Sedimentary denitrification rates from the Bering, Chuckchi and Beaufort Seas

By

Allan H Devol

University of Washington, School of Oceanography

Box 357940, Seattle, WA 98195

Phone: (206)-543-1292

Fax: (206)-685-3351

e-mail: devol@u.washington.edu

Introduction

This report contains the sedimentary denitrification rates from the Bering, Chuckchi and Beaufort Seas made during August-September 1992, and rates obtained in the Beaufort Sea off Pt. Barrow, Alaska, under late wintertime conditions (March 1993). The estimates made during August-September were based on both deployments of an automated *in situ* benthic flux chamber tripod and on pore water chemical profiles from cores analyzed aboard the R/V *Alpha Helix.* Wintertime observations were obtained using scaled-down versions of the *in situ* benthic flux chamber that were deployed through land-fast ice. The complete results are published by Devol, A.H., Codispoti, L.A. and Christensen, J.P. (1997).

Methods

Samples were taken both during the summer of 1992 (August-September) and the late winter of 1993 (March). The summer sampling was accomplished on cruise 165 of the *R/V Alpha Helix* and consisted of seven stations (Table 1) denoted by letters on Figure 1. The winter station locations are denoted by numbers (1,2, and 3) in the inset to Figure 1.

During the summer experiment, benthic flux measurements (Table 2) for dissolved oxygen, nitrogen, dissolved inorganic carbon, nitrate, and ammonium were made using the automated *in situ* benthic flux tripod “lander”. Both the lander and the analytical methods are described by Devol, Codispoti and Christensen (1997).

During the winter an 8-wheel drive "Rolligan" (a large truck-like vehicle for driving across the ice) equipped with a 2-foot diameter ice auger and portable GPS system was used to reoccupy the two stations north of Point Barrow. Winter benthic fluxes (Table 2) were measured using a smaller version of the flux chamber. Nutrient samples were frozen and returned to the University of Washington for analysis by autoanalyzer (Devol, Codispoti and Christensen 1997).

During the summer cruise, sediment cores were also collected for the determination of pore water profiles of dissolved oxygen, nitrate and ammonium (Fig. 2) and for measurement of sulfate reduction rates ($^{35}SO_4^{=}$ technique, Christensen 1989). Cores for determination of solute concentration profiles were taken with a HAPS corer (Kannerworff, 1973). High resolution (0.07 cm) oxygen and nitrate pore water sampling was accomplished by a whole core squeezing technique (Bender et al., 1987; Brandes and Devol, 1995). In addition, coarse resolution (0.5 to 1.0 cm) pore water samples for nitrate, ammonium, pH and alkalinity analysis were obtained by sectioning and subsequent centrifugation. Squeeze core nitrate and dissolved oxygen, and sectioned core ammonium measurements for summer cruise sediment cores, by depth, are detailed in Table 3.

References

Bender M., W. Martin, J. Hess, F. Sayles, L. Ball, and C. Lambert. (1987) A whole-core squeezer for interfacial pore-water sampling. *Limnol. Oceanogr.* **32**, 1214-1225.

Brandes J. A. and A. H. Devol. (1995) Simultaneous oxygen and nitrate respiration in coastal sediments: evidence for discrete diagenesis. *J. Mar. Res.* **52**, 771-797.

Christensen J. P. (1989) Sulfate reduction and Carbon oxidation rates in continental; shelf sediments, an examination of offshelf carbon transport. *Cont. Shelf Res.* **9**, 223-246.

Devol, A.H., Codispoti, L.A. and Christensen, J.P. (1997) Summer and winter denitrification rates in western Arctic shelf sediments. *Continental Shelf Research*, Vol 17, No.**9** pp. 1029-1050.

Kannerworff E. and W. Nicolaisen. (1973) The "Haps" a frame-supported bottom corer. *Ophelia* **10**, 119-129.

Whitledge T. E., S. C. Malloy, C. J. Patton, and C. D. Wirick. (1981) Automated nutrient analysis in seawater. Brookhaven National Laboratory.

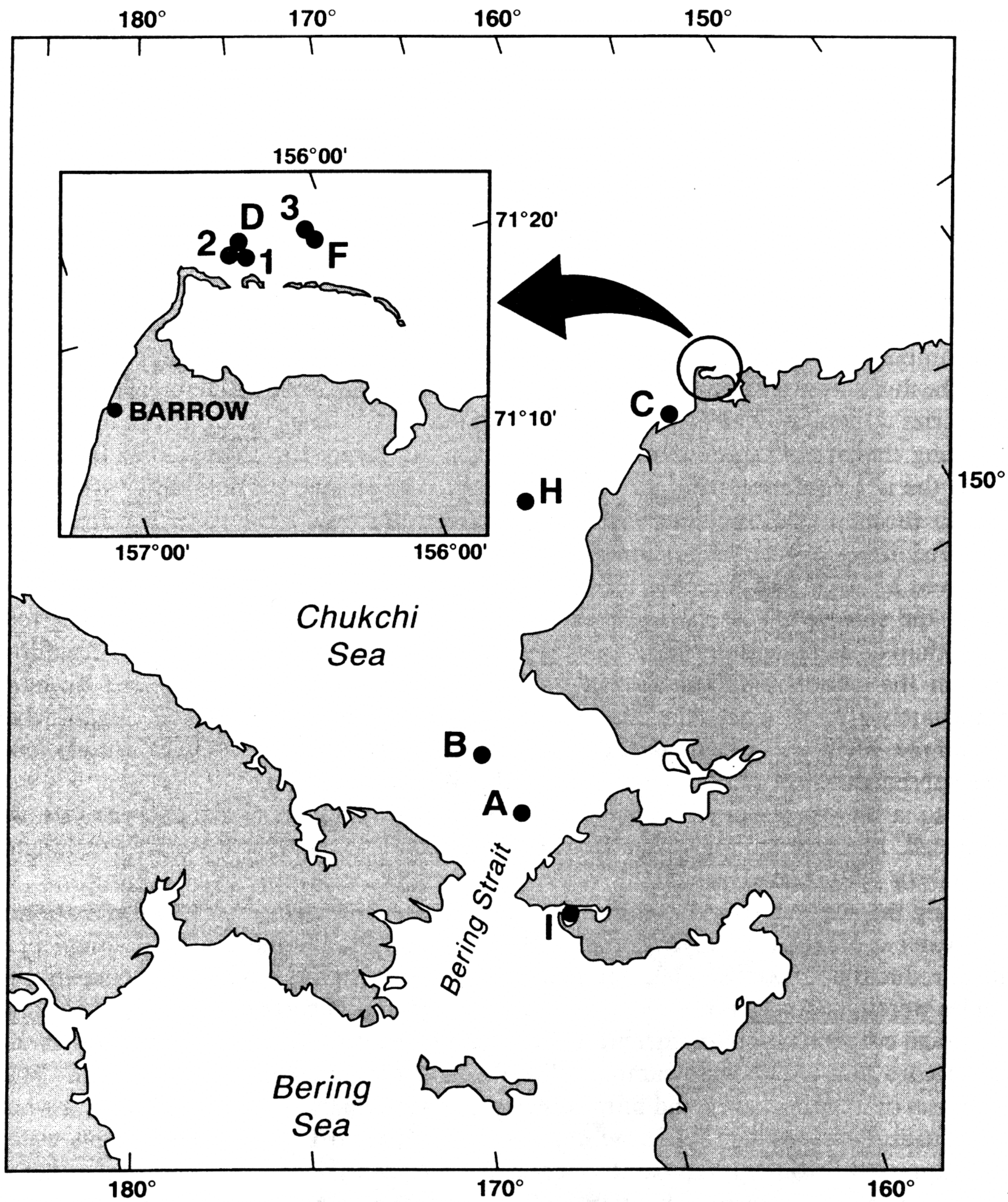

Fig. 1. Station locations. Stations occupied during the summer cruise are denoted by letters and locations of winter stations north of Pt. Barrow are denoted by numbers.

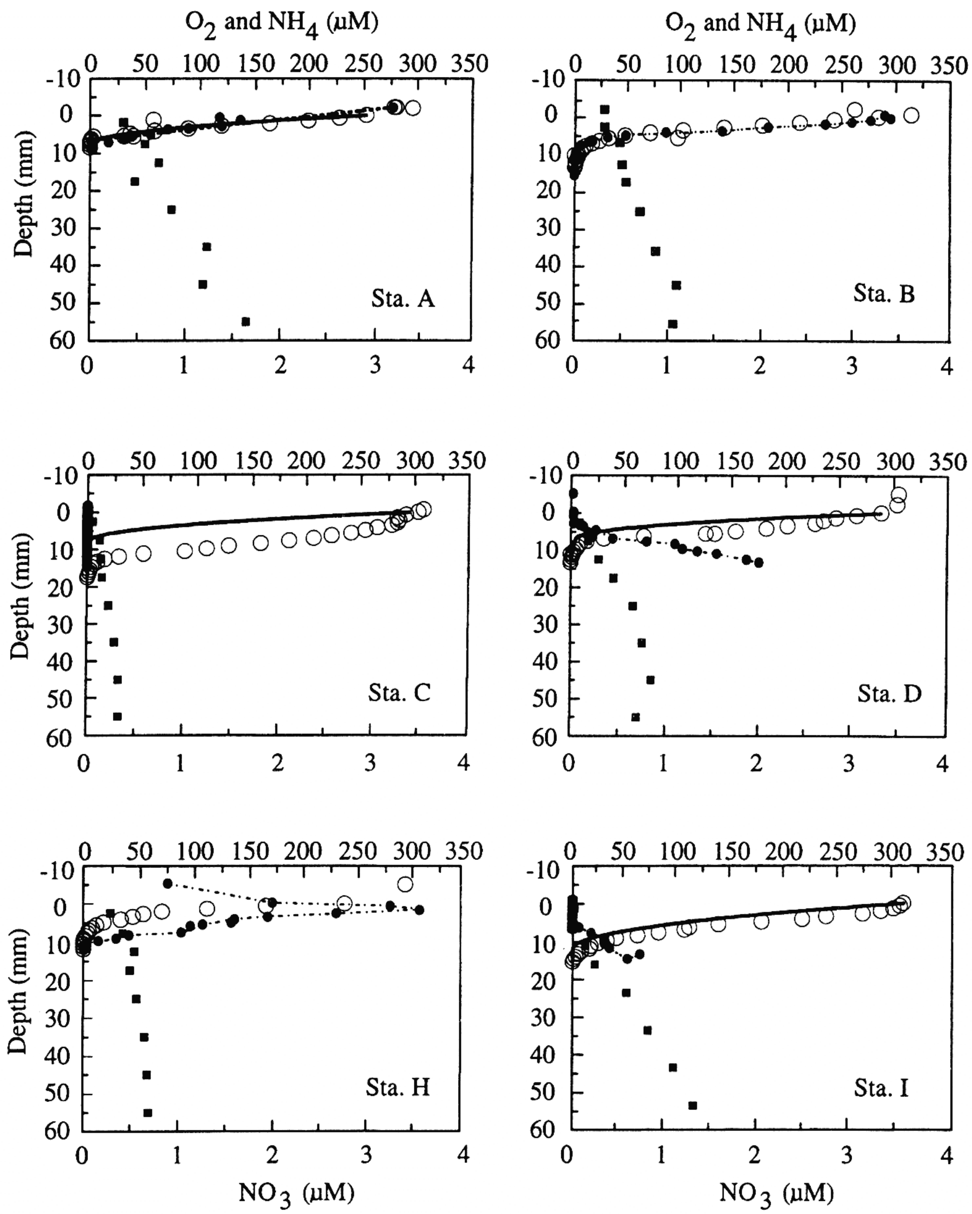

Fig. 2. Pore water profiles of dissolved oxygen (open circles), NO_3^- (filled circles with dotted line), and NH_4^+ (solid squares) at six sampling sites. Solid lines show deconvoluted model fit to the oxygen data. Deconvolution was done using a constant reaction rate with depth. Although this is likely not the true form of the rate distribution (Brandes and Devol, 1995), it does result in a good fit to the profile and, thus, a reasonable estimate of the gradient and diffusive flux of oxygen. Note that at stations B and H, there was very little tilt of the sediment–water interface relative to the core tube and the observed profiles represent the true *in situ* profile shapes.

Table 1. Latitude, Longitude, depth, surface sediment carbon content and bottom water characteristics at the sampling stations. Units are: Depth in m, Temperature in ^{o}C, Salinity in PSU, Dissolved oxygen in μM, and carbon content in percent of dry weight.

Station	Latitude	Longitude	Depth	Temp.	Salinity	D.O.	Wt. % C
Sta. A	66^{o}40.47”N	167^{o}22.71”W	35	3.81	32.30	329	1.1
Sta. B	67^{o}24.15”N	168^{o}54.71”W	48	3.13	32.69	327	1.2
Sta. C	70^{o5}52.65”N	158^{o}20.40”W	12	5.77	29.19	317	0.5
Sta. D	71^{o}23.97”N	156^{o}16.62”W	11	4.94	28.40	316	1.5
Sta. F	71^{o}24.24”N	156^{o}06.95”W	14	5.89	29.12	316	-
Sta. H	70^{o}19.22”N	164^{o}37.11”W	41	3.78	32.21	322	0.9
Sta. I	65^{o}17.58”N	166^{o}26.21”W	11	8.65	25.09	252	2.1

Table 2. Fluxes of the varrious chemical species measured in the lander flux chambers and sulfate reduction rate (SO_4-R). All fluxes are in mmoles m^{-2} d^{-1} except N_2 gas and urea, which are in mg-atom m^{-2} d^{-1}. Lower case a and b represent the two replicate flux chambers of the large lander used during the summer. Stations 1, 2, and 3 are the stations occupied north of Pt. Barrow during the winter.

Summer	O_2	N_2	CO_2	NO_3^-	NH_4^+	Urea	SO_4-R
Station A-a	12.3			0.1	-0.71	-0.07	5.65
Station A-b	19.8			0.07	-0.39	-0.15	
Station B-a							
Station B-b	18	1.69	-25.2	0.15	-0.75	-0.01	5.79
Station C-a	15.2	0.94	-16.6	0	-0.39	-0.07	
Station C-b	11.2		-15.2	0	-0.52	0	2.98
Station D-a	10.8			-0.1	-0.10	-0.14	4.64
Station D-b	10.5	0.49	-16.4	-0.11	0.00	-0.14	
Station F-a	14.1	2.8	-22.8	-0.11	-0.56	-0.09	4.64
Station F-b	9.4	1.4	-23.2	0.02	-0.41	-0.29	
Station H-a	8.3	1.3	-16.8	-0.11	-0.01	-0.03	4.68
Station H-b	6.5	0.9	-6.8	-0.12	-0.09	-0.01	
Station I-a	8.5	1.8	-11.7	-0.09	0.00	0.01	3.66
Station I-b	7.5		-10.5	-0.19	-0.80	0.04	
Station 1	10.1		-15.1	-0.65	0.00		
Station 1	7.6		-12.8	-0.07	0.01		
Station 1	8.1	1.38	-9.3	-0.02	-0.05		
Station 2	15		-17.6	-0.09	-0.03		
Station 2	14.5	2.1	-12.4				
Station 2	13.9			-0.08	-0.03		
Station 3	4.5	0.45	-5.2	-0.15	0.04		
Station 3	5.4	1.28		-0.02	0.00		
Station 3	5.5	0.78	-8.2				

Sta A

Squeeze core

Depth (mm)	NO3 (uM)	O2 (uM)
-2.1		296.0408
-1.4		279.8031
-0.7	3.1589	278.0623
0	1.3589	252.2799
0.7	1.5512	236.6615
1.4	1.3846	207.1383
2.1	1.0358	170.2344
2.8	0.8179	123.3306
3.5	0.641	92.61701
4.2	0.4512	60.71295
4.9	0.359	58.33205
5.6	0.2154	43.09429
6.3	0	37.61822
7	0	27.85653
7.7		2.3809
8.4		0
9.1		0
9.8		0

Sectioned core

Depth (mm)	NH4 (uM)
2.5	41.24
7.5	50.11
12.5	57.9
17.5	44.5
25	74.4
35	106.9
45	103.48
55	142.88

Sta B

Squeeze core

Depth (mm)	NO3 (uM)	O2 (uM)
-1.4	3.2625	312.9629
-0.7	3.3187	282.4074
0	3.1267	241.8518
0.7	2.9166	211.1111
1.4	2.65	174.074
2.1	2.0687	138.8185
2.8	1.5708	100.9259
3.5	0.9979	70.3703
4.2	0.5625	46.8518
4.9	0.3833	29.6262
5.6	0.1834	95.1851
6.3	0.1042	22.2223
7	0.0527	17.56726
7.7	0	11.40423
8.4		9.007501
9.1	0	6.874146
9.8		4.819803
10.5	0	4.3984
11.2		3.450242
11.9	0	2.31772
12.6		1.685614
13.3		1.606601
14		1.343224
14.7		1.132522

Sectioned core

Depth (mm)	NH4 (uM)
-1.5	28.03
2.5	28.03
7.5	45.86
12.5	44.94
17.5	48.56
25	60.56
35	76.23
45	96.16
55	91.61

Sta C

Squeeze core

Depth (mm)	NO3 (uM)	O2 (uM)
-0.7	0	317
0	0	311.9034
0.7	0	300.5109
1.4	0	292.0619
2.1	0	293.9425
2.8	0	292.498
3.5	0	287.047
4.2	0	273.2016
4.9	0	261.9181
5.6	0	248.6451
6.3	0	230.2754
7	0	213.4592
7.7	0	190.4562
8.4	0	163.5285
9.1	0	133.6028
9.8	0	112.9709
10.5	0	92.66615
11.2	0	54.31872
11.9	0	31.17943
12.6	0	18.01539
13.3	0	11.06543
14		7.68584
14.7		5.50546
15.4		4.333505
16.1		3.543118
16.8		2.779985
17.5		1.744304
18.2		2.316654

Sectioned core

Depth (mm)	NH4 (uM)
2.5	4.3
7.5	11.29
12.5	12.16
17.5	13.48
25	19.68
35	25.37
45	29.25
55	29.44

Sta D

Squeeze core

Depth (mm)	NO3 (uM)	O2 (uM)
-7		301.6872
-5	0	300.9875
-1.2	0	294
0	0	260.3846
0.7	0	241.923
1.4	0	230.7692
2.1	0	221.7307
2.8	0	218.3534
3.5	0.07515	177.8846
4.2	0.12525	149.423
4.9	0.2505	131.1538
5.6	0.187875	123.0769
6.3	0.2191875	67.3076
7		30.7693
7.7	1.0959375	15.3846
8.4		11.1538
9.1	1.1585625	7.5
9.8	1.189875	5.576
10.5	1.3464375	5.38462
11.2	1.5468375	3.0773
11.9		2.6923
12.5		1.2692
12.6	1.87875	0.0518
13.3	2.0102625	0
14		0
14.7		0

Sectioned core

Depth (mm)	NH4 (uM)
2.5	8.33
7.5	16.33
12.5	26.23
17.5	40.26
25	58.63
35	67.57
45	76.23
55	62.42

Sta H

Squeeze core			Sectioned core	
Depth (mm)	**NO3 (uM)**	**O2 (uM)**	**Depth (mm)**	**NH4 (uM)**
-5	0.88176	298	2.5	24.82
0	1.99064	237.6085	7.5	36.12
0.7	3.2398	159.4316	12.5	46.98
1.4	3.56044	100.7098	17.5	42.69
2.1		74.32133	25	49
2.8	2.672	52.71	35	55.99
3.5	1.9372	45.8357	45	58.83
4.2	1.6028	36.5538	55	59.81
4.9	1.58316	24.6126		
5.6	1.28256	18.2186		
6.3	1.120358	10.26224		
7		7.072881		
7.7	1.0282678	5.853419		
8.4	0.4751046	4.127411		
9.1	0.3852	2.15751		
9.8	0.2136	0.375219		
10.5		1.801052		
11.2	0	0.956809		
11.9		1.425833		
12.5	0			
13.3	0			

Sta I

Squeeze core			Sectioned core	
Depth (mm)	**NO3 (uM)**	**O2 (uM)**	**Depth (mm)**	**NH4 (uM)**
-5	0		2.5	3.08
0	0	318.4213	7.5	5.49
0.7	0	311.3447	12.5	8.43
1.4		301.2724	17.5	17.11
2.1	0	290.8106	25	36.04
2.5		273.8002	35	75.76
2.8	0	240.7864	45	98.81
3.5		218.8263	55	111.52
4.2	0	180.4983		
4.9		140.0133		
5.6	0	113.6041		
6.3	0.0754	108.8765		
7		85.593		
7.5		64.5965		
7.7	0.1941	42.2042		
8.4		34.0487		
9.1	0.3117	25.6549		
9.8		18.5242		
10.5	0.3254	15.4723		
11.2	0.4215			
11.9		8.0514		
12.6		4.1044		
14		1.4285		
14.7	0.749	0.5368		
15.4	0.6078	0		