

*[Paleoceanography]*

Supporting Information for

**Ventilation history of Nordic Seas overflows during the last (de)glacial period revealed by species-specific benthic foraminiferal  $^{14}\text{C}$  dates**

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**Introduction**

Figure S1 provides information about the species abundance of benthic foraminifera in sediment core JM-FI-19PC. Tables S1, S2 & S3 include the data discussed in the article.

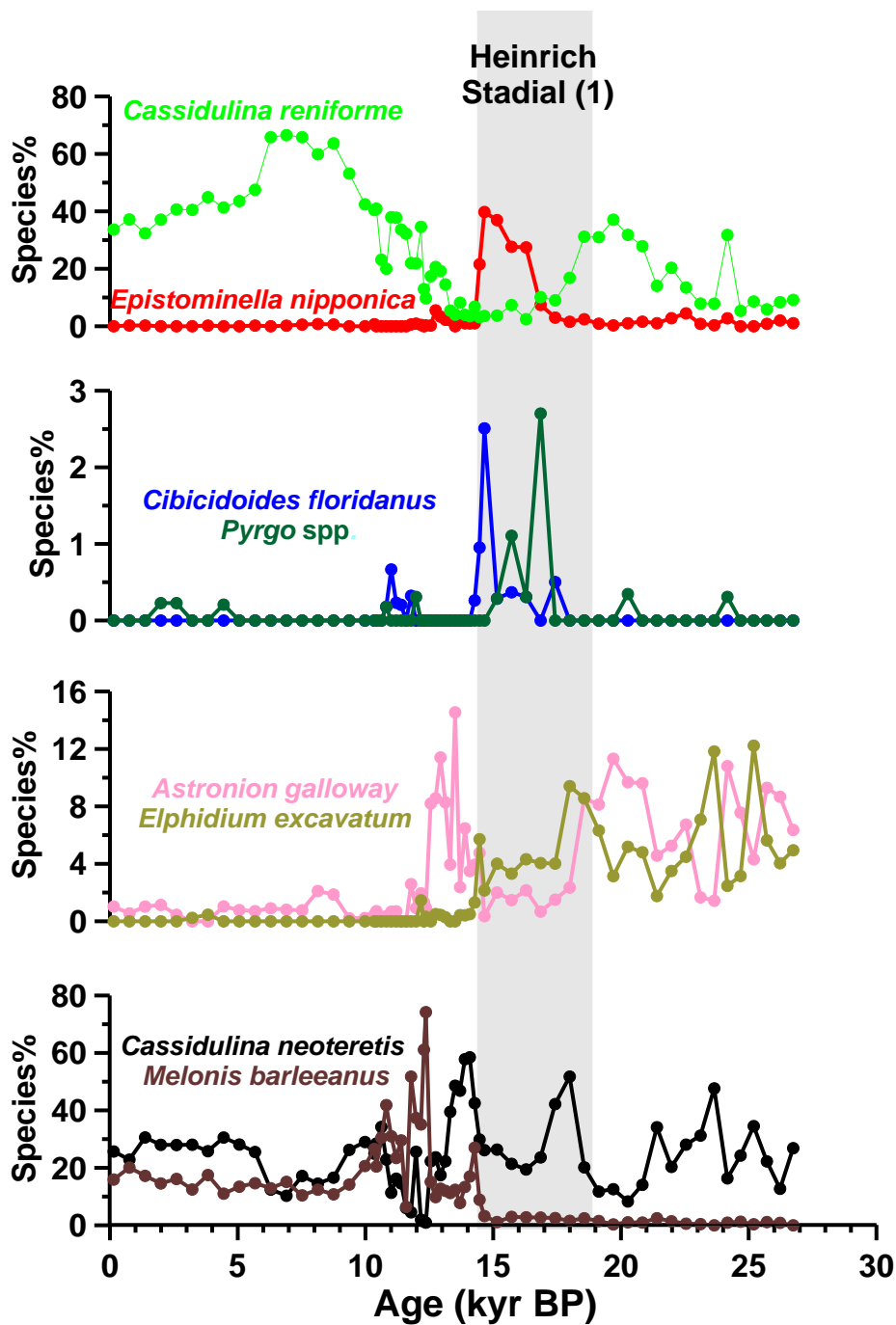


Fig. S1. Relative abundance of benthic foraminifera (size fraction 100–1000  $\mu\text{m}$ ) in sediment core JM-FI-19PC. Methods are explained in Ezat *et al.* [2014]. The majority of our benthic  $^{14}\text{C}$  dates have been measured in mixed samples of *Cassidulina neoteretis*, *Melonis barleeanus*, *Elphidium excavatum*, *Oridorsalis umbonatus* and *Astronion*

*gallowayi*. Monospecific samples of *Cibicidoides floridanus* (sometimes including specimens of *Cibicidoides* sp.) were  $^{14}\text{C}$  dated near the top of Heinrich stadial (HS)1, where it was relatively abundant. *Pyrgo* and other large miliolid species were very rare in the size fraction 100–1000  $\mu\text{m}$  (<0.02%), however, a few specimens (up to 10 specimens) were available in the size fraction >500  $\mu\text{m}$  mid and near the top of HS1 and thus we were able to obtain dates from this interval. *Pyrgo* spp. and large miliolids were otherwise very rare or absent in the core. Because of the very small size of *Cassidulina reniforme* and *Epistominella nipponica*, it was not possible to pick enough monospecific materials (> 0.5 mg) of them for accurate  $^{14}\text{C}$  dating.

<b>Depth (cm)</b>	<b>Age (ka)</b>	<b>Species</b>	<b>size fraction</b>	<b><math>\delta^{18}\text{O}</math></b>	<b><math>\delta^{13}\text{C}</math></b>
195	14.65	<i>Pyrgo depressa</i>	>250 $\mu\text{m}$	3.46	0.61
195	14.65	<i>Cibicidoides floridanus</i>	>150 $\mu\text{m}$	3.00	0.69
195	14.65	<i>Cibicidoides lobatulus</i>	>150 $\mu\text{m}$	3.69	0.69
195	14.65	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	4.17	-1.12
195	14.65	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	4.35	-1.43
197	14.8	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	4.39	-1.71
198	14.92	<i>Cibicidoides floridanus</i>	>150 $\mu\text{m}$	2.95	0.71
198	14.92	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	4.11	-1.03
198	14.92	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	4.45	-1.89
199	14.92	<i>Cibicidoides floridanus</i>	>150 $\mu\text{m}$	2.88	0.45
200	15.15	<i>Cibicidoides floridanus</i>	>150 $\mu\text{m}$	3.06	0.73
200	15.15	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	3.14	-1.41
200	15.15	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	3.10	-1.18
205	15.72	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	3.45	-1.09
210	16.29	<i>Pyrgo depressa</i>	>250 $\mu\text{m}$	3.47	0.91
210	16.29	<i>Cibicidoides wuellerstorfi</i>	>150 $\mu\text{m}$	3.39	0.90
210	16.29	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	3.24	-1.15
210	16.29	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	3.85	-0.71
212	16.51	<i>Pyrgo depressa</i>	>500 $\mu\text{m}$	3.52	0.92
212	16.51	<i>Pyrgo depressa</i>	250–500 $\mu\text{m}$	3.60	0.90
212.5	16.57	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	3.29	-0.70
215	16.85	<i>Cassidulina neoteretis</i>	150–250 $\mu\text{m}$	3.62	-0.98
215	16.85	<i>Melonis barleeanus</i>	150–315 $\mu\text{m}$	3.62	-0.21
216	16.97	<i>Pyrgo depressa</i>	>1000 $\mu\text{m}$	3.70	0.70
216	16.97	<i>Pyrgo depressa</i>	>1000 $\mu\text{m}$	3.74	0.68
216	16.97	<i>Pyrgo depressa</i>	>1000 $\mu\text{m}$	3.68	0.68
216	16.97	<i>Pyrgo depressa</i>	250–500 $\mu\text{m}$	3.70	0.84

220	17.42	<i>Cassidulina neoteretis</i>	150–250µm	4.57	-0.61
220	17.42	<i>Melonis barleeanus</i>	150–315µm	3.92	0.26
225	17.99	<i>Cassidulina neoteretis</i>	150–250µm	4.95	-0.30
225	17.99	<i>Melonis barleeanus</i>	150–315µm	4.80	0.20
230	18.56	<i>Cassidulina neoteretis</i>	150–250µm	4.57	-0.61
230	18.56	<i>Melonis barleeanus</i>	150–315µm	5.19	-0.42

**Table S1. Benthic foraminiferal stable isotope data from sediment core JM-FI-19PC for Heinrich Stadial (HS) 1 period. *Melonis barleeanus* and *Cassidulina neoteretis* data are from Ezat *et al.* [2014].**

Depth (cm)	Mid-depth (cm)	Age (ka) ±error	Sample ID	<sup>14</sup> C age (years) ±error	Sample Description	B-A <sup>14</sup> C (years) ±error	P-A <sup>14</sup> C (years) ±error	B-P <sup>14</sup> C (years) ±error
101–103	102	11.08	UBA-30358	9998 ±57	<i>Neogloboquadrina pachyderma</i>		318 ±115	
101–103	102	11.08	UBA-30345	10197 ±117	Infaunal benthic foraminifera with no miliolid species*	580 ±154		199 ±174
120.5–121.5	121	11.82	UBA-30205	10594 ±85	Infaunal benthic foraminifera with no miliolid species*	427 ±131		
129.5–130.5	130	12.17	UBA-21490	10905 ±50	<i>Neogloboquadrina pachyderma</i> ****		523 ±112	
131.5–132.5	132	12.25	UBA-24807	11043 ±46	<i>Neogloboquadrina pachyderma</i>		633 ±100	
136–137.5	136.7	12.43	UBA-24701	10378 ±47	<i>Neogloboquadrina pachyderma</i>			
146–147	146.5	12.80	UBA-30207	12293 ±62	<i>Neogloboquadrina pachyderma</i>		1316 ±114	
148–146	147	12.82	UBA-30206	12275 ±67	Infaunal benthic foraminifera with no miliolid species*	1273 ±119		
149.5–150.5	150	12.93	UBA-21594	12186 ±50	<i>Neogloboquadrina pachyderma</i>		1133 ±115	
151–152	151.5	12.98	UBA-24704	12496 ±54	<i>Neogloboquadrina pachyderma</i>		1424 ±124	
166–167	166.5	13.57	UBA-24707	13021 ±65	<i>Neogloboquadrina pachyderma</i>		1263 ±125	
171–172	171.5	13.76	UBA-24708	12676 ±58	<i>Neogloboquadrina pachyderma</i>		745 ±137	
171–172	171.5	13.76	UBA-24709	12717 ±68	Infaunal benthic foraminifera with no miliolid species*	786 ±142		41 ±126
174.5–176.5	175.5	13.91	UBA-30208	12612 ±118	Infaunal benthic foraminifera with no miliolid species*	564 ±144		
175.5–177	176.25	13.94	UBA-24710	12901 ±63	<i>Neogloboquadrina pachyderma</i>		845 ±145	
183.5–185.5	184.5	14.25	UBA-24683	12921	<i>Neogloboquadrina pachyderma</i>		573 ±169	
183.5–185.5	184.5	14.25	UBA-24689	13046	Infaunal benthic foraminifera with no miliolid species*	698 ±183		125
185.5–186.5	186	14.31	UBA-24712	13174 ±66	<i>Neogloboquadrina pachyderma</i>		793 ±92	

185.5–186.5	186	14.31	UBA-24713	13341 ±99	Infaunal benthic foraminifera with no miliolid species*	960 ±118		167 ±165
190.5–191.5	191	14.50	UBA-24714	13346 ±51	<i>Neogloboquadrina pachyderma</i>		924 ±123	
192–193	192.5	14.56	UBA-30210	13474 ±108	<i>Neogloboquadrina pachyderma</i>		1041 ±140	
192–193	192.5	14.56	UBA-30209	13496 ±77	Infaunal benthic foraminifera with no miliolid species*	1063 ±118		22 ±185
194.5–195.5	195	14.65	UBA-21595	13493 ±60	<i>Neogloboquadrina pachyderma</i> ****		1045 ±218	
195.5–196.5	196	14.69	UBA-24718	13244 ±54	<i>Neogloboquadrina pachyderma</i>		778 ±247	
195.5–196.5	196	14.69	UBA-24719	21602 ±127	<i>Pyrgo</i> species**	9136 ±273		8358 ±181
196.5–198.5	197.5	14.86	UBA-24705	13793 ±61	Epifaunal benthic foraminifera***	1255 ±256		***** 193 ±115
196.5–198.5	197.5	14.86	UBA-24715	20137 ±108	<i>Pyrgo</i> species**	7599 ±271		***** 6537 ±162
199.5–200.5	200	15.15	UBA-24720	13708 ±53	<i>Neogloboquadrina pachyderma</i>		996 ±363	
200–205	202.5	15.43	UBA-24716	14792 ±68	Infaunal benthic foraminifera with no miliolid species *	1851 ±406		***** 920 ±123
200–205	202.5	15.43	UBA-24706	15125 ±67	Epifaunal benthic foraminifera***	2184 ±406		***** 1253 ±122
200–205	202.5	15.43	UBA-24711	21204 ±131	<i>Pyrgo</i> species**	8263 ±421		***** 7332 ±186
203–204	203.5	15.55	UBA-24722	13937 ±55	<i>Neogloboquadrina pachyderma</i>		963 ±420	
206–207	206.5	15.89	UBA-24724	14026 ±63	<i>Neogloboquadrina pachyderma</i>		805 ±463	
206–207	206.5	15.89	UBA-24725	20665 ±113	<i>Pyrgo</i> species**	7444 ±473		6639 ±176
211–212	211.5	16.46	UBA-24726	14293 ±56	<i>Neogloboquadrina pachyderma</i>		637 ±532	
210–213	211.5	16.46	UBA-24703	14714 ±63	Infaunal benthic foraminifera with no miliolid species*	1058 ±533		421 ±119
210–213	211.5	16.46	UBA-24699	15089 ±64	Epifaunal benthic foraminifera***	1433 ±533		796 ±120
211–212	211.5	16.46	UBA-24727	20386 ±125	<i>Pyrgo</i> species**	6730 ±544		6039 ±181

215–216	215.5	16.91	UBA-24728	14561 ±57	<i>Neogloboquadrina pachyderma</i>		639 ±470	
214–217	215.5	16.91	UBA-24697	15202 ±70	Infaunal benthic foraminifera with no miliolid species *	1280 ±631		641 ±127
214–217	215.5	16.91	UBA-24702	15410 ±90	Epifaunal benthic foraminifera***	1488 ±633		849 ±147
214–217	215.5	16.91	UBA-24729	15613 ±79	Shell fragments			
217–218	217.5	17.14	UBA-31839	21676± 94	<i>Pyrgo</i> species**	7574 ±615		
221–222	221.5	17.59	UBA-24731	15225 ±64	<i>Neogloboquadrina pachyderma</i>		783 ±779	
221–222	221.5	17.59	UBA-29400	15525 ±66	Infaunal benthic foraminifera with no miliolid species*	1083 ±779		300 ±130
226–227	226.5	18.16	UBA-24732	15384 ±60	<i>Neogloboquadrina pachyderma</i>		435 ±592	
226–227	226.5	18.16	UBA-30211	16449 ±147	Infaunal benthic foraminifera with no miliolid species*	1500 ±893		1065 ±207
226–227	226.5	18.16	UBA-24734	16161 ±68	Infaunal benthic foraminifera with no miliolid species and shell fragments			777 ±128
229.5–230.5	230	18.56	UBA-21492	15786 ±80	<i>Neogloboquadrina pachyderma</i> *****		510 ±635	
231–232	231.5	18.73	UBA-24735	15878 ±65	<i>Neogloboquadrina pachyderma</i>		420 ±640	
231–232	231.5	18.73	UBA-24736	16155 ±77	Infaunal benthic foraminifera with no miliolid species*	697 ±732		277 ±142
236–237	236.5	19.30	UBA-24737	16323 ±82	<i>Neogloboquadrina pachyderma</i>		318 ±565	
236–237	236.5	19.30	UBA-24738	16959 ±78	Infaunal benthic foraminifera with no miliolid species*	954 ±831		636 ±160
241–242	241.5	19.87	UBA-24739	17200 ±77	<i>Neogloboquadrina pachyderma</i>		750 ±639	
241–242	241.5	19.87	UBA-29399	17412 ±61	Infaunal benthic foraminifera with no miliolid species*	962 ±721		212 ±138
241–242	241.5	19.87	UBA-24740	17691± 78	Shell fragments and infaunal benthic foraminifera with no miliolid species			
246–247	246.5	20.44	UBA-24741	17904 ±87	<i>Neogloboquadrina pachyderma</i>		978 ±667	



246–247	246.5	20.44	UBA-24742	18554 ±86	Infaunal benthic foraminifera with no miliolid species*	1628 ±666		650 ±173
249.5–250.5	250	20.84	UBA-31841	19513 ±200	Shells (Bivalvia)			
251–252	251.5	21.01	UBA-24743	18931 ±88	<i>Neogloboquadrina pachyderma</i>		1510 ±618	
251–252	251.5	21.01	UBA-30212	19607 ±171	Infaunal benthic foraminifera with no miliolid species *	2186 ±635		676 ±259
251–252	251.5	21.01	UBA-24744	19856 ±106	Infaunal benthic foraminifera (no precise notes are available)			
298–299	298.5	26.07	UBA-24761	23610 ±143	<i>Neogloboquadrina pachyderma</i>	1725 ±227		
298–299	298.5	26.07	UBA-30214	23681 ±134	Infaunal benthic foraminifera with no miliolid species*	1796 ±222		71 ±277
300.5–301.5	301	26.33	UBA-24762	23484 ±108	<i>Neogloboquadrina pachyderma</i>		1346 ±314	
300.5–301.5	301	26.33	UBA-30215	24098 ±195	Infaunal benthic foraminifera with no miliolid species*	1960 ±354		614 ±303
301.5–304.5	303	26.53	UBA-24763	23960 ±144	<i>Neogloboquadrina pachyderma</i>		1652 ±179	
304.5–305.5	305	26.74	UBA-21493	23962 ±170	<i>Neogloboquadrina pachyderma</i> ****		1491 ±435	
304.5–305.5	305	26.74	UBA-30216	24526 ±135	Infaunal benthic foraminifera with no miliolid species*	2055 ±422		564 ±305

**Table S2. Planktic and benthic <sup>14</sup>C data from sediment core JM-FI-19PC.**

\* *Cassidulina neoteretis*, *Melonis barleeanus*, *Elphidium excavatum*, *Oridorsalis umbonatus* and *Astronion gallowayi*. \*\* *Pyrgo serrata* with sometimes specimens of *Pyrgo depressa* and other miliolid species. \*\*\* *Cibicidoides floridanus* (sometimes including specimens of *Cibicidoides* sp.). \*\*\*\* from *Ezat et al.* [2014]. \*\*\*\*\* No planktic <sup>14</sup>C dates were available at these depths, and thus B-P <sup>14</sup>C age offsets are based on interpolation between closeby planktic <sup>14</sup>C dates. The grey-shaded planktic <sup>14</sup>C date has not been used in the reservoir age estimates because the used foraminiferal specimens, in contrast to all other samples, were highly fragmented.

Reference	Depth (cm)	Mid depth (cm)	Age (Ka)	Sample ID	Species	<sup>14</sup> C age		B-A <sup>14</sup> C
						years	error	
*	40–42	41	10.660	OS-75785	Mixed incl. <i>Pyrgo</i>	10000	50	581
*	49–54	52	11.728	OS-75801	Mixed incl. <i>Pyrgo</i>	10850	45	745
*	97–100	98	12.171	OS-75786	Mixed incl. <i>Pyrgo</i>	13250	55	2868
*	112–114	113	12.435	OS-75677	Mixed incl. <i>Pyrgo</i>	12700	55	2190
*	119–122	121	12.576	OS-75787	Mixed incl. <i>Pyrgo</i>	12650	55	2046
*	127–130	129	12.717	OS-75788	Mixed incl. <i>Pyrgo</i>	12950	60	2128
*	134–137	136	12.840	OS-75798	Mixed incl. <i>Pyrgo</i>	13700	65	2678
*	139–142	141	13.217	OS-75789	Mixed incl. <i>Pyrgo</i>	14900	55	3528
*	142–150	146	13.595	OS-75800	Mixed incl. <i>Pyrgo</i>	13100	60	1283
*	150–161	155	14.274	OS-75805	Mixed incl. <i>Pyrgo</i>	13050	70	688
this study	165–173	169	14.670	OS-105955	Mixed excl. <i>Pyrgo</i> (mainly <i>Elphidium excavatum</i> , <i>Nonionella</i> , <i>Cibicides</i> spp., <i>Melonis barleanuum</i> )	14100	75	1645
this study	177	177	14.840	OS-105956	Bivalve	13100	70	568
this study	177–183	180	14.874	OS-105641	Mixed excl. <i>Pyrgo</i> (mainly <i>Elphidium excavatum</i> , <i>Nonionella</i> , <i>Cibicides</i> spp., <i>Melonis barleanuum</i> )	14050	75	1510

this study	185– 189	187	15.009	OS- 105621	Mixed incl. <i>Pyrgo</i>	14850	50	2261
*	190– 195	192	15.077	OS- 75790	Mixed excl. <i>Pyrgo</i> (mainly <i>Cibicidoides</i> <i>floridanus</i> )	15650	55	3017
this study	216– 218	217	15.502	OS- 105627	<i>Pyrgo serrata</i>	18900	75	5937
this study	222– 226	224	15.621	OS- 105957	Mixed incl. <i>Pyrgo</i> (all miliolid)	15700	70	2677
this study	233– 234	233	15.774	OS- 105642	Mixed incl. <i>Pyrgo</i> (mainly Miliolida)	16950	70	3812
this study	244	244	15.960	OS- 105643	Mixed incl. <i>Pyrgo</i> (all miliolid)	18250	85	4983
this study	247– 249	248	16.028	OS- 105644	<i>Pyrgo serrata</i>	20400	80	7082
this study	254	254	16.130	OS- 105645	<i>Pyrgo serrata</i>	20600	110	7199
this study	256– 257	256	16.164	OS- 105628	<i>Pyrgo serrata</i>	20400	80	6973
this study	262– 263	262	16.266	OS- 105646	Mixed incl. <i>Pyrgo</i> (all miliolid)	20100	80	6581
this study	268– 271	270	16.403	OS- 105647	Mixed incl. <i>Pyrgo</i> (mainly Miliolida)	17950	120	4321
this study	278– 283	280	16.574	OS- 105648	Mixed incl. <i>Pyrgo</i> (Miliolida and <i>Elphidium</i> )	16350	65	2616
this study	286– 289	288	16.711	OS- 105649	Mixed incl. <i>Pyrgo</i> (mainly miliolid)	17050	110	3233
this study	293– 300	296	16.848	OS- 105650	<i>Elphidium</i> <i>excavatum</i>	16200	75	2312
this study	313– 316	314	17.156	OS- 105958	Mixed incl. <i>Pyrgo</i> (mainly miliolid)	17050	95	2936
this study	319	319	17.242	OS- 105651	Bivalve	15650	100	1476

this study	322– 326	324	17.327	OS- 105959	Mixed incl. <i>Pyrgo</i>	16100	85	1887
this study	351– 353	352	17.807	OS- 105630	<i>Elphidium excavatum</i>	15750	80	1151
this study	359– 361	360	17.944	OS- 105763	<i>Elphidium excavatum</i>	16850	110	2102
this study	368– 369	368	18.081	OS- 105761	<i>Elphidium excavatum</i>	15800	75	912
this study	385	385	18.372	OS- 105629	Bivalve	15950	60	831
this study	389– 394	392	18.492	OS- 105960	Mixed incl. <i>Pyrgo</i>	17400	90	2186
this study	403– 406	405	18.714	OS- 105764	Mixed incl. <i>Pyrgo</i>	17100	75	1663
this study	407– 410	408	18.766	OS- 105765	Mixed excl. <i>Pyrgo</i> (mainly <i>Elphidium excavatum</i> and <i>C. neoteretis</i> )	16700	70	1199

**Table S3. Benthic <sup>14</sup>C data from sediment core RAPiD-10-1P.**

\* Thornalley *et al.* [2011].