Biogeochemistry, Microbial Activity, and Microbial Distributions in Sediments of the Deep Slope

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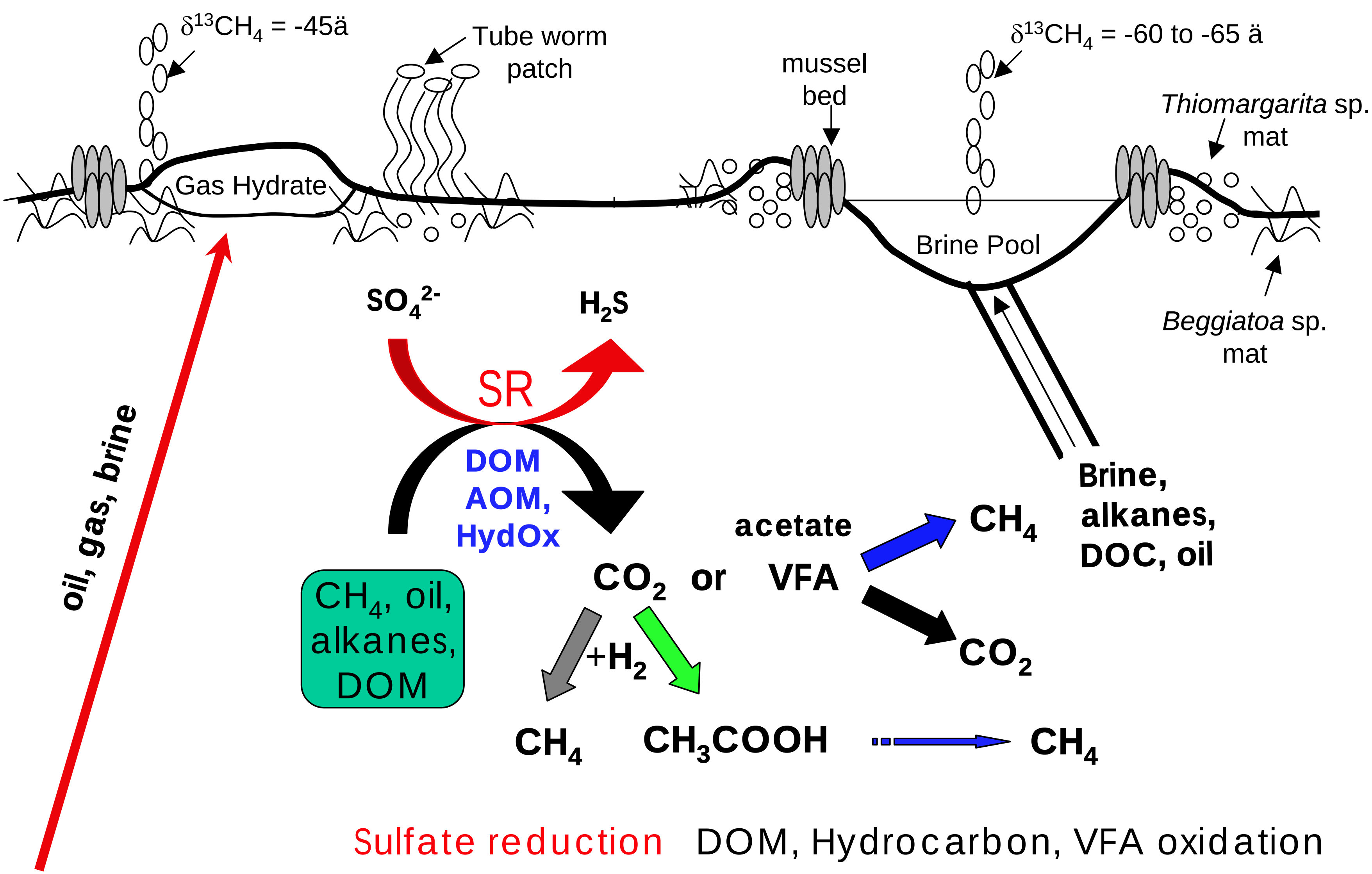
The Geobiological Engine



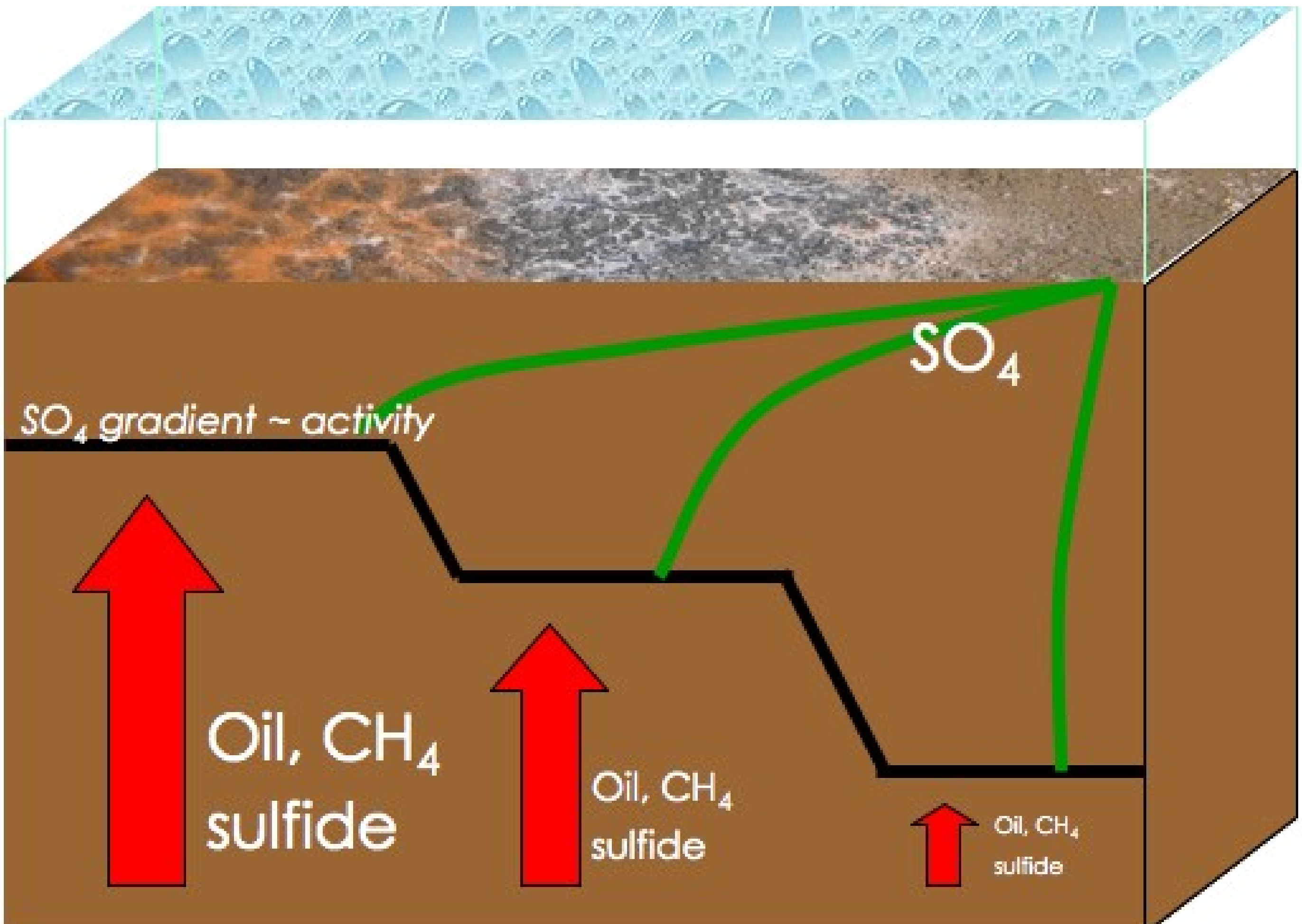
Sulfate reduction DOM, Hydrocarbon, VFA oxidation

Methanogenesis (CO_2, acetate); Homoacetogenesis

Microorganisms-Macrofauna: positive and negative interactions possible

Macrofauna Response

Toxic? *Optimal?* *Energy limited?*



Joye et al. 2004

Biogeochemistry

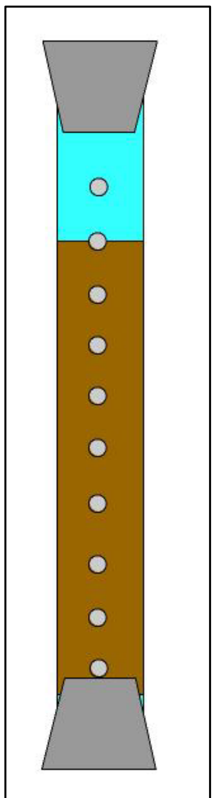
- biogeochemistry
  - salts, dissolved gases, nutrients, organic matter
- microbial activity
  - sulfate reduction, methane oxidation, methane production

2006: *29 cores processed from 9 different sites*
- greater depth resolution, little replication between sites and/or habitats

2007: *71 cores processed from 9 different sites*
- goal was to evaluate within/between habitat/site variability (more cores but decreased depth resolution)

Geochemistry

Cores sectioned and pore water extracted with a mechanical "squeezer"; pore water split and preserved for analyses.

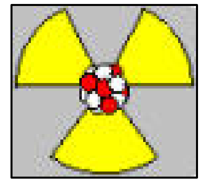


push core

Microbial Activity

Measuring microbial activity with radiotracers:

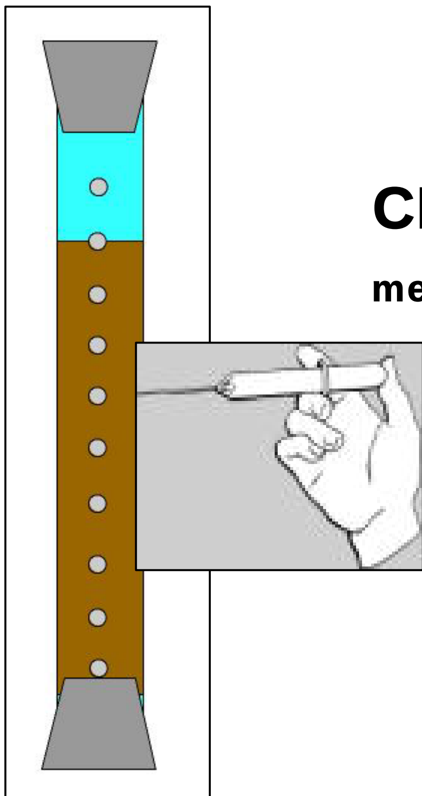
^{14}C carbon



^{35}S sulfur

$$CH_4 + SO_4^{2-} \rightarrow CO_3^{2-} + H_2S + H_2O$$

methane, sulfate, bicarbonate, hydrogen sulfide, water



push core

The microbial turnover of radioactive methane and sulfate is a way to measure anaerobic oxidation of methane (AOM) and sulfate reduction (SR) rates

Microbiology

Molecular Biology (ongoing)

- DNA extraction and clone libraries
- quantify abundance of specific groups by FISH

Organic Geochemistry (ongoing, Helge Niemann)

- biomarkers

Classic Microbiology (ongoing)

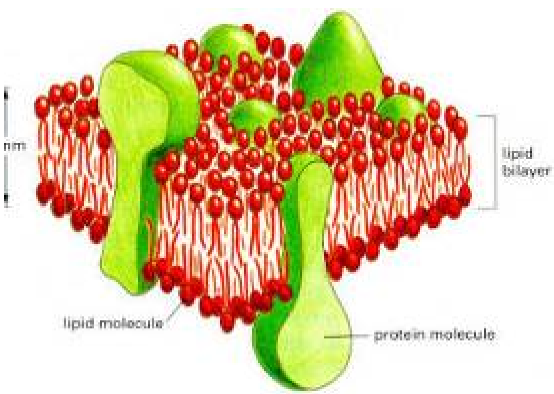
- cell counts

Methods to target 'live' biomass

Who is there and What are they doing ?

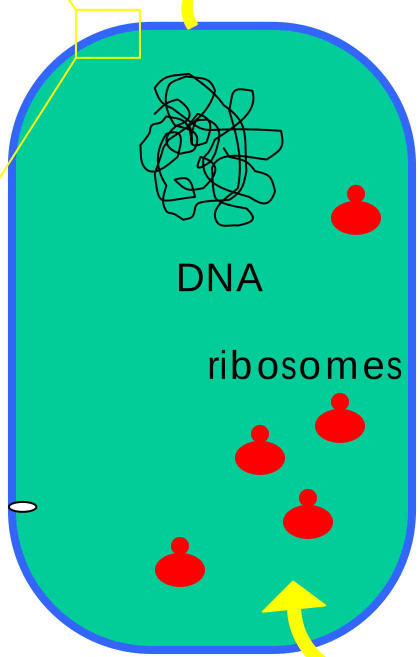
Identification by lipid biomarkers

cell wall



What do I eat?

$\delta^{13}C$ composition of cell material

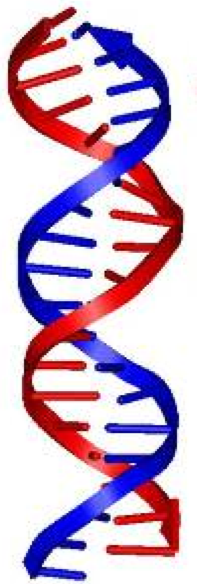


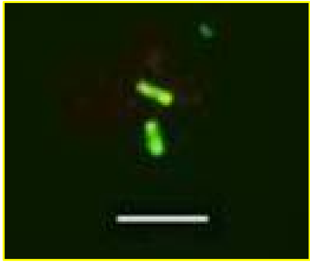
Identification by molecular phylogeny

Amplify 16S rDNA genes from environmental samples

Develop markers for specific groups of organisms

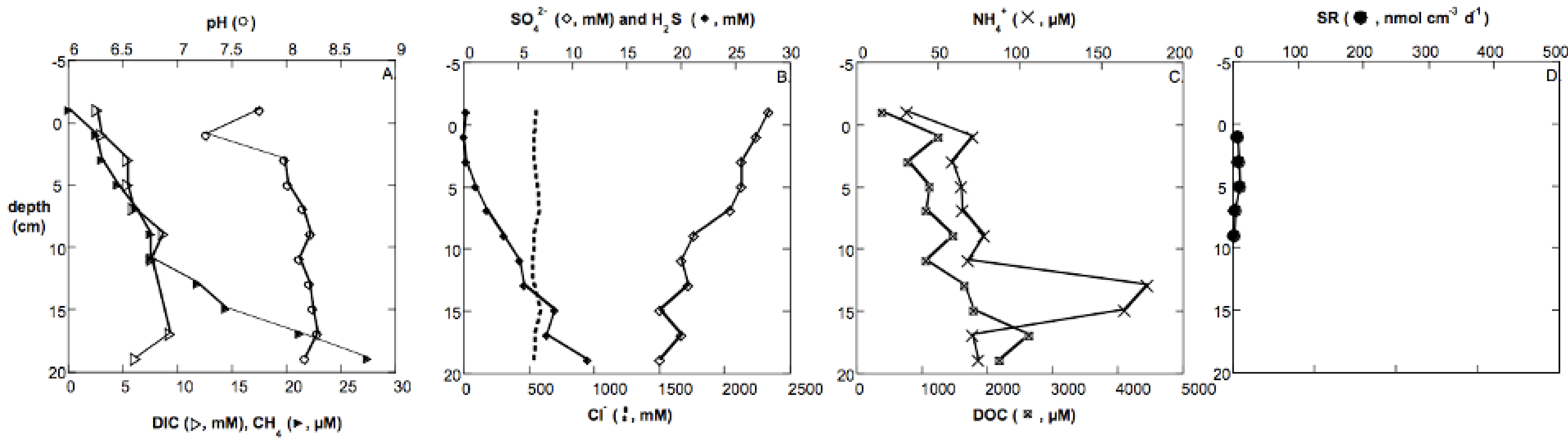
Hybridize ribosomes in intact cells with fluorescent markers (FISH)





Cartoon by B. Orcutt

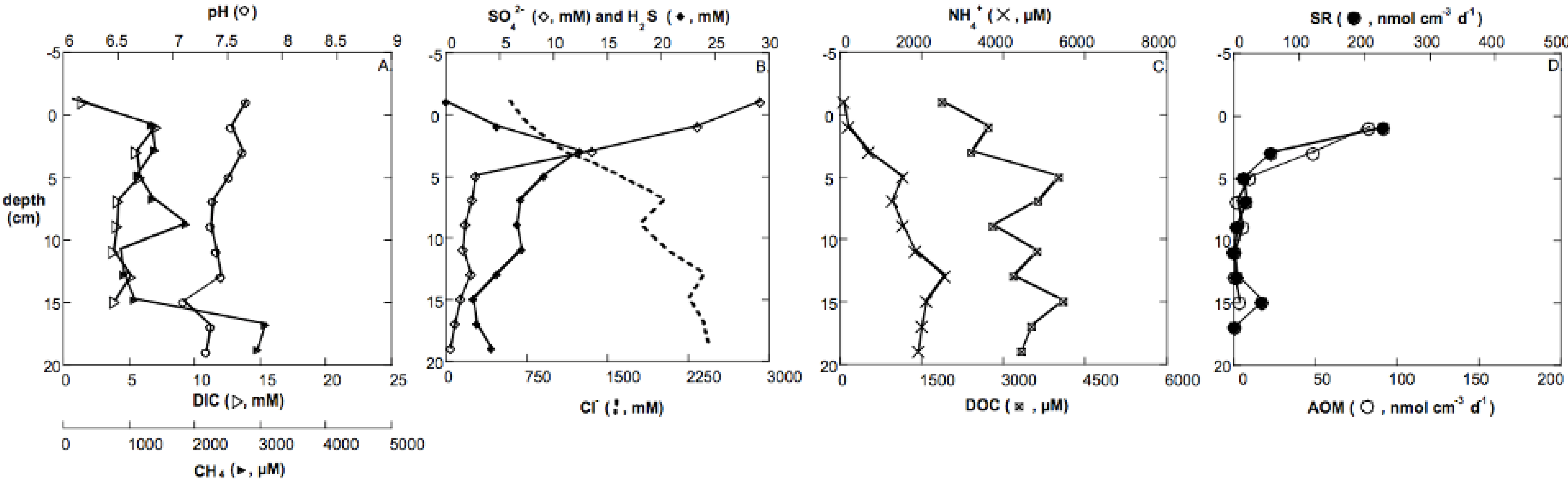
Habitat Differences: Control



Control Core (no seepage), GC852

- low CH_4 and DIC
- evidence for SO_4^{2-} consumption and H_2S production but available SR rates are extremely low
- DOC and CH_4 increase with depth so could fuel deeper SR

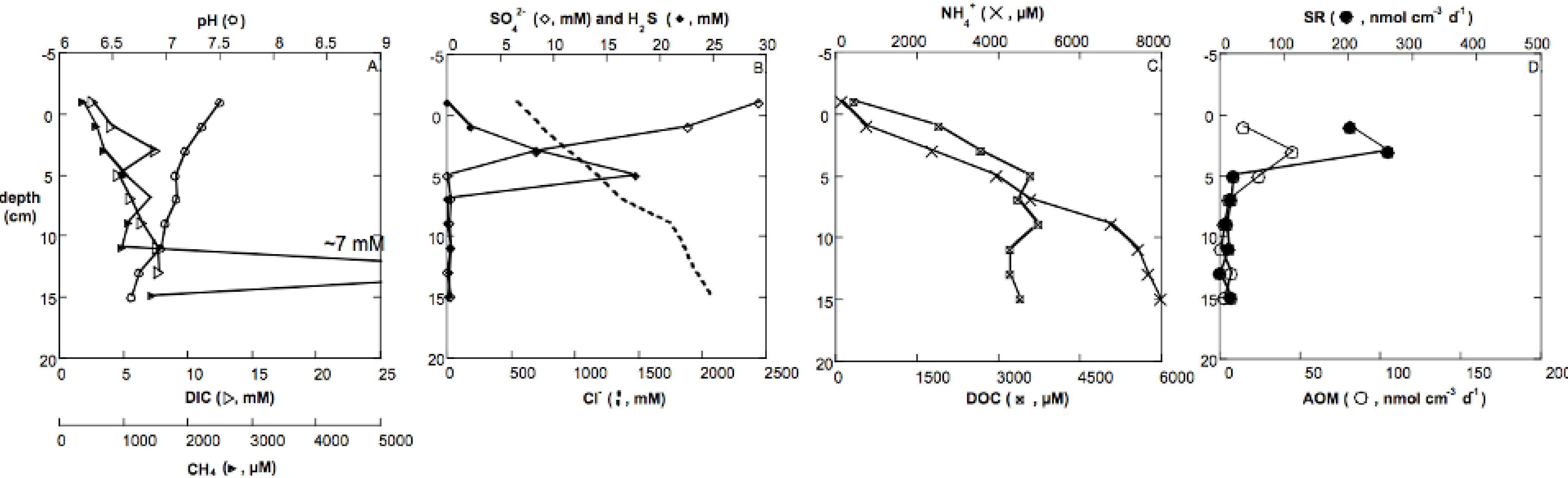
Habitat Differences: Brine



Brine Flow Core, AT340

- extremely high CH_4 but not DIC (carbonate precipitation?)
- rapid SO_4^{2-} depletion (SR plus upward brine advection)
- DOC and NH_4^+ concentrations elevated within brine
- AOM rates are ~50% of SR rates; a reductant other than CH_4 is used by SRB

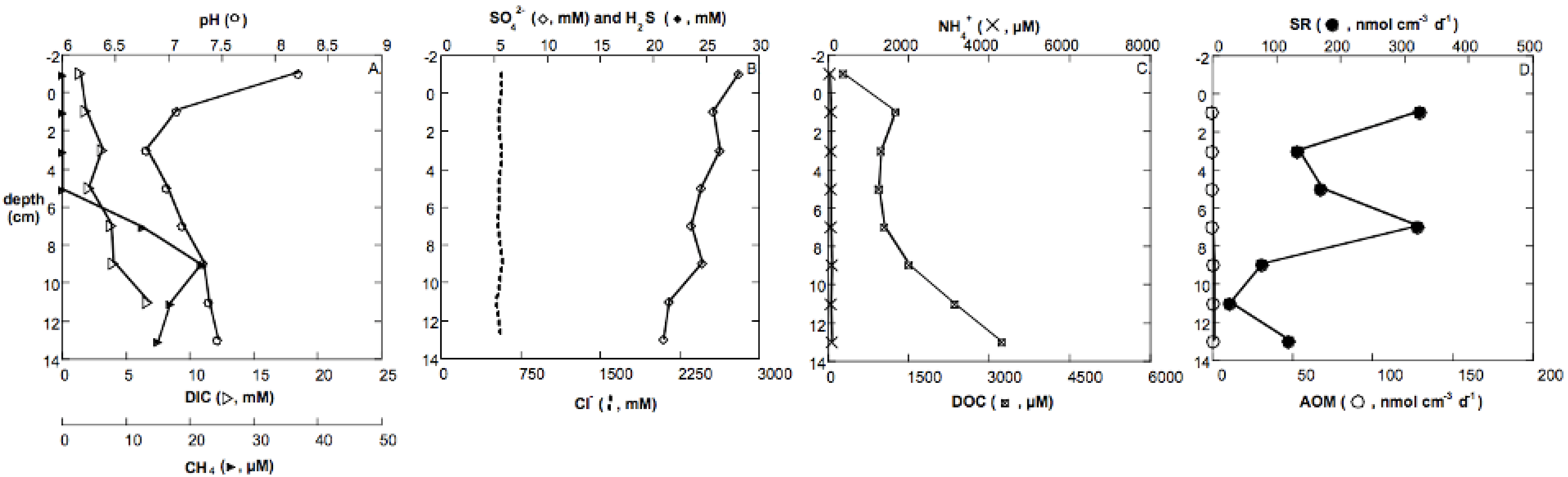
Habitat Differences: Oily Brine



Oily Brine Flow Core, MC853

- extremely high CH_4 but, again, low DIC (carbonate ptt?)
- rapid SO_4^{2-} depletion, limited H_2S accumulation (faster advection?)
- DOC and NH_4^+ concentrations highest measured
- AOM rates are ~50% of SR rates; additional reductant

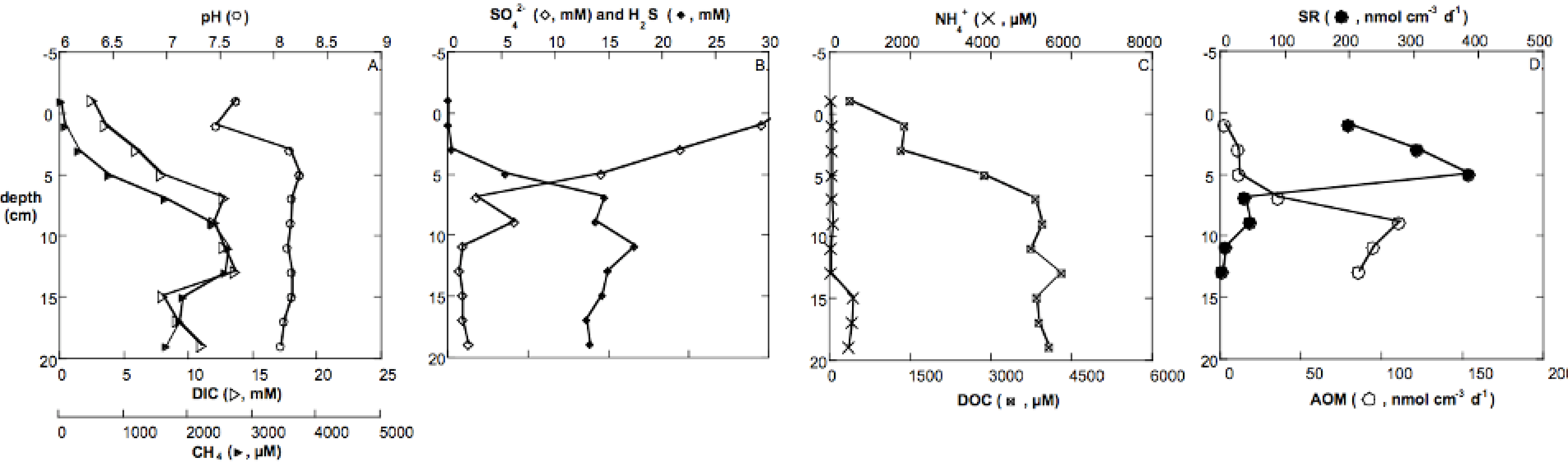
Habitat Differences: *Beggiatoa* mat



Beggiatoa mat core, AT340

- low CH_4 and DIC; subsurface pH minimum due to H_2S oxidation
- little SO_4^{2-} depletion (rapid re-oxidation)
- low NH_4^+ but DOC increases substantially with depth
- AOM rates below detection; SR rates high (variable)

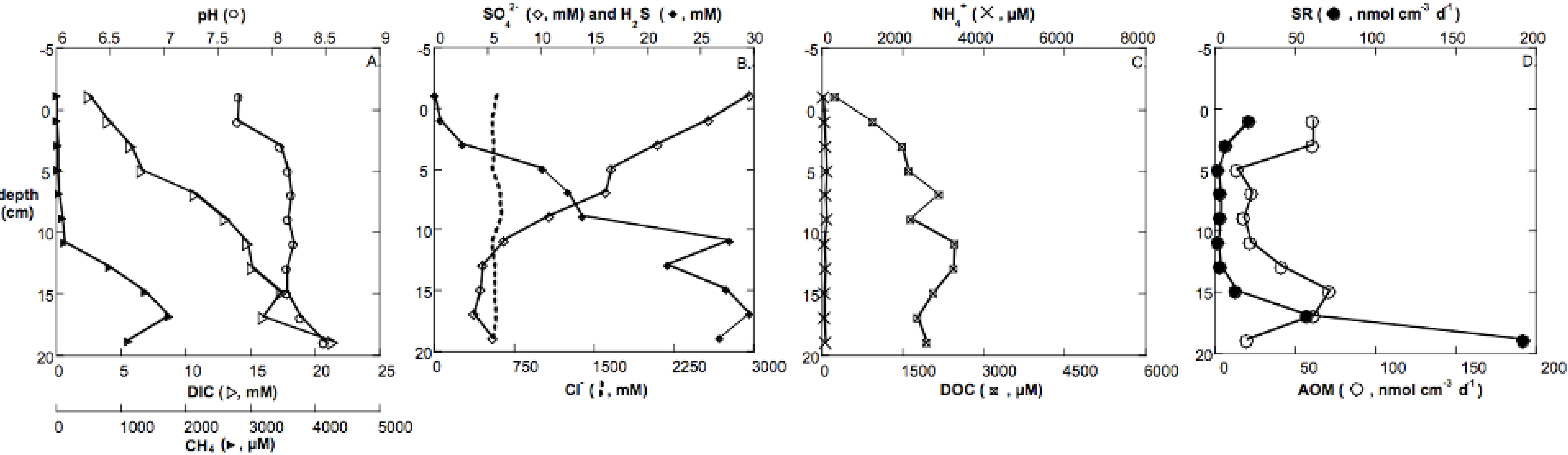
Habitat Differences: Pogonophora



Pogonophoran core, WR269/270

- high CH_4 and DIC; elevated pH w/ depth
- rapid SO_4^{2-} depletion and H_2S accumulation
- low NH_4^+ but very high DOC (exudate from pogos?)
- unusual patterns of AOM and SR (decoupled)

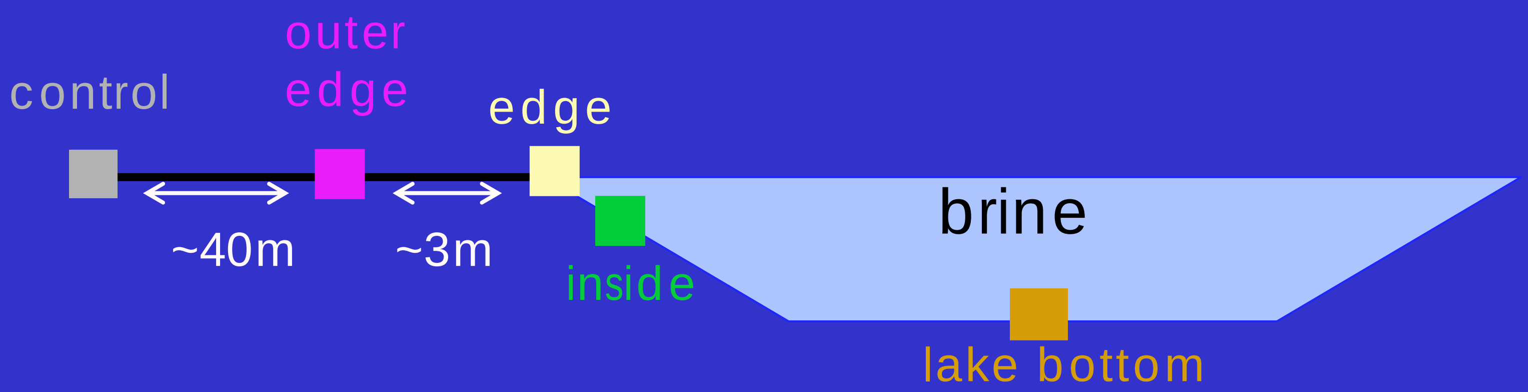
Habitat Differences: Urchin

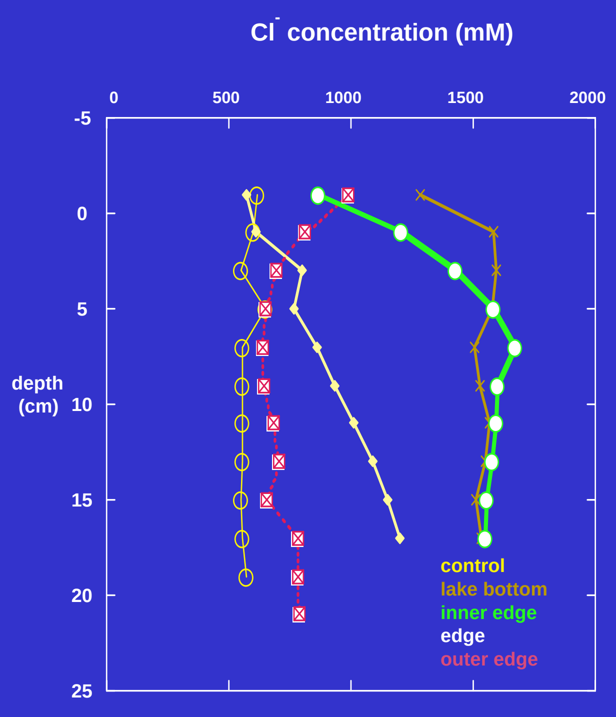


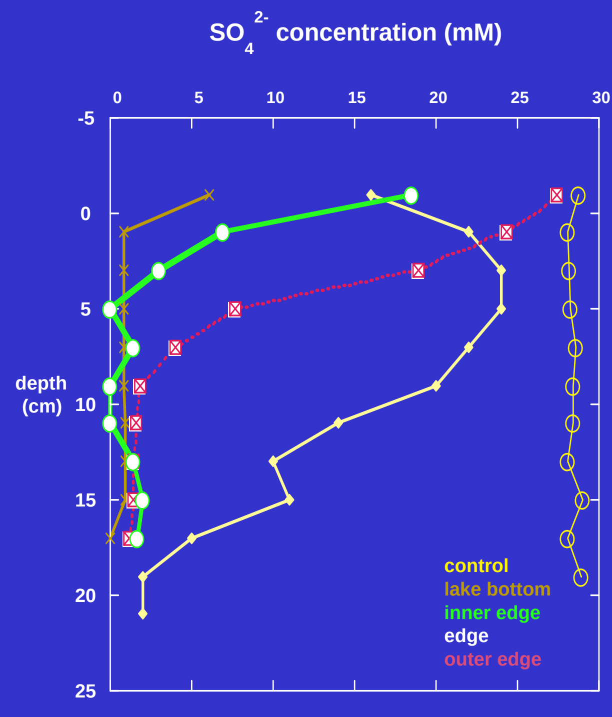
Urchin core, AC818

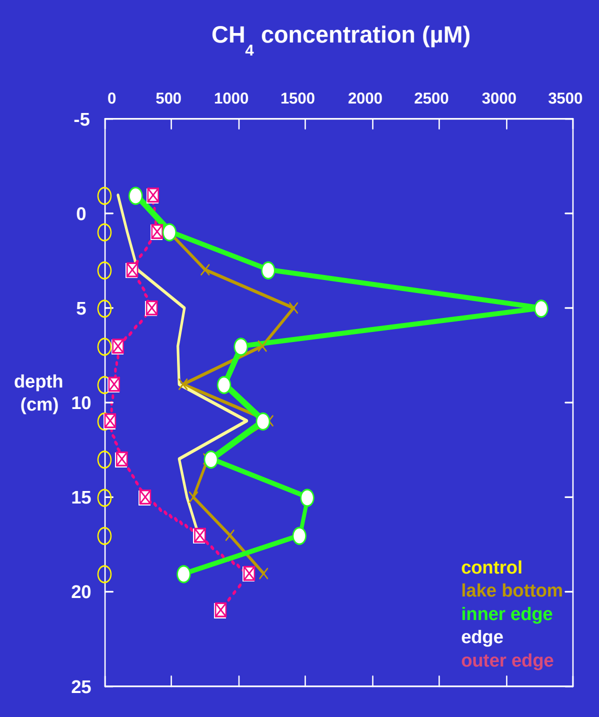
- high CH_4 and DIC (highest observed)
- rapid SO_4^{2-} depletion and H_2S accumulation
- low NH_4^+ but high DOC (related to urchins/urchin activity?)
- AOM and SR on same scale; AOM > SR

Habitat Differences: AC601 Brine Pool

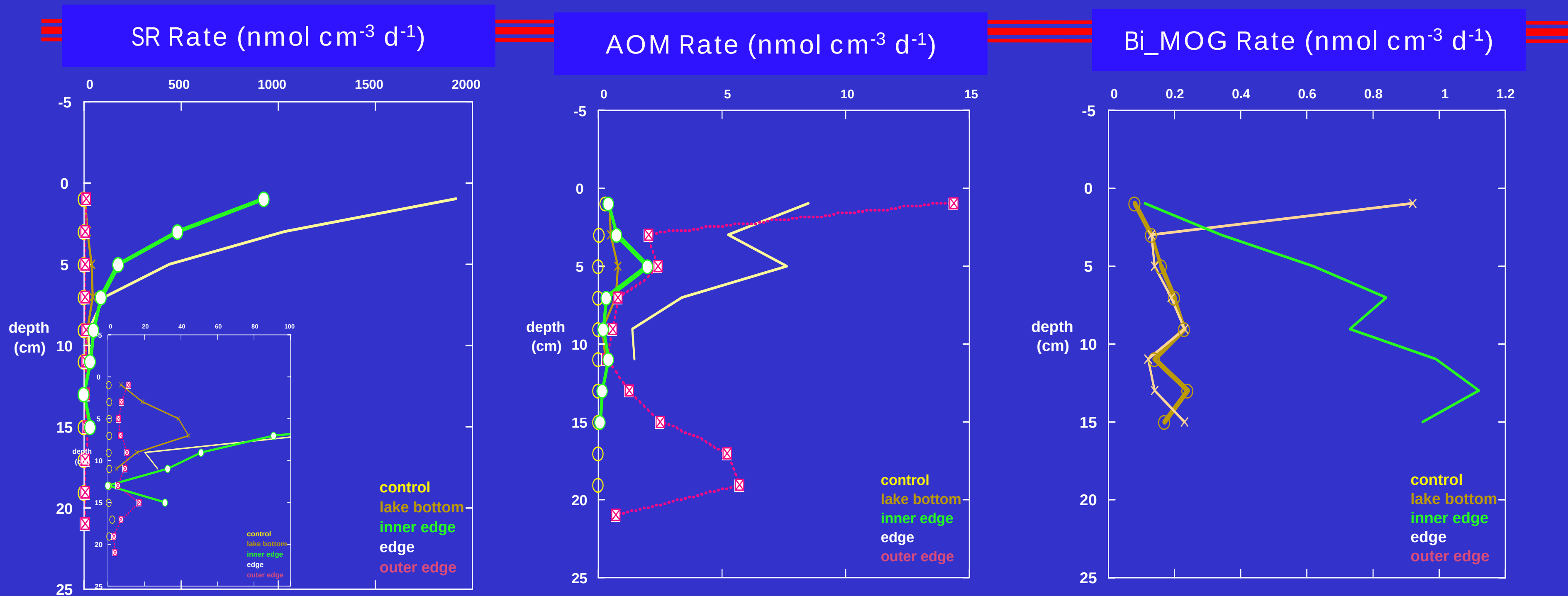






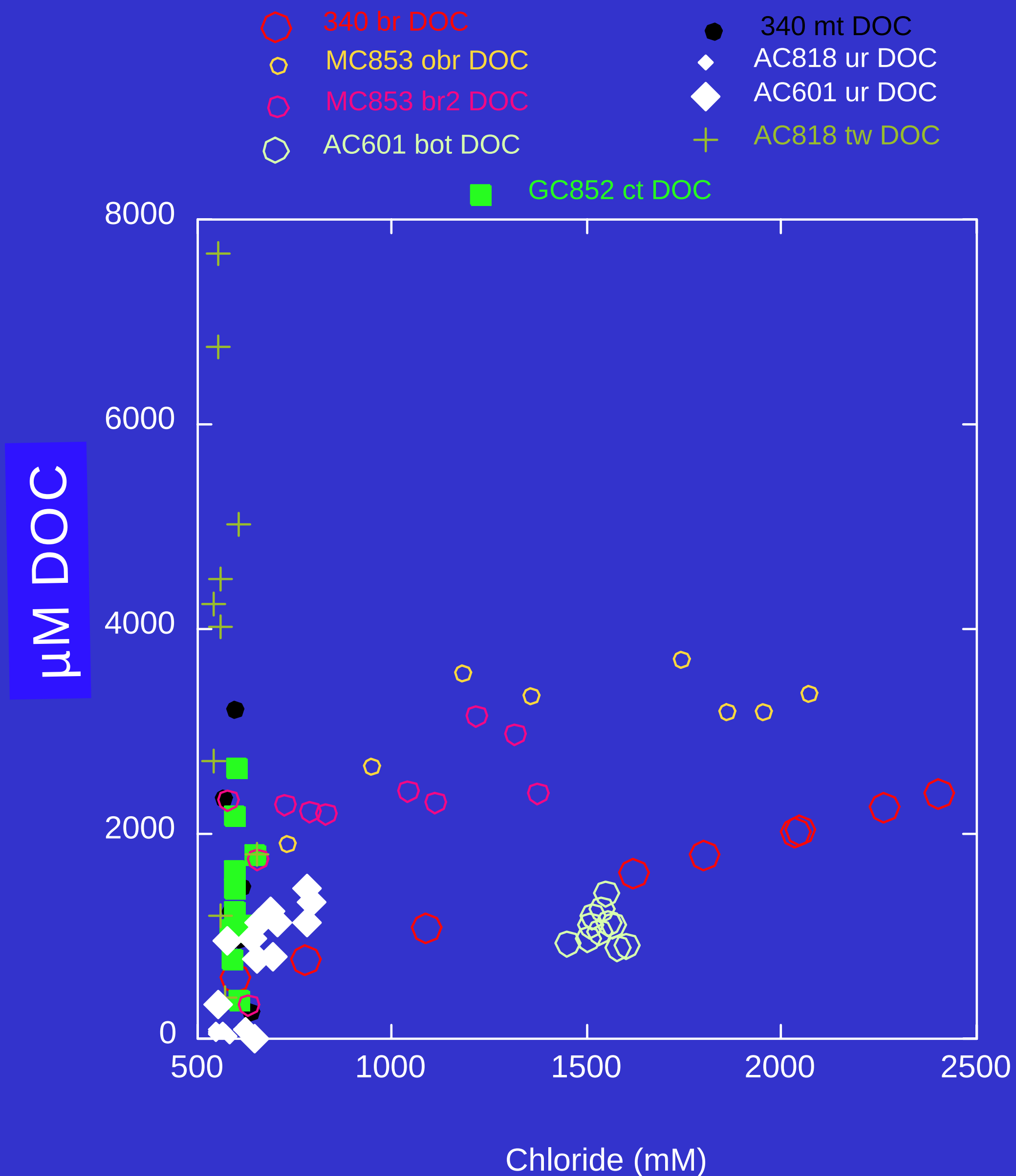


Habitat Differences: AC601 Brine Pool



Integrated Rates		SR	AOM	% coupled	Bi-MOG
(mmol m-2 d-1)	control	0.09	0.004	4	n.d.
	outer edge	0.89	0.36	40	n.d.
	edge	35.4	0.28	0.8	0.02
	inner edge	18	0.04	0.2	0.06
	lake bottom	1.3	0.03	2	0.01

DOC vs. Cl^-

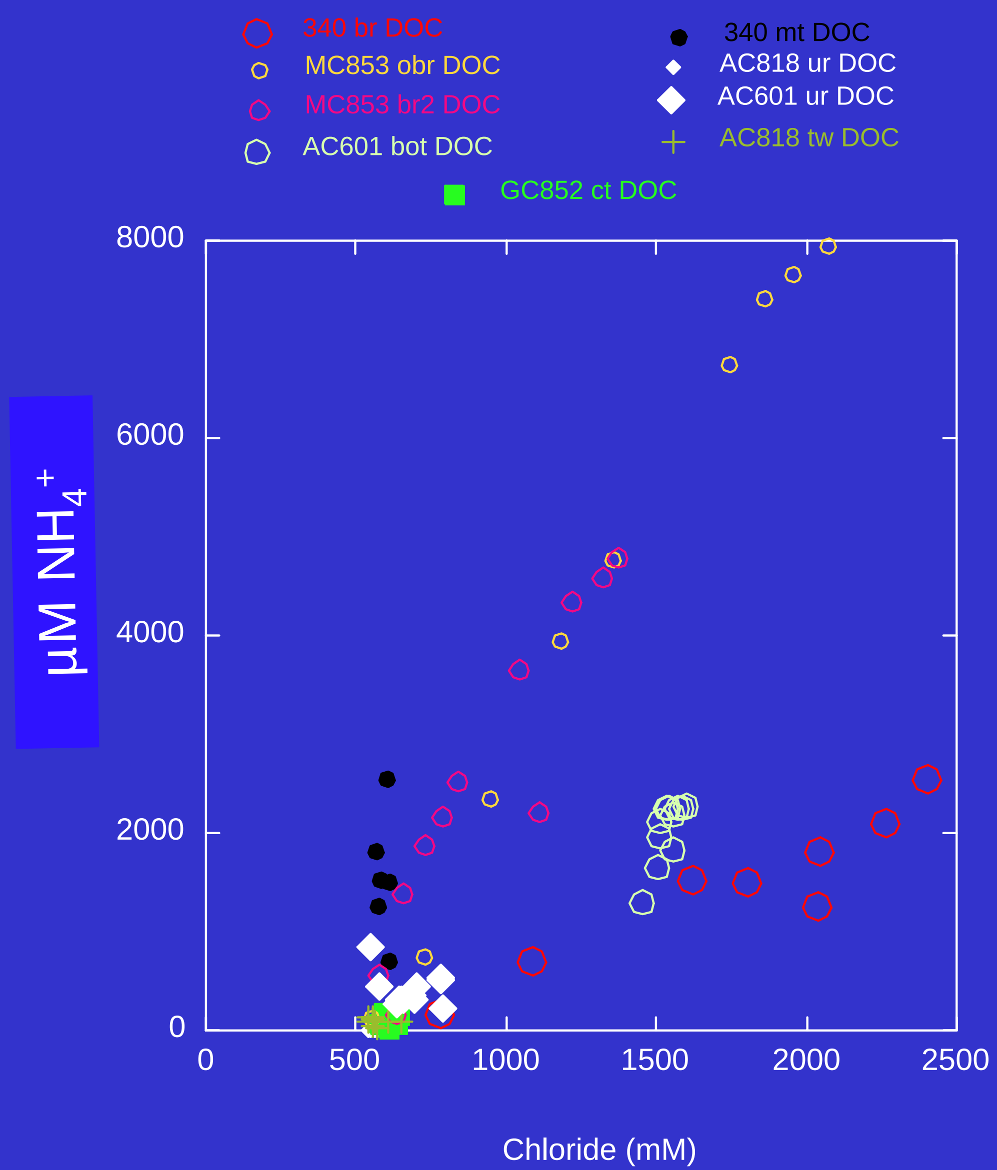


Brines are enriched with DOC

Animal cores show increases with DOC over depth independent of salt; TW most extreme

Controls also show some increase with depth

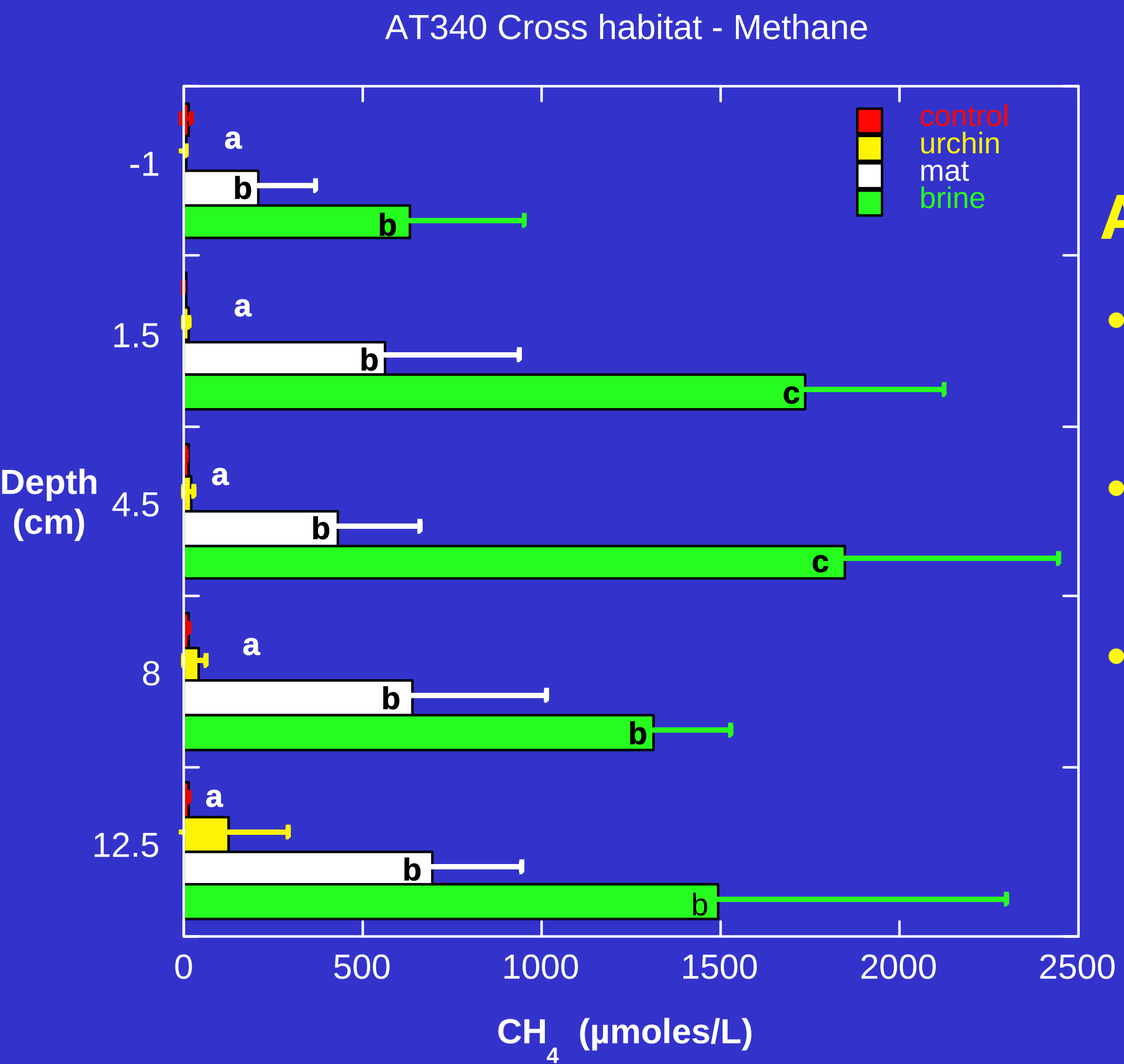
NH_4^+ vs. Cl^-



Brines are enriched with NH_4^+; differences b/t brines (MC > AT = AC)

Animal cores little enrichment with depth (except for AT340 mat)

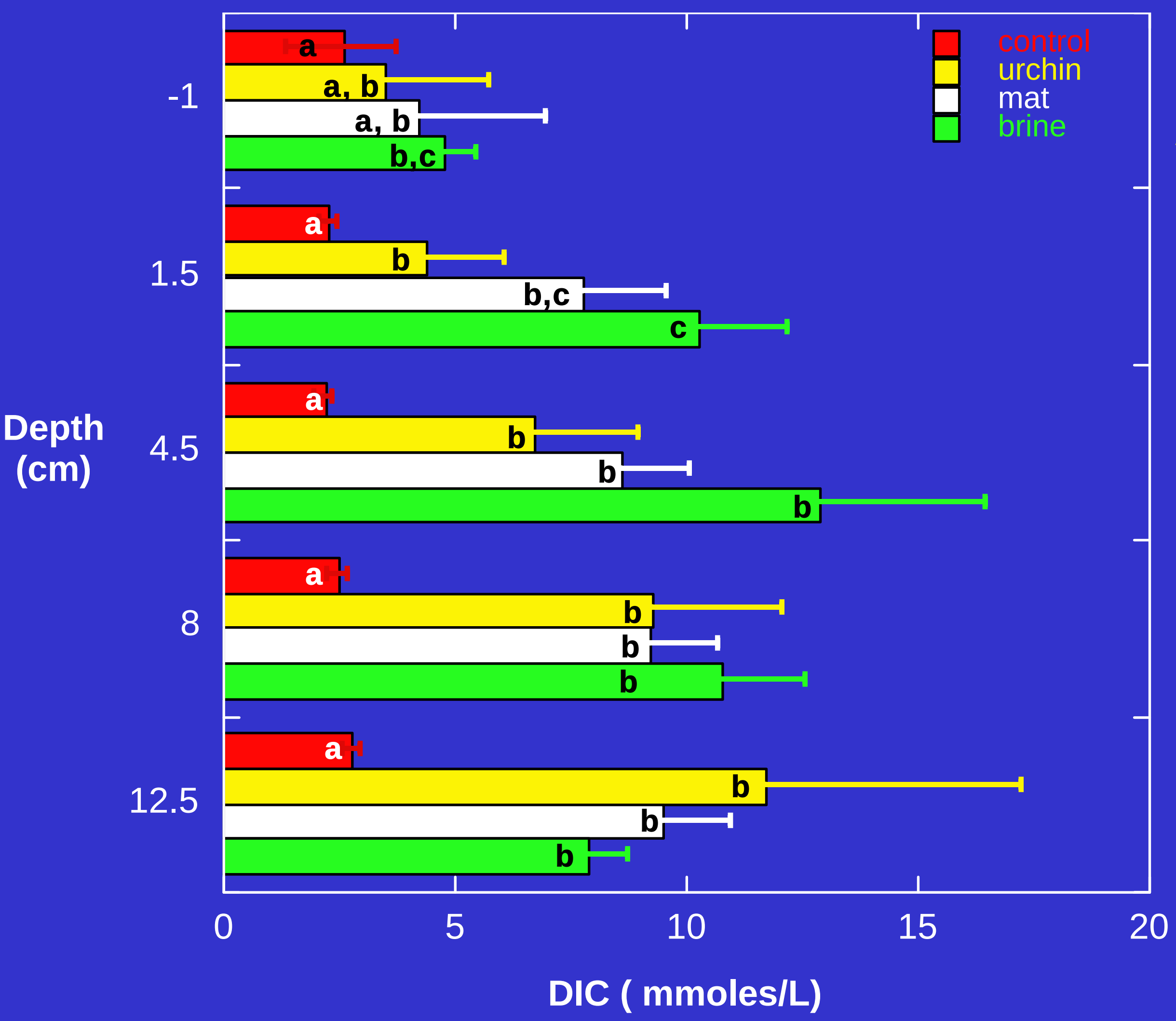
Habitat Differences: Within Site



AT340-CH_4

- highest CH_4 in mat and brine environments
- increases with depth at all sites (less control)
- means with different letters are significantly different at $\alpha = 0.05$ level

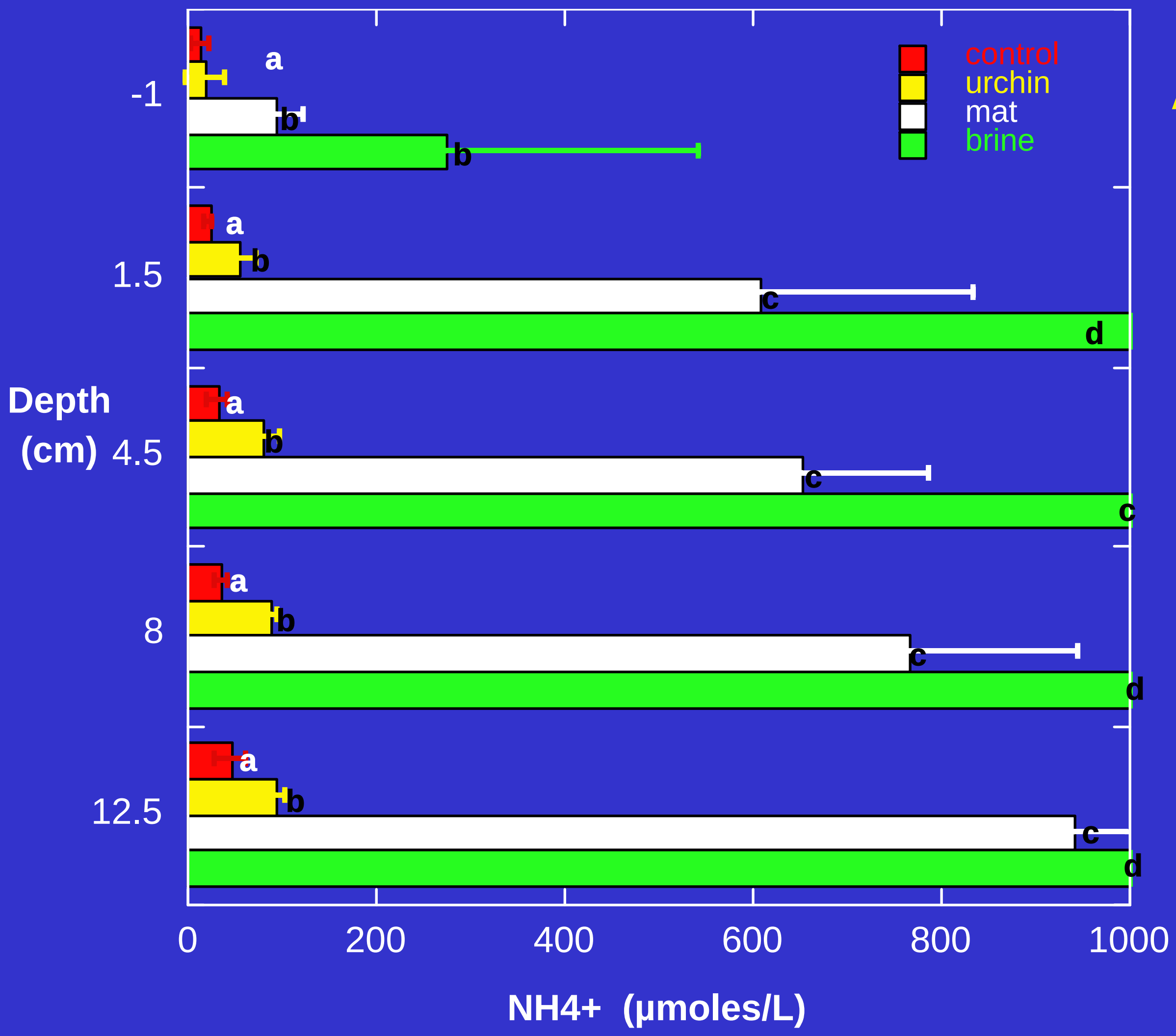
Habitat Differences: Within Site



AT340-DIC

- highest DIC in brines
- increases with depth at all sites (less control)
- means with different letters are significantly different at $\alpha = 0.05$ level

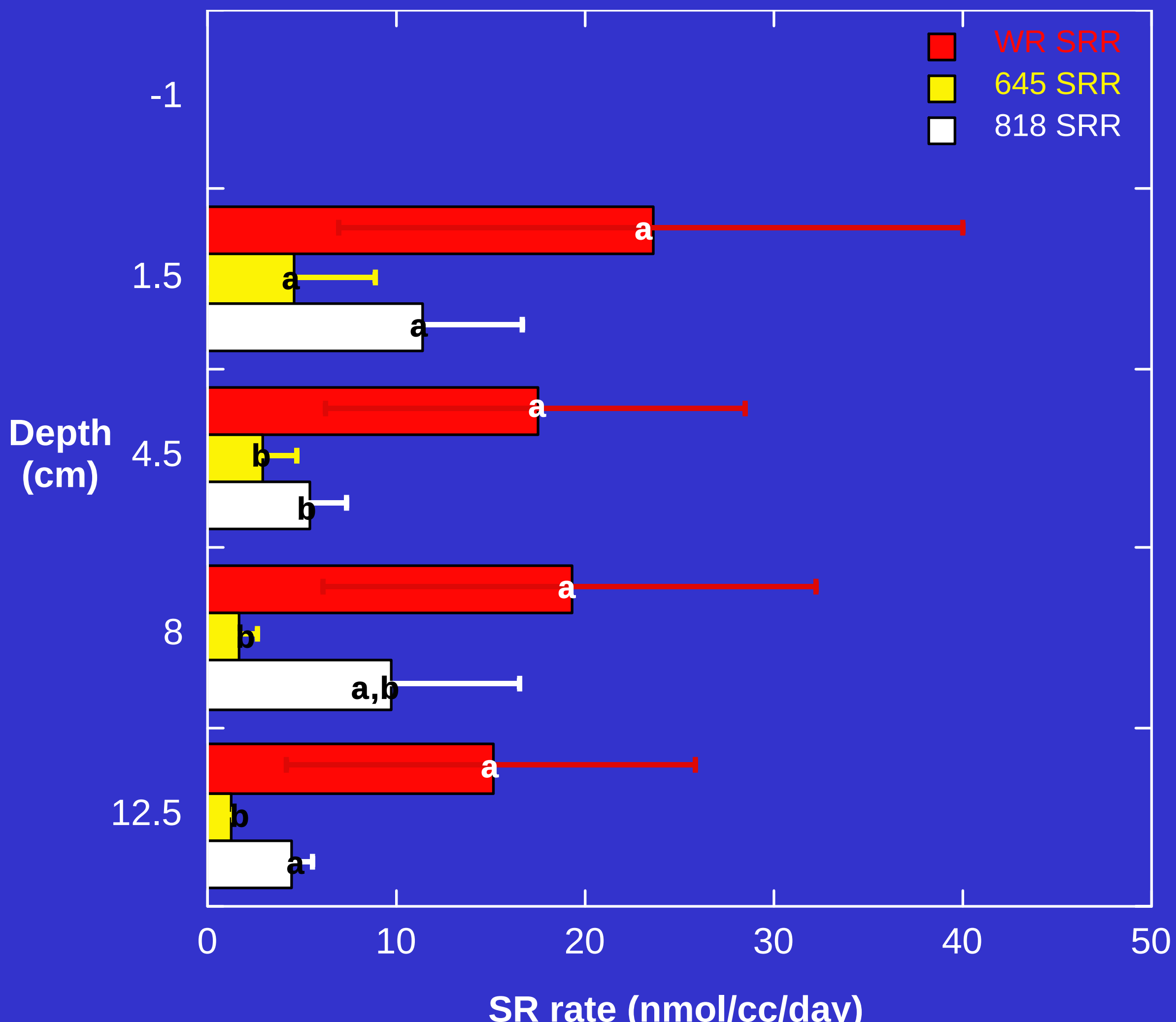
Habitat Differences: Within Site



AT340-NH_4^+

- highest NH_4^+ in brines (mat, brine)
- increases with depth at all sites (less control)
- means with different letters are significantly different at $\alpha = 0.05$ level

Habitat Differences Across Sites-Pogos



Pogonophoran-SR rates

- maximal SR rates at WR269/270
- rates in pogo cores from WR269 and AC818 comparable; AC645 lower
- means with different letters are significantly different at $\alpha = 0.05$ level

Summary

1. ***Substantial habitat-associated variability in geochemistry and microbial activity***: SR rates highest at brine sites; brines > microbial mats > pogos ~ tubeworms > urchins

2. ***Variability also noted in AOM rates***: AOM rates highest at pogo sites (pogos > urchins > tubeworms > mats >>> brines)

3. ***Brine flow limits microbial activity***: advection limits SO_4^{2-} availability and thus SR rates; AOM also hindered (salt?)

4. ***AC601 brine pool***: highest SR activity at pool edges--best of both worlds (SW-SO_4^{2-} and brine DOC?); AOM hindered and equal to MOG in the brine

Summary

5. **Brines are a source of DOC and NH_4^+**: Can see differences in source fluids evident in slopes of chloride vs. DOC/NH4 plots.

6. **Animals also a source of DOC?**: Appears so. Labile organic C profiles will shed light on this (ongoing)

7. **Significant differences between habitats within a site?**: Yes! Replication between n=4 cores per habitat surprisingly good. Interactions between animals and microbial activity is clear; driving factors less clear

Remaining Work

Molecular biology: detailed studies of habitat variation (AT340 and AC601) and between site (pogos @ WR269, AC645 and AC818)

Remaining Geochemistry: labile DOC components (VFA); cations

Contributions to DSR Special Issue

Joye, S.B., M.W. Bowles, V.A. Samarkin, K.S. Hunter, and H. Niemann. Submitted. Biogeochemical signatures and microbial activity of different cold seep habitats along the Gulf of Mexico lower slope. Submitted to Deep Sea Research.

Orcutt, B.N., S.B. Joye, S. Kleindienst, K. Knittel, A. Ramette, A. Reitz, V.A. Samarkin, T. Truede, and A. Boetius. Submitted. Impact of natural oil and higher hydrocarbons on microbial diversity, distribution and activity in Gulf of Mexico cold seep sediments. Submitted to Deep Sea Research.

Wankel, S.D., S.B. Joye, V.A. Samarkin, S. Shah, G. Friderich, J. Melas-Kryiazi, and P.R. Girguis. Submitted. New constraints on diffusive methane fluxes and rates of anaerobic methane oxidation in a Gulf of Mexico brine pool through the use of a deep sea *in situ* mass spectrometer. Submitted to Deep Sea Research.

Planned Publications

Bowles et al. Methanogenesis at brine sites

Joye et al. AC601 brine lake (2006 cruise data)

Two to three additional biogeochemistry papers:

Joye et al. Habitat differences (2007 cruise data)

Joye et al. Brines comparison (2007 cruise data)

Joye, Roberts, et al. AC601 brine lake

Two to three molecular papers to be written by post doc Melitza Crespo-Medina: AT 340 paper, AC 601 paper and also a possible pogo paper

Reference

Joye, S.B., A. Boetius, B.N. Orcutt, J.P. Montoya, H.N. Schulz, M.J. Erickson, and S.K. Lugo. 2004. The anaerobic oxidation of methane and sulfate reduction in sediments from Gulf of Mexico cold seeps. Chemical Geology 205:219–238.