Introduction

Trace element to calcium ratios in calcifying organisms can be used as effective proxies for climate, ocean temperature, and chemistry. Bamboo corals, which live for 100-300 years and grow 100μm-scale bands similar to tree rings, have been proposed as high-resolution deep-sea climate archives. More work is needed to test the reproducibility and reliability of trace elemental proxy records from bamboo corals before they can be used to provide information about deep-ocean temperature and circulation. In addition, there has been very little characterization of deep-sea coral growth bands. The coral skeletons are made of high-magnesium calcite, which can have many crystal structures and orientations. Though some have proposed that the different colors present in the coral are due to changes in crystal orientation, this hypothesis has never been tested (Nee and Dullo, 2006). In order to answer some of these questions, analysis was performed on two corals from the Gulf of Alaska (collected live at 720m and 634m in 2002; 48°37', 132°44'W). Creating evidence for deep-ocean climate changes, including temperature and productivity, in the lifespan of the corals could strengthen the body of data on rapid climate change.

Methods

Laser ablation data were collected from three replicate radii in each coral. Each line was a different length because of inconsistent coral growth (see figure 3). Each line was measured 2 or 3 times, with the first pass removing surface contamination (and therefore not shown on figure 3). Visible bands measured with a petrographic microscope (figure 4) were used to align the 3 lines onto one shared x-axis.

Once the lines were aligned, the average growth rate, based on high-resolution 14C data collected from the organic nodes of the coral, was used to assign a chronology to this coral (using age data from Roark et al. 2005). This allowed for comparison of laser ablation data to Pacific Decadal Oscillation (PDO), El Nino/Southern Oscillation (ENSO), and North Pacific Gyre Oscillation (NPGO) indices using Analysers (Di Lorenzo et al., 2008; Paillard and Yiou, 1996).

Figure 1. Two bamboo coral samples were collected in the Gulf of Alaska at the Warwick Seamount (48°37', 132°44'W) at 720m and 634m.

Figure 2. Cross section of the calcitic innerzone of the coral from 720m. Laser ablation and growth band analyses were both performed on this cross section. Blue arrows mark laser ablation lines, and mark radial growth direction (coral grows outward from core to rim).

Figure 3. Trace element data before they were aligned with the coral growth band measurements. The three lines were different lengths (~6mm to ~11mm) and it was unclear if they were reproducible. See figure 6 for results after alignment.

Figure 4. (a) Partial image of the coral from 720m showing three laser ablation lines and visible growth bands. This image is a composite of photomicrographs taken with a Leica microscope. (b) Example of measurement process.

Figure 5. Preliminary EBSD results show that crystal orientation (modeled by grey prisms) does not show a banded pattern. Differing colors represent differing orientation.

Results and Discussion

• Laser ablation lines are reproducible for Mg, Ba, and B (mean R = 0.789 ± 0.043), but are more variable in terms of Sr (mean R = 0.943 ± 0.067).
• There is a statistically significant difference in the Ba:Ca ratio during a cold regime of the Pacific Decadal Oscillation (figure 7).
• Prominent growth bands (such as those highlighted in figure 6) do not produce a consistent response in the trace element data, suggesting that trace element bands are affected by an outside force, which strengthens the proxy (Figure 6).

Conclusions

• Reproducibility for Mg, Ba, and B and growth band data suggest that variability in these elements is a response to the external environment. Sr may be influenced by processes internal to the corals.
• Decreased water Ba concentration (due to mixing of water masses during PDO; Chavez et al., 2003) could produce a lower signal in the coral.
• Crystals have a preferred orientation that does not correlate with visible growth bands; unlikely that growth bands are caused by differences in crystal orientation.

Further Research

• Analysis of the 634m coral is planned to determine if trace element to calcium anomalies occur during the same time periods in both corals, which would provide further support that the trace element data represent an external signal.
• The amount of Ba decrease during cold PDO regimes could be studied to see if it correlates to strength of water mass shift.
• More work is needed to understand the calcite crystal matrix orientation, which will include improving the method of sample preparation.

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Electron Backscatter Diffraction Analysis (EBSD)

A method was developed for collodion silica polishing of coral samples to detect calcite crystal orientation by increasing the polishing time until the band contrast (a measure of sample quality) reached 90 (figure 5).

Preliminary results from the analysis suggest that growth bands are not caused by differences in crystal orientation, which differs from published hypotheses (Nee and Dullo, 2006; Figure 5). There appears to be a preferred crystal orientation unrelated to visible growth bands.