Hydrothermal Plume

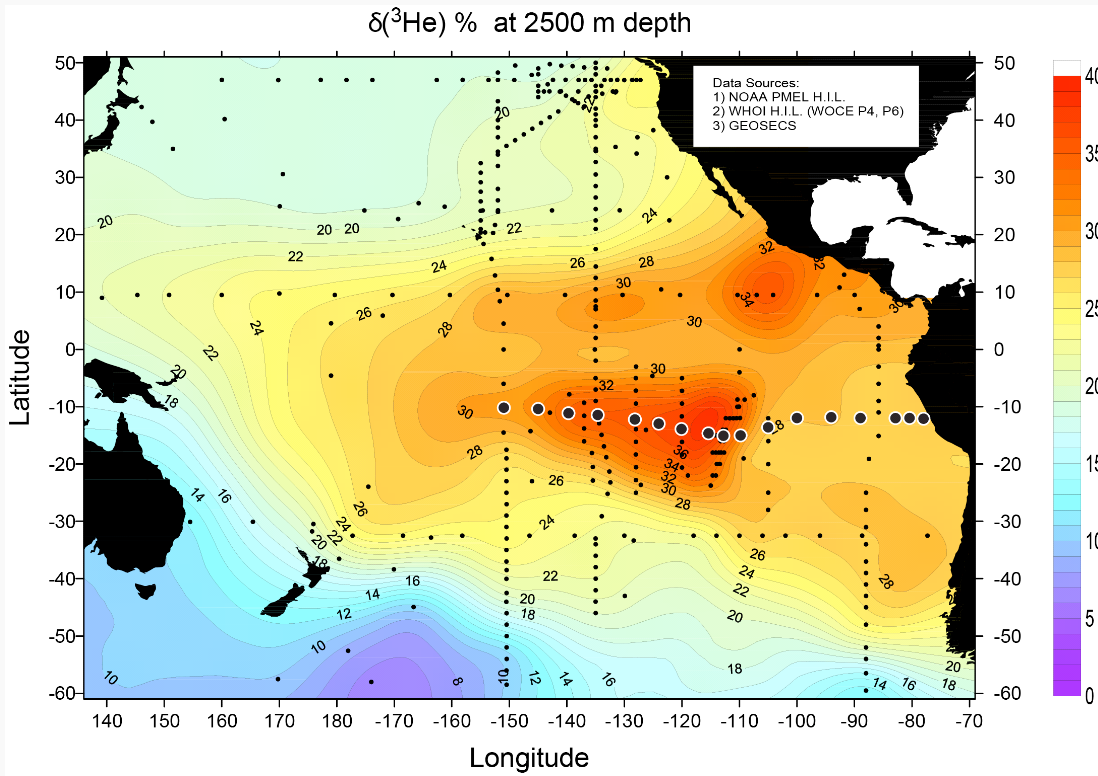
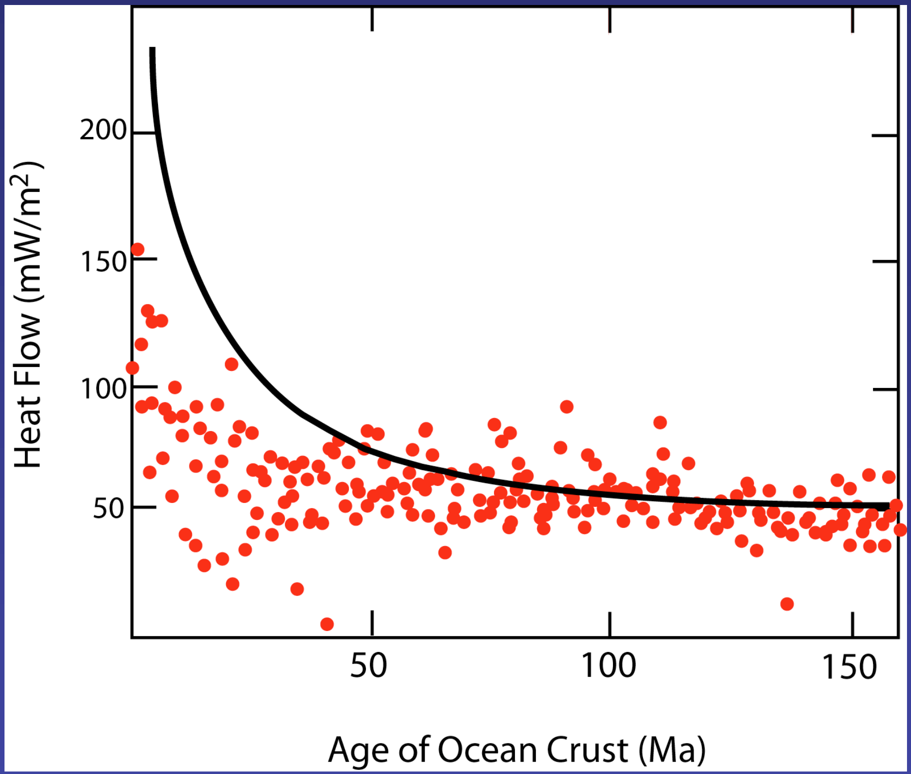


Figure 3 Cruise track showing ^{3}He plume at 2500m

Chris German (WHOI)

Why is hydrothermal activity important?

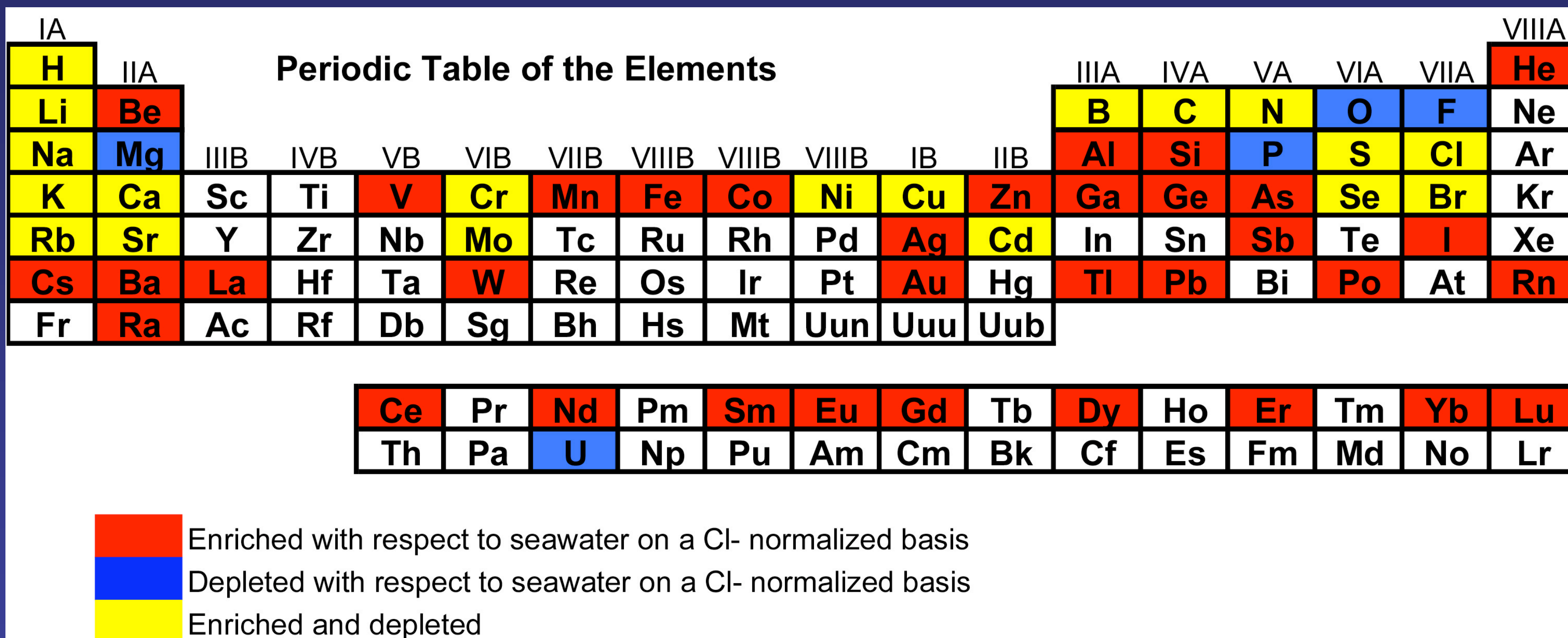
Heat Flux from the Earth's Interior = 43 TW
Seafloor Hydrothermal Heat Flux = 11 TW



The entire volume of the oceans is cycled through hi-T vents every ca. 10Ma

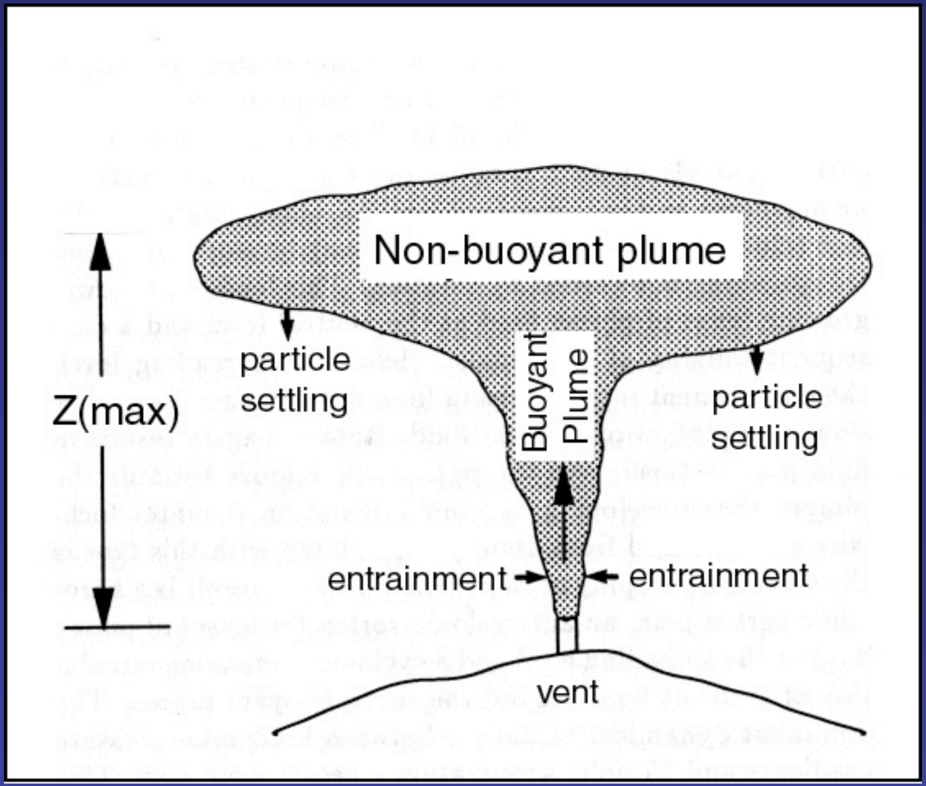
(Stein et al.,*Geophys Monogr.* 1995)

Why is hydrothermal activity important?



(German & Von Damm, *Treatise of Geochem.*, 2004)

Physics of hydrothermal plumes



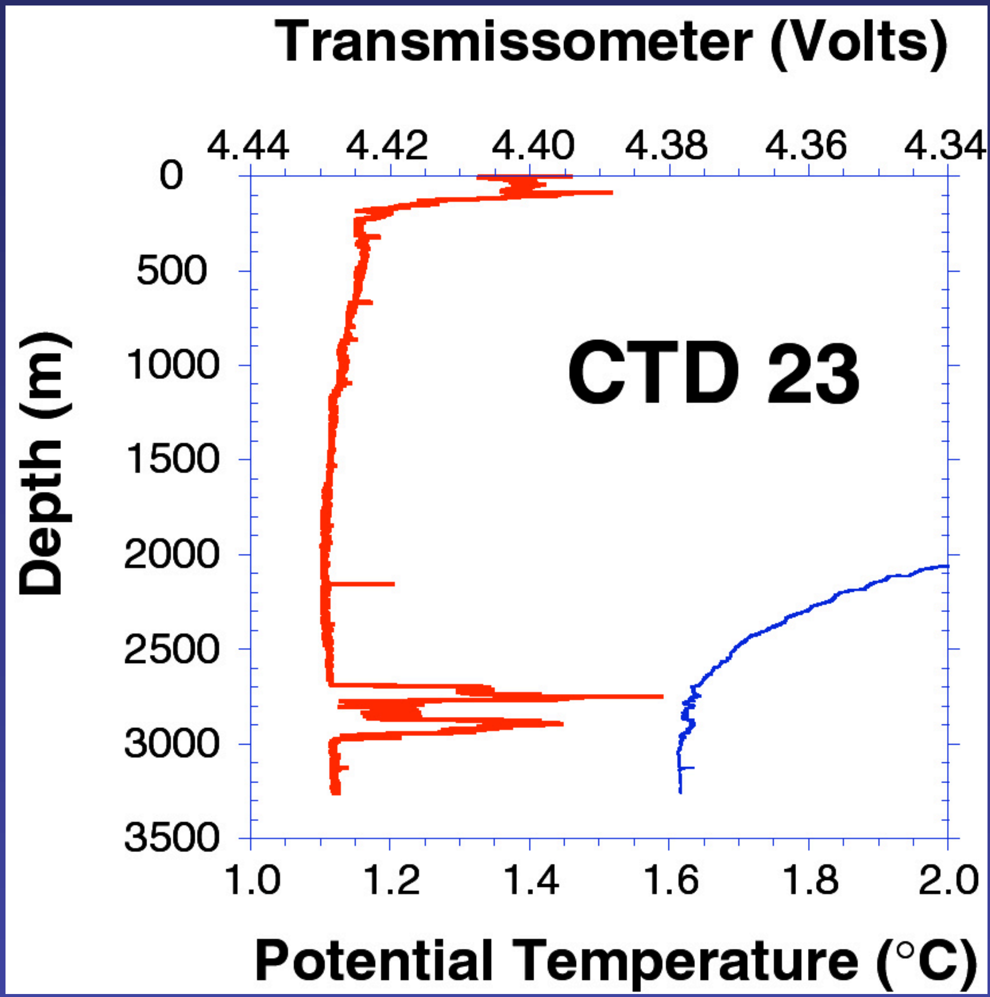
$$z_{max} = 3.76\ F_0^{1/4} N^{-3/4}$$

$$N^2 = -(g/\rho_0).d\rho/dz$$

$$\tau = \pi N^{-1}$$

(Helfrich & Speer, *Geophys Monogr.*, 1995)

Physics of hydrothermal plumes



(*data from* Sands et al., *EPSL*., *in review*)

Time-scales for Hydrothermal Circulation

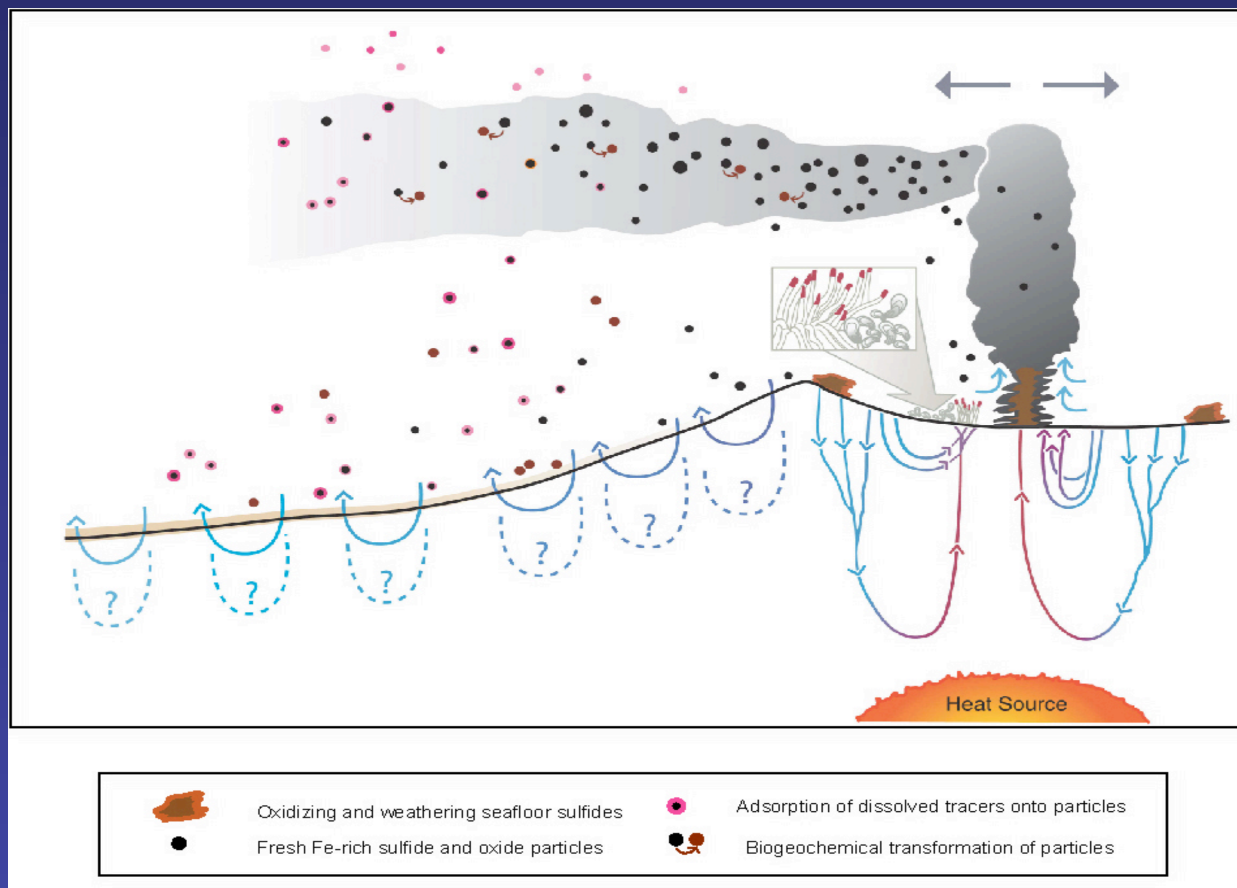
Global hydrothermal fluxes: heat and volume

	Heat Flux (TW)	Water Flux (10^{16} g.yr^{-1})
Axial Flow (0-1 Ma Crust)		
a) if 100% as Hi-T (350°C) fluids	2.8	5.6
b) if 50% @ 350°C; 50% @ 5°C	2.8	240
Off-Axis Flow (1-65 Ma Crust)	7.0	~2500
Riverine Discharge (approx)		~4000
Hydrothermal plumes (50% of 0-1 Ma)		~28,000

(*revised from* Elderfield & Schultz, *Ann.Rev.Earth.Planet.Sci*., 1996)

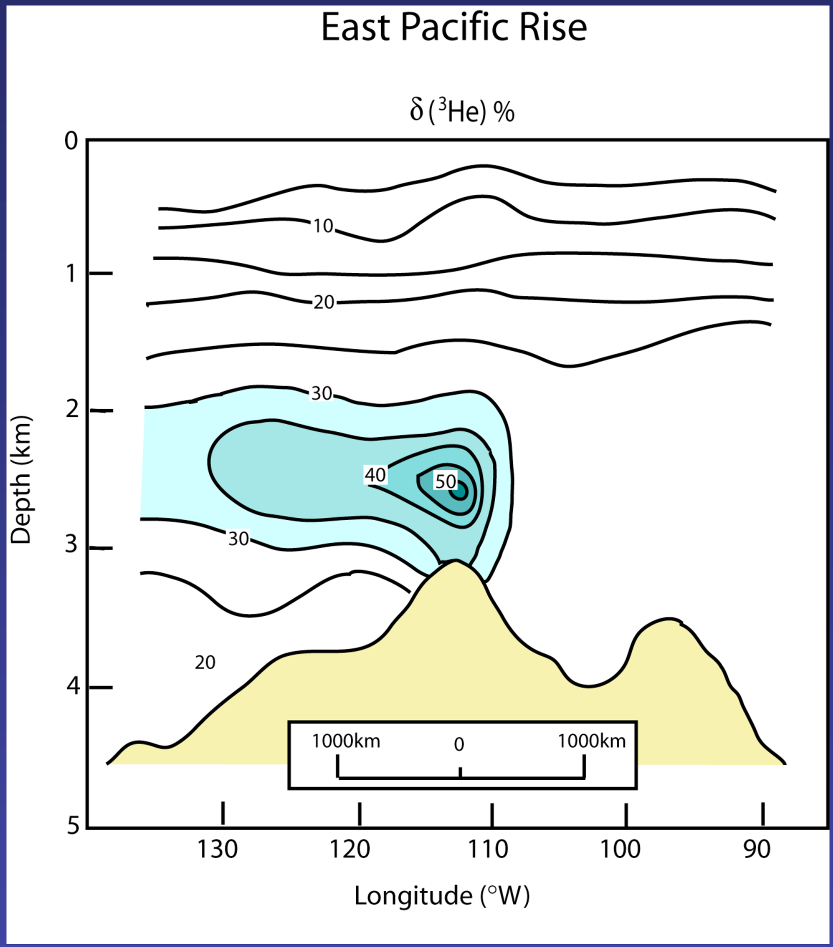
Time-scales for Hydrothermal Circulation

Entire volume of oceans cycled through plumes every ~2kyr?



(German & Von Damm, *Treatise of Geochem.*, 2004)

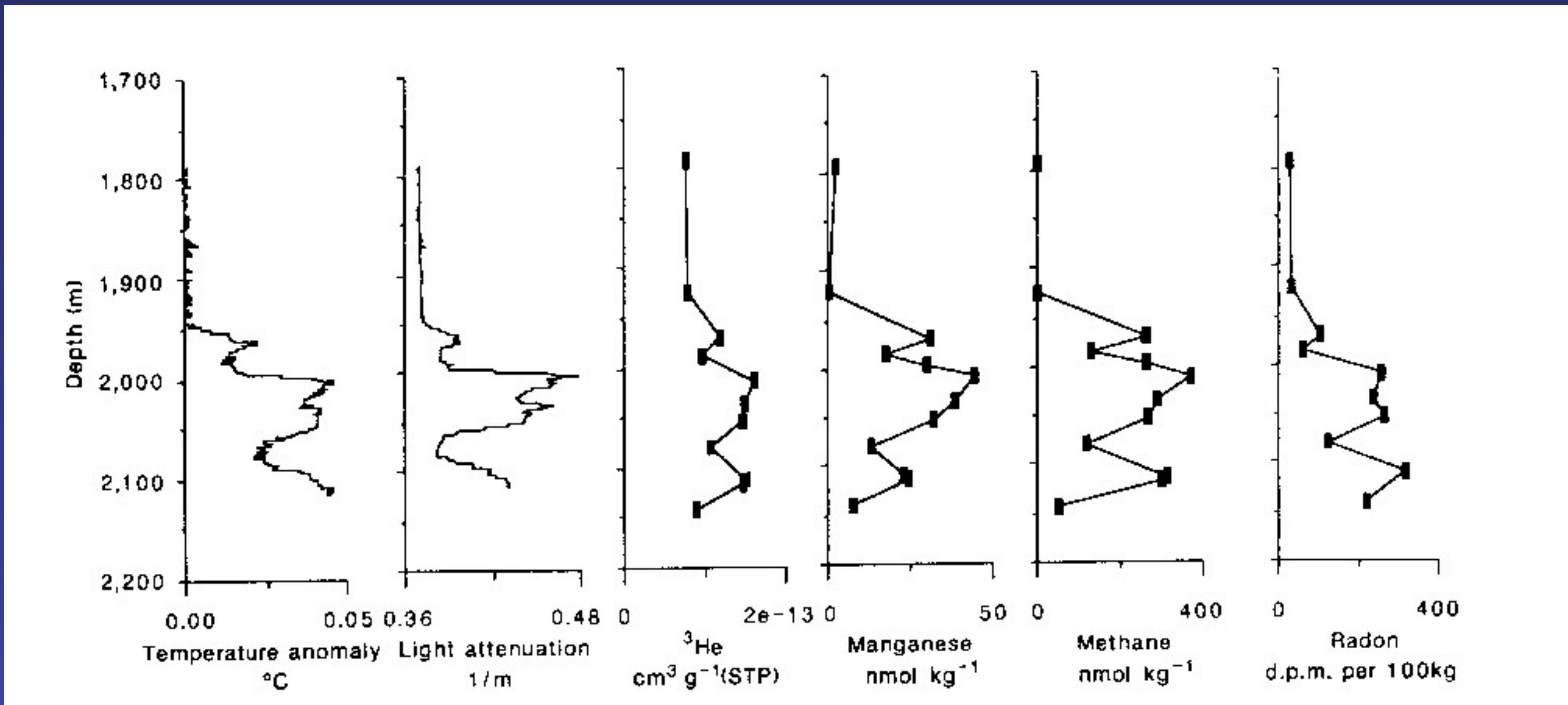
Hydrothermal Plume Geochemistry



- Noble Gases
- Reduced gases
- Fe & Mn
- Other metals
- Microbes
- Larvae

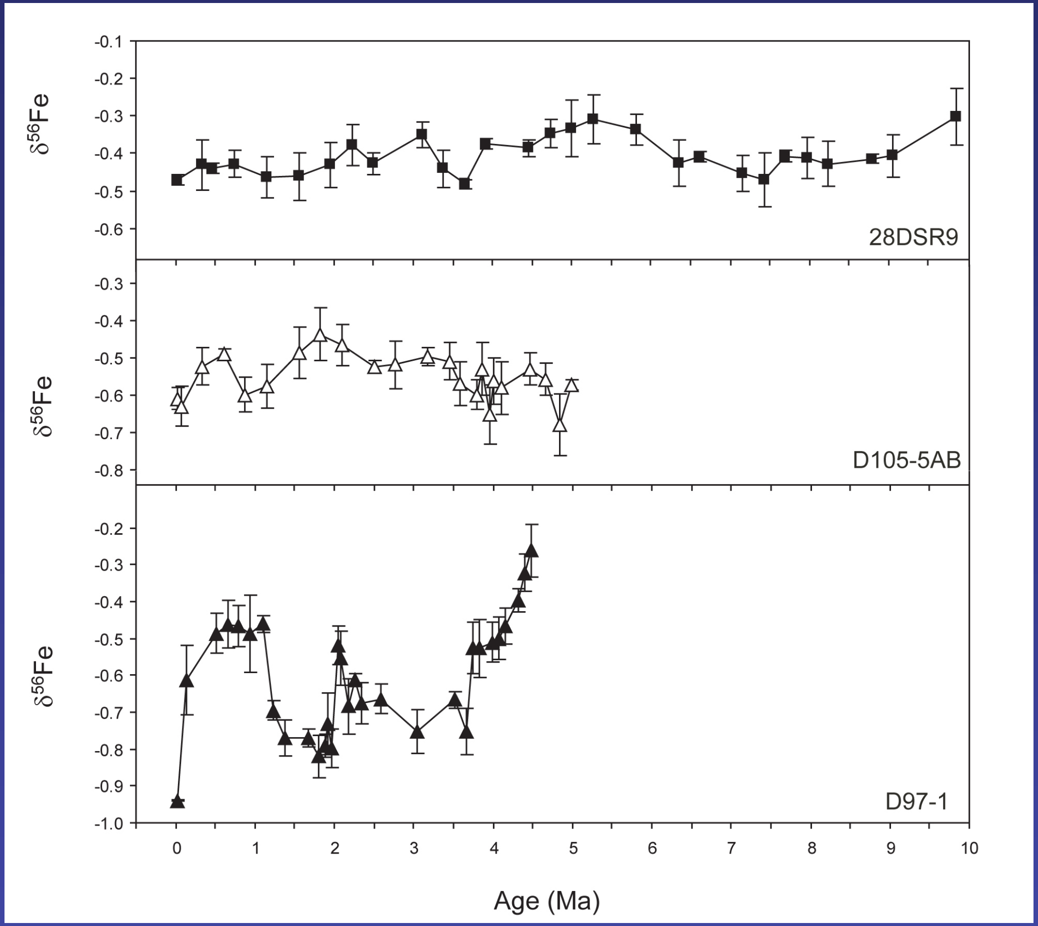
(*after* Lupton & Craig, *Science*, 1981)

Plume Geochemistry - Reactive Tracers



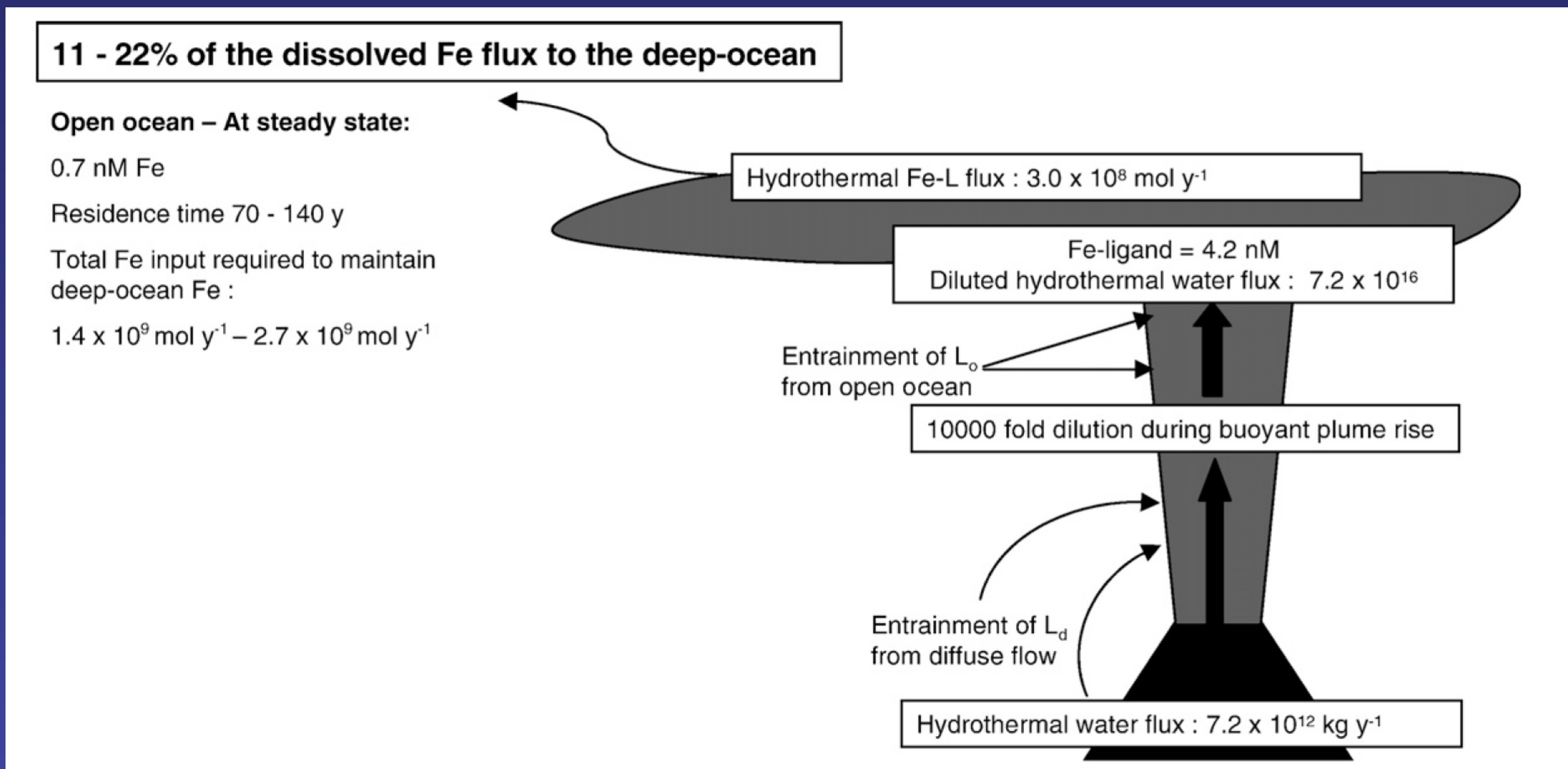
(Kadko et al., *EPSL*, 1990)

How much deep-ocean Fe is hydrothermal?



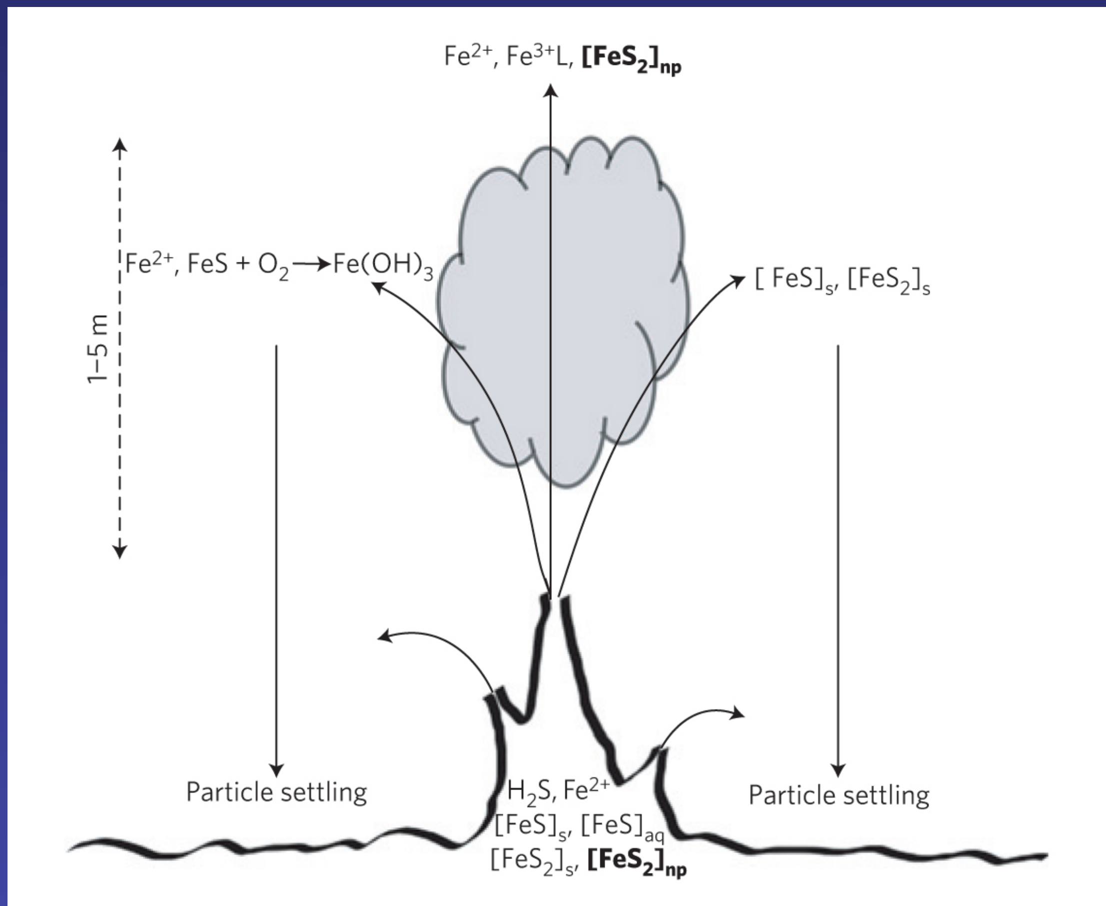
(Chu et al., *EPSL*, 2006)

How much deep-ocean Fe is hydrothermal?



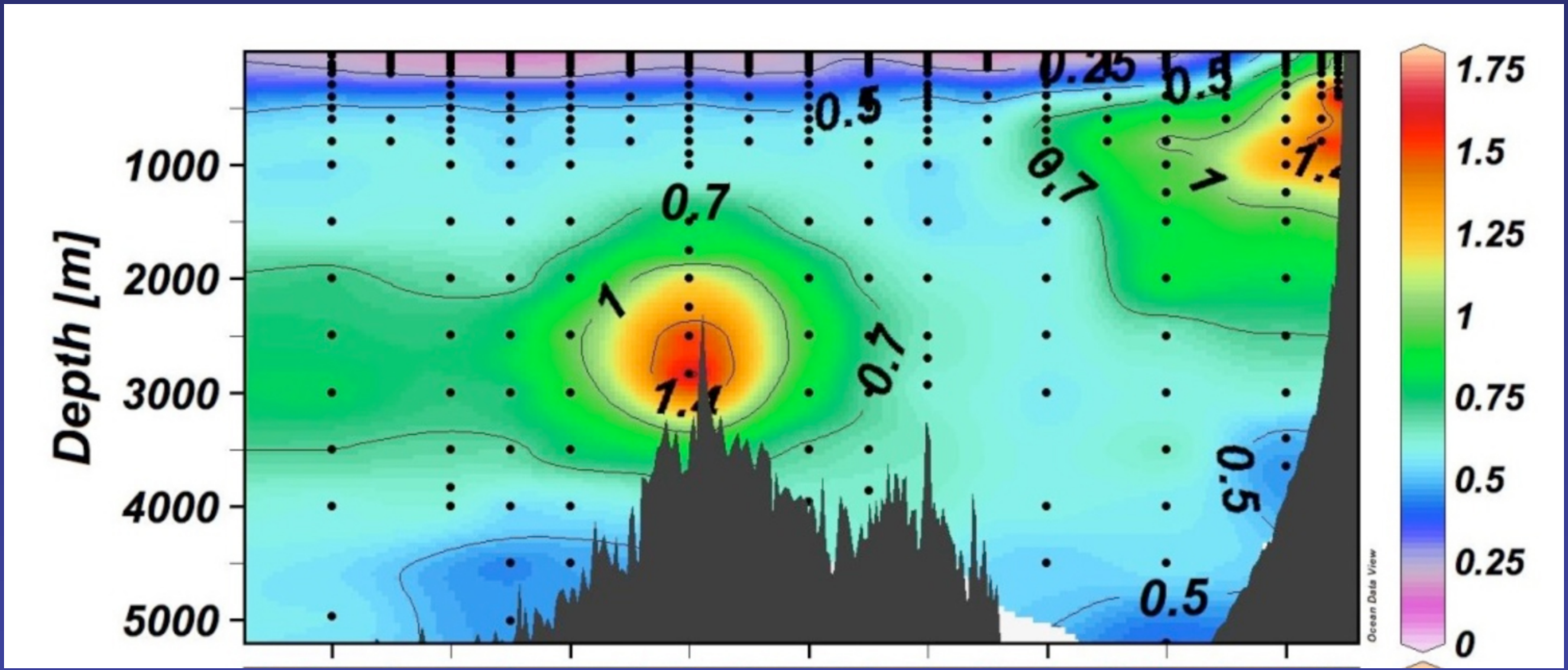
(Bennett et al., *EPSL*, 2008)

How much deep-ocean Fe is hydrothermal?



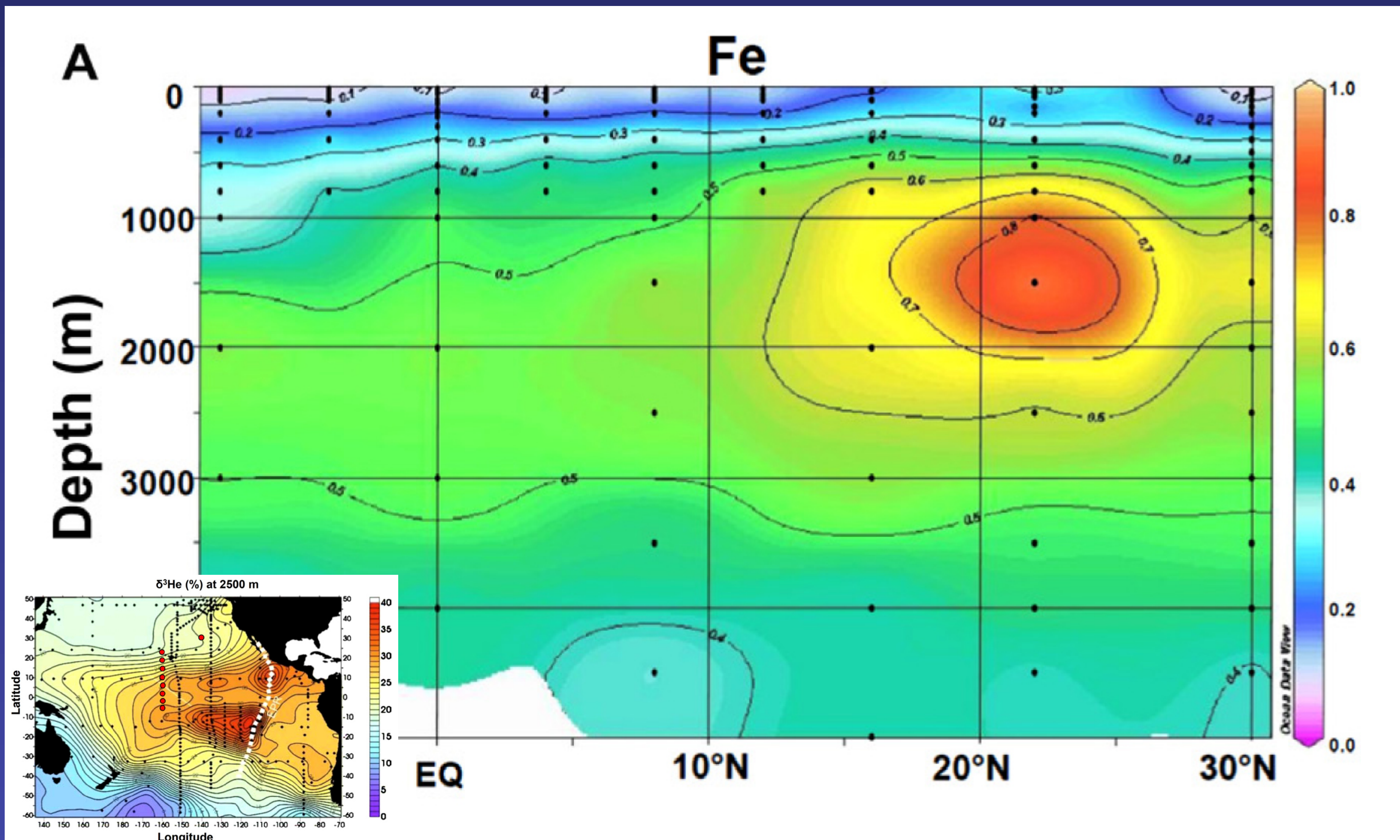
(Yucel et al., *Nat. Geosci.*, 2011)

How much deep-ocean Fe is hydrothermal?



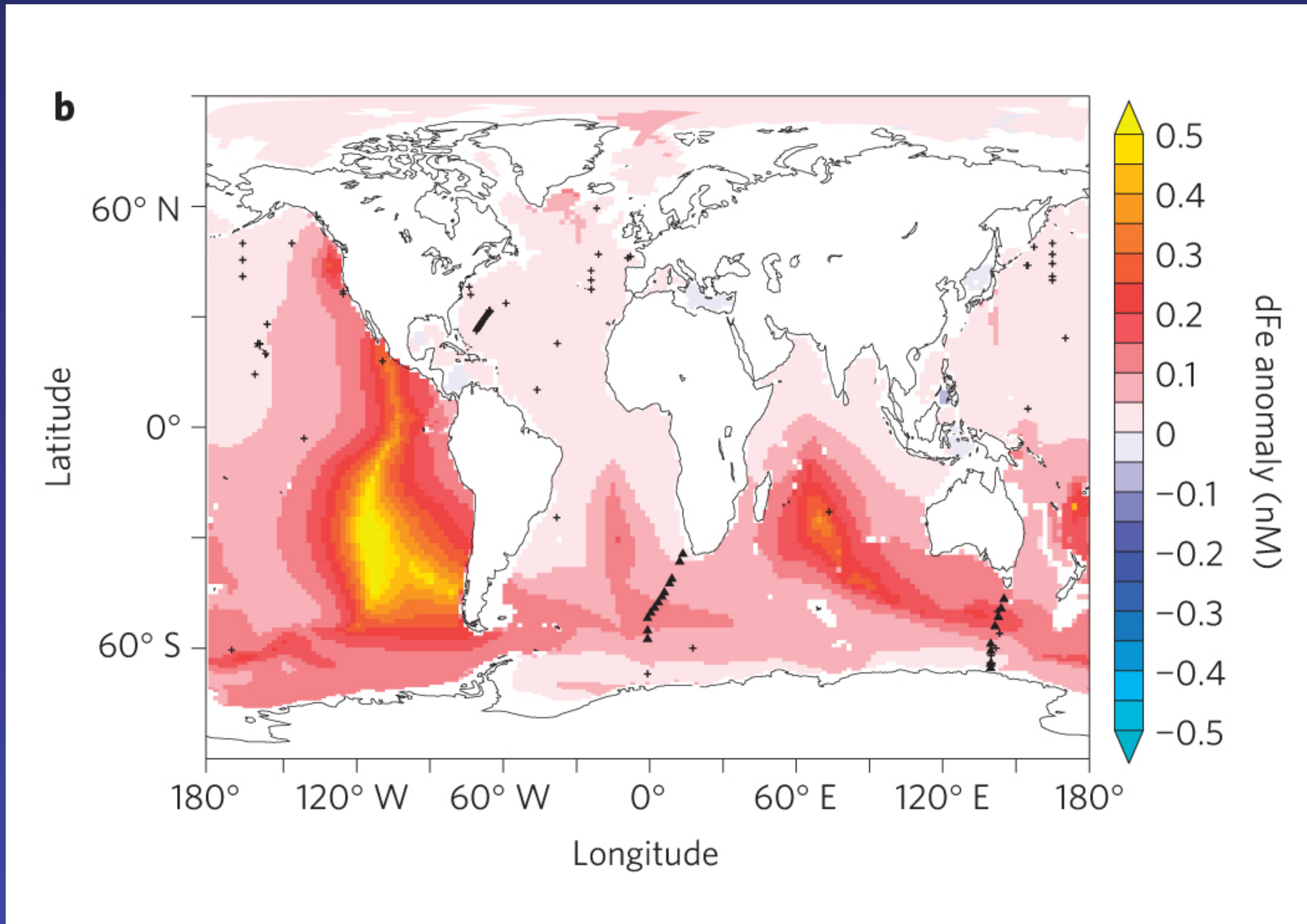
(M.Saito et al., *CoFeMUG Cruise*, 2007)

How much deep-ocean Fe is hydrothermal?



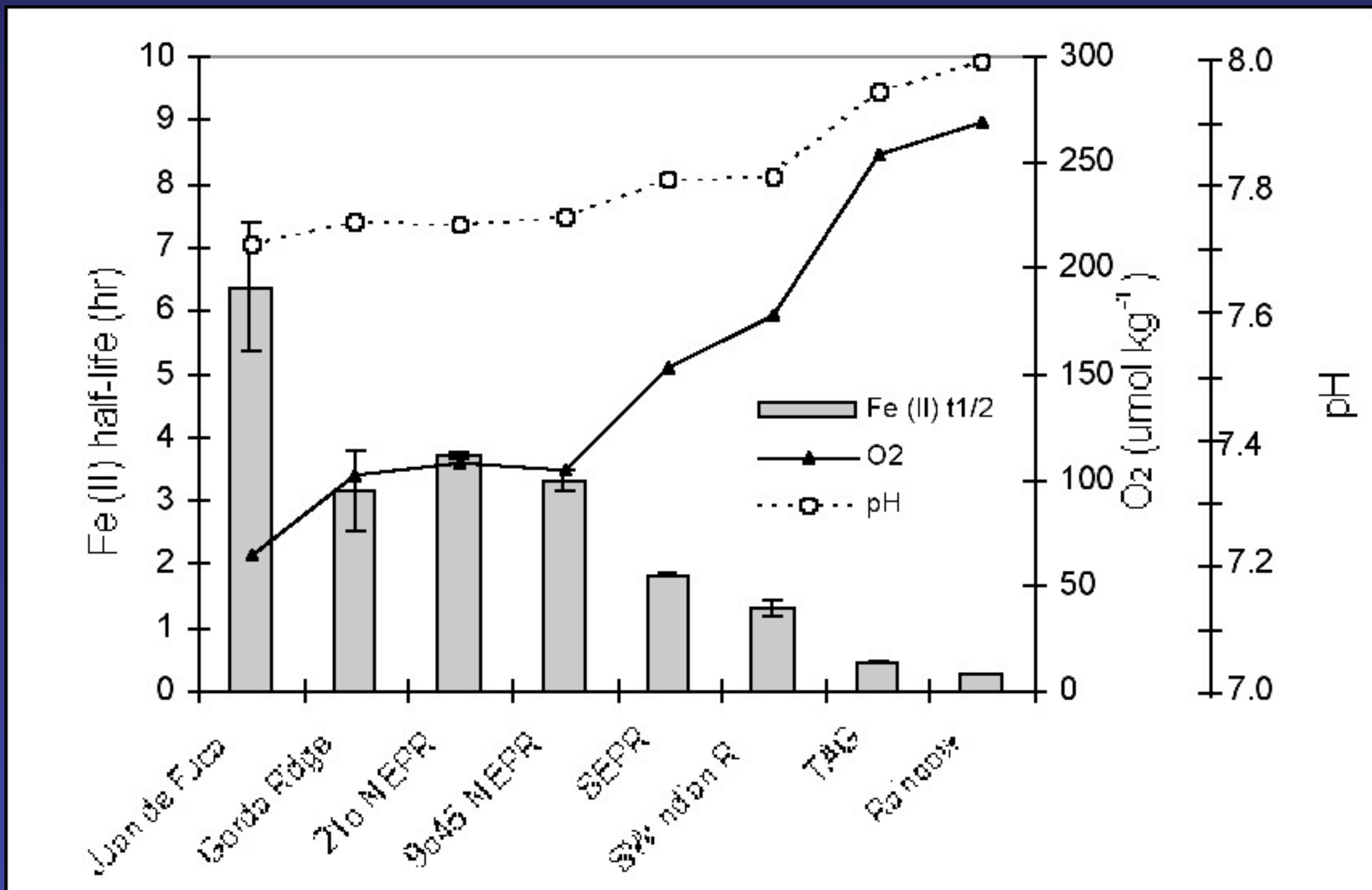
(Wu et al., *GCA*, 2011)

How much deep-ocean Fe is hydrothermal?



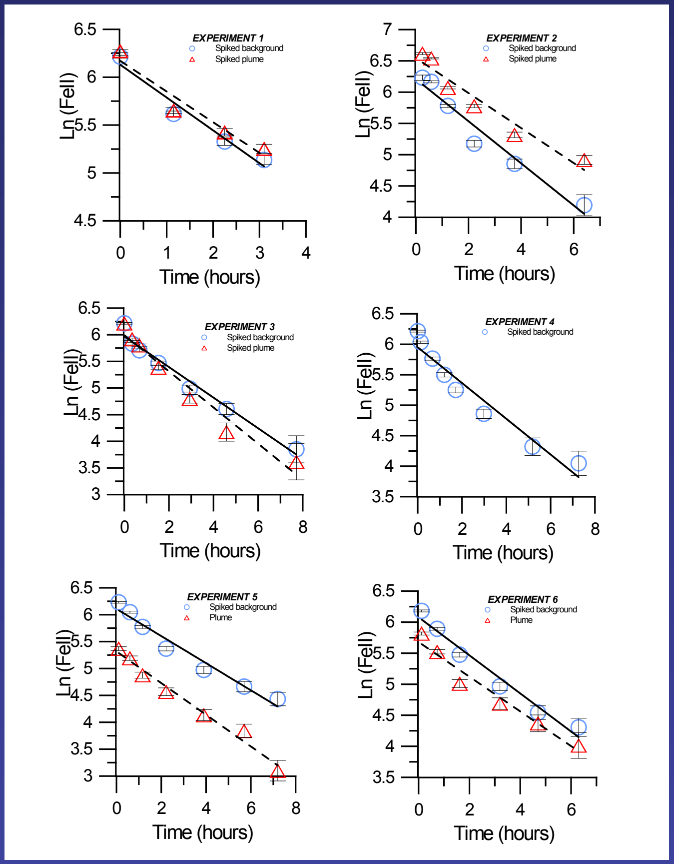
(Tagliabue et al., *Nat. Geosci.*, 2010)

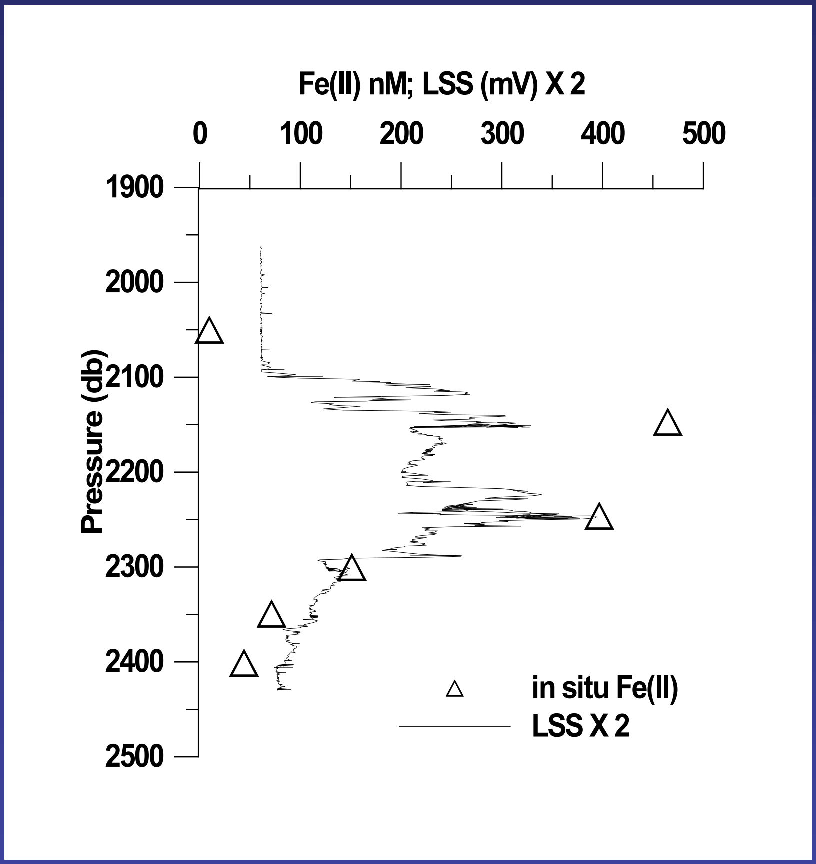
Plume Geochemistry - Fe oxidation



(Field & Sherrell, *GCA*, 2000)

Indian Ocean
Fe oxidation: t(1/2) = 2.3 ± 0.2 hours



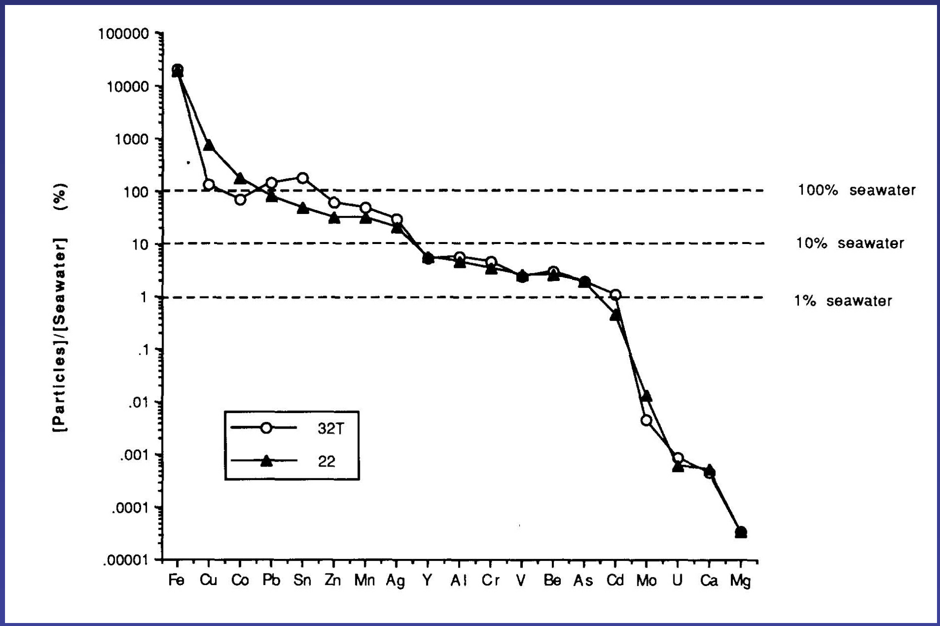


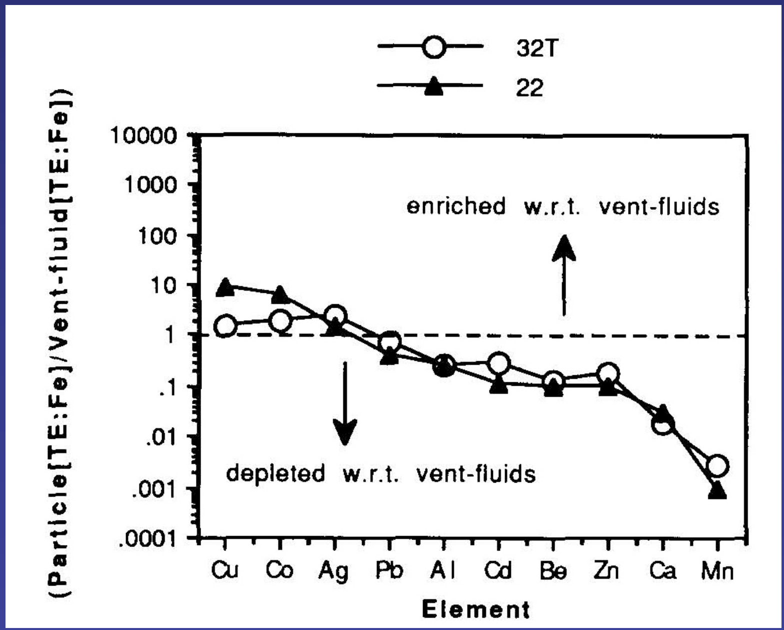
Order 50% of vent-Fe arrives at plume-height as dissolved Fe(II)

(Statham et al., *EPSL*, 2005)

Plume Particle Geochemistry:

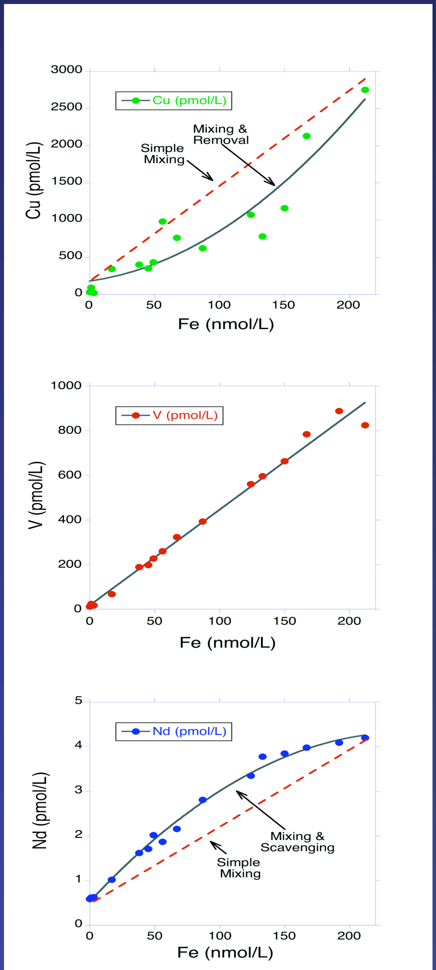
Modification of hydrothermal vent-fluxes





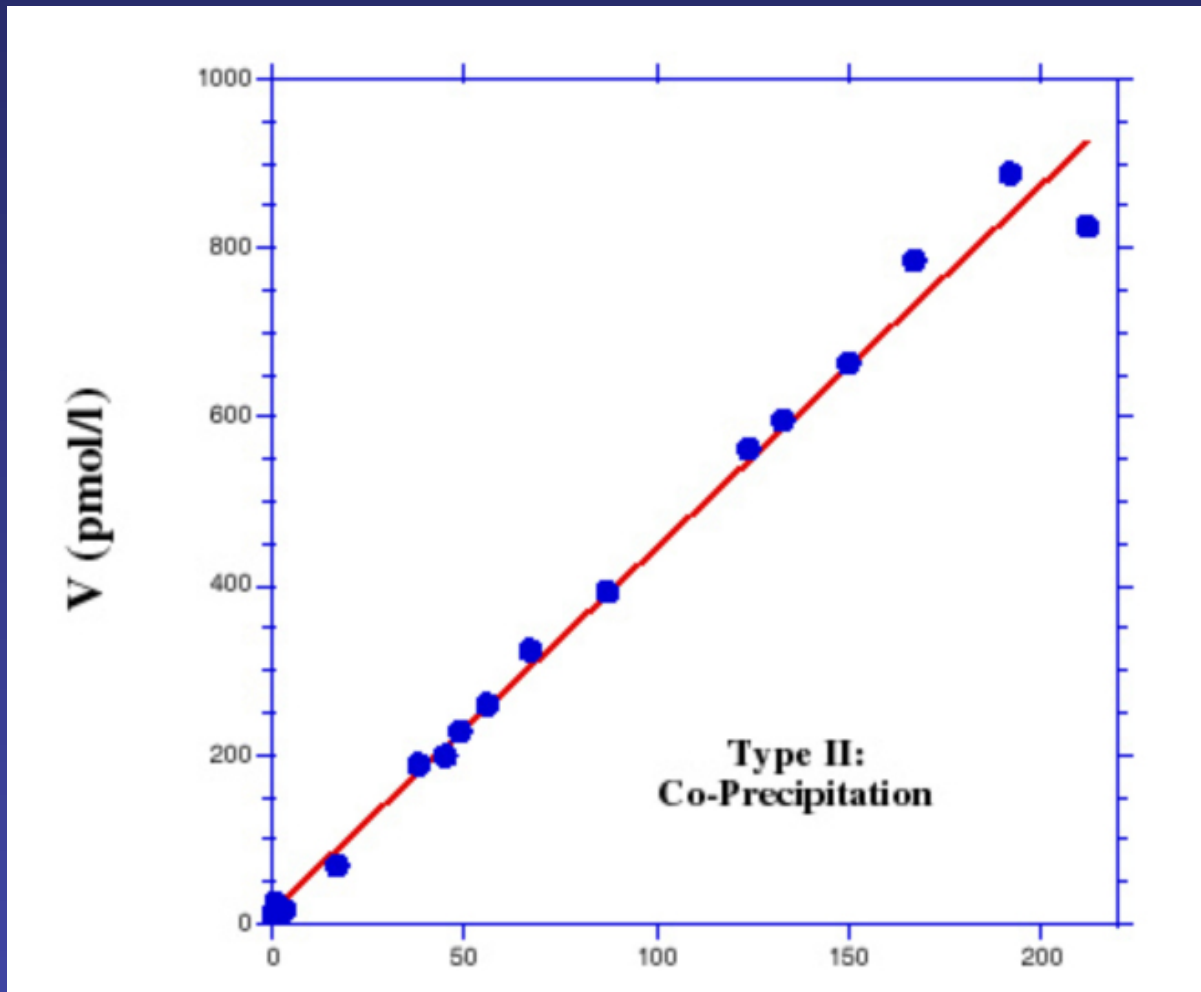
(German et al., *EPSL*, 1991)

Hydrothermal Scavenging: 3 forms



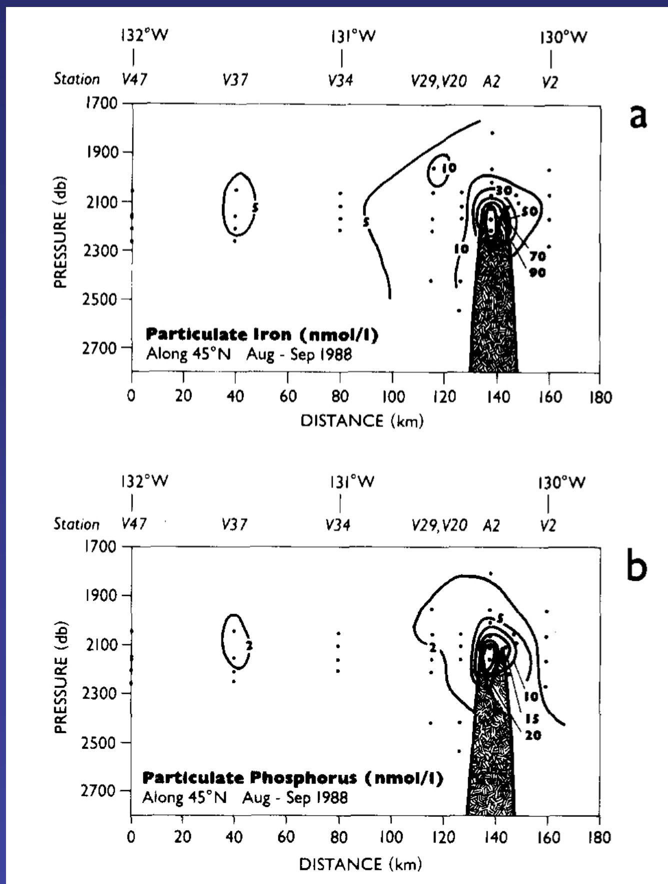
(German & Von Damm, *Treatise on Geochemistry*, 2004)

“Oxyanions”: P, V, As, Cr, U



(*data from* German et al., *EPSL*, 1991)

Hydrothermal Phosphorous Cycling



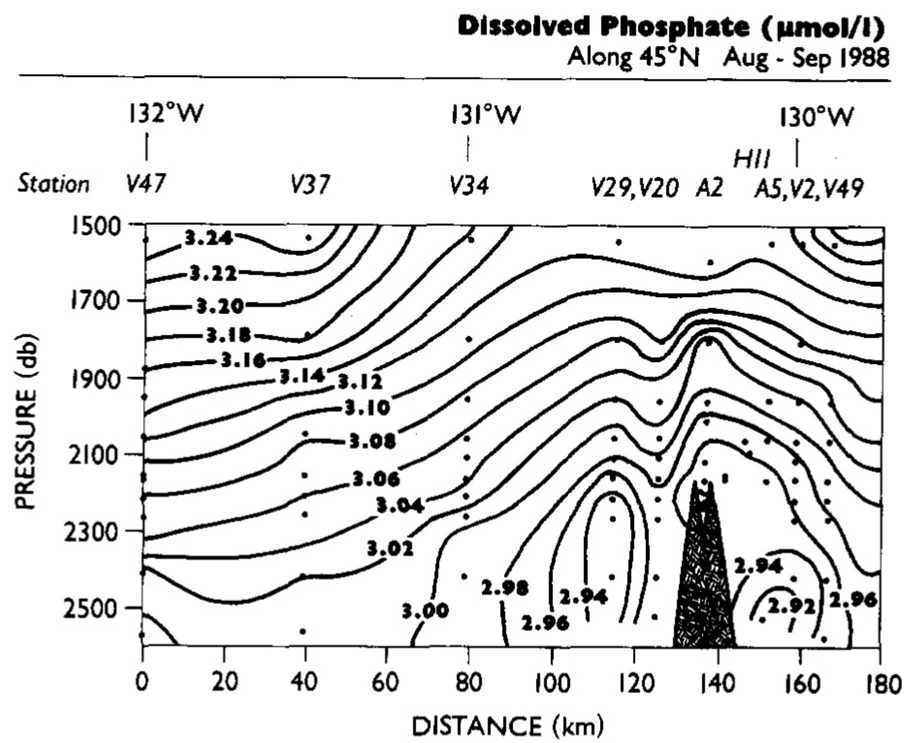
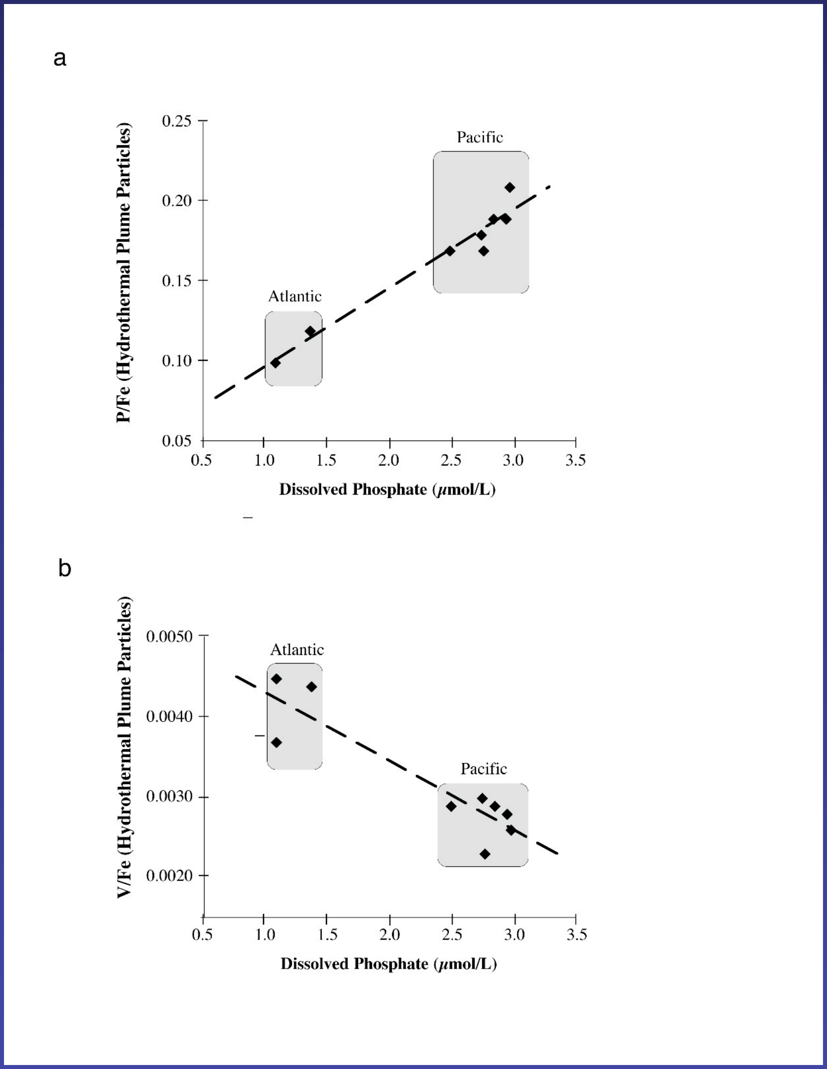


Fig. 4. East–west section of dissolved phosphate normal to the Juan de Fuca Ridge along 45° N from 129° W to 132° W.

(Feely et al., *EPSL*, 1990)

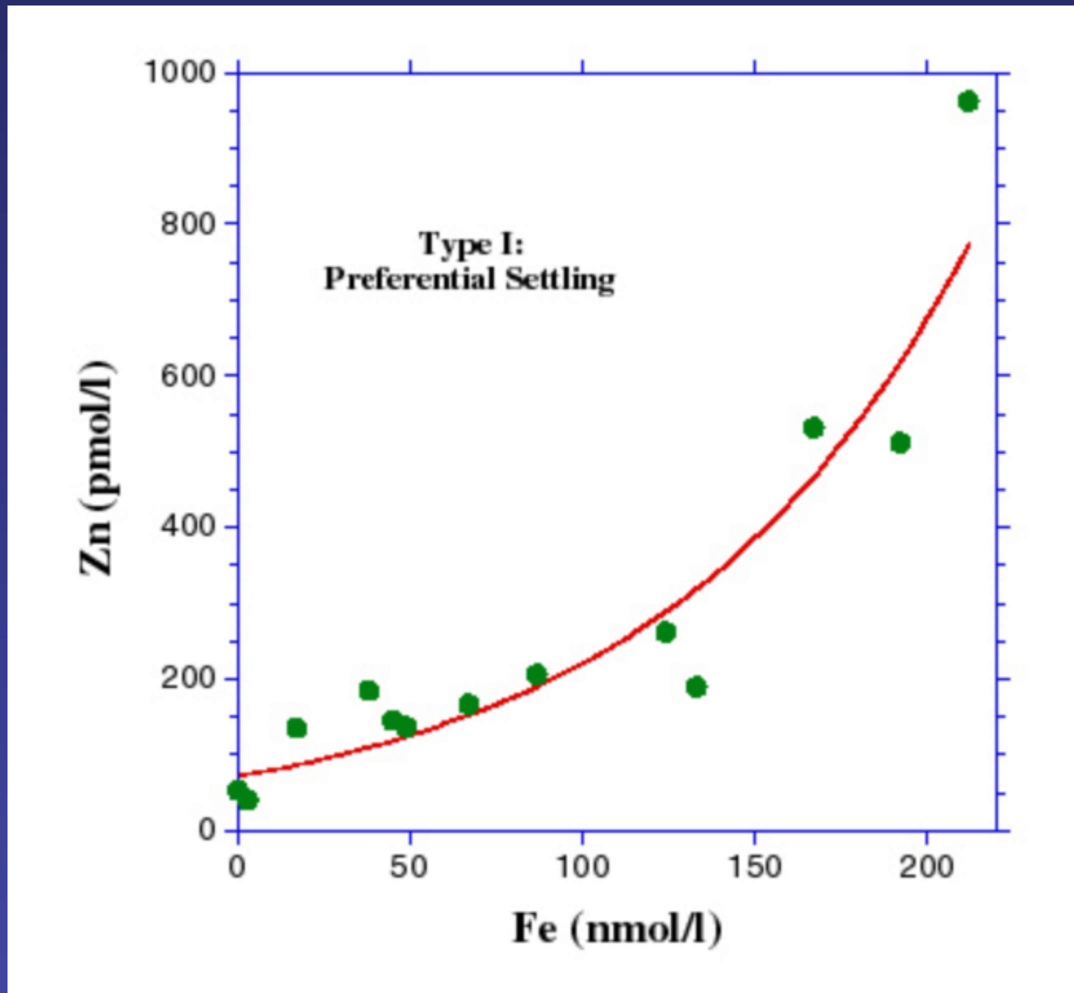
Hydrothermal Phosphorous Cycling



Can hydrothermal sediments
be used to trace global climate change?

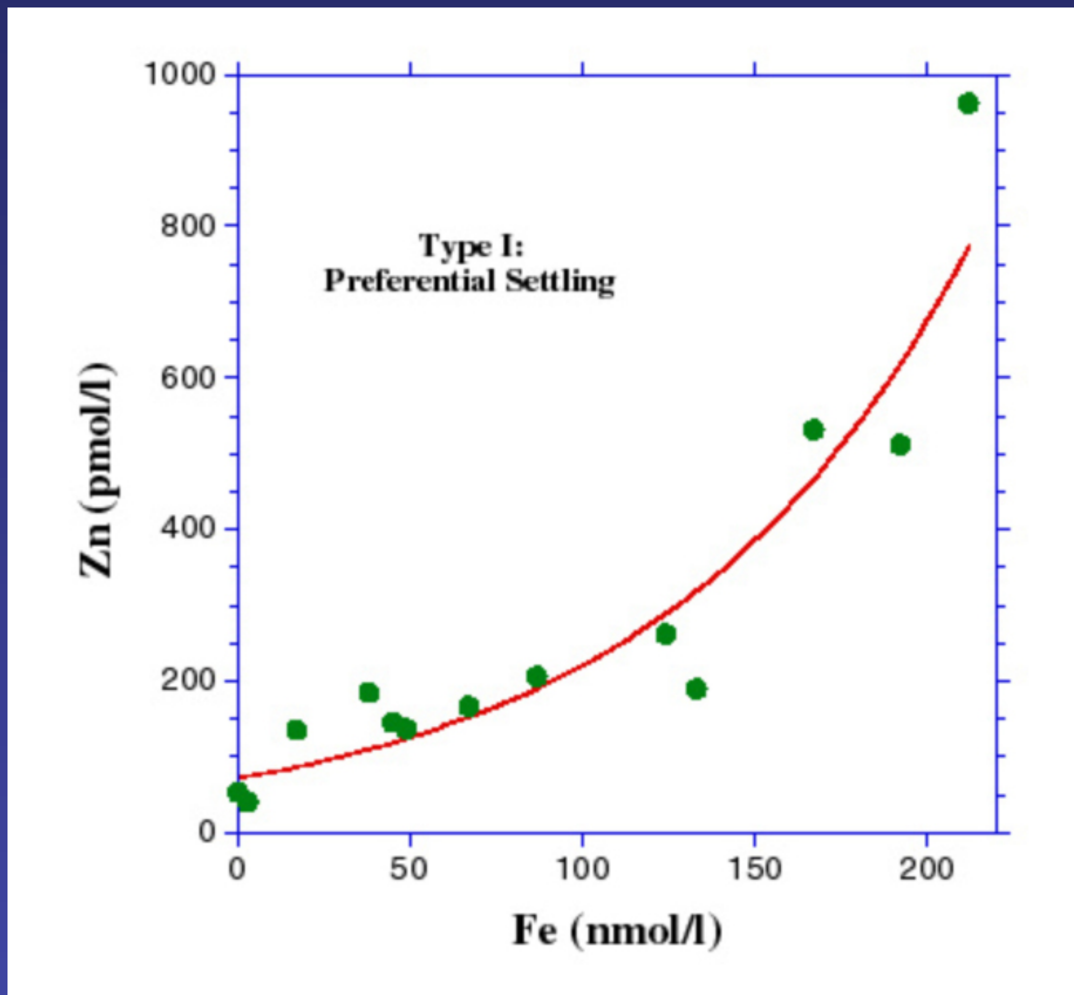
(Feely et al., *GRL*, 1998)

“Chalcophiles”: Cu, Zn, Pb, Cd, Ag



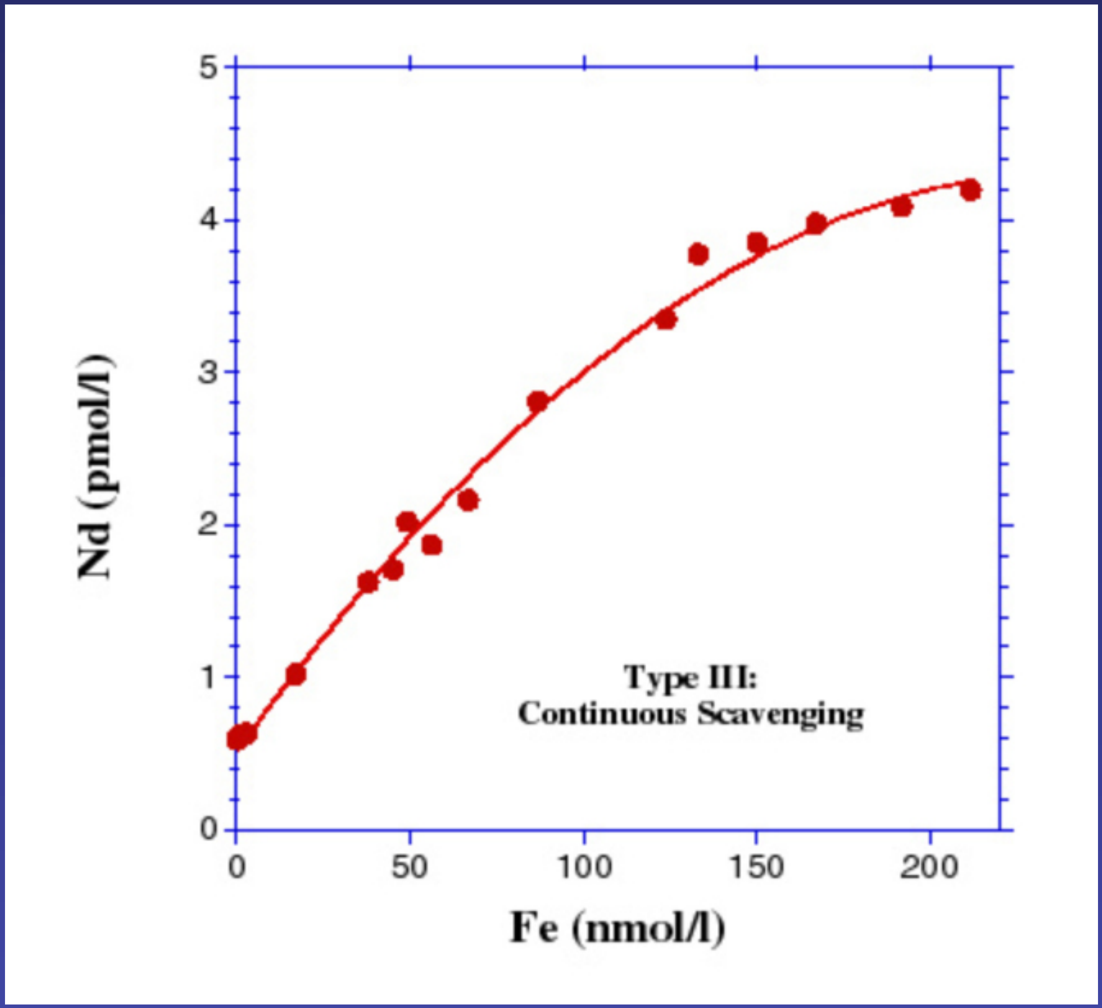
(*data from* German et al., *EPSL*, 1991)

Alternately: Oxidative Dissolution?



(*see* Metz & Trefry, *JGR*, 1993)

“Scavenged”: Be, Y, REE, Th, Pa



(*data from* German et al., *Nature*, 1990)

Alternately: Dissolved REE pool depleted?

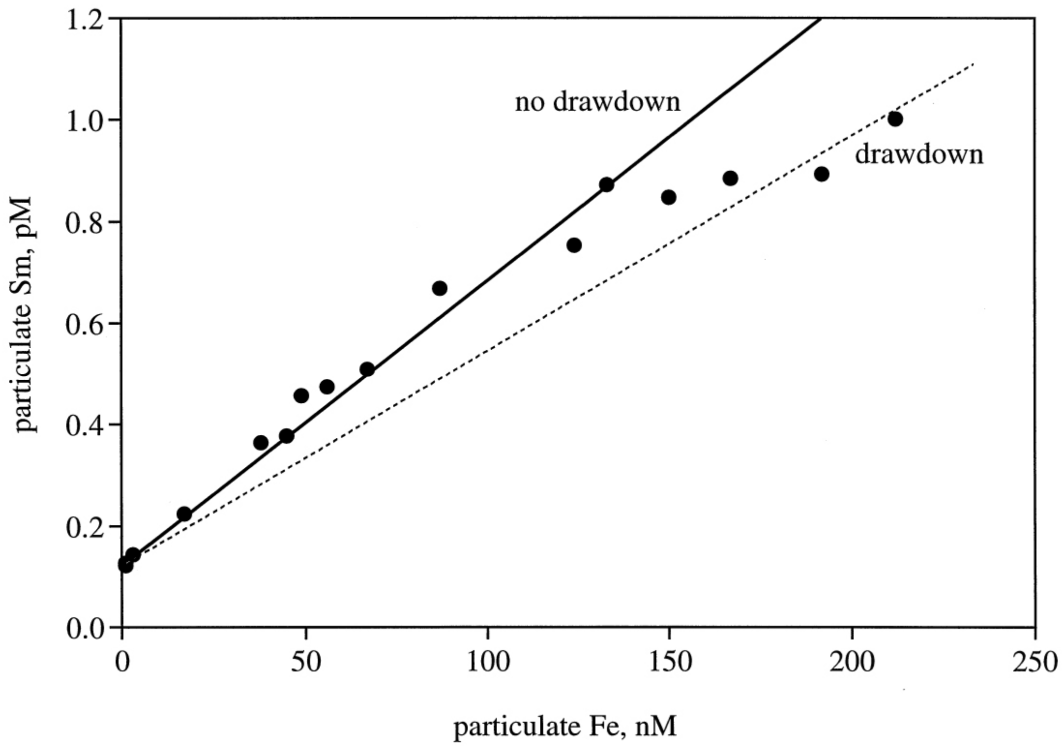
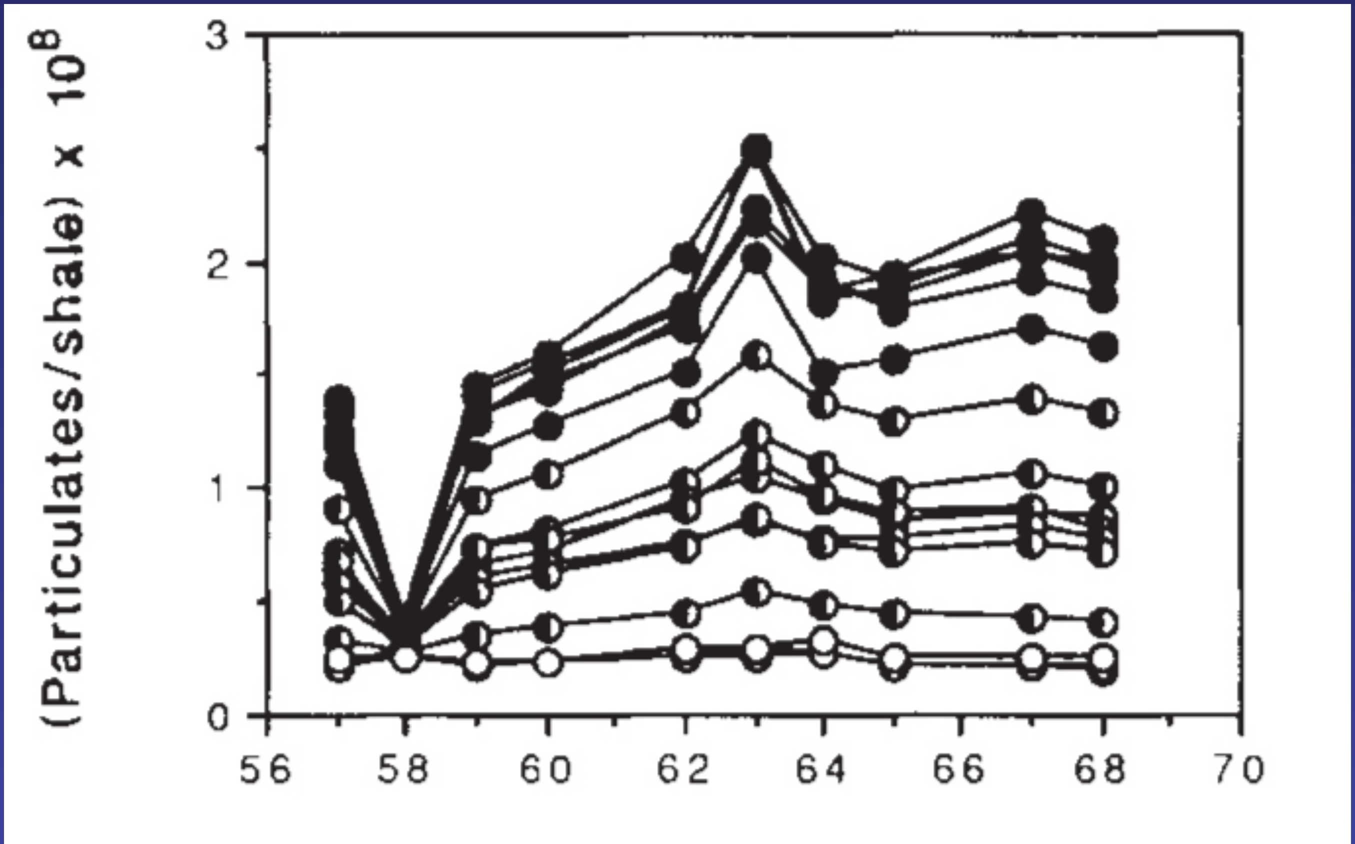


Fig. 8. Sm vs. Fe for TAG plume particles (after German et al., 1990), indicating response of particulate Sm to dissolved Sm drawdown at high particulate Fe (dashed line), and conservative mixing which would be observed in the case of no drawdown of the dissolved REE pool (solid line).

(Sherrell et al., *GCA*, 1999)

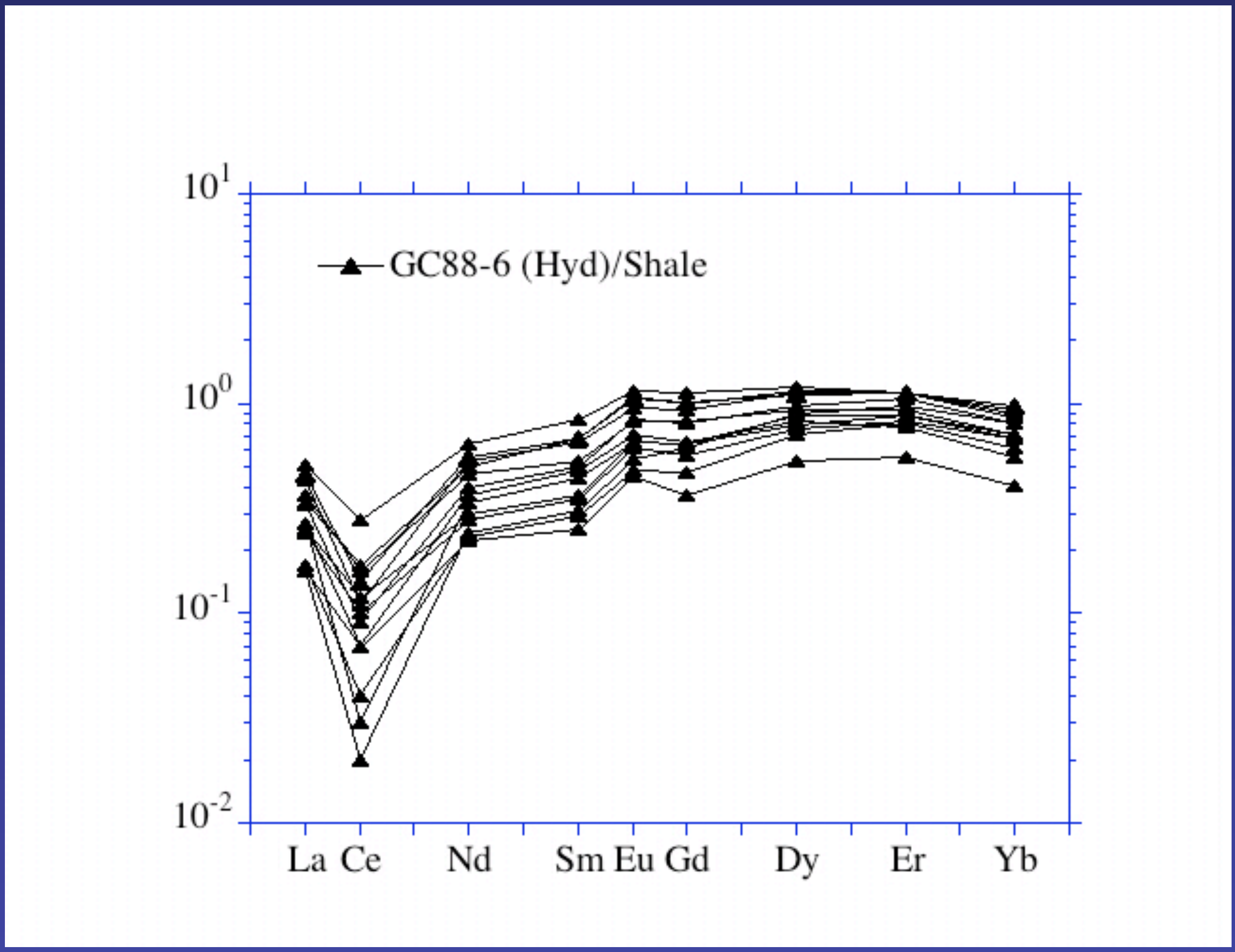
REEE: Hydrothermal *vs* Seawater Sources



(German et al., *Nature*, 1990)

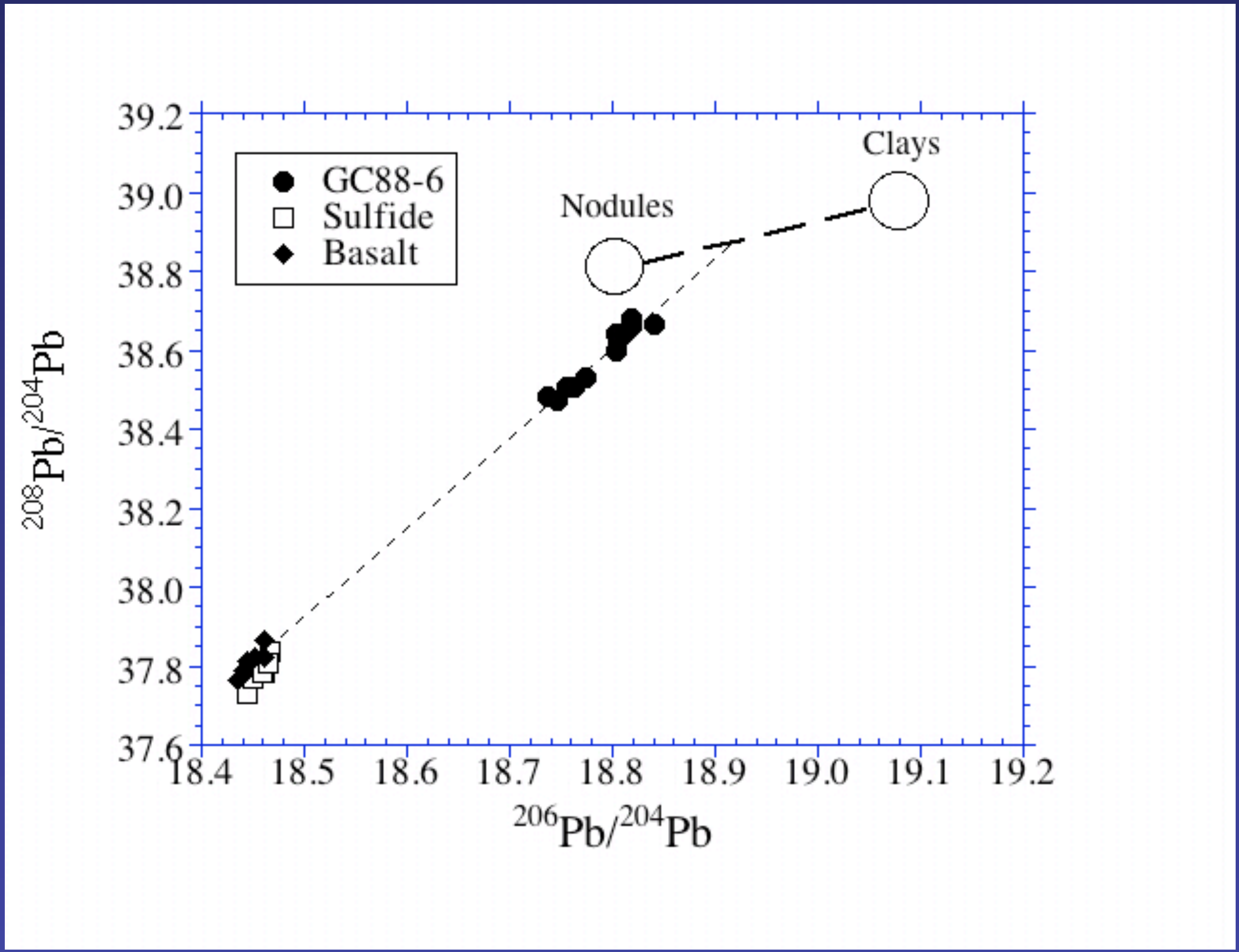
REEE: Hydrothermal *vs* Seawater Sources

REEE: Hydrothermal *vs* Seawater Sources



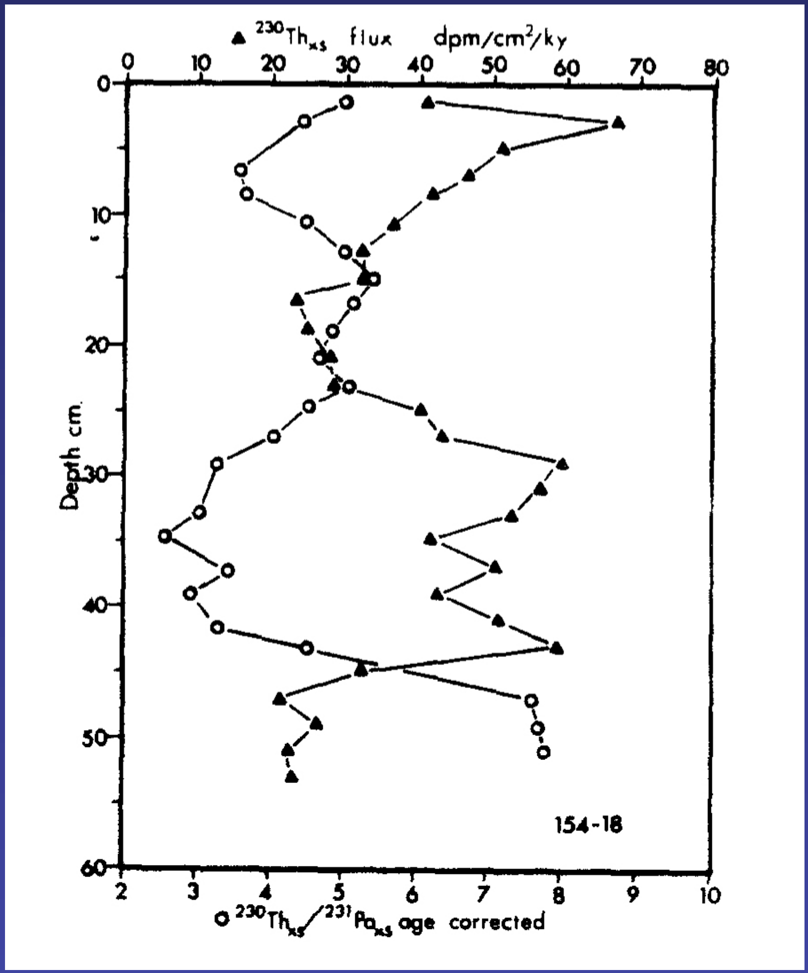
(German et al., *GCA*, 1997)

Pb isotopes: Mantle *vs* Seawater Sources



(German et al., *GCA*, 1997)

Hydrothermal *vs* Boundary Scavenging



(Shimmield & Price, *GCA*, 1988)

Hydrothermal *vs* Boundary Scavenging

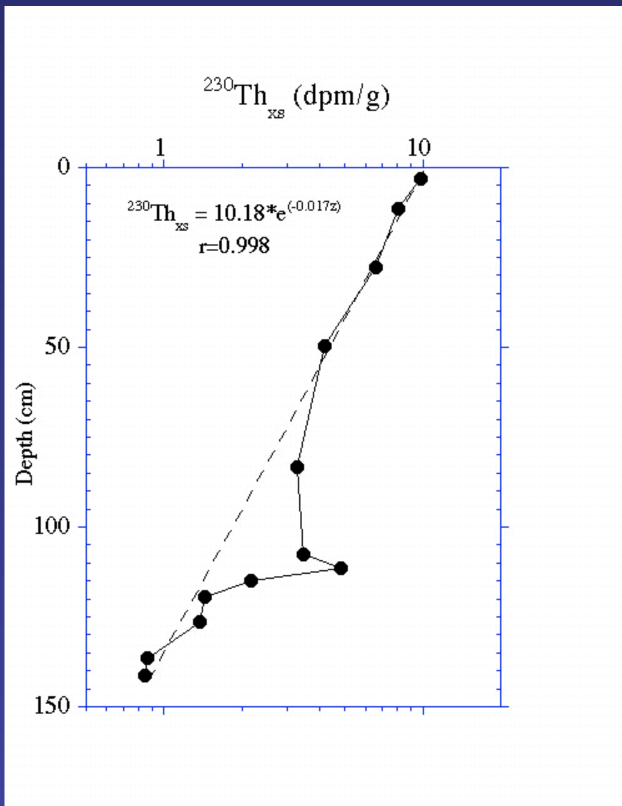
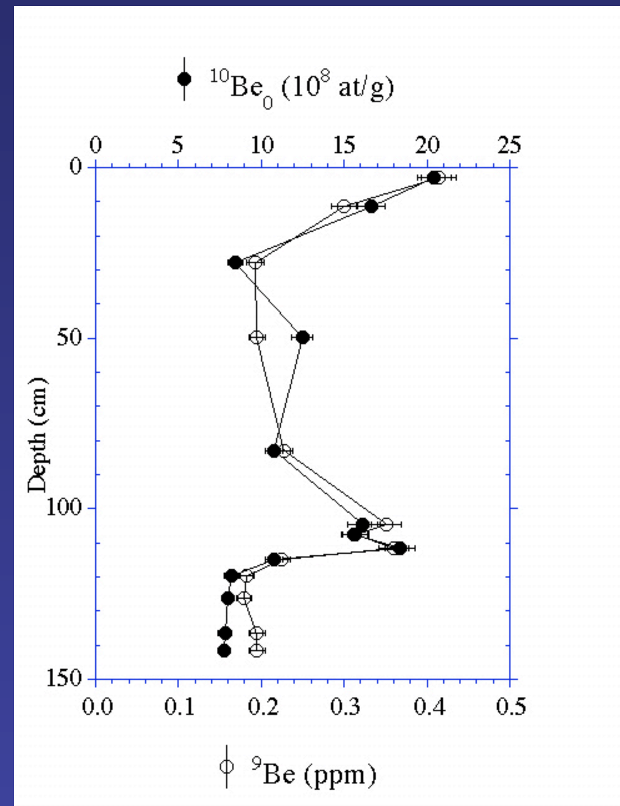


Table 7: Be-Th fractionation in core GC88-6

Core (Location)	Depth (cm)	10Be(0)/ 230Thxs(0) (10e9at/dpm)	ID[Be]
GC88-6 (J.d.F.)	2.0-4.0	0.199	2.72
	11.0-12.0	0.171	2.34
	27.5-28.0	0.080	1.10
	49.5-50.0	0.128	1.75
	83.0-83.5	0.079	1.09
	104.5-105.0	-	-
	107.5-108.0	0.072	0.99
	111.0-112.0	0.057	0.78
	114.5-115.5	0.070	0.96
	119.0-120.0	0.075	1.02
	126.0-126.5	0.067	0.92
	136.0-137.0	0.088	1.21
	140.0-143.0	0.083	1.14
TAG-2182* (M.A.R.)	8.0-9.0	0.045	0.37
	9.0-10.0	0.049	0.40
	10.0-11.0	0.028	0.23
TT154-10† (E.P.R.)	1.2-2.4	0.110	1.51
	4.2-6.0	0.096	1.32
V19-55† (E.P.R.)	0.0-2.0	0.117	1.60
	8.0-10.0	0.116	1.59

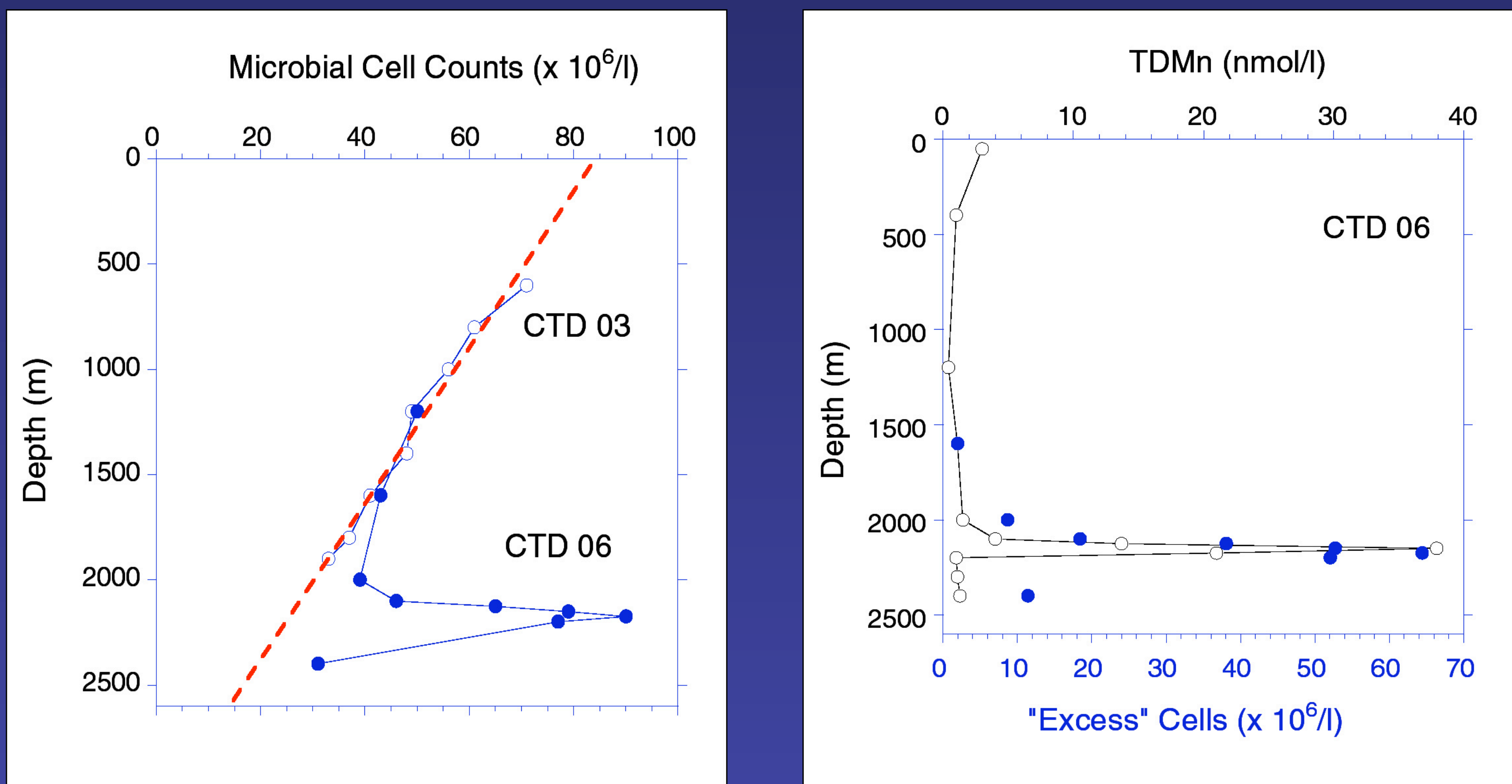
* Data from Bourlès et al. (1994)
† Data from Anderson et al. (1990) & Anderson (pers.comm., 1997)



(German et al., *GCA*, 1997)

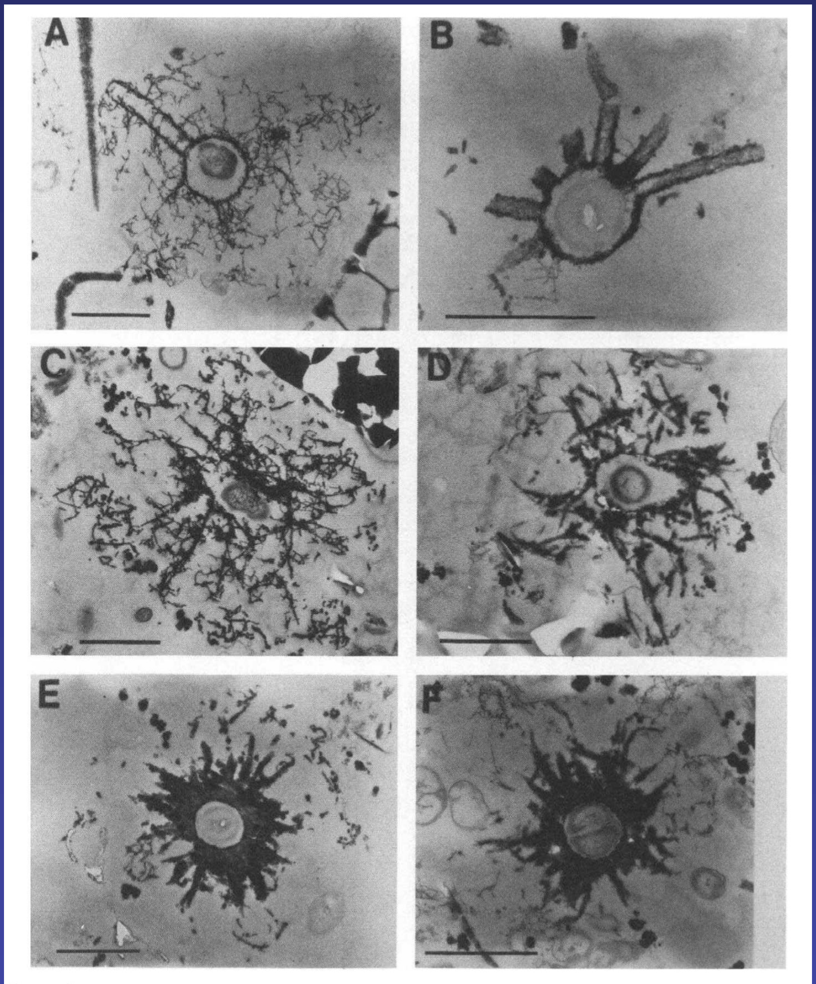
Plume *Bio*geochemistry

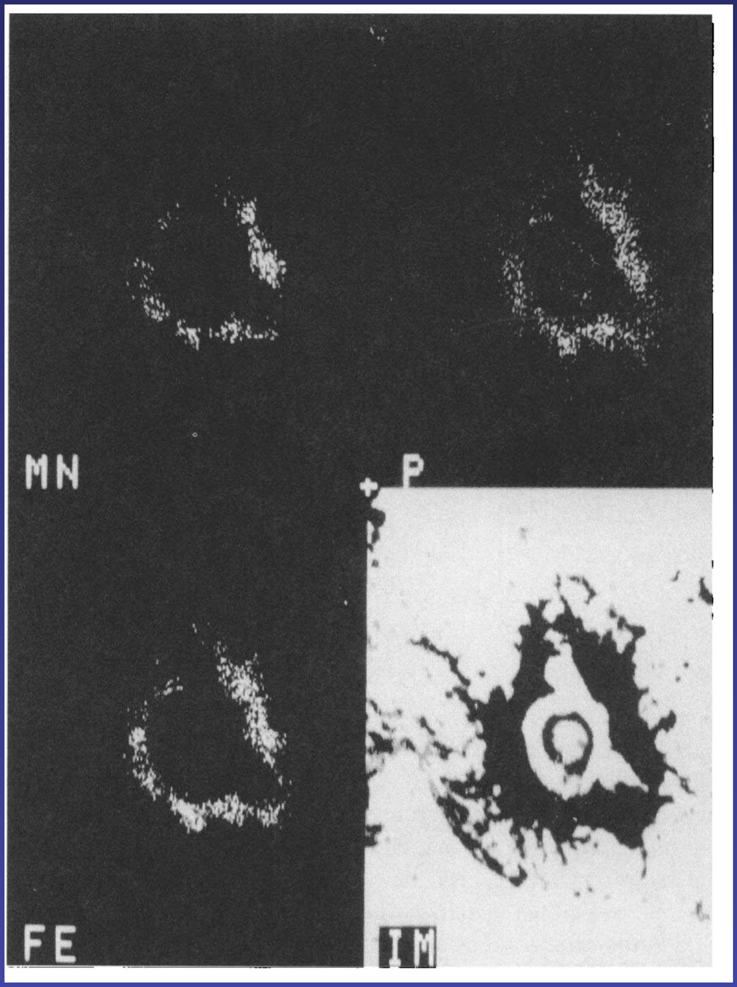
Rainbow plume cell counts > 300% background for NADW



(*data from* O'Brien & Patching, *EPSL*, 1998)

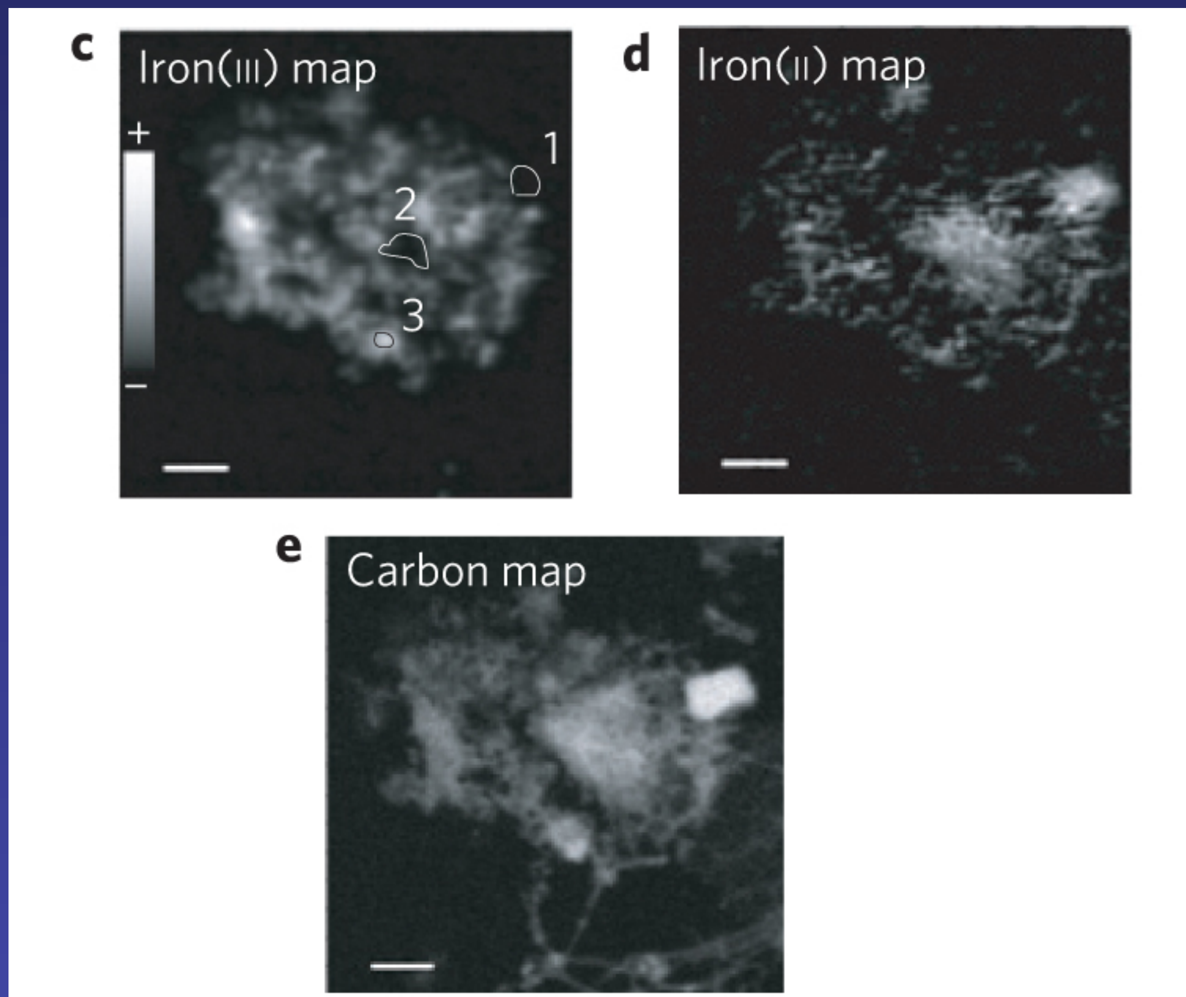
Plume *Bio*geochemistry





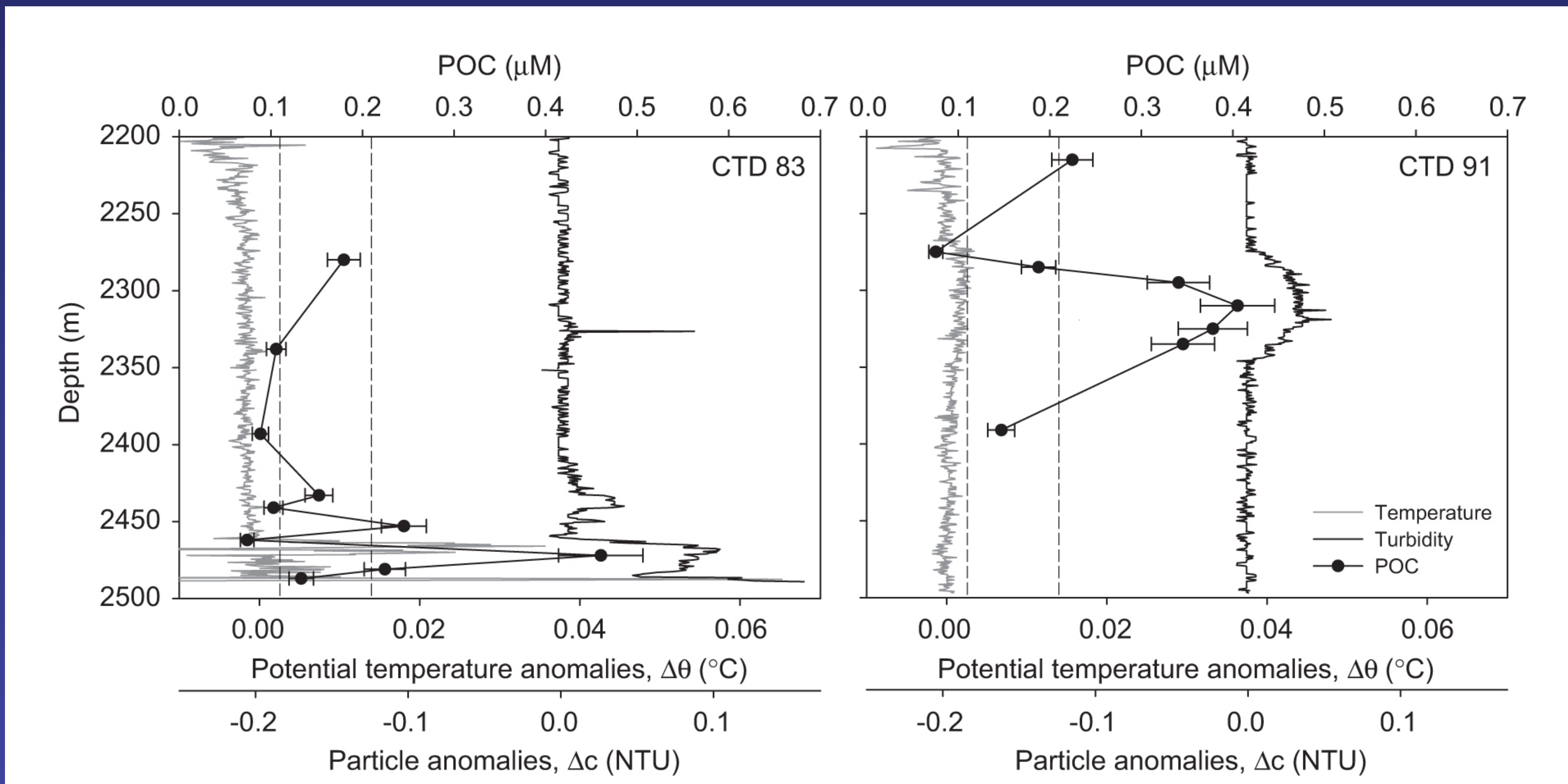
(Cowen & Li, *J. Mar. Res*, 1991)

Plume *Bio*geochemistry



(Toner et al., *Nat. Geosci.*, 2009)

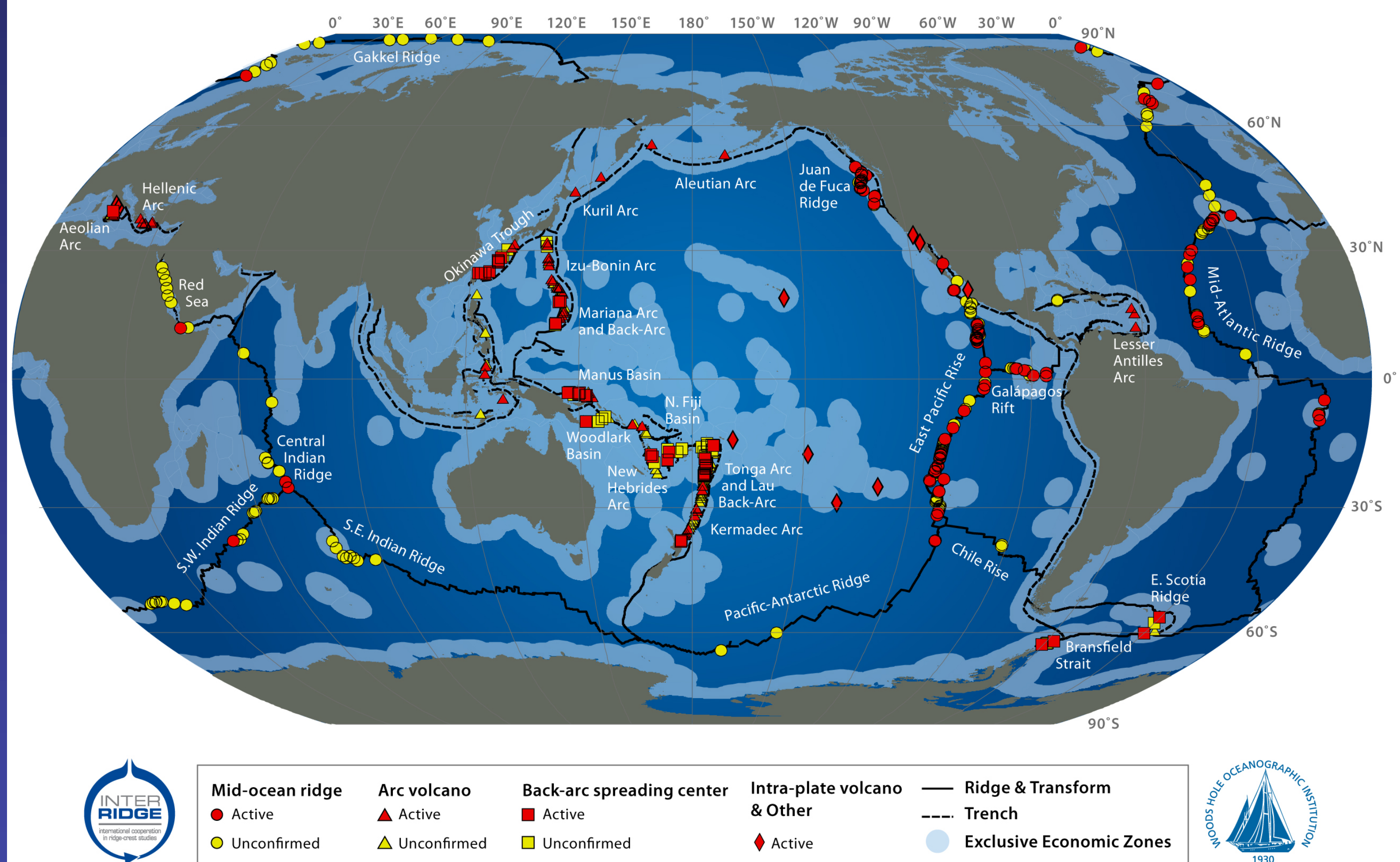
Plume *Biogeochemistry*



(Bennett et al., *Deep Sea Res.*, 2011)

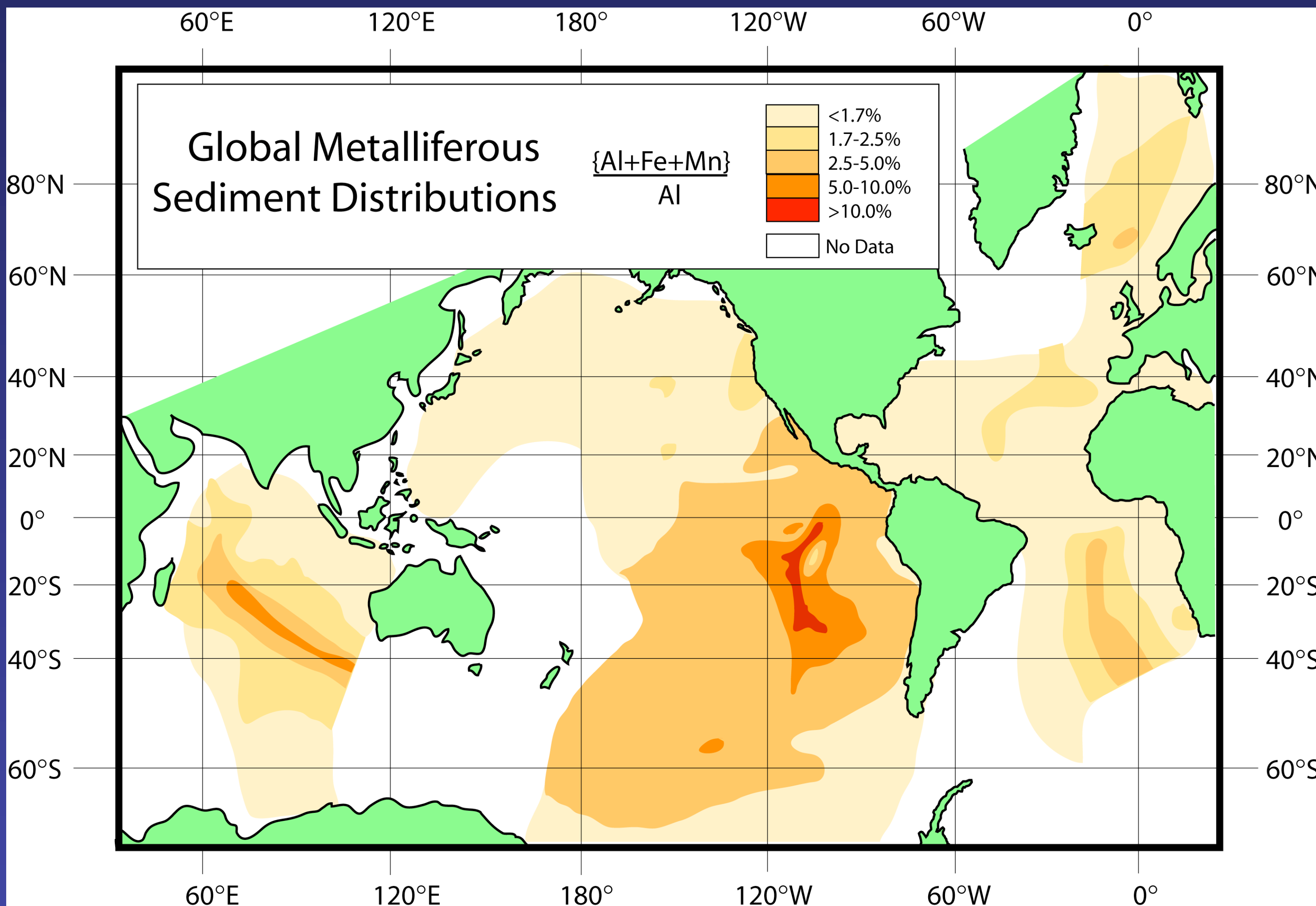
Why the Southern EPR?

Global Distribution of Hydrothermal Vent Fields



(www.interridge.org/irvents/)

Why the Southern EPR?



(*after* Boström et al., *JGR,* 1966)

Why the Southern EPR?

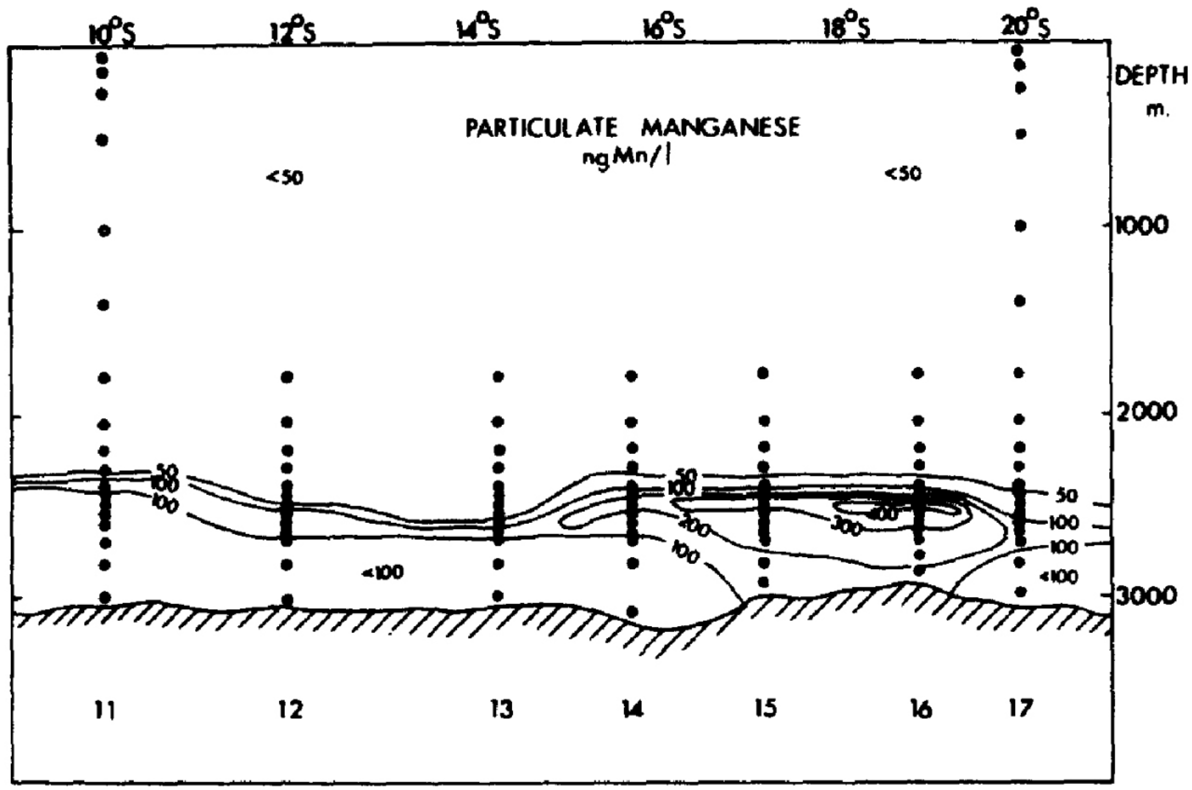
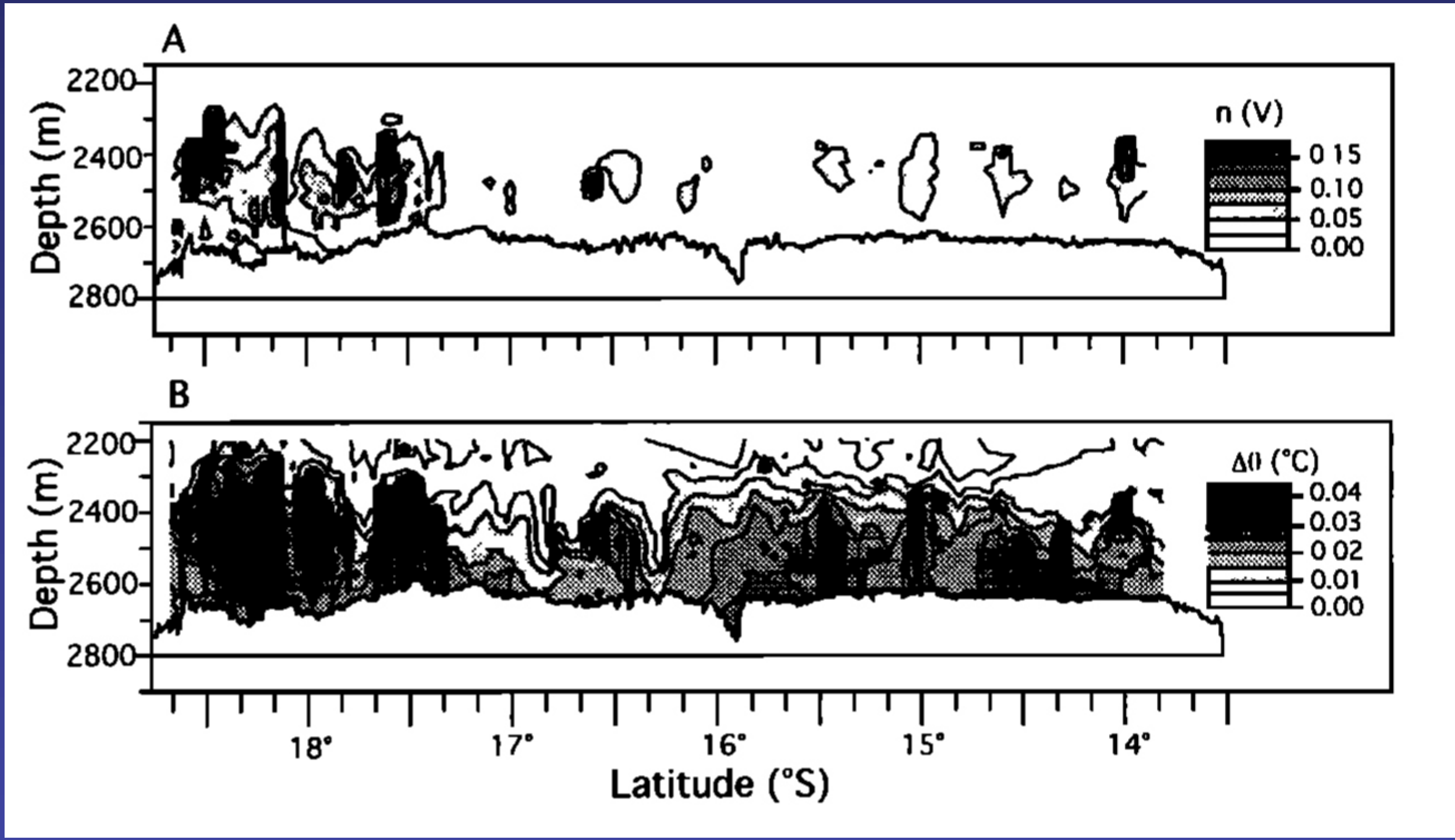


FIG. 6. The distribution of water column particulate Mn (ng/l) at stations parallel to the EPR ridge crest. Note the intense activity at 19°S and the plume ceiling of 2400 m.

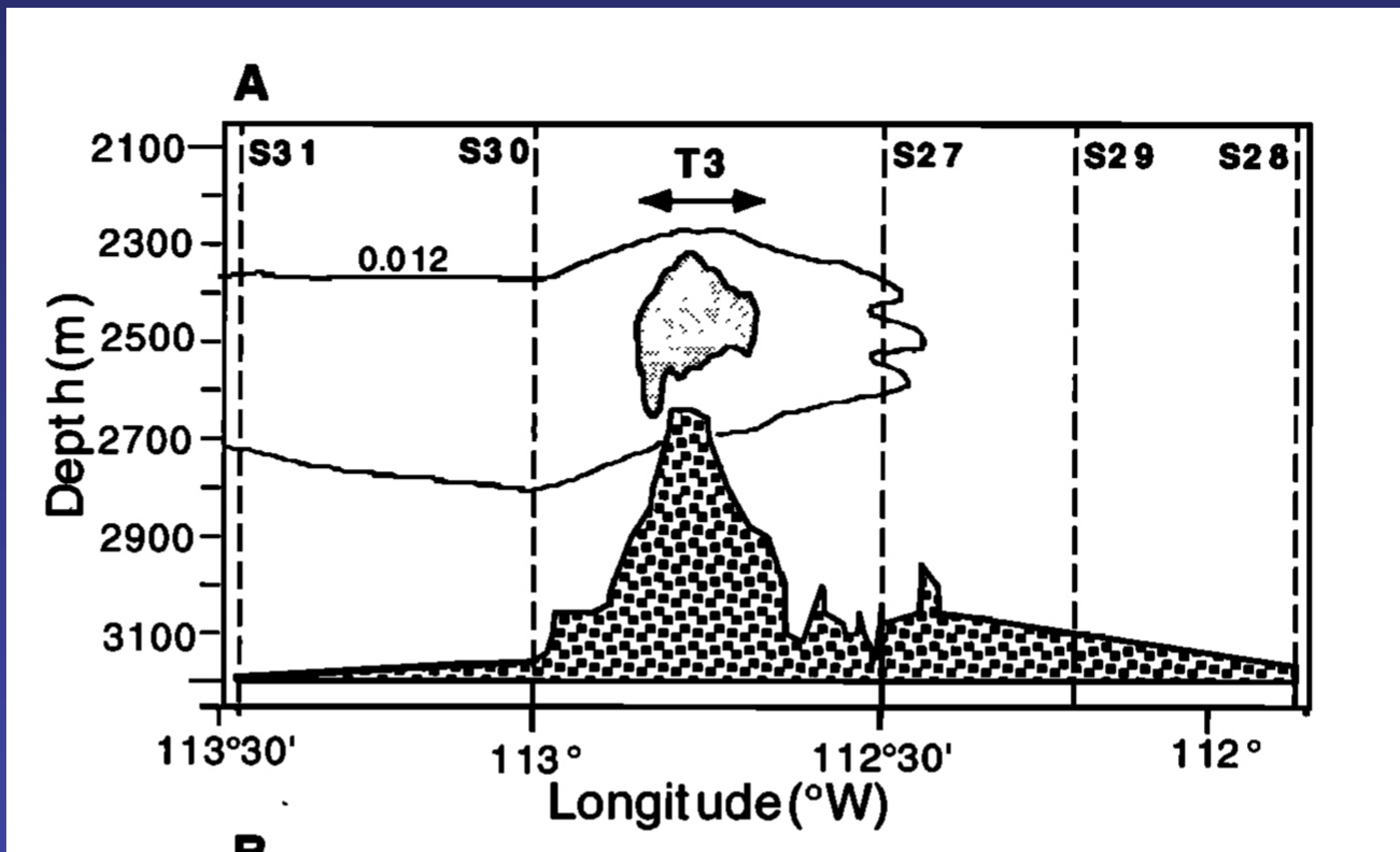
(Shimmield & Price, *GCA*, 1988)

Southern EPR Plume Dispersion



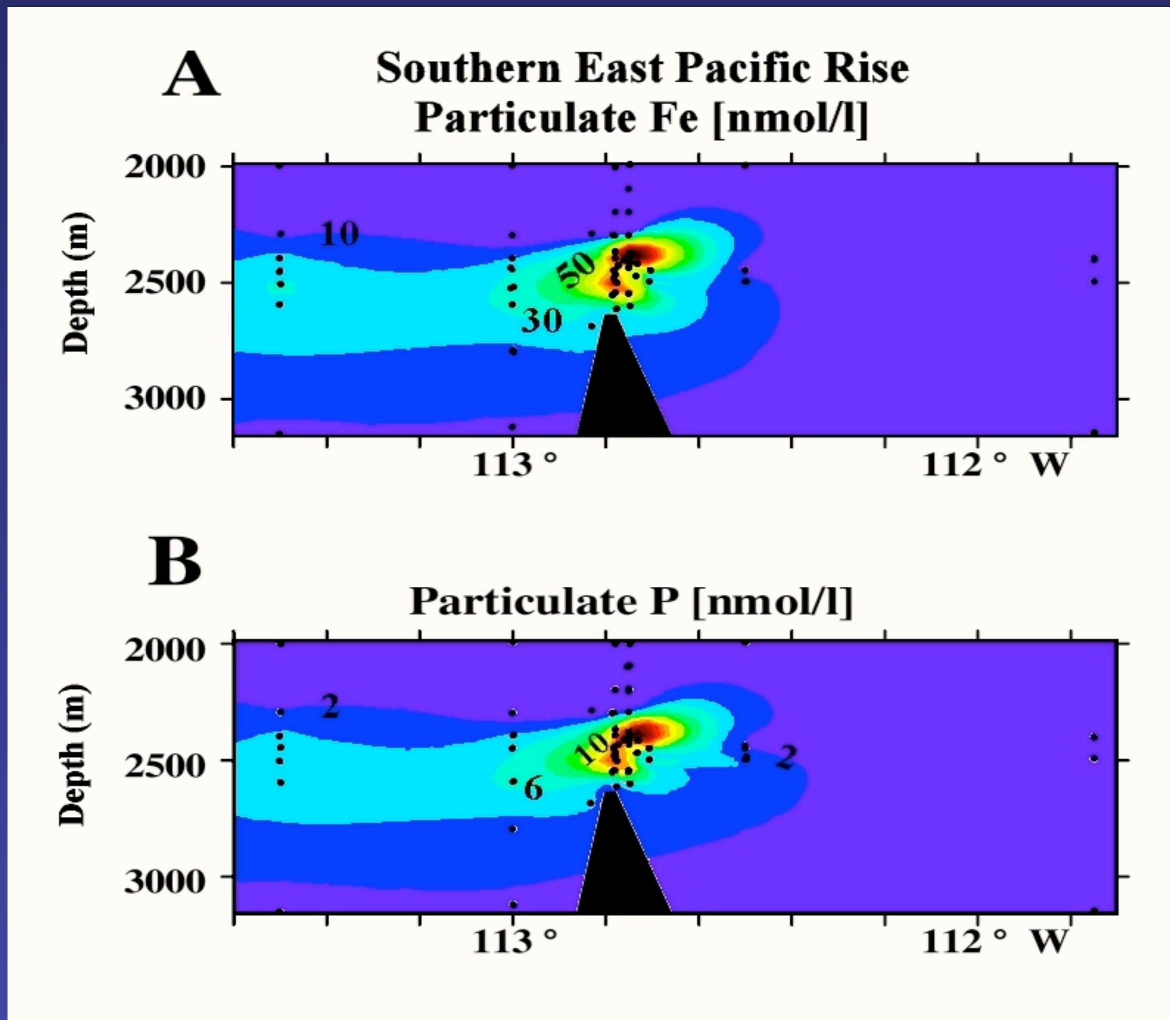
(Baker & Urabe, *JGR*, 1996)

Southern EPR Plume Dispersion



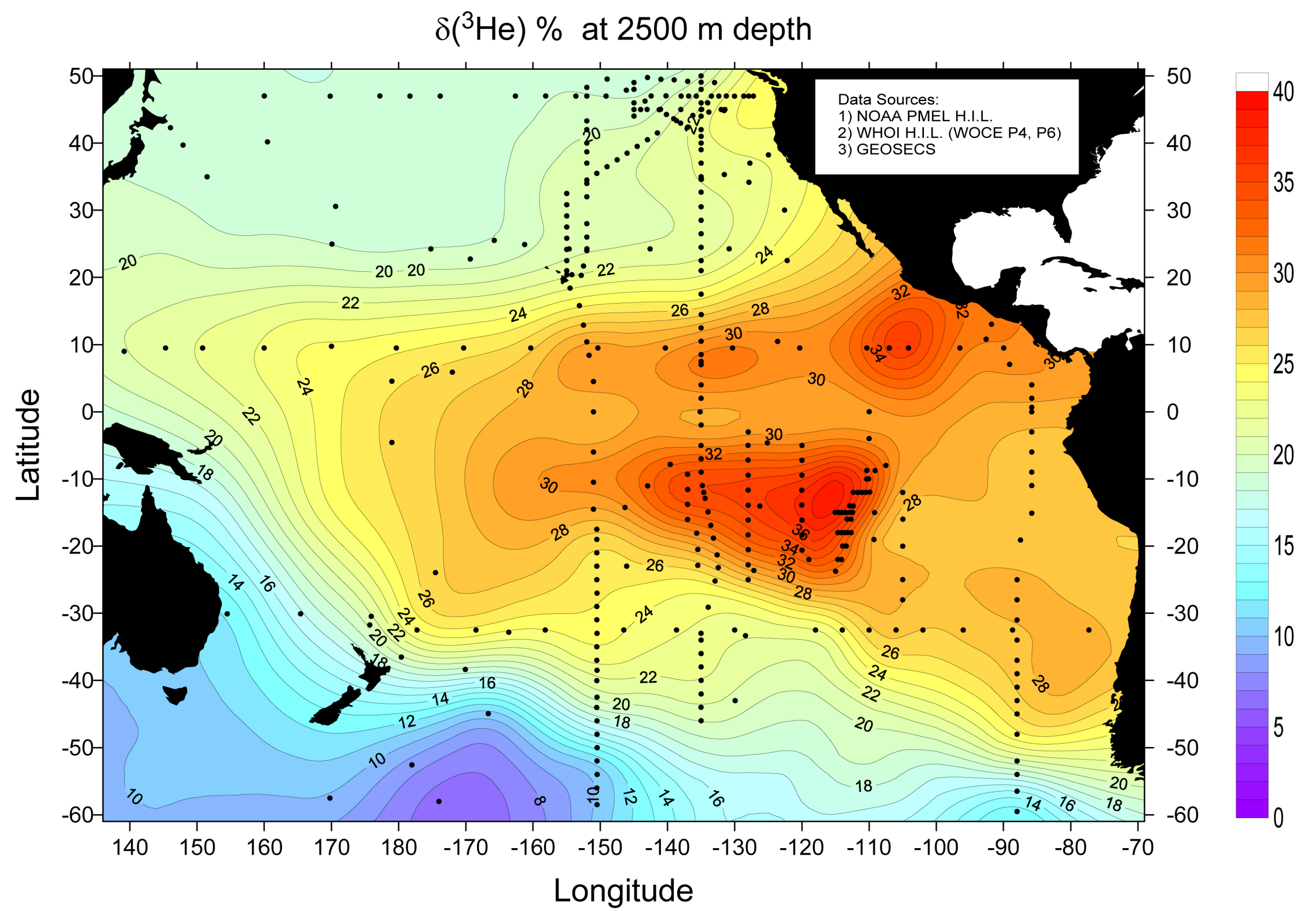
(Baker & Urabe, *JGR*, 1996)

Southern EPR Plume Dispersion

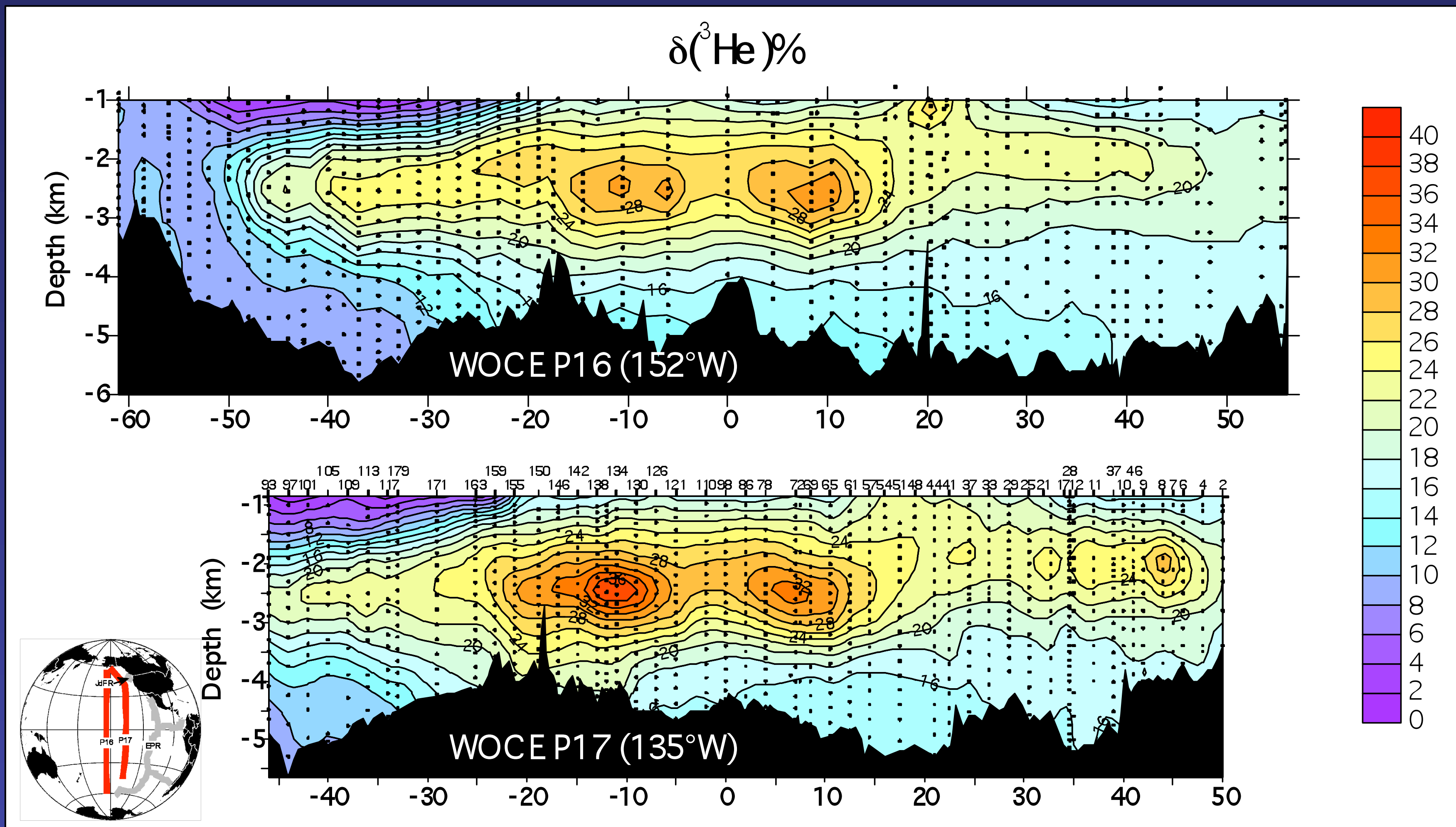


(Feely et al., *GCA.*, 1998)

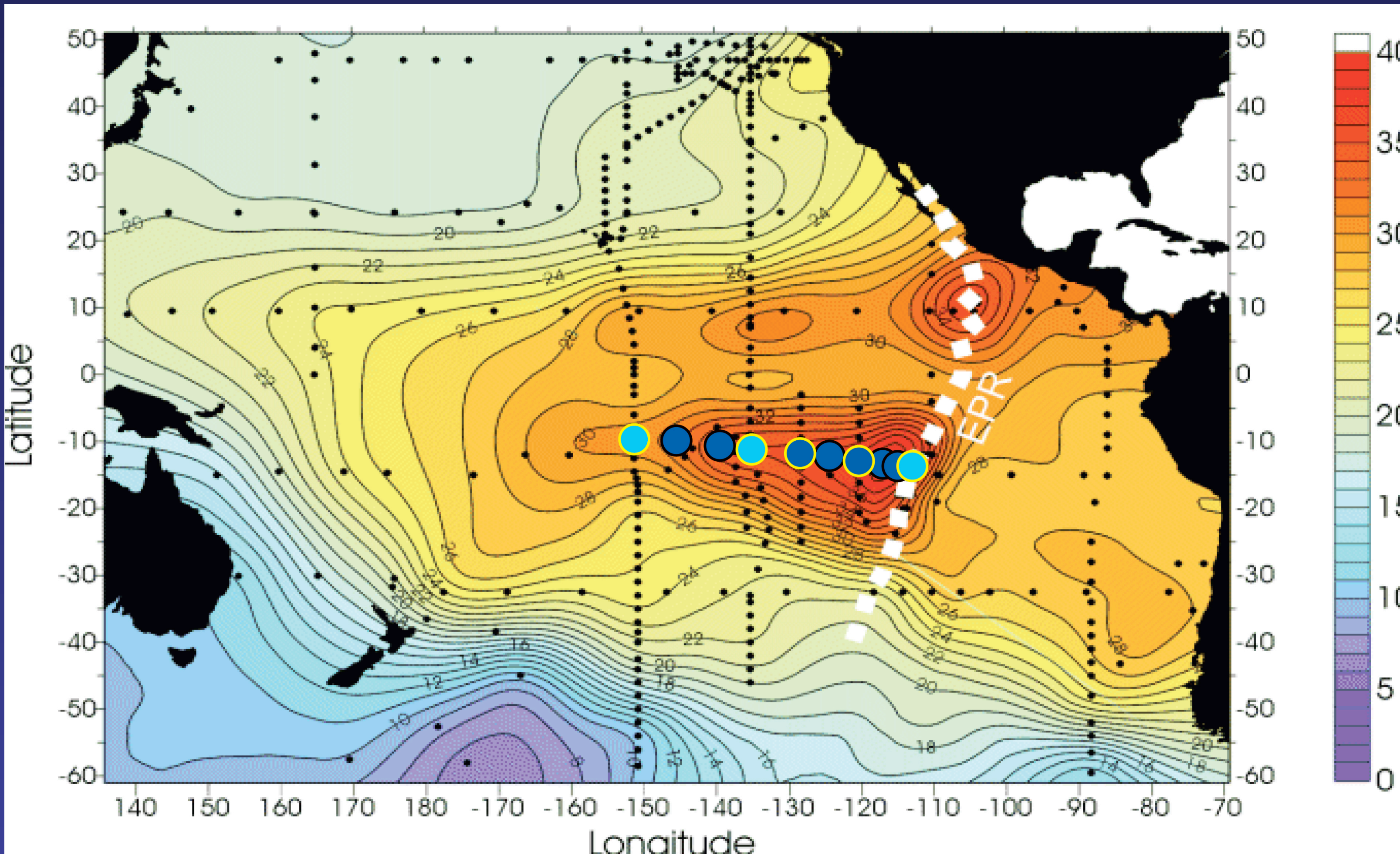
Southern EPR Plume Dispersion



Southern EPR Plume Dispersion



(Lupton, *JGR*, 1998)



9 or 10 Full-depth Stations (*3 super)
Possible Longitudes:
*150, 145, 140, *135, 128, 125, 120, 115, 113.5, *112.8