STEMM-CCS

Structure of vents

using high resolution studies

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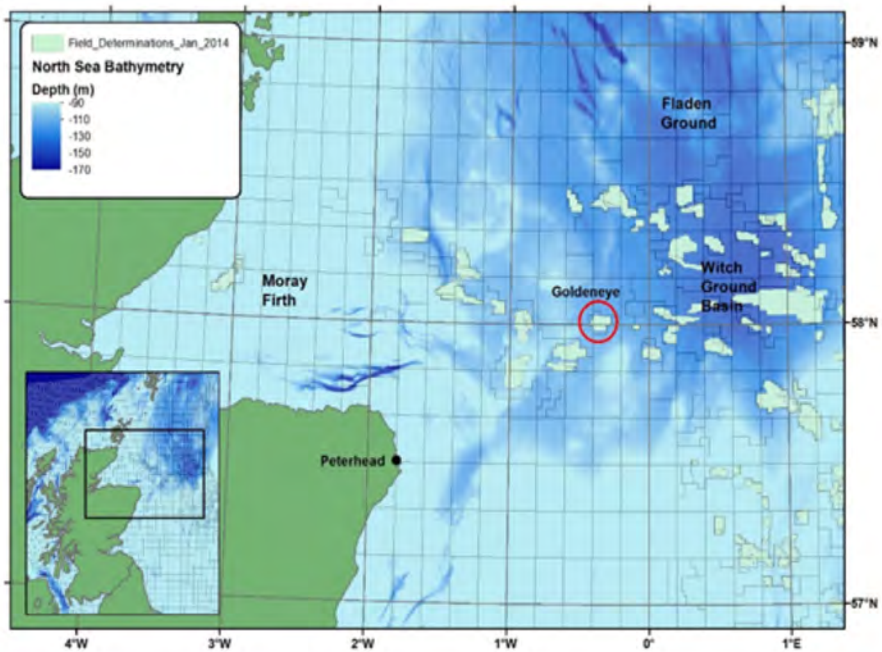
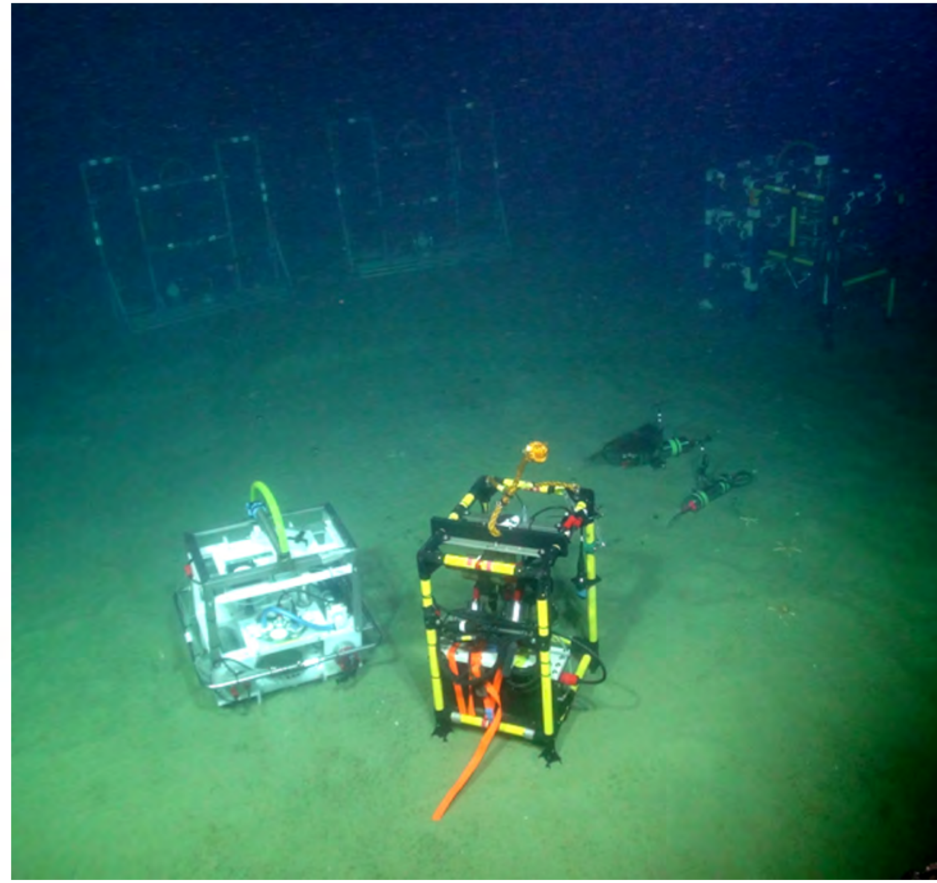
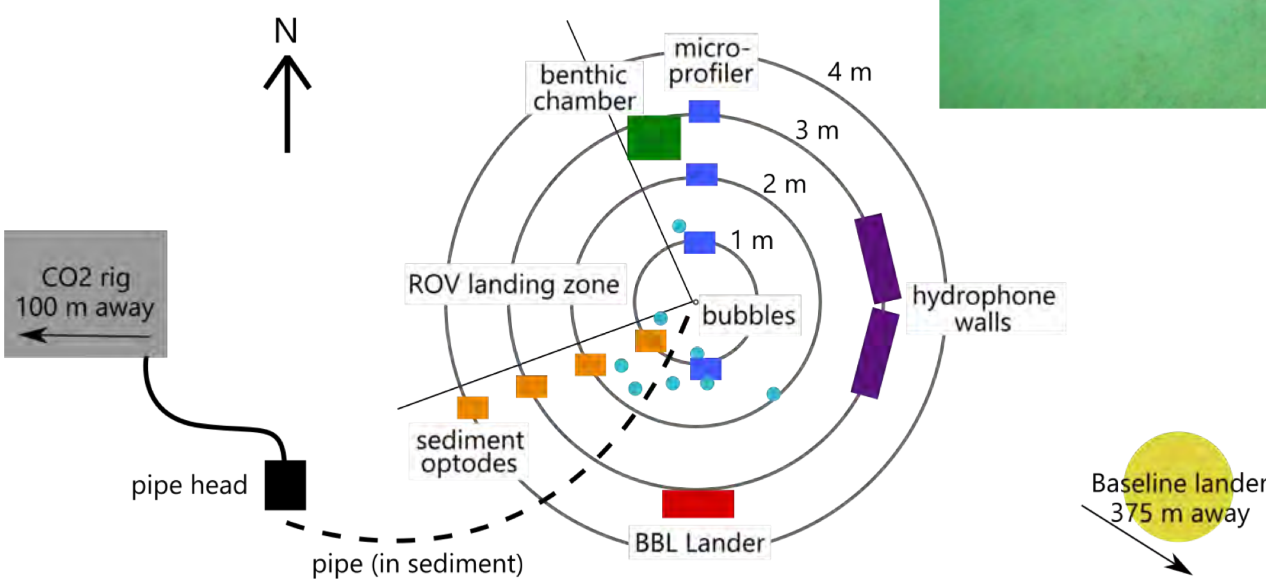
Dirk Koopmans, Moritz Holtappel

MPI-NOCS-AWI



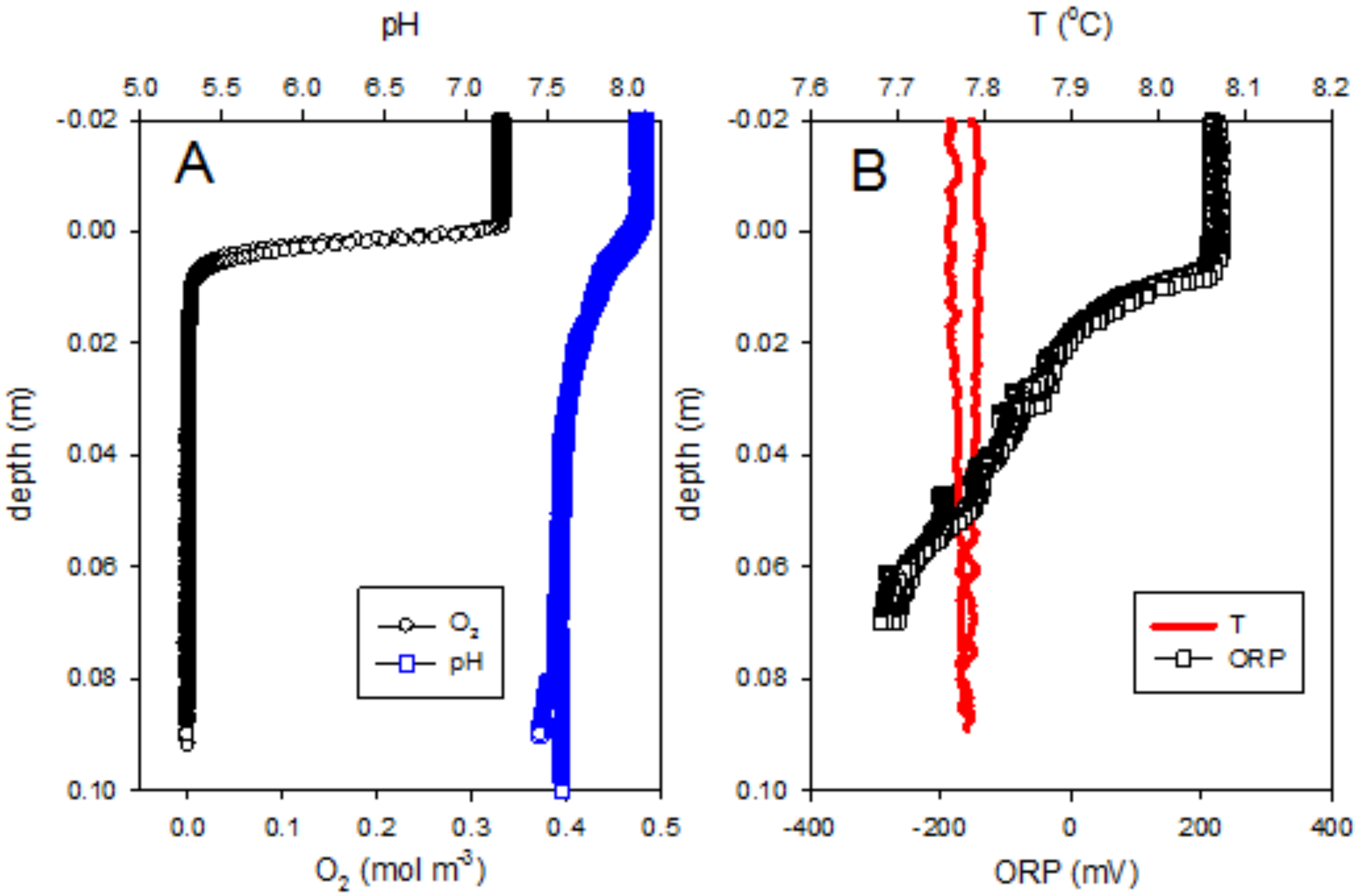
Field_Determinations_Jan_2014
North Sea Bathymetry
Depth (m)
-90
-110
-130
-150
-170
Fladen Ground
Moray Firth
Goldeneye
Witch Ground Basin
Peterhead
59°N
58°N
57°N
4°W
3°W
2°W
1°W
0°
1°E



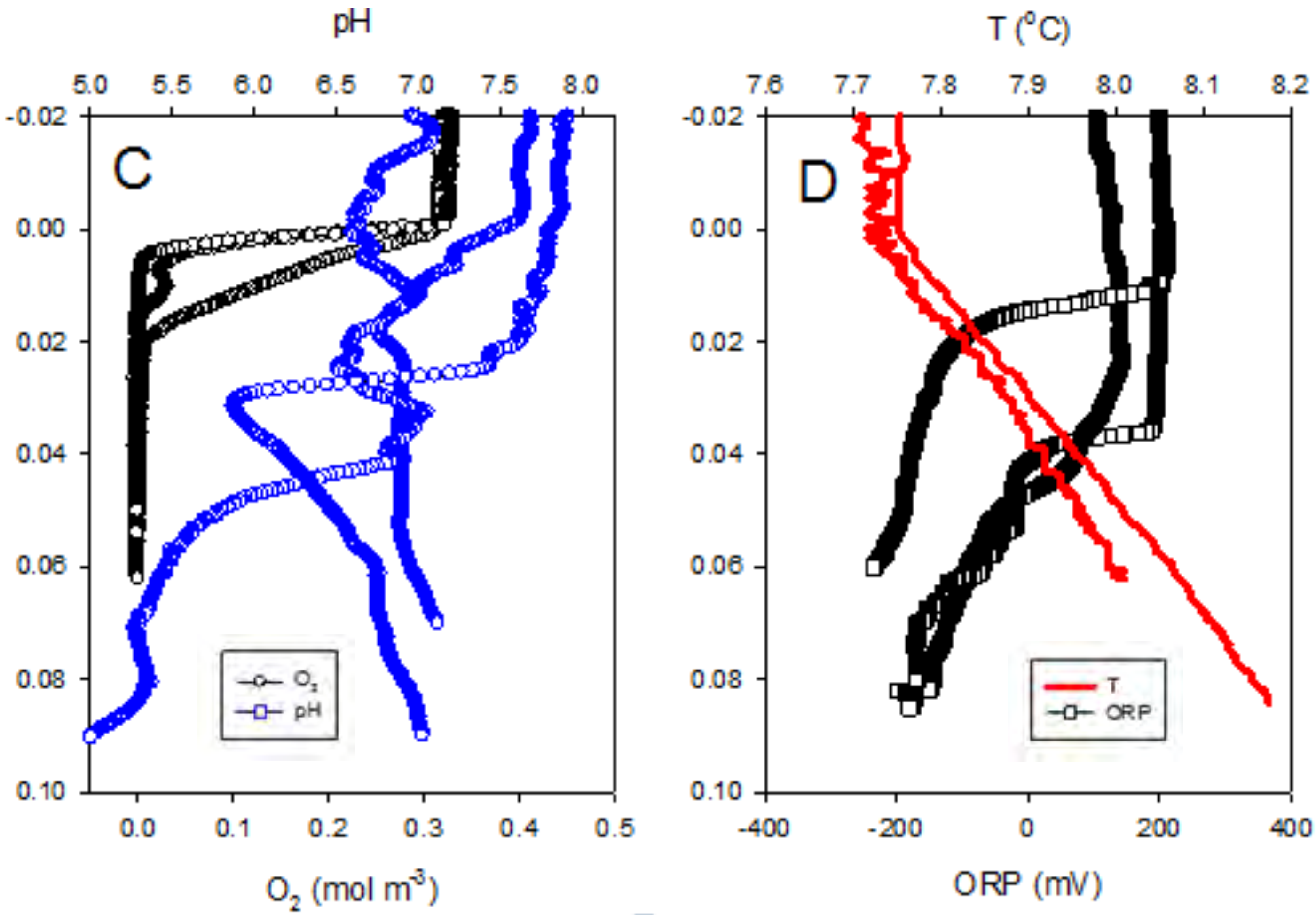


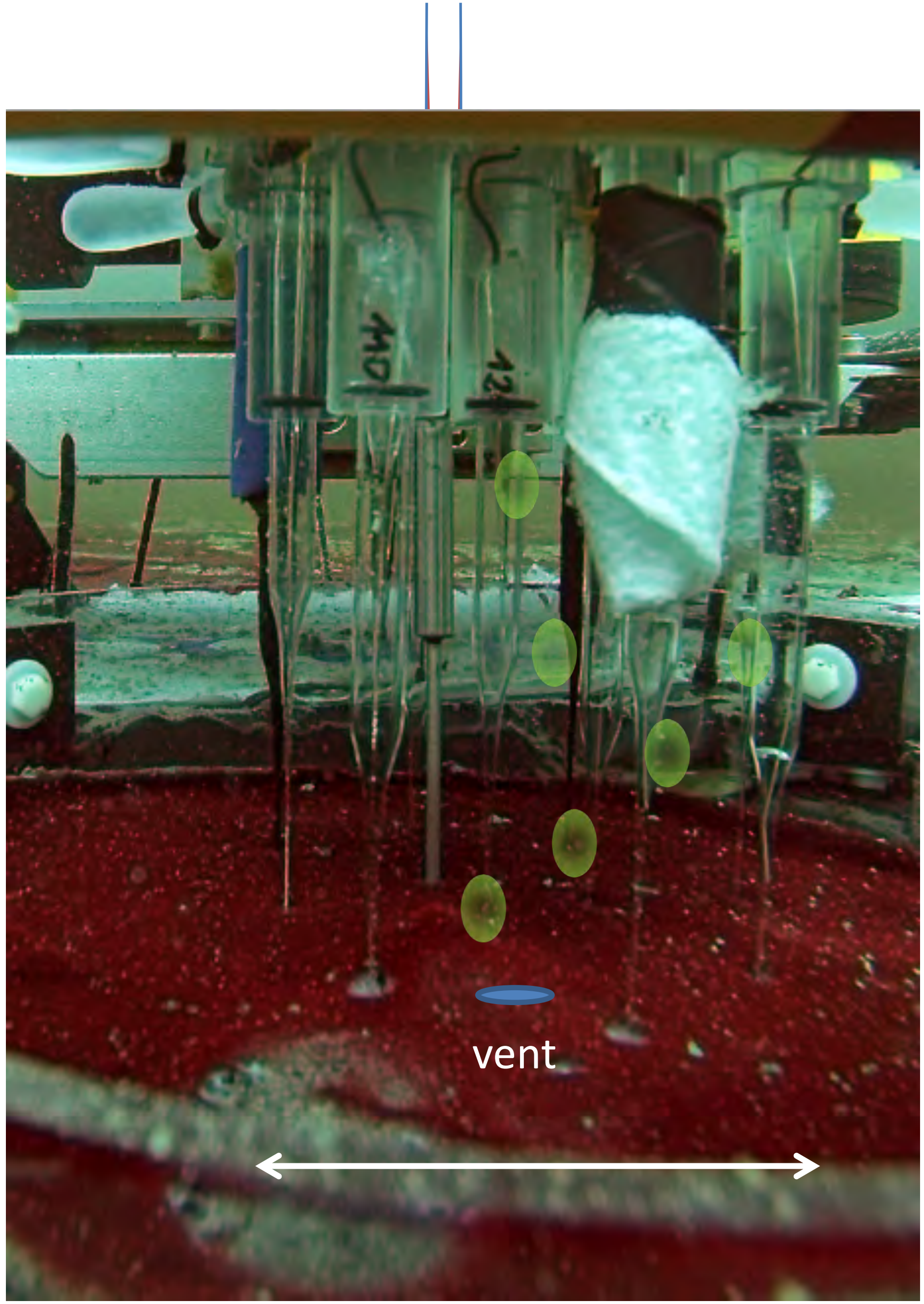
N
benthic chamber
micro-profiler
4 m
3 m
2 m
1 m
CO2 rig 100 m away
ROV landing zone
bubbles
hydrophone walls
sediment optodes
pipe head
pipe (in sediment)
BBL Lander
Baseline lander 375 m away

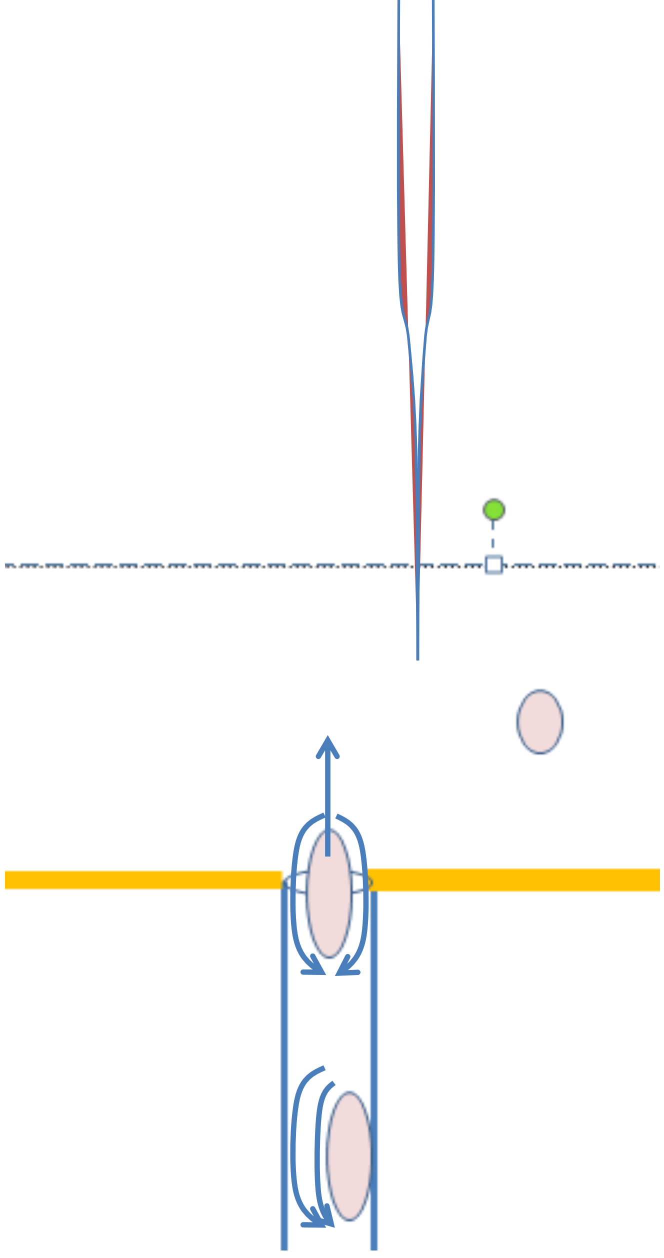
Background profiles



Profiles in vent




vent

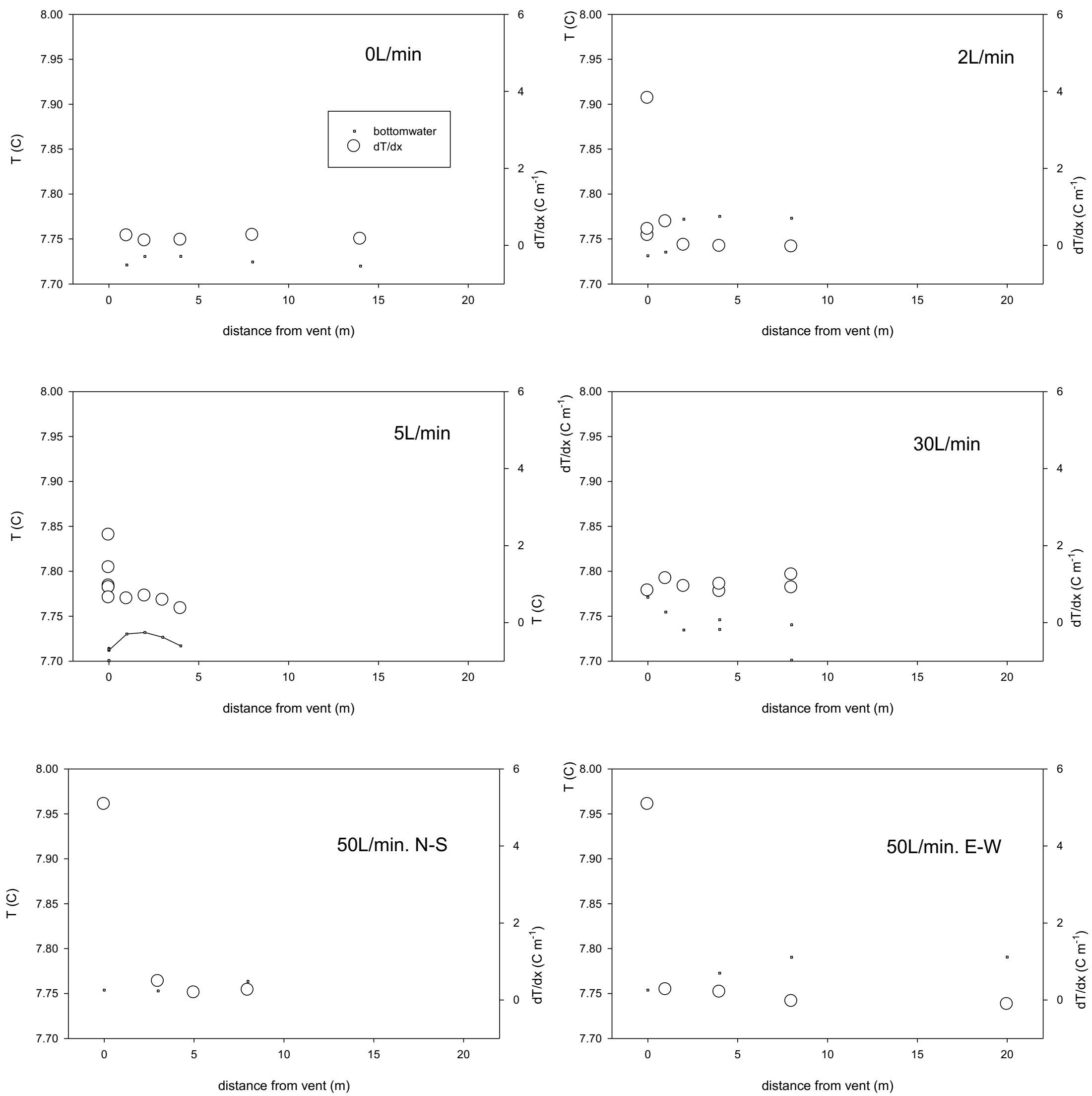


T transects

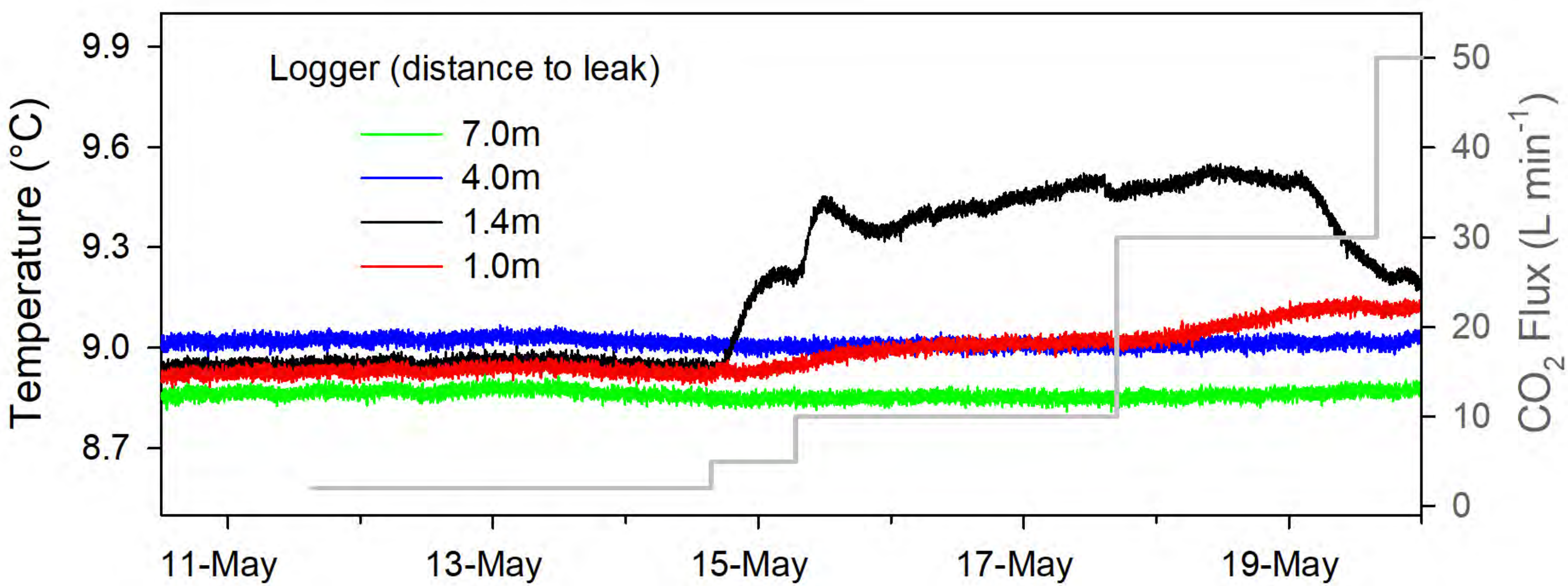
T-gradients local (<1 m from vent)

Not proportional to CO_2 release and variable

No T in bottom water



Heat generation



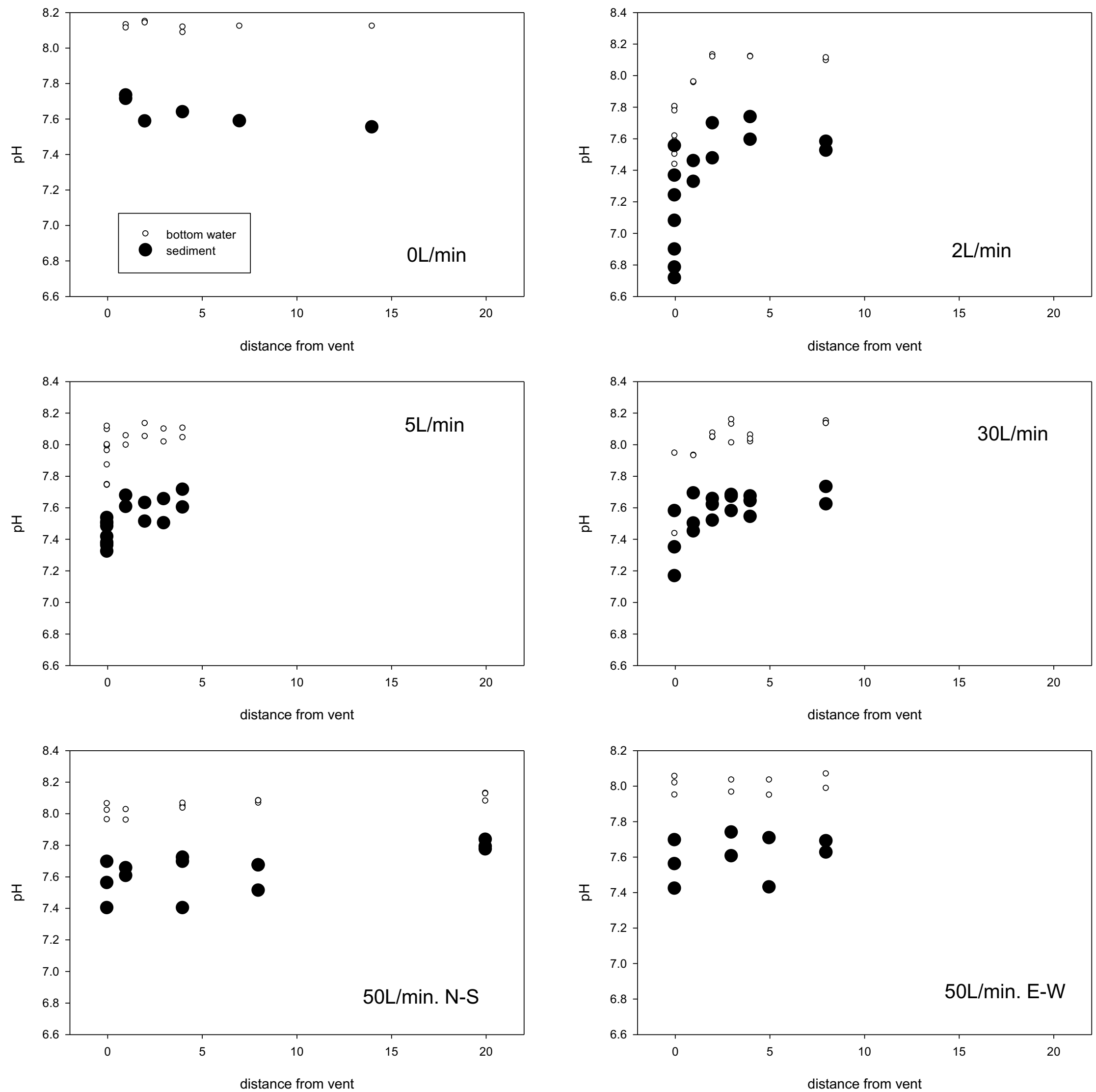
Loggers from Moritz Holtappel, **30 cm depth**

pH

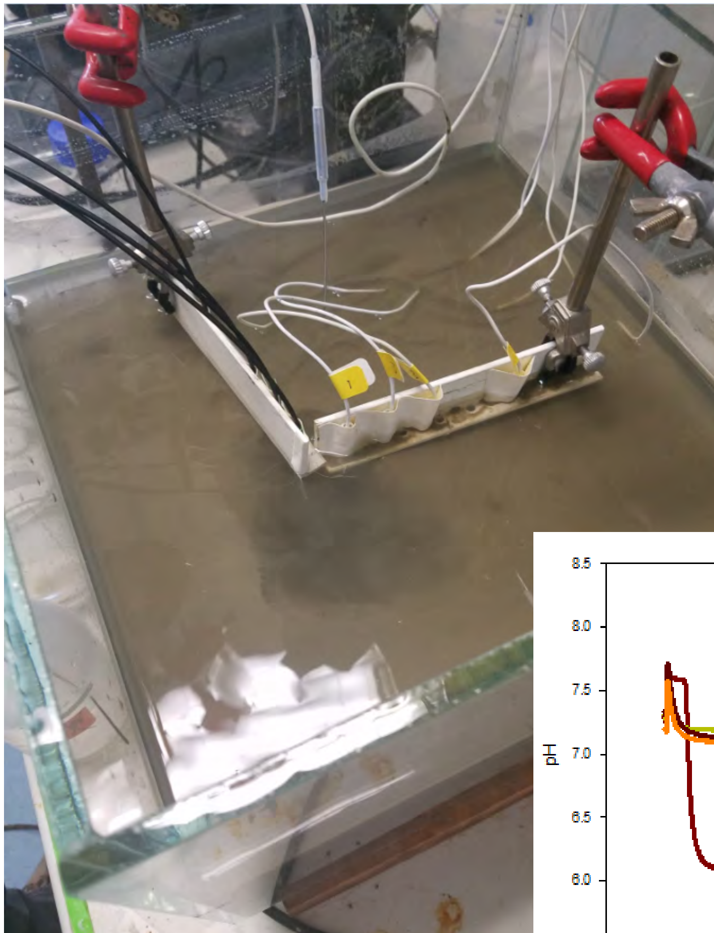
pH decrease local
(<1 m from vent)

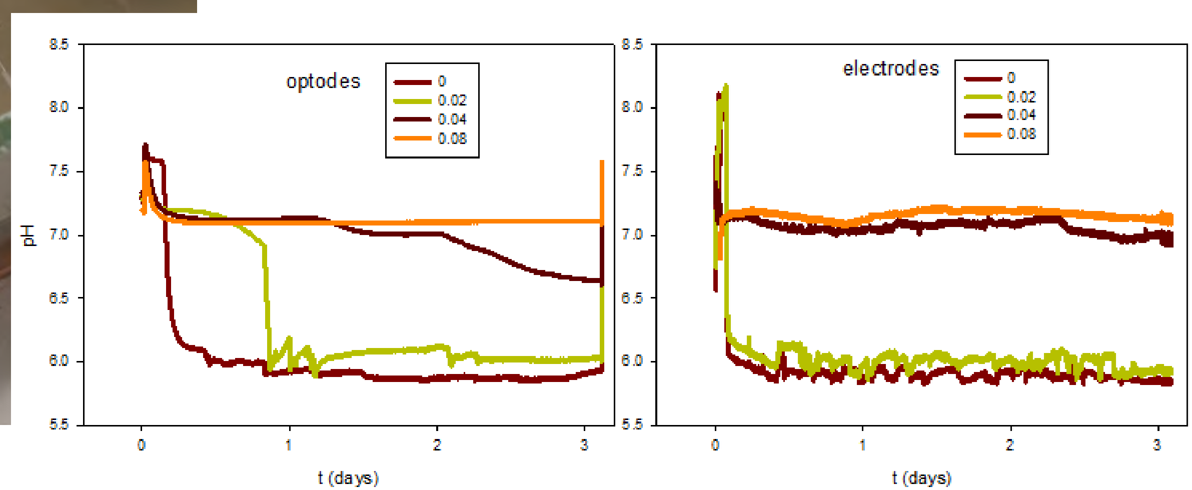
Variable &
not proportional

Local effect in
bottom water

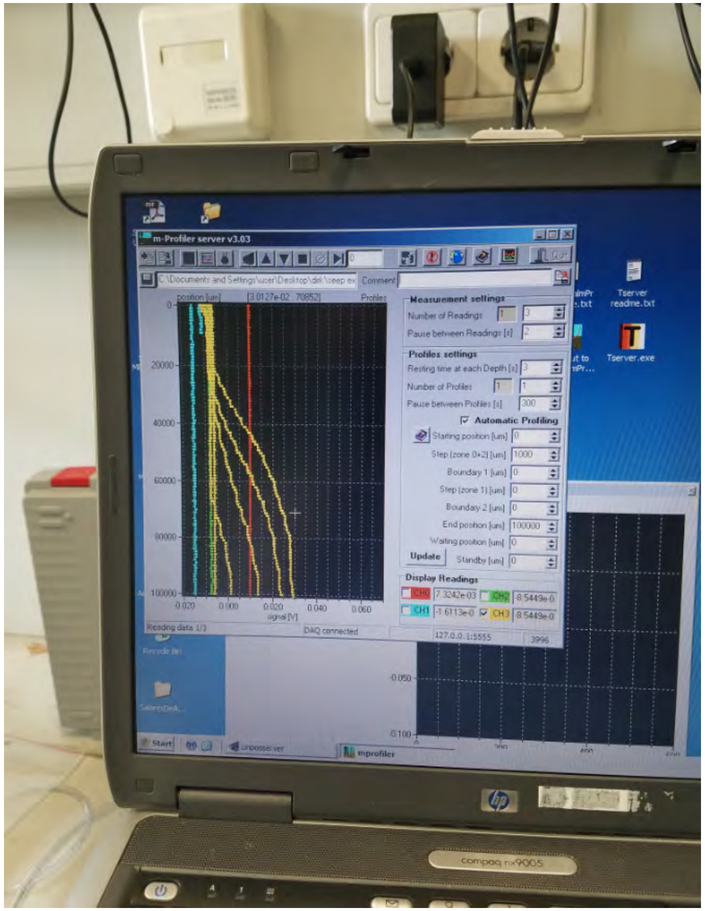


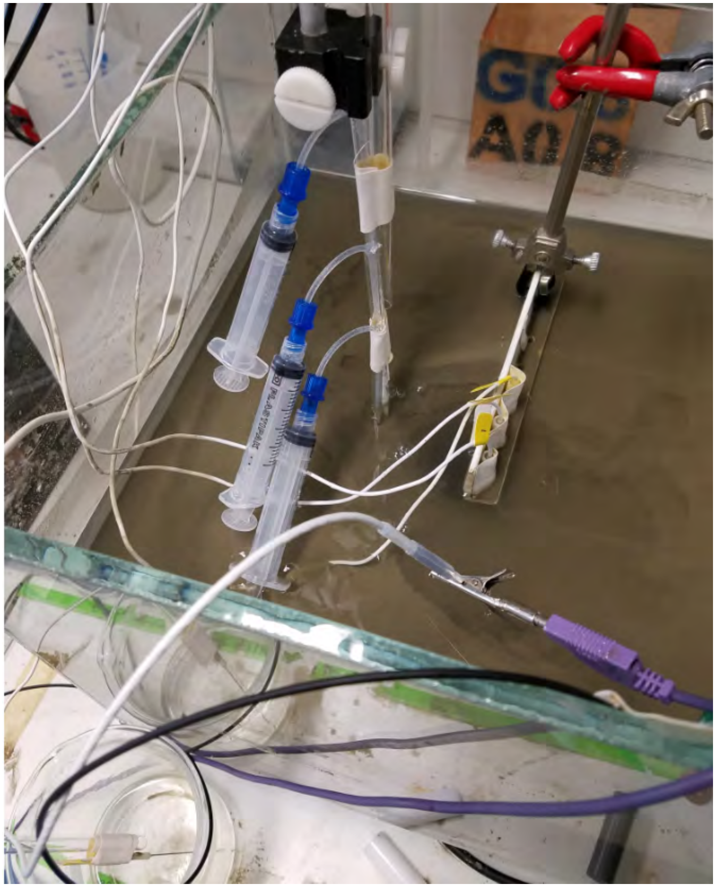
Lab experiment



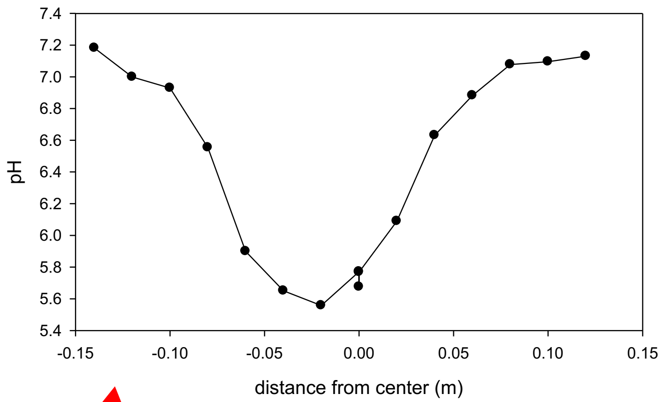


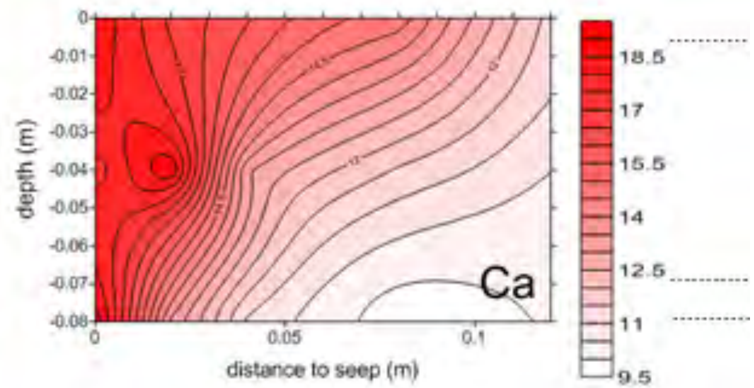
At day 4

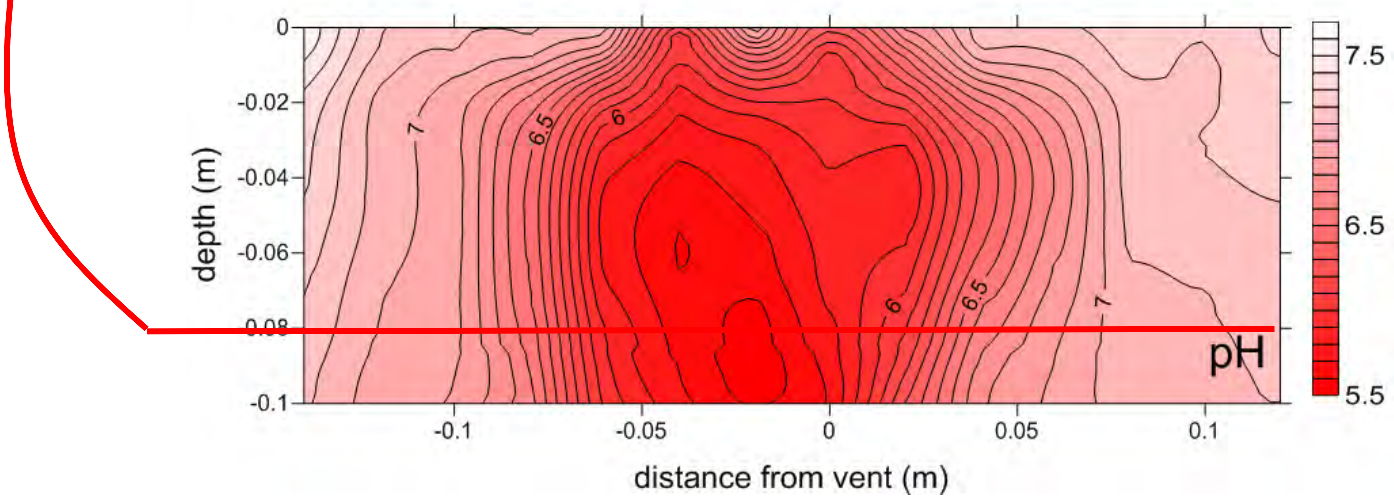

m-Profiler server v3.03
C:\Documents and Settings\user\Desktop\dirk\seep ex
Comment
position [um]
[3.0127e-02 , 70852]
Profiles
Measurement settings
Number of Readings
Pause between Readings [s]
Profiles settings
Resting time at each Depth [s]
Number of Profiles
Pause between Profiles [s]
Automatic Profiling
Starting position [um]
Step (zone 0+2) [um]
Boundary 1 [um]
Step (zone 1) [um]
Boundary 2 [um]
End position [um]
Waiting position [um]
Update
Standby [um]
Display Readings
CH0
7.3242e-03
CH1
-1.6113e-0
CH2
-8.5449e-0
CH3
-8.5449e-0
signal [V]
Reading data 1/3
DAQ connected
127.0.0.1:5555
3996
Tserver readme.txt
Tserver.exe
Start
compaq nx9005


PLASTIPAK

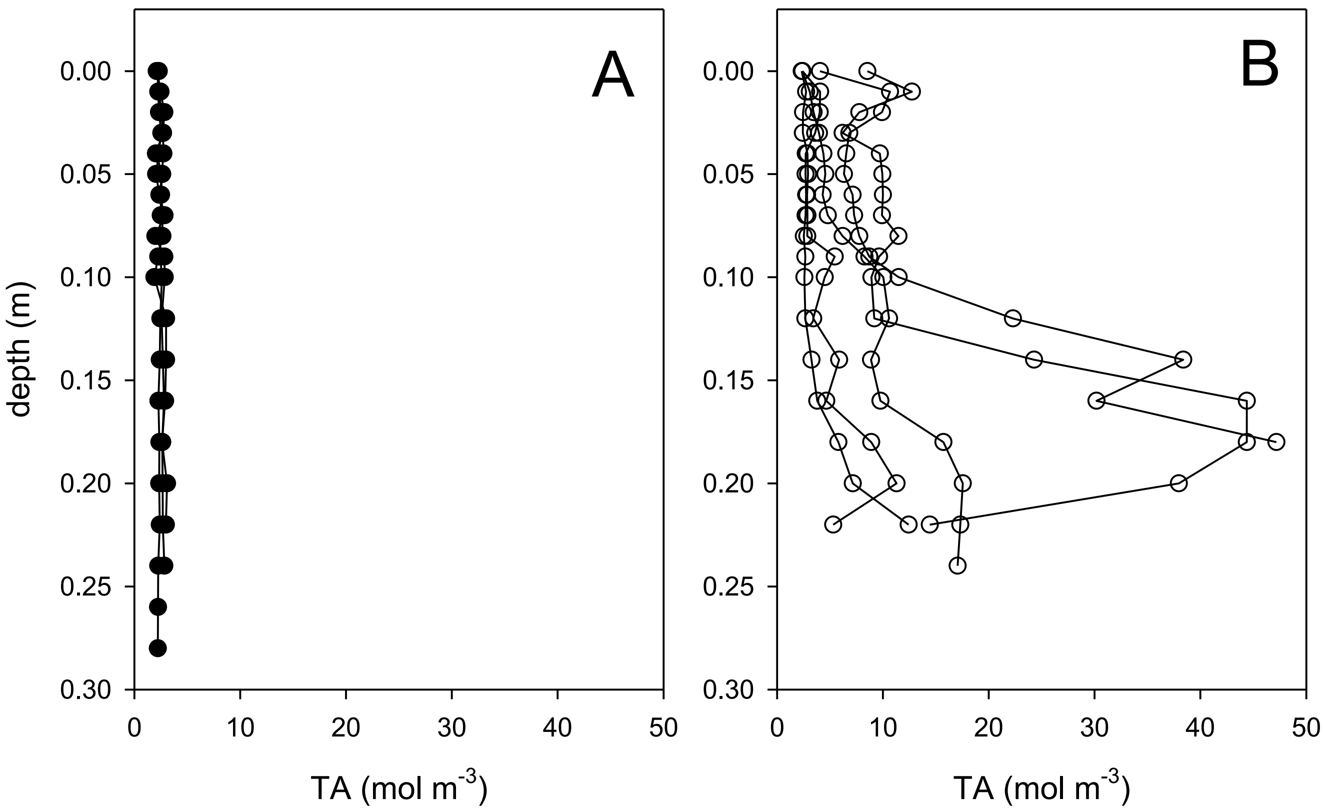
Portrait of a vent







TA values *in situ*

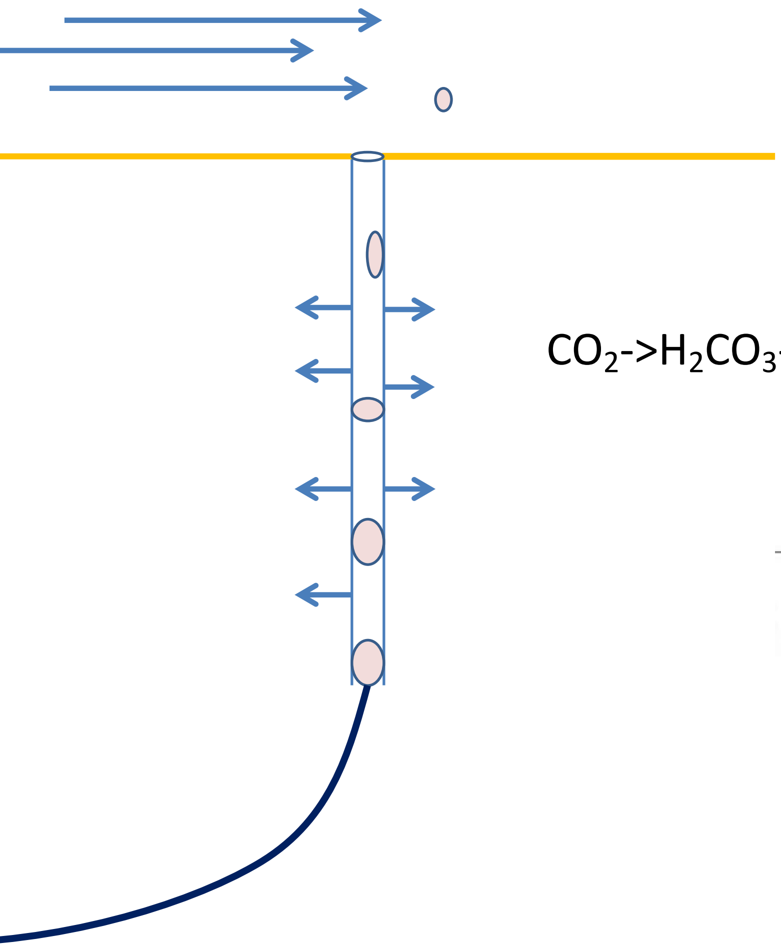


Calcite dissolution (+silicate???)

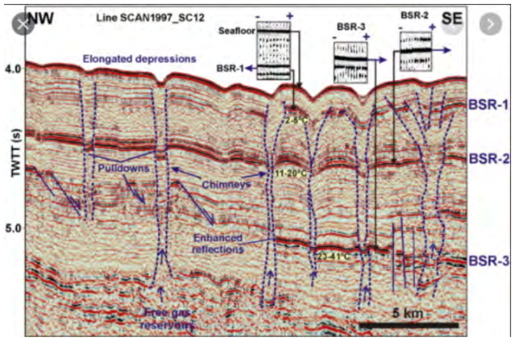
Kate Peel, Anita Flohr

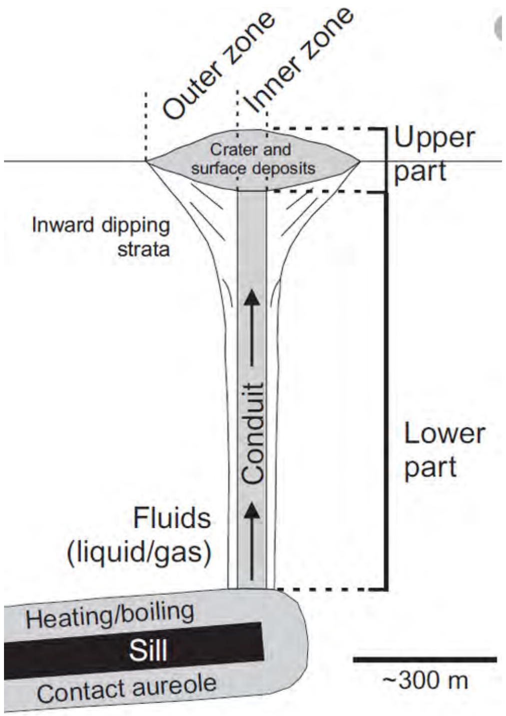
Top 10 cm ventilated by escaping bubbles
(Michael Stöhr: bubble out, water in)

Vent=cylinder in infinite medium



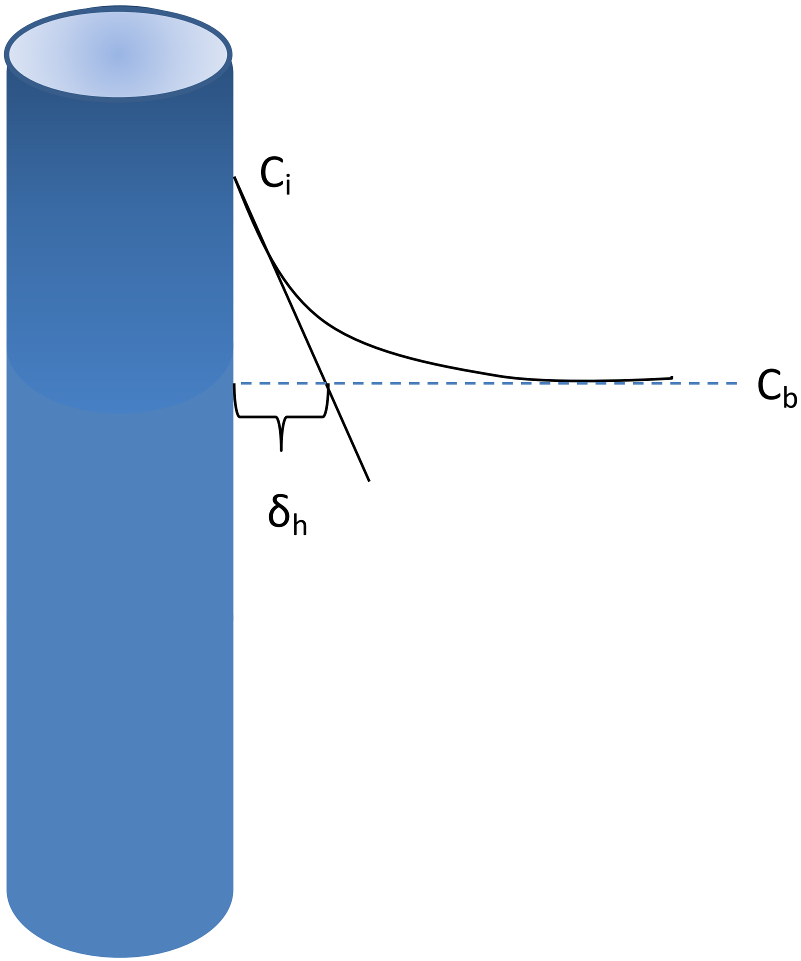
CO_2->H_2CO_3->HCO_3^-+H^+





Svensen, H. etal 2006 Journal of the Geological Society 163, 671-682.

Cylindrical source: effects are local



$J=k(C_b-C_i)$

$k=D/\delta_h$ k=mass transfer coefficient (m s^{-1}),

δ_h=effective boundary layer

$$Sh = 0.3 + \frac{0.62 Re^{\frac{1}{2}} Sc^{\frac{1}{3}}}{\left(1 + (\frac{0.4}{Sc})^{\frac{2}{3}}\right)^{\frac{1}{4}}} (1 + (\frac{Re}{282000})^{\frac{5}{8}})^{\frac{4}{5}}$$

$$= \frac{kd}{D}$$

In absence of flow Re=0 thus: Sh = 0.3.

As $Sh = \frac{kd}{D}$ and $k = \frac{D}{\delta_h}$ $\delta_h = \frac{d}{Sh} = 3d$

bubble~2 cm, δ_h~6 cm

diameter plume ~14 cm

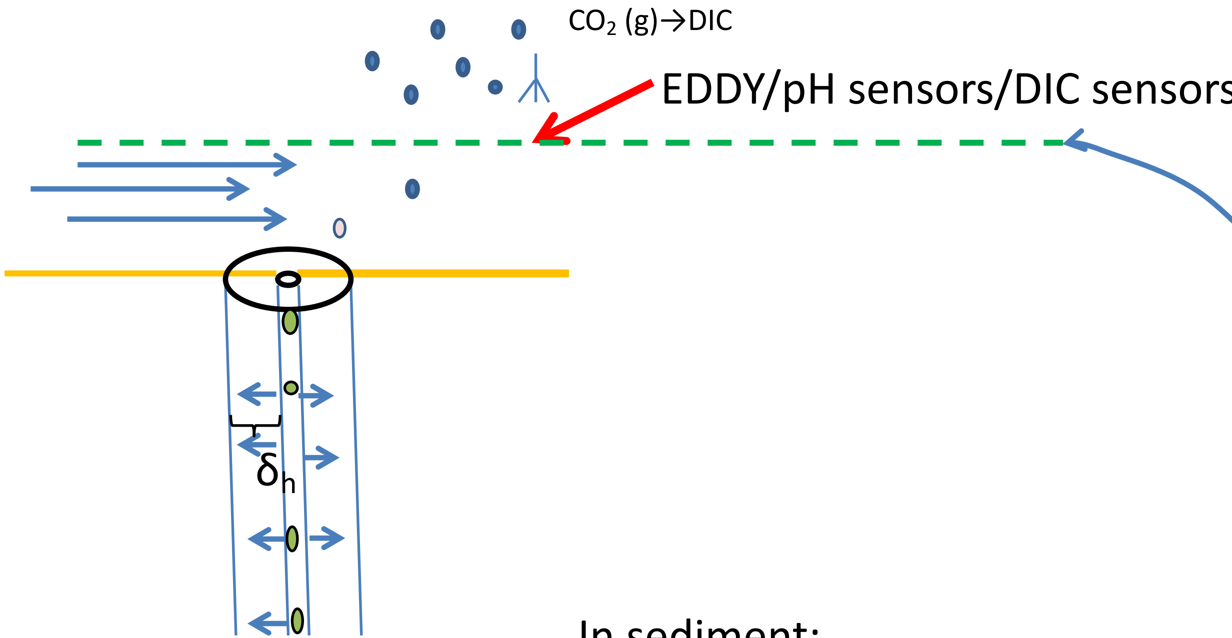
In steady state and in absence of reactions:

Effective boundary layer is finite and about 3x the diameter

δ_h independant from D, both for mass and heat

Churchill SW, Bernstein M. 1977. A Correlating Equation for Forced Convection From Gases and Liquids to a Circular Cylinder in Crossflow. Journal of Heat Transfer **99:**300-306.

Mass loss (DIC)



In sediment:

>Lateral DIC diffusion

>Reactions with sediment

Above sediment:

>Plume above measuring horizon

>CO_2(l) ($CO_2 \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$ slow)

D? k?

mass transfer mechanism?

Pulsating channel….

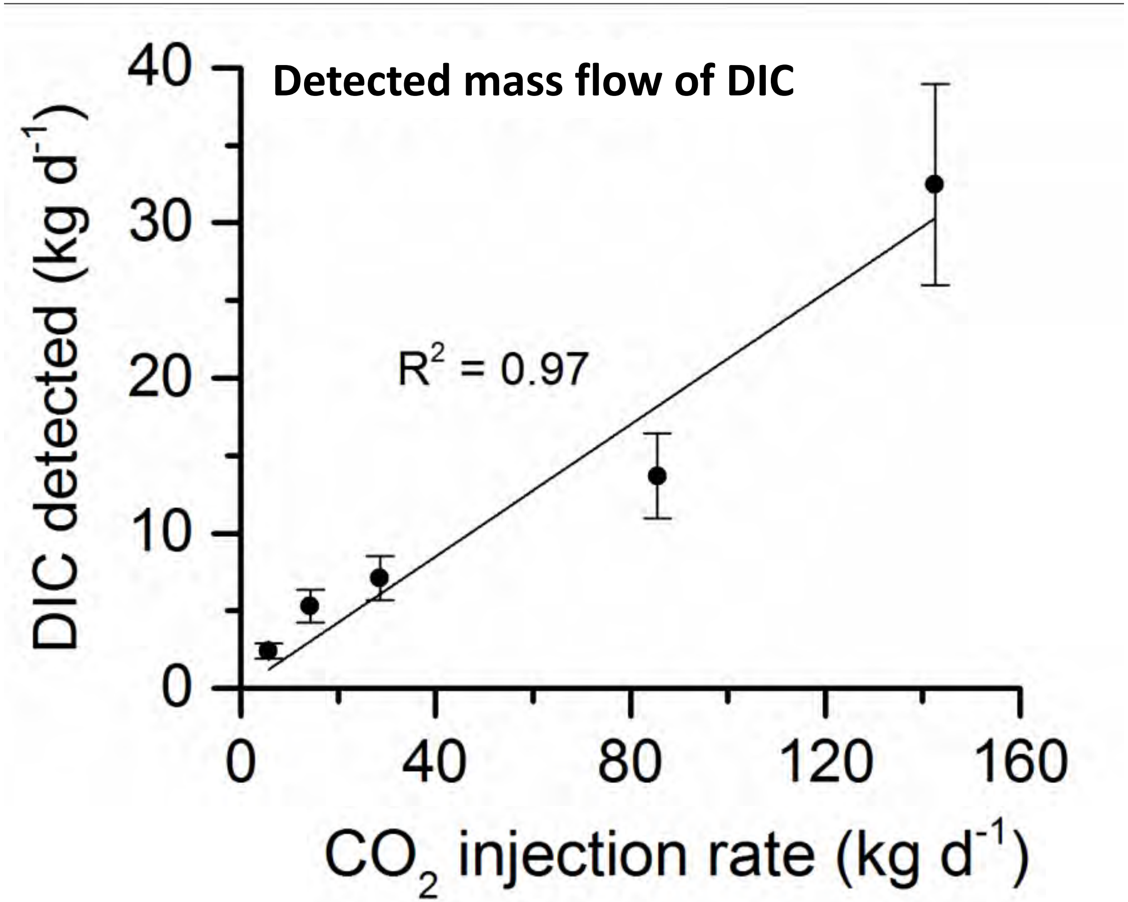
Carbonate equilibrium?

Kinetics of calcite dissolution?

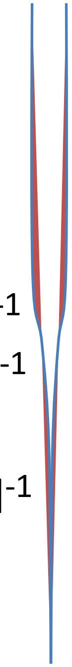
Kinetics of silicate weathering?

75%?

- Poster Dirk Koopmans:



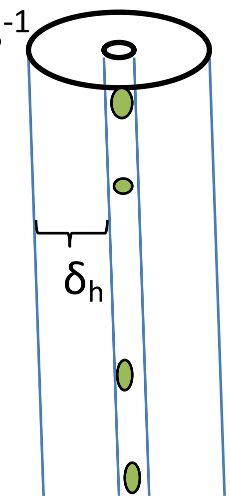
Heat generation



1. CO_2 (g) -> CO_2 (aq) ΔH -20000 J mol^{-1}
2. $CaCO_3 + CO_2$ (aq) + $2H_2O$-> $Ca^{2+} + 2HCO_3^{-} + H_2O$ ΔH -10900 J mol^{-1}
3. $MeSiO_3 + 2CO_2$ (aq) + $4H_2O$ -> $MeSiO_3 + 2HCO_3^{-} + 2H_3O^{+}$ ->
   $Me^{2+} + H_4SiO_4 + 2HCO_3^{-} + H_2O$ ΔH -73000 J mol^{-1}

Heat flux: 3 J m^{-2} s^{-1}
(from thermal conductivity and T gradient, underestimation!)

Assume cylinder of 3m long, 2 cm bubble channel plus 6 cm δ_h: 0.13 J s^{-1}



This heat is generated by:
CO_2 reactions 1+2: 0.00013 mol s^{-1}
CO_2 reactions 1+3: 0.00004 mol s^{-1}

2 L CO_2 min: 0.0015 mol s^{-1}

Stumm W, Morgan JJ. 2012. Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters, 3 ed. Wiley.

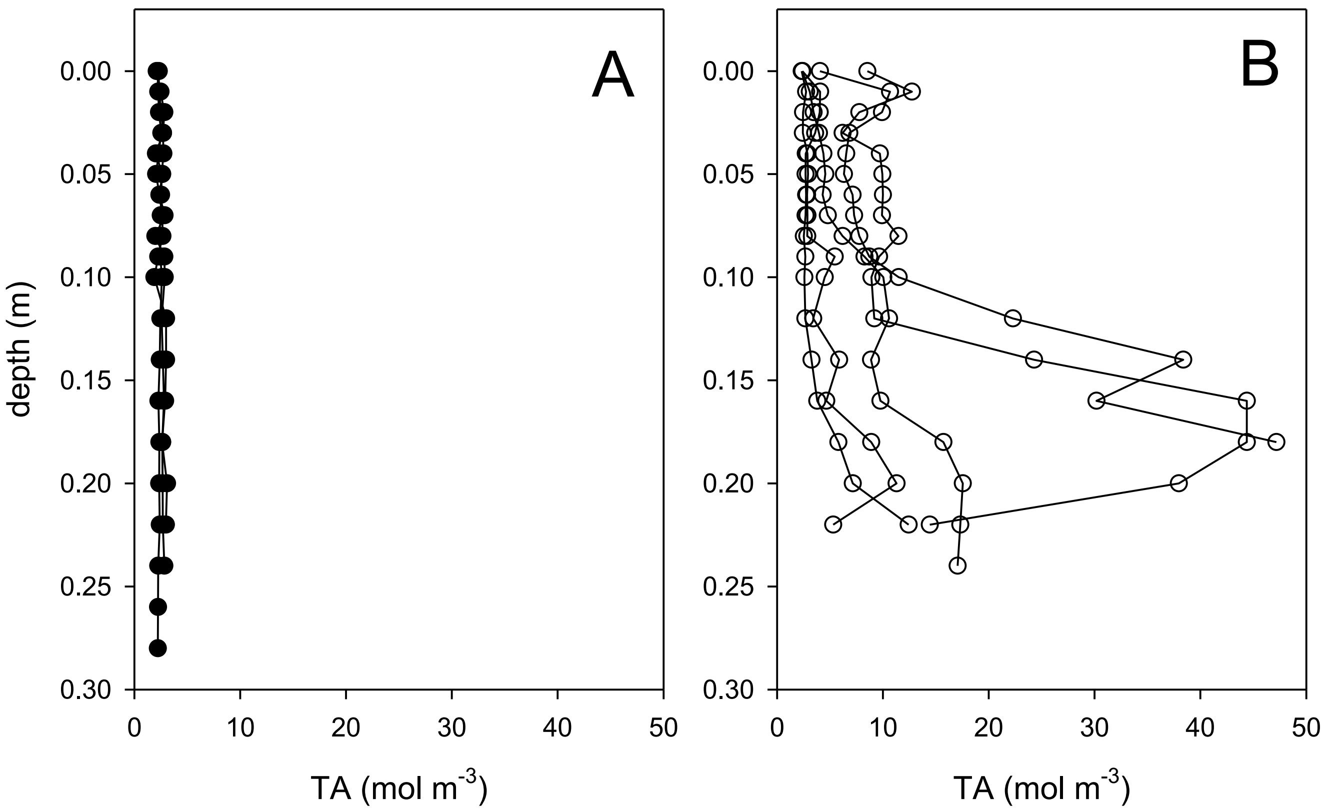
Conclusions

- Vent channels are narrow and have only local effects
- ➢ MBL 3x diameter, if d=2 cm MBL 6 cm total diameter influenced sediment 2+2x6=14 cm

- CO_2 input generates DIC and heat
- Heat and DIC partially dissipated laterally in sediment

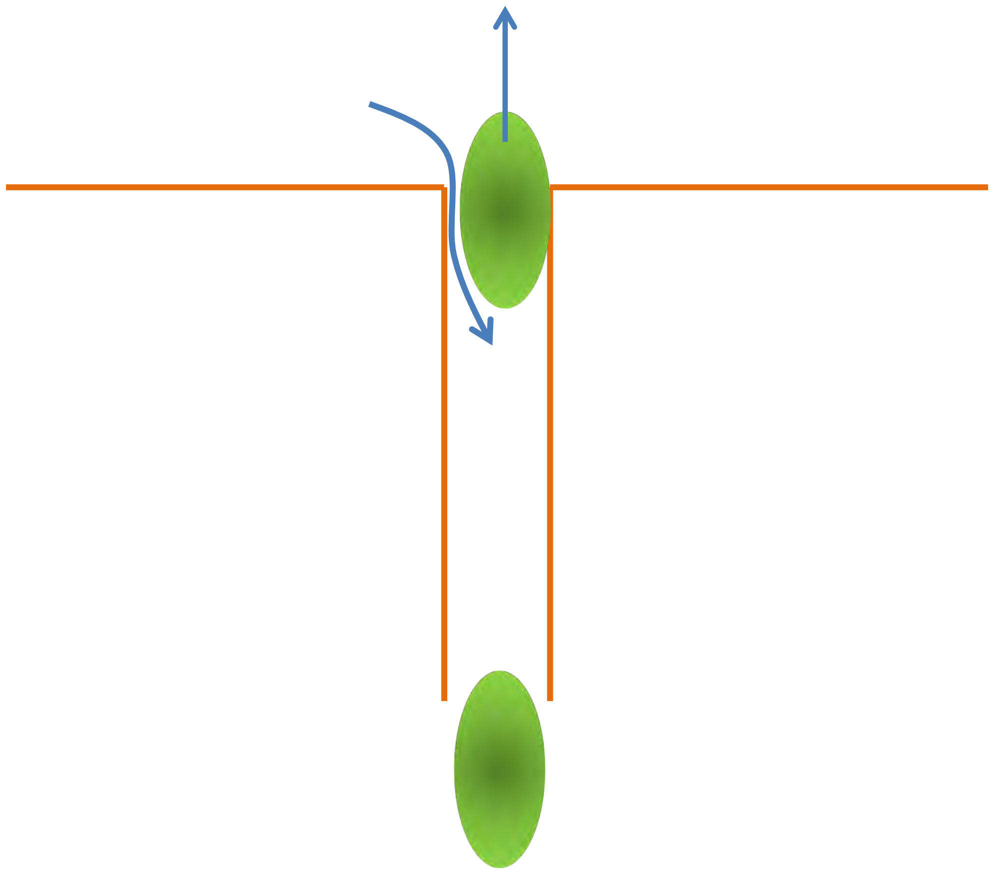
- **Heat** needs inclusion in vent **modeling** (kinetics and viscosity)

TA values *in situ*



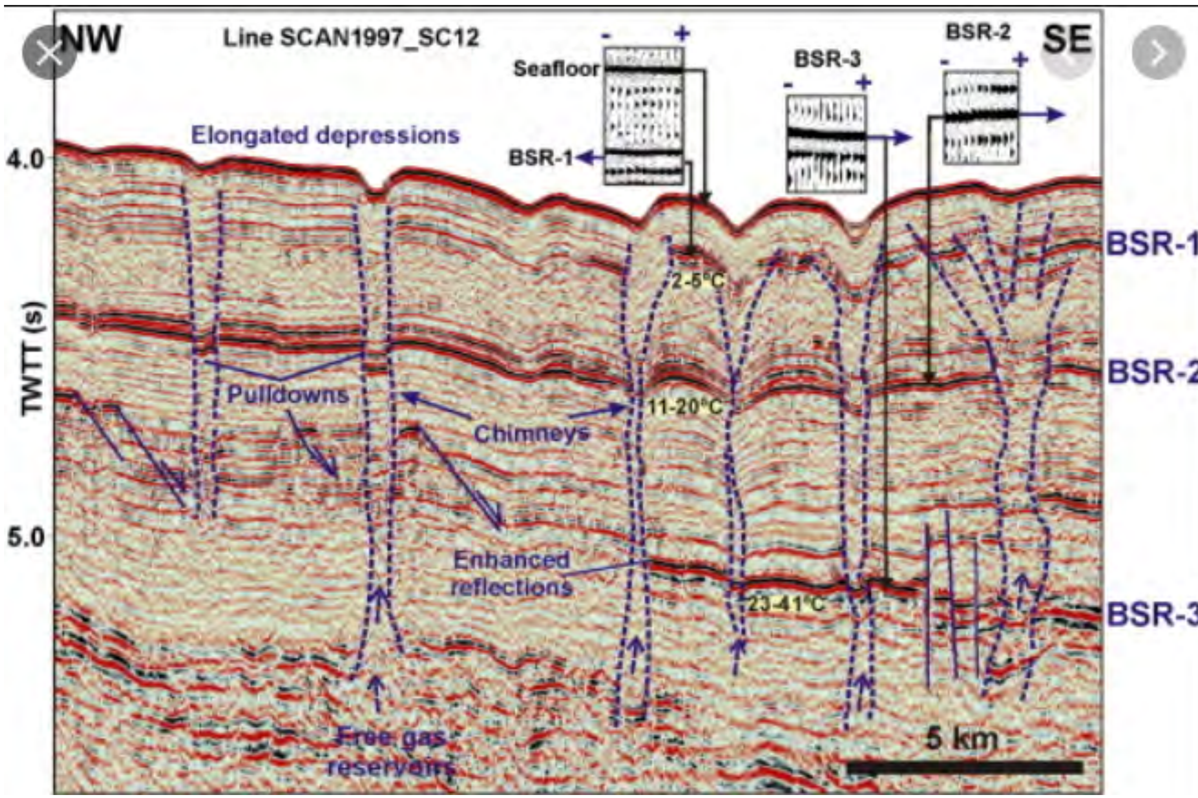
Very variable, top 10 cm ventilated by escaping bubbles
(Michael Stöhr: bubble out, water in)

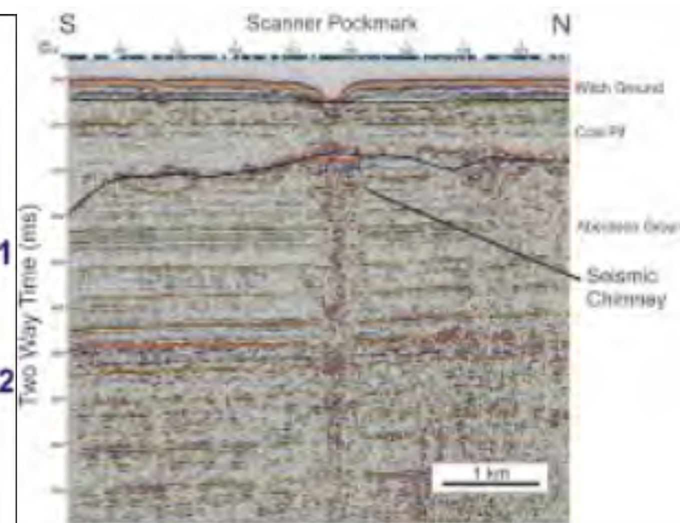
Kate Peel, Anita Flohr



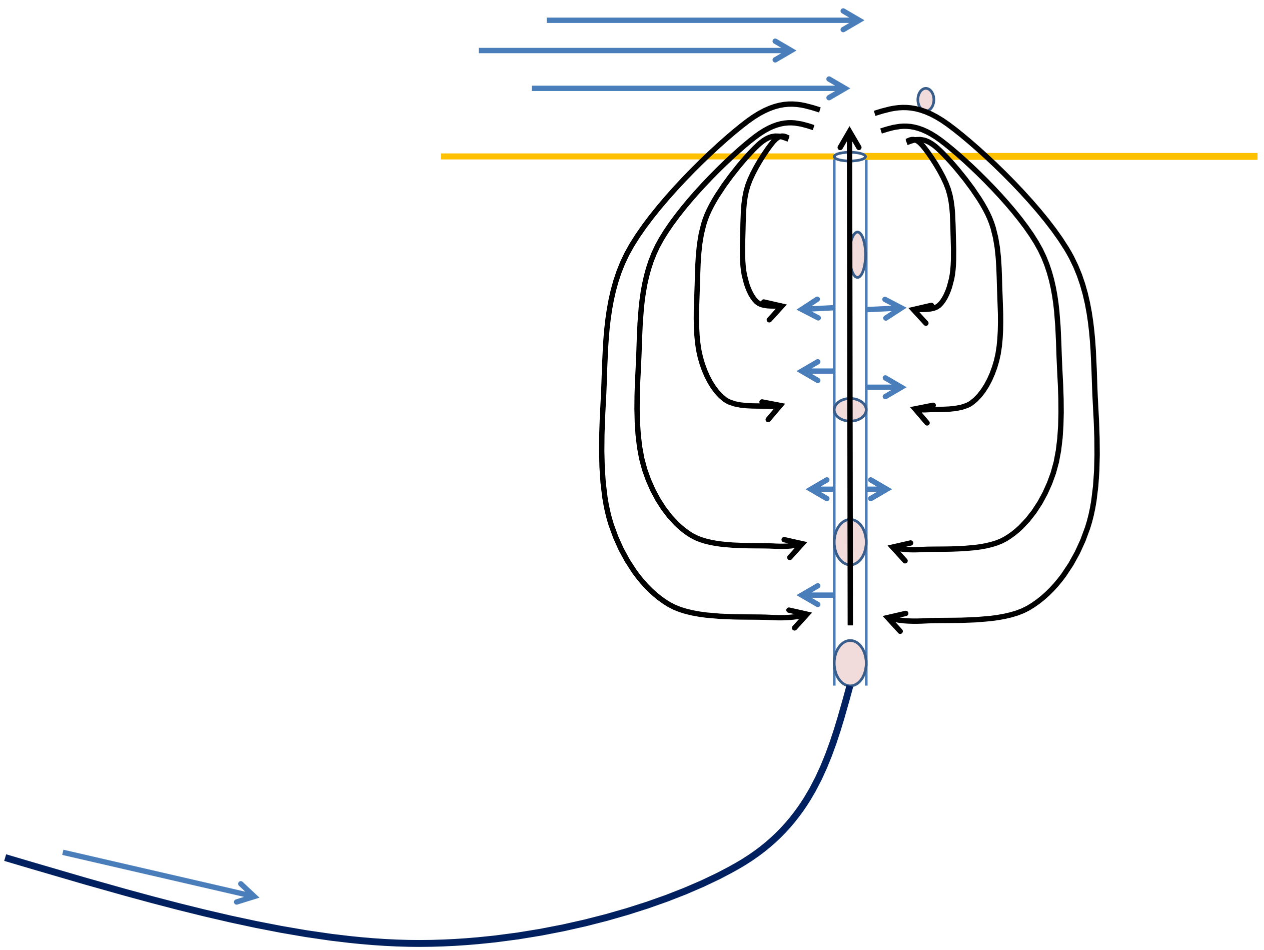
Stöhr et al, 2004

	mass			heat					
alk	50								
DIC in	10000								
J=	0.000166667	mol/m2s		3	J/m2s				
A=	0.4396			0.4396			L/min		
l=	3			3			2	0.001488	mol/s
Area cyl	1.3188			1.3188					
total flow	0.0002198	mol/s		3.9564	J/s				
			Calcite	0.000128039	mol/s				
			Silicate	4.25419E-05	mol/s				


NW
Line SCAN1997_SC12
Seafloor
BSR-1
BSR-3
BSR-2
SE
Elongated depressions
4.0
5.0
TWTT (s)
2-5°C
11-20°C
23-41°C
Pulldowns
Chimneys
Enhanced reflections
Free gas reservoirs
5 km
BSR-1
BSR-2
BSR-3

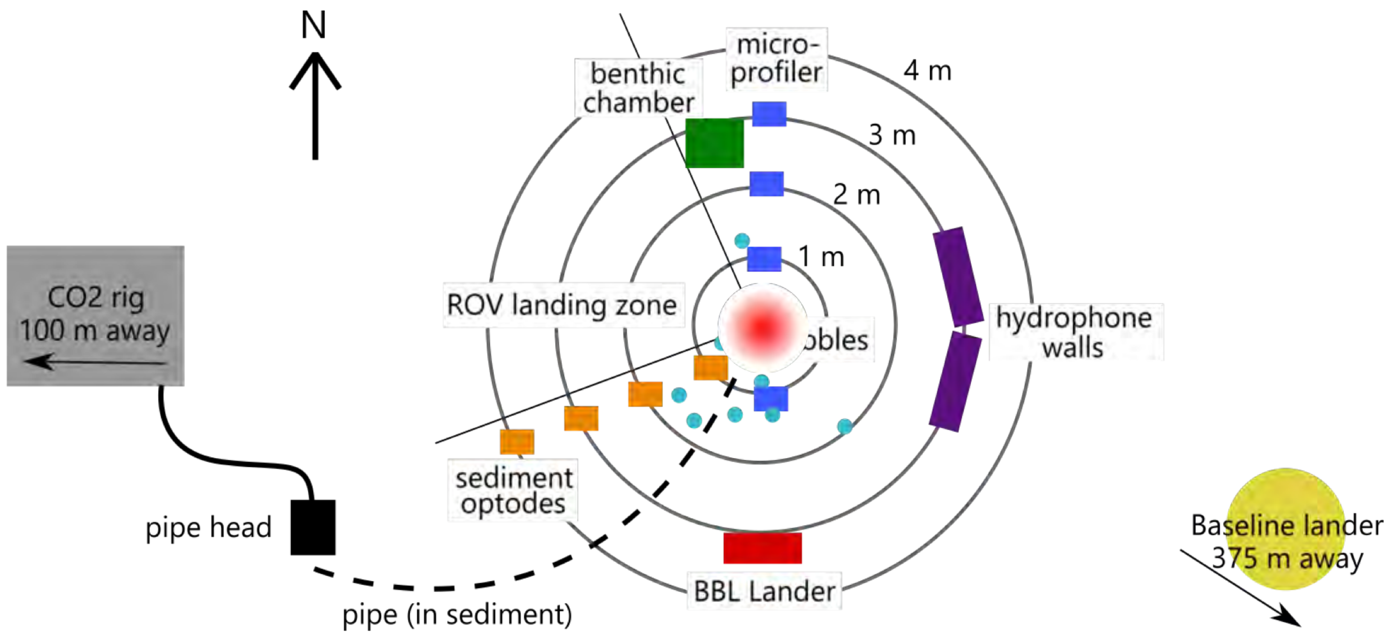

S
Scanner Pockmark
N
Witch Ground
Coal Pit
Aberdeen Ground
Seismic Chimney
Two Way Time (ms)
1 km

Advection cell in vent



Sh ↑ thus δ_h ↓
-> more local

Haeckel M, Boudreau BP, Wallmann K. 2007. Bubble-induced porewater mixing: A 3-D model for deep porewater irrigation. Geochimica Et Cosmochimica Acta **71:**5135-5154


N
micro-
profiler
benthic
chamber
4 m
3 m
2 m
1 m
CO2 rig
100 m away
ROV landing zone
hydrophone
walls
sediment
optodes
pipe head
BBL Lander
pipe (in sediment)
Baseline lander
375 m away

Ecology and geochemistry

Sulfate reduction lower

(=35% total mineralization)

No effect O_2 uptake

pH decrease only local

No animals deterred