



Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Foraminiferal proxy response to ocean temperature variability and acidification over the last 150 years in the Santa Barbara Basin (California)

Dorothy K. Pak^{a, *}, Ingrid L. Hendy^b, James C. Weaver^c, Arndt Schimmelmann^d, Lily Clayman^a

^a Marine Science Institute, University of California at Santa Barbara, Santa Barbara, CA 93106, USA

^b Department of Geological Sciences, University of Michigan, Ann Arbor, MI 48109, USA

^c Wyss Institute for Biologically Inspired Engineering, Harvard University, Cambridge, MA 02138, USA

^d Department of Geological Sciences, Indiana University, Bloomington, IN 47405, USA

ARTICLE INFO

Article history:

Available online xxx

Keywords:

California margin
Sea surface temperature
Ocean acidification
Planktic foraminifera

ABSTRACT

The last 150 years on the California margin have been marked by high variability in precipitation, temperature, sea surface temperature, and ocean chemistry, in response to both natural and anthropogenic changes. Deciphering climate history from ocean sediments is dependent on our understanding of the various influences on marine proxies. Sediment from Santa Barbara Basin (SBB), California (box core SPR0901-10BC) provides an opportunity to compare multiple marine proxies with instrumental records of climate of the past 150 years and extend them beyond the historical record. Here we use three planktonic foraminiferal proxies, $\delta^{18}\text{O}_{\text{calcite}}$, Mg/Ca, and size-normalized shell weight, to reconstruct the surface temperature and $\delta^{18}\text{O}_{\text{water}}$ in SBB California at near-annual resolution from AD 1850–2000. Results indicate that *Globigerina bulloides* Mg/Ca reflects the instrumental temperature trends over the last 150 years, with average Mg/Ca temperatures approximately 2 °C lower than instrumental values, due to the slightly deeper habitat preference of *G. bulloides*. Similarly, temperature is the dominant control on *G. bulloides* $\delta^{18}\text{O}_{\text{calcite}}$, and both Mg/Ca and $\delta^{18}\text{O}_{\text{calcite}}$ reflect variability consistent with changes in the intensification of ENSO over the past 150 years.

Shell weights of the planktic foraminifer *G. bulloides* are inversely correlated with historical sea surface temperatures over the last 150 years in SBB sediments. Greater shell weight associated with cooler surface ocean temperatures does not support the anticipated relationship between coastal upwelling of cool, low pH water and shell thinning due to CO_3^{2-} undersaturation. However, in contrast to the previous 130 years, *G. bulloides* shells deposited on the sea floor since the late 1970s exhibit a distinctive smooth shell structure indicative of partial dissolution. We hypothesize that a mid-1970s shift in intermediate water flow from predominantly equatorward to anomalously poleward led to the influx of relatively corrosive bottom water into SBB with subsequent carbonate dissolution at the sediment–water interface.

© 2016 Elsevier Ltd and INQUA. All rights reserved.

1. Introduction

Concern over anthropogenic climate change has increased interest in the natural variability of marine coastal environments and their response to climate change. Coastal upwelling systems, such as the California Current System, are at once vitally important to the

health of marine ecosystems and exceptionally sensitive to climate-induced variability. Over the past 200 years, anthropogenic increase in atmospheric CO_2 has led to an increase in ocean temperature and ocean uptake of CO_2 (Caldeira and Wickett, 2003; Feely et al., 2004; Sabine et al., 2004; Orr et al., 2005). The resulting ocean acidification has been documented as a shoaling of the aragonite and calcite saturation horizon in the eastern Atlantic, northern Indian, and Pacific Oceans (Feely et al., 2004, 2008). Likewise, sea surface temperatures (SST) have increased by approximately 1 °C over the past 150 years (e.g. Smith et al., 2008

* Corresponding author.

E-mail address: pak@geol.ucsb.edu (D.K. Pak).

and sources within). The effect of these changes on marine ecosystems and calcifying organisms, however, is still largely unknown. While some marine calcifying organisms exhibit decreased calcification rates under conditions of decreased ocean pH (Kleypas et al., 1999; Riebesell et al., 2000; Barker and Elderfield, 2002; Fabry et al., 2008) others species show the opposite effect (e.g., some coccolithophorids; Iglesias-Rodriguez et al., 2008; Grelaud et al., 2009). Furthermore, it can be difficult to isolate the effects of one factor, such as ocean pH, on calcifying organisms, from other environmental factors such as temperature and nutrient availability, which can also affect calcification and growth rate, and may covary with pH.

Planktic foraminiferal $\delta^{18}\text{O}$ is widely used in paleoclimate studies as a proxy for past sea surface temperature. Foraminiferal shell $\delta^{18}\text{O}_{\text{calcite}}$ is dependent on both the temperature fractionation during calcification and the $\delta^{18}\text{O}$ of the water in which the foraminifera calcifies, requiring an estimate of the $\delta^{18}\text{O}_{\text{water}}$ in order to calculate paleotemperature. Although the major cause of variations in $\delta^{18}\text{O}_{\text{water}}$, change in continental ice volume (Lambeck et al., 2014), was not a significant factor during the late Holocene, $\delta^{18}\text{O}_{\text{water}}$ is also affected by variations in regional patterns of precipitation, evaporation and run-off, and advection of water masses of variable $\delta^{18}\text{O}_{\text{water}}$. Foraminiferal Mg/Ca can be used in conjunction with $\delta^{18}\text{O}_{\text{calcite}}$ records to deconvolve the $\delta^{18}\text{O}_{\text{water}}$ and temperature components, and to quantify the effects of precipitation and evaporation on $\delta^{18}\text{O}_{\text{water}}$. Differences in water mass $\delta^{18}\text{O}$ influence $\delta^{18}\text{O}_{\text{calcite}}$ values of the late Quaternary on the eastern Pacific margin (Mortyn et al., 1996; Hendy, 2009; Pak et al., 2012; Taylor et al., 2015), and is an important factor in the interpretation of SST changes beyond the instrumental temperature record in this area.

Foraminiferal size-normalized shell weight has been widely used as a proxy for seawater dissolved carbonate (CO_3^{2-}) concentrations of the past ocean (Lohmann, 1995; Broecker, 2001). This method makes the assumptions that shell weight is a function of shell thinning due to post-depositional dissolution under conditions of calcite undersaturation at the sediment–water interface, and that initial shell thickness is unrelated to environmental conditions (i.e. the shell thickness of live foraminifera does not vary according to growth conditions such as ambient CO_3^{2-} , light, temperature, and nutrient availability) (Broecker and Clark, 2002). This second assumption has been challenged (Bijma et al., 2002); culture experiments of the planktic foraminifera *Orbulina universa* and *Globigerinoides sacculifer* indicate that the shell weight of live foraminifera is positively correlated with ambient CO_3^{2-} . Thus, it is unknown whether foraminiferal size normalized shell weight in sediments is due to post-depositional dissolution, due to growth conditions, specifically CO_3^{2-} concentrations or sea surface temperature, or whether foraminiferal shell weight is positively or negatively correlated with CO_3^{2-} ion concentration.

Santa Barbara Basin, California sediments provide an ideal opportunity to ground truth climate proxies in a region that is sensitive to climate changes, well-studied, and capable of yielding exceptionally high-resolution records from calcite-shelled organisms. Here, we analyzed shell $\delta^{18}\text{O}$, Mg/Ca, and size-normalized shell weight of the planktonic foraminifera *G. bulloides* in an approximately annually resolved sediment record from SBB that spans the interval from AD 1850–2000 to better understand the response of foraminiferal proxies to controls on foraminiferal calcification and their relationship to 20th century sea surface temperature and ocean acidification. We compared the foraminiferal proxy records to the average annual sea surface temperature (SST) using the ERSSTv3b historical temperature record for 34°N, 120°W from AD 1854–2000 (NOAA Extended Reconstructed Sea Surface Temperature ERSST v3b; Smith et al., 2008) to establish the

relationship between widely used foraminiferal proxies of temperature and pH to the instrumental records. These records serve to improve our understanding of the response to high-resolution ocean variability on the highly sensitive California margin over the last 200 years and beyond.

2. Materials and methods

Box core SPR0901-10BC was recovered by the R/V Robert Gordon Sproul in 2009 from the center of SBB (Fig. 1; 585.5 m water depth; 34° 16.847'N, 120° 02.268'W) using a Soutar box corer. The 67 cm long core represents continuously varved sediment from AD 1780–2009, with the exception of a 6 cm turbidite that rests on the 1923 varve (Schimmelmann and Zayin, 2010) and a probable second turbidite or bioturbated interval associated with the ca. 1841 *Macoma* shell layer. Although the core recovered sediment from AD 1780–2009, we focused on the interval from 1850 to 2000 for better comparison with the historical temperature record, which began in 1854, and because insufficient numbers of *G. bulloides* were present between 2003 and 2009 for analysis. Chronology for the core was determined through (i) identification of gray layers (flood events; Hendy et al., 2015) in epoxy-embedded and polished sections from an adjacent sub-core and cross-correlation with previous varve-counted box core records and (ii) wiggle matching of the porosity profile over depth (Schimmelmann et al., 1990).

On recovery, the core was stored for three months in a refrigerated core locker at Indiana University to allow dewatering before subsampling at ~2 mm resolution with a vertical extruder by scraping sediment slices in parallel with distinct color differences that often coincide with varve boundaries. Weight percent water was used to cross-correlate the sampled subcore to established porosity profiles along the varve-count chronology (Schimmelmann et al., 1990). The chronology of the upper sediment was determined via varve-counts and distinct color differences in close comparison with overlapping epoxy-embedded thin sections from a parallel subcore of the same boxcore. Sample resolution was approximately annual. Samples were disaggregated and washed over a 125 μm sieve. Individual *G. bulloides* were picked from the 250–300 μm fraction, sonicated briefly in methanol to remove adhering or infilling particles, and air dried. Size-normalized shell weights were determined by weighing pooled (>10; mean = 28) specimens of *G. bulloides* from the 250–300 μm size fraction of SPR0901-10BC on a microbalance (0.001 mg) and calculating the average shell weight. Samples with fewer than 10 individual *G. bulloides* in this size fraction were not included. Oxygen isotopic analyses were conducted on the 250–300 μm size fraction of *G. bulloides*, except in a few cases where there were insufficient numbers of *G. bulloides* it was necessary to pool the 125–300 μm size fraction. Analyses were conducted on approximately 50 μg samples, or about five to seven specimens of *G. bulloides*. Oxygen isotopic analyses were performed at the University of California at Santa Barbara on a Thermo Scientific MAT 253™ isotope ratio mass spectrometer coupled with a Kiel IV carbonate preparation device. Long-term isotopic precision was $\pm 0.07\text{‰}$ $\delta^{18}\text{O}$ based on 457 replicates of the standard NBS 19. Intersample variability was 0.23‰ based on nine sample replicates. Fewer than 2% of the samples were rejected due to small sample size.

The Mg/Ca analyses were conducted on the 250–300 μm size fraction of *G. bulloides*. Samples were cleaned following the UCSB standard foraminiferal cleaning protocol (Lea et al., 2000; Martin and Lea, 2002), which includes both oxidative and reductive cleaning steps. Calcite recovery after the cleaning process averaged 38%. Overall, fewer than 2% of the individual analyses were rejected based on low recovery or Fe or Al contamination. Cleaned samples

Download English Version:

<https://daneshyari.com/en/article/7450292>

Download Persian Version:

<https://daneshyari.com/article/7450292>

[Daneshyari.com](https://daneshyari.com)