Tectonophysics 607 (2013) 1–16

Contents lists available at ScienceDirect

Tectonophysics

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

The Paleogene pre-rift to syn-rift succession in the Dhofar margin (northeastern Gulf of Aden): Stratigraphy and depositional environments

J. Robinet [a,b,c,*], P. Razin [c], J. Serra-Kiel [d], A. Gallardo-Garcia [d], S. Leroy [a,b], J. Roger [e], C. Grelaud [c]

[a] UPMC, Univ Paris 06, UMR 7193, ISTEP, F-75005 Paris, France
[b] CNRS, UMR 7193, ISTEP, F-75005 Paris, France
[c] ENSEGID, University of Bordeaux III, France
[d] University of Barcelona, Spain
[e] Olivet, France

ARTICLE INFO

Article history:
Received 1 October 2012
Received in revised form 14 March 2013
Accepted 17 April 2013
Available online 28 April 2013

Keywords:
Gulf of Aden
Pre-rift
Syn-rift
Biostratigraphy
Paleoenvironments
Sequence analysis

ABSTRACT

The Paleogene deposits on the northern passive margin of the Gulf of Aden record the transition from the pre-rift to the syn-rift stages of the southern Arabian plate margin. In southern Oman (Dhofar Region), the relative continuity of the sedimentary record offers the possibility to investigate the early deformation phases of the Aden rift system. A new detailed sedimentological and biostratigraphic analysis of the Cuisian to Rupelian deposits of the Dhofar region allows to define a second-order transgressive–regressive cycle, that can be further subdivided into four third-order sequences between the Late Cuisian and the Early Rupelian time. The sequence stratigraphy established in this study has major implications for the understanding of the time equivalent deposits described in the eastern Arabian plate and illustrates the polyphased history of the initiation of the Aden Gulf rift system. The first two depositional sequences are controlled by a phase of deformation that only affects the eastern Oman margin, in relation with the tectonic activity at the Arabian–Indian plate boundary, during the Late Cuisian–Middle Lutetian. The last two depositional sequences record a westward migration of the deformation within the eastern realm of the proto-Gulf of Aden from the Bartonian. Priabonian uplift resulted in the basinward shift of the depositional system followed by a phase of tectonic subsidence that is recorded by the aggradation of lacustrine deposits in localized fault bounded basins. A subsequent major regional relative sea level fall related to domal uplift is recorded by terrigenous deposits (lower part of the Ashawq Formation) prior to the main phase of syn-rift tectonic subsidence (upper part of the Ashawq and Mughsayl formations) in Rupelian–Chattian times.

1. Introduction

The Arabian plate is bounded by a transform margin in the east and a divergent margin in the south (Fig. 1). The transform margin was initiated in the Late Jurassic during the separation between the African–Arabian plate and the Indian–Madagascar–Seychelles plate (Beurrier, 1987; Coffin and Rabinowitz, 1992; Gnos et al., 1997; Marquer et al., 1998; Peters and Mercolli, 1998; Rabinowitz et al., 1983; Salman and Abdula, 1995). The divergent margin developed from rifting phases initiated around the Eocene–Oligocene boundary (33.9 Ma) leading to oceanic spreading during the Early Miocene (17.6 Ma) in the Gulf of Aden (Autin et al., 2010; Leroy et al., 2004, 2012; Roger et al., 1989; Watchorn et al., 1998). However, the first expression of rifting remains unclear and we attempt through this study to characterize the transition from the pre-rift to a syn-rift system in the Gulf of Aden. This complex issue requires a characterization of the relations between the southern and eastern Oman margins. Our work provides a first understanding of the relations between deformation phases recorded by Paleogene deposits in Dhofar and tectonic events related either to the southern rifted margin or the eastern transform margin.

The description of the lower Eocene–lower Oligocene sedimentary succession follows the stratigraphic framework established in western Dhofar during the geological mapping project of the Sultanate of Oman entrusted to BRGM by the Ministry of Petroleum and Minerals of the Sultanate of Oman (Platel et al., 1992a,c; Roger et al., 1989, 1992a,b). The chronostratigraphic and biostratigraphic data are calibrated with the Geological Time Scale according to Ogg et al. (2008) and Serra-Kiel et al. (1998).

This study is based on eleven outcrop sections, combined to construct two composite reference sections illustrating the Cuisian–Rupelian succession in western and eastern Dhofar. These sections are accurately calibrated by a paleontological study based on thin sections and isolated specimen analysis, which allows the development

* Corresponding author at: UPMC, Univ Paris 06, UMR 7193, ISTEP, F-75005 Paris, France.
E-mail address: robinetjeremy17@gmail.com (J. Robinet).

0040-1951/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.tecto.2013.04.017

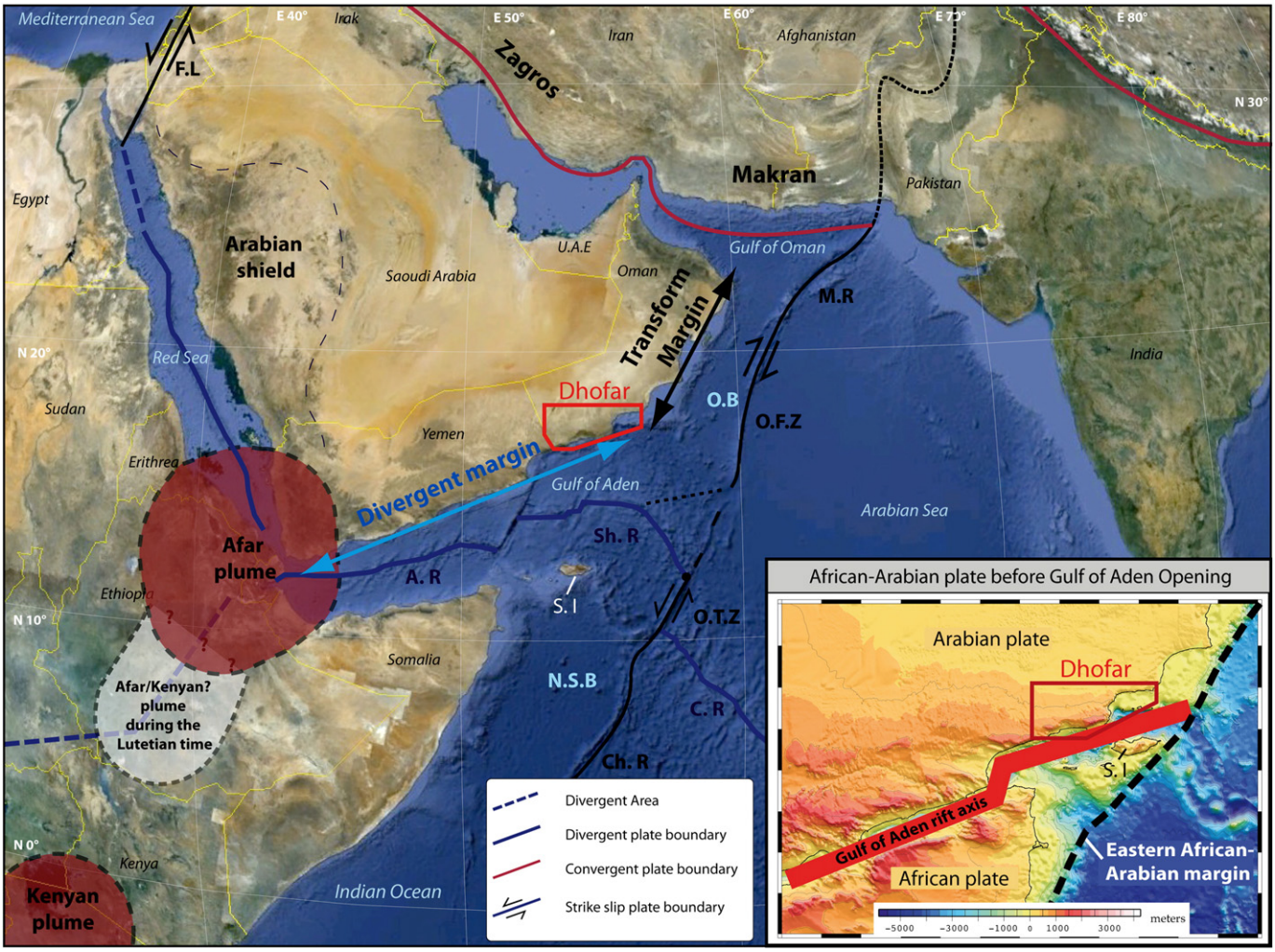

Fig. 1. Main structures surrounding the southeastern part of the Arabian plate. O.B.: Owen Basin, N.S.B.: North Somalian Basin, A.R.: Aden Ridge, Sh.R.: Sheba Ridge, M.R.: Murray Ridge, O.F.Z.: Owen Fracture Zone, O.T.Z.: Owen Transform Zone, Ch.R.: Chain Ridge, C.R.: Carlsberg Ridge, F.L.: Levant Fault, S. I.: Socotra Island. The red rectangle corresponds to the location of the studied area (Dhofar).
Inset: Original map of the Gulf of Aden area before its opening is from Leroy et al. (2012). Topographic and bathymetric data are from Sandwell and Smith (1997). The location of the Afar plume is based on Sicilia et al. (2008) and Leroy et al. (2010a). The location of the Kenyan plume is based on Weeraratne et al. (2003). Its approximate location during the Lutetian is based on George et al. (1998) and Rogers et al. (2000).

of a new biostratigraphic framework. Moreover, the combination of micropaleontological and sedimentological analysis enabled us to constrain paleoecological and paleoenvironmental interpretations. The evolution of the sedimentary system was then studied within this detailed temporal framework, allowing us to define stratigraphic sequences and their correlation throughout the whole Dhofar area. The geometries highlighted by these correlations are a major key interpretation of the tectono-stratigraphic development of the sedimentary system in relation to the evolution of the eastern and southern Arabian plate margins.

The results document the progressive transition from the pre-rift to the syn-rift stages, initiated by a large-scale geodynamic event around the Lutetian–Bartonian boundary (c. 40.4 Ma). This deformation phase precedes the well-established rifting processes starting in Rupelian time along the Gulf of Aden.

2. Geological and stratigraphic setting

The upper Paleocene–lower Miocene deposits, widely exposed in southern Oman (Dhofar), are divided into two lithostratigraphic groups separated by a disconformity: the Hadhramaut and the Dhofar Groups (Roger et al., 1989) (Figs. 2 and 3). These deposits overly the Cretaceous deposits and underlie the Middle Miocene deposits with angular unconformities (Roger et al., 1989) (Fig. 2).

The Hadhramaut Group, dated as Late Paleocene–Late Eocene, comprises four formations separated by disconformities: the Umm er Radhuma, Rus, Dammam and Aydim formations (Beydoun, 1964; Platel et al., 1992c; Powers, 1968; Roger et al., 1989). The Umm er Radhuma, Rus and Dammam formations and their time equivalent deposits are widely preserved across the Arabian plate whereas the Aydim Fm is only preserved on the edge of the southeastern part of the plate (Roger et al., 1989). The rocks of the Hadhramaut Group represent the onset of a global shallow marine carbonate platform system colonized by large foraminifera. These deposits record two large transgressive phases of Thanetian–Cuisian age (Umm er Radhuma Fm) and Early Lutetian to Priabonian age (Dammam Fm and Aydim Fm). These two carbonate platforms are separated by a confined depositional system associated with evaporitic deposits (Rus Fm). Some authors consider that the lower part of the Rus Fm belongs to the highstand systems tract of the Umm er Radhuma Fm and that the upper part of the Rus Fm belongs to the transgressive systems tract of the Dammam Fm (Platel et al., 1992c; Roger et al., 1989, 1992a).