Understanding the Sediment Budgets of Atoll Islands Through Radiometric Dating of Seabed Sediments

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Introduction

- With international concern of climate change and sea level rise due to anthropogenic effects increasing day to day, the future state of low-lying reef islands continues to be of scientific debate.
- Global average rate of sea level rise = 2.0 mm yr^{-1} [1]
- Carbonate budget forming atoll islands and reefs are >70% sourced from local coral reefs [5].
- Schematic atoll models highlight long-term affects to the sediment budget from geomorphologic changes [3].
- Other studies utilize radiometric dating to analyze atoll development in terms to chronology and sediment origin [9].
- **Goals: (1) look at the age structure of modern reefal sediments using uranium/thorium dating and (2) assess the patters of biogenic carbonate sediment production associated with coral reefs surrounding the atoll islands in the Chagos Archipelago.**

Methods

- Study site: Chagos Archipelago (British Indian Ocean Territory). Collected in The Living Oceans Foundation Global Reef Expedition (2011-2017) [7].
- The procedure can be summarized as follows:
  1. Isolate coral fragments (> 3 mm) from the other sediment constituents in each sample.
  2. Clean each fragment and confirm mineralogy (corals > 90% aragonite, <10% HMC) via X-Ray Diffraction.
  3. Complete radiometric dating using Isotope Dilution Mass Spectrometry following the algorithm proposed by Dr. Ali Pourmand [6].
  4. Analyze uncorrected ages (years) in Microsoft Excel and Minitab.

Figure 1 Example of a BIOT sample with an array of biogenic carbonates.

Figure 2 Example of a pristine coral fragment sample.

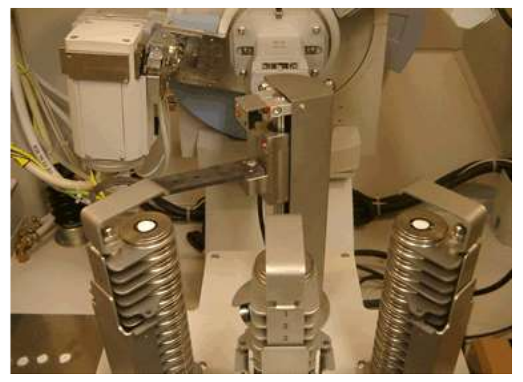

Figure 3 X-Ray Diffractometer at RSMAS, University of Miami.

Figure 4 Multi-Collector Inductively Coupled Plasma Mass Spectrometer, Neptune Isotope Lab, UM.

Results

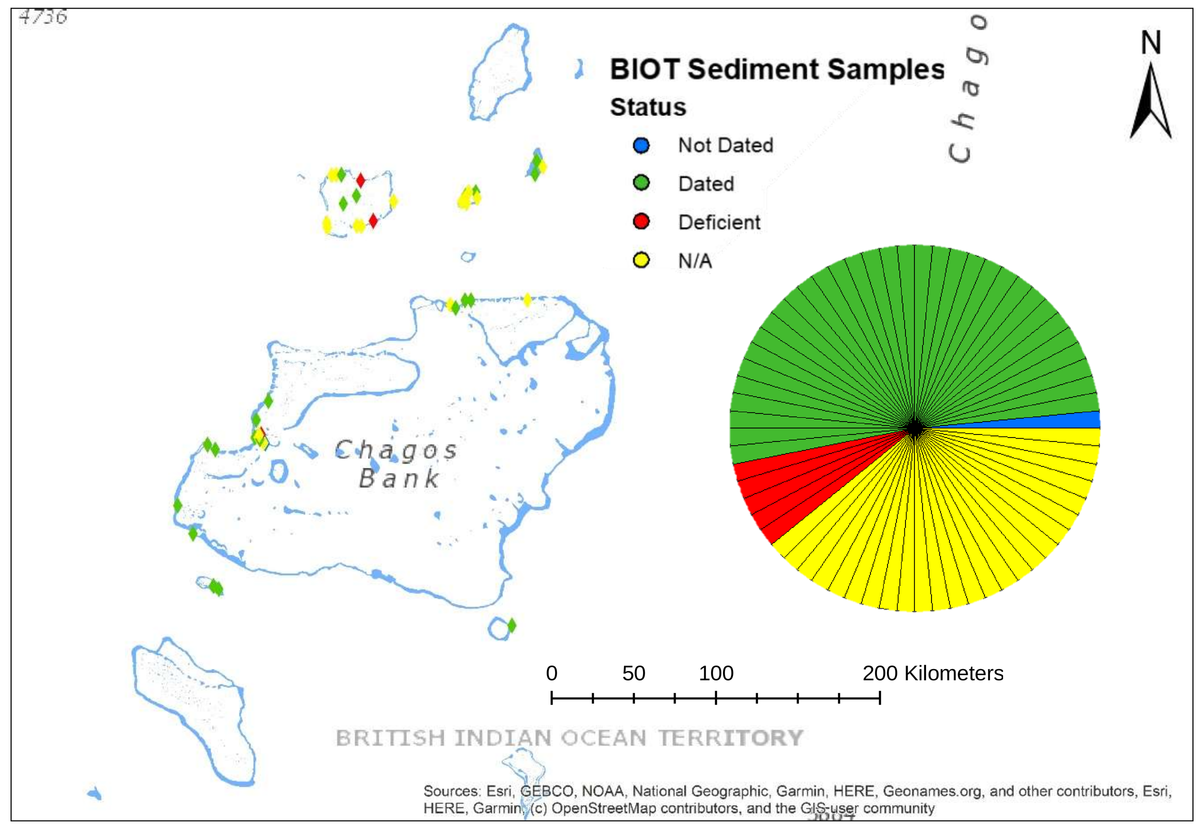

Figure 5 The comparative status of collected BIOT samples: collected (but not yet dated), dated, deficient (< 90% aragonite, >10% HMC), and N/A (< 3 mm sediment).

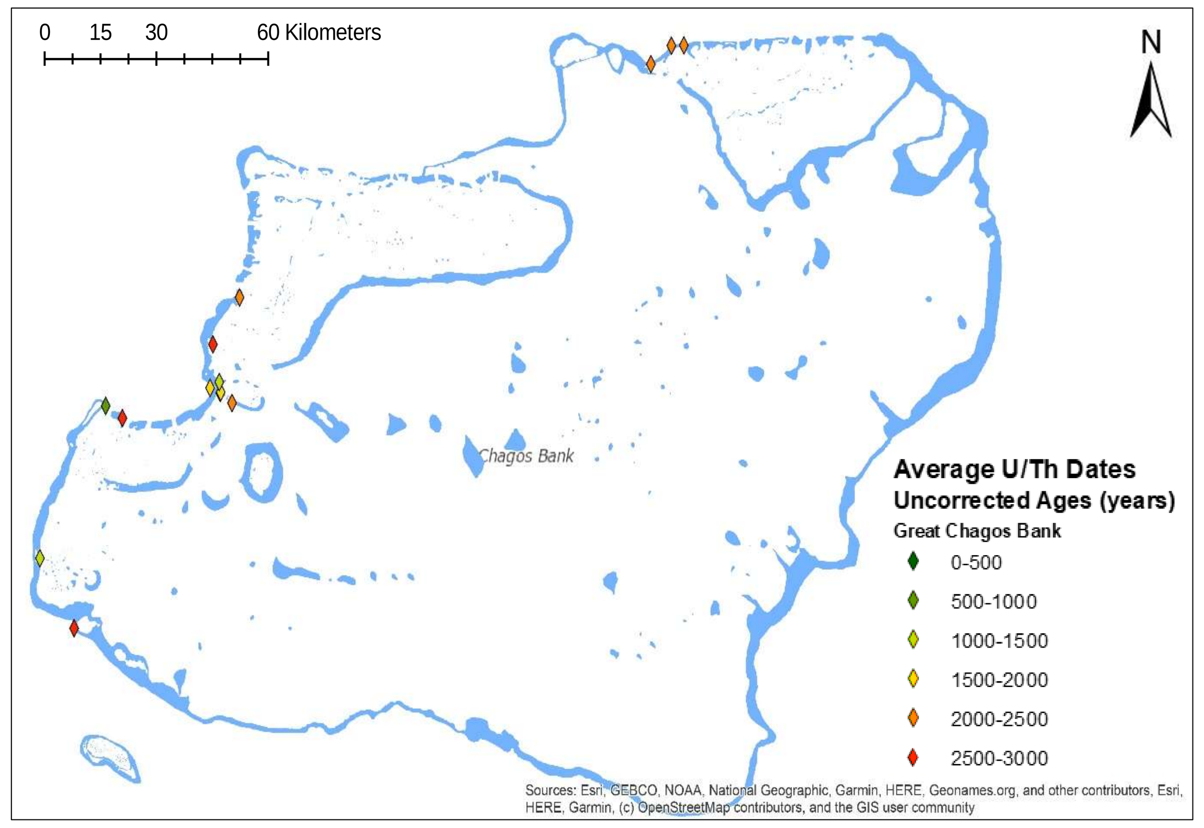

Figure 6 Map of the Chagos Archipelago showing the average U/Th dates calculated for the Great Chagos Bank (n = 52).

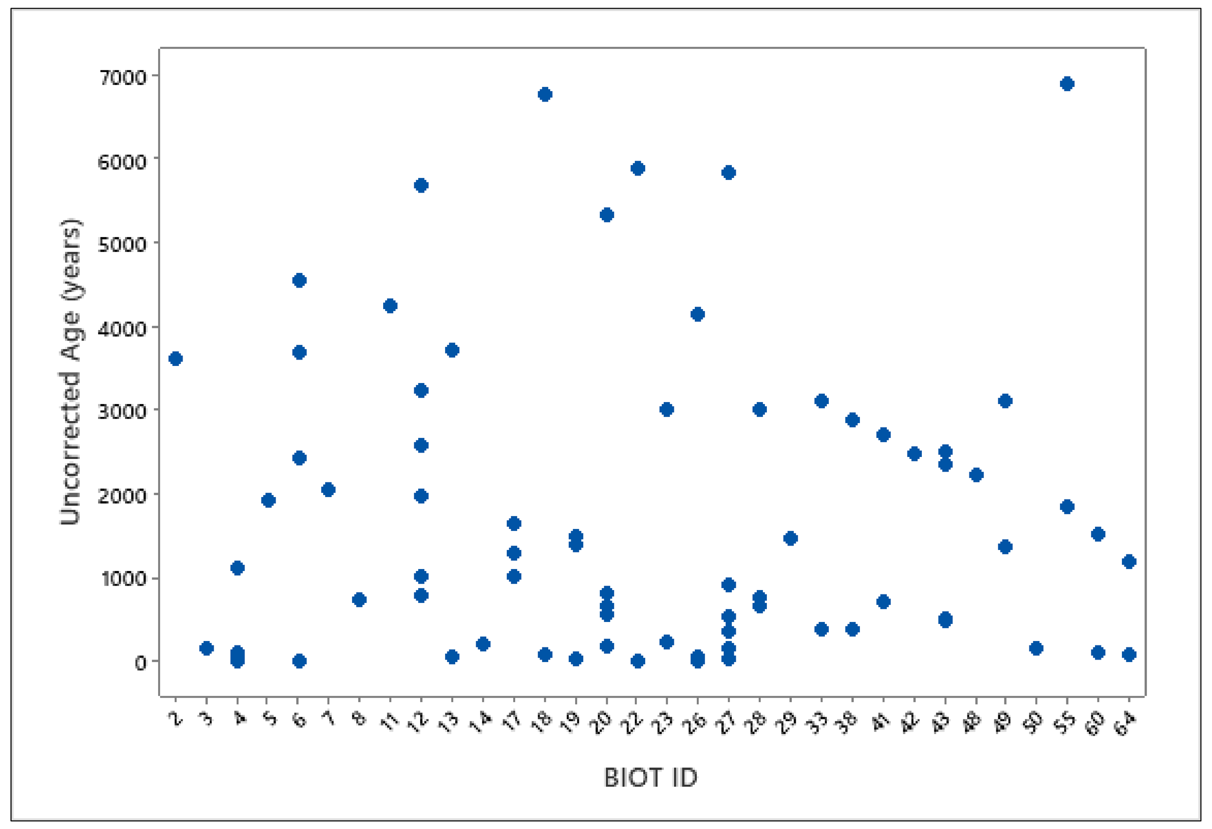

Figure 7 Uncorrected ages (years) calculated from all 33 samples collected and dated from the Chagos Archipelago, excluding BIOT-1 (outlier = 17317 years, n = 1, Cauvin Bank).

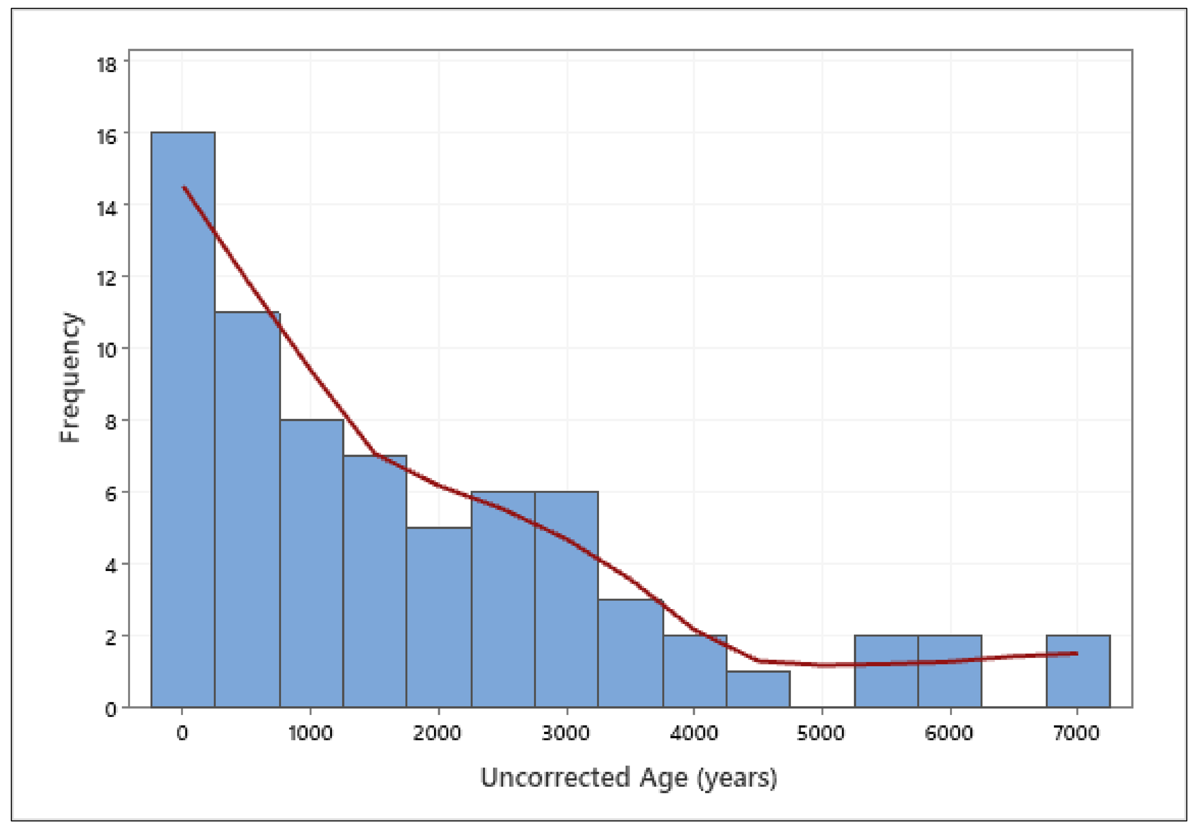

Figure 8 Age distribution of coral fragments across the Chagos Archipelago over the past 8000 years with a lowess smoother line to highlight exponential increase.

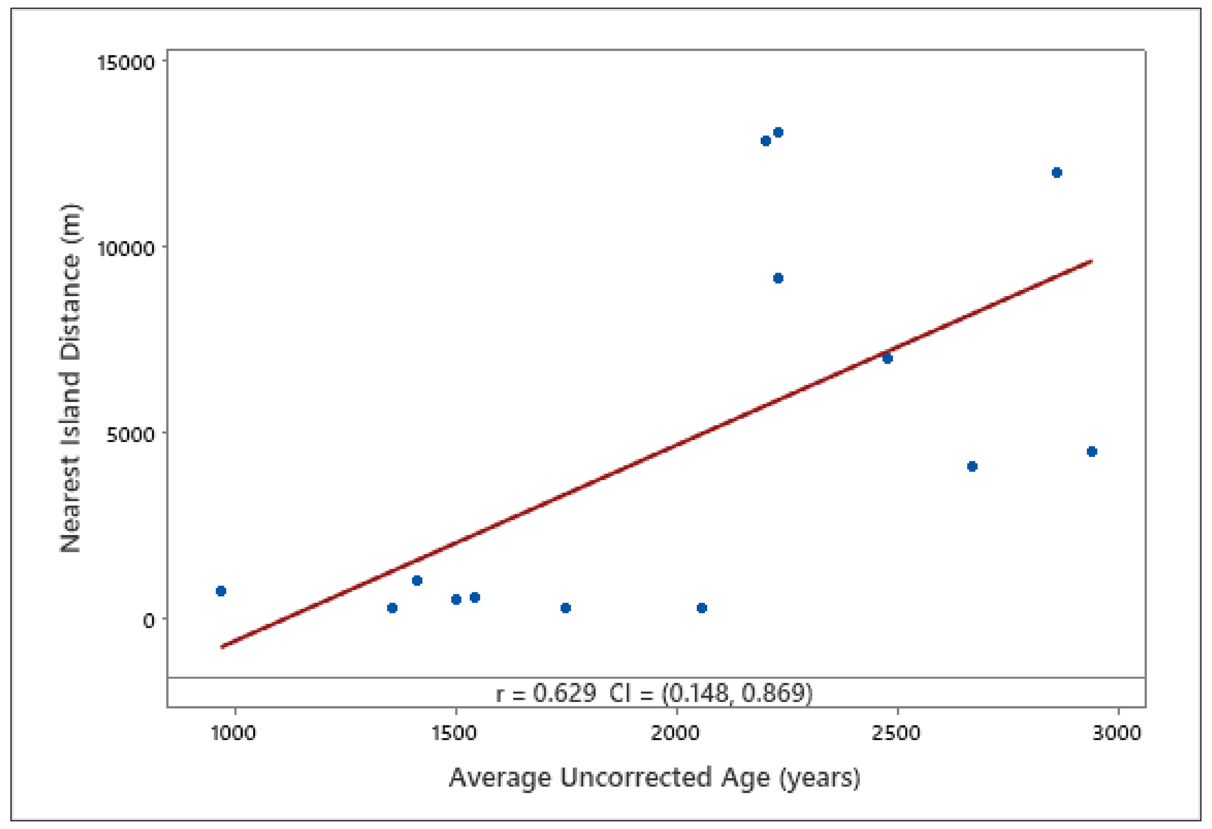

Figure 9 Linear regression plot (95% confidence interval) of the average uncorrected ages (years) of the Great Chagos Bank versus the nearest island distance (m).

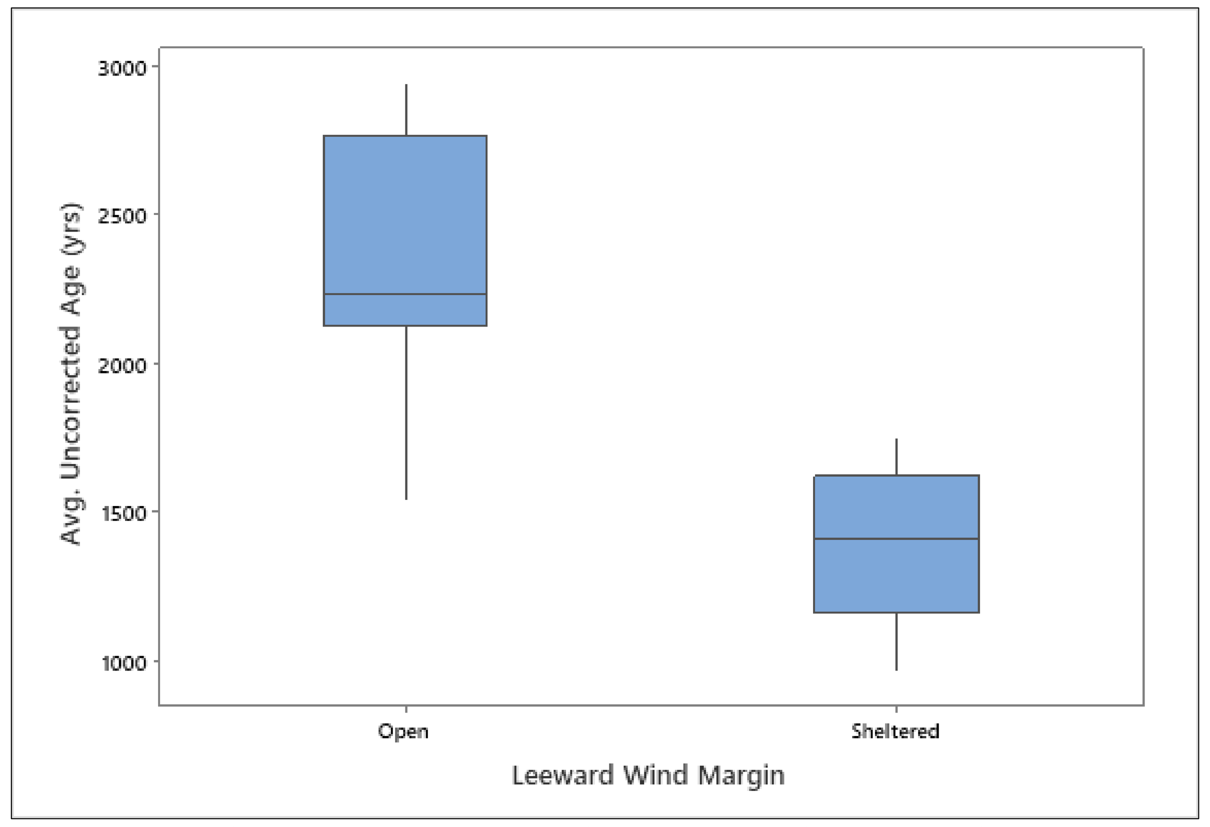

Figure 10 Box (median and 50% quantile) and whisker (95% quantile) plot showing relationship between average uncorrected ages (years) and exposure regime in the Great Chagos Bank.

Discussion

- **Results indicate a time lag of decades to millennia existing between the production of reef detritus and its incorporation in the sediment budget.**
- **Age range = modern sediments to over 6,000 years across Chagos Archipelago!**
  - Older fragments in atoll could be attributed to higher percentage of submerged, inactive reefs.
- Based on Great Chagos Bank (GCB) data:
  - **Youngest coral fragments clustered around low-lying reef islands.**
    - Due to prolonged time to break down and migrate within the atoll, sediments tend to stay close to source of carbonate production [2].
  - **Older fragments clustered around those sites with an exposure to the trade winds (SE).**
    - Increased wind exposure → increased bioerosion rates → high carbonate production rates → new sediment deposits [5].
  - **Trade winds (SE) serve as a mode of transportation for coral fragments as they distribute across the reef (windward vs. leeward).**
    - The net rate of island migration (-0.02 m yr^{-1}) can pose as the minimal rate at which detritus is moving away from the carbonate source (km's per thousands of years) [10].
  - **Carbonate response to eustacy represent changes in carbonate sediment production and accumulation [3]:**
    - Initial reef growth = 7000-8000 years ago
    - Catch-up reef growth = 2000-4000 years ago
    - Keep-up reef growth = last 2000 years
- Future research should finish analyzing all of the samples in the Chagos and perform the same project in other atolls for comparison, and take coral bleaching [8] into consideration.

Acknowledgments

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References

[1] Church et al., 2006
[2] Dawson et al., 2014
[3] Kendall and Schlager, 1981
[4] McLean and Kench, 2015
[5] Perry et al., 2015
[6] Pourmand et al., 2014
[7] Purkis et al., 2019
[8] Sheppard et al., 2020
[9] Woodroffe, 1999
[10] Wu, 2020 (UD)