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Climate of the Past Discussions

Interactive comment on "Variations in intermediate and deep ocean circulation in the subtropical northwestern Pacific from 26 ka to present based on a new calibration for Mg/Ca in benthic foraminifera" *by* Y. Kubota et al.

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We thank the reviewer for reviewing our manuscript and recommending publishing. We believed that comments and suggestions by them had led to improved quality of the manuscript. The following is our reply to queries and comments raised.

Reply to reviewer #1

Reply to major comments:

Mg/Ca calibration:

Concerning Mg/Ca calibration, we thank his/her constructive comments that suggested that we should consider carbonate ion influence and draw comparison with previous calibrations. First, as suggested, we add plots of Mg/Ca values versus depth and calcite saturation state, Δ[CO32−]. Calcite saturation state in this area is estimated CO2sys.xls (Ver. 12) (Pelletier et al., 2005) with parameters including pressure, bottom water temperature (BWT) (°C), salinity, total CO2 (μmol/kg), and alkalinity (μmol/kg). BWT and salinity data are from World Ocean Atlas station #664355 (Locarnini, et al., 2013; Zweng et al., 2013), and total CO2 (μmol/kg), and alkalinity (μmol/kg) are from Global Ocean Data Analysis Project (GLODAP) site #28582 (Key et al., 2004). The equilibrium constants K1 and K2 are those from Dickson and Mellero (1987), and the dissolution constant KSO4 for the bisulfate ion is from Dickson (1990). Carbonate saturation state is defined as Δ[CO32−]=[CO32−]−[CO32−]sat. [CO32−]sat is calculated by [CO32−]sat =[CO32−] /Ω, where Ω is the solubility ratio of calcite.

Previous studies show that Mg/Ca of a benthic foraminifera C. wuellerstorfi are controlled not only by temperature but also by carbonate chemistry of seawater, especially at lower temperatures (lower carbonate ion saturation state) (Elderfield et al., 2006; Yu and Elderfield, 2008; Raitzsch et al., 2008; Healey et al., 2008). Raitzsch et al. (2008) argued that Mg/Ca from C. wuellrestorfi is more dependent on dissolved inorganic carbon (DIC=[CO2]aq+[HCO3−]+ [CO32−]) rather than on Δ[CO32−]. Δ[CO32−] decreases with decreasing [CO32−], while DIC increases with decreasing [CO32−]. Since both Δ[CO32−] and DIC are linked to [CO32−], here Δ[CO32−] is used to discuss the influence of the carbonate ion.

Mg/Ca of the surface sediment samples versus depth, bottom water temperature (BWT), and Δ[CO32−] are plotted in Fig. 1. In Fig. 1a, Mg/Ca drops rapidly with depth to ∼1000 m water depth, resulting from steeper gradient of BWT and Δ[CO32−] in upper 1000 m in the water column. On the other hand, a slope of the Mg/Ca to the water depth became gentle due to lower gradient of BWT and Δ[CO32−]. Mg/Ca dependence on BWT had been already described in our previous manuscript. Our

Mg/Ca data show a strong positive correlation with Δ[CO32−] (R2 =0.97). Mg/Ca dependence on Δ[CO32−] is 0.016 mmol/mol per umol/kg. However, the two effects are hardly quantified because there is a robust relationship between them in a wider range. Then we use the modern BWT vs Δ[CO32−] diagram in order to discuss more about the each effects of BWT and Δ[CO32−] on Mg/Ca. In a lower BWT range (< $\sim$ 5°C) the modern Δ[CO32−]s are relatively constant ($\sim$10 umol/kg), where BWT effect can be solely evaluated (Fig. 1d). Then, the correlation becomes weaker in the lower BWT range (< $\sim$ 5°C) but is still statistically significant (R2=0.57, p <0.0001, Fig. 1e). The slop of this relationship becomes lower than that in the wide BTW range, suggesting the carbonate ion effect appears to amplify the BWT sensitivity due to the positive relationship between BWT and Δ[CO32−]. Δ[CO32−] sensitivity at BWTs below $\sim$5 °C, where the previous studies reported higher Δ[CO32−] sensitivity (<25 umol/kg) (Elderfield et al., 2006; Yu and Elderfield, 2008), cannot be evaluated by our study since the variation range of the modern Δ[CO32−] is narrow at these BTWs. Although the sensitivity of 0.10 mmol/mol per °C is slightly higher than that for C. wuellerstorfi with Δ[CO32−] correction of Yu and Elderfield (2008) (0.03-0.07 mmol/mol per °C), it is close to sensitivity for Uvigerina spp in the Pacific (0.10 mmol/mol per °C) that little affected by bottom water carbonate saturation because of its infaunal habitat (Elderfield et al., 2012).

For comparison with previous calibrations, all of the published Mg/Ca data for C. wuellerstorfi are plotted (Fig. 2a). A number of data came from the Atlantic but limited in temperature range (<$\sim$6 °C), and less from the Pacific and other ocean basins. The temperature range was extended to 8.7 °C in Pacific by a data set from Rathburn and De Decker (1997) in which neither oxidative nor reductive cleaning steps had been conducted. Most of the published Mg/Ca data were scattered more or less around one linear line ($\sim$0.5 mmo/mol per °C) except for those from Norwegian Sea that has very low BWT and high bottom water Δ[CO32−] (Yu and Elderfield, 2008). Our Mg/Ca data are deviated from previous data at higher temperatures ($\sim$>4-5 °C), and mostly show lowest values than data from both the Atlantic and Pacific.

Difference in cleaning procedure should be taken into account because a cleaning step without oxidative or reductive steps sometimes increases Mg/Ca values by more than $\sim$1 mmol/mol (Baker et al., 2003). The Pacific Mg/Ca data from Rathburn and De Decker (1997) were produced with the cleaning step without oxidative or reductive steps, and those from Martin et al. (2002) that originally from Rosenthal et al. (1997) were done with both steps. The Rathburn and De Decker' s data appeares to follow the linear fitting line, and also data from Martin et al. (2002), thus, the those values are unlikely raised by the different cleaning procedure. In addition, difference in obtained Mg/Ca between the oxidative and reductive methods is relatively small ($\sim$0.09 mmol/mol) (Yu and Elderfield, 2008). Therefore, the lowest sensitivity of Mg/Ca on the temperature is not due to the difference in the cleaning protocols. This sensitivity difference is explained to some extent by the carbonate ion effect but not all as discussed below. At a bathyal depth (1200 m case in Key et al., 2004) the total alkalinity (TA) and DIC show substantial south to north gradients in the Pacific (Key et al., 2004). The 1200-m DIC gradients are greater than those for TA reflecting lower [CO32−] (Δ[CO32−]) in the high and mid-latitude North Pacific than equatorial and South Pacific ([CO32−]$\sim$TA-DIC). The higher Mg/Ca in the Coral Sea (Rathburn and De Decker, 1997) and Ontong Java Plateau (Martin et al., 2002) may be explained partly by their higher Δ[CO32−] than those in the western subtropical North Pacific.

In order to look into the relationship between Mg/Ca and Δ[CO32−] these data together with previously published data are plotted in Fig. 2b. Only three literatures presents Δ[CO32−] values together with their Mg/Ca values (Elderfield et al., 2006; Yu and Elderfield et al., 2008; Raitzsch et al., 2008; Tisserand et al., 2013). Among these data Mg/Ca values from Tisserand et al. (2013) appear to be deviated from the other data. Except for Tisserand's data, there is a positive correlation (R2=0.87) between the BWT and Δ[CO32−] in a wide range. The sensitivity of the Mg/Ca on Δ[CO32−] (0.016 mmol/mol per umol/kg) is rather higher than 0.0083-0.010 mmol/mol per umol/kg reported by the previous works (Elderfield et al., 2008; Healey et al., 2008; Raitzzsch et al., 2008; Yu and Elderfield, 2008). This might be due to a steeper temperature rise versus $\Delta[CO32-]$ in the subtropical northwestern Pacific than in other regions (Fig. 2c).

Yu and Elderfield (2008) concluded that considering $\Delta[CO32-]$ factor gave a satisfactory explanation for difference in absolute Mg/Ca values of C. wuellerstorfi among different oceanic basins. In their study the Mg/Ca sensitivity on temperature decrease to 0.3∼0.7 mmol/mol per °C if $\Delta[CO32-]$ effect is taken into account. In contrast, Tisserand et al. (2013) shows a much different Mg/Ca dependence on temperature (19% increase per °C) even when $\Delta[CO32-]$ effect can be negligible (Fig. 2a). That is, these results suggest that the slop of the temperature to Mg/Ca could change depending on $\Delta[CO32-]$ even among same species. As mentioned by Marchitto et al. (2007), benthic foraminifera would incorporate less Mg/Ca when calcifying in both undersaturated and very supersaturated conditions. Yu and Elderfield (2008) suggested a possible existence of a $\Delta[CO32-]$ threshold for changes in C. wuellrestorfi Mg/Ca at 25 μmol/kg. When $\Delta[CO32-]$ is <25 μmol/kg, C. wuellrestorfi Mg/Ca seems to be less sensitive to temperature changes. However, at this moment the other threshold cannot be adequately identified without a larger data set extending into super saturated waters for C. wuellrestorfi. In addition, we cannot exclude a possibility that difference in C. wuellrestorfi types might affect Mg/Ca dependence through physiological differences.

It is interesting to show a comparison between our Mg/Ca and Cibicidoides pachyderma. Among other Cibicidoides species Mg/Ca of C. pachyderma in the Florida Strait from Marchitto et al. (2007) fits well with our Mg/Ca of C. wuellerstorfi type B in Mg/Ca-BWT plots (Fig. 2e). These Mg/Ca data are in good agreement with our Mg/Ca in Mg/Ca-BWT plot although it is more more scattered in Mg/Ca-$\Delta[CO32-]$ plot (Fig. 2e). An overlapping variation patter of BWT versus $\Delta[CO32-]$ might lead to the similarity in Mg/Ca values between C. wuellerstorfi B and C. pachyderma (Fig. 2g). Alternatively, one might argue that the similarity results from their common habitat or physiological characteristics. Raitzsch et al. (2008) argued that the interspecies differences in microhabitat might explain Mg/Ca differences. Typical C. wuellerstorfi prefers

elevated position above the sediment-water interface (Lutze and Thiel, 1989), while C. pachyderma, similar to C. mudulus, live in deeper depth but within the sediment-water interface (Rathburn and Corliss, 1994). Although our knowledge on ecology of C. wuellerstorfi type B is very poor, C. wuellerstorfi type B might be influenced by the low pH pore water easier than typical C. wuellerstorfi if it lives in deeper depth than typical C. wuellerstorfi.

Downcore reconstruction:

He/She concerned about the possible carbonate ion effect on the downcore Mg/Ca result, thus we add discussion about it. Based on the positive relationship between BWT and Mg/Ca at temperatures below 5°C, we regards BWT as a still important factor that control Mg/Ca even at lower $\Delta[CO32-]$ where though the temperature sensitivity became weaker. As described later, we add a qualitative proxy for carbonate saturation state, suggesting that $\Delta[CO32-]$ unlikely affects the downcore Mg/Ca variation.

-Conversion of foraminiferal Mg/Ca to temperature:

In the revised manuscript we report two Mg/Ca-BWT conversion equations depending on temperature range. Equation (1) contains the carbonate ion component, while equation (2) does little. Beside, modern BWT of the core site is 3.0 °C that is within the range of equation (2). Therefore, equation (2) is more appropriate for conversion of downcore Mg/Ca record. Using equation (2) (sensitivity of 0.10 mmol/mol per °C) the variability of the BWT becomes larger than equation (1) (sensitivity of 0.14 mmol/mol per °C) due to lower temperature sensitivity. However, difference between estimated and measured temperature (ΔBWTmearure-estimated) are largere in equation (2) because of the more gradual temperature sensitivity. The average ΔBWTmearure-estimated is about ±0.8 °C that is applied to the error for downcore BWT record.

-Evaluation of carbonate saturation effect on Mg/Ca:

Although the core site is located well above the carbonate lysocline depth (∼2000 m in the subtropical northwestern Pacific; Feely et al., 2004), the potential effect of $\Delta[CO_3^{2-}]$ should be evaluated when interpreting downcore Mg/Ca record. In order to estimate the carbonate ion effect on the temporal Mg/Ca changes, we present another proxy, an index using Globorotalia menardii fragmentation, which could reflect the carbonate saturation state though it is qualitative. Tests of palnktic foraminifer G. menardii are sensitive to carbonate dissolution, and attrition of G. menardii tests correlates well with the fraction of calcite dissolved (Ku and Oba, 1978; Mekik et al., 2002). All specimens of G. menardii were picked from an assemblage sample and counted numbers of a) undamaged specimens, b) specimens with small whole or remaining more than half of the original one, c) specimens remaining only less than half of the original one, and d) fragments of keels only (Mekik et al., 2002) (Table 3). G. menardii fragmentation index (MFI: Mekik et al., 2002) was calculated by the following equation of Mekik et al. (2002).

MFI=(b + (c/3) +d/5)/ (a+ b + (c/3) +d/5)

MFI record of GH08-2004 is exhibited together with percentage of perfect tests (Fig. 3), showing more or less better carbonate preservation during the glacial time than the Holocene. It may be related to higher saturation state at <$\sim$ 2 km water depth during the glacial time possibly due to lower atmospheric CO_2 concentration (e.g., Bertram et al., 1995). During the deglaciation the carbonate preservation state does not correlate with Mg/Ca, suggesting carbonate saturation state seems unlikely affect Mg/Ca. There is no correlation between benthic Mg/Ca and % dissolution (R=0.052, P=0.754), suggesting the carbonate saturation effect on Mg/Ca is not a main control on downcore Mg/Ca. As suggested by the reviewer, for planktic foraminiferal Mg/Ca, post depositional carbonate dissolution decreases Mg/Ca at below saturation (bottom water $\Delta[CO_3^{2-}]$ <30 μmol kg^{-1}) (Regenberg et al., 2014). However, this is the case for planktic foraminifers and dissolution effect on Mg/Ca is negligible for benthic foraminifers (Lear et al., 2002; Elderfield et al., 2006).

-Propagated error of local $\delta^{18}O_w$ ($\Delta\delta^{18}O_w$):

To calculate a $\Delta\delta^{18}O_w$, the ice volume offset (Waelbroeck et al., 2002) is subtracted from $\delta^{18}O_w$. Eventually $\pm$0.34‰ of $\Delta\delta^{18}O_w$ error is derived by $\pm$0.1‰ for error of the ice volume offset that adds to $\pm$0.24‰ (1σ) of propagated error of $\delta^{18}O_w$ from BWT reconstruction when BWT error of $\pm$1.9 °C is applied (0.25‰ per 1 °C).

Reply to minor comments:

-Title and also throughout the text: » As we follow the comments by both reviewers, we change the title as below. “Bottom water variability in the subtropical northwestern Pacific from 26 ka to present based on Mg/Ca and carbon and oxygen isotopes of benthic foraminifera”

-Section 1

1. Lines 3-4, delete or move backwards “of benthic foraminifera”, i.e. all three proxies are based on benthics. » Will be deleted.

2. Lines 12-13, remove “s” from records; using “millennial scale variation” (also later in the text) is a bit presumptious when only 15 data points are covering this part. I would change this to mention that the data suggest changes that seem to follow Heinrich, BA, and YD. » We follow his/her advice and revise the sentence as below. “Mg/Ca record suggests changes that seem to follow Heinrich, B/A and YD.”

3. Lines 18-25, this is an example of the over interpretation. How can this be concluded based on just the one, new downcore record which is presented? »We reconsider our interpretation on the downcore record and omit these sentences.

4. p.4, Line 24: Okazaki et al. 2011 is missing from the references, which include Okazaki et al. 2010 and 2012. » We apologize that this is a mistake. This should be Okazaki et al. 2012.

5. p.5, line 14: delete “In paleoceanographic field” » Will be deleted.

6. p.6, line 4: add References to the text. » Okazaki et al. (2010) will be added.

7. p.6, line 18: this is a very sudden jump from model results (is it relevant for this study that two models show different numbers for N-Pacific deep water?) to stable carbon isotopes on forams. The introduction can be more focused on the northwestern Pacific. » We agree with this advice. Introduction will be revised and more focused on North Pacific.

8. p.6, line 21: add “stable” before oxygen and carbon. »Will be added.

Section 2 – Oceanography

1. The oceanography part can be condensed significantly. For example, location and pathways in the South Pacific of the AAIW is not necessary for this study, only that AAIW probably contributes to local water. On the other hand, this section gives a very clear definition of the different intermediate water masses and their signatures. This would be a perfect basis to interpret any downcore variations in temperature, salinity, and d13C. » We follow his/her advice and omit the location and pathways in the South Pacific of the AAIW. Considered together with comments by reviewer #2, we focus more on North Pacific.

2. p.7, line 1: “the study area is: : :”; » Will be corrected.

3. line 4: add water to depth; » Will be added.

4. Line 8: “a total flow”; » Will be corrected.

5. line 17: delete “the”; » Will be deleted.

6. lines 19-20: “Salinity increases..”; » Will be corrected.

7. lines 21, 24: rephrase “bottom of the site”. » Will be corrected.

Section 3:

1. Line 17: Grab sampler: how were samples taken from these? 0-1 cm? Also, have any surface samples been dated to show that modern samples were taken? » Top 0-2

cm of the surface sediment samples were taken for this study. Although we have not conducted 14C dating for these samples, among 450 sites in the cruise, locations of the sampling were carefully selected where sediments were stably accumulated based on geography of the studied area and seismic survey done by Geological Survey of Japan. Sediment reworking seems to be unlikely for these sampling sites. Besides, most of the planktic foraminiferal tests are clean and well-preserved and don’t look like reworked tests. Therefore, we consider that the surface sediment samples are modern.

2. p.9,line 8: 2.2 cm intervals? » As is also pointed out by reviewer #2, we don’t use all of 2.2 cm interval sample. We apologize for the confusing expression. We revise it as below. “The core material was sampled at 2.2 cm intervals, and roughly a half of the horizons were processed.”

3. Line 21: add references for both types of wuellerstorfi; “overgrown surface” suggests a diagenetic overprint instead of something which is really part of the foram. » For typical C. wuellerstorfi (Schwager), we refer to description in recently published benthic foraminifera atlas summarized by Holbourn et al. (2013). However, we cannot find any reference of C. wuellerstorfi type B. C. wuellerstorfi type B might be an endemic subspecies in this area. Taxonomic study should and will be done in elsewhere, but not here. If the granular surface is a consequence of the authigenic calcite, the granular texture should be seen on both sides of the foraminifer. However, based on SEM images, the granular texture is seen only on umbilical side, whereas texture on spiral side is similar to that of type A. In Holbourn et al. (2013), they describe Planulina renzi Cushman and Stainforth, which is related species to C. wuellerstorfi (=Planulina wuellerstorfi), having granular surface in appearance. The surface texture of C. wuellerstorfi type B looks like that of P. renzi, suggesting that the granular surface texture of C. wuellerstorfi type B is also primary calcite, not a diagenetic overprint. Since the expression “overgrown surface” would give confusing impression to readers, we revise it to “ granular surface”.

Section 4:

1. this can be part of section 3.2 p.10, line 15: delete “clay materials”, these should have been removed already in the previous step. » Will be deleted.

2. Line 16: “d18O and d13C were measured: : :”. Delete the bit in-between. »Will be deleted.

3. Line 16-26: move this part to the end of the section, i.e. after the analytical part for the Mg/Ca. »Will be deleted.

4. p.11, was Al/Ca also measured to monitor clay contamination? ; »As we did not measure Al/Ca, we have no choice but to evaluate efficiency of the cleaning steps by using Mn/Ca. We will explain how we discard the Mn/Ca data in the next paragraph. As we cleaned samples 5 times with water and 2 times with methanol and rinse them several times with water after reductive and oxidative steps, we believe that clay contamination is very small.

5 . lines 6-7: “most” of the samples were under 65. So, a samples with 66 was discarded? And how many were then discarded? I think it is better to define outliers, e.g. samples which were more than 2sd away from the average, then a specific value. » Among all samples we measured several samples have extremely high Mn/Ca (>1000 μmol/mol). Average of Mn/Ca is 88 μmol/mol and standard deviation is 356 μmol/mol (1σ). Mn/Ca data over 1σ than the average are discarded.

Section 5

1. I suggest moving this up to between sections 3.1 and 3.2. » Will be moved.

2. Lines 13-14: is mixing shallow and deep living forams for 14C not going to give skewed results? » We don’t think that mixing the species skew 14C results. Because the ages from deeper dwelling species (G. menardii and G. truncatulinoides) are in line with an estimate interpolated or extrapolated by ages from surface dwelling species, it is highly unlikely that mixing these species give skewed results. This is supported by an unpublished 14C age of G. truncatulinoides from 172.8-175.1 cm depth is in the

range of 2σ error (T. Itaki, personal communication).

Section 6:

1. Mg/Ca values as high as 3.1 mmol/mol from a water depth of just 300 m make me wonder if this is really wuellerstorfi? » We describe that specimens from shallower sites does not seem to differ from those from deeper sites in morphology and found typical C. wuellerstorfi (=C. wuellerstorfi type A) in the surface sediment sample #261 (water depth of 336 m). C. wuellerstorfi type B cannot be distinguished morphologically from type A. Holbourn et al. (2013) mentioned that this species could be a bathymetric indicator deeper than ~800 m, whereas Hayward et al. (2010) reported this species at 400- 3000 m water depth around New Zealand. This species might change their living depth depending on availability of foods. Surface primary production is less in the subtropical northwestern Pacific due to oligotrophic Kuroshio water in the surface. Thus, C. wuellerstorfi might broaden their habitat depth to shallower depths in this area.

2. This section should be written in the present tense; values and temperatures are not smaller but lower. » Will be revised.

3. p.13, lines 26-27: remove “millennial scale changes”. » Will be removed.

3. Results and figures in general: add error bars. For example, p.13, line 27: “appeared to be negligible”, give statistics here. » Will be added.

Section 7

1. Start: rephrase, see comments on millennial variations before. p.16, » Will be added.

2. line 14: only Lee et al. 2004 is in the References. » This should be Lee et al., 2013.

3. Line 17: define subthermocline vs intermediate. » We delete “subthermocline”.

4. Line 24: see also before, how significant is a 1_C warming in a range which is probably affected by the carbonate ion effect? » The carbonate ion effect would be

evaluated by G. menardii fragmentation index. As the index does not show increase in carbonate saturate state, Mg/Ca increase at 17 ka can be interpreted as increase in BWT. Taking into account the error bar in the ure, this warming can be regarded as significant.

5. Line 26: “suggests upwelling”, where? » Upwelling in North Pacific. The deep Pacific is ventilated from the south by the densest waters such as Antarctic Bottom Water and lower Circumpolar Deep Water that upwell to middle-depth in the North Pacific and returns south as Pacific Deep Water (PDW) (Schmitz, 1996). As pointed out by the reviewer #2, the bottom water of the studied site is mainly composed of PDW with some portion of NPIW. Therefore, we interpret the downcore record as a reflection of changes in mixing ratio between PDW and NPIW or each water mass itself.

6. p.17, lines 12 and on: rapid changes in BWT and d18Ow lead to a very wide interpretation. I would bring this more carefully. » We omit “rapid” because the time resolution is not so high to conclude that it was a rapid change.

7. p.18: would it not be more logical to show the Nd record from Huang than the one from Pena from the east Pacific? » As suggested, we will show the Nd data from Huang et al. with our data.

8. Fig.1 and 3 can be combined into one. Delete the depth contours from Fig. 3b. » We combine Fig.1 and 3 in the previous manuscript, and delete the depth contours from Fig. 3b.

9. Fig.2: it may be more helpful to show profiles covering the site location. The figure can then be combined with Fig. 4 »We agree with this comment, but separate Fig. 2 from Fig. 4 in the previous manuscript because d13C (DIC) data, which was suggested to include in this manuscript by reviewer #2, is few and best approximation to our site is WOCE line P10. We would like to show d13C together with temperature, salinity, and phosphate profiles to show likes to water mass difference. We include these profiles as Fig. 2 in a revised manuscript as we follow the comment by the reviewer #2.

Figure captions

Fig.1. Mg/Ca values of surface sediment versus water depth (a), BWT(b), Δ[CO32-] (c). BWT versus Δ[CO32-]. Mg/Ca values in lower temperature range (e) and (f).

Fig. 2. Comparison to previous Mg/Ca data. Mg/Ca values of C. wuellerstorfi (a), (b), (c) and C. pachyderma (d), (e), (f) plotted against bottom water temperatures (BWT) and Δ[CO32-].

Fig. 3. (a) Mg/Ca, (b) perfect test % and MFI, (c) BWT versus calendar age for GH08-2004.Bold line in (c) is w-point running mean.

Please also note the supplement to this comment:
http://www.clim-past-discuss.net/10/C1122/2014/cpd-10-C1122-2014-supplement.pdf

Interactive comment on Clim. Past Discuss., 10, 1265, 2014.

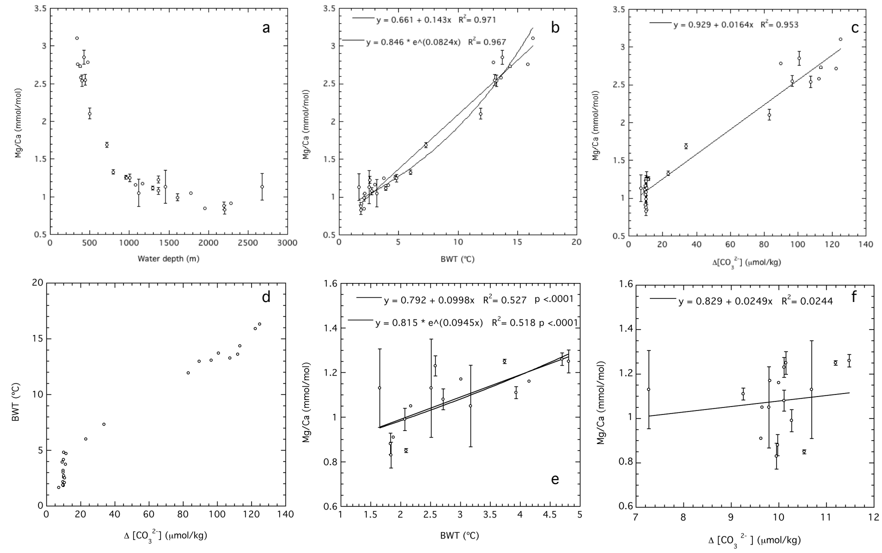

a
b
c
d
e
f
Mg/Ca (mmol/mol)
Water depth (m)
BWT (°C)
Δ[CO3 2-] (μmol/kg)
y = 0.661 + 0.143x R2 = 0.971
y = 0.846 * e^(0.0824x) R2 = 0.967
y = 0.929 + 0.0164x R2 = 0.953
y = 0.792 + 0.0998x R2 = 0.527 p <.0001
y = 0.815 * e^(0.0945x) R2 = 0.518 p <.0001
y = 0.829 + 0.0249x R2 = 0.0244

Fig. 1.

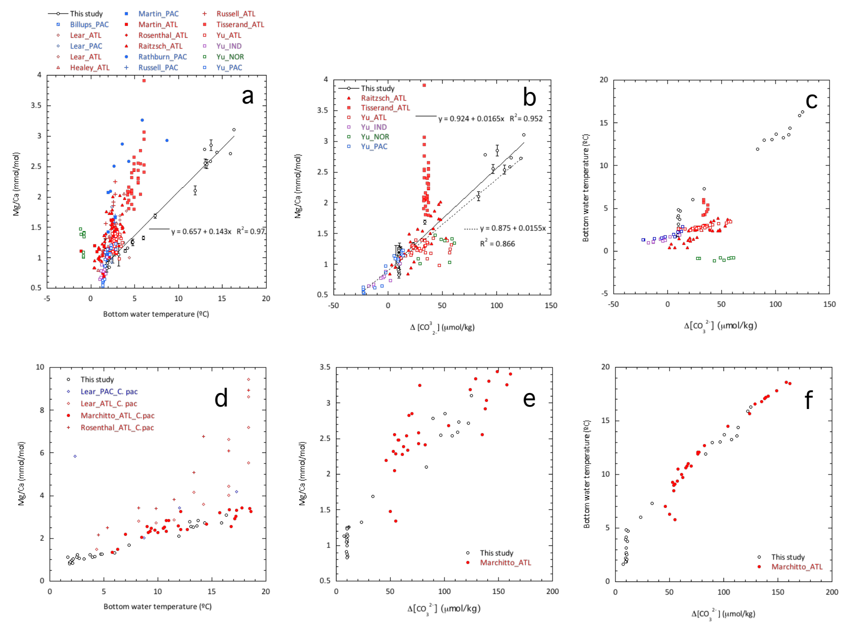
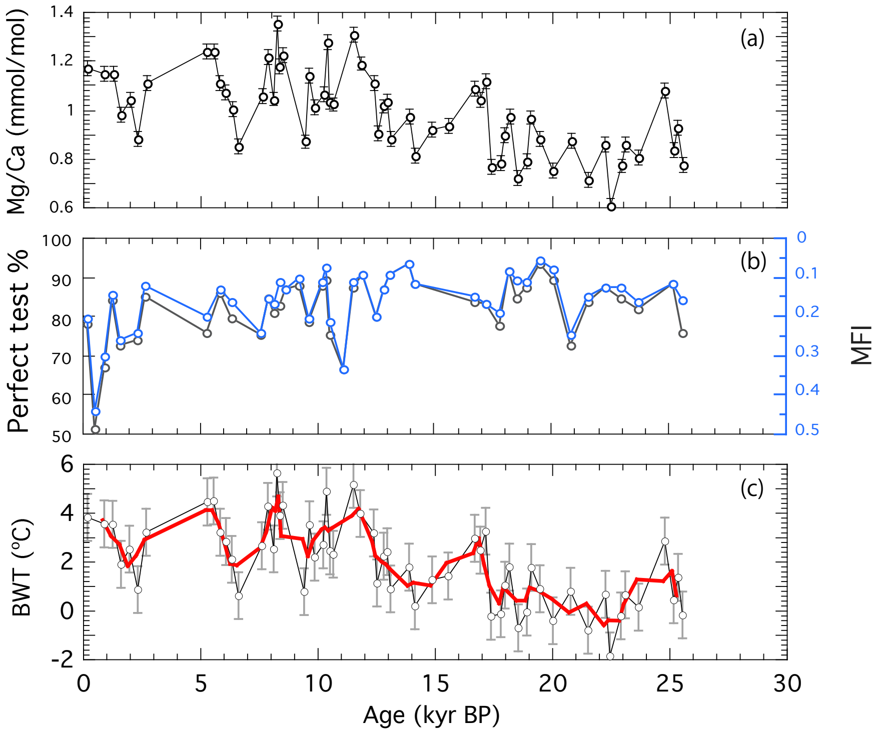

This study
Billups_PAC
Lear_ATL
Lear_PAC
Lear_ATL
Healey_ATL
Martin_PAC
Martin_ATL
Rosenthal_ATL
Raitzsch_ATL
Rathburn_PAC
Russell_PAC
Russell_ATL
Tisserand_ATL
Yu_ATL
Yu_IND
Yu_NOR
Yu_PAC
a
b
c
d
e
f
Mg/Ca (mmol/mol)
Bottom water temperature (ºC)
y = 0.657 + 0.143x R2 = 0.97
Δ [CO3 2-] (μmol/kg)
y = 0.924 + 0.0165x R2 = 0.952
y = 0.875 + 0.0155x
R2 = 0.866
Lear_PAC_C. pac
Lear_ATL_C. pac
Marchitto_ATL_C.pac
Rosenthal_ATL_C.pac
Marchitto_ATL

Fig. 2.



Mg/Ca (mmol/mol)
1.4
1.2
1
0.8
0.6
(a)
Perfect test %
100
90
80
70
60
50
0
0.1
0.2
0.3
0.4
0.5
MFI
(b)
BWT (°C)
6
4
2
0
-2
(c)
0
5
10
15
20
25
30
Age (kyr BP)

Fig. 3.