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Supplement of

Bottom-water deoxygenation at the Peruvian margin during the last deglaciation recorded by benthic foraminifera

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Supplementary Information: Figures and Tables

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Figure S.1. Graph showing the relative percentage (% total calcareous) distributions of abundant living benthic foraminifera. X-axis indicates the stations (water depth(m)) which are grouped according to the prevailing bottom-water-oxygen concentrations (black for microxic (<5 µmol/kg), orange for dysoxic (5-45 µmol/kg), green for oxic (>45 µmol/kg)).
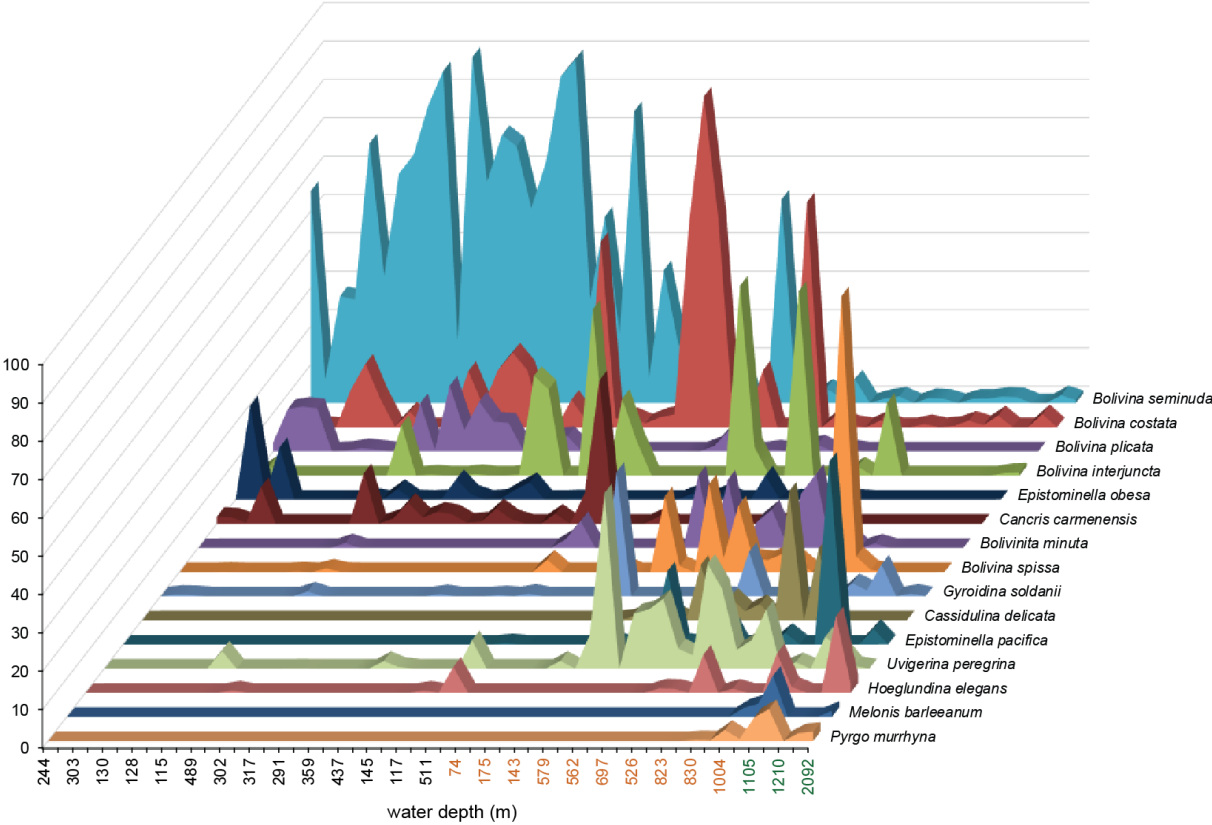
Figure S.2: *Q*-mode hierarchical cluster analysis (UPGMA Bray-Curtis similarity index) applied on living taxa.
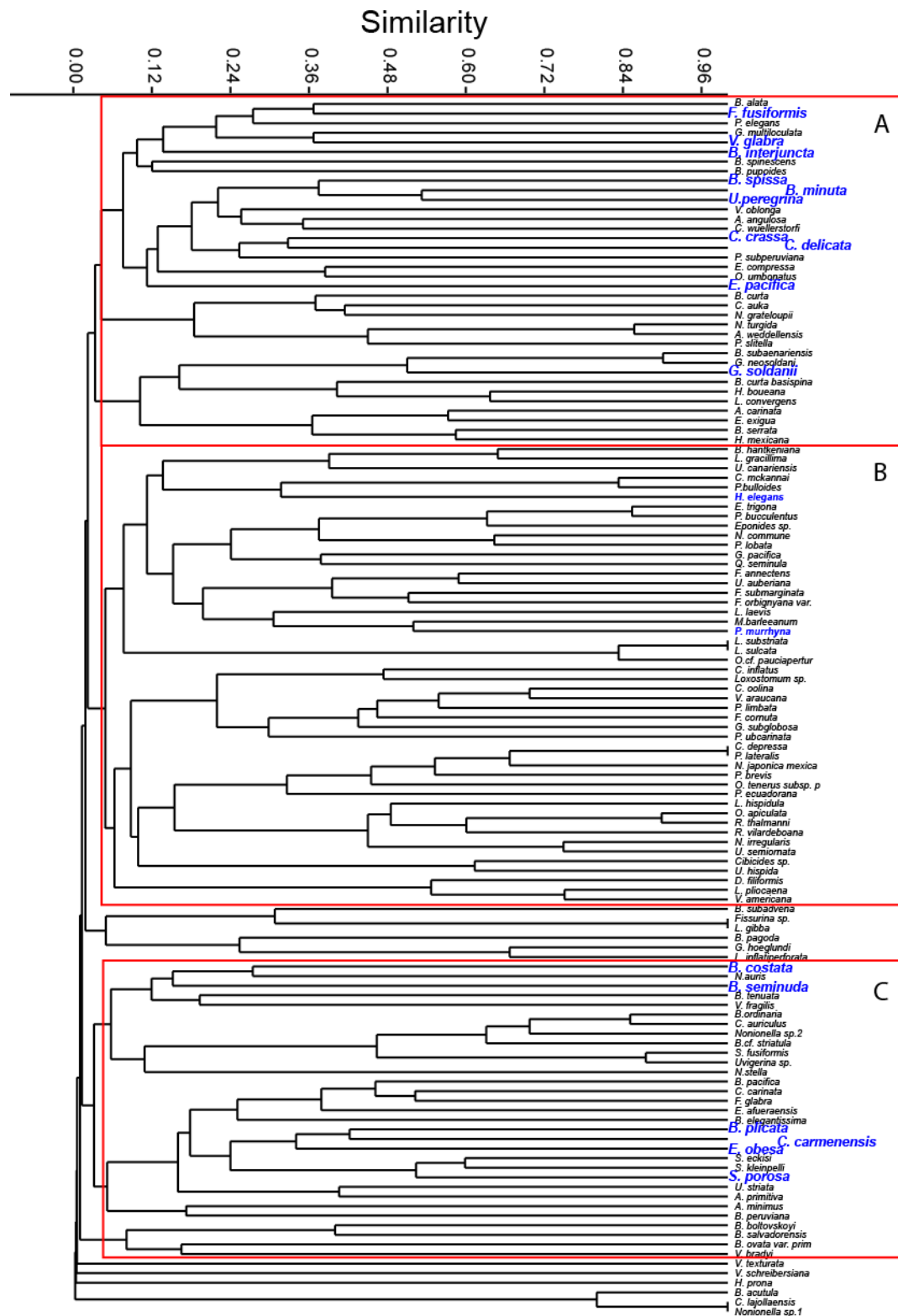
Figure S.3: Canonical Correspondence Analysis (CCA) results applied to living foraminifera census dataset. Blue dots indicate the species and crosses indicate the samples. Abundant species included in the quantification approach together with species mentioned in the text are shown in bold and with their names.
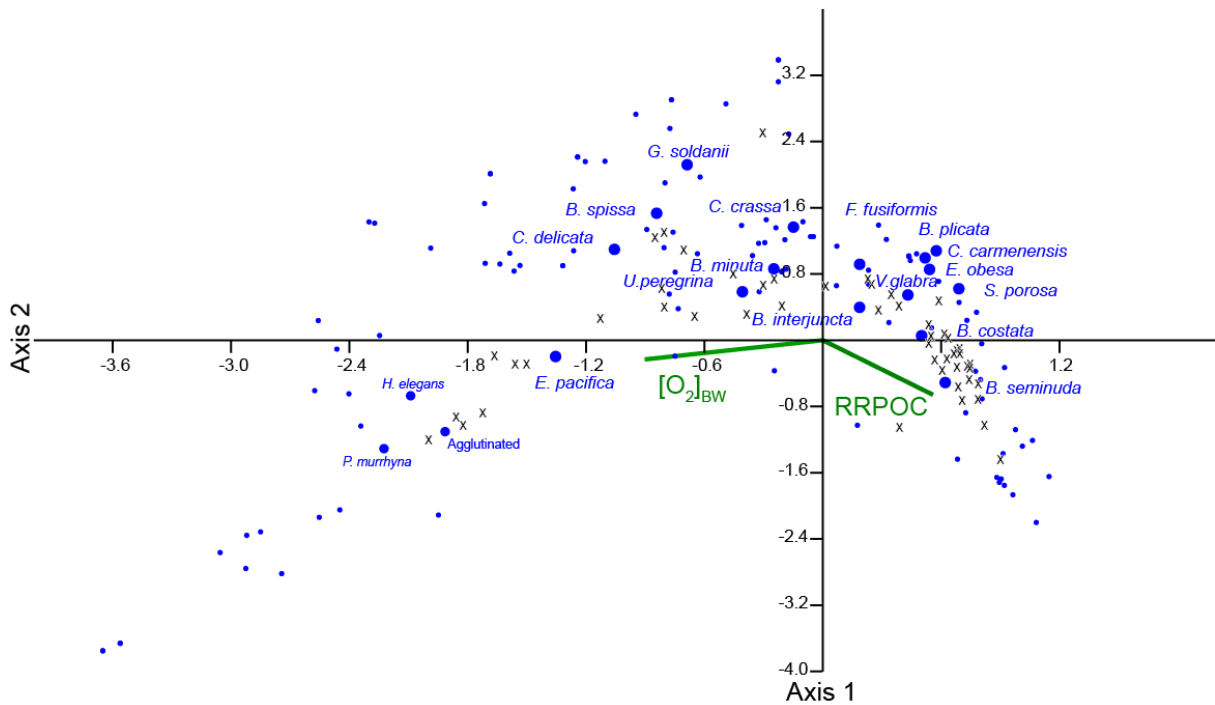

Figure S.4: Canonical Correspondence Analysis (CCA) results applied to reduced dataset (the most abundant 16 species) considered in this study. Blue dots indicate the species and black dots indicate the sample locations. Both in census dataset and reduced dataset certain species showed similar relationship with $[O_2]_{BW}$. For example: *E. pacifica* showing a positive relation with increasing oxygen whereas *B. plicata* group in with similar species showing a negative relation with oxygen concentrations. CCA results also show that the 'oxic' samples are not well represented in this dataset (fewer sampling stations fall positive side of the $[O_2]_{BW}$.
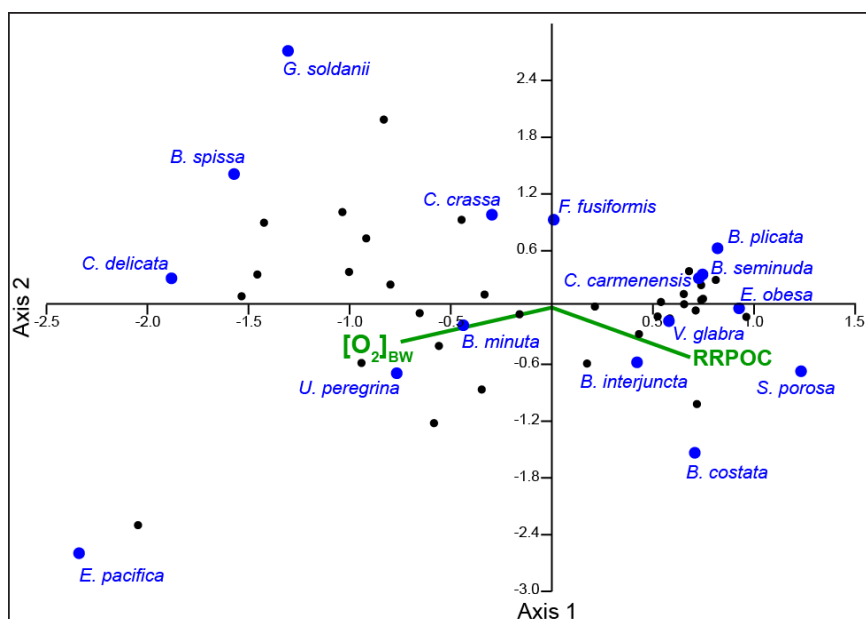
Supplementary information Table 1. Results of bottom-water oxygenation estimations ($[O_2]_{BW}$) in 3 sediment cores with the core depth and calibrated age point information.

	M77/2-50-4 8°S 1013 m				M77/2-52-2 5°S 1249 m				M77/2-59-1 3°57'S 997 m			
	Core depth (cm)	Age (cal ka)	$[O_2]_{BW}$ (µmol/kg)	error	Core depth (cm)	Age (cal ka)	$[O_2]_{BW}$ (µmol/kg)	error	Core depth (cm)	Age (cal ka)	$[O_2]_{BW}$ (µmol/kg)	error
late Holocene					90	3.1	32.40	12.42	143	3	8.91	21.88
					110	3.8	25.58	14.18	163	3.4	6.79	22.14
		HIATUS			120	4.2	31.01	12.11	183	3.8	-9.91	28.54
					130	4.5	23.29	14.41	203	4.2	3.84	22.85
					140	4.9	31.30	11.98	223	4.5	11.36	20.88
									243	4.8	25.37	15.68
early Holocene					230	8.1	13.67	16.88	403	8.1	30.76	14.64
					240	8.5	18.43	14.22	443	8.6	22.20	17.46
		HIATUS			250	8.8	30.15	12.15	483	9.1	19.84	17.82
					260	9.2	25.81	12.75	523	9.6	11.15	20.44
					270	9.5	24.85	12.94	563	10.1	13.25	20.38
					280	9.9	19.74	14.66				
BA/ACR	70	13.5	12.05	17.45	350	12.7	25.47	14.58	803	13.1	17.98	18.95
	80	14.1	9.97	18.32	360	13.2	9.90	20.27	843	13.5	36.47	12.17
	90	14.4	15.02	16.03	370	13.6	43.91	11.39	883	13.9	49.34	9.74
	100	14.6	14.13	13.71	380	13.8	35.62	12.04	923	14.2	48.87	10.03
	110	14.8	23.89	13.71	390	14	53.07	10.10	963	14.6	63.32	8.12
Heinrich Stadial 1	130	15.3	21.54	15.48	400	14.3	51.85	9.13	1043	15.1	34.55	13.28
	150	15.8	29.55	13.86	410	14.6	56.22	8.74	1163	15.6	43.56	11.53
	170	16.3	26.16	20.62	420	15	46.66	12.53	1243	16.3	57.41	9.05
	190	16.8	37.23	12.23	430	15.3	52.94	11.59	1323	17.1	59.96	9.09
	210	17.2	30.68	17.35	440	16.1	58.08	10.46				
	230	17.6	40.20	13.79	450	16.3	55.73	9.79				
Last Glacial Max	330	20	39.40	15.56	500	19.1	58.74	8.46				
	340	20.3	40.96	16.68	510	19.5	60.88	8.21				
	350	20.6	39.68	13.74	520	19.9	55.1	9.36				
	370	20.9	42.93	13.63	530	20.6	58.49	10.06		NO RECORD		
	390	21.2	35.89	14.61	540	22.2	52.2	10.72				
	410	21.4	43.12	11.97								
	430	21.7	40.05	9.70								
	450	22	35.44	13.16								

Information on polynomial transfer function and description to calculations

The polynomial transfer function is given in the form of eq.1:

Eq.1:
$$x = C + \sum RCo_n \cdot \%_n$$

where x is the environmental variable that should be reconstructed with the transfer function (in this case $[O_2]_{BW}$ or RRPOC); C is a constant from the multiple regression (tab. 5); RCo_n is the regression coefficient for the foraminiferal species n (tab. 5); and $\%_n$ is the percentage of the foraminiferal species n within the assemblage.

For the calculation of the errors for x (i.e. $[O_2]_{BW}$ or RRPOC) a complete error propagation has been done including the 1σ errors of all species within the polynomial transfer function. The error propagation has been applied to the polynomial transfer function (Eq. 1) in the form of equation Eq. 2:

Eq.2:
$$\sigma_x = \sqrt{\left(\frac{\partial x}{\partial C} \cdot \sigma_C\right)^2 + \sum \left(\frac{\partial x}{\partial RCo_n} \cdot \sigma_{RCo_n}\right)^2 + \sum \left(\frac{\partial x}{\partial \%_n} \cdot \sigma_{\%_n}\right)^2}$$

where σ_x is the standard deviation (1sd) of the environmental variable x (i.e. $[O_2]_{BW}$ or RRPOC) σ_C is the error of the constant C (tab.5); σ_{RCo_n} is the standard error for the regression coefficient RCo for the foraminiferal species n (tab.5); and $\sigma_{\%_n}$ is the standard error for $\%_n$. Solution of the derivatives in Eq.2 results in Eq.3:

Eq.3:
$$\sigma_x = \sqrt{\sigma_C{}^2 + \sum\left(\%_n \cdot \sigma_{RCo_n}\right)^2 + \sum\left(RCo_n \cdot \sigma_{\%_n}\right)^2}$$

We have to state that we neglect the last term in equations 2 and 3 because we do not know $\sigma_{\%_n}$, since three replicates would be necessary for each sample to determine this error. In this study all downcore samples were counted by a single investigator. Previous studies showed that population densities of sample replicates, which have been picked dry by a single investigator had an accuracy (1σ) of ± 2 % (Schönfeld et al., 2013). Thus, in comparison with the high σ_C and σ_{RCo_n} (tab.5) the error $\%_n$ should be negligible. Nevertheless, the proportions of frequent species within the same assemblage may differ by 2–7 % between different picking modes or laboratories (Schönfeld et al., 2013).

Links to open access datasets related to this study

Living benthic foraminifera (rose Bengal stained) dataset can be reached through the following link:

https://doi.pangaea.de/10.1594/PANGAEA.901840

Radiocarbon ages of core M77/2-52-2: https://doi.pangaea.de/10.1594/PANGAEA.877426

Radiocarbon ages of core M77/2-50-4: https://doi.pangaea.de/10.1594/PANGAEA.902616

Reference

Schönfeld, J., Golikova, E., Korsun, S., Spezzaferri, S.: The Helgoland Experiment – assessing the influence of methodologies on Recent benthic foraminiferal assemblage composition, Journal of Micropaleontology, 32, 161-182, doi: 10.1144/jmpaleo2012-022, 2013.