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The Sawqirah contourite drift system in the Arabian Sea (NW Indian Ocean): A case study of interactions between margin reactivation and contouritic processes

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ABSTRACT

The relationships between oceanic circulation in the Arabian Sea and Late Cenozoic climate changes, including variations in monsoon intensity at the million year time-scale, remain poorly investigated. Using multibeam and seismic data, we provide the first description of a contourite drift in the Arabian Sea, along the south-eastern Oman margin. This contourite drift is referred as the “Sawqirah Contourite Drift System”. Late Miocene reactivation of the south-eastern Oman margin resulted in the formation of a complex anticline system, which shaped the seafloor topography above which the Sawqirah Drift subsequently developed. The drift resulted from the circulation of bottom currents within the North Intermediate Indian Water. Major seismic unconformities identified within the Sawqirah Drift were tied to Ocean Drilling Program (ODP) drill holes, and allowed defining distinct episodes of drift construction. At least two of these unconformities record reorganizations of the oceanic circulation at ~4.5–4.8 Ma and ~2.4 Ma. The 4.5–4.8 Ma-old unconformity is coeval with the onset of upwelling of deep and cold waters in the Owen Basin. The 2.4 Ma-old unconformity records a major episode of Indian monsoon intensification (at the million year time scale) over the Arabian Sea, indicating strong coupling between oceanic and atmospheric circulation processes.

1. Introduction

The global oceanic circulation underwent several reorganization phases during the Late Cenozoic in response to plate tectonics events and climate-eustatic changes. In the Early Miocene, intermediate and deep-water masses in the Atlantic and Pacific Oceans all originated from water masses surrounding Antarctica, and aged towards the Arctic (Woodruff and Savin, 1989). Several tectonic events contributed to the development of the thermohaline circulation and the differentiation of the isotopic signature of water masses (Billups, 2002; Bickert et al., 2004; Poore et al., 2006): the closure of the Panama Strait beginning in the Middle Miocene (Montes et al., 2015), the opening of the Gibraltar Strait in the Central Atlantic at 5.3 Ma (Hernández-Molina et al., 2014), and the closure of the Indonesian Seaway in south-east Asia at ~3–4 Ma (Fig. 1; Cane and Molnar, 2001). The sea level drop-down induced by the onset of permanent ice-sheets in the northern hemisphere around 2.7 Ma (Bailey et al., 2013) also contributed to the emergence of the straits (Molnar, 2008; Miller et al., 2011).

Major changes in thermohaline circulation have strong effects on sedimentation. Currents generate deposits known as contourite drifts, and several types of erosive features forming contourite channels, moats or terraces. The architecture, distribution, and stratigraphy of contourite drift systems provide strong constraints on long term (10^5–10^6 years) intermediate and deep-sea circulation changes (Faugères et al., 1999; Rebesco et al., 2014). Since the onset of the thermohaline circulation, several continental margins experienced tectonic reactivation, expressed by inversion of rifted structures or gravity-driven tectonics that influenced the build-up of contourite drift systems (for instance in the Alboran Sea, Ercilla et al., 2016; Juan et al., 2016).

Contourite drifts are poorly documented along the Indian Ocean's margins (Rebesco et al., 2014). The best-studied area of contourite deposition is the Maldives carbonate platform (Betzler et al., 2013; Lüdmann et al., 2013). In the western Indian Ocean, a few preliminary studies also document contourites in the vicinity of the Amirante Ridge south to the Seychelles (Damuth and Johnson, 1989), in the Mozambique Basin (Preu et al., 2011), and off South Africa, where the Indian and the Atlantic oceans connect (Ben-Avraham et al., 1994; Niemi et al., 2000; Uenzelmann-Neben et al., 2011; Wiles et al., 2014; Gruetzner and Uenzelmann-Neben, 2016). Where available, stratigraphic constraints within these contourite drift systems document a Middle

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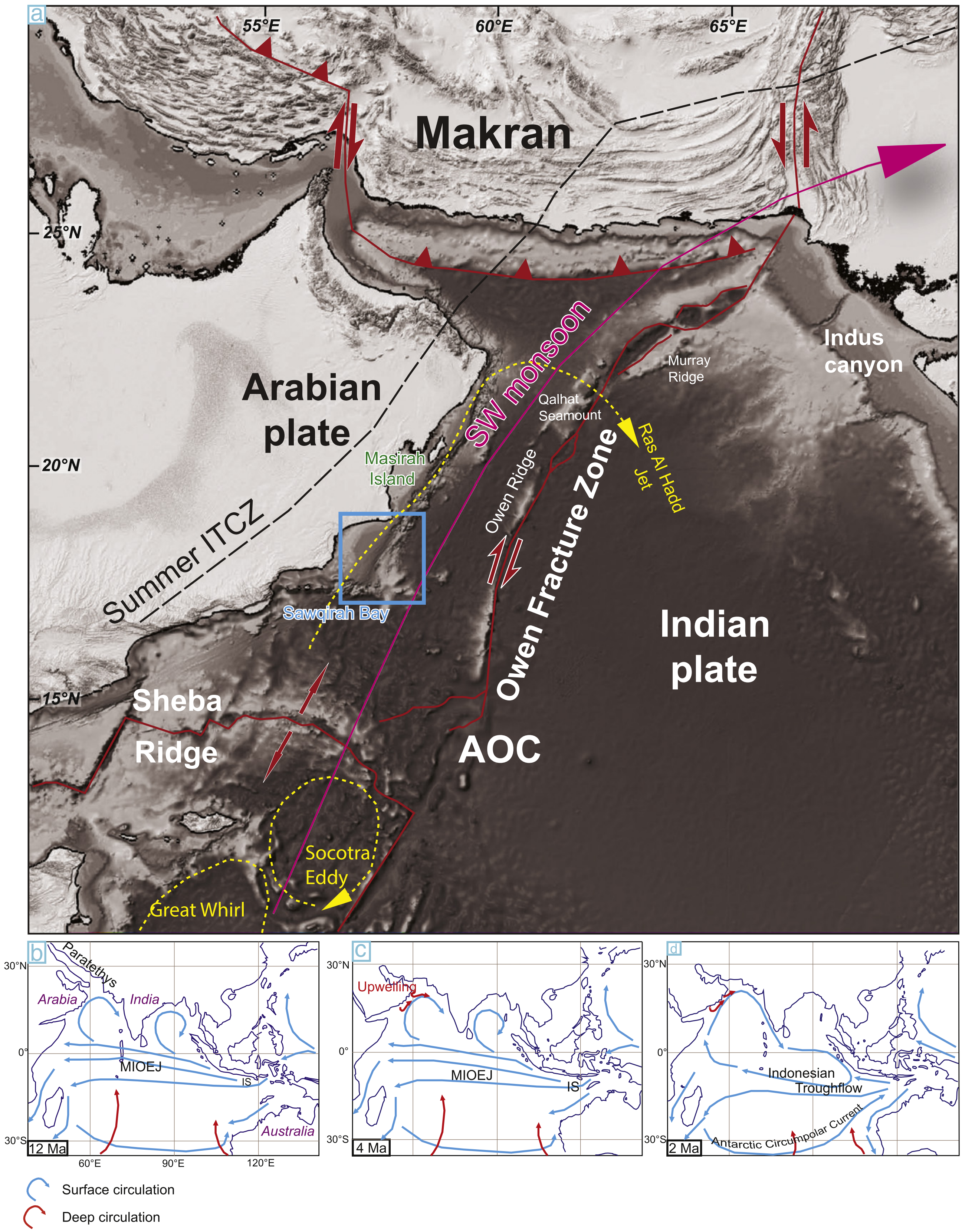

Fig. 1. a) Regional tectonic map of the Arabian Sea. The black dashed arrow represents the position of the summer Inter-Tropical Convergence Zone (ITCZ), and the yellow dotted line the path of the Ras Al Hadd Jet and other local surface currents (for the summer monsoon configuration; Schott and McCreary, 2001). The pink line represents the summer monsoon winds. AOC: Aden-Owen-Carlsberg triple junction, configuration according to Fournier et al., 2008. b) to d): schematic reconstructions of oceanic circulation in the Indian Ocean since Tortonian times, modified from Gourlan et al. (2008). Plate reconstructions are from Seton et al. (2012). For more detailed reconstructions of the present-day oceanic circulation, including its seasonal changes in response to fluctuations in the monsoon regime, see Schott and McCreary, 2001. MIOEJ: Miocene Indian Ocean Equatorial Jet, IS: Indonesian Seaway.