

ABRUPT CLIMATE VARIABILITY IN THE RED SEA: INSIGHT FROM THE $\delta^{234}\text{U}$ AND U-SERIES CHRONOLOGY OF DEEP-WATER CORALS

Morgan I. Chakraborty, Haoyu Li, Francois Tissot, Arash Sharifi, Ali Pourmand, and Sam J. Purkis

PROJECT OBJECTIVES

- Quantify the $\delta^{234}\text{U}$ and trace-metal variability in Red Sea deep-water corals to reconstruct Quaternary climate extremes
- Improve resolution of Red Sea coral geochronology using a larger sample set
- Compare deep-sea-derived signals with Arabian paleoclimate archives

PROJECT RATIONALE

The aim of this study is to understand how Quaternary climate variability in Arabia is recorded by Red Sea deep-water corals (DWCs). The Red Sea occupies a climatically sensitive position at the intersection of the African monsoon, the Mediterranean westerlies, and the Afro-Asian dust belt. Its semi-restricted connection to the Indian Ocean renders the Red Sea highly responsive to shifts in atmospheric circulation and regional hydroclimate, establishing it as a natural laboratory for investigating climate extremes in rift basins.

Building on the framework from Chakraborty et al. (2025), we explore the potential of uranium-series disequilibria in DWCs as a proxy for terrigenous input and hydroclimate. By quantifying the sensitivity of the $^{234}\text{U}/^{238}\text{U}$ ratio to weathering, riverine discharge, and aeolian dust flux, we develop a framework linking atmospheric circulation, Arabian rainfall, and seawater $\delta^{234}\text{U}$, and apply U–Th geochronology to resolve Late Quaternary climate variability. Together, these advances position Red Sea DWCs as a robust deep-sea archive for reconstructing abrupt hydroclimate events in a dynamically forced region.

APPROACH

We will expand the existing dataset from Chakraborty et al. (2025) by analyzing an additional 17 DWCs collected from the northern Red Sea. These samples will increase temporal resolution and extend the record beyond 17.8 ka, the age of the oldest coral analyzed to date. Using high-resolution MC-ICP-MS, we will measure uranium-series isotopes and trace-metal concentrations and perform U–Th geochronology to generate a comprehensive, well-dated record of Late Quaternary hydroclimate variability in the Red Sea.

The resulting coral-based record will be evaluated alongside existing terrestrial and atmospheric archives from Arabia, including records of monsoon intensity, dust flux, and regional precipitation from speleothems. By integrating seawater $\delta^{234}\text{U}$ variability with independently constrained atmospheric circulation proxies, we aim to identify the timing, magnitude, and mechanisms of abrupt hydroclimate events and assess how shifts in large-scale circulation systems are transmitted from the atmosphere to the marine environment and archived in DWCs.

SIGNIFICANCE

Deep-water corals (DWCs) are valuable archives of past U-isotope compositions. The Red Sea offers a unique opportunity to exploit this archive, as we have in hand fossil DWCs, recovered using submersibles and remotely operated vehicles (ROVs) from depths and settings inaccessible to traditional sedimentary records (>250 m water depth). These samples enable direct reconstruction of past seawater $\delta^{234}\text{U}$ in primary skeletons that have not been exposed subaerially during the last sea-level lowstand.

We contend that when the $\delta^{234}\text{U}$ value deviates from the global average (Chen et al., 2016), it provides evidence for changes in terrigenous input into the basin, as mediated by aeolian dust and ephemeral rivers, which reciprocally vary during wet and dry climate shifts. Arabian climate is controlled by the interplay of Hadley cell systems around the Red Sea, including the African Monsoon System (AMS), Mediterranean westerlies, and the Afro-Asian dust belt. We aim to disentangle how these atmospheric systems regulate Arabian rainfall (Purkis et al., 2025). This project investigates how coupled atmospheric and hydrologic processes interact in the marine system and are then archived in DWCs. By linking atmospheric circulation, hydroclimate, and seawater $\delta^{234}\text{U}$, this work bridges processes across Earth's atmosphere and hydrosphere, establishing DWCs as a novel integrative archive for reconstructing Quaternary climate variability in the Middle East.

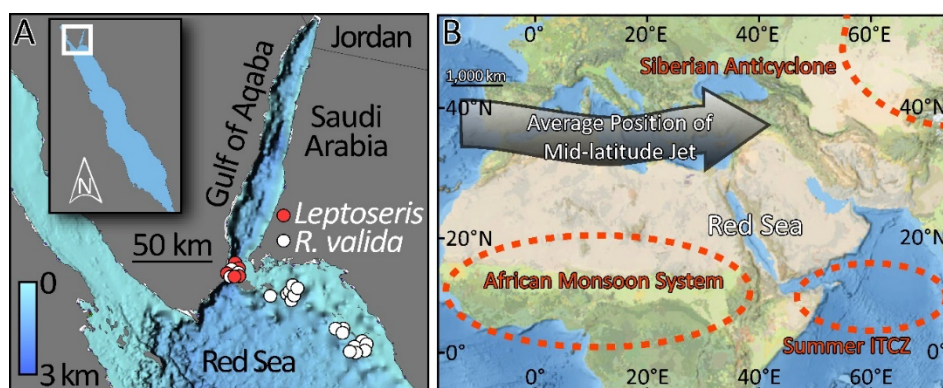


Figure 1: Regional map and sample location. (A) Location of the sampled corals atop multibeam bathymetry data acquired during three research cruises. (B) Set-up of the large-scale atmospheric circulation systems which moderate Arabian climate.

REFERENCES

- Chakraborty, M.I., Sharifi, A., Benzoni, F., Tissot, F.L., Pourmand, A., Taviani, M., Howes, B., Swart, P.K., Lu, C., Rodrigue, M. and Purkis, S.J., 2025. Deep-water corals indicate the Red Sea survived the last glacial lowstand. *Proceedings of the National Academy of Sciences*, 122(8), p.e2415559122.
- Chen, T., Robinson, L.F., Beasley, M.P., Claxton, L.M., Andersen, M.B., Gregoire, L.J., Wadham, J., Fornari, D.J. and Harpp, K.S., 2016. Ocean mixing and ice-sheet control of seawater $^{234}\text{U}/^{238}\text{U}$ during the last deglaciation. *Science*, 354(6312), pp.626-629.
- Purkis, S.J., Ward, S.N., Howes, B.J., Longenecker, J.M., Chakraborty, M.I., Kalman, A., Clement, A.C., Sharifi, A., Benzoni, F., Clarke, C. and Rodrigue, M., 2025. A 1600-year record of extreme rainfall in northern Arabia. *Science Advances*, 11(8), p.eadq3173.