CLIMATE MODULATION OF SILICICLASTIC INPUT INTO THE RED SEA RIFT

Sam J. Purkis, Bolton J. Howes, Jake M. Longenecker, Morgan I Chakraborty, and Akos Kalman

PROJECT OBJECTIVES

- To examine the climatic feedbacks that link terrigenous and marine processes in mixed depositional rift settings.

PROJECT RATIONALE

Deep-sea sediment cores provide a comprehensive picture of past climate. Understanding the variability of past climate is essential to frame uncertainties surrounding future climate forecasts. Quaternary paleoclimate of the Middle East oscillated between periods of amplified rainfall and extreme drought (Arz et al., 2003; Parker et al., 2006; Purkis et al., 2010). The region is noteworthy for its high climate variability during the Holocene, an era which, at global scale, is considered to be relatively stable. Accordingly, scientists cast the Middle East as a climate change hotspot and a key calibration point for future climate projections.

The upland side of the northern Saudi Arabian Red Sea shoreline comprises ephemeral desert stream systems (wadis) that collectively drain >500,000 km^2 of mountainous drylands and deliver siliciclastic sediment to the coast in episodic flash floods. Periods of amplified rainfall in the region therefore induce pulsed delivery of massive volumes of siliciclastics into the rift basin. The near-absence of a continental shelf forces the photozoan-dominated carbonate factory to hug the resultant siliciclastic-dominated coast and delivers little studied mixed-system sedimentary interactions, specific to arid rift basins.

APPROACH

This study focuses on the Gulf of Aqaba, an extension of the northern Red Sea. In winter, the northern hemisphere Middle East Subtropical Jet (MESTJ) is situated above the Gulf (Sharifi et al., 2018). The MESTJ is a component of the jet stream and comprises a narrow and strong westerly wind belt. The position of the MESTJ and its strength mediate the intensity and location of precipitation over the Gulf of Aqaba and beyond (Ren et al., 2022; Wei et al., 2022). Under certain configurations, the MESTJ emplaces a large and humid warm air mass above the usually hyper-arid Gulf, generating extreme rains. These events can amount to several years of rain in a couple of hours (Klein, 2000).

Extreme rains fill the high mountain watersheds surrounding the Gulf, activate ephemeral rivers, so-called ‘wadis’, and transport freshwater plumes laden with terrigenous sediments into the sea (Fricke, 1996). By virtue of their high relative density, the plumes sink as muddy submarine hypo- and hyperpycnal flows (Mulder et al., 2001). These flows settle to the seabed as classic fining-upward Bouma-type turbidites, emplacing a sedimentary record of extreme rainfall events seaward of canyon heads. The fining-upward nature of individual turbidites conveniently distinguishes each rain event from that preceding it. Thus, counting and dating the terrigenous turbidite layers in seabed cores offers a means of reconstructing rainfall over geological timescales.

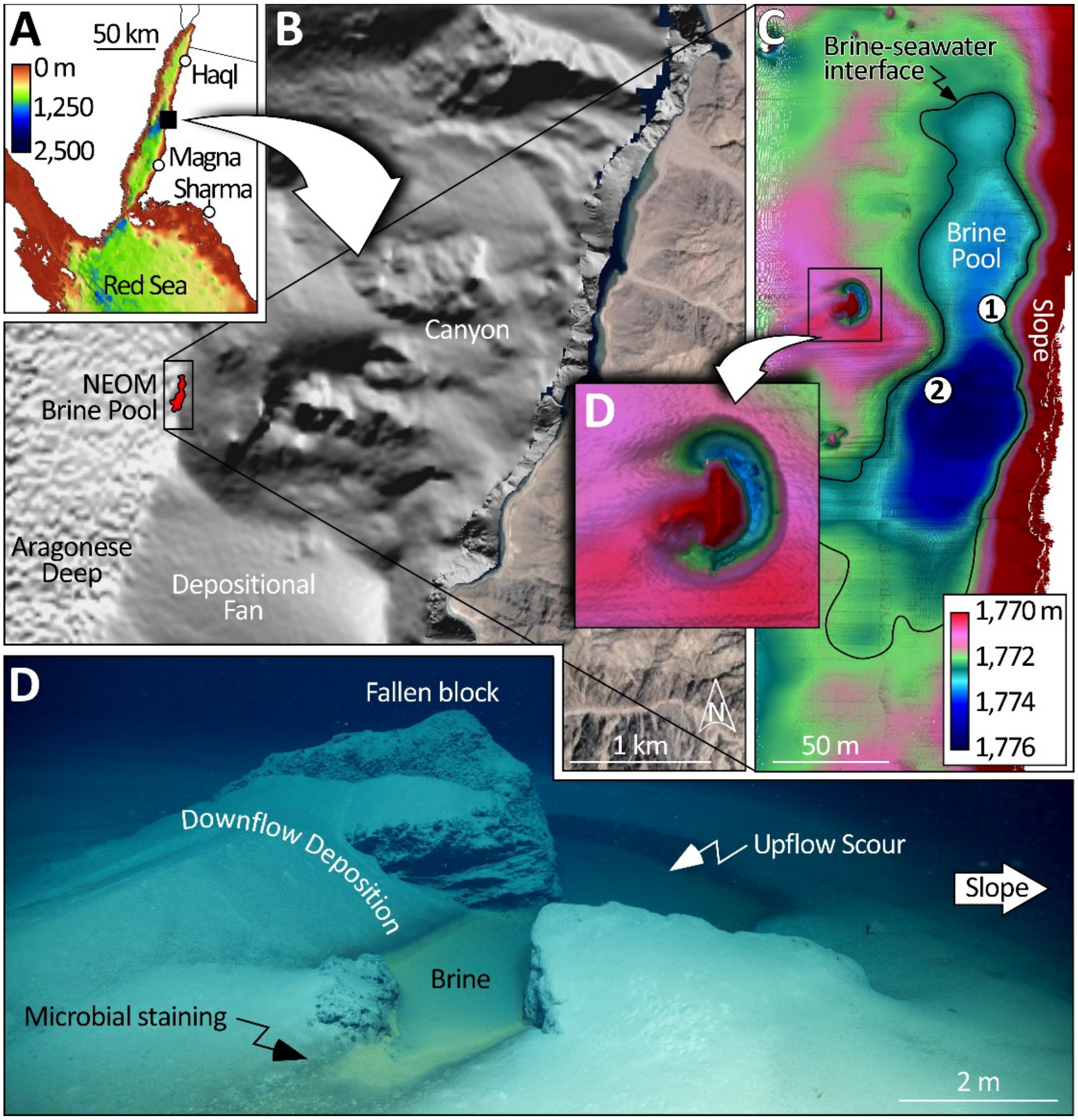

Figure 1. Depositional setting of the NEOM brine pool. (A) The brine pool is located at 1,772 m water depth at the toe-of-slope of the Saudi coastal margin in the Aragonese Deep, the deepest point in the Gulf of Aqaba. Mapped here atop hill-shaded multibeam data, the pool, situated just 2 km from the coast, is excellently positioned to receive episodic fluvial outwash from the Saudi coastal plain (B). High-resolution multibeam of the brine pool acquired from the Argus remotely operated vehicle (C) shows the brine pool to be 10,000 sq. m in area and 6 m deep at its deepest point. Two push cores (white circles) were acquired through the bed of the pool. Smaller brine pools have been created in seabed depressions created by blocks falling down the slope into the Aragonese Deep (D), which subsequently fill with brine. Note how the seabed scours landward of these blocks whereas sediment deposits seaward of them, indicating down-slope flow of cascading density currents.

SIGNIFICANCE

Arz et al. (2003) used flood deposits in deep-sea cores to reconstruct Gulf of Aqaba hydroclimate. Their study extends back 7,000 years and identifies amplified fluvial input between 9.25 and 7.25 kyr BP as representing the northern Red Sea humid interval. By 5.5 kyr BP, this input abruptly diminishes, marking the onset of regional hyperaridity. A crucial, confounding factor to linking flood deposits in cores to hydroclimate is the reworking of marine sediments by burrowing benthic organisms (bioturbation). Work by Steiner et al. (2016) emphasizes how bioturbation effectively erases short term events from the deep Gulf's sedimentary record. Their study, as well as those of Katz et al. (2015) and Bialik et al. (2022), advises that biological activity is capable of mixing many decades of sediment deposition. Bioturbation limited the temporal fidelity of the rainfall record retrieved by Arz et al. (2003) to broad precipitation trends played out over millennia.

The deep-sea 'NEOM' brine pool discovered by Purkis et al. (2022) at a water depth of 1,770 m in the Gulf of Aqaba offers a unique opportunity to reconstruct the region's hydroclimate because the pervasive anoxia, low pH, and hypersalinity of the brine excludes all metazoans. Thus, the sedimentary sequences that accumulate on the bed of the NEOM pool are entirely undisturbed by bioturbation. Moreover, all of the other pools so far discovered in the Red Sea trend along the central axis of the rift, far from land. Uniquely, the NEOM brine pool is located just 2 km from the coast (Fig. 1), perfectly positioned to receive fluvial outwash from extreme rains. Cores from the 10,000 m^2 pool retrieved by Purkis et al. (2022) extend back to 1.6 kyr and exquisitely preserve stacked mm-scale terrigenous Bouma sequences. In this study we pair the cores retrieved by Purkis et al. (2022) and others acquired in 2022, with computer simulations of the Gulf of Aqaba watershed outwash, to deliver the first high-resolution Late Holocene record of Red Sea hydroclimate.

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