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The Red Sea – 50 years of geological and geophysical research

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ABSTRACT

The Red Sea displays lithosphere that is in transition from rifting to drifting and therefore provides enormous opportunity to understand incipient seafloor spreading development. Despite more than 50 years of extensive geological and geophysical research, there remains significant conjecture concerning the timing of sea-floor spreading initiation, the extent of spreading along the axis of the Red Sea, and the geodynamic processes responsible for the onset of crustal extension. Red Sea tectonic models based on geological data are dominated by single stage rift models involving protracted stretching of continental crust followed by sea floor spreading at ca 5 Ma, and include both asymmetric and symmetrical extension models. Geophysical data suggest that an oceanic crust occurs beneath the Red Sea shelves, although exactly how this crust has evolved remains undecided. Equally, arguments have been made in favor of the sedimentary shelves forming on extended continental crust, and that oceanic crust is restricted to the present day Red Sea axial valley. However, our synthesis shows that none of the models proposed so far is applicable to the entire Red Sea basin. The distribution and timing of the Red Sea crustal extension and sea-floor spreading may have been influenced by subduction-related far field forces due to complex plate interactions along the northern edge of the Arabian plate during Early Miocene. Our reassessment suggests that following the arrival of the Afar plume the southern Red Sea underwent rapid extension culminating in the transition from rifting to seafloor spreading, which stalled during the early Miocene in the central Red Sea due to either slowing of the convergence between Arabia and Eurasia or the onset of the Arabian plate passive margin collision with Eurasia. Off axis magmatism is focused on the Arabian margin and Afar depression and has been episodically active since the Miocene. We consider a formation of the Red Sea as a hybrid process involving both "active and passive" rifting.

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1. Introduction

There is an extensive documentation regarding the continental record of structures that are related to new accretionary plate boundaries located above hot spots in the mantle (Ghebreab, 1998). The relatively narrow small rifts and oceans such as the Red Sea and Gulf of Aden at the boundary between the African and Arabian plates represent examples of this process (Fig. 1). Such rifts have been considered the closest modern analogs to continental lithosphere rifting and rupturing and to seafloor spreading initiation, and thus, they are an integral part of our understanding of plate tectonic theory. The Red Sea rift belongs to a rift system that includes the East African, Afar and the Gulf of Aden rifts in the south and the Gulf of Suez and Aqaba in the north (e.g. Guiraud et al., 1985). The Red Sea and Gulf of Aden rifts converge with the East African rift at the Afar triple junction.

The Red Sea represents a natural laboratory to understand processes responsible for early rift-related magmatic systems and ocean basin formation influenced by both active and passive rifting processes. The processes responsible for the transition from continental rifting to oceanic spreading have been inferred by the study of the ancient geological

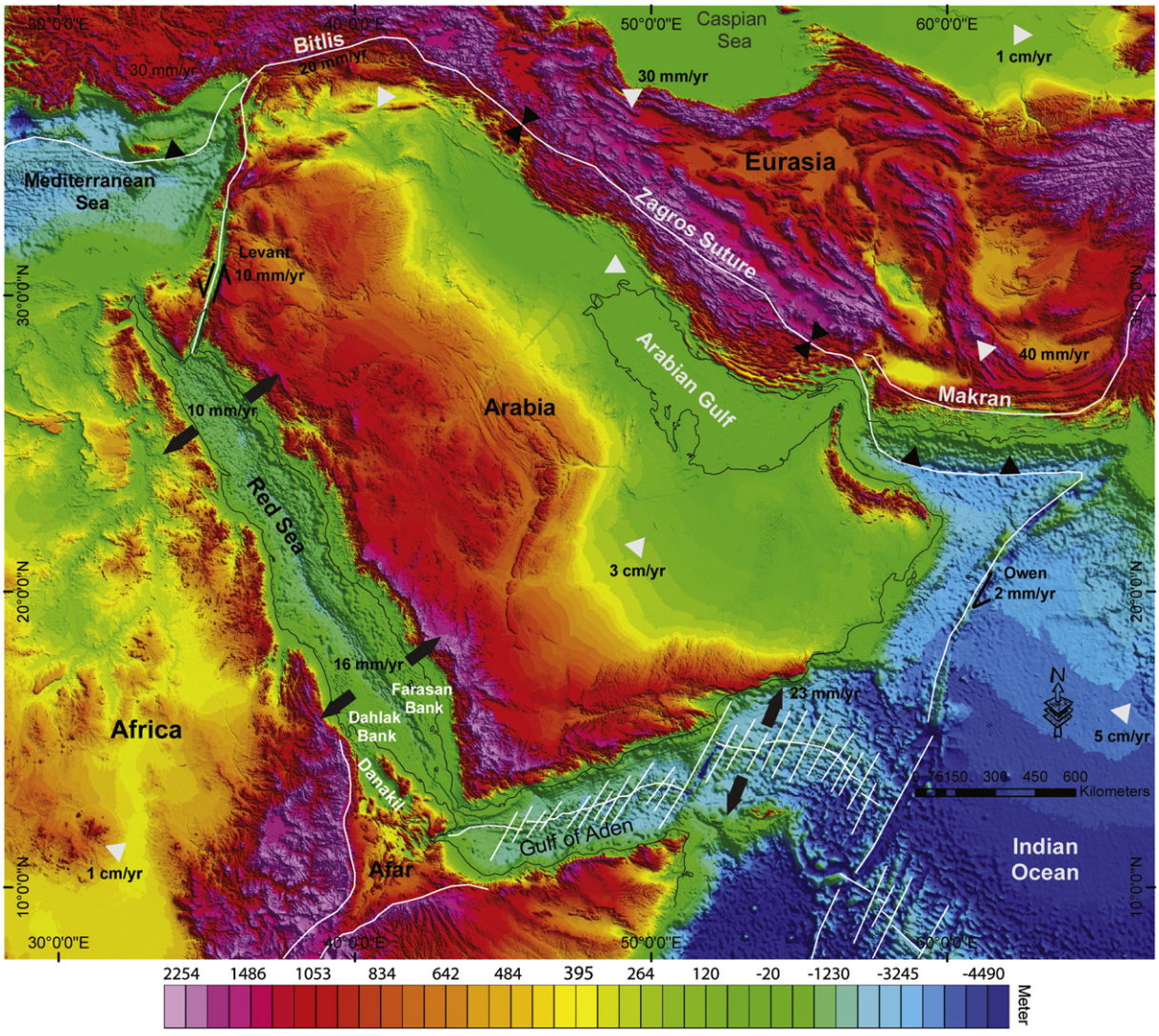

Fig. 1. Bathymetry and elevation features of the Red Sea and surrounding area at 30-arc seconds resolution after Becker et al (2009). Tectonic framework of the Arabian plate and plate motion with residual velocities after Bellahsen et al. (2003) and ArRajehi et al. (2010).