Trace metal uptake and remineralization and their impact on upper ocean stoichiometry

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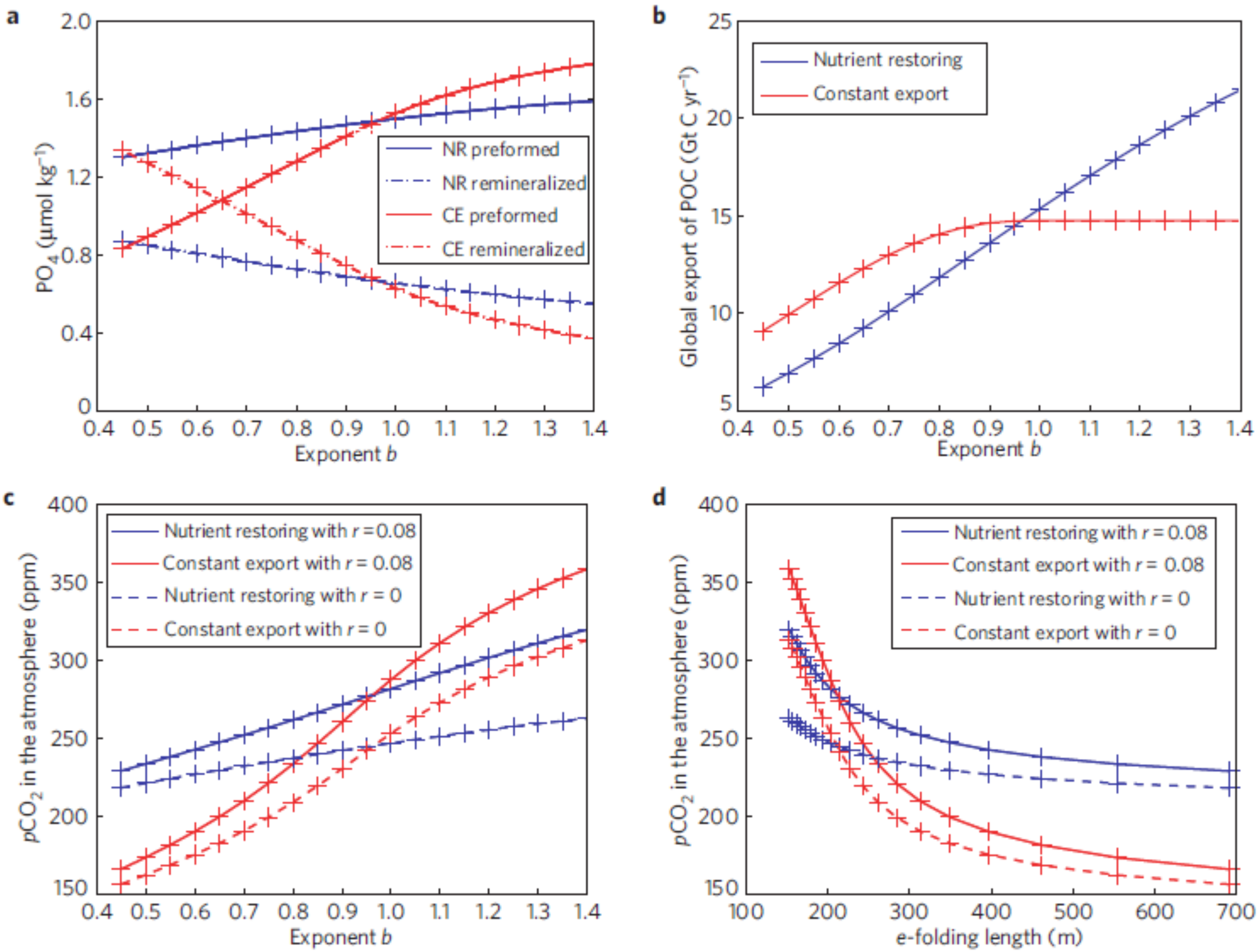
U.S. GEOTRACES

Why worry about trace metal remineralization from sinking (biogenic) particulate matter?



(Kwon et al. 2009)

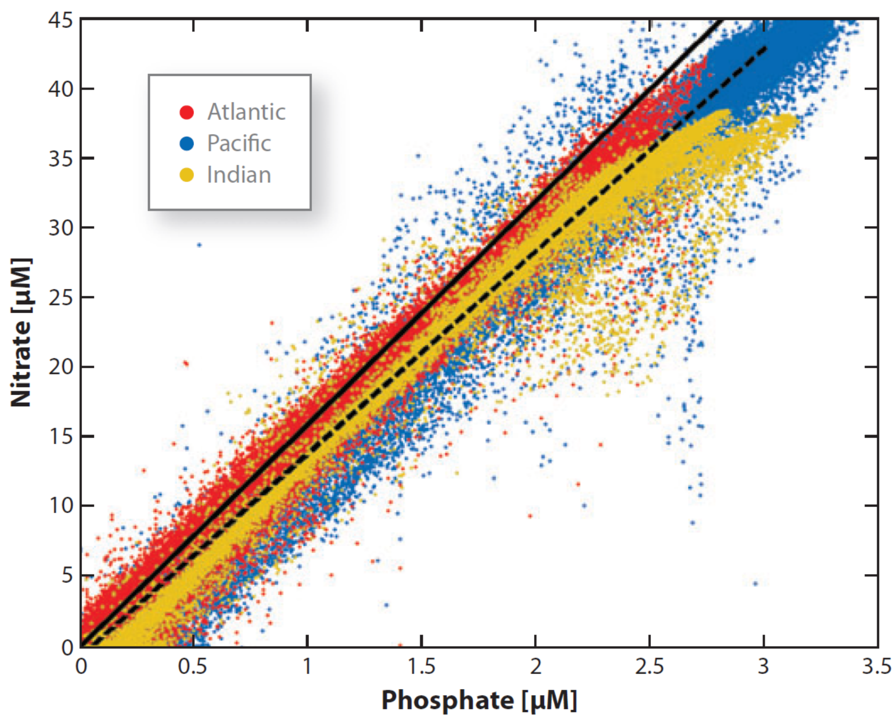
Outline

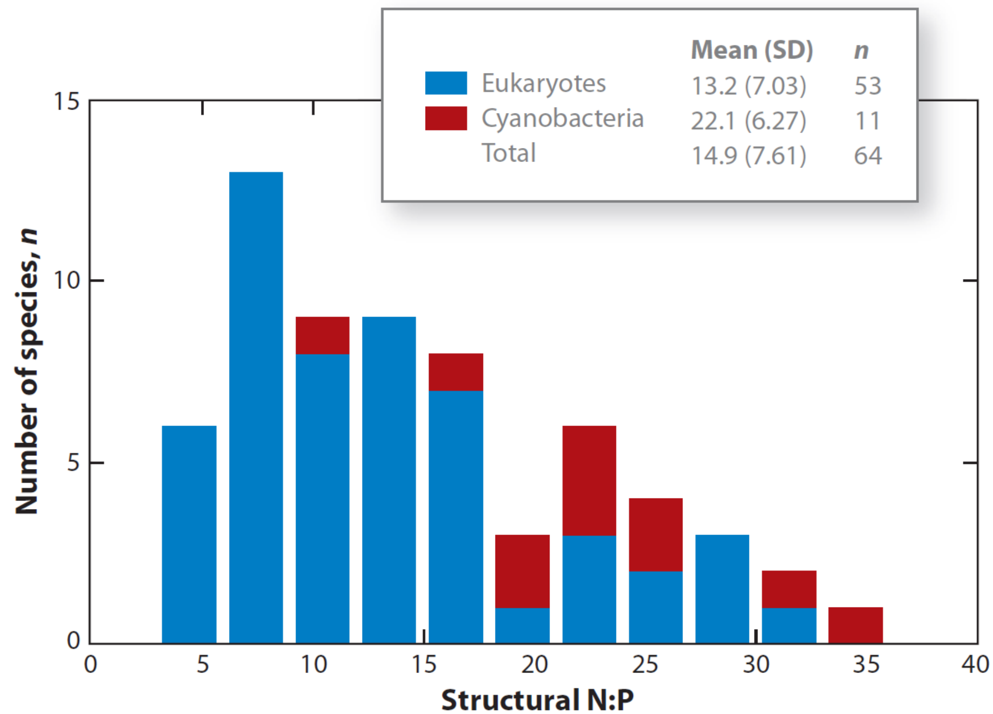
- Coupled element cycles and stoichiometry
- Trace element micronutrients and macronutrients: coupled or uncoupled?
- Pre-GEOTRACES and FeCycle II data
- Particle remineralization in GEOTRACES NAZT and EPZT datasets

Macronutrient stoichiometries

- Redfield ratio

- Correspondence of dissolved and particulate N:P ratios
  → similar chemical lability (?)

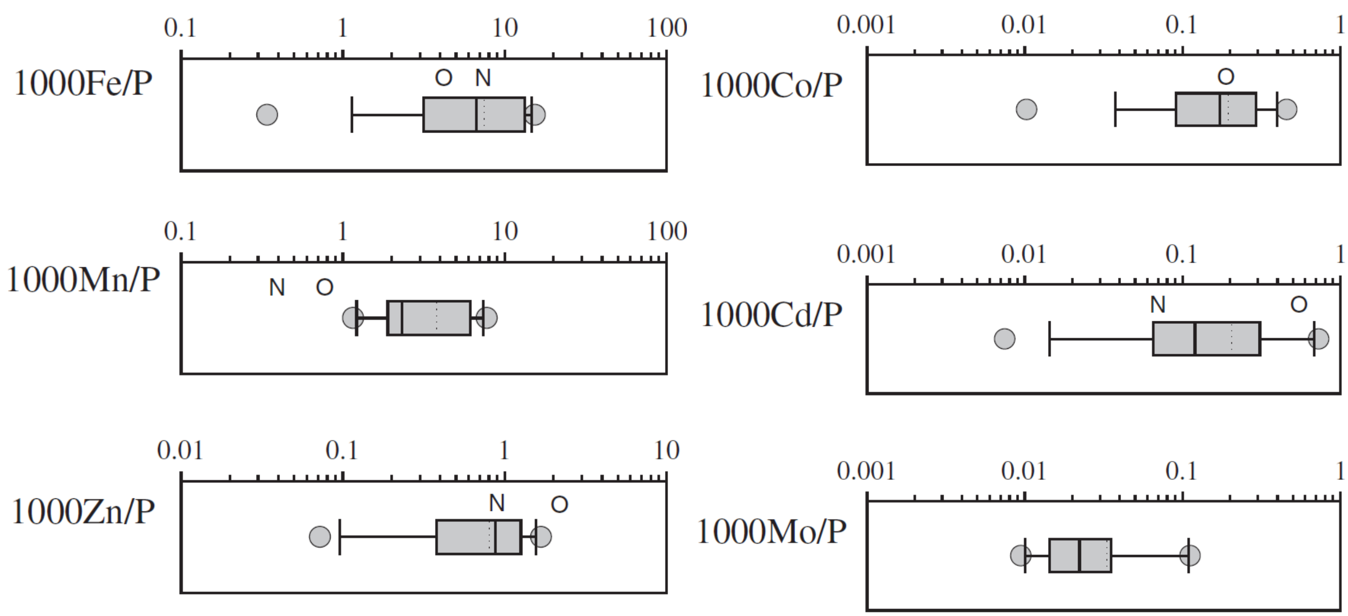




(Deutsch & Weber 2012)

The extended Redfield ratio

- Morel & Hudson 1985
- Bruland et al. 1991
- Numerous Sunda studies



$$(C_{124}N_{16}P_{1}S_{1.3})_{1000}Fe_{7.5}Zn_{0.8}Cu_{0.38}Co_{0.19}Cd_{0.21}Mo_{0.03}$$

(Ho et al. 2003)

The extended Redfield ratio

Table 3 P-normalized metal stoichiometries for the North Atlantic, North Pacific, and Southern Oceans, as calculated from regressions of dissolved concentrations in the upper water column (typically <800 m)

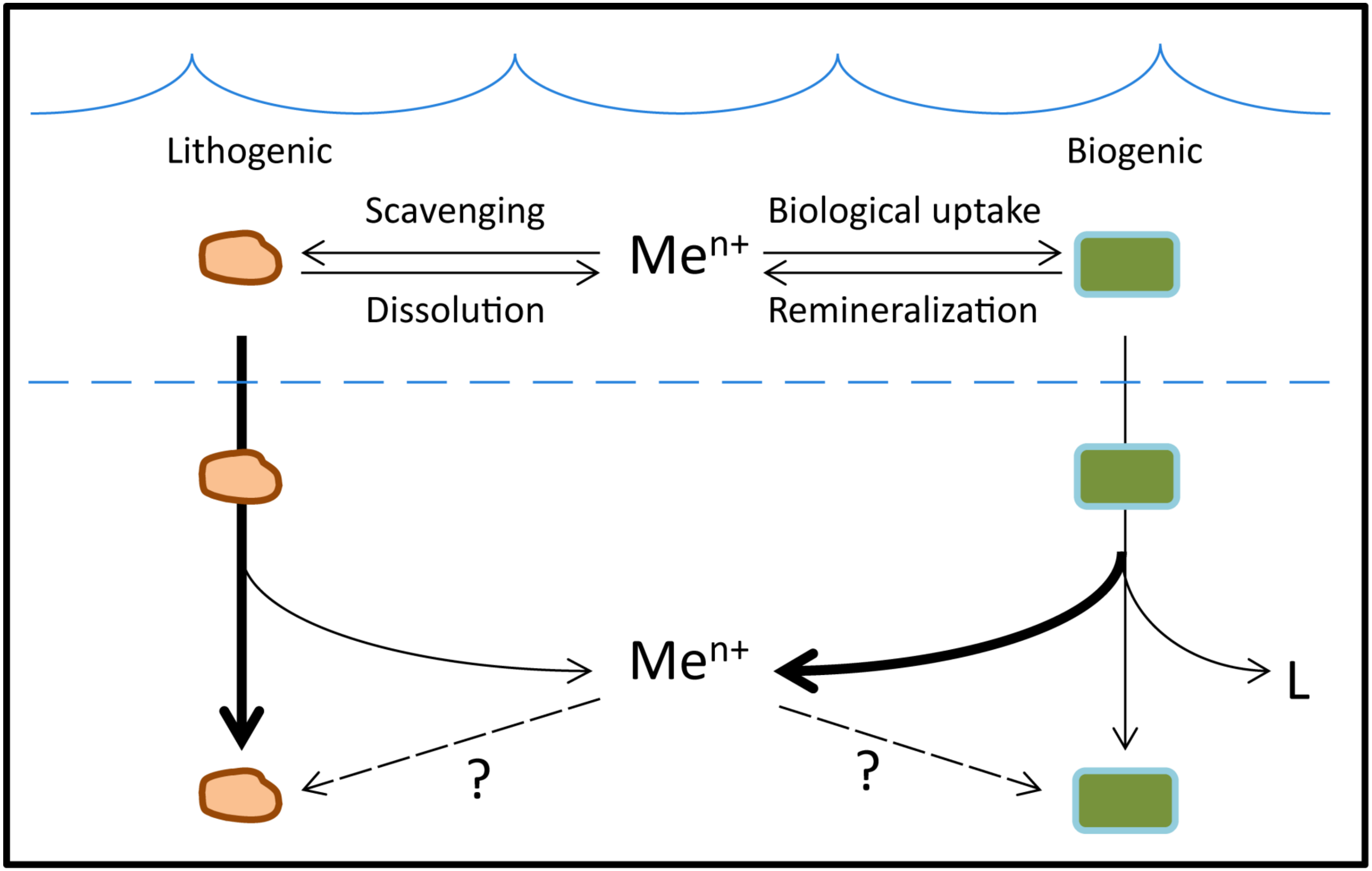
Site	Metal:P ratio (mmol mol^{-1})[a]						References
	Fe[b]	Zn[c]	Ni[d]	Cu[e]	Co[f]	Cd[g]	
North Atlantic Ocean	1.1 ± 0.4	2.6 ± 1.0	1.6 ± 0.1	0.30	0.061	0.24 ± 0.12	Bruland & Franks 1983, Yeats & Campbell 1983, Martin et al. 1993, Sunda 1997, Lane et al. 2009
North Pacific Ocean	0.5 ± 0.3	3.9 ± 1.2	1.0 ± 0.1	0.41 ± 0.08	0.038 ± 0.002	0.40 ± 0.11	Sclater et al. 1976, Bruland 1980, Martin et al. 1989, Sunda 1997, Lane et al. 2009
Southern Ocean	0.2 ± 0.04	6.0 ± 2.6	1.8 ± 0.1	0.53 ± 0.13	0.041 ± 0.005	0.65 ± 0.30	Sunda 1997, Löscher 1999, Ellwood 2008, Lane et al. 2009, Saito et al. 2010, Bown et al. 2011, Croot et al. 2011
Ca.	0.6	4	1.5	0.4	0.045	0.43	

(Twining & Baines 2013)

$$(C_{124}N_{16}P_1S_{1.3})_{1000}Fe_{7.5}Zn_{0.8}Cu_{0.38}Co_{0.19}Cd_{0.21}Mo_{0.03}$$

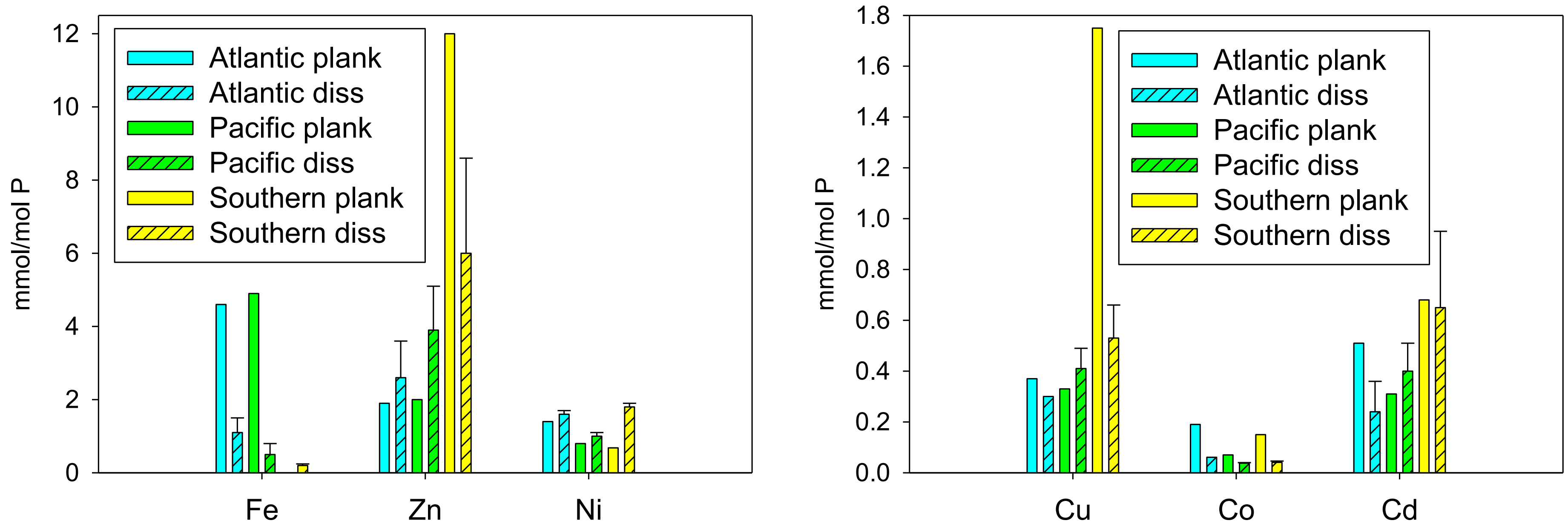
(Ho et al. 2003)

Contribution of lithogenic and scavenged fractions



(Twining et al. 2016)

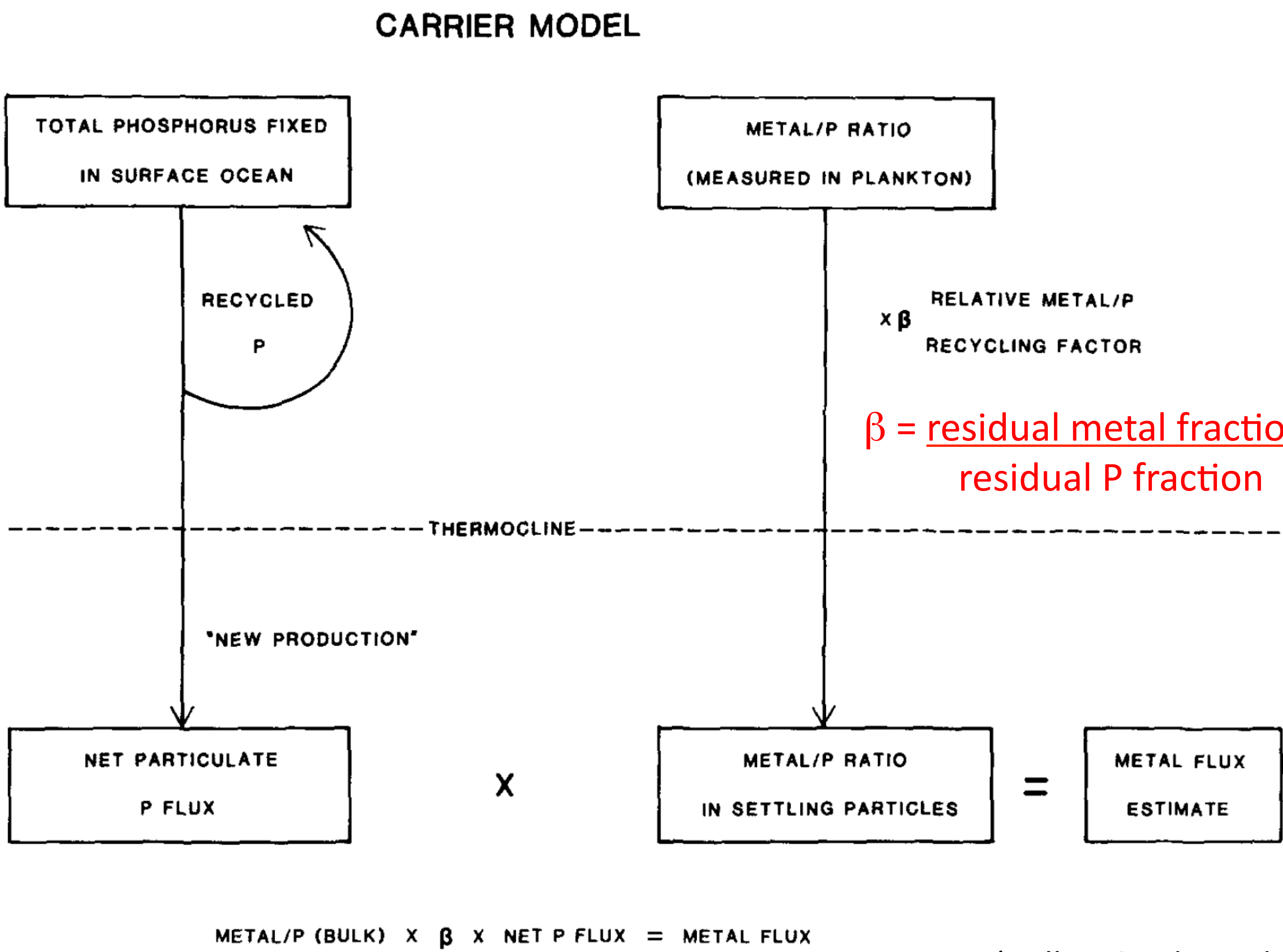
Correspondence of bulk plankton and dissolved remineralization ratios in pre-GEOTRACES field data



(Twining & Baines 2013)

Is there clear evidence for decoupling of TMs during remineralization?

Early estimates of TEI-nutrient decoupling



$$\beta = \frac{\text{residual metal fraction}}{\text{residual P fraction}}$$

(Collier & Edmond 1984)

Early estimates of TEI-nutrient decoupling

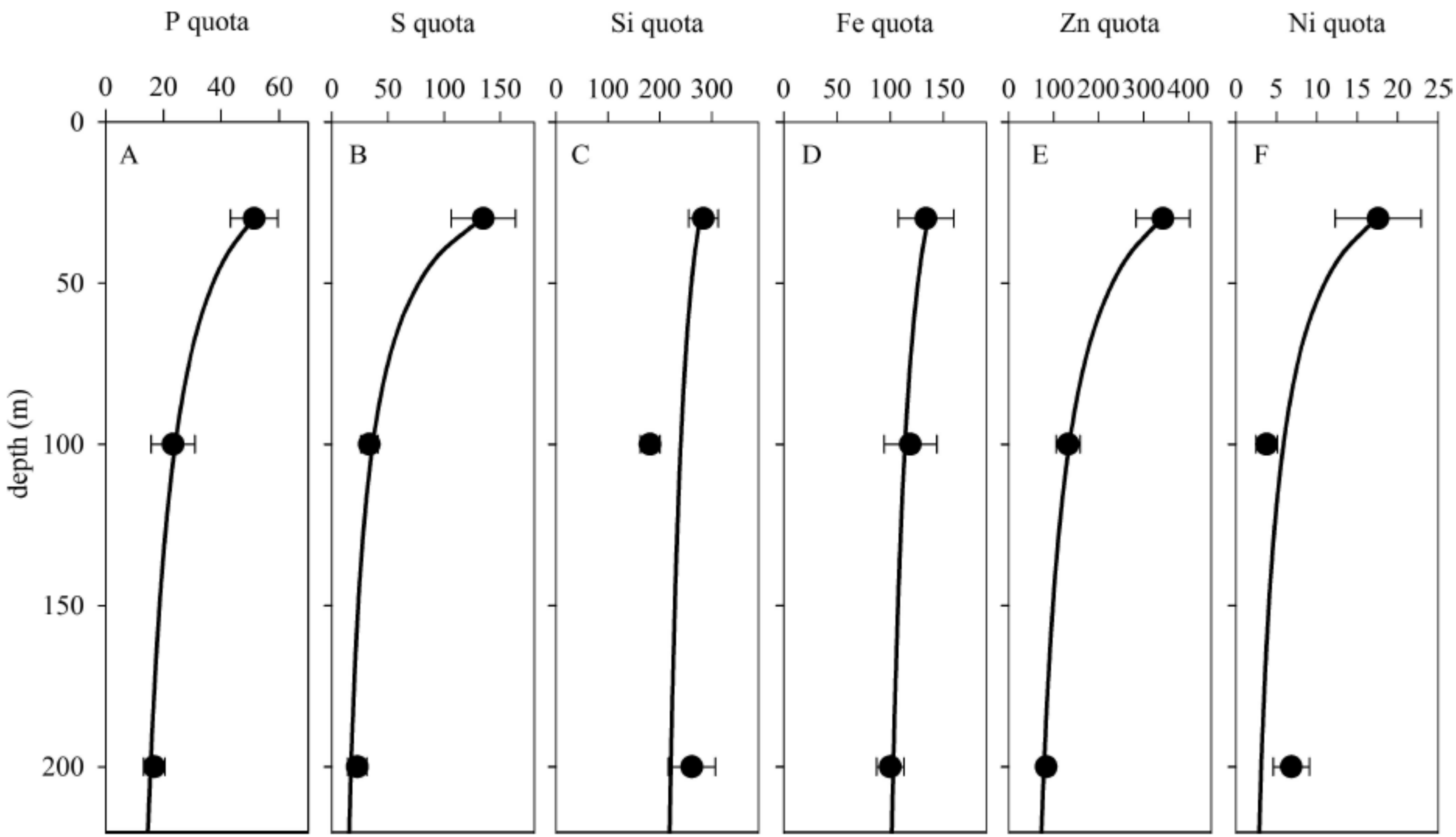
$$\beta = \frac{\text{residual metal fraction}}{\text{residual P fraction}}$$

Element	β
Cd	0.5 – 0.9
Ni	2.4
Cu	3.4
Mn	2
Zn	?
Fe	6

β estimated from shipboard leaching / element loss experiments

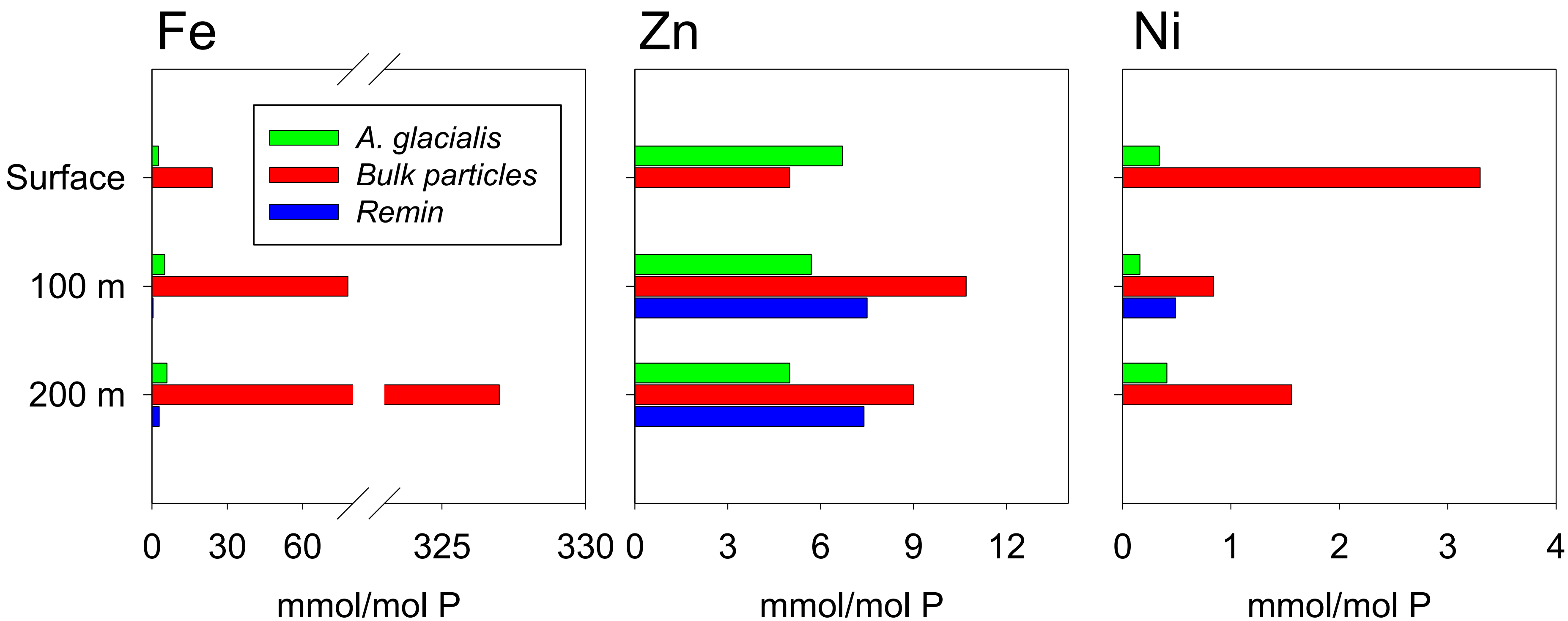
(Collier & Edmond 1984)

Decoupled TEI remineralization during a GEOTRACES process cruise



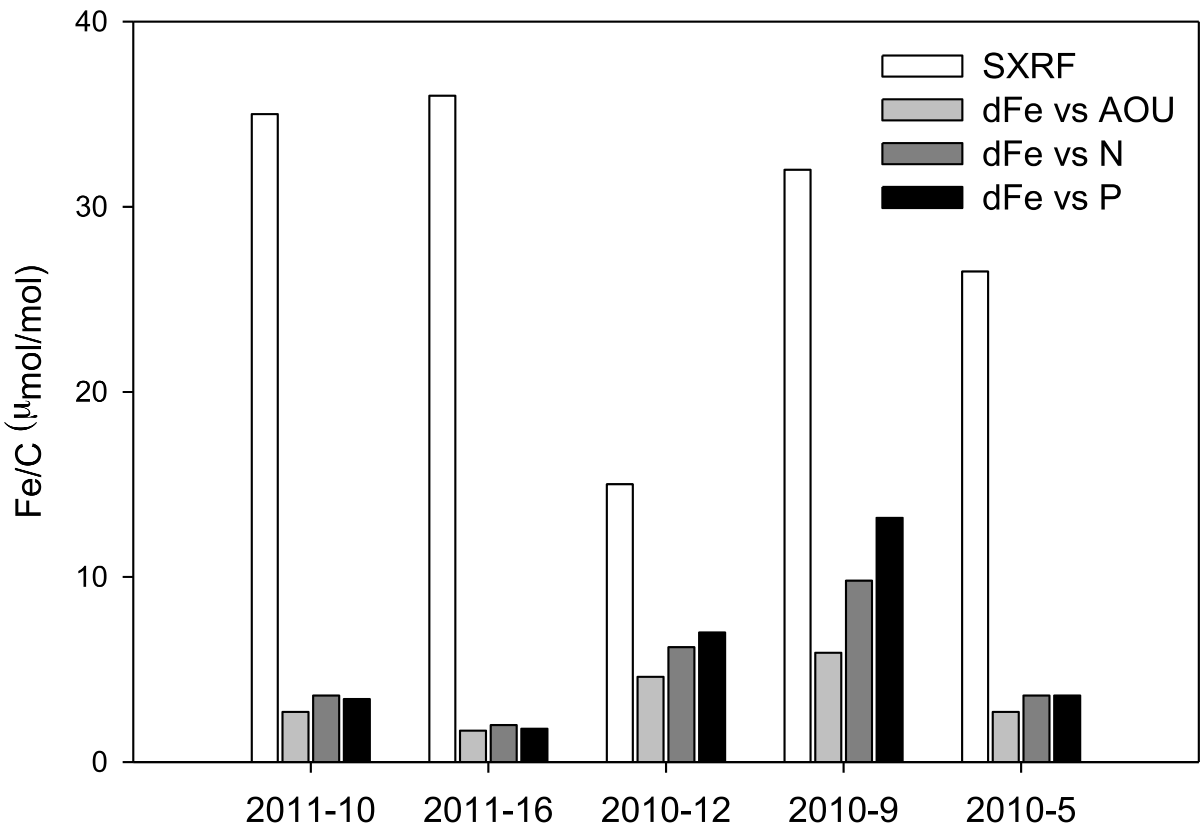
(Twining et al. 2014)

Remineralization stoichiometries during FeCycle II spring bloom

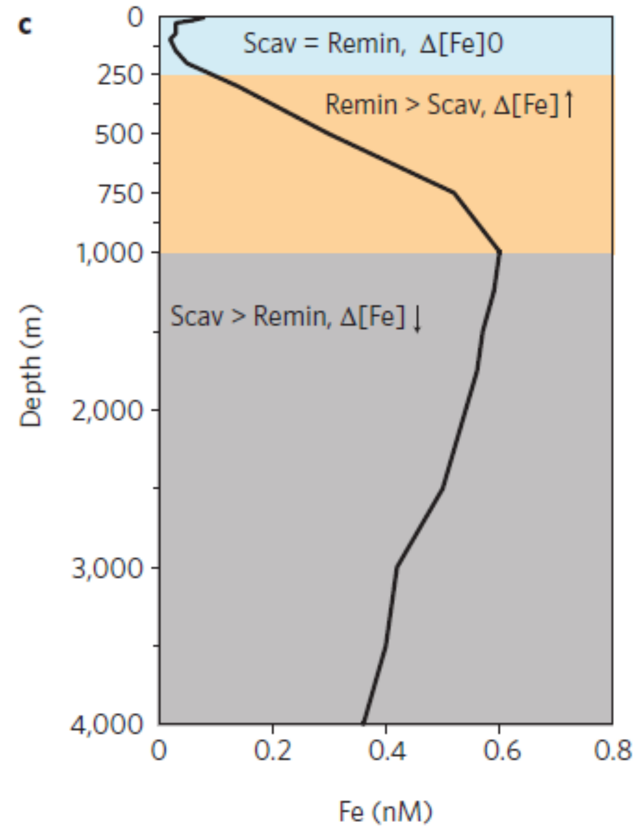


(Twining et al. 2014)

Remineralization stoichiometries along North Atlantic Zonal Transect

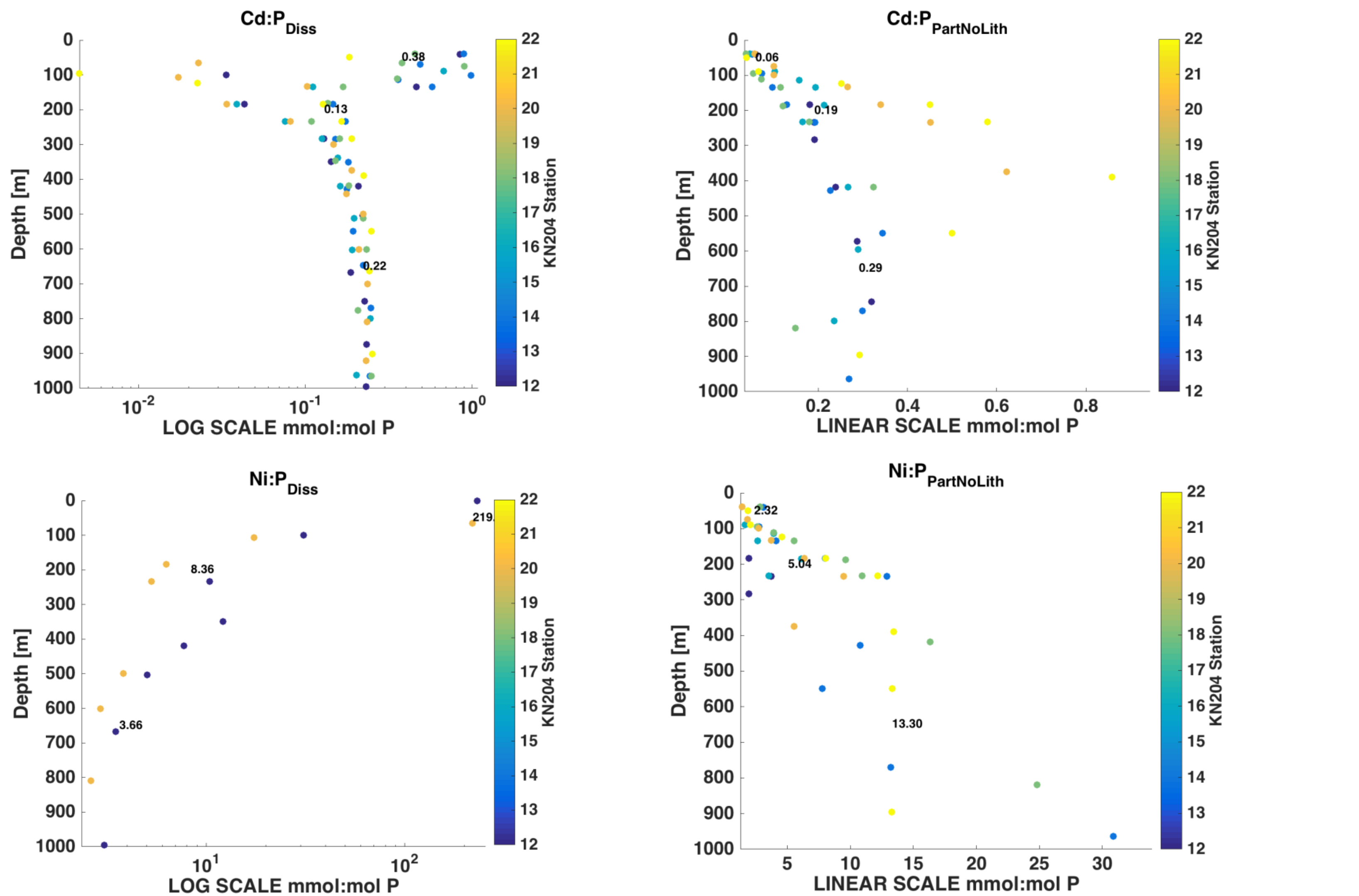


(Twining et al. 2015)

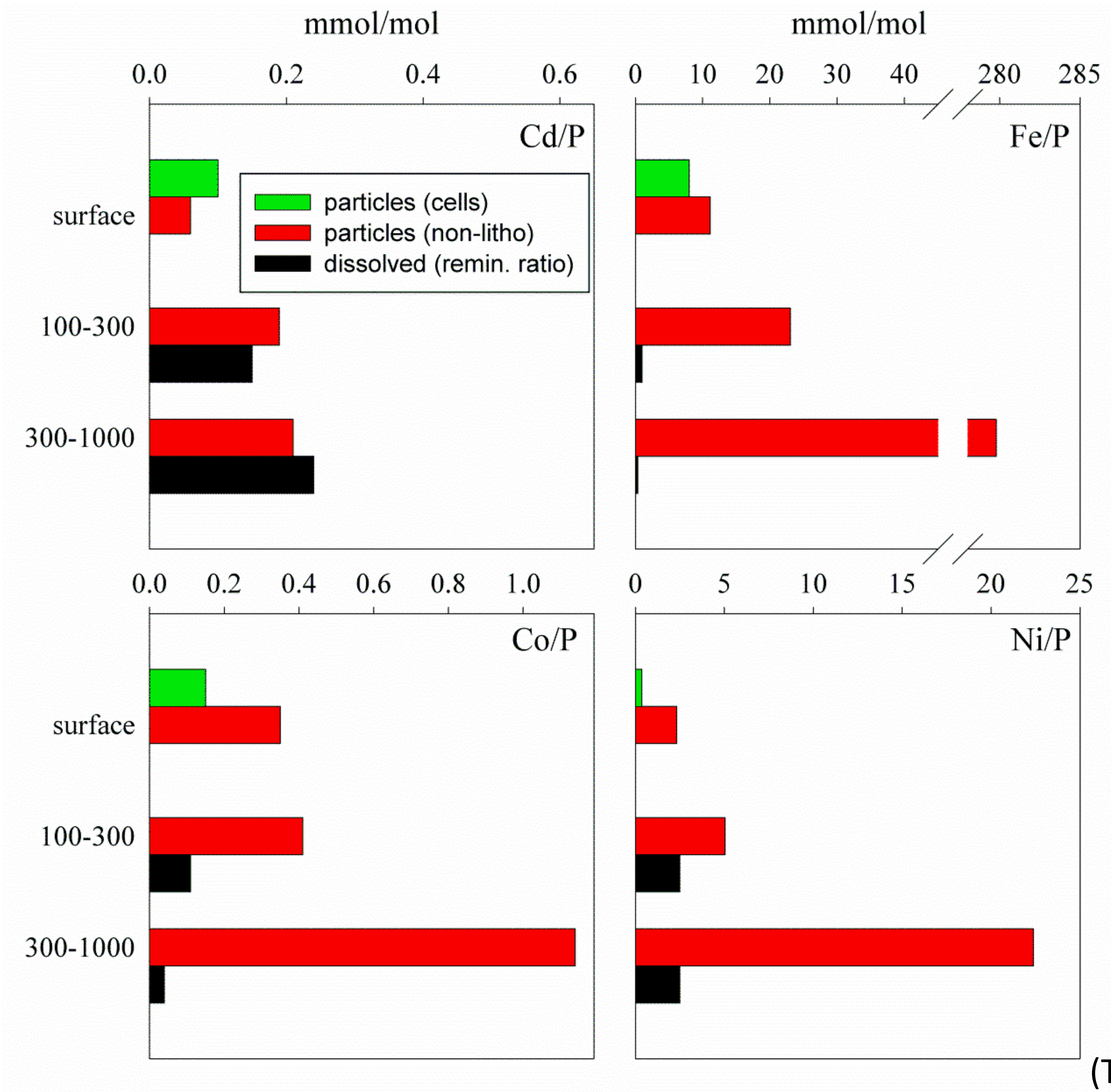


(Boyd & Ellwood 2010)

Comparison of remineralization stoichiometries for additional NAZT trace metals



Particulate data taken from pumps (Ohnemus and Lam) and corrected for lithogenic fraction



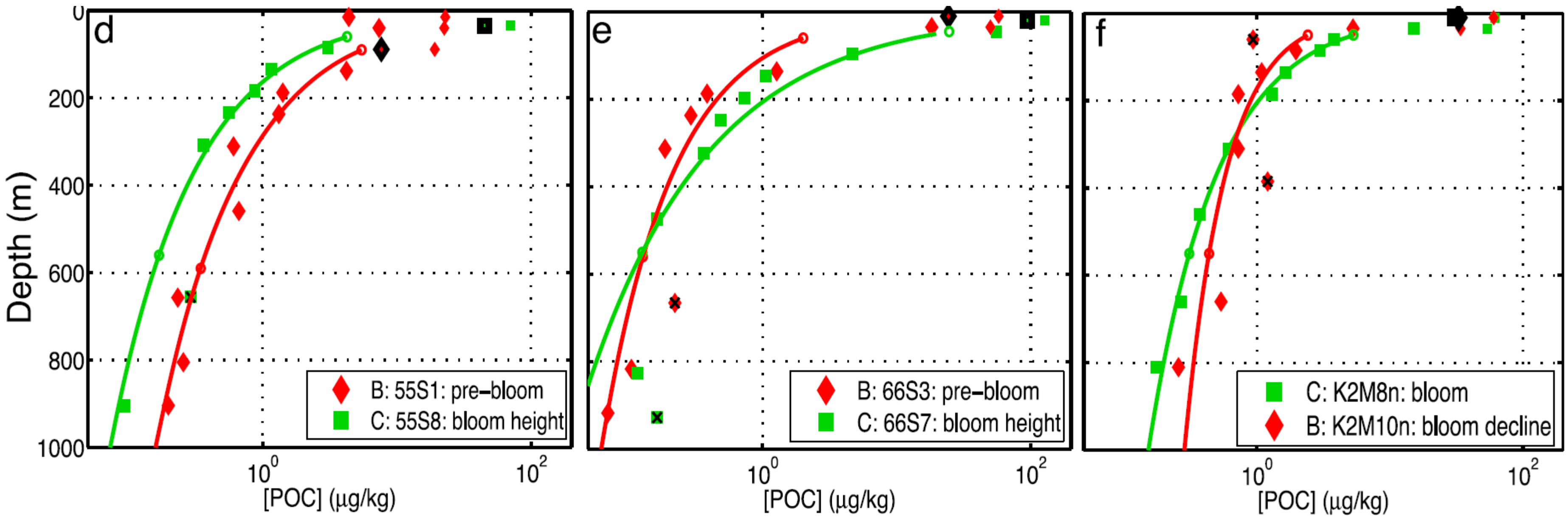
NAZT stations 12-22

Means

Error bars coming

(Twining et al. 2016)

Investigating decoupled remineralization through power curve fits

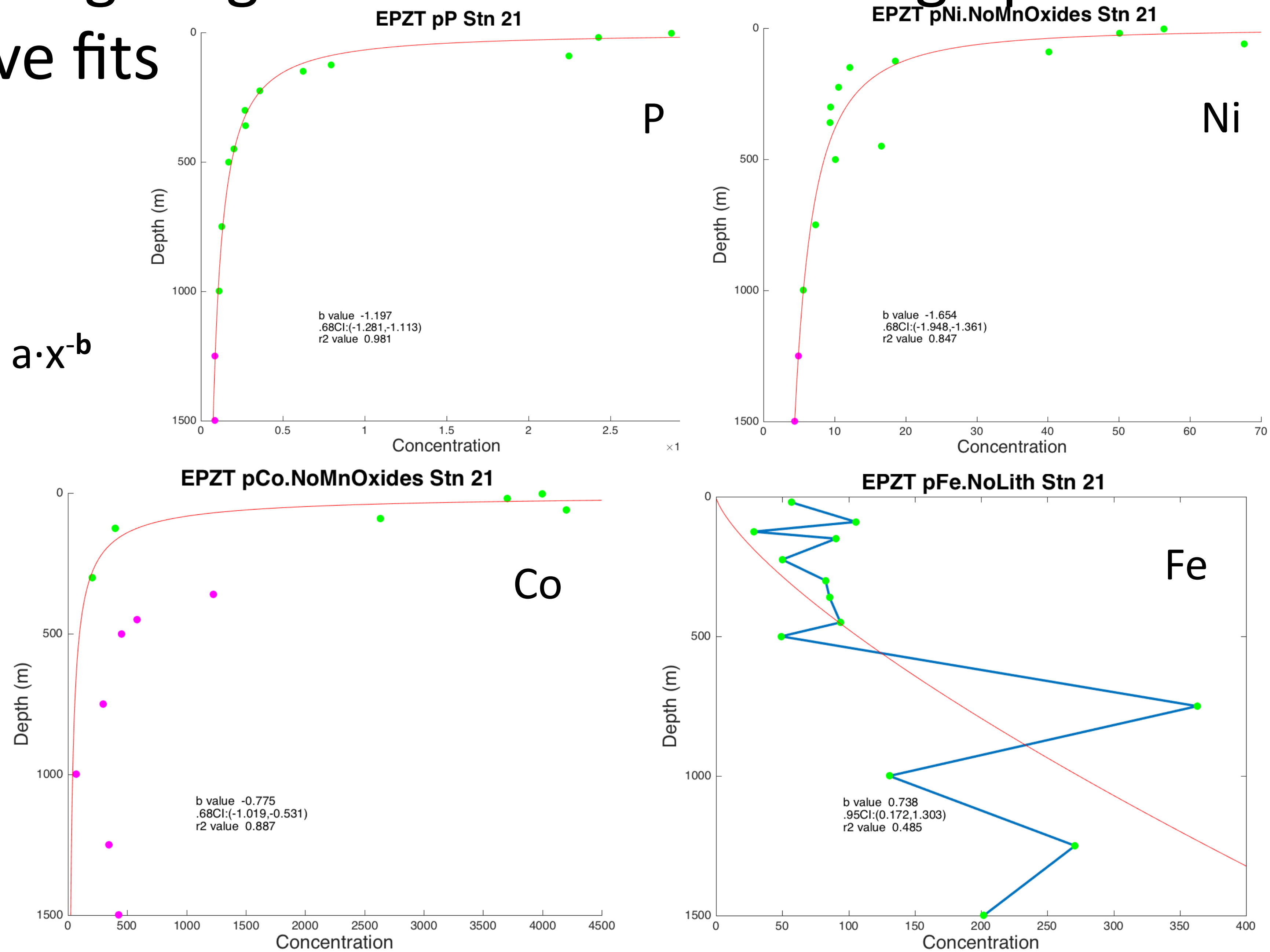


Martin et al. (1987): $$P(z) = P_0 \left(\frac{z}{z_0}\right)^{-b}$$

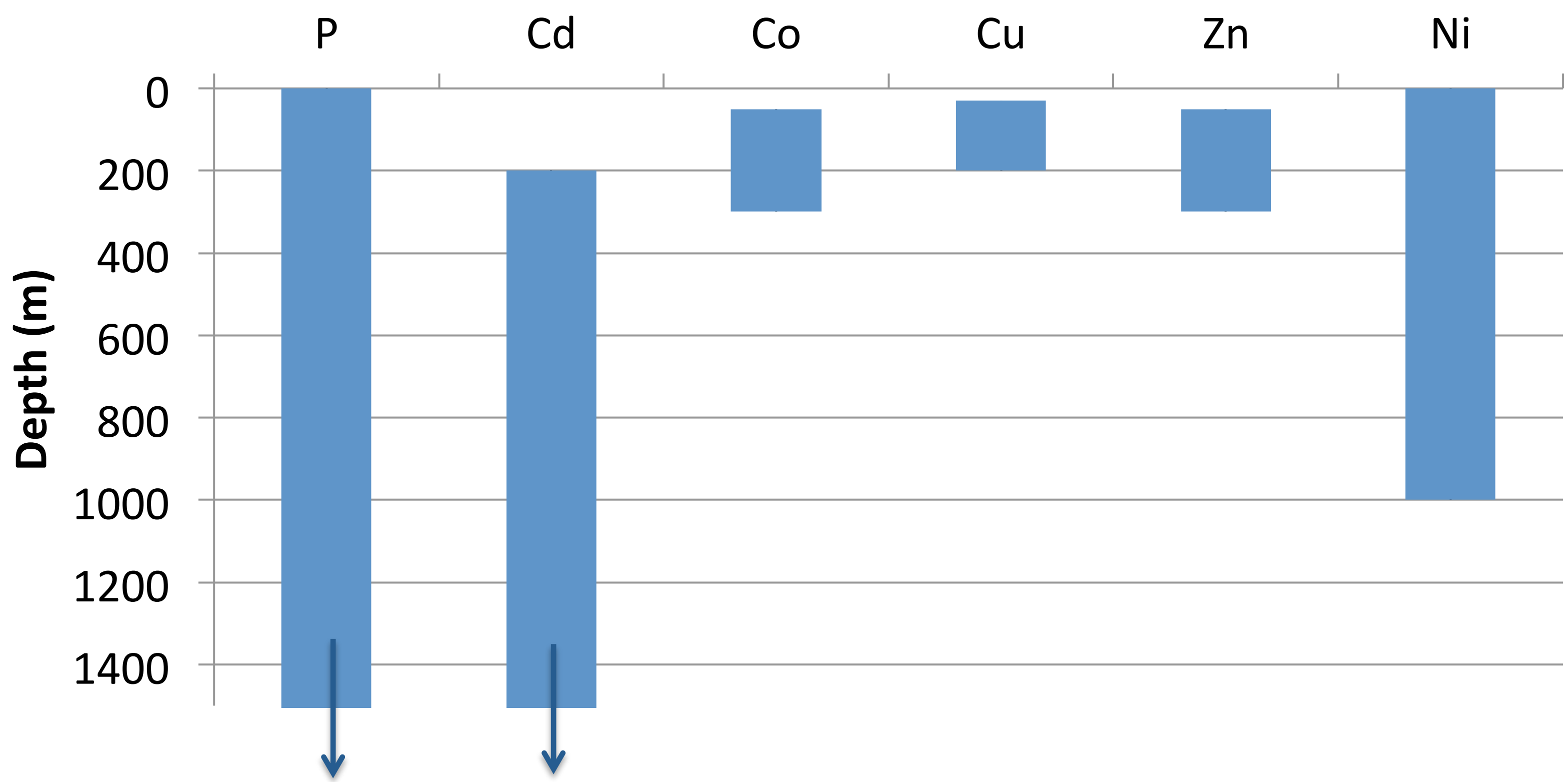
(Lam et al. 2011)

Investigating remineralization through power curve fits

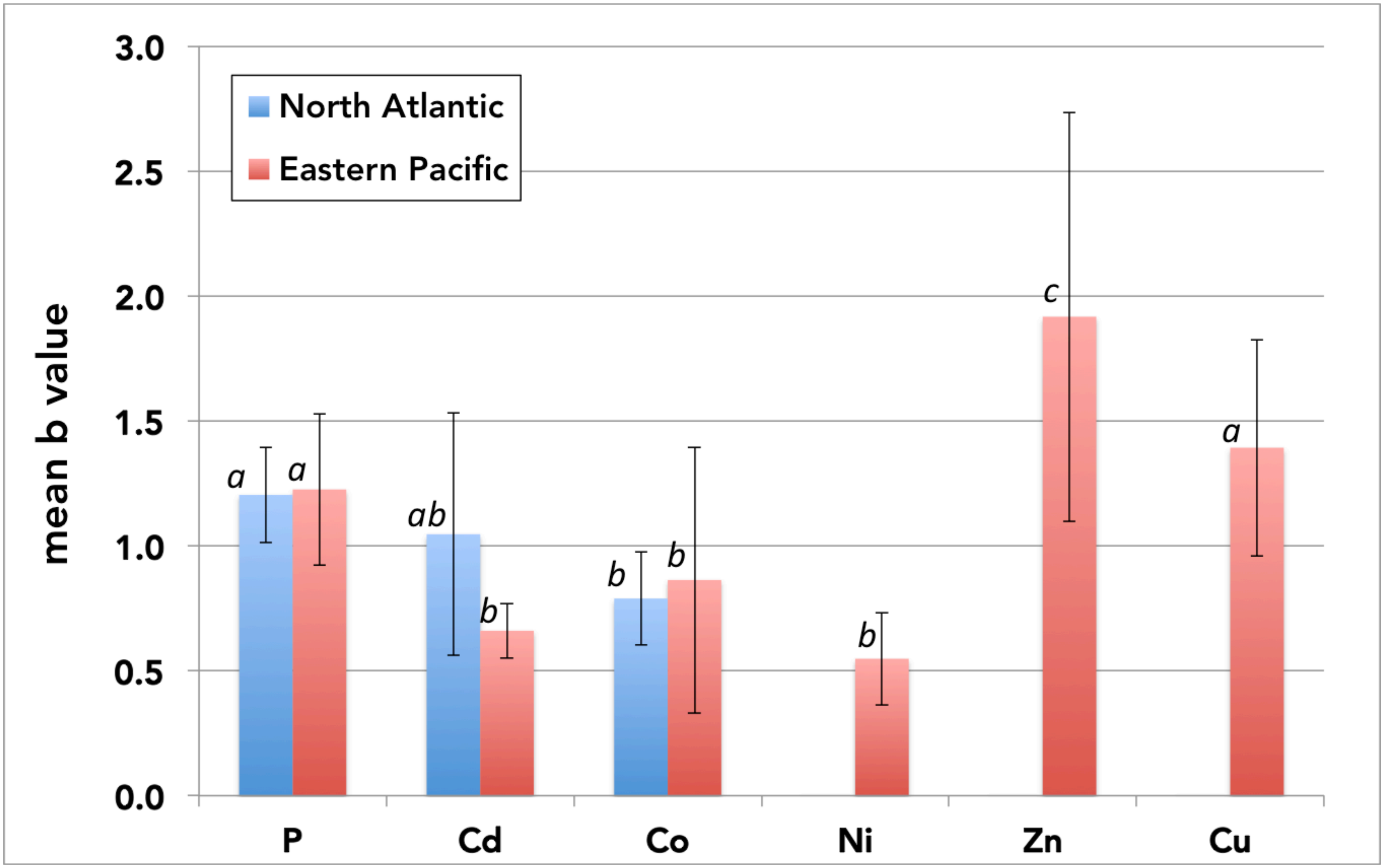
$$y = a \cdot x^{-b}$$



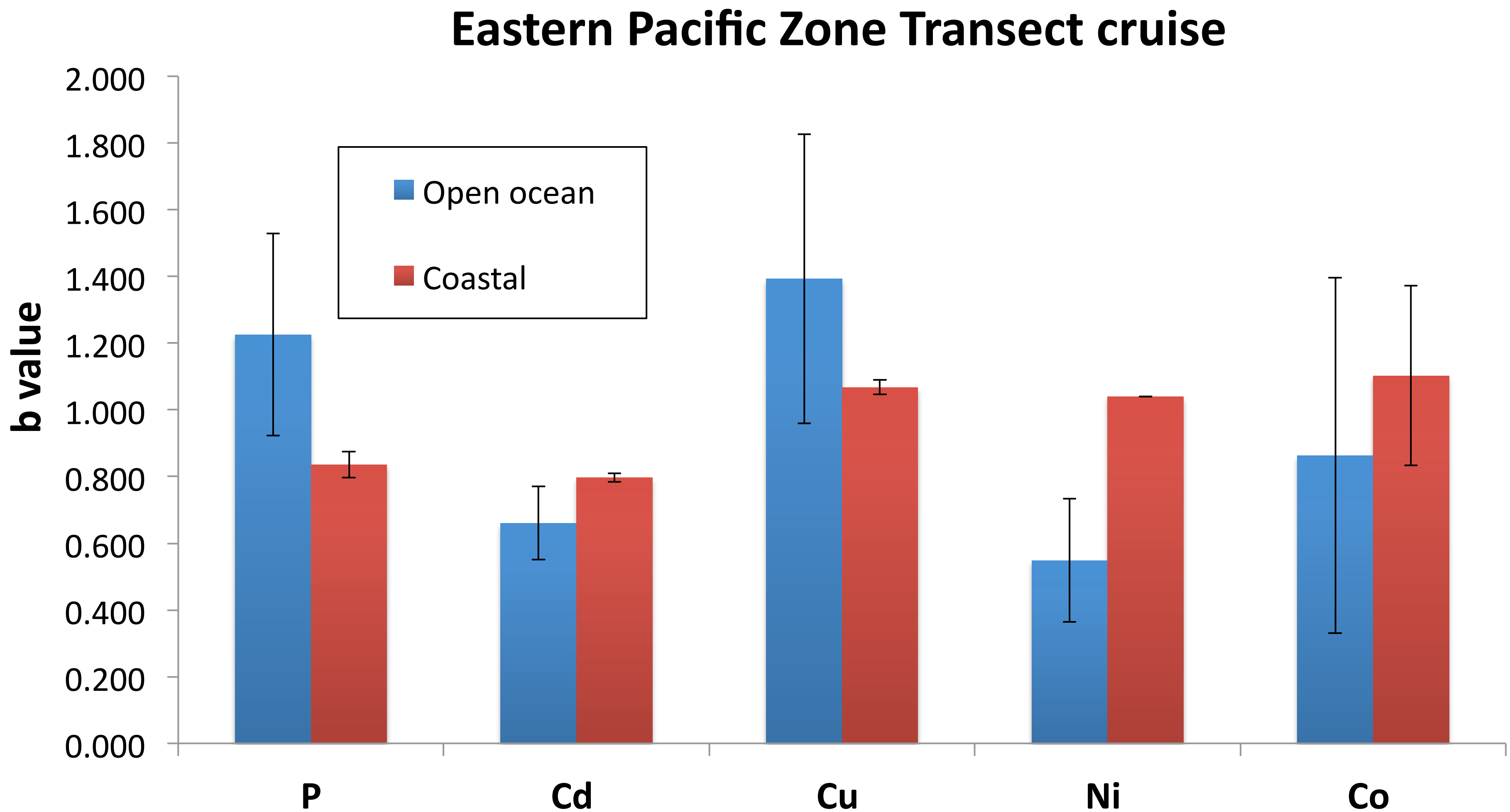
Over what depth ranges can power curves be used to model remineralization?



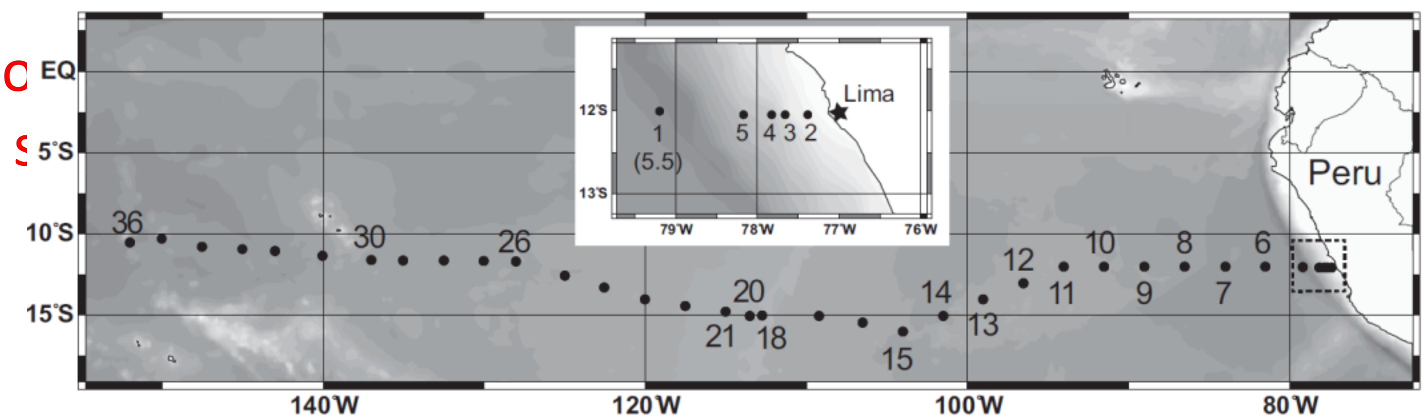
Comparison of b values between ocean basins



Caveats: pumps vs. bottles; comparison restricted to offshore stations



EPZT coastal static
EPZT open ocean s



Outstanding questions

- Can scavenging and the contribution of non-biogenic particle fractions be better constrained?
- Is trace metal remineralization from sinking biogenic matter truly decoupled? If so, what controls this decoupling?
- Do resulting vertical fluxes for nutrients match independent estimates?
- What spatial and temporal variability is there in these processes?

Acknowledgements

- Bottle particles: Sara Rauschenberg , Pete Morton, Rob Sherrell
- Pump particles: Phoebe Lam
- Dissolved data: many groups on NAZT and EPZT
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