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Morphotectonics of young passive margins and rift basins: Observations from the northern Red Sea and Gulf of Aqaba

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Understanding the morphotectonics of young passive margins and active rift basins provides an insight into their history and a predictive tool of offshore sedimentation. The northern Red Sea is bounded to the east by the Midyan rift embayment, an onshore Miocene rifted and highly extended margin, complicated by the Mid-Miocene to Recent Gulf of Aqaba strike-slip tectonics to the north-west. This study shows how drainage evolution along the NE Red Sea margin can be used to constrain its tectonic and geodynamic history, bridging the gap inherent in limited uplift data and limited exposures of structures and strata. Ultimately, this feeds into the assessment of sediment transport routes and volumetrics within the syn-rift and passive margin depocentres.

Drainage patterns were extracted from an ASTER (∼30 x 30 m) digital elevation model using ArcGIS to characterise the relationship between drainage and early rift structures. The Cenozoic uplift history was then calculated using an inverse model (onshore area between 24°00'N and 29°33'N) that utilises retreat of longitudinal stream knickpoints, whose rates are controlled by upstream drainage area, uplift and lithology. Furthermore, a minimum erosion volume from the rift flank catchments has been estimated using watershed boundaries as inputs to create an initial hypothetical surface, from which present-day topography is removed.

Along the margin, two zones of high escarpments are semi-parallel to the coastline, separated by a zone of subdued topography that is covered by the largest catchment (RS20) and a major relay zone. Smaller catchments closer to the coastline are associated with normal faults and represent footwall drainage. These small catchments separate larger catchments of more evolved drainage encompassing different structural elements (i.e. hangingwall and footwall blocks and relay zones) or single hangingwall drainages. Throughout the study area, major knickpoints have minimal spatial correlation with lithological boundaries and signifies the dominance of uplift as a cause for knickpoint migration. From drainage inverse modelling, uplift during early rift (18-15Ma) started in the southern parts before migrating generally northwards, affecting the Midyan Peninsula and then the Gulf of Aqaba margin more prominently during the interval 12-0Ma. The area of low uplift in between the northern and southern uplift loci coincides with the major relay zone and the lower reaches of RS20 (Wadi Al Hamd). The minimum bulk erosion map shows an 80-60 km-wide swath of eroded volume in the south, narrowing to 20-40 km-wide east of the Midyan Peninsula. East of the Gulf of Aqaba, erosion is currently focussed in the mountainous region north of the Midyan Basin becoming more distributed further north. Catchment RS20 appears to have contributed the largest volume (5354 km3).

Drainage analysis is shown to be a useful tool in revealing early rift structures, uplift history and bulk minimum erosion contributions within an evolutionary tectono-geomorphic model of the northern Red Sea and Gulf of Aqaba margins, providing a predictive tool for the position and contributions of major sediment point sources into the offshore basin. Such point sources are associated with relay zones and outlets of major catchments.