Evaluating Drivers of Reefal Transitions Over ~16Myr, Enewetak Atoll

Colleen Brown, Megan Smith, Peter K. Swart, and Amanda M. Oehlert

PROJECT OBJECTIVES

- Examine trace element and stable isotopic composition of well-preserved corals and sediments from Pliocene and Miocene sections for comparison with the Modern.
- Quantify geochemical signatures including $\delta^{11}B$, B/Ca, Sr/Ca, P/Ca, U/Pb, $\delta^{13}C_{carb}$, $\delta^{18}O$, and various trace elements.
- Consider the timing and causes of transition from reefal boundstones to skeletal grainstones over the past ~16 Myr.

PROJECT RATIONALE

Over geologic time, the ecological framework of reefal environments has shifted from the first stromatolitic reefs to the Modern scleractinian coral-dominated reefs, with many variations in between. Drivers of ecological shifts have been attributed to major climatic changes, sea-level changes, and subsidence. To understand the environmental conditions that precipitate such ecological changes, the historical stress response of corals in the geologic record can provide key insight into the tempo and frequency of reefal transitions through time. Paleoseawater conditions have been shown to be recorded in coral skeletons and carbonate sediments, and geochemical proxies ($\delta^{11}B$, $\delta^{13}C_{carb}$, $\delta^{18}O$, B/Ca, Sr/Ca, P/Ca) can be useful in constraining changes in environmental conditions through time. The goal of this project is to reconstruct the paleoclimate and/or paleoceanographic changes that instigated reef decline, re-growth, and sedimentary facies shifts throughout the Enewetak KAR-1 core.

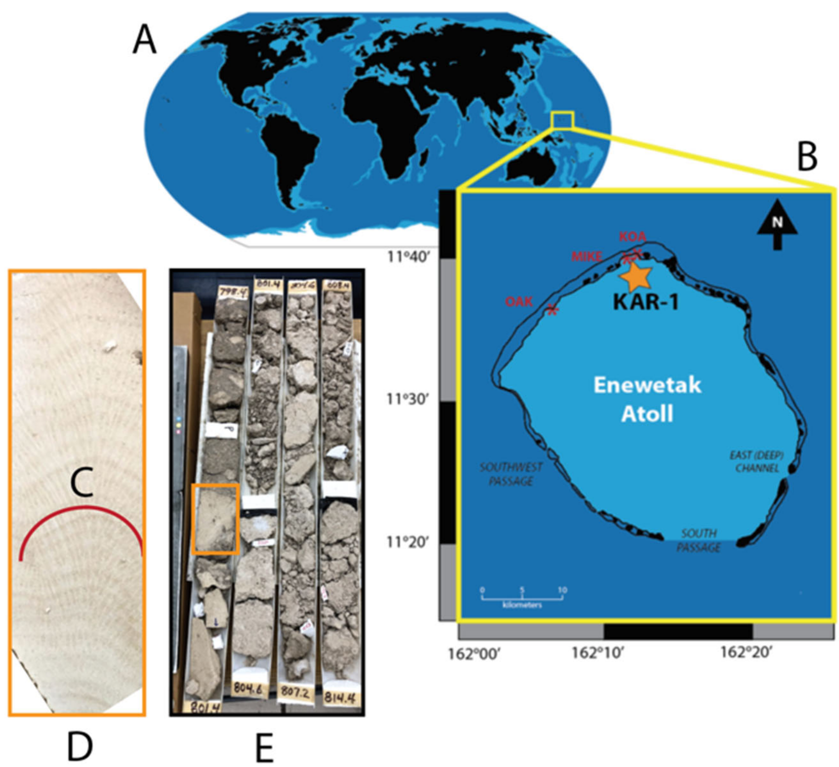

Figure 1. (A, B) Location map of KAR-1 in the Enewetak Atoll. (C) Growth band of (D) coral head. (E) KAR-1 sediment core

APPROACH

The KAR-1 core drilled into the Enewetak Atoll contains a sedimentary record with two sections that are proposed analogs for predicted 2030 and 2100 climate; the Mid-Pliocene warm period (~3.3-3.0 Ma; Burke et al., 2018), and the Miocene Climate Optimum (~17-14.7 Ma; Holbourn et al., 2015). KAR-1 was collected from Enewetak Atoll in the Marshall Islands, just outside the KOA crater that resulted from nuclear bomb testing in the late 1960s. More than 350 sediment samples and 35 coral skeleton slabs from the KAR-1 core (Fig. 1) will be analyzed in this study. Unaltered (>80% aragonite) fossil coral skeletons will be analyzed for stable isotopes ($\delta^{13}C_{carb}$ and $\delta^{18}O$ values) at the Stable Isotope Laboratory and the isotopic composition of boron, as well as elemental concentrations and ratios ($\delta^{11}B$, B/Ca, Sr/Ca, P/Ca, U/Pb), will be analyzed on the QQQ-ICP-MS. These coral based records will be compared to the same geochemical proxies analyzed in the bulk sediments. In particular, this study will focus on the transitions from reefal boundstones to skeletal grainstones. Coral extension rates and skeletal density will be analyzed for each coral head, and compared to the geochemically resolved conditions of paleoseawater to determine growth response to stress that may have precipitated an ecological shift. Proxies for climatic and oceanographic conditions in sediments across major transition zones between reefal boundstones and skeletal grainstones will be compared to determine climatic and oceanographic drivers for facies shifts.

SIGNIFICANCE

Reef growth on a geologic timescale has been suggested to be predominantly controlled by sea level, current configurations, and climatic fluctuations. In this study, we compare known sea-level oscillations and their sedimentary response (DNA, 1986) with new reconstructions of geochemical proxies for upwelling, sea surface temperature, and carbonate chemistry. Such environmental conditions are known to impact reef growth, as corals are restricted to environments with narrow ranges in temperature for optimal growth (26-28°C; Hubbard, 2015). In concert, these analyses will enable an evaluation of the relative importance of varying sea surface temperature, sea-level oscillations, and oceanographic conditions on reef development and facies shifts in a tropical atoll environment over the past 16 Mys.

REFERENCES

Burke, K., Williams, J., Chandler, M., Haywood, A., Lunt, D. and Otto-Bliesner, B., 2018. Pliocene and Eocene provide best analogs for near-future climates. Proceedings of the National Academy of Sciences, 115(52), pp.13288-13293.

Defense Nuclear Agency (DNA), 1986. Part 2: Paleontology and Biostratigraphy of Enewetak Atoll, Marshall Islands: Application to OAK and KOA Craters. U.S. Geological Survey.

Holbourn, A., Kuhnt, W., Kochhann, K., Andersen, N. and Sebastian Meier, K., 2015. Global perturbation of the carbon cycle at the onset of the Miocene Climatic Optimum. Geology, 43(2), pp.123-126.

Hubbard, Dennis K. (2015). Reef Biology and Geology–Not Just a Matter of Scale. In C. Birkeland (Ed.). Coral Reefs in the Anthropocene, 43-66. Houten: Springer Netherlands.