



Supplement of

Changes in the Red Sea overturning circulation during Marine Isotope Stage 3

Raphaël Hubert-Huard et al.

Correspondence to: Raphaël Hubert-Huard (raphael.hubert-huard@uni-hamburg.de)

The copyright of individual parts of the supplement might differ from the article licence.

Supplement

Supplement 1

Table S1 Oxygen and carbon stable isotope data set used for establishing the epibenthic foraminifera composite isotope record of the KL11 core.

Mean depth (cm)	Age (ka B.P.)	$\delta^{18}\text{O}$ <i>Cibicides mabahethi</i> (‰ VPDB)	$\delta^{18}\text{O}$ <i>Discorbinella bertheloti</i> s.l. (‰ VPDB)	$\delta^{18}\text{O}$ <i>Hanzawaia boueana</i> s.l. (‰ VPDB)	$\delta^{18}\text{O}$ Composite (‰ VPDB)	$\delta^{13}\text{C}$ <i>Cibicides mabahethi</i> (‰ VPDB)	$\delta^{13}\text{C}$ <i>Discorbinella bertheloti</i> s.l. (‰ VPDB)	$\delta^{13}\text{C}$ <i>Hanzawaia boueana</i> s.l. (‰ VPDB)	$\delta^{13}\text{C}$ Composite (‰ VPDB)
194.5	28.44	4.199			4.199	1.603			1.603
196.5	28.78	4.231	4.412		4.225	1.862	1.871		1.821
198.5	29.12	4.156	3.753	4.010	3.914	1.674	1.342	1.492	1.529
200.5	29.46	4.016	4.735	3.778	4.118	1.572	2.144	1.320	1.705
202.5	29.8	3.847		3.824	3.844	1.605		1.278	1.527
204.5	30.14	3.801	4.356	3.786	3.922	1.413	1.899	1.436	1.609
206.5	30.49	3.900	3.684	3.858	3.755	1.525	1.454	1.367	1.475
208.5	30.83	3.622	3.604	3.810	3.620	1.445	1.360	1.339	1.408
210.5	31.17	3.760	4.167		3.867	1.383	1.728		1.510
212.5	31.51	3.295			3.295	1.164			1.164
214.5	31.85	3.756	3.797		3.680	1.515	1.517		1.470
216.5	32.19	3.745	3.943	3.571	3.694	1.457	1.598	1.283	1.472
218.5	32.53	3.398	3.516	3.323	3.354	1.190	1.055	0.948	1.091
220.5	32.88	3.211	3.647	3.021	3.234	1.064	1.421	0.715	1.093
222.5	33.22	3.650	3.611	3.459	3.515	1.440	1.285	0.969	1.258
224.5	33.56	3.613	4.182	3.627	3.749	1.389	1.892	1.197	1.519
226.5	33.9	3.274	3.905	3.470	3.491	1.014	1.685	0.954	1.244
228.5	34.24	3.449	3.695		3.475	1.355	1.385		1.324
230.5	34.58	2.747	3.109		2.831	1.166	1.258		1.166
232.5	34.93	2.852			2.852	1.061			1.061
233.5	35.1	3.286	3.034	3.061	3.068	1.330	1.182	0.996	1.196
234.5	35.27	3.635	3.773	2.898	3.377	1.394	1.539	1.076	1.363
236.5	35.61	3.317	3.831	3.332	3.435	1.186	1.628	1.280	1.391
238.5	35.95	3.402	3.610	3.631	3.489	1.433	1.503	1.188	1.401
240.5	36.29	3.503	3.629	3.287	3.414	1.478	1.540	1.140	1.412
242.5	36.63	3.078		3.201	3.148	1.281		1.195	1.323
244.5	36.98	2.680	2.952	2.769	2.742	1.007	1.371	0.998	1.152
246.5	37.32	2.579	2.501	2.848	2.584	0.981	0.884	1.024	0.989
248.5	37.66	2.556	3.190	2.847	2.806	1.024	1.442	0.995	1.180
249.5	37.83	2.440	2.535	2.498	2.432	1.086	1.047	0.864	1.025
250.5	38			2.580	2.597			0.787	0.958

252.5	38.38	2.729		2.636	2.691	1.122		0.82	1.056
254.5	38.77	3.921			3.921	1.608			1.608
256.5	39.15	3.645	3.998		3.725	1.313	1.890		1.556
258.5	39.54		3.885		3.692		1.540		1.449
260.5	39.92	3.385	3.955		3.573	1.581	1.853		1.671
262.5	40.31	3.524	3.993		3.662	1.455	1.643		1.503
264.5	40.69		3.357		3.164		1.169		1.078
266.5	41.07		3.539		3.346		1.541		1.450
268.5	41.46	3.000			3.000	0.99			0.99
272.5	42.23	3.284	3.765	3.888	3.587	1.602	1.597	1.957	1.745
276.5	42.99	2.755	3.207	2.268	2.685	1.244	1.457	0.681	1.154
278.5	43.38	2.590	1.638	2.605	2.219	1.255	0.433	1.158	0.975
280.5	43.74	3.213	3.023	3.263	3.108	1.428	1.506	1.334	1.449
282.5	44.1	3.397	3.375		3.289	1.688	1.522		1.559
284.5	44.47		3.217		3.024		1.642		1.551
286.5	44.83	2.705	2.717	2.727	2.658	1.383	1.338	1.186	1.329
288.5	45.19	2.610	2.997	2.264	2.565	1.309	1.331	0.669	1.129
290.5	45.55	2.452	2.827	2.652	2.585	1.265	1.607	1.095	1.349
292.5	45.92	2.045	2.355	2.292	2.172	0.973	0.908	1.046	1.002
293.5	46.09	2.162	2.582	2.152	2.240	0.922	1.339	0.946	1.095
295.5	46.44		2.553		2.360		0.949		0.858
297.5	46.79	3.553			3.553	1.524			1.524
299.5	47.13		4.043		3.850		2.003		1.912
301.5	47.48		3.094		2.901		1.258		1.167
303.5	47.82		2.875		2.682		1.465		1.374
305.5	48.17			2.758	2.775			0.989	1.160
307.5	48.52		3.402		3.209		1.753		1.662
309.5	48.86	2.702			2.702	1.361			1.361
311.5	49.21	2.643		2.437	2.549	1.260		1.013	1.222
313.5	49.55	2.558			2.558	1.290			1.290
315.5	49.9	2.536	2.767	2.221	2.449	1.260	1.328	0.888	1.185
317.5	50.25	2.416		2.491	2.462	1.195		1.126	1.246
319.5	50.59	2.136		2.437	2.295	1.095		1.083	1.174
321.5	50.94	2.228			2.228	1.056			1.056
323.5	51.29	2.230	2.336		2.186	1.182	1.248		1.169
325.5	51.63	2.442			2.442	0.923			0.923
326.5	51.8	1.997	2.729	2.127	2.226	0.857	1.102	0.992	1.010
326.5	51.8	2.159	2.693		2.329	1.097	1.305		1.155
327.5	51.98	2.354	2.661		2.411	0.985	1.054		0.974
329.5	52.32	2.990	3.257		3.027	1.192	1.193		1.147
331.5	52.67	3.305	3.349		3.230	1.153	1.296		1.179
334	53.07	2.864	3.062		2.866	1.123	1.113		1.072
335.5	53.31	2.561	2.846		2.607	1.082	1.055		1.023
337.5	53.63	2.632	2.682		2.560	1.023	1.079		1.005
339.5	53.95	2.903	2.822	2.899	2.816	1.144	0.992	0.905	1.040
341.5	54.27	2.961	3.359	2.969	3.038	1.209	1.148	0.913	1.116
343.5	54.59		3.146	2.851	2.911		1.305	0.892	1.138

345.5	54.91	2.627	2.825	2.553	2.610	1.040	1.163	0.858	1.047
347.5	55.23		2.448	2.621	2.447		0.764	1.106	0.975
349.5	55.55		2.805		2.612		1.202		1.111
351.5	55.87		2.597	2.386	2.404		1.086	0.766	0.966
353.5	56.19		3.395		3.202		1.007		0.916
355.5	56.51		3.198	3.224	3.123		1.017	0.838	0.967
357.5	56.83		2.868		2.675		0.837		0.746
358.5	56.99		2.878		2.685		0.885		0.794
359.5	57.15		3.374		3.181		0.947		0.856
361.5	57.47		3.249		3.056		0.991		0.9
363.5	57.79		3.237		3.044		0.67		0.579
364.5	57.95	3.389	3.549		3.372	1.026	0.96		0.947
365.5	58.11	3.629	3.674		3.555	0.944	1.119		0.986
367.5	58.43	3.694	3.578		3.539	1.206	1.040		1.077
369.5	58.75	3.712	3.657		3.588	1.173	1.176		1.129
371.5	59.07		3.577		3.384		1.075		0.984
373.5	59.39	3.748	3.716		3.635	1.267	1.229		1.202
375.5	59.71	3.870	3.799		3.738	1.319	1.209		1.218
377.5	60.04	3.762	3.720		3.644	1.199	1.257		1.182
379.5	60.36	3.727	3.941		3.737	1.301	1.465		1.337
381.5	60.68	3.895			3.895	1.378			1.378
383.5	61	3.815	3.918		3.770	1.379	1.460		1.374
385.5	61.32		4.294		4.101		1.801		1.710
387.5	61.64		3.710		3.517		1.417		1.326
389.5	61.96		3.871		3.678		1.572		1.481
390.5	62.12		3.850		3.657		1.543		1.452

Table S2 Stable carbon isotope data of *Globigerinoides ruber* white for core GeoB5844-2.

Mean depth (cm)	Age (ka B.P.)	$\delta^{13}\text{C}$ <i>Globigerinoides ruber</i> white (‰ VPDB)
0.5	0.58	1.02
1.5	0.71	1.22
2.5	0.85	1.14
3.5	0.99	1.28
4.5	1.12	1.12
5.5	1.26	1.29
6.5	1.39	1.25
7.5	1.53	1.2
8.5	1.67	1.25
9.5	1.8	1.26
10.5	1.96	1.22
11.5	2.13	1.32
12.5	2.3	1.08
13.5	2.47	1.25
14.5	2.64	1.37
15.5	2.82	1.33
16.5	2.99	1.2
17.5	3.16	1.19
18.5	3.33	1.13
19.5	3.5	1.24
20.5	3.68	1.26
21.5	3.87	1.22
22.5	4.06	1.3
23.5	4.25	1.19
24.5	4.44	1.1
25.5	4.62	1.17
26.5	4.81	1.07
27.5	5	1
28.5	5.19	1.23
29.5	5.38	1.11

30.5	5.52	1.26
31.5	5.63	1.25
32.5	5.74	1.29
33.5	5.85	1.22
34.5	5.96	1.11
35.5	6.07	0.94
36.5	6.18	1.17
37.5	6.29	1.1
38.5	6.4	1.22
39.5	6.51	1.13
40.5	6.64	1.11
41.5	6.79	1.17
42.5	6.94	1.16
43.5	7.09	0.85
44.5	7.24	1.09
45.5	7.39	1.23
46.5	7.54	1.06
47.5	7.69	0.9
48.5	7.84	1.07
49.5	7.99	1.06
50.5	8.14	1.05
51.5	8.29	1.05
52.5	8.44	1.12
53.5	8.59	1.04
54.5	8.74	1.1
55.5	8.88	0.89
56.5	9	1.05
57.5	9.13	1.05
58.5	9.25	1.09
59.5	9.37	1
60.5	9.49	1.19
61.5	9.61	0.89
62.5	9.74	0.75
63.5	9.86	0.7

64.5	9.98	0.76
65.5	10.1	0.65
66.5	10.22	
67.5	10.35	
68.5	10.47	
69.5	10.59	
70.5	10.74	
71.5	10.92	
72.5	11.1	
73.5	11.28	
74.5	11.46	
75.5	11.64	
76.5	11.82	
77.5	12.01	
78.5	12.19	
79.5	12.37	
80.5	12.55	
81.5	12.73	
82.5	12.91	
83.5	13.09	
84.5	13.27	
85.5	13.41	
86.5	13.51	
87.5	13.61	
88.5	13.71	
89.5	13.8	
90.5	13.9	
91.5	14	
92.5	14.1	
93.5	14.2	
94.5	14.3	
95.5	14.4	
96.5	14.49	
97.5	14.59	

98.5	14.69
99.5	14.79
100.5	14.9
101.5	15.01
102.5	15.12
103.5	15.24
104.5	15.35
105.5	15.46
106.5	15.58
107.5	15.69
108.5	15.81
109.5	15.92
110.5	16.03
111.5	16.15
112.5	16.26
113.5	16.37
114.5	16.49
115.5	16.6
116.5	16.71
117.5	16.83
118.5	16.94
119.5	17.06
120.5	17.17
121.5	17.28
122.5	17.4
123.5	17.51
124.5	17.62
125.5	17.72
126.5	17.8
127.5	17.88
128.5	17.96
129.5	18.04
130.5	18.12
131.5	18.2

132.5	18.28
133.5	18.36
134.5	18.44
135.5	18.52
136.5	18.6
137.5	18.68
138.5	18.75
139.5	18.83
140.5	18.91
141.5	18.99
142.5	19.07
143.5	19.15
144.5	19.23
145.5	19.31
146.5	19.39
147.5	19.47
148.5	19.55
149.5	19.63
150.5	19.71
151.5	19.79
152.5	19.87
153.5	19.95
154.5	20.04
155.5	20.12
156.5	20.2
157.5	20.28
158.5	20.36
159.5	20.44
160.5	20.52
161.5	20.6
162.5	20.69
163.5	20.77
164.5	20.85
165.5	20.93

166.5	21.01
167.5	21.09
168.5	21.17
169.5	21.25
171.5	21.42
175.5	21.74
176.5	21.83
177.5	21.92
178.5	22
179.5	22.09
180.5	22.18
181.5	22.26
182.5	22.35
183.5	22.44
184.5	22.52
185.5	22.61
186.5	22.7
187.5	22.79
188.5	22.87
189.5	22.96
190.5	23.05
191.5	23.13
192.5	23.22
193.5	23.31
194.5	23.39
195.5	23.48
196.5	23.57
197.5	23.65
198.5	23.74
199.5	23.83
200.5	23.91
201.5	23.98
202.5	24.06
203.5	24.13

204.5	24.2
205.5	24.28
206.5	24.35
207.5	24.43
208.5	24.5
209.5	24.57
210.5	24.65
211.5	24.72
212.5	24.8
213.5	24.87
214.5	24.94
215.5	25.02
216.5	25.09
217.5	25.17
218.5	25.24
219.5	25.31
220.5	25.39
221.5	25.46
222.5	25.54
223.5	25.61
224.5	25.68
225.5	25.8
226.5	25.95
227.5	26.11
228.5	26.26
229.5	26.41
230.5	26.57
231.5	26.72
232.5	26.88
233.5	27.03
234.5	27.19
235.5	27.34
236.5	27.5
237.5	27.65

238.5	27.8
239.5	27.96
240.5	28.11
241.5	28.27
242.5	28.42
244.5	28.73
245.5	28.89
247.5	29.19
248.5	29.35
249.5	29.5
250.5	29.6
251.5	29.64
252.5	29.69
253.5	29.73
254.5	29.77
255.5	29.82
256.5	29.86
257.5	29.9
258.5	29.95
259.5	29.99
260.5	30.03
261.5	30.08
262.5	30.12
263.5	30.16
264.5	30.21
265.5	30.25
266.5	30.29
267.5	30.34
268.5	30.38
269.5	30.42
270.5	30.47
271.5	30.51
272.5	30.55
273.5	30.6

274.5	30.64	
275.5	30.7	
276.5	30.79	0.32
277.5	30.88	
278.5	30.97	0.33
279.5	31.06	
280.5	31.15	0.24
281.5	31.24	
282.5	31.33	0.3
283.5	31.42	0.35
284.5	31.51	0.29
285.5	31.6	0.25
286.5	31.69	0.29
287.5	31.78	0.28
288.5	31.86	0.25
289.5	31.95	0.19
290.5	32.04	0.17
291.5	32.13	-0.22
292.5	32.22	-0.17
293.5	32.31	0.03
294.5	32.4	-0.05
295.5	32.49	0.05
296.5	32.58	0.15
297.5	32.67	0.03
298.5	32.76	0.34
299.5	32.85	
300.5	32.96	0.28
301.5	33.11	
302.5	33.25	0.27
303.5	33.4	
304.5	33.54	0.43
305.5	33.68	0.36
306.5	33.83	0.3
307.5	33.97	0.17

308.5	34.12	0.36
309.5	34.26	0.49
310.5	34.41	0.38
311.5	34.55	0.39
312.5	34.7	0.26
313.5	34.84	0.3
314.5	34.98	0.42
315.5	35.13	0.39
316.5	35.27	
317.5	35.42	0.2
318.5	35.56	0.3
319.5	35.71	0.4
320.5	35.85	0.33
321.5	35.99	0.39
322.5	36.14	0.5
323.5	36.28	0.4
324.5	36.43	0.4
325.5	36.57	0.42
326.5	36.72	0.42
327.5	36.87	0.47
328.5	37.02	0.43
329.5	37.16	0.45
330.5	37.31	0.36
331.5	37.46	0.47
332.5	37.6	0.51
333.5	37.75	0.41
334.5	37.9	
335.5	38.05	0.34
336.5	38.19	0.4
337.5	38.34	0.44
338.5	38.49	0.39
339.5	38.63	0.3
340.5	38.78	0.29
341.5	38.93	0.37

342.5	39.08	0.39
343.5	39.22	0.4
344.5	39.37	0.35
345.5	39.52	0.28
346.5	39.67	0.32
347.5	39.81	0.34
348.5	39.96	0.25
349.5	40.11	0.43
350.5	40.25	0.25
351.5	40.4	
352.5	40.55	
353.5	40.7	0.22
354.5	40.84	0.35
355.5	40.99	0.47
356.5	41.14	0.43
357.5	41.28	0.47
358.5	41.43	0.28
359.5	41.58	0.2
360.5	41.73	0.2
361.5	41.87	0.3
362.5	42	0.3
363.5	42.14	0.47
364.5	42.28	0.7
365.5	42.41	0.54
366.5	42.55	0.56
367.5	42.68	0.58
368.5	42.82	0.55
369.5	42.95	0.58
370.5	43.09	0.44
371.5	43.23	0.4
372.5	43.36	0.4
373.5	43.5	
374.5	43.63	0.38
375.5	43.77	

376.5	43.9	0.43
377.5	44.04	0.45
378.5	44.18	0.47
379.5	44.31	0.44
380.5	44.45	0.57
381.5	44.58	0.54
382.5	44.72	0.45
383.5	44.85	0.48
384.5	44.99	0.74
385.5	45.13	0.37
386.5	45.26	0.42
387.5	45.4	0.49
388.5	45.53	0.63
389.5	45.67	0.53
390.5	45.8	0.42
391.5	45.94	0.43
392.5	46.08	0.15
393.5	46.21	-0.47
394.5	46.35	0.42
395.5	46.48	0.52
396.5	46.62	0.34
397.5	46.75	0.5
398.5	46.89	0.34
399.5	47.03	0.44
400.5	47.16	0.93
401.5	47.3	
402.5	47.43	0.25
403.5	47.57	0.29
404.5	47.7	0.34
405.5	47.84	0.55
406.5	47.98	0.43
407.5	48.11	0.45
408.5	48.25	0.37
409.5	48.38	0.5

410.5	48.52	0.58
411.5	48.65	0.5
412.5	48.79	0.6
413.5	48.93	0.25
414.5	49.06	0.48
415.5	49.2	0.38
416.5	49.33	0.56
417.5	49.48	0.27
418.5	49.65	0.55
419.5	49.82	0.64
420.5	49.98	0.08
421.5	50.15	0.57
422.5	50.32	0.62
423.5	50.49	0.81
424.5	50.65	0.22
425.5	50.82	0.63
426.5	50.99	0.58
427.5	51.15	
428.5	51.32	
429.5	51.49	0.3
430.5	51.65	0.31
431.5	51.82	0.25
432.5	51.99	0.32
433.5	52.16	0.44
434.5	52.32	0.08
435.5	52.49	0.38
436.5	52.66	0.45
437.5	52.82	0.33
438.5	52.99	0.39
439.5	53.16	0.37
440.5	53.32	0.55
441.5	53.49	0.44
442.5	53.66	0.39
443.5	53.83	0.47

444.5	53.99	0.45
445.5	54.16	0.41
446.5	54.33	0.36
447.5	54.49	0.53
448.5	54.66	0.62
449.5	54.83	0.24
450.5	54.99	0.42
451.5	55.16	0.4
452.5	55.33	0.54
453.5	55.5	0.63
454.5	55.66	0.46
455.5	55.83	0.1
456.5	56	0.23
457.5	56.16	0.25
458.5	56.33	0.23
459.5	56.5	0.19
460.5	56.66	0.32
461.5	56.83	0.23
462.5	57	0.32
463.5	57.17	0.2
464.5	57.33	-0.14
465.5	57.5	-0.02
466.5	57.67	0.2
467.5	57.83	-0.5
468.5	58	-0.42
469.5	58.17	-0.15
470.5	58.33	-0.26
471.5	58.5	0.12
472.5	58.67	0.13
473.5	58.84	-0.04
474.5	59	0.21
475.5	59.17	0.34
476.5	59.34	0.1
477.5	59.5	0.14

478.5	59.67	0.24
479.5	59.84	0.09
480.5	60	0.34
481.5	60.17	0.22
482.5	60.34	0.37
483.5	60.51	0.22
484.5	60.67	0.2
485.5	60.84	0.21
486.5	61.01	-0.04
487.5	61.17	0.28
488.5	61.34	0.41
489.5	61.51	0.15
490.5	61.67	0.28
491.5	61.84	0.3
492.5	62.01	0.27
493.5	62.18	0.51
494.5	62.34	0.41
495.5	62.51	0.4
496.5	62.68	-0.01
497.5	62.84	0.33
498.5	63.01	0.32
499.5	63.18	0.64
500.5	63.34	0.76
501.5	63.51	0.53
503.5	63.85	0.66
504.5	64.01	0.49
505.5	64.18	0.65
506.5	64.35	0.62
507.5	64.51	0.79
508.5	64.68	0.74
509.5	64.85	0.66
510.5	65.01	0.71
511.5	65.18	0.75
512.5	65.35	0.62

513.5	65.52	0.6
514.5	65.68	0.79
515.5	65.85	0.78
516.5	66.02	0.86
517.5	66.18	0.89
519.5	66.52	0.91
521.5	66.85	0.83
523.5	67.19	0.75
525.5	67.52	0.82
527.5	67.85	0.81
529.5	68.19	0.81
531.5	68.52	0.73
533.5	68.86	0.68
535.5	69.19	
537.5	69.52	0.64
539.5	69.86	0.63
541.5	70.19	0.5
543.5	70.53	0.62
545.5	70.86	0.61
546.5	71.03	
547.5	71.19	
549.5	71.53	
551.5	71.86	0.86
553.5	72.2	1.16
555.5	72.53	1
557.5	72.86	0.79
559.5	73.2	0.92
561.5	73.53	0.63
563.5	73.87	1.09
565.5	74.2	0.78
567.5	74.53	0.9
569.5	74.87	0.7
571.5	75.2	0.86
573.5	75.54	0.88

575.5	75.87	0.83
577.5	76.2	0.75
579.5	76.54	0.8
581.5	76.87	
583.5	77.21	1.11
585.5	77.54	1.14
587.5	77.87	1.36
589.5	78.21	1.28
591.5	78.54	1.03
593.5	78.88	1.18
595.5	79.21	0.97
597.5	79.54	0.9
599.5	79.88	0.85
601.5	80.21	0.81
605.5	80.88	0.8
609.5	81.55	0.7
613.5	82.22	0.69
617.5	82.88	0.72

Supplement 2

Figure S1 Composite stable carbon isotope records for the interval ~62–28 ka B.P. of KL11, representing the vital effect-corrected averages of *Cibicides mabahethi*, *Discorbinella bertheloti* s.l. and *Hanzawaia boueana* s.l. (blue line) while the orange line excludes *H. boueana*. The inclusion of *H. boueana* allows to complete the isotopic record along the MIS 3, especially with two samples where the two other species are absent. The composite record without *H. boueana* follows the same pattern and closely resembles the composite record with *H. boueana* included.

