Supplementary Materials to accompany: ***"Size-dependent response of foraminiferal calcification to seawater carbonate chemistry"*** by Henehan, Evans *et al.*

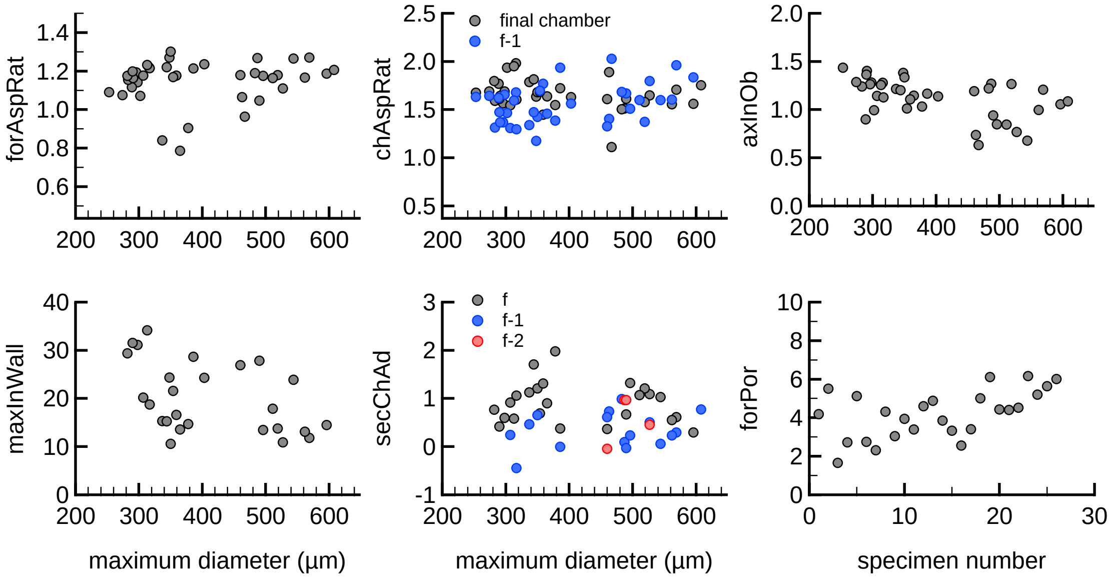

Figure S1: Measurements of *G. ruber* used to constrain the initial model parameters. These are based on core-top *G. ruber* from the equatorial Atlantic; see main text Section 2.4.1 for full description. Because we observe no significant trend in any of these parameters as a function of size, we use the mean of all measurements to derive the numbers stated in the main text Table 1. Accurate measurements of test diameter were not available for samples used to measure porosity ('forPor', bottom right panel), which are instead plotted against specimen number. We note that these specimens span a smaller size range than those from which the other measurements were taken (250-425 μm), so we cannot constrain possible ontogenetic changes in porosity based on this dataset. See main text Table 2 for definitions.

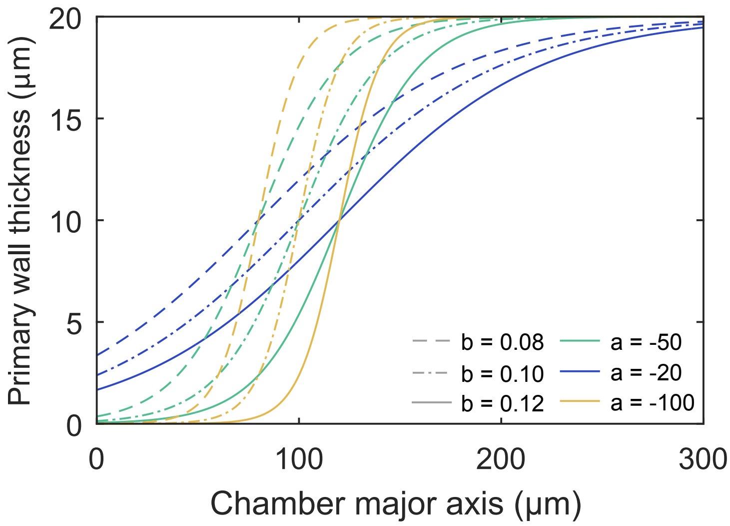

Figure S2: Schematic illustration of the effect of constants a and b on the relationship between wall thickness and test size.

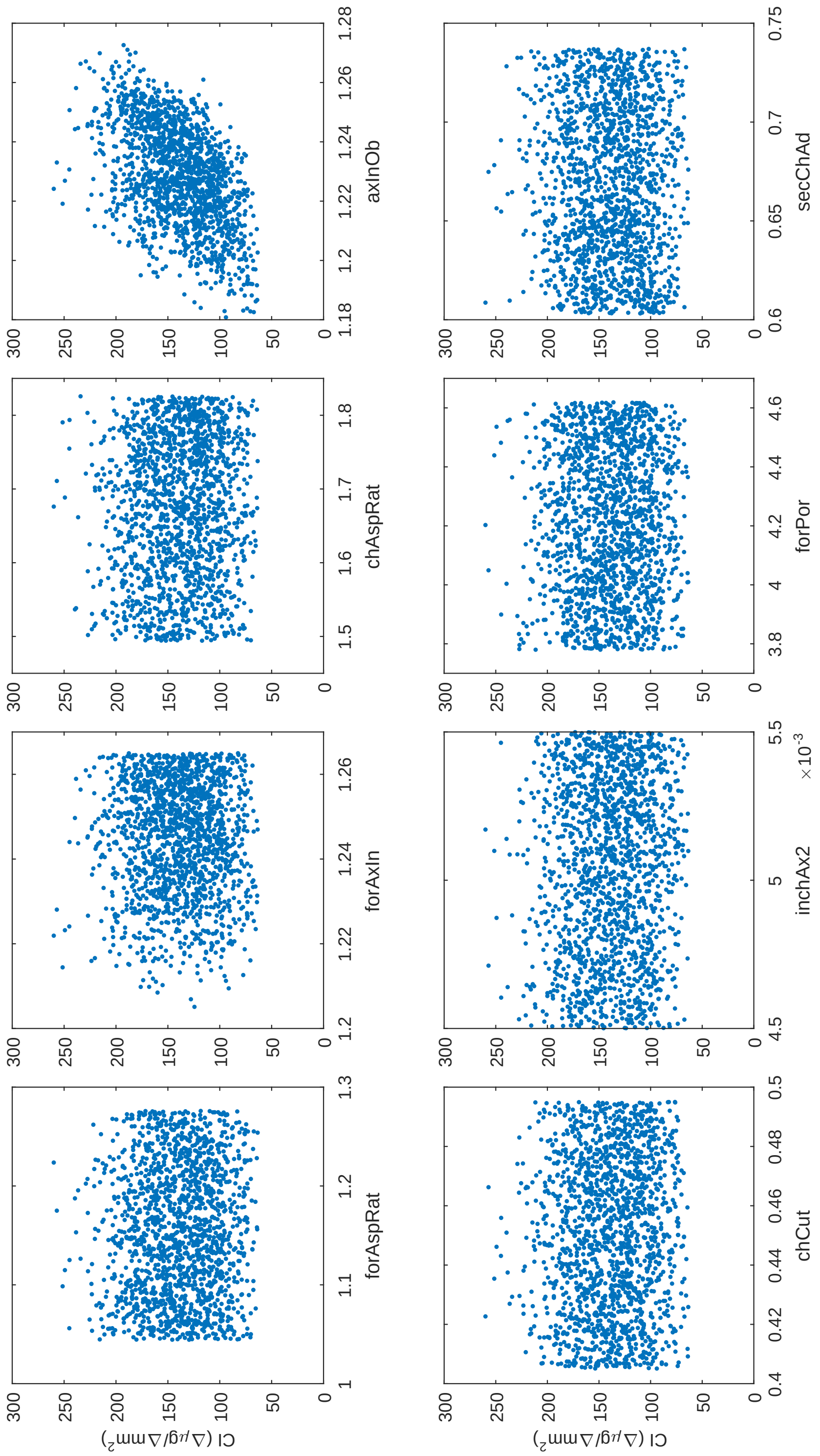

Figure S3: Relationship between model CI and input parameters. Model parameters were allowed to vary randomly and independently of each other. The relationship between modelled CI against all input parameters is plotted (at a body size of ∼0.1 mm^2, for the case of two chamber additions). None of these parameters alone drives CI, which as we discuss in the main text, has the implication that a change in one may be offset by a change in another (that shifts CI in the opposite direction) in order to produce foraminifera that conform – within tolerances – to the observed size-weight relationship for this species. This leaves wall thickness to dominate CI change, with the possible exception of 'axInOb', which is the ratio of the major axis of any given chamber to the major axis of the chamber that proceeded it. See main text Table 2 for parameter descriptions.

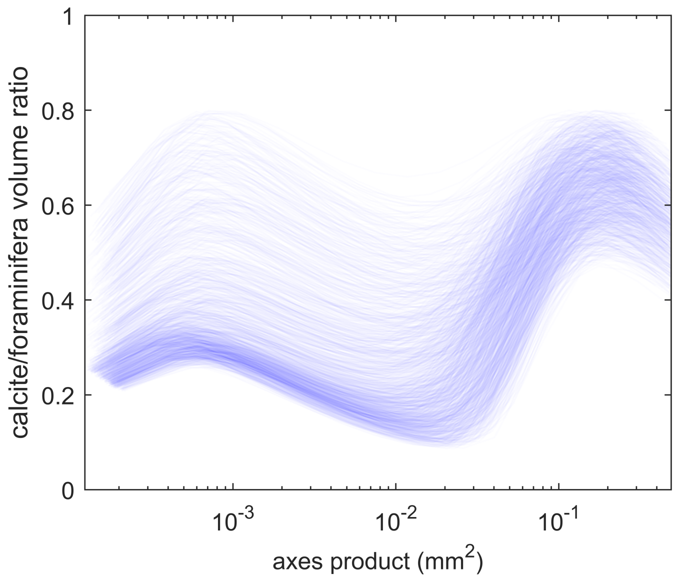

Figure S4: Modelled variation in volume-normalised mass through ontogeny. Main text Section 4.2 deals with the complication associated with using size-normalised shell weight of foraminifera from wide size fractions to reconstruct calcification, namely that doing so assumes no dependency of such metrics on body size which we demonstrate is unlikely to be the case. It has similarly been suggested that volume normalisation may be used to reconstruct past changes in calcification (Foster *et al.*, 2013). As a comparative exercise, this figure shows the model output of the evolution of the foraminifer calcite volume/total volume ratio through ontogeny. The majority of models predict that this ratio changes substantially over the body size range of interest, indicating that volume normalisation is unlikely to be a useful metric of calcification unless measured on samples of equivalent size/ontogeny.

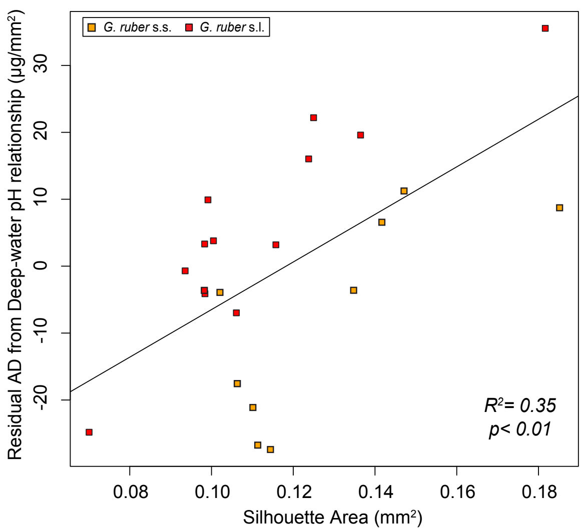

Figure S5: Residual variation in ρ_A around the relationship with deep ocean pH is significantly correlated with test silhouette area (R^2=0.35, $p < 0.01$).

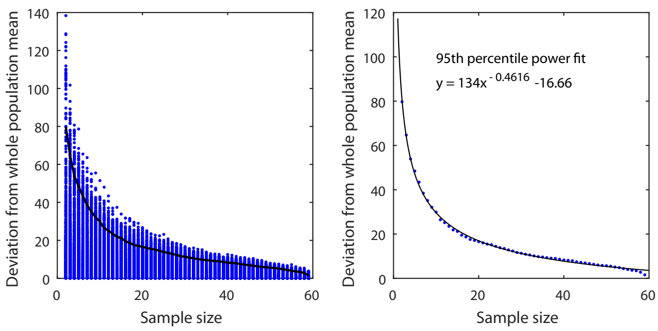

Figure S6: The relationship used to calculate our bounds of uncertainty on culture CI data. With repeated subsamples from a large population of cultured individuals, the deviation of the mean of that subsample from the true mean was calculated. This allowed us to consider the effect sampling small numbers from a population with a large degree of inter-individual variability.

Table S1: Measurements of *G. ruber* used to constrain the initial model parameters. See main text table 1 for definitions. Numbers are dimensionless except where stated. f, f-1 and f-2 refer to the final, penultimate and antepenultimate chambers respectively.

ax_1 (μm)	forAspRat	chAspRat (f)	chAspRat (f-1)	axInOb	wallTh (μm)	secChAd (f)	secChAd (f-1)	secChAd (f-2)
569	1.27	1.71	1.96	1.21	11.8	0.61	0.30	
365	0.79	1.64	1.46	1.15	13.5	0.90		
487	1.27	1.51		1.27			0.09	0.97
527	1.11	1.65	1.80	0.77	10.9	1.09	0.50	0.45
463	1.06	1.89	1.40	0.74			0.73	
490	1.05	1.61	1.67	0.94	27.8	0.67	-0.03	0.97
460	1.18	1.61	1.33	1.19	26.9	0.36	0.61	-0.04
519	1.18	1.58	1.37	1.27	13.8	1.21		
467	0.96	1.11	2.03	0.63				
378	0.90	1.55	1.39	1.03	14.7	1.98		
302	1.07	1.93	1.47	0.99				
298	1.14	1.69	1.65	1.28	31.1	0.60		
289	1.12	1.77	1.62	0.90				
253	1.09	1.68	1.63	1.43				
296	1.19	1.57	1.37	1.26				
283	1.16	1.59	1.31	1.24				
348	1.27	1.64	1.18	1.38	24.3			
307	1.18	1.55	1.31	1.14	20.2	0.91	0.24	
274	1.07	1.69	1.64	1.29				
316	1.22	1.98	1.68	1.28				
291	1.16	1.64	1.37	1.40				
317	1.21	1.60	1.30	1.13	18.8	1.06	-0.44	
350	1.30	1.68	1.43	1.34	10.6	1.21	0.66	
282	1.18	1.80			29.4	0.77		
313	1.23	1.95	1.59	1.25	34.2	0.58		
290	1.20	1.61	1.47	1.36	31.5	0.42		
386	1.21	1.72	1.94	1.17	28.7	0.38	-0.01	
337	0.84	1.79	1.34	1.21	15.3	1.13	0.46	
344	1.22	1.82	1.47	1.20	15.2	1.71		
403	1.24	1.63	1.56	1.14	24.3			
359	1.18	1.45	1.77	1.11	16.6	1.31		
354	1.17	1.68	1.70	1.01	21.6	0.69		
496	1.18		1.51	0.85	13.4	1.32	0.23	
544	1.27		1.60	0.68	23.9	1.03	0.06	
511	1.16		1.60	0.85	17.8	1.07		
596	1.19	1.56	1.83	1.06	14.5	0.30		
608	1.21	1.75		1.09			0.77	
483	1.19	1.50	1.68	1.22			0.99	
562	1.17	1.56	1.61	1.00	13.1	0.55	0.23	

Table S2: Core-top shell weight measurements, with *in situ* carbonate system estimates. Deepwater saturation and pH is derived from Goyet *et al.* (2000), calculated from bathymetry, dissolved inorganic carbon concentrations and total alkalinity using van Heuven *et al.* (2011).

Site	**Lat. (°N)**	**Long. (°E)**	**Species**	**Sieve Size Fraction (μm)**	n	**Mean ρ_A (μg/ mm^{-2})**	**±2sd**	**Mean Silhouette Area**	**±2sd**	**Surface pH**	**±2sd**	**Deep water pH**	**Deep water $\Omega_{calcite}$**
MC497	23.53	63.31	ruber ss	250-300	25	72.4	26.0	0.114	0.032	8.156	0.020	7.726	1.46
MC423	17.75	-65.59	ruber sl	250-300	26	129.4	35.2	0.098	0.025	8.174	0.011	7.969	1.74
MC423	17.75	-65.59	ruber sl	250-300	26	129.9	10.5	0.098	0.025	8.174	0.011	7.969	1.74
MC423	17.75	-65.59	ruber ss	250-300	26	106.8	29.0	0.111	0.027	8.174	0.011	7.969	1.74
MC420	17.04	-66.00	ruber sl	250-300	26	113.0	37.1	0.100	0.021	8.173	0.013	7.794	0.78
MC420	17.04	-66.00	ruber ss	250-300	25	88.0	45.8	0.110	0.031	8.173	0.013	7.794	0.78
MC577-17b	45.57	-17.40	ruber sl	250-300	26	116.8	31.7	0.094	0.028	8.188	0.004	7.854	0.88
FR1/97-GC09	-22.90	152.64	ruber sl	300-400	24	156.8	45.2	0.136	0.030	8.169	0.013	7.995	4.06
FR1/97-GC09	-22.90	152.64	ruber ss	300-400	20	148.5	72.8	0.147	0.050	8.169	0.013	7.995	4.06
Q633	-38.46	148.89	ruber sl	250-300	25	90.9	33.3	0.070	0.028	8.193	0.001	7.841	1.15
MC436	39.80	-21.06	ruber sl	300-355	16	126.1	32.2	0.116	0.028	8.201	0.017	7.892	0.92
MC120	12.47	45.38	ruber ss	300-355	26	140.6	13.3	0.102	0.031	8.092	0.068	8.048	2.98
MC655	38.42	5.40	ruber ss	250-300	23	118.3	17.8	0.106	0.022	8.161	0.050	7.985	2.54
MC655	38.42	5.40	ruber sl	250-300	26	139.1	34.7	0.098	0.025	8.161	0.050	7.985	2.54
G4	-28.42	167.25	ruber sl	300-355	23	146.5	26.8	0.125	0.025	8.207	0.030	7.902	1.91
J39	-37.00	170.00	ruber sl	300-355	8	114.6	60.0	0.099	0.019	8.188	0.010	7.762	1.02
GGC48	0.00	161.00	ruber ss	300-355	24	108.1	30.5	0.142	0.087	8.108	0.044	7.739	0.79
GGC48	0.00	161.00	ruber sl	300-355	26	94.5	33.9	0.106	0.054	8.108	0.044	7.739	0.79
T327	-11.51	174.51	ruber ss	300-355	25	104.0	33.3	0.135	0.074	8.159	0.026	7.783	1.14
T327	-11.51	174.51	ruber sl	300-355	25	123.7	29.6	0.124	0.058	8.159	0.026	7.783	1.14
T329	-12.96	173.57	ruber sl	300-355	24	146.5	18.9	0.182	0.050	8.175	0.023	7.807	1.68
T329	-12.96	173.57	ruber ss	300-355	24	119.7	20.4	0.185	0.048	8.175	0.023	7.807	1.68

Table S3: Regression coefficients for multiple linear regression analysis of controls on area density (ρ_A) in core-tops. Deep ocean pH, shell size (as parameterised by shell silhouette area) and species (*G. ruber* sensu stricto *vs.* sensu lato) are significant controls on area density. Note that surface ocean pH has no significant contribution to the model, and according to Akaike Information Criteria it would be removed from the model. However, we list it here for illustrative purposes to demonstrate the lack of surface ocean pH control as its inclusion does not significantly alter the other coefficients or overall model fit. Other related parameters such as $[CO_3^{2-}]$ (Model $R^2 = 0.69$) and $\Omega_{calcite}$ (Model $R^2 = 0.70$) at the site of coretops were also tested in lieu of pH, but model fits were weaker in both cases, and so pH at the site of coretop is preferred here (R^2=0.86, see below).

Regression Coefficients:				
	Coefficient	S.E.	p	
(Intercept)	-620.21	562.56	0.29	
Deep Ocean pH	165.74	17.86	4.58×10^{-8}	*
Silhouette Area (mm^2)	503.77	70.04	1.50×10^{-6}	*
Species	24.24	4.13	1.85×10^{-5}	*
Surface Ocean pH	-81.14	68.42	0.25	
		**indicates significance to* p <0.001		
Residual standard error:	8.26	(d.f. = 17)		
R^2 (adjusted):	0.86			
F-statistic:	32.6	(on 4 and 17 d.f.)		
Model p-value:	9.06×10^{-8}			