Earth and Planetary Science Letters 302 (2011) 247–252

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

journal homepage: www.elsevier.com/locate/epsl

Owen Fracture Zone: The Arabia–India plate boundary unveiled

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ARTICLE INFO

Article history:
Received 16 June 2010
Received in revised form 6 December 2010
Accepted 10 December 2010
Available online 3 January 2011

Editor: R.D. van der Hilst

Keywords:
plate kinematics
strike-slip faults
pull-apart basins
Arabia–India plate boundary
Owen Fracture Zone

ABSTRACT

We surveyed the Owen Fracture Zone at the boundary between the Arabia and India plates in the NW Indian Ocean using a high-resolution multibeam echo-sounder (Owen cruise, 2009) for search of active faults. Bathymetric data reveal a previously unrecognized submarine fault scarp system running for over 800 km between the Sheba Ridge in the Gulf of Aden and the Makran subduction zone. The primary plate boundary structure is not the bathymetrically high Owen Ridge, but is instead a series of clearly delineated strike-slip fault segments separated by several releasing and restraining bends. Despite an abundant sedimentary supply by the Indus River flowing from the Himalaya, fault scarps are not obscured by recent deposits and can be followed over hundreds of kilometres, pointing to very active tectonics. The total strike-slip displacement of the fault system is 10-12 km, indicating that it has been active for the past ~3 to 6 Ma if its current rate of motion of 3 ± 1 mm yr^{-1} has remained stable. We describe the geometry of this recent fault system, including a major pull-apart basin at the latitude 20°N, and we show that it closely follows an arc of small circle centred on the Arabia–India pole of rotation, as expected for a transform plate boundary.

1. Introduction

The Arabia–India plate motion is currently accommodated along the Owen Fracture Zone (OFZ) in the NW Indian Ocean (Gordon and DeMets, 1989; Matthews, 1966; Whitmarsh, 1979; Wilson, 1965). The OFZ belongs to the large strike-slip plate boundaries like the San Andreas, Dead Sea, North Anatolian and Alpine faults in the continental domain, and the Macquarie Ridge in the oceanic domain (Le Pichon et al., 2005; Lebrun et al., 2003; Mann, 2007; Massell et al., 2000; Stein et al., 1997; Weber et al., 2009). The OFZ is marked by a moderate seismicity and by a prominent bathymetric ridge, the Owen Ridge, up to 2000-m high with respect to the surrounding seafloor (Fig. 1). The Owen Ridge acts as a barrier to turbidites of the Indus deep-sea Fan and prevents their sedimentation towards the west into the Owen Basin (Clift et al., 2001; Mountain and Prell, 1990). As indicated by dextral strike-slip focal mechanisms of earthquakes along the OFZ (Fournier et al., 2001; Gordon and DeMets, 1989; Quittmeyer and Kafka, 1984), the Arabian plate moves northwards slightly faster than the Indian plate at a differential rate of 2 to 4 mm yr^{-1} estimated independently from geodetic (Fournier et al., 2008a) and geological (DeMets et al., 1990, 1994, 2010) data. We recently surveyed the OFZ onboard the *R/V Beautemps-Beaupré* (Owen cruise, 2009) using a high-resolution deep-water multibeam echo-sounder and a 3.5 kHz sub-bottom seismic profiler to identify surficial traces of active faults and characterize the geometry of the fault system in relation with its kinematics. Magnetic and gravity measurements were also routinely acquired.

2. Geometry of the plate boundary

Multibeam bathymetric data reveal an outstanding active submarine fault system between the Beautemps-Beaupré Basin to the south (Fig. 1; Fournier et al., 2008b) and the Dalrymple Trough to the north (Edwards et al., 2008). The fault scarps are well preserved on the seafloor and run at the base of the east-facing escarpment of the Owen Ridge, except at its southern extremity and in its central part where the faults crosscut the ridge (Fig. 1). The fault system is remarkably linear and focused on a single strand along much of its length. Six main fault segments can be identified, apparently uninterrupted over lengths between 60 and 180 km (Fig. 2). The overall geometry of the fault system hereafter described, including releasing and restraining bends, pull-apart basins localized on releasing bends, and basins ending the fault system, is consistent with a dextral strike-slip motion.

We used an oblique Mercator projection with the Arabia–India pole of rotation as pole of projection to test if the trace of the OFZ follows a small circle of the Arabia–India motion (Fig. 2a). In this coordinate system, transform faults should be horizontal straight lines if they strictly follow small circles. The trace of the OFZ is generally

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0012-821X/$ – see front matter
doi:10.1016/j.epsl.2010.12.027

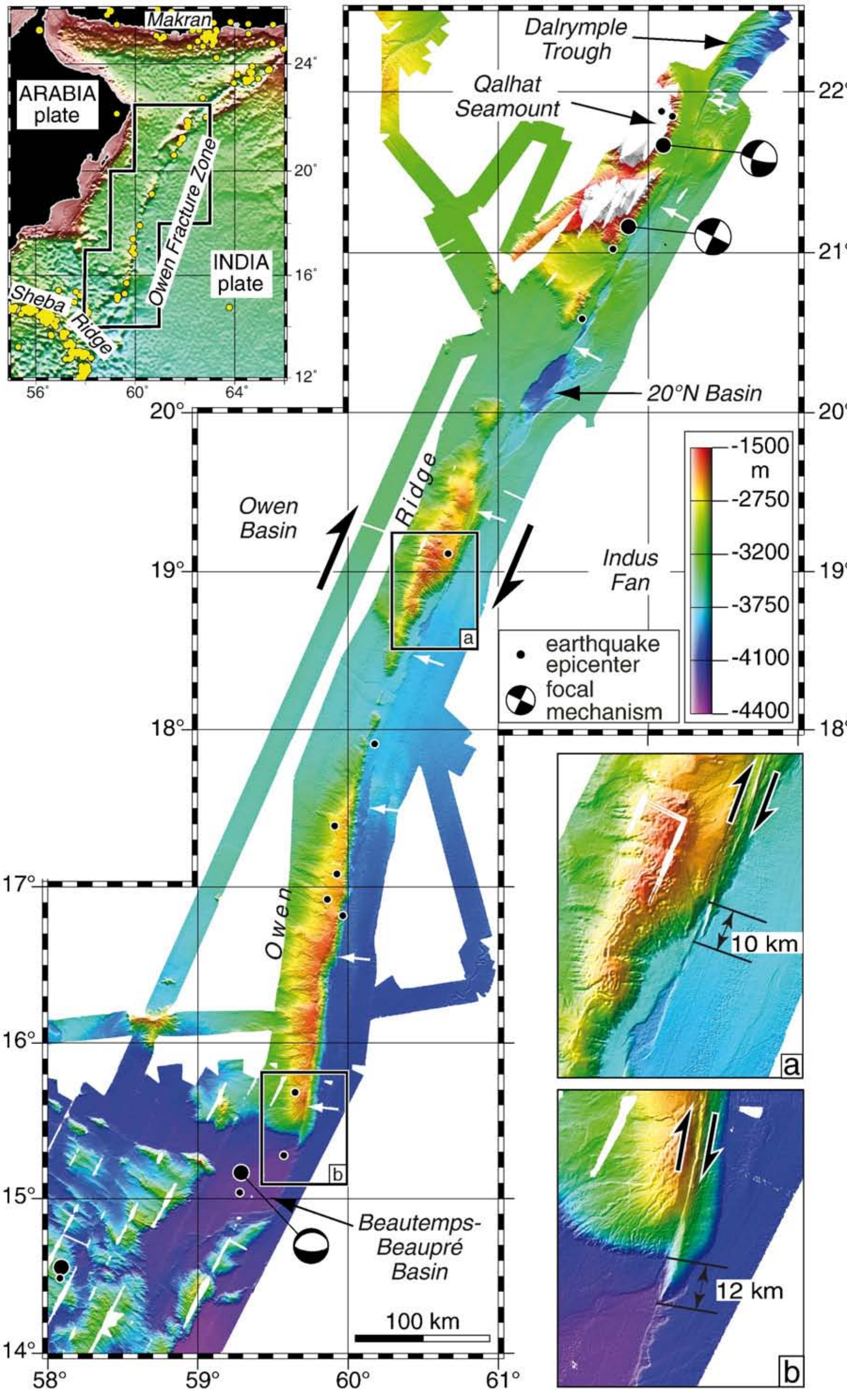

Fig. 1. Active fault scarps of the OFZ mapped with a multibeam echo-sounder can be followed over 800 km from the Beautemps–Beaupré Basin to the Dalrymple Trough (white arrows). The OFZ is bounded to the east by the Indian plate oceanic floor of Paleocene age formed at the Carlsberg Ridge (Chaubey et al., 2002; Royer et al., 2002), overlain by thick deposits (up to 12 km) of the Indus Fan (the second largest deep-sea fan), and to the west by the Owen Basin floored with oceanic crust of poorly constrained age between Late Jurassic and Eocene (Edwards et al., 2000; Mountain and Prell, 1990; Whitmarsh, 1979). The Owen Ridge is made up of three distinct portions separated by two thresholds at 18.2°N and 20°N. The southern ridge is asymmetric with a steep east-facing scarp and a gentle western flank, whereas the central ridge displays a dome morphology elongated in the direction of the Owen fracture zone. The southern and central ridges do not bear any magnetic signal. In contrast, the northern ridge, which rises ~2500 m above the surrounding seafloor and is topped by a flat platform at depths of 400 m below present sea level, is characterized by high amplitude magnetic anomalies attesting to a volcanic origin. It corresponds to the Qalhat Seamount, a volcanic guyot of probable Cretaceous age like the Little Murray Ridge in the Oman Basin (Edwards et al., 2000; Ellouz-Zimmermann et al., 2007; Gaedicke et al., 2002). a) and b) Strike-slip geomorphologic offsets of the active faults reach 10 to 12 km.

parallel to a small circle and is diverted from it between 16.5°N and 20.3°N, where a system of adjacent releasing and restraining bends constituting a paired bend (Mann, 2007) is observed. The releasing bend is made up of two pull-apart basins, a small rhomboidal basin at 18.6°N (see Fig. 1a) and a larger basin at a change in trend of the OFZ at 20°N (see Section 4). Between 16.5°N and 18°N, the fault trace slightly deviates from the direction of the interplate slip vector, leading to the development of a gentle restraining bend. Minor