Hydrothermal vent fauna habitats: biological and geochemical controls

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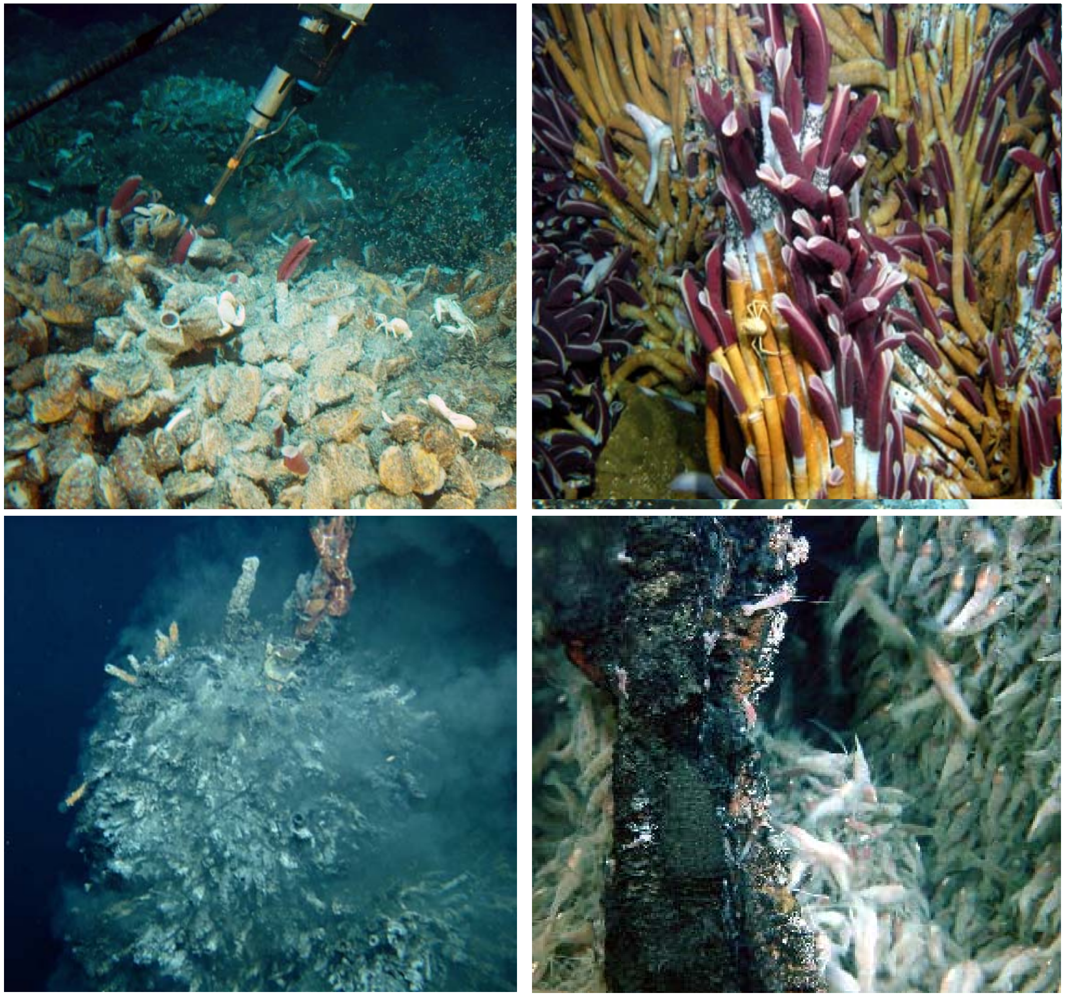
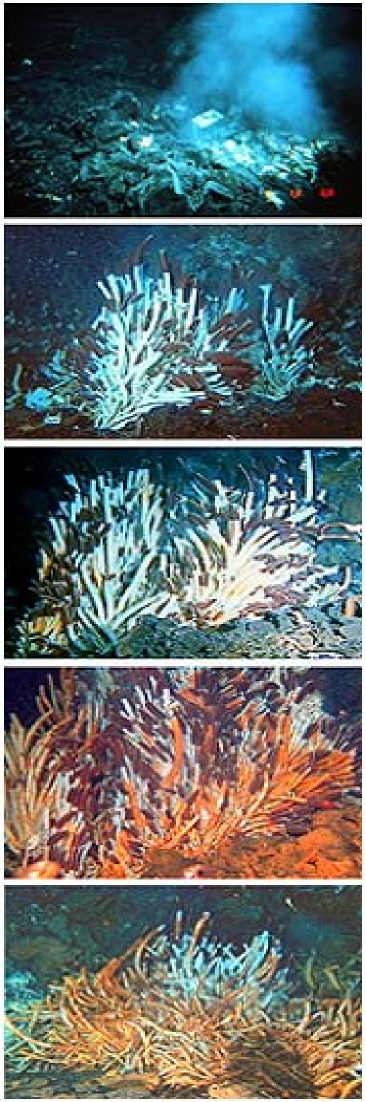
Vent fauna habitats: patchy agregations of invertebrates around vents



Biologically & geologically diverse environments

Interaction of the biological and abiotic components of these environments

- Species adaptation to extreme env. conditions
- Microbial diversity and biogeochemical processes
- Chemoautotrophic symbioses
- Evolution of communities



What do we know about the processes driving physico-chemical variability in these habitats?

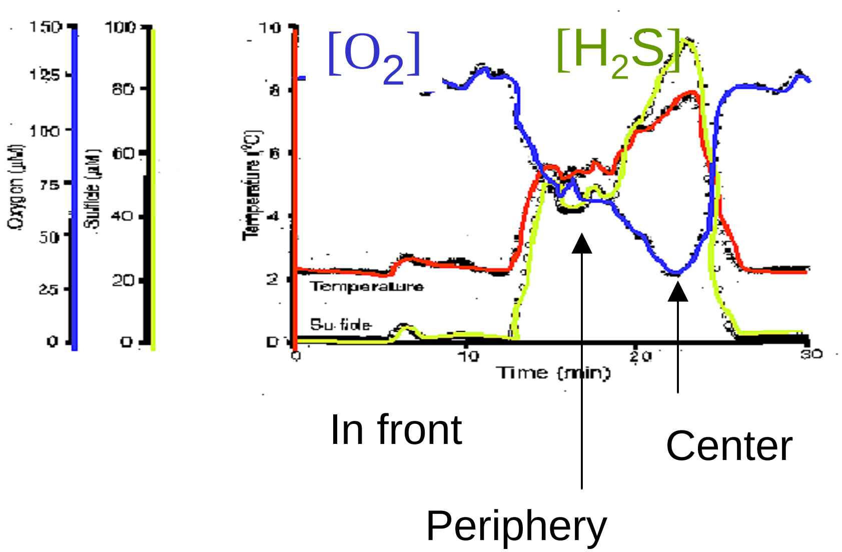
- The basic ‘mixing zone’ model
- Tools
- Validity of the model at ‘geo-scales’ (vent field, vent site)
- Validity of the model at ‘bio-scales’ (assemblage/organism)
- Conclusion & perspectives

First Model : Rose Garden

Johnson et al. (1986, 1988)

- **Narrow transition zone** *Steep gradients*

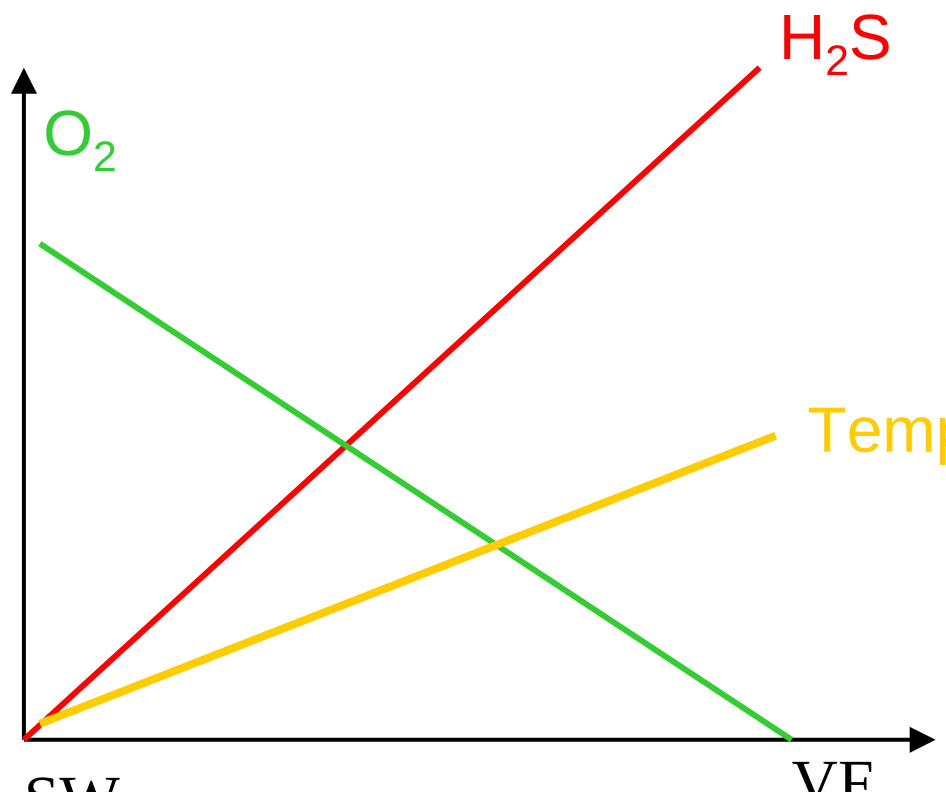
Johnson et al. (1986)



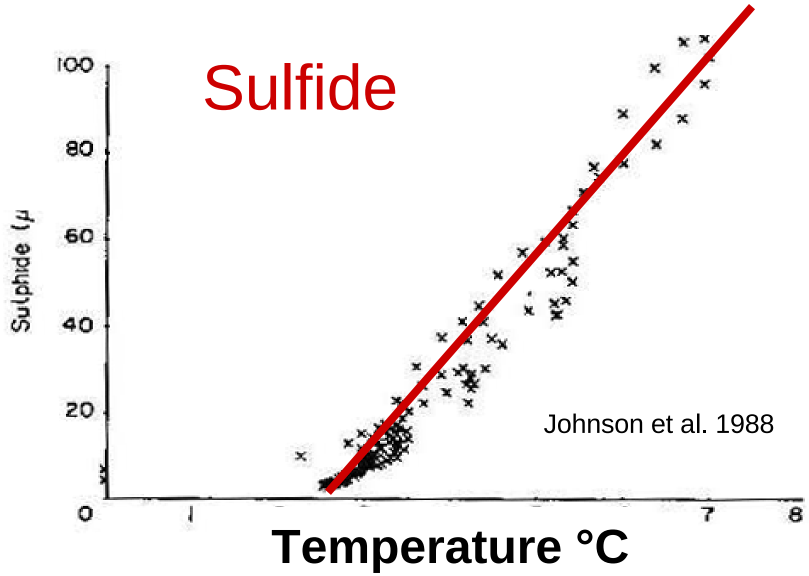
- **Non-equilibrium**

Coexistence of oxidizing species and reducing species

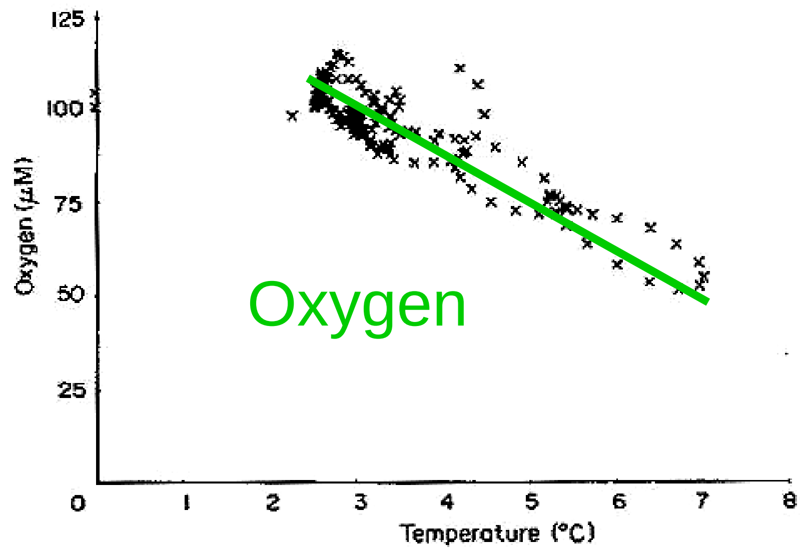
1st Model : *Dynamic mixing of vent fluid and seawater primarily drives physico-chemical gradients*



• Fluid chemical compounds positively correlate w/T°C



• Seawater chemical compounds negatively correlate w/T°C



Can this model be extrapolated?

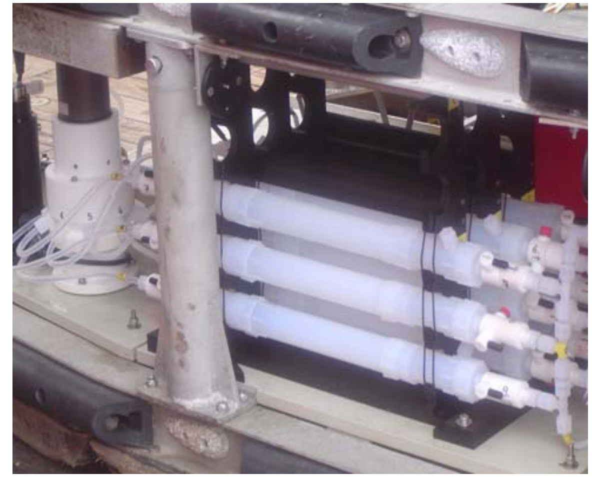
1. At site scale,over the vent field?

2. Over a whole assemblage, at organism scale?

Sampling

Ti-multisampler (IFREMER)

200-750 ml

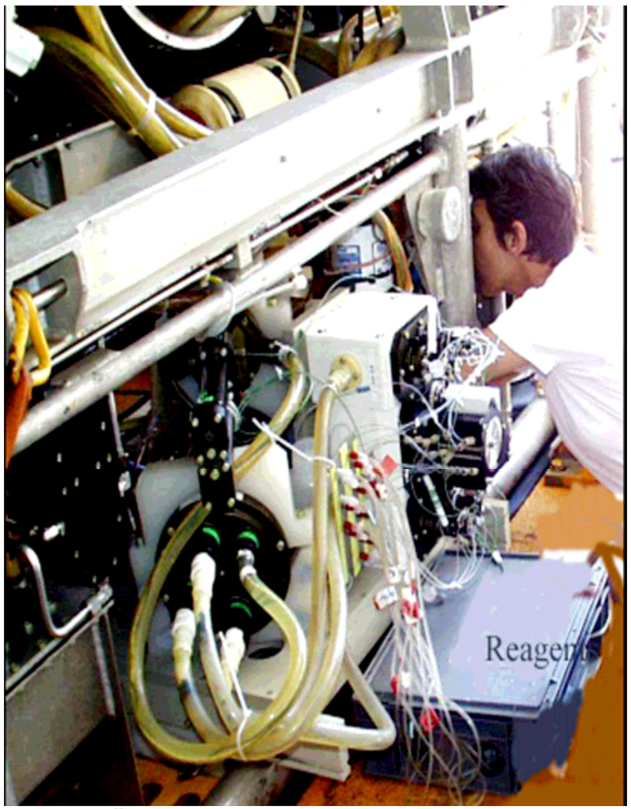


Kipps sampler (MARUM/QUEST)

- Tracers of fluid (Si, Mn) and seawater (Mg)
- Electron donors ΣS, CH_4, H_2, Fe^{II}
- Electron acceptors O_2, NO_3^-, SO_4^{2-}, Fe^{III}
- Other key parameters: pH, CO_2, NH_4^+, Cu, Cd, Pb

In situ analyzers

- SCANNER (Johnson et al., 1986) — ΣS, Si
- SUAVE (Massoth, 1994) — ΣS, Si, Mn
- ALCHIMIST (Le Bris et al. 2000) — ΣS, $(NO_3^- + NO_2^-)$, Fe^{II} or Fe_T
- ISUS (Johnson et al. 2002) — HS^-, NO_3



– micro-flow techniques

– on-line colorimetric reaction & visible spectrophotometry

or

– direct UV detection

Alchimist on the ROV VICTOR

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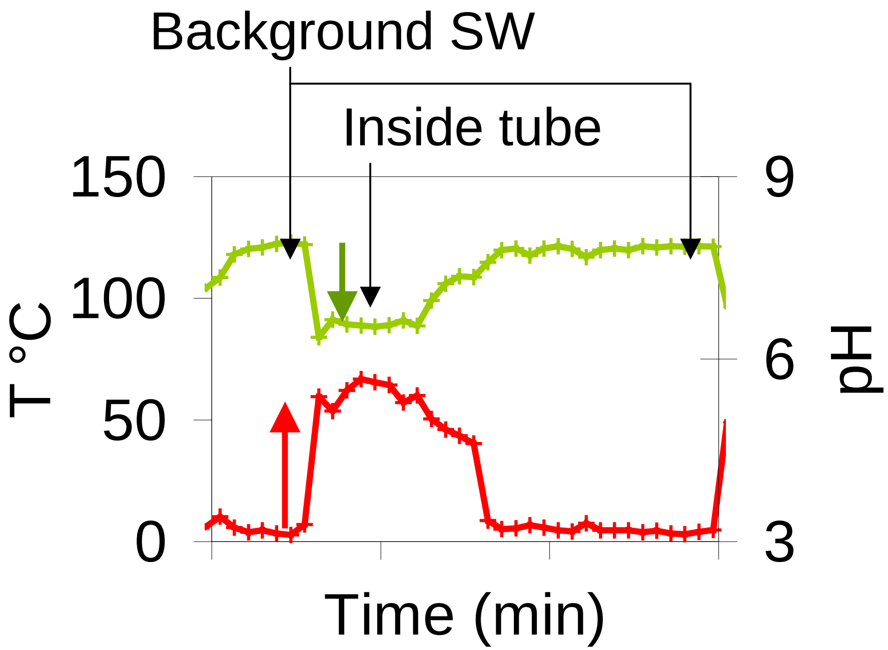
Electrochemical sensors

- O_2 (Clarck electrode, Johnson et al., 1986, 1988)
- H_2S, FeS, O_2 ,.. (voltametry, Luther et al. 1999, 2001, in press)
- pH (glass electrode, Le Bris et al. 2001, 2003, 2005, 2006)
- S_2-, pH (potentiometry, Ding et al., 2004)
- H_2S, O_2 (amperometric microsensors, Zelinsky and Dubilier, 2005)

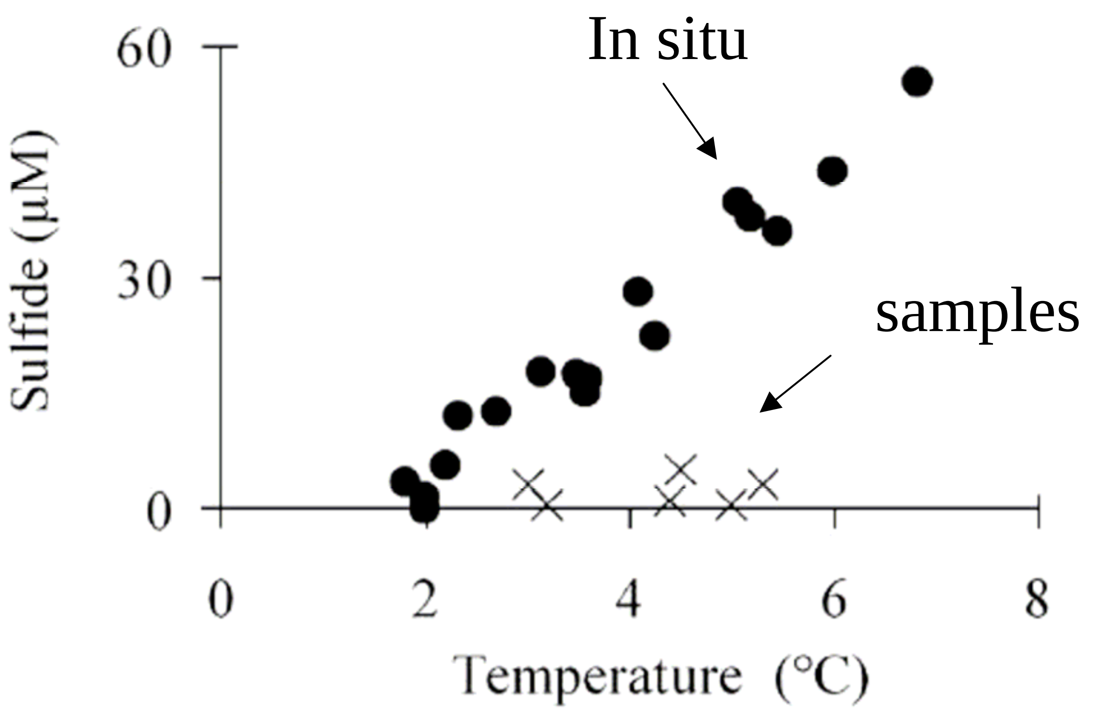
In situ measurements: resolve gradients at the scale of an assemblage

….or of an organism



Le Bris et al. (2005) DSR I

Avoid samples degradation



Le Bris et al.. (2006) Cah. Biol. Mar. 47 : 465-470

Information on ***in situ*** chemical speciation

‘ free sulfide ’ — metal complexes — precipitates

$$\Sigma S = [H_2S] + [HS^-] + [FeS_{aq}] + [Fe(HS+)\ldots + [FeS_p] + \ldots$$

Electrochemistry

Colorimetric analyzers

- ≠ Toxicity
- ≠ Bioavailability

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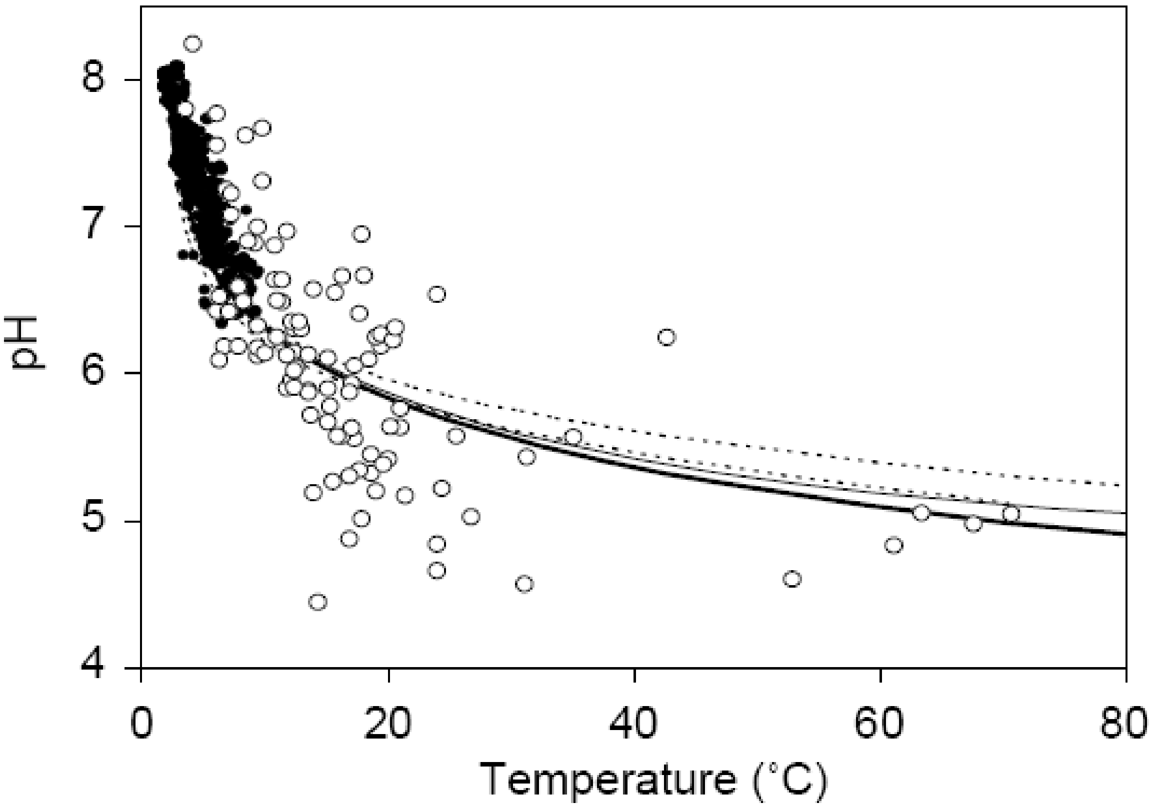
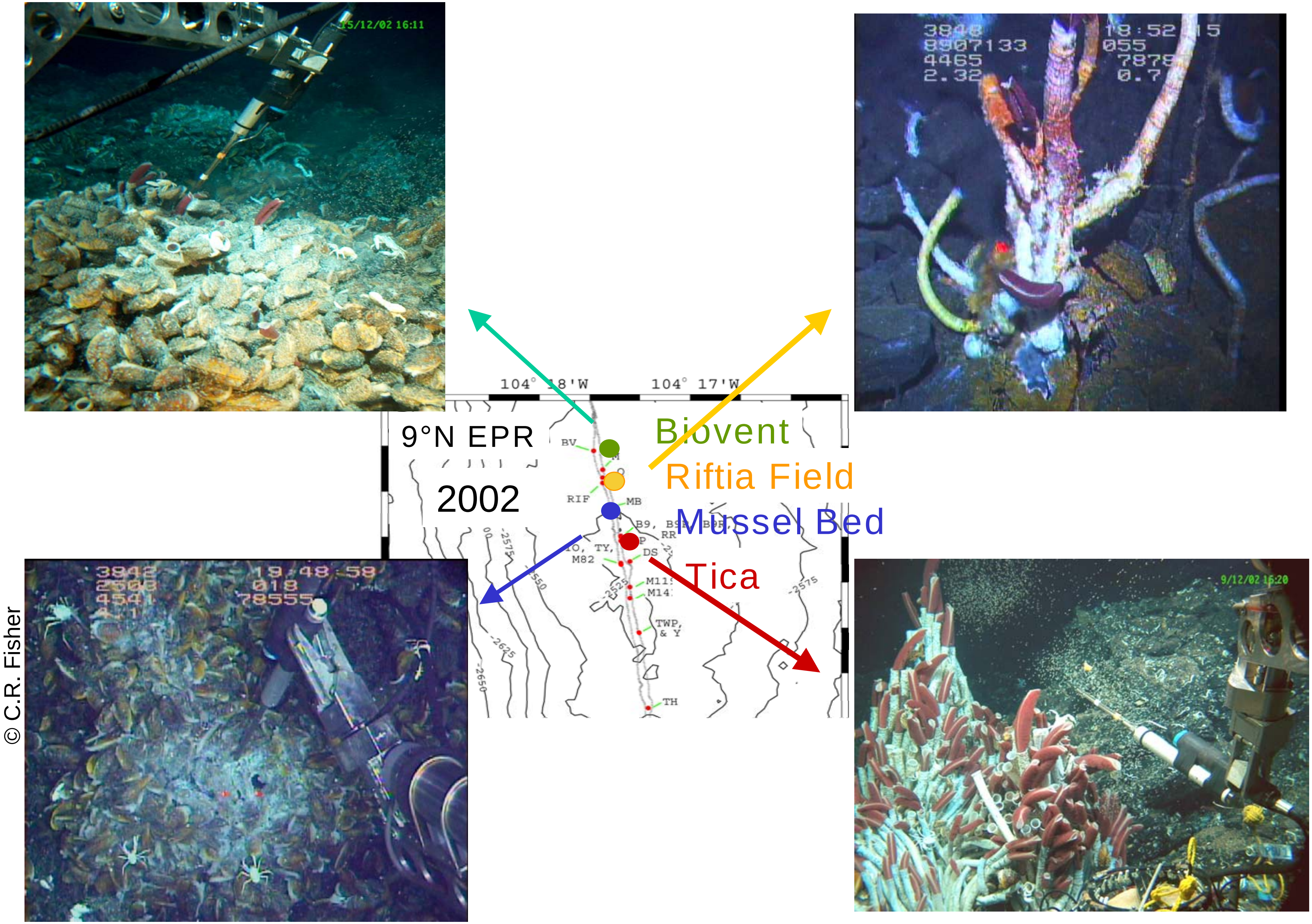
Modelling



Le Bris et al. (2003)

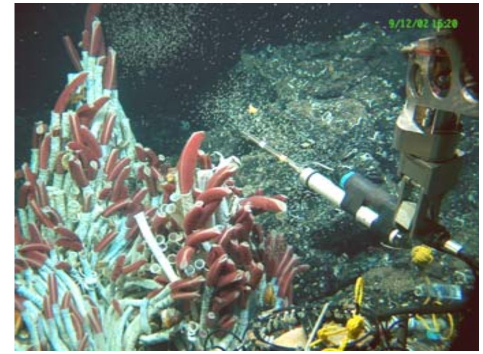
Variability at vent field scale


15/12/02 16:11
104° 18'W
104° 17'W
9°N EPR
2002
Biovent
Riftia Field
Mussel Bed
Tica
BV
RIF
MB
DS
TWP,
& Y
TH
-2575
-2625
-2650
9/12/02 15:20
© C.R. Fisher

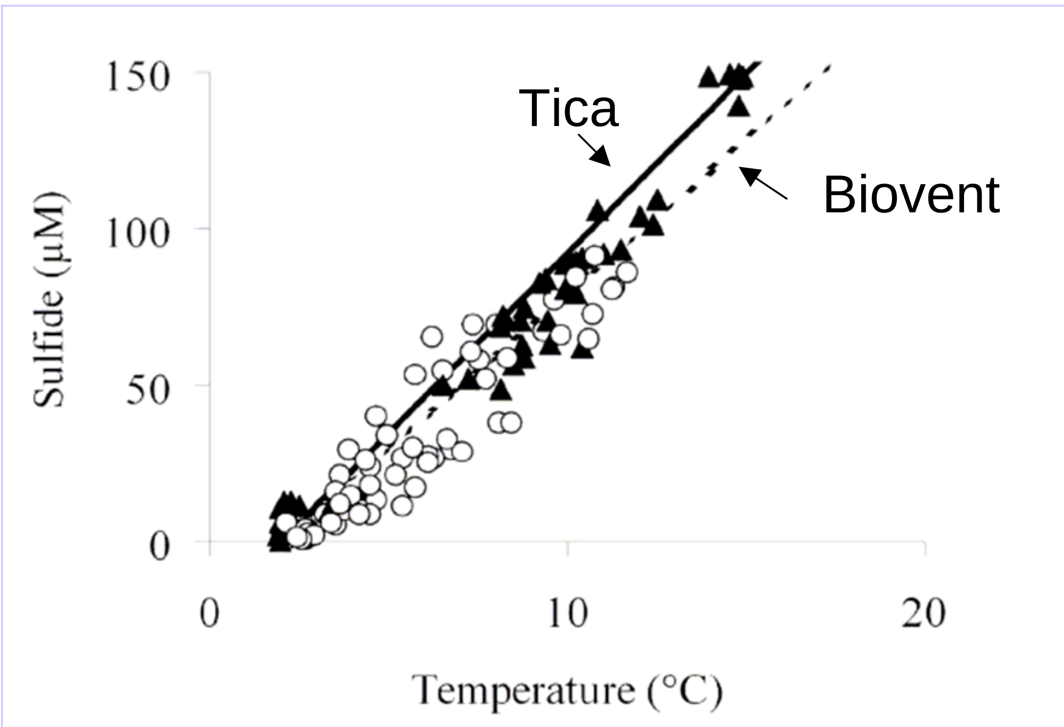
Different vent fluids…

Site	Max. T (°C)	Max ΣS (µM)
Tica	32	283
Biovent	15	156

Le Bris et al. (2006) Mar Chem. 98:167-182



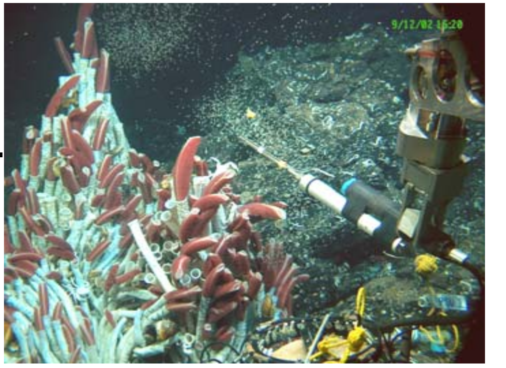
Le Bris et al. (2006). Cah Biol. Mar.47



…but similar correlation of sulfide w/ T°C

Different vent fluids…

	T max (°C)	Max ΣS(µM)
Riftia Field	54	77
Tica	32	283



Le Bris et al. (2006) Mar Chem. 98:167-182

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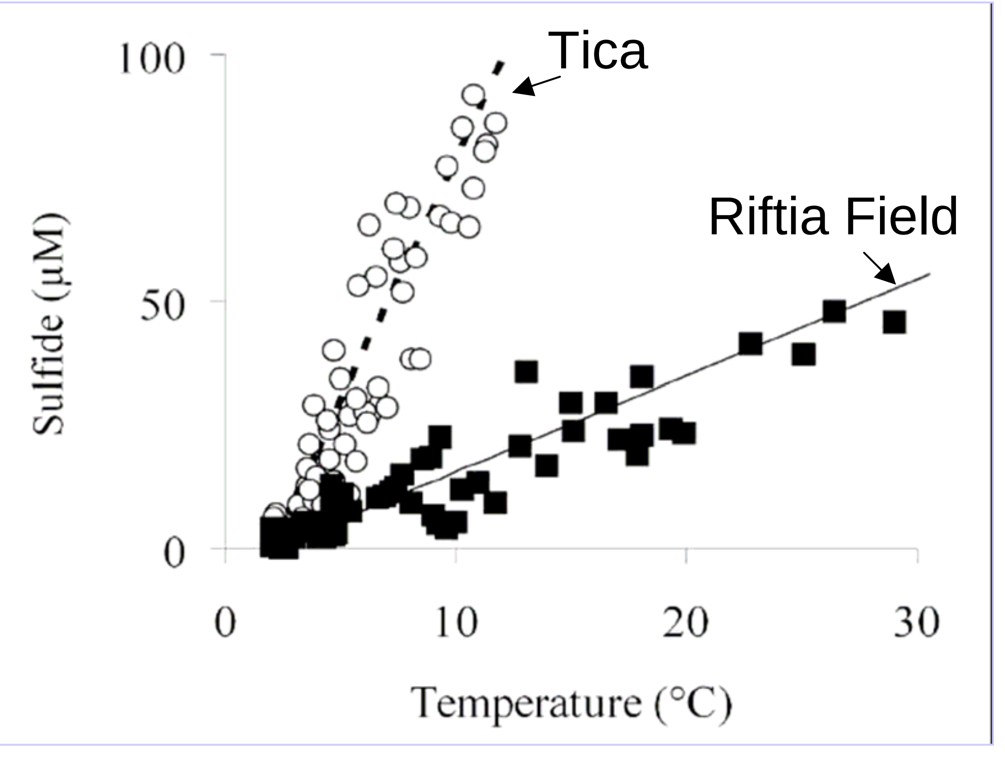
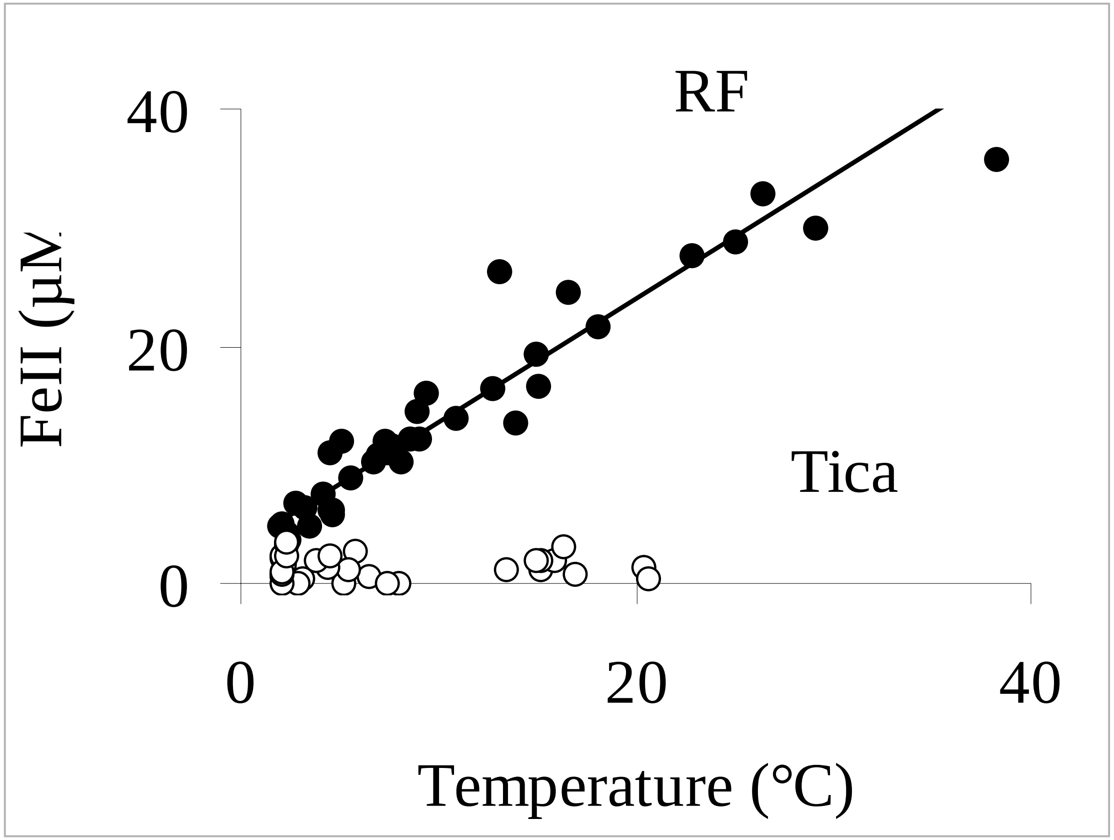


Different sulfide-T°C correlation…

Different vent fluids…

	T max (°C)	Max ΣS(µM)	Fe:S	Min pH
Riftia Field	54	77	0.7	4.4
Tica	32	283	~ 0	5.7

Le Bris et al. (2006) Mar Chem. 98:167-182



End-member evolution?
+subsurface processes ?

$$H_2S + Fe^{II} \rightarrow FeS + 2\,H^+$$

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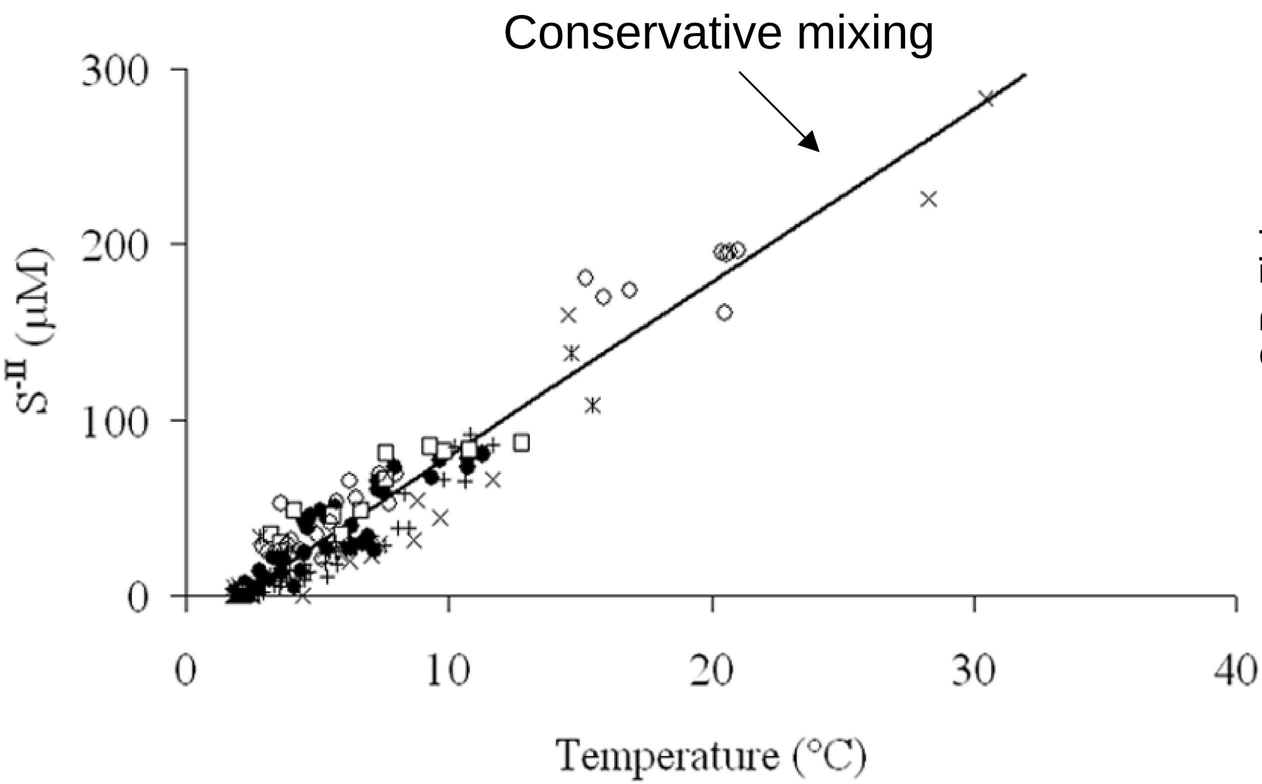
Site with a single end-member

• Single end-member, same type of venting, variable subsurface dilution



Le Bris et al. (2006) Mar Chem. 98:167-182

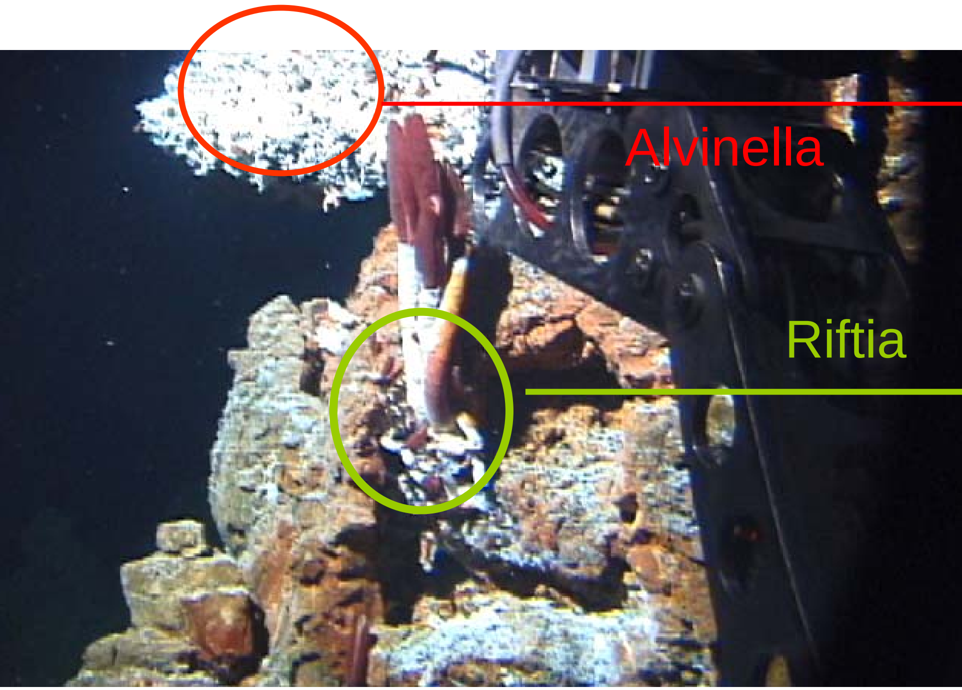
Tica (2002)

C.R. Fisher

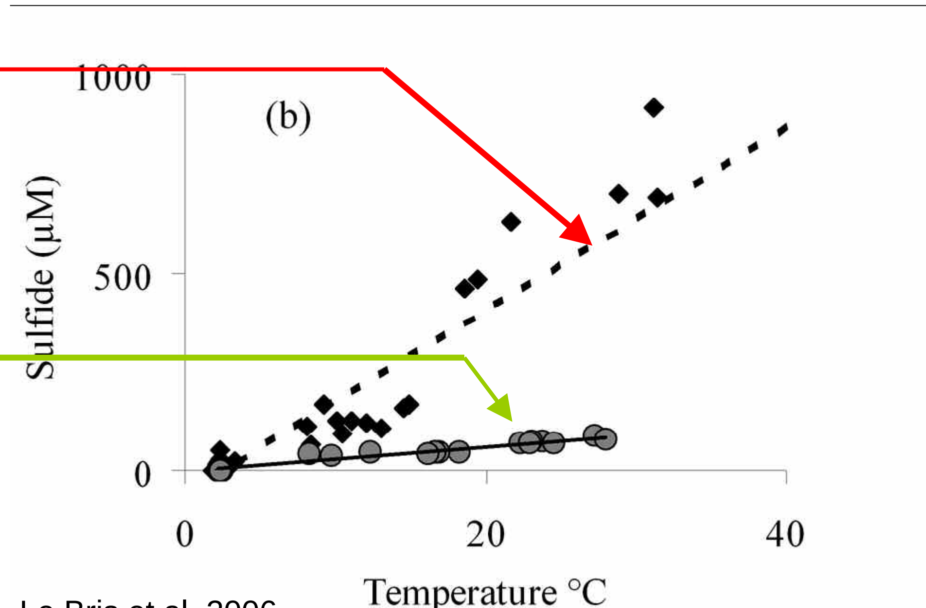
Ifremer

• Single end-member, different types of venting

M-Vent2002



C.R. Fisher



Le Bris et al. 2006

The ‘conservative mixing’ model is valid

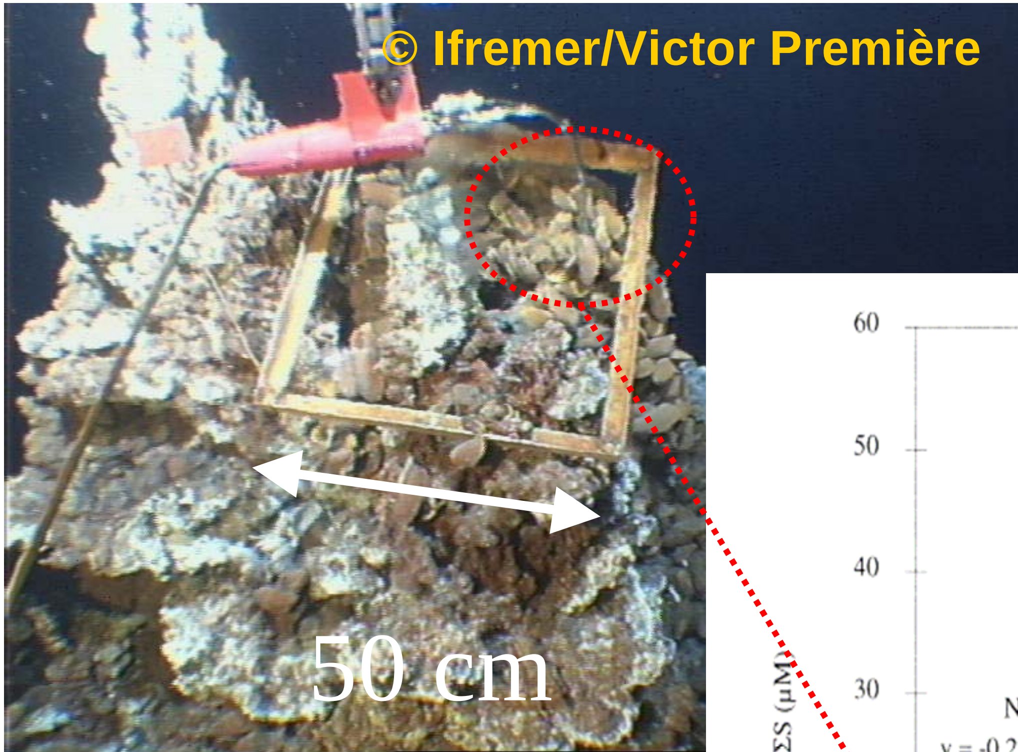
• in first assumption, within a site for different assemblages associated with low-T vents

But large differences should be expected between

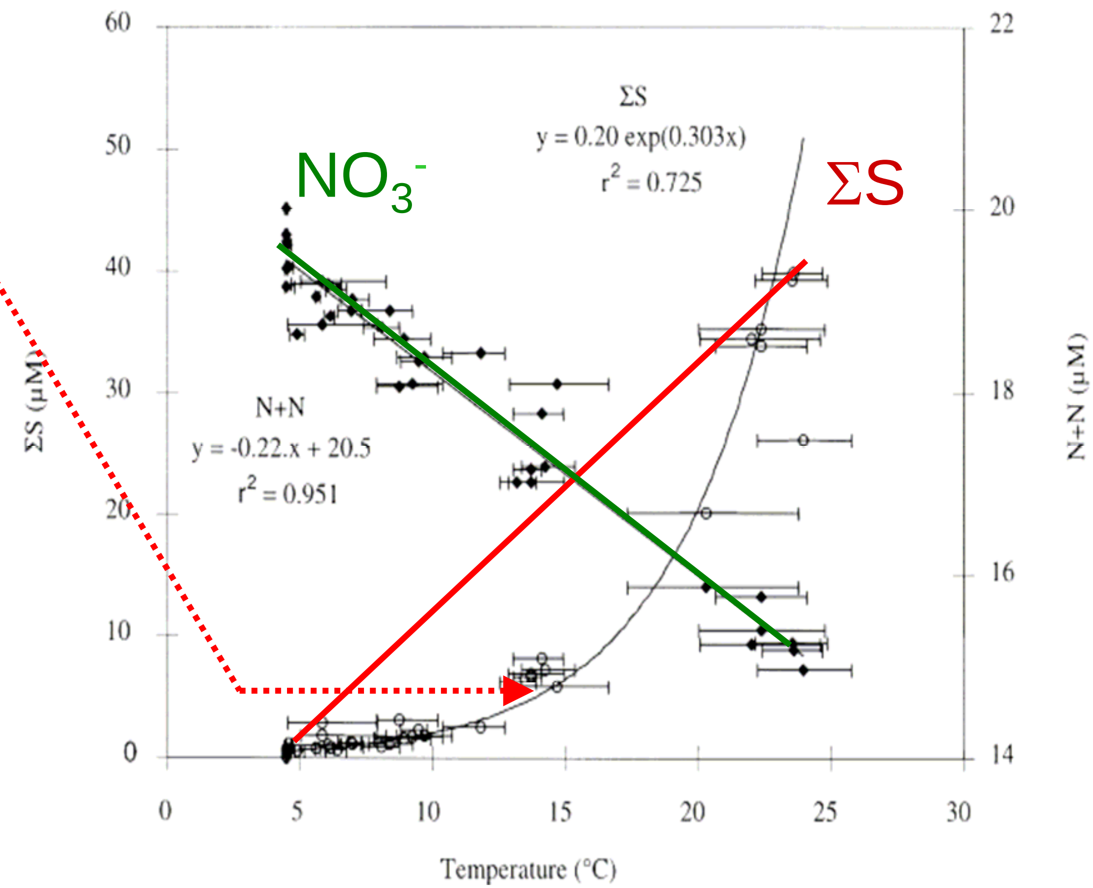
• low and high-T vents

• distinct sites of different end-member composition

Non-conservative processes at assemblage scale



Lucky Strike, MAR



Role of organismes ?

Le Bris et al. (2000) Marine Chemistry 72:1-15

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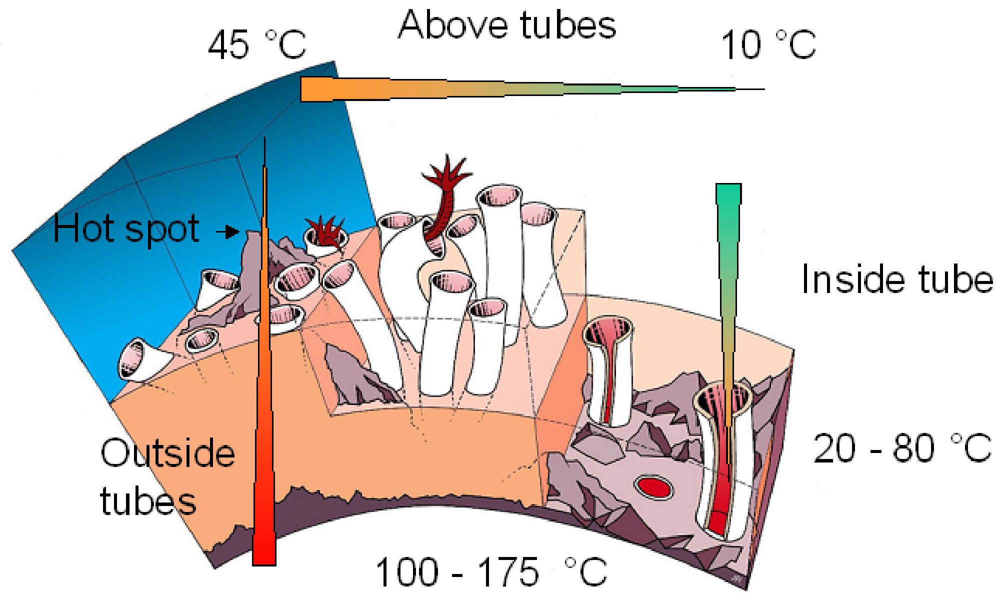
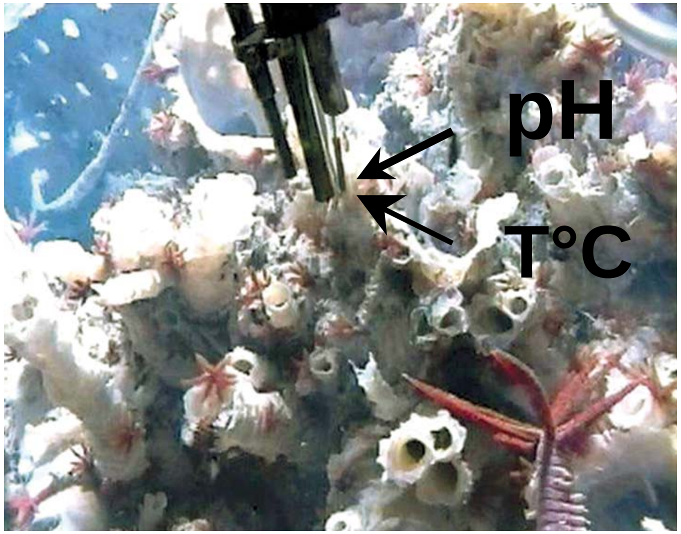
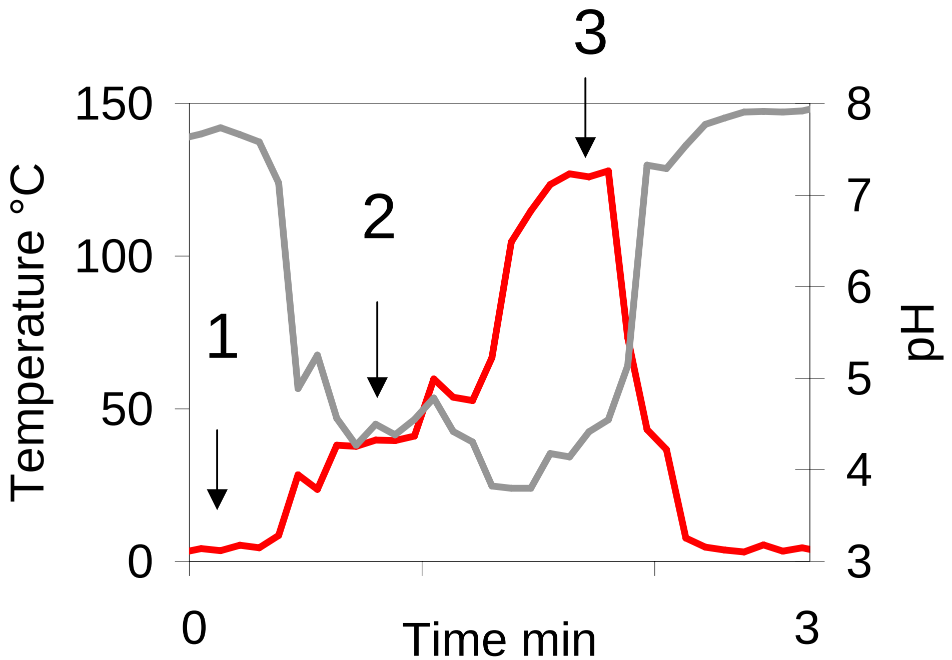
Structuration of the mixing interface



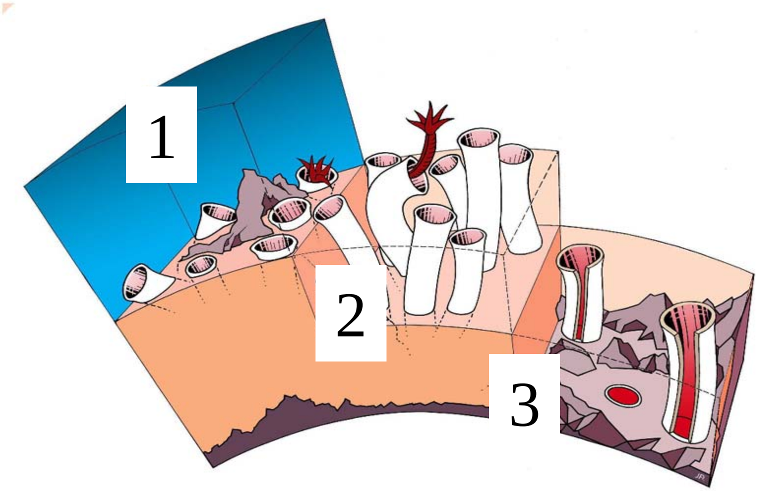
Le Bris and Gaill (2007)
Rev. Environ Sci Biotechnol 6:197–221

Extreme temperature gradients over the thickness of Alvinella colonies on smoker walls



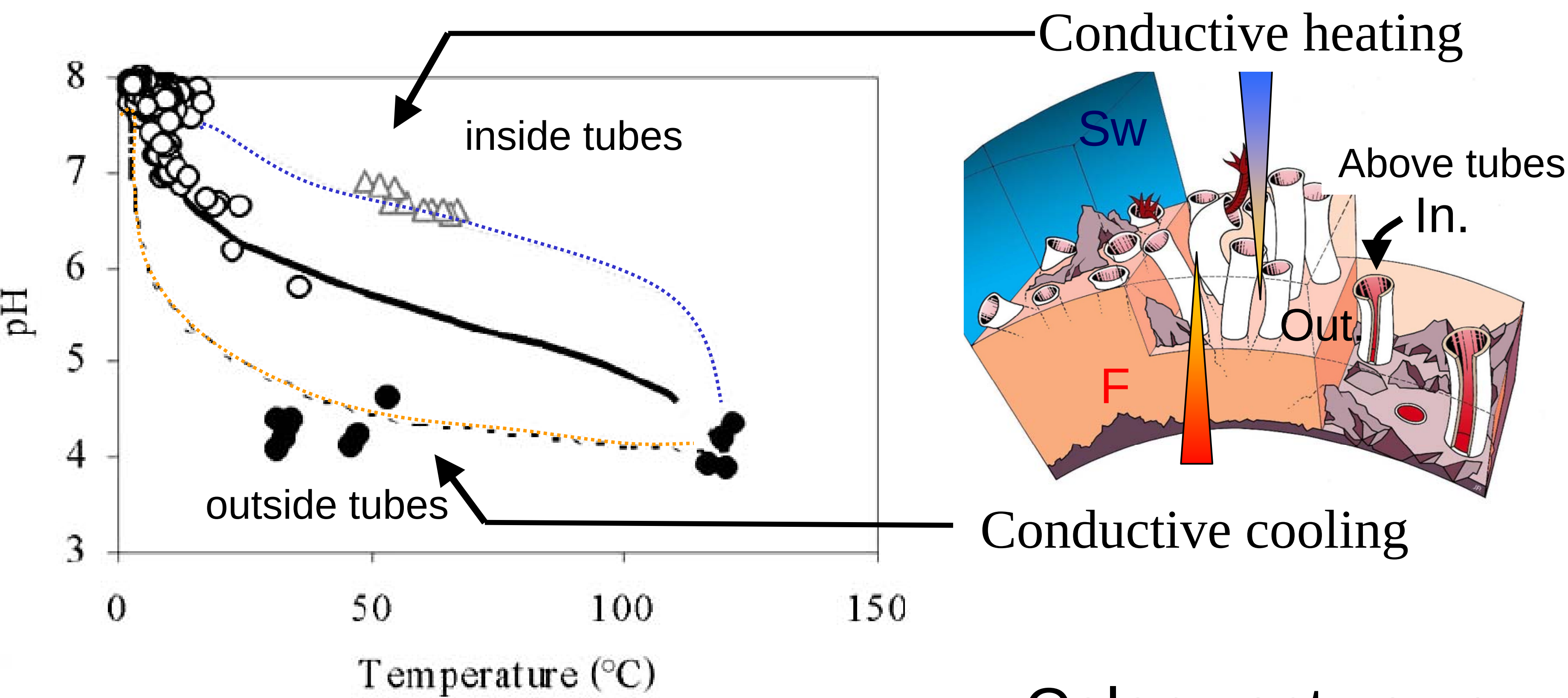


Le Bris et al. 2005, Deep-Sea Res. 52: 1071-1083



The Alvinella colony seggregate the hot fluid at the surface of the chimney

Conductive cooling and heating



Le Bris et al. 2005, Deep-Sea Res. 52: 1071-1083

Colony acts as a heat exchanger

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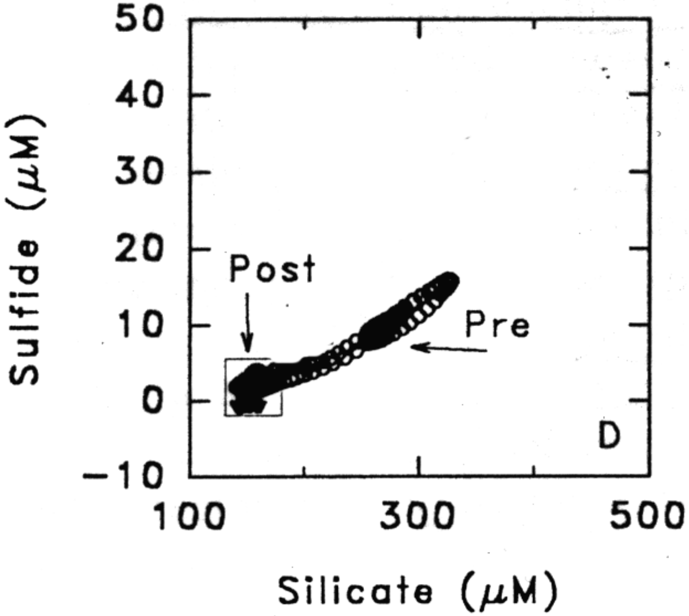
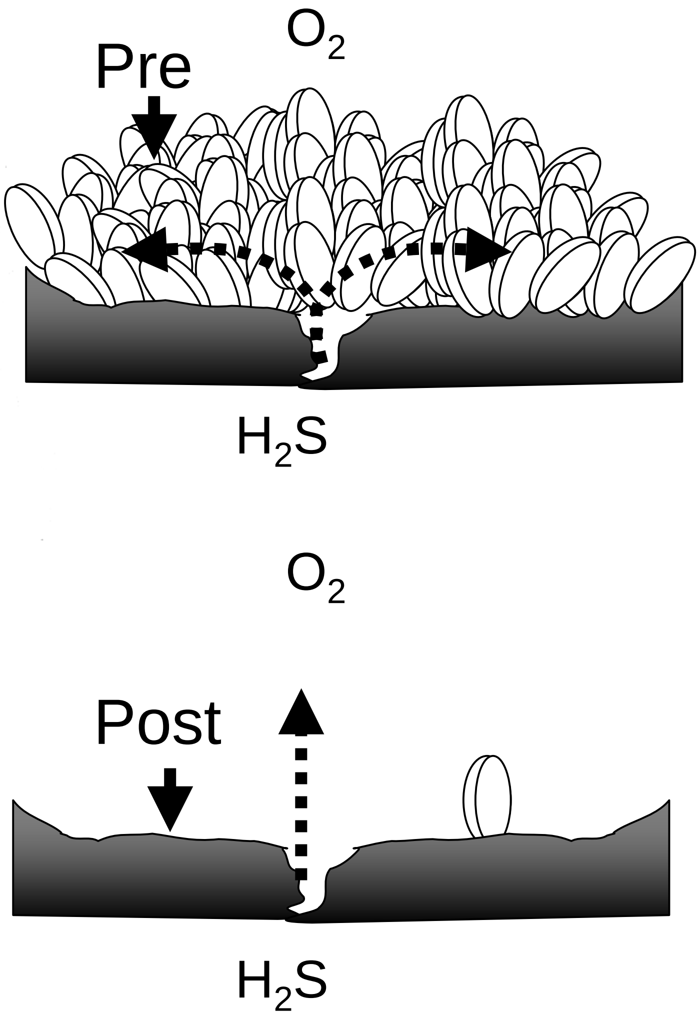
Structuration of the interface

Clearance experiments
Johnson et al. 1994

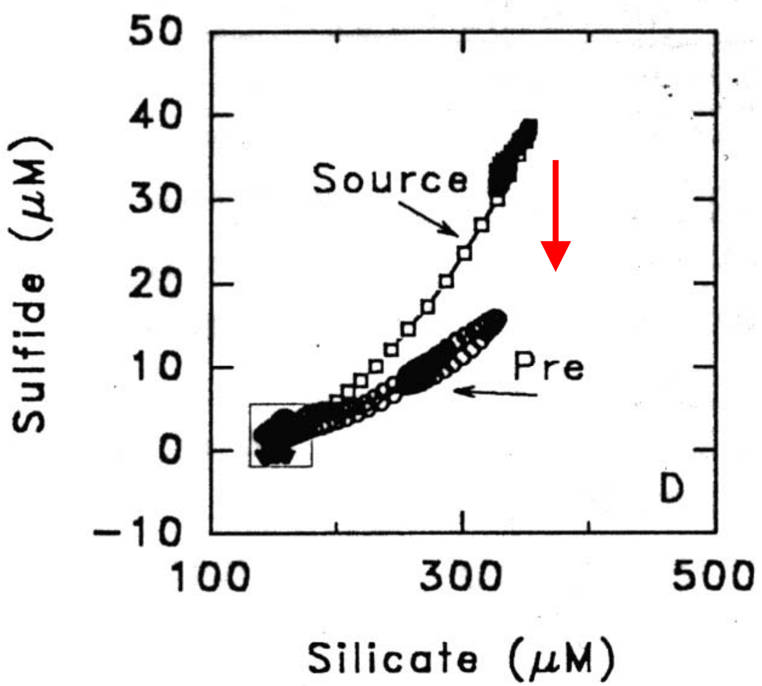


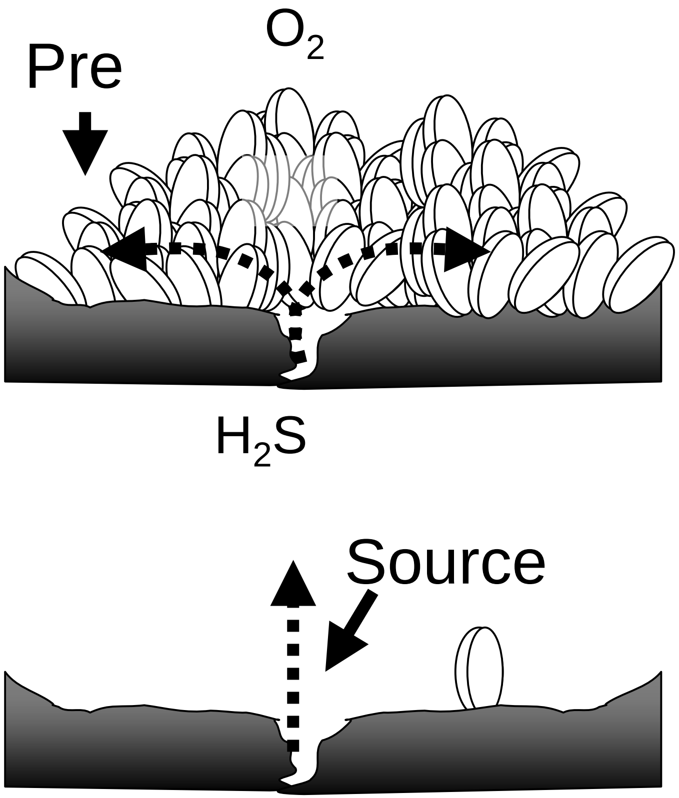


Mussels disperse the flow laterally

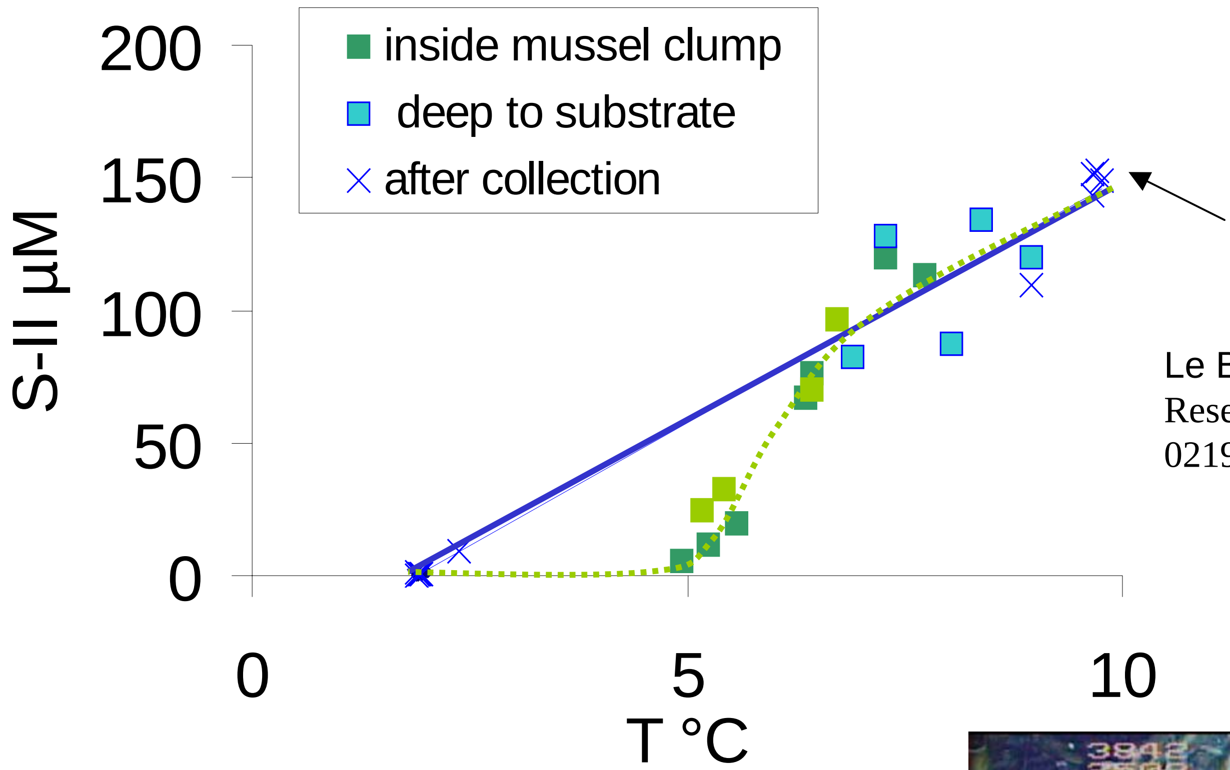
Consumption

Clearance experiments
Johnson et al. 1994





Sulfide depletion in mussel patches

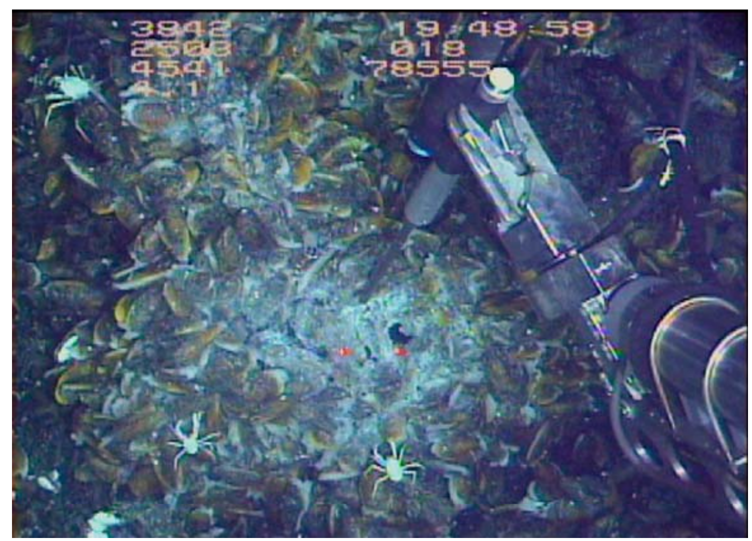


Conservative dilution of local source

Le Bris et al. Geophysical Research Abstracts, Vol. 7, 02191, 2005

Sulfide consumption by microbial mats?

Le Bris et al. (2006) Mar Chem. 98:167-182



Conclusion

- **Geological context**

1. End-member chemistry
2. Venting regime (HighT & LowT)
3. Subsurface dilution

- **Biological influence**

1. Structuring the mixing interface
2. Thermal exchange
3. Consumption

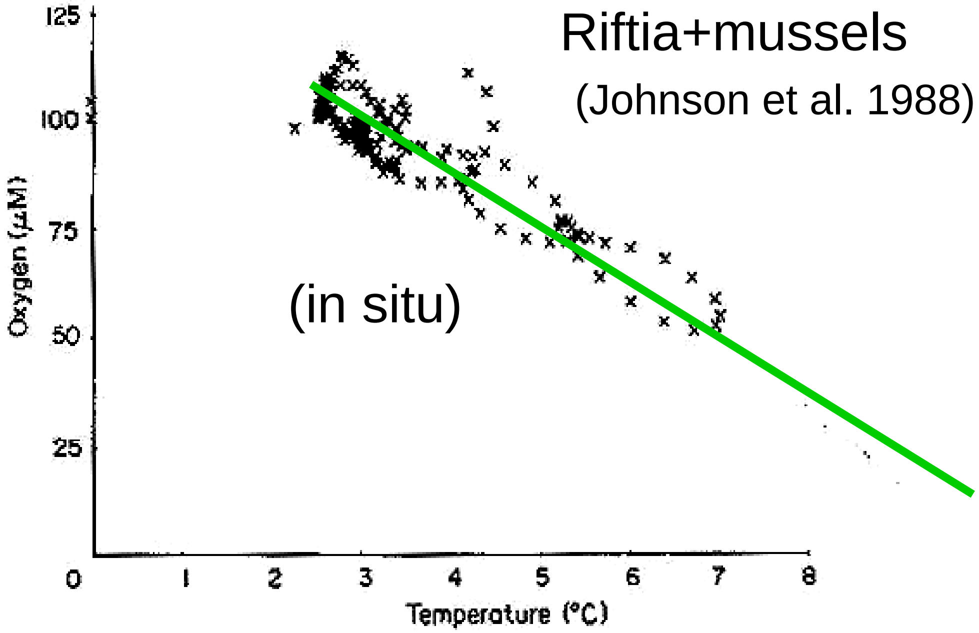
Perspectives

- other relevant parameters

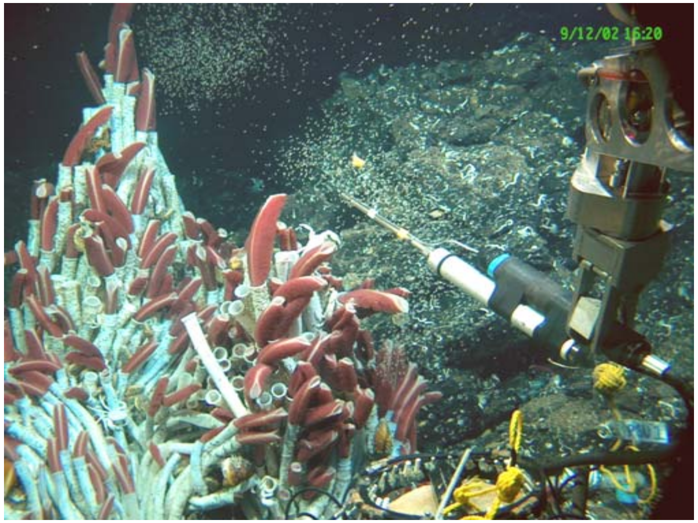
- longer time scales

Oxygen

Rose Garden
Riftia+mussels
(Johnson et al. 1988)



11 °C



Biogeochemical

(Johnson et al. 1988)

$$HS^{-} + 2O_2 \rightarrow SO_4^{2-} + H^{+}$$

$$HS^{-} + \frac{1}{2} O_2 + H+ \rightarrow S^{\circ} + H_2O$$

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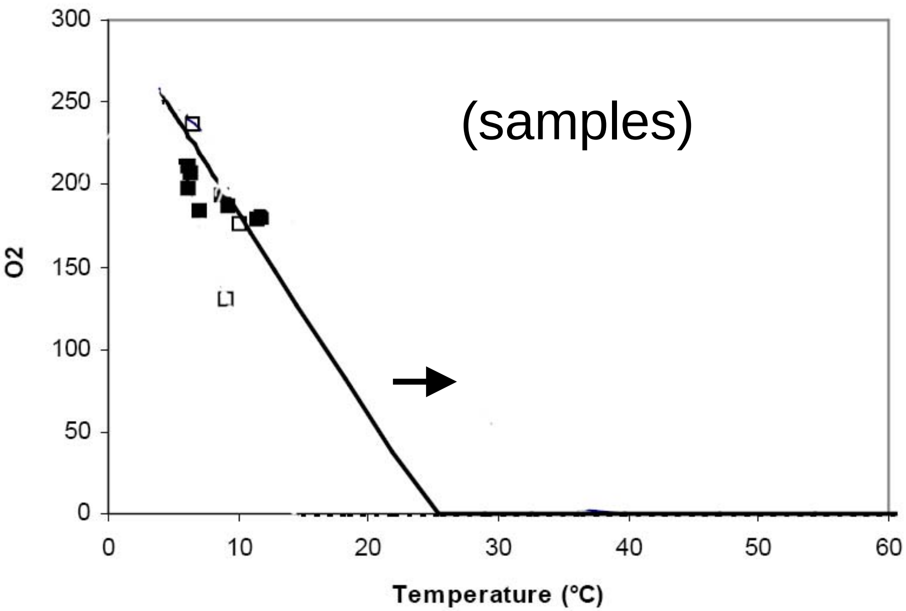
Oxygen



Rainbow MAR, Rimicaris shrimps
Tlimit in situ > 25 °C

Schmidt et al. In press. Marine Chemistry

$$CH_4 + 2O_2 \rightarrow HCO_3^- + H^+ + H_2O$$

$$Fe^{2+} + \frac{1}{4} O_2 + \frac{3}{2} H_2O \rightarrow FeOOH + 2H^+$$

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$$

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Oxygen and electron donors

$$CH_4 + 2O_2 \rightarrow HCO_3^- + H^+ + H_2O$$

biogeochemical

$$Fe^{2+} + \frac{1}{4} O_2 + \frac{3}{2} H_2O \rightarrow FeOOH + 2H^+$$

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$$

purely chemical
or
biogeochemical?

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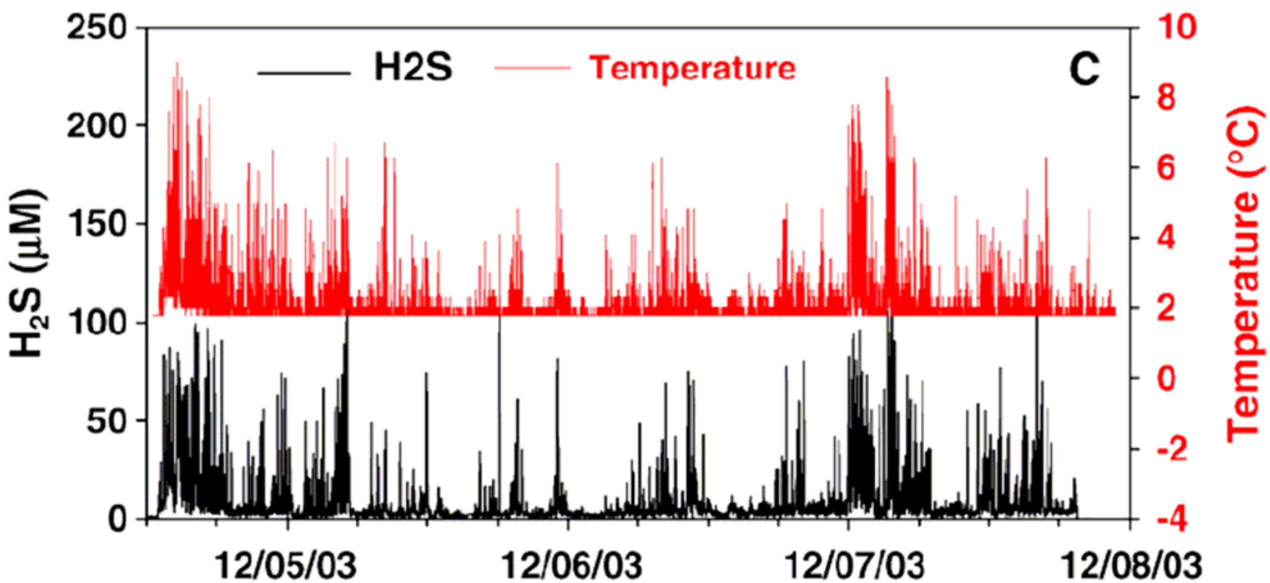
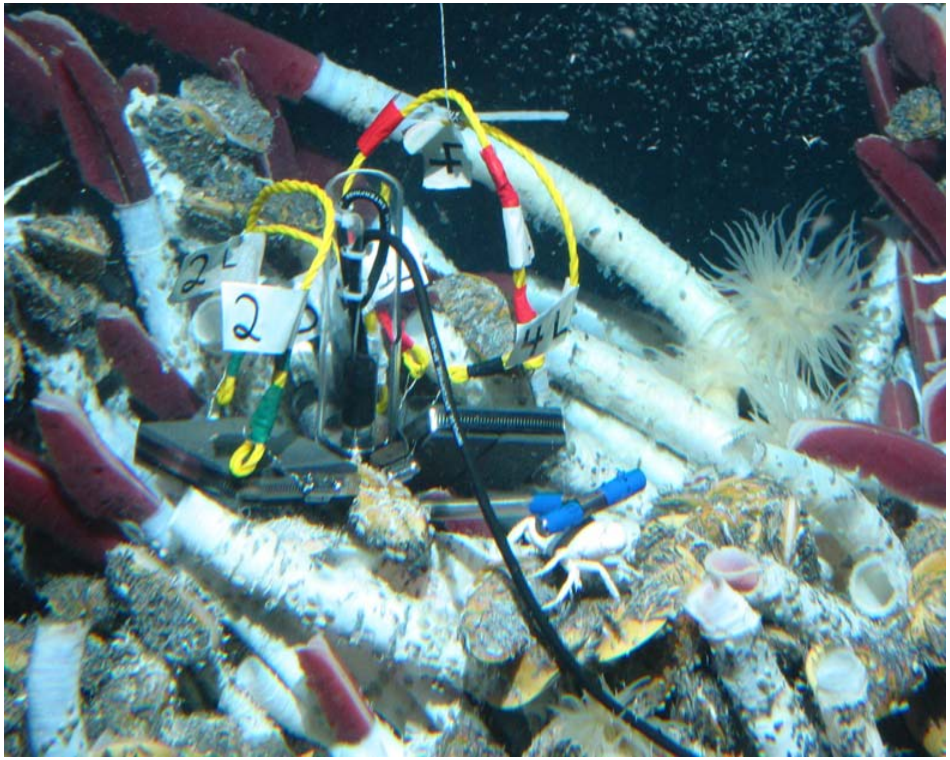
Temporal variability

- Temperature fluctuations
- Chemical variability



Luther III et al. Mar. Chem. in press

Integrated experiments



Ding et al., EOS Trans. AGU, 85(47)

Shank et al., EGU 2006.

http://www.whoi.edu/oceanus (photo: S. Beaulieu)

Thanks for your attention