NERC IAPETUS 2 DTP PhD studentship (2023-24 entry)

University of St Andrews | FOUNDED 1413

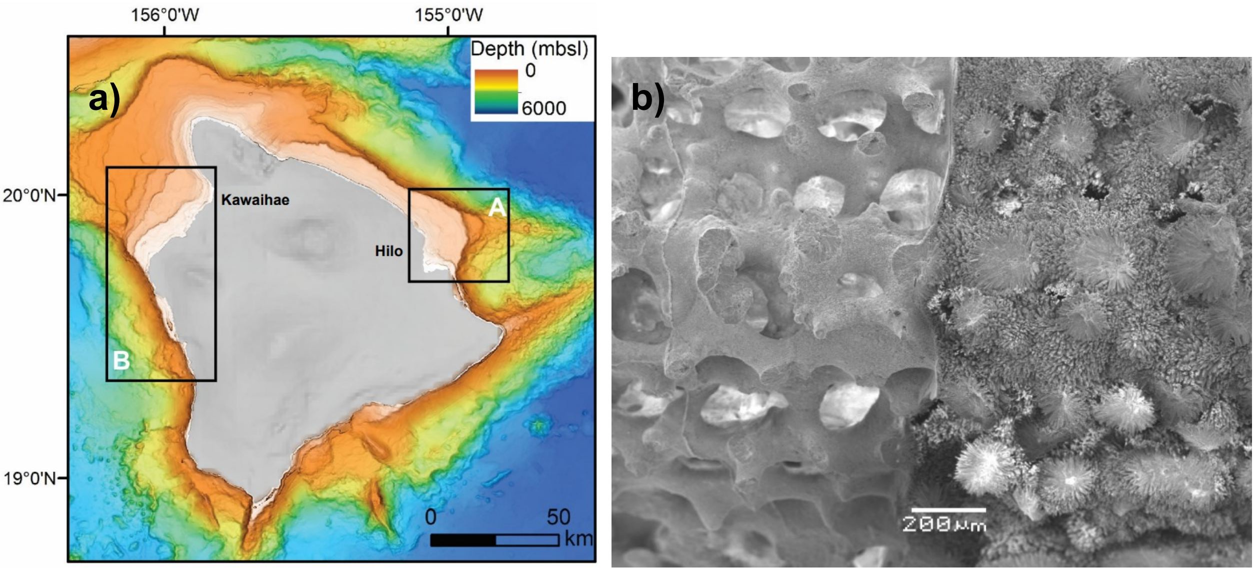
Snapshots of climate variability in the Central Pacific over the last 500ka from drowned Hawaiian coral reefs

Supervisors: Dr Nicola Allison, University of St. Andrews & Dr Cees van der Land, Newcastle University
Project collaborator: Dr Jody Webster, University of Sydney

Overview: The aim of this project is to reconstruct climate variability in the Central Pacific by analysing *Porites* spp. fossil corals from the Hawaiian Islands. The aragonite skeletons of tropical corals are invaluable archives of past climate information, recording information on the seawater composition, temperature and pH at the time of their deposition (Thompson, 2022). For example, skeletal $\delta^{18}O$ indicates seawater temperature and ice volume, Sr/Ca and Sr/U relate to temperature and $\delta^{11}B$ reflects seawater pH. Massive *Porites* spp. corals are commonly used in climate reconstruction. They are widespread in tropical and sub-tropical Indo-Pacific reefs and produce robust skeletons which are well preserved in modern and ancient environments. They accrete rapidly and can yield high temporal resolution (sub-annual) records which track the frequency and magnitude of climate events e.g. El Niño Southern Oscillation (Jiang et al., 2021).

The Hawaiian islands sit in the North Pacific Subtropical Gyre, at a location which is sensitive to shifts in the Pacific Decadal Oscillation and El Niño Southern Oscillation (Kavanaugh et al., 2018), making them an ideal location to track climate change. The islands are shield volcanos that formed over a volcanic hotspot and then subsided as they move away from the hotspot. Fringing coral reefs formed around the islands and accreted rapidly to keep pace with the change in relative sea level (as the island subsided). During periods of rapid relative sea level rise the reefs gave up and drowned, forming multiple terraces that are preserved at depths from ~150m to >1000m below present sea level (Figure 1a). A large suite of fossil *Porites* spp. have been collected from the terraces using a manned submersible, a remote operated vehicle and by rebreather diving. Dating demonstrates that the reefs grew episodically but contain corals that record climate information leading up to, during and after the last five to six glacial cycles. The reefs are a unique resource for reconstruction of climate and sea level (Sanborn et al., 2017).

Figure 1a). High-resolution multibeam bathymetry data around the Big Island of Hawaii indicating drowned reefs at Hilo and Kawaihae (after Sanborn et al., 2017). b) Scanning electron micrograph of a coral from the 225-276 ka terrace. A dissepiment, running vertically, divides the pristine skeleton on the left from the skeleton infilled with aragonite cement on the right.



Methodology: The student will visit the University of Sydney to select coral samples from the existing Hawaiian coral collection held there and to research the geologic and paleoenvironmental context of the reefs. The student will also have access to additional materials obtained during IODP 389 Hawaiian Drowned Reefs. This expedition will drill the reef terraces around the Big Island of Hawaii in 2023. Corals will be examined carefully (XRD, petrography) to identify diagenetic alteration (Figure 1b) which can significantly alter the geochemistry of the primary coral skeleton and overwrite the climate signature (Allison et al., 2007). The student will analyse selected modern and fossil Hawaiian coral specimens for palaeoproxies to reconstruct past seawater temperatures and conditions (Thompson 2022). Selected specimens will be drilled at ~monthly resolution and analysed by ICP-MS or will be analysed by secondary ion mass spectrometry to allow selective analysis of the primary coral skeleton (Allison et al., 2005). The data will be used to infer climate utilising recent advances in the interpretation of palaeoproxies (e.g. Cole et al., 2021). The student will estimate seasonal sea surface temperature (SST) variations, glacial-interglacial temperature change and the amplitude and frequency of interdecadal climate events. Such high resolution palaeoproxy data are critical for understanding global palaeoclimate and in testing and validating global climate models for predicting 21st century climate change.

Training and Skills: The student will develop a multidisciplinary skillset gain in geochemical laboratory techniques as well as training and expertise in coral sedimentology, biomineralisation, isotope geochemistry and palaeoclimate reconstruction. The student will join a NERC-funded team studying coral biomineralisation and carbonate palaeoproxy development in the School of Earth and Environmental Sciences at the University of St Andrews. In addition, the student will gain transferable skills in scientific writing, data analysis, statistics, problem solving and presenting. The student will be a member of the Marine Alliance for Science and Technology for Scotland (www.masts.ac.uk), enabling wider access to training and networking opportunities.

Applications: Contact Nicola Allison for further enquires (na9@st-andrews.ac.uk). General information about eligibility, studying at the University of St Andrews, and the online application form can be found at http://www.st-andrews.ac.uk/study/pg/apply/. This project is eligible for full funding (fees, stipend and research training grant) for 3.5 years from NERC IAPETUS 2. Up to 30% of the studentships can be awarded to international (non-UK) applicants.

References:

Allison N, Finch AA, Tudhope AW, Newville M, Sutton SR, Ellam R, Reconstruction of deglacial sea surface temperatures in the tropical Pacific from selective analysis of a fossil coral, Geophysical Research Letters, 32, L17609, doi: 10.1029/2005GL023183, 2005.

Allison N, Finch AA, Webster JM, Clague DA, Palaeoenvironmental records from fossil corals: the effects of submarine diagenesis on temperature and climate estimates, Geochim. Cosmochim. Ac., 71, 4693-4703, 2007.

Cole C, Finch AA, Hintz C, Hintz K, Yu Y, EIMF and Allison N, Massive Porites spp. corals exhibit reduced skeletal Sr/Ca temperature sensitivity at low seawater pCO_2. Geochimica et Cosmochimica Acta, 314, 55-67, 2021.

Jiang L, Yu K, Han T, Tao S and Zhang H, Coral perspective on temperature seasonality and interannual variability in the northern South China Sea during the Roman Warm Period. Global and Planetary Change, 207, p.103675, 2021.

Kavanaugh MT, Church MJ, Davis CO, Karl DM, Letelier RM, Doney SC. ALOHA from the edge: Reconciling three decades of in situ Eulerian observations and geographic variability in the North Pacific Subtropical Gyre. Frontiers in Marine Science, 20;5:130, 2018.

Sanborn KL, Webster JM, Yokoyama Y, Dutton A, Braga JC, Clague DA, Paduan JB, Wagner D, Rooney JJ, Hansen JR. New evidence of Hawaiian coral reef drowning in response to meltwater pulse-1A. Quaternary Science Reviews, 175:60-72, 2017.

Thompson DM. Environmental records from coral skeletons: A decade of novel insights and innovation. Wiley Interdisciplinary Reviews: Climate Change.13(1):e745, 2022