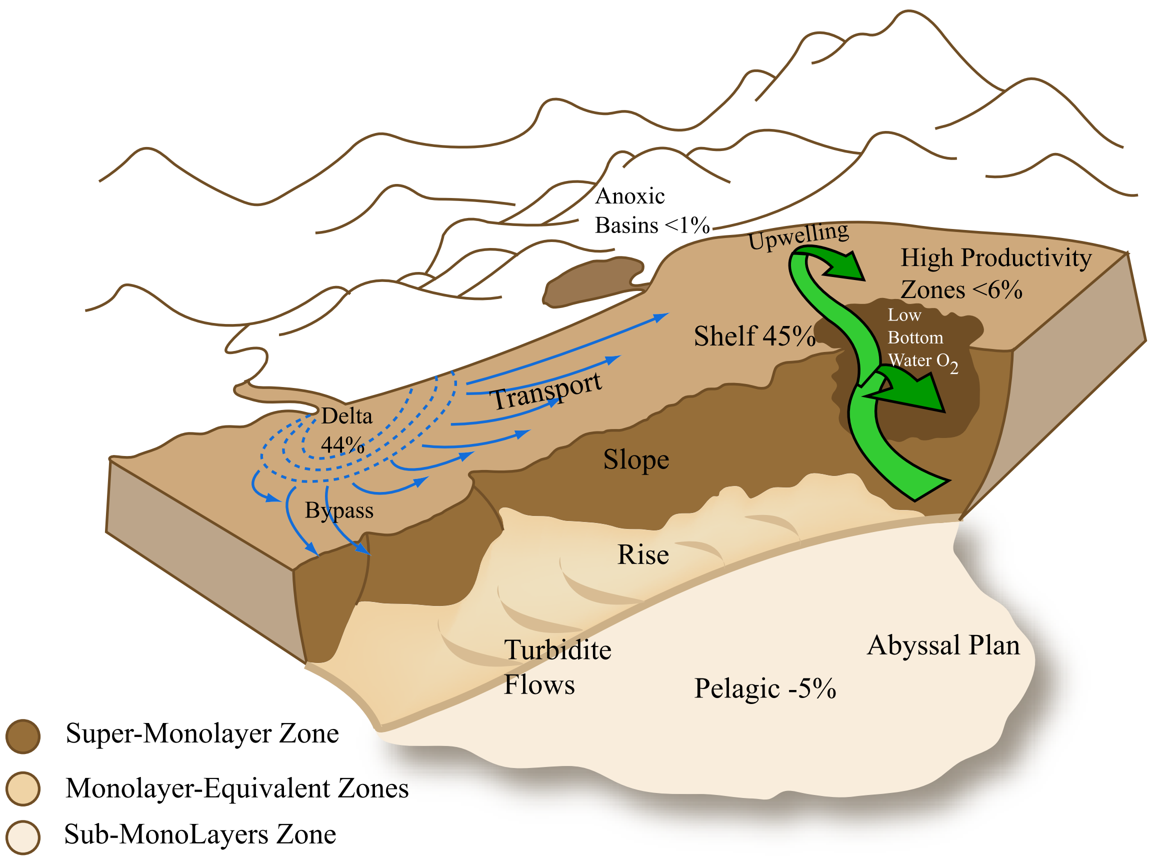


Fig.1 Idealized diagram depicting current estimates of the percentage of the total organic matter burial occurring within various marine sediment types (see Table 2). Light sections represent sediments which contain organic loading lowe yr than a monolayer equivalent stippled sediments contains monolayer-equivqlent loadings, and dark sediments contain loadings that are more than monolayer-equivalent.

Figure by MIT OCW.

Tabulation of C burial in marine sediments

Organic Carbon Burial Rates (and percentages) in Different Ocean Regimes

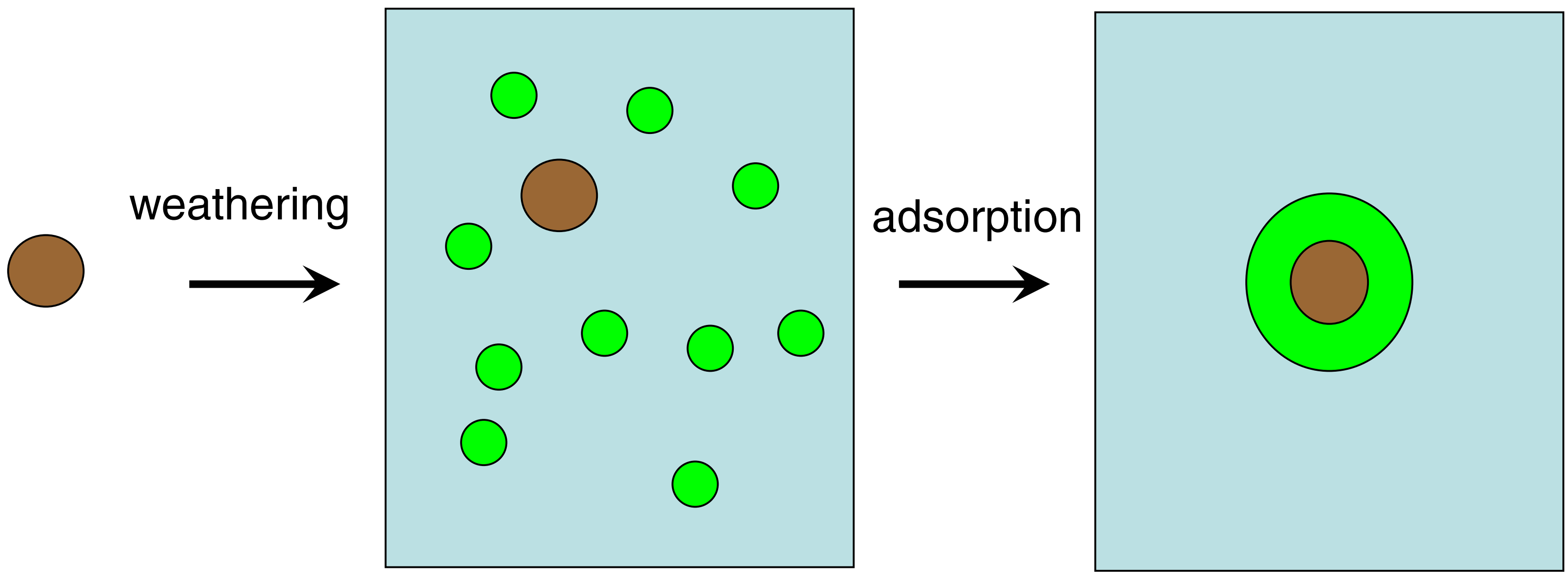
Sediment type	Deltaic	Shelf	Slope	Pelagic	Total
Data from Gershanovich et al. (1974)					
All sediment types	0 (0)	23 (10)	195 (88)	5 (2)	223
					e = 223
Data from Berner (1989)					
Terrigenous deltaic-shelf sediments	104 (82)	0	0	0	104
Biogenous sediments (high-productivity zones)	0	0	7 (6)	3 (2)	10
Shallow-water carbonates	0	6 (5)	0	0	6
Pelagic sediments (low-productivity zones)	0	0	0	5 (4)	5
Anoxic basins (e.g. Black Sea)	0	1 (1)	0	0	1
					Σ = 126
Recalculation of data from Berner (1989)					
Deltaic sediments	70 (44)	0	0	0	70
Shelves and upper slopes	0	68 (42)			68
Biogenous sediments (high-productivity zones)	0	0	7 (4)	3 (2)	10
Shallow-water carbonates	0	6 (4)	0	0	6
Pelagic sediments (low-productivity zones)	0	0	0	5 (3)	5
Anoxic basins (e.g. Black Sea)	0	1 (0.5)	0	0	1
					Σ = 160

Units are 1012 gCyr-1 (parenthetical units = percent of total burial).
*Deltaic-shelf sediments were reapportioned assuming that 33% of the sediment discharge from rivers is deposited either along non-delatic shelves or upper slopes, and assuming that those deposits have total loadings of 1.5% organic carbon rather than 0.7% as in delatic regions. Estimate for all other regions remain the same.

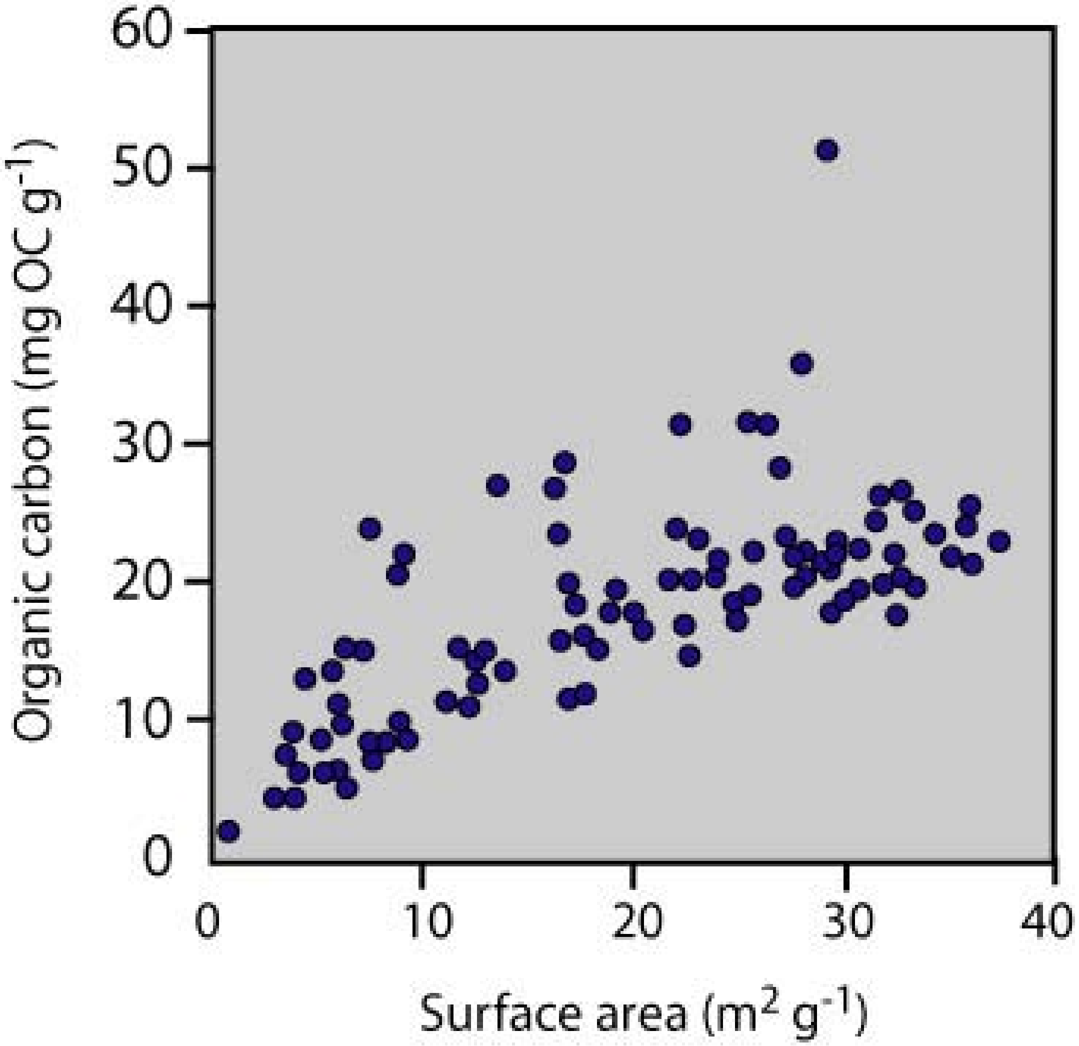
Figure by MIT OCW.

Protection and preservation of C on mineral surfaces

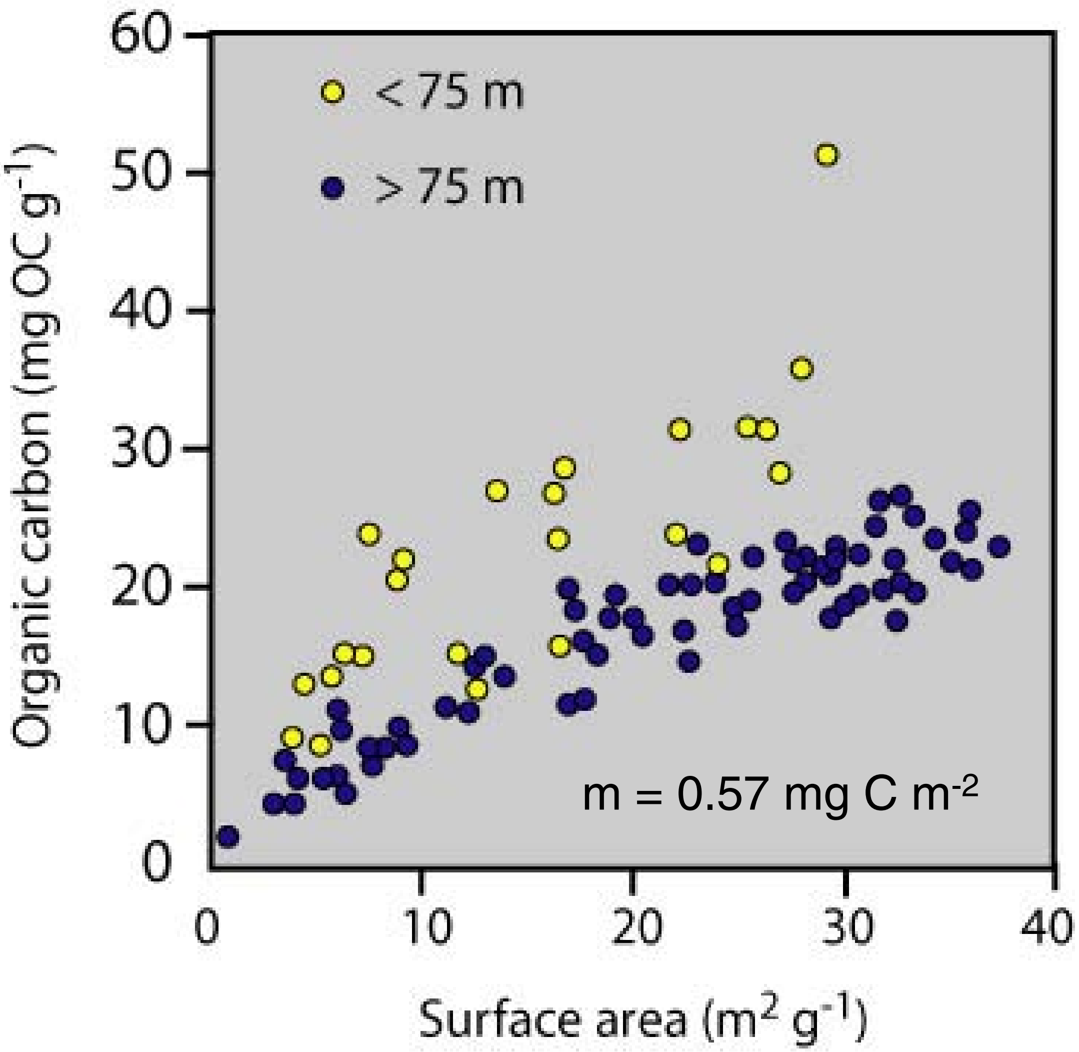
Larry Mayer and others reasoned that there is no such thing as a naked mineral surface in seawater. Further, the amount of C that can be loaded onto a sediment particle is proportional to its surface area.



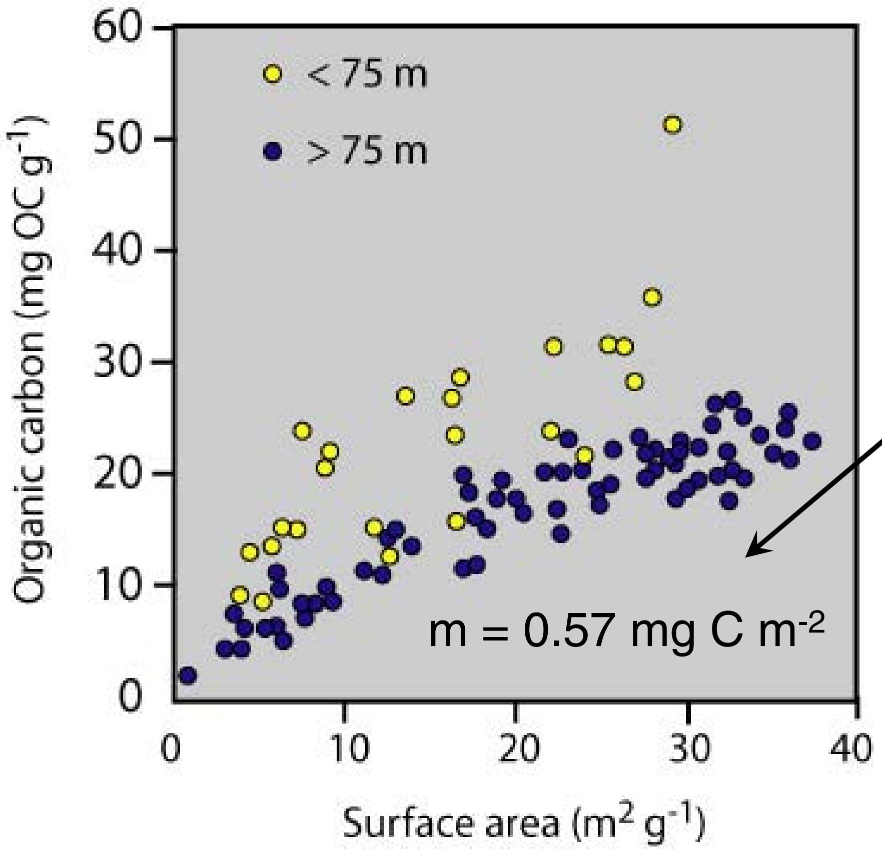
Organic carbon *vs* surface area for sediments from the Gulf of Maine



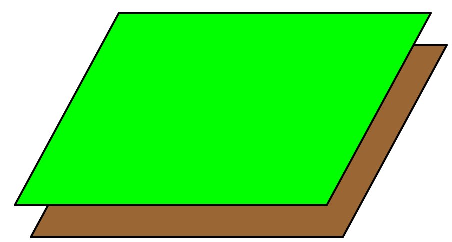
Organic carbon *vs* surface area for sediments from the Gulf of Maine



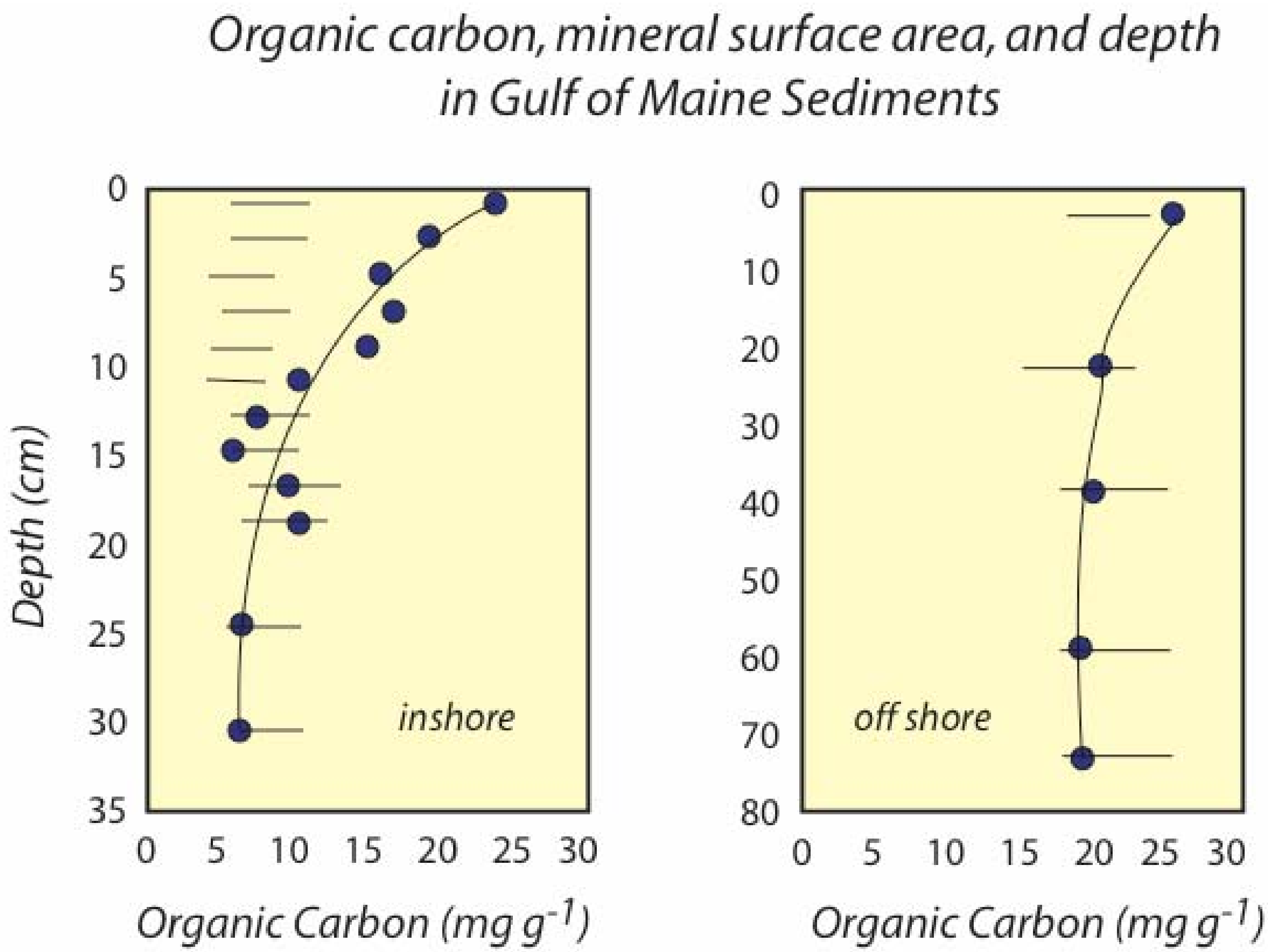
Organic carbon *vs* surface area for sediments from the Gulf of Maine



Monolayer equivalent (ME) loading



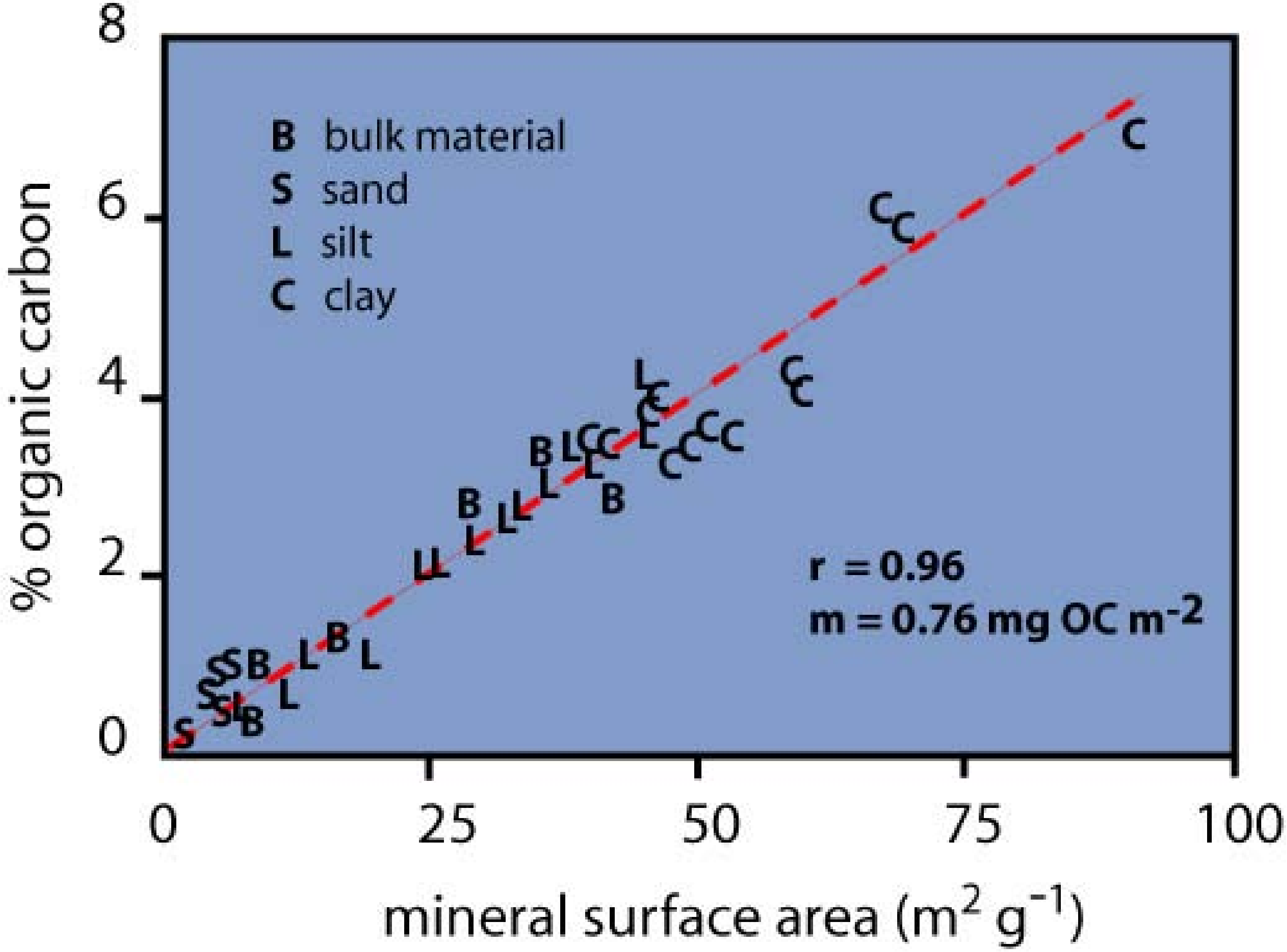
Surfaces are coated with organic matter to the equivalent of one molecule thick…



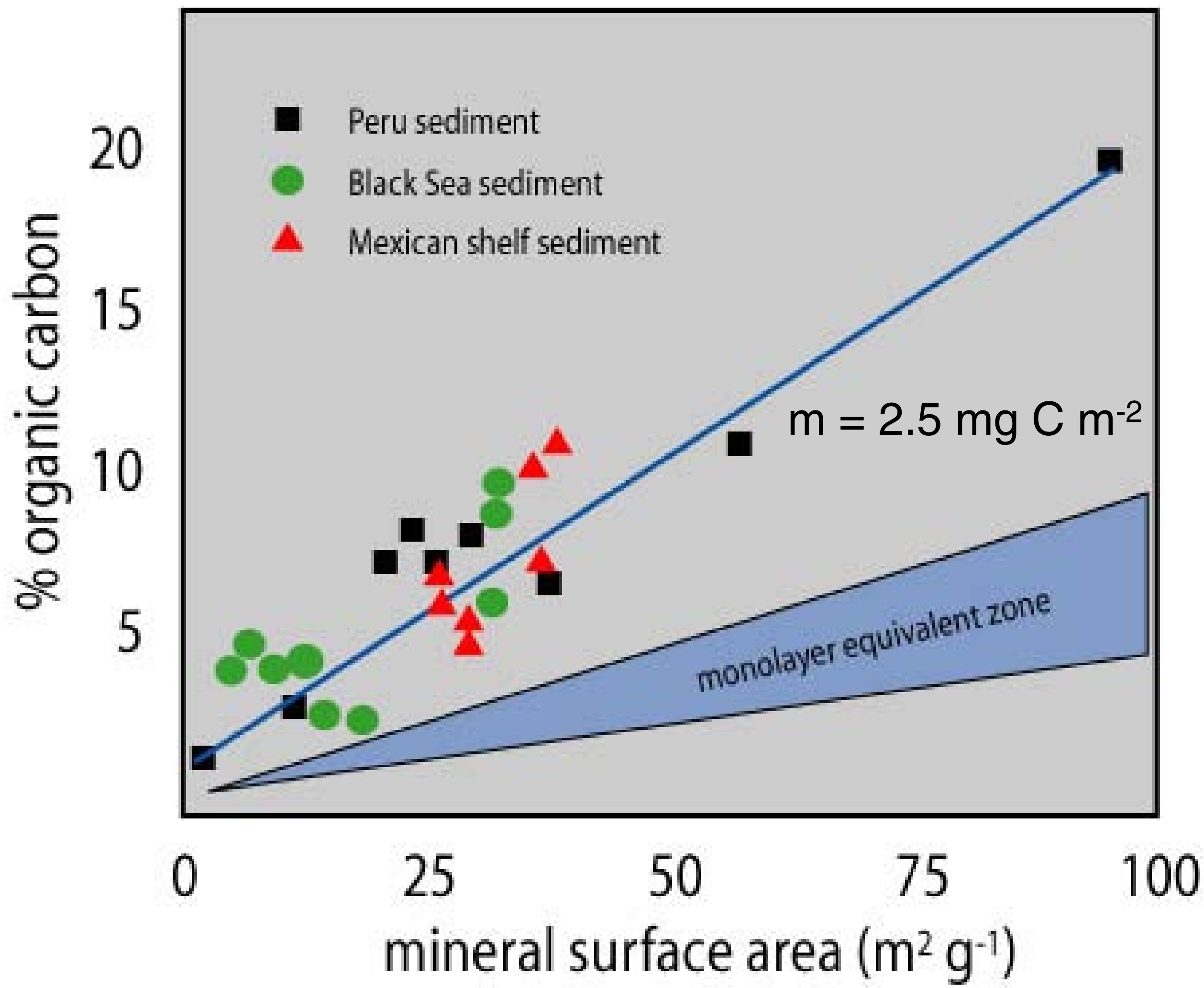
Sediments may be overloaded with C due to biogeochemical cycling, but eventually diagenesis will reduce the C load to a set surface area vs %OC value

Mineral surface area vs %organic carbon for Columbia River Sediments

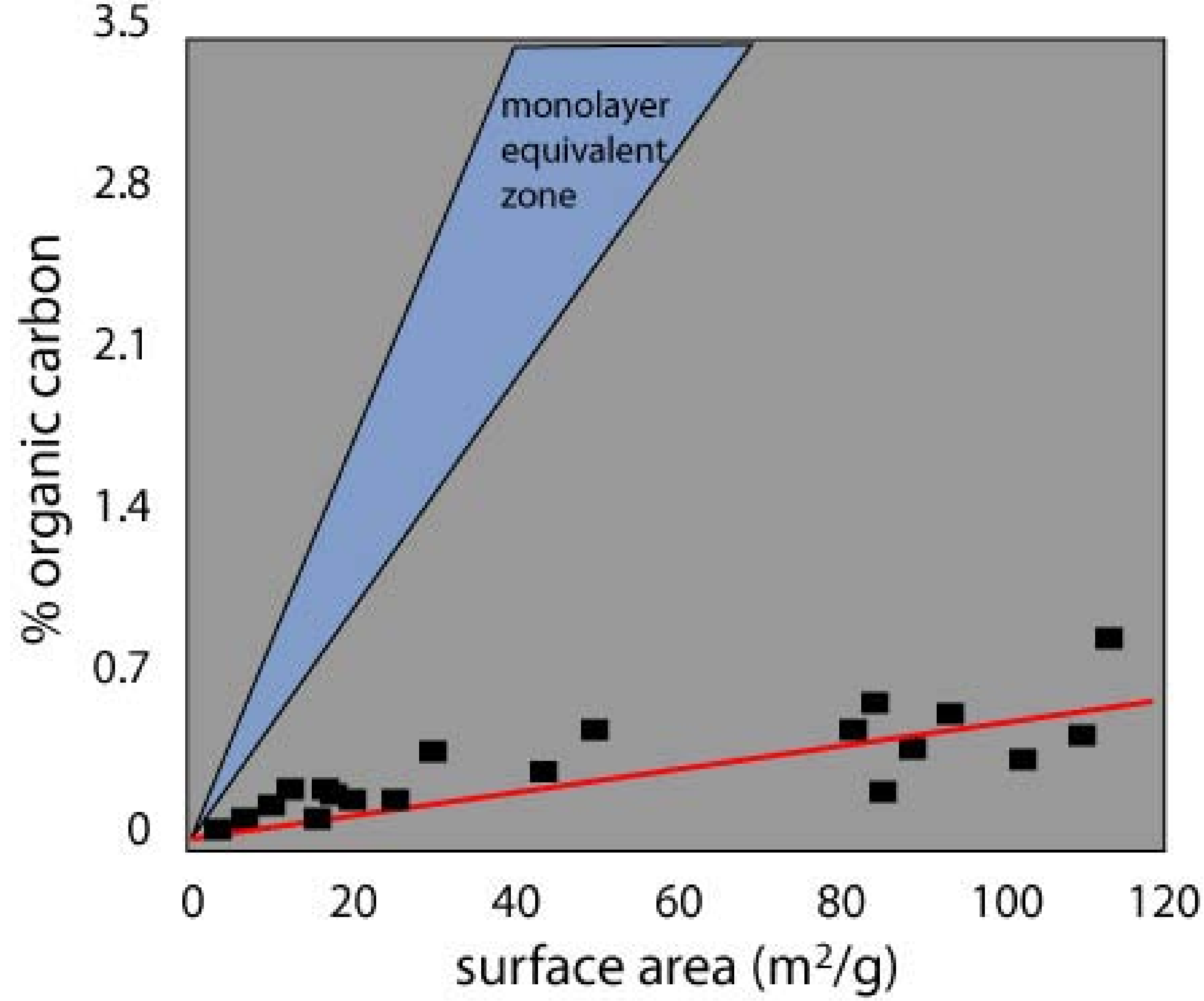
(Hedges and Keil, Mar. Chem (1995) 49, 81-115.)



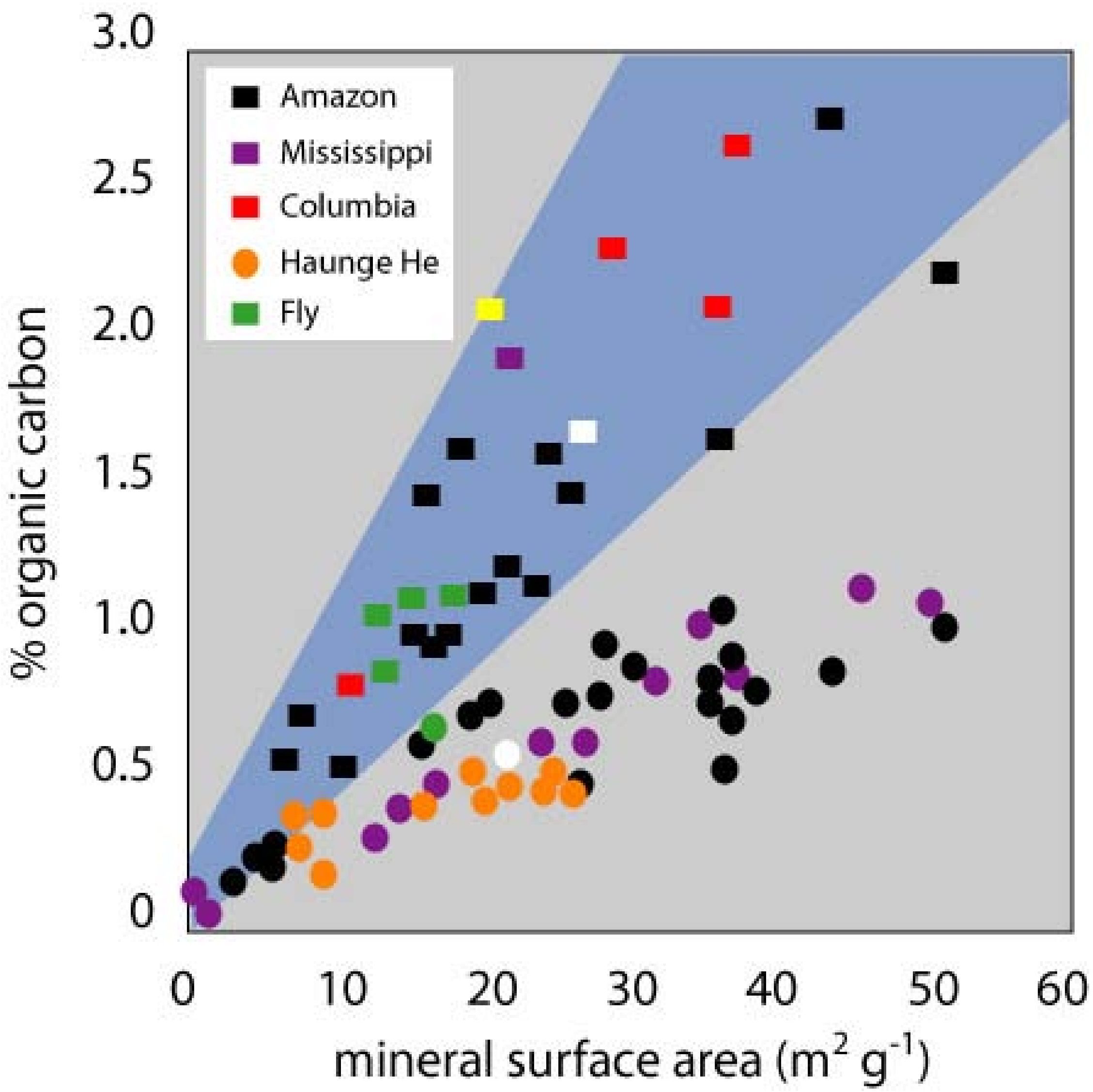
Surface area vs %organic carbon for sediments from low oxygen depositional regimes



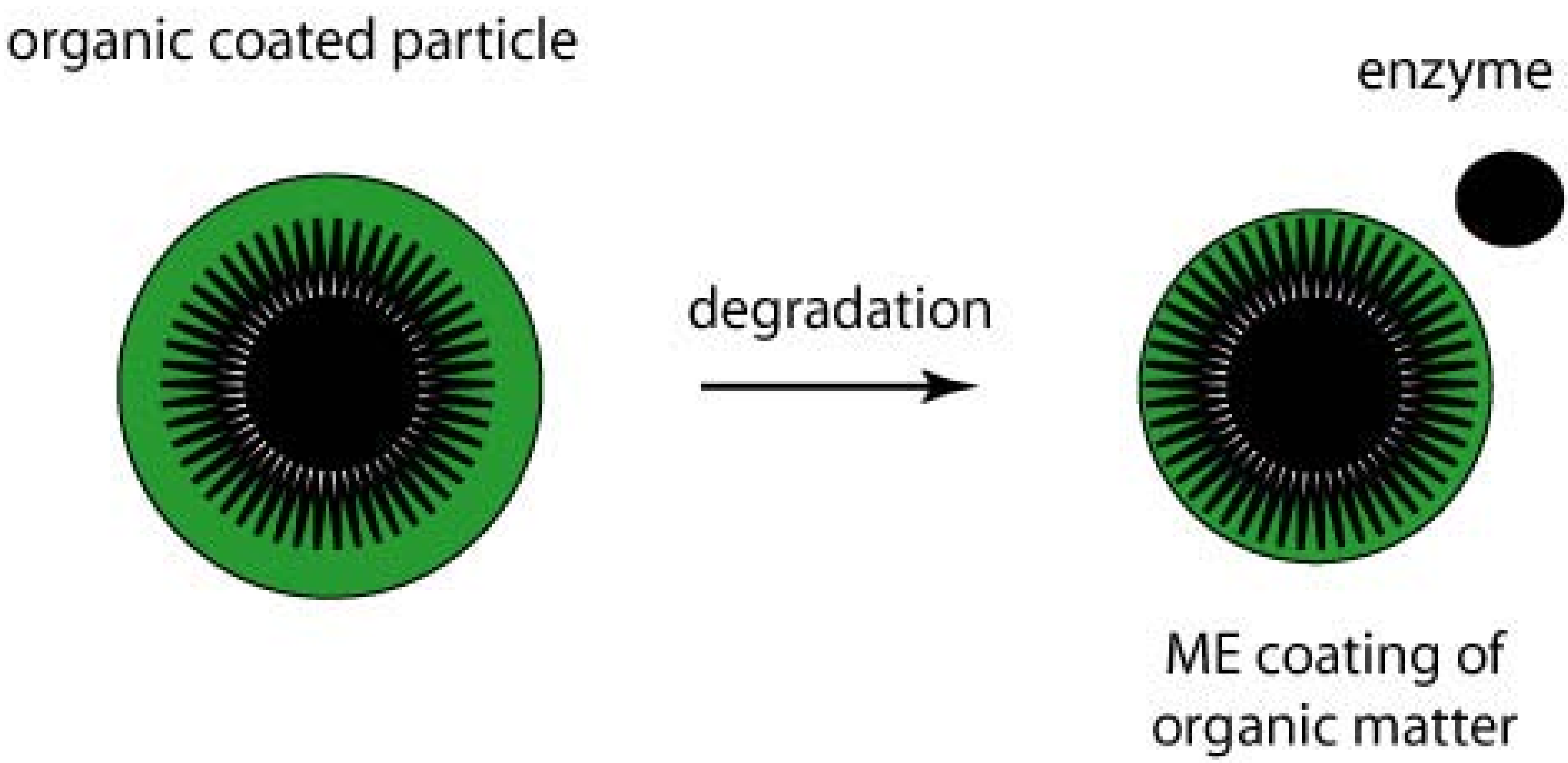
Surface area vs % organic carbon for Equatorial Pacific sediments



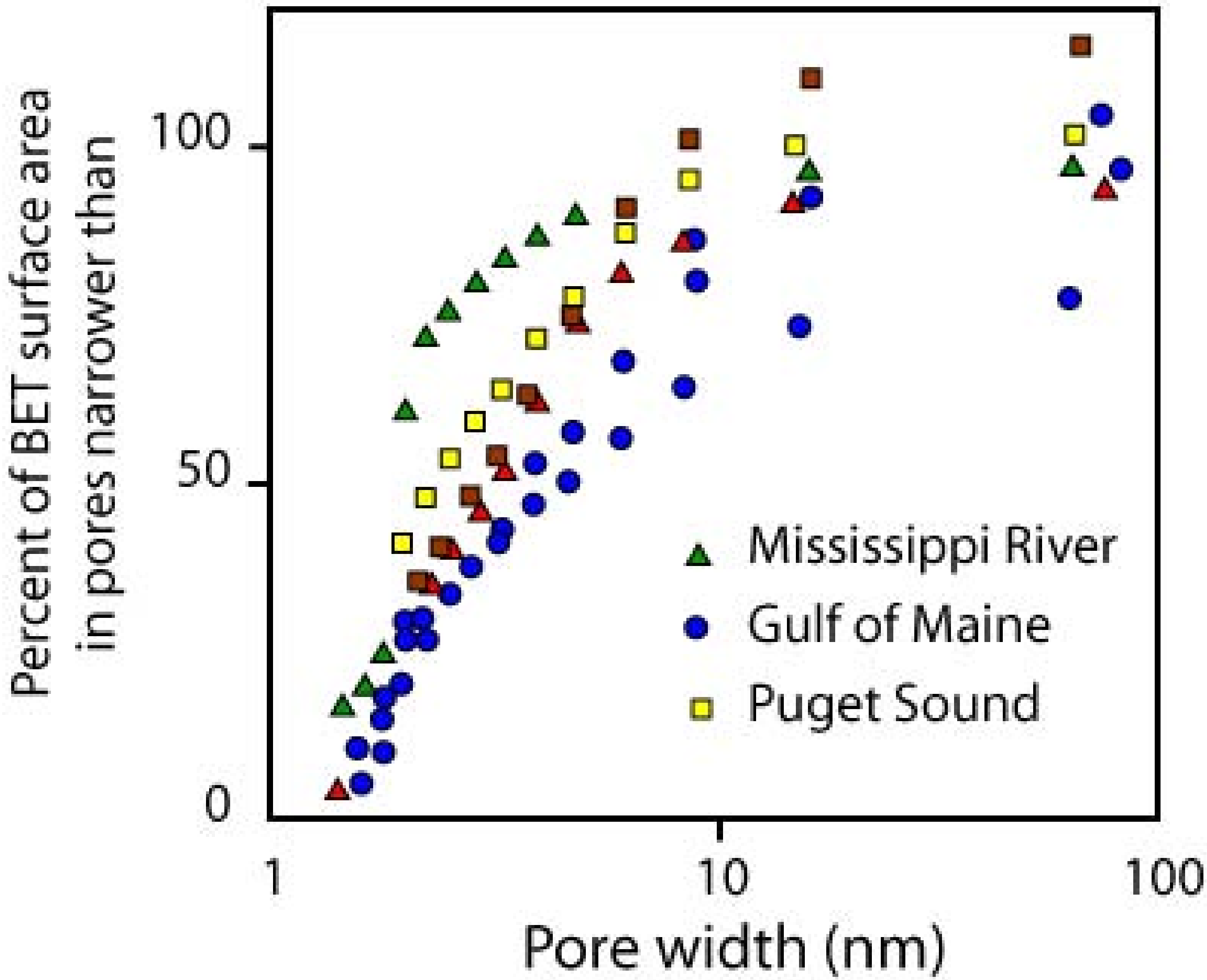
Surface area vs % organic carbon for deltaic and river sediments



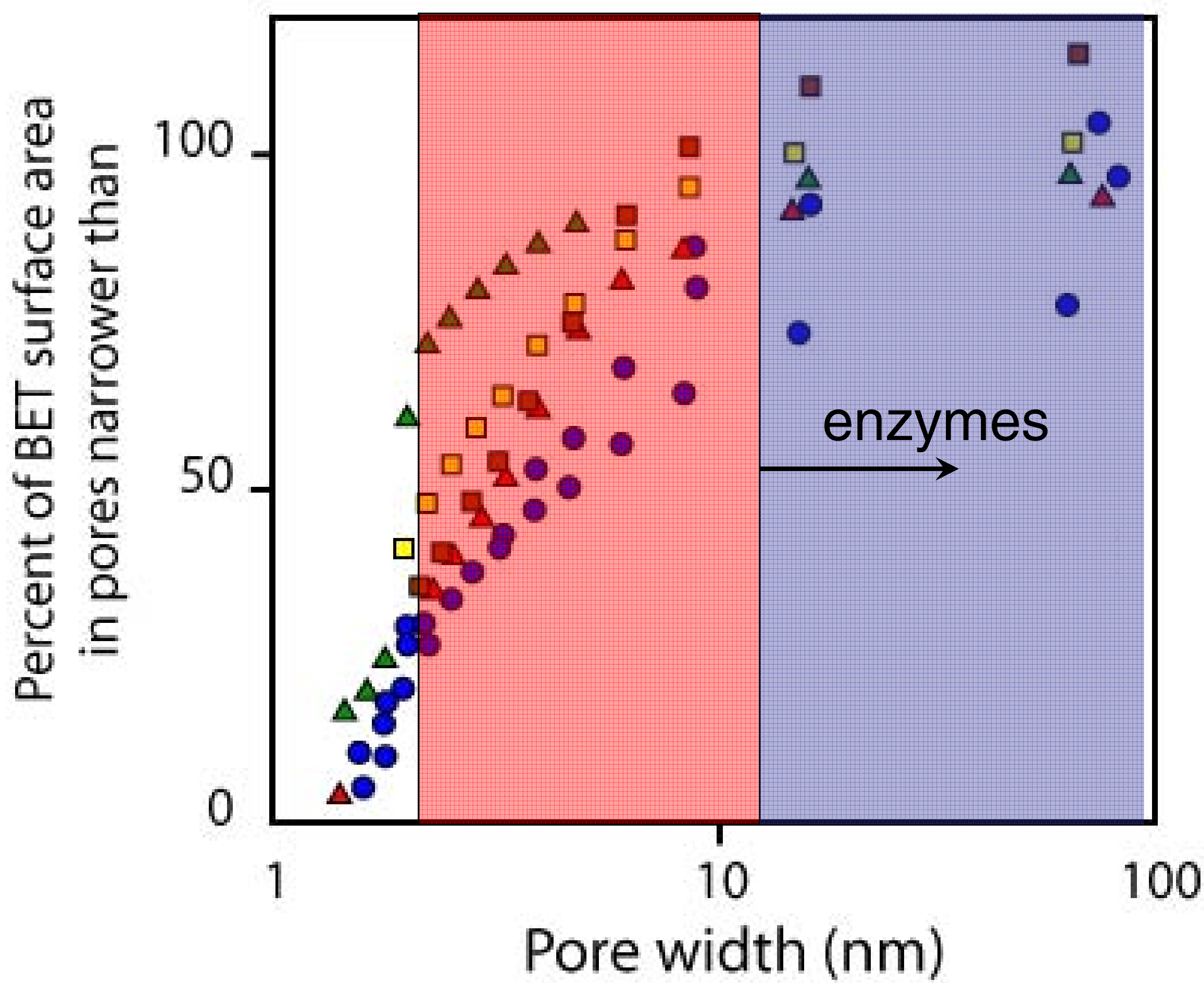
Proposed mechanism for surface protection
adsorption of organic matter into very small pores



Distribution of mineral pore sizes in marine sediments



Distribution of mineral pore sizes in marine sediments



Surface area control on OC preservation in marine sediment..

Weathering introduces new mineral surfaces constantly to the environment.

These surfaces ultimately become coated with organic matter, at approximately a monolayer equivalent loading.

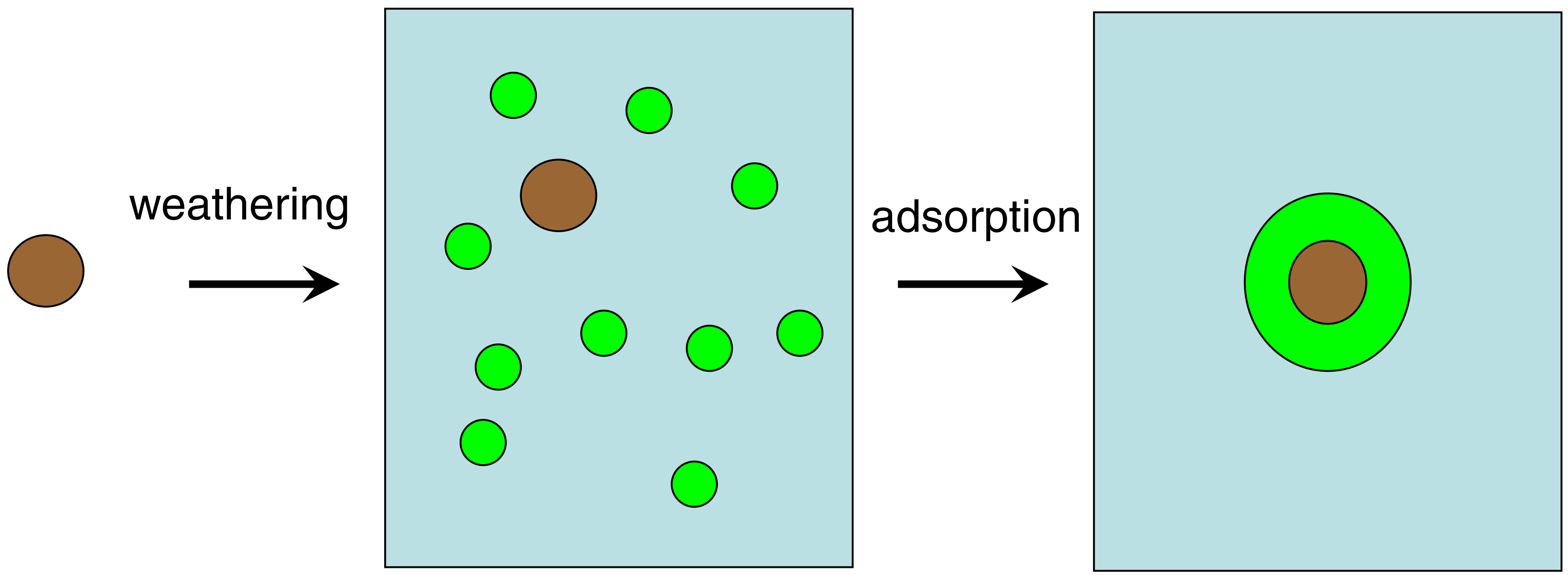
Under conditions that are typical for sediment deposition on continental margins (where most C is buried) degradation proceeds to the ME loading and slows sufficiently there after to preserve this amount of carbon.

In open ocean setting, where oxygen exposure times are much longer, degradation proceeds to < ME loadings. In anoxic basins, where oxygen exposure times are much shorter, loadings are > ME.

Mechanism is preservation in small pores that are inaccessible to enzymes.
e.g. ***physical protection***.

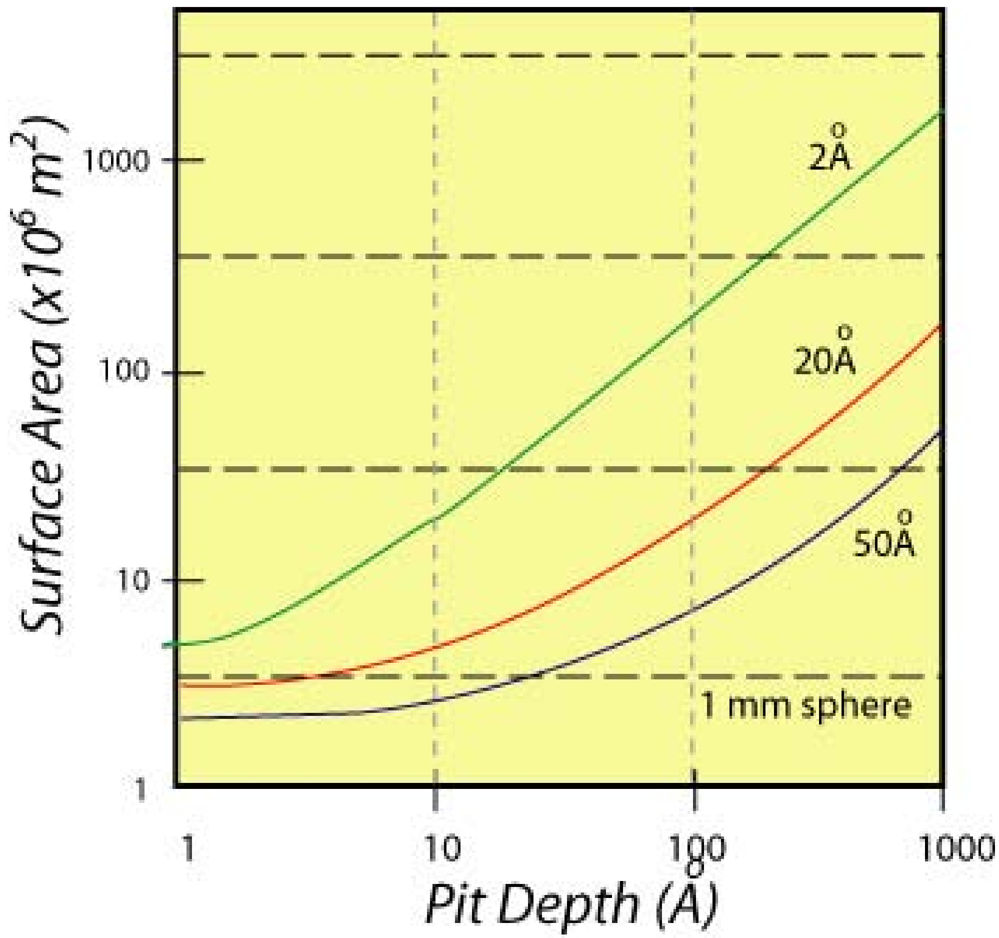
What is the problem with this model???

Hint……think of the $\delta^{13}C$ of marine sediments.



The rebuttal to surface area control on OC preservation……

Theoretical surface area of a 1 mm pitted spherical particle

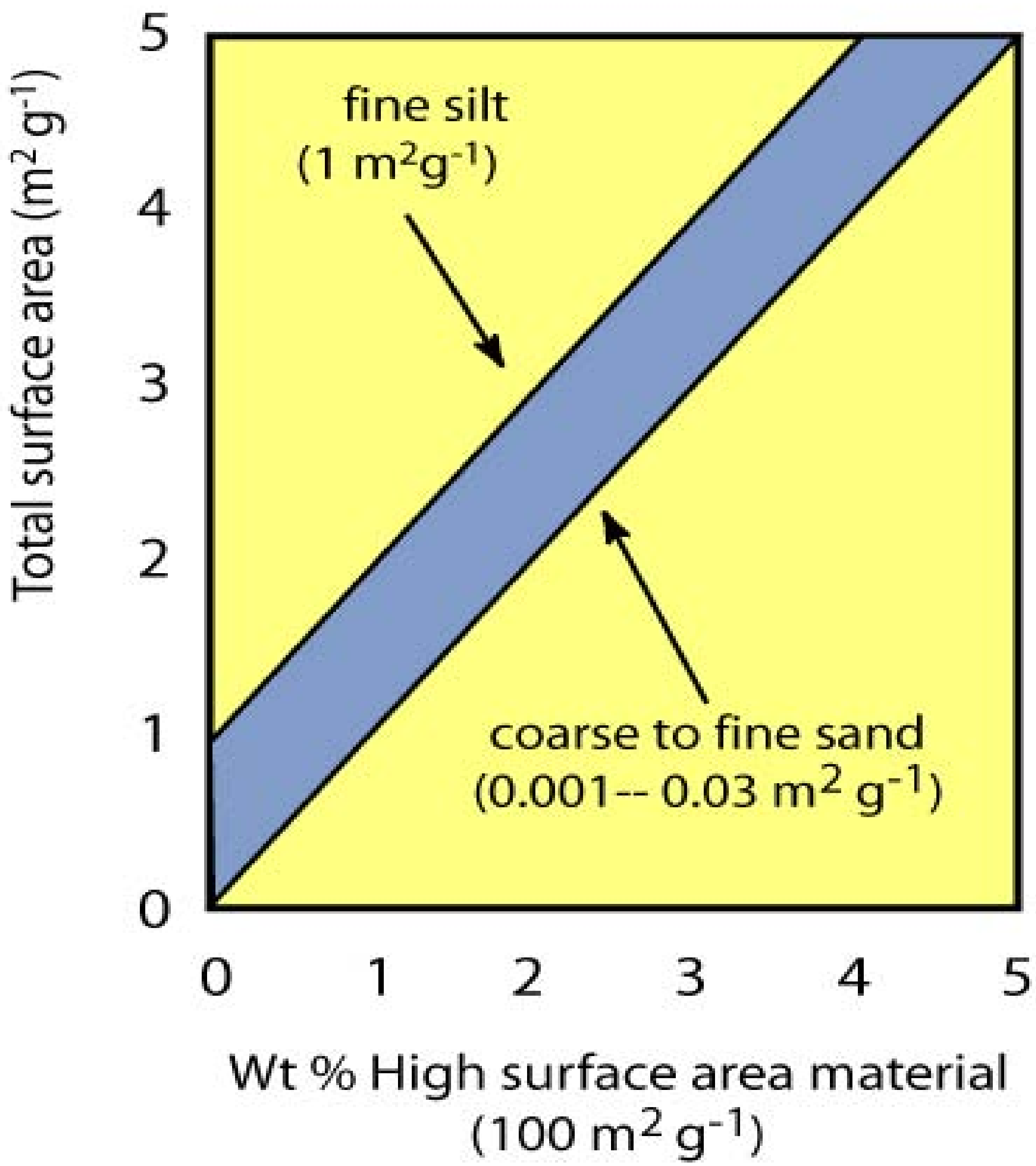


It is impossible to physically protect that much organic matter in pits & cracks

Ransom et al., GCA (1998) 62, 1329-1345

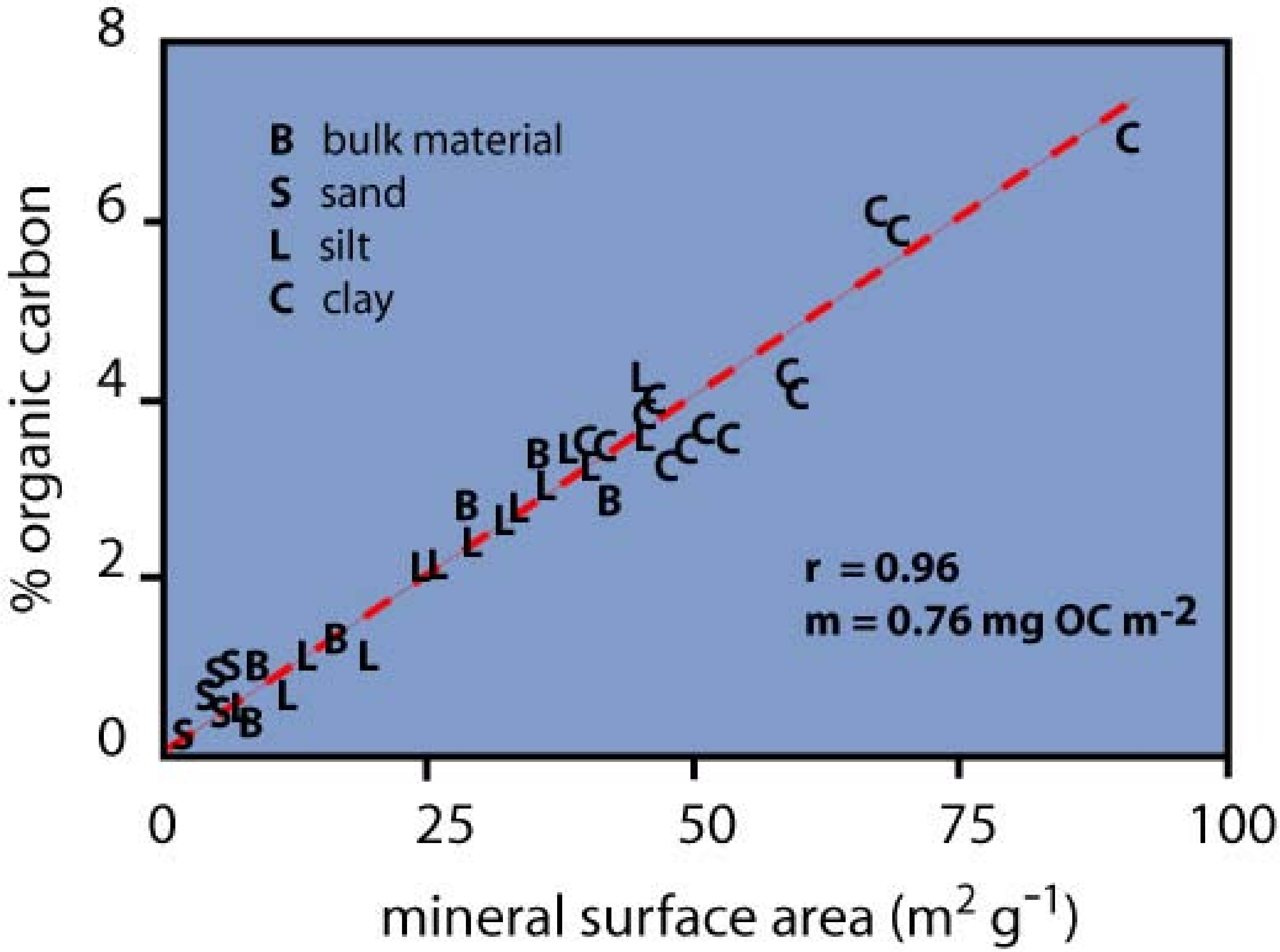
Effect of high surface area material on total surface area

Ransom et al., GCA (1998) 62, 1329-1345



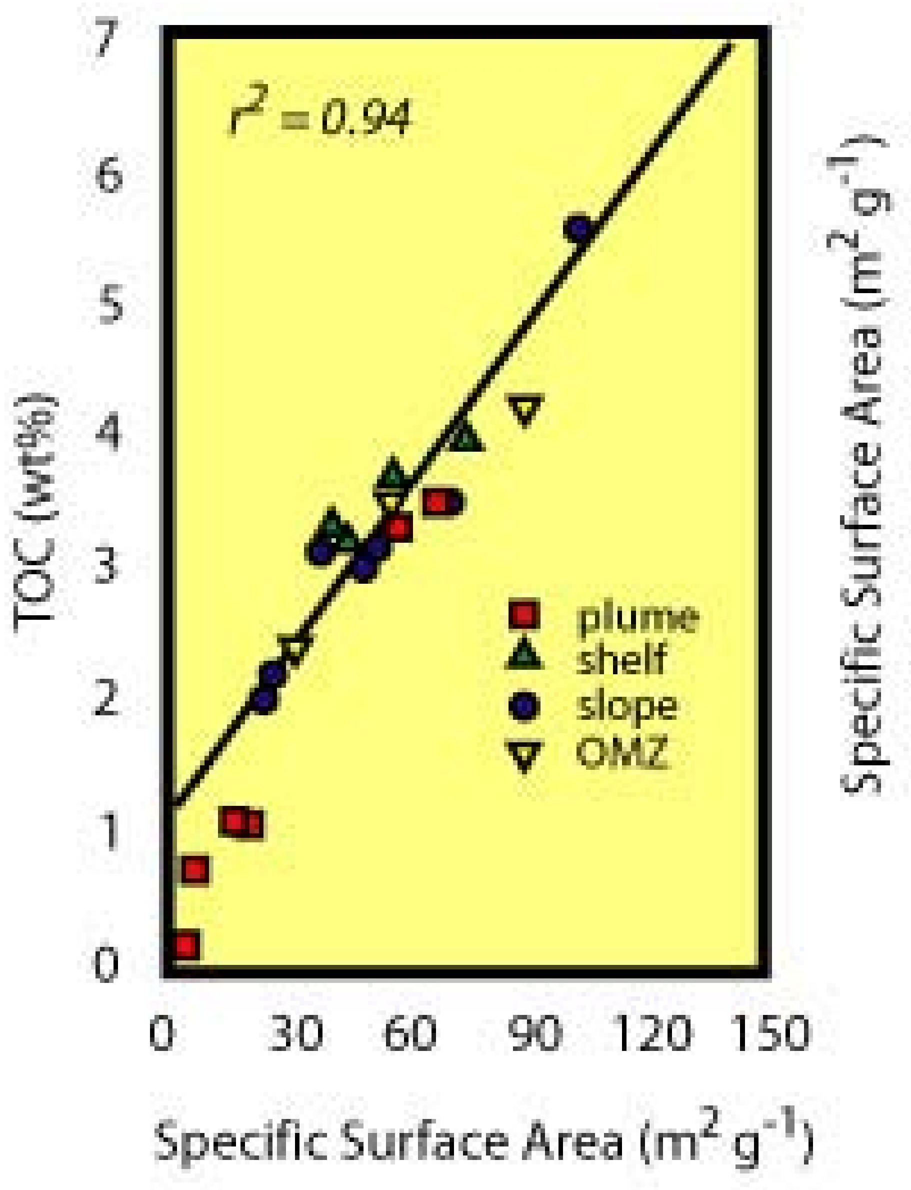
Mineral surface area vs %organic carbon for Columbia River Sediments

(Hedges and Keil, Mar. Chem (1995) 49, 81-115.)

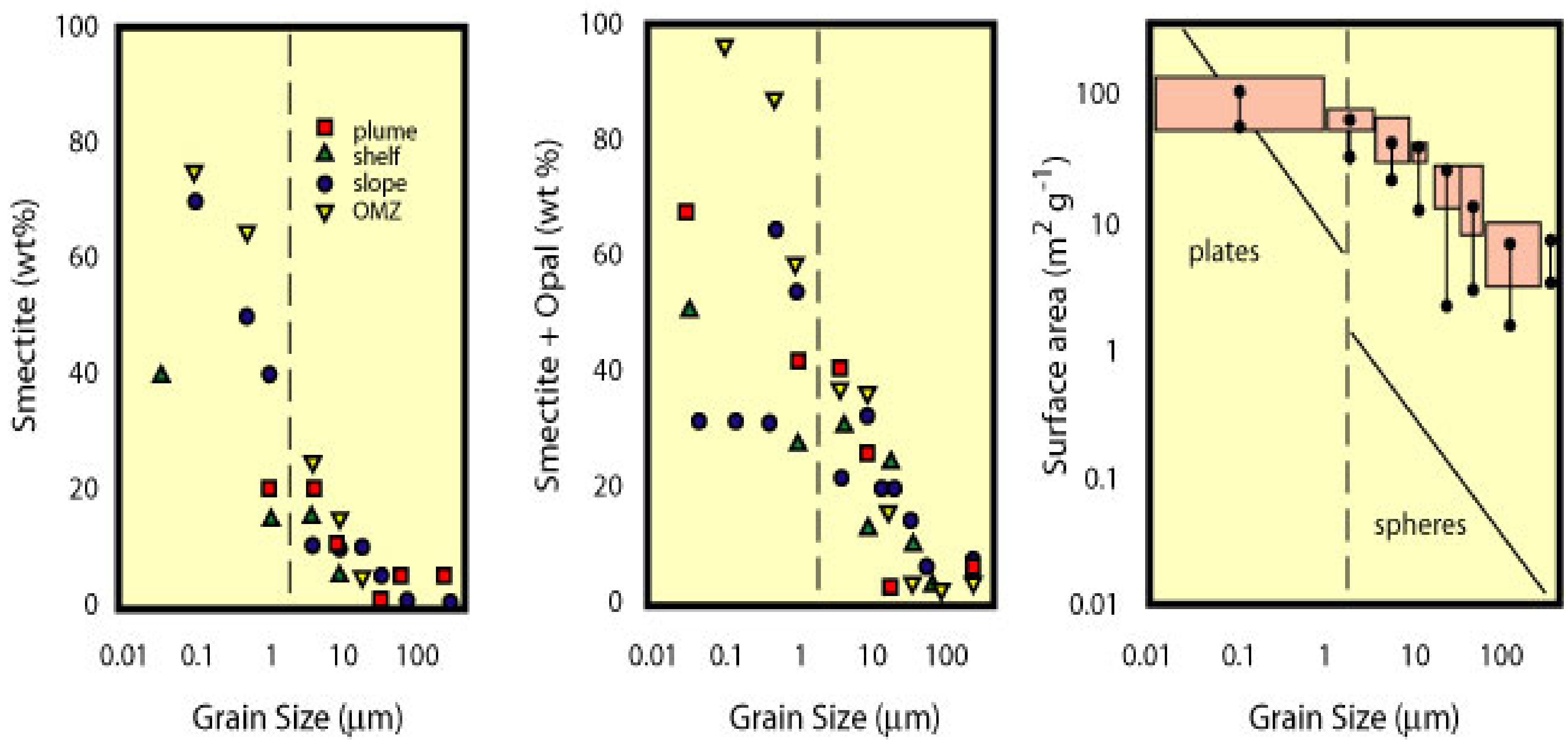


Surface area vs %TOC in Washington margin sediments

(Keil et al, (1994) GCA, 58, 879-893.

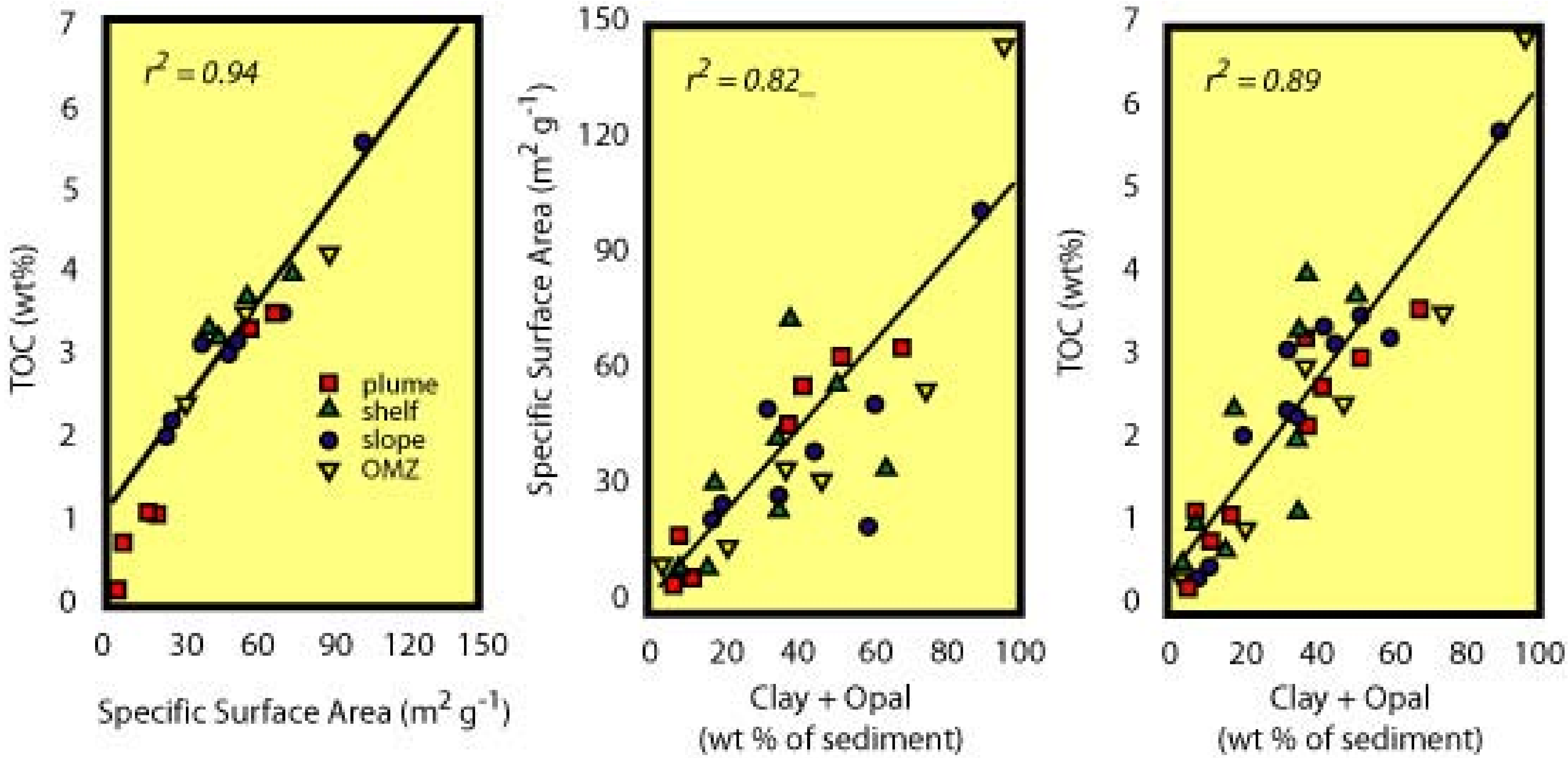


Grain size, smectite, opal, and surface area in Washington margin sediments



Ransom et al., GCA (1998) 62, 1329-1345

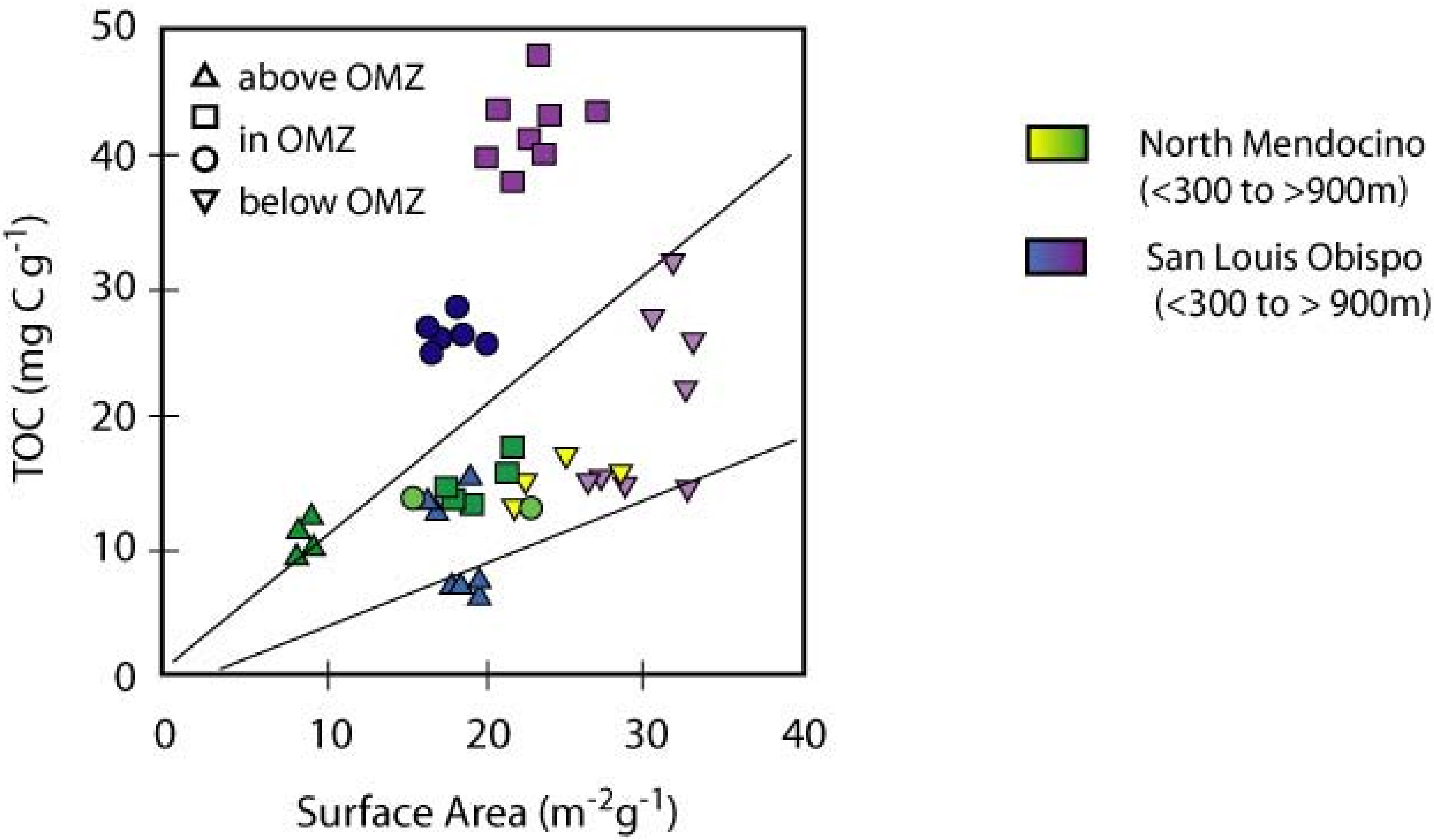
Correlation of surface area, TOC, Clay minerals+opal in Washington margin sediments



Ransom et al., GCA (1998) 62, 1329-1345

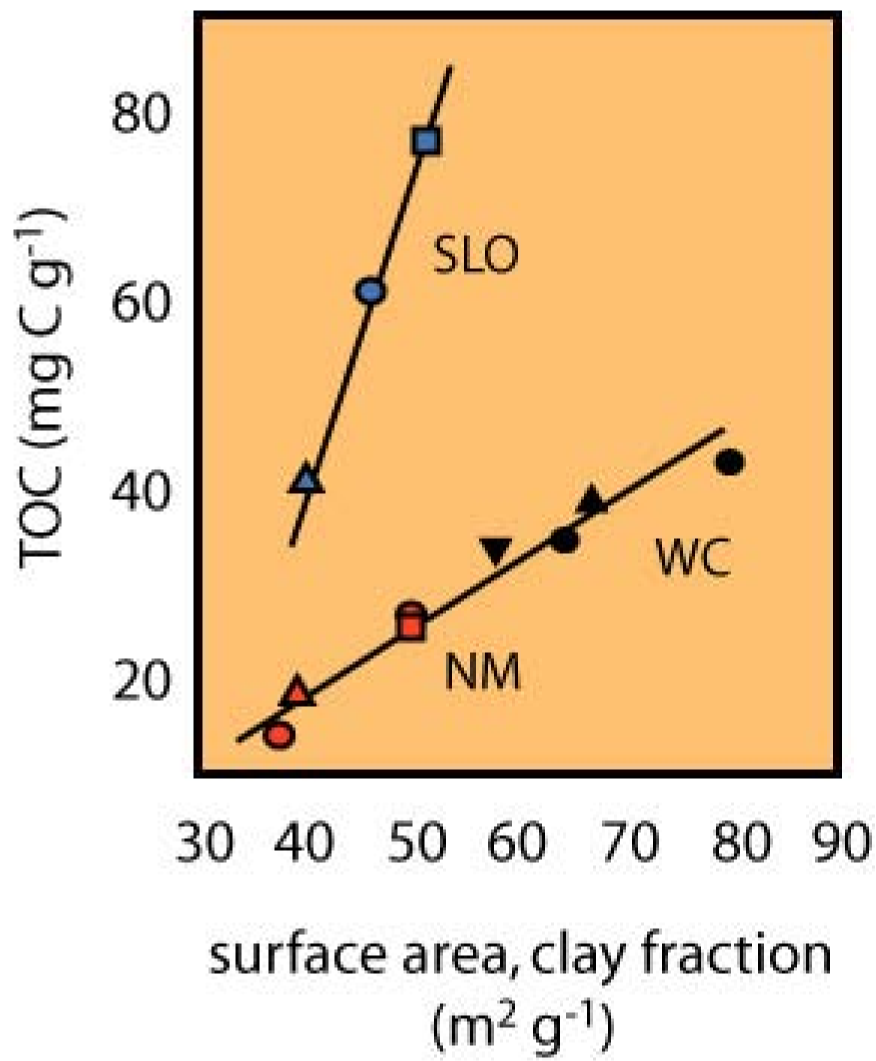
TOC vs surface are for California margin sediments

Ransom et al., GCA (1998) 62, 1329-1345



Correlation of clay minerals with TOC in coastal sediments

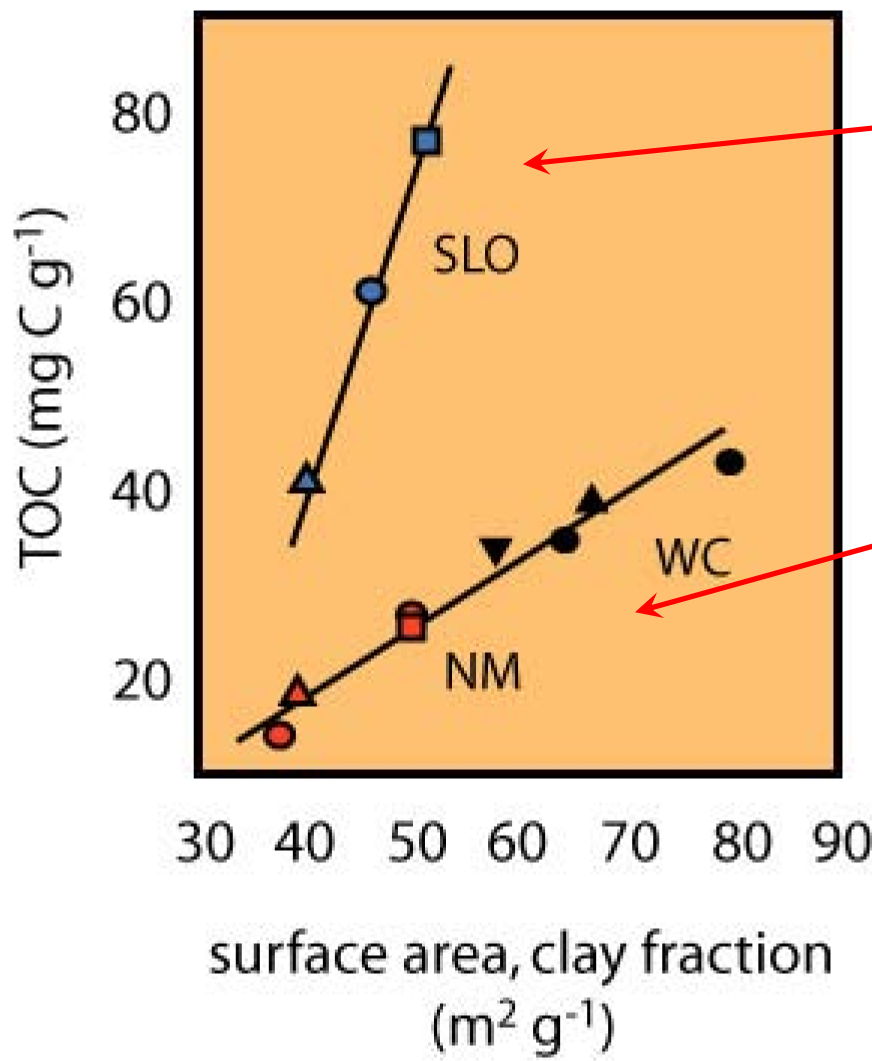
Ransom et al., GCA (1998) 62, 1329-1345



Correlation of clay minerals with TOC in coastal sediments

SLO clays
21-29% smectite
0-3% chlorite

NM clays
3-13% smectite
13-24% chlorite

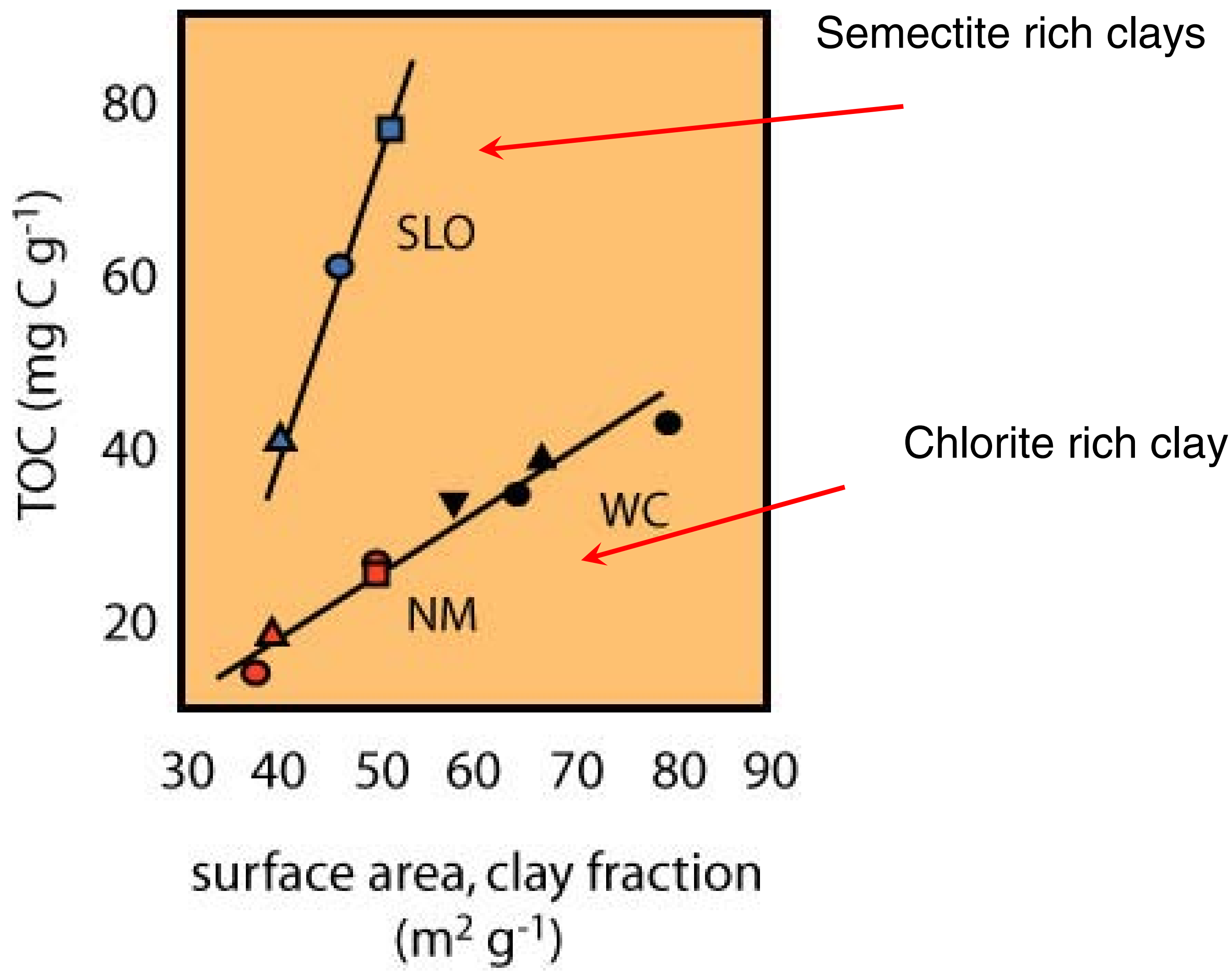


Semectite rich clays

Chlorite rich clay

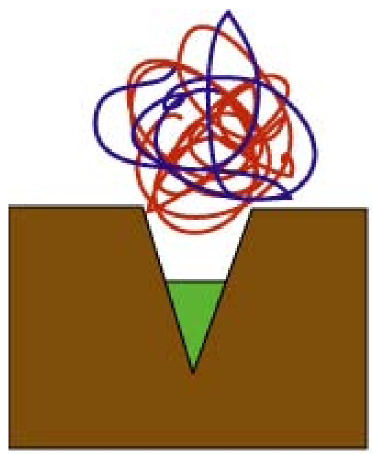
Clay mineralogy, not simple surface area drives OC preservation

Ransom et al., GCA (1998) 62, 1329-1345



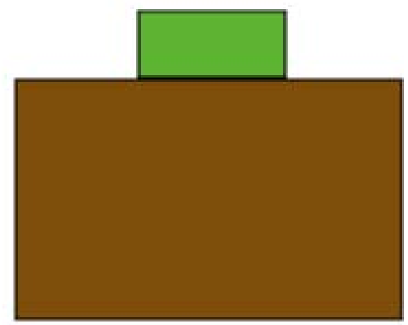
…..and finally the mechanism of preservation….

Mayer-Hedges-Keil hypothesis



Physical protection from enzymatic degradation in small pores/cracks

Ransom hypothesis



No physical protection
OM is on surface and only a small fraction is in contact with mineral.

Things to remember…..

Most OM is preserved in continental margin sediments

Carbon loading is proportional to surface area

Sedimentation rate, or rate of burial may be a factor

Effect of oxygen is open, some evoke it, some do not.
not clear if or how it is a factor.

Mechanism of C preservation is also open. Physical protection has been argued, but how this works may not be understood.